DIVAIRCITY

The power of Diversity & Inclusion for Climate Neutral Cities

Key Performance Indicators and monitoring metrics for DivAirCity specifications

Deliverable 2.1 - Public

Lead beneficiary: DTI

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List of Acronyms

Acronym	Meaning
AB	Advisory Board
CA	Consortium Agreement
DoA	Description of Actions
ESRC	Economic and Social Research Council
GA	Grant Agreement
GeA	General Assembly
ICT	Information and Communication Technologies
PC	Protected Categories
PCU	Project Coordination Unit
WP	Work Package
D&IGCI	Diversity and Inclusion Green City Index
D&ICerS	Diversity & Inclusion City Certification Schemes
D&I	Diversity and Inclusion
KPI	Key performance indicator
NBS	Nature Based Solutions
SCCC	Smart Cities Climate Contracts
SDG	Sustainable Development Goal
IHW	Inclusive Health and Wellbeing

This deliverable is intended as a live document during the project. ToR can change in the future months according to the deployment of the actions

1 Background and introduction

The following section outlines the purpose and definitions of this document, before summarising the methodological approach used to identify the KPIs and key metrics selected for the various parts of the DivAirCity project. Finally, the key target impact areas are summarised as a table in order to contextualise the need for the indicators which are presented throughout the remainder of the document.

1.1. Purpose of document

The purpose of this document is to identify the KPIs and monitoring metrics that will be used in all DivAirCity project activities. This includes both the co-creation phase as well as the assessment and monitoring of the urban economic, social, and environmental performance of the interventions in the five cities of DivAirCity, namely Aarhus, Bucharest, Castellon, Orvieto and Potsdam. Throughout this document we therefore define indicators for easy assessment and communication of air quality and decarbonization progress, as well integrate data to improve the modelling capacity for atmospheric air pollutants and carbon concentration. This document will also provide indicators and metrics for measuring the social diversity and inclusion of vulnerable groups. This will be done through the co-creation of solutions and access to benefits of participatory processes and implemented NBS. In turn this will help make possible the generation of indicators and the integration of data into maps and apps to check green and low pollution routes, for example. To help achieve these aims, the task will utilise past project references and their outputs, as well as open definitions of the KPI Task Force for H2020 NBS projects.

The KPIs will be grouped thematically and focus on the three key impact areas, which are as follows:

1) Social (including diversity, health and social inclusion metrics)
2) Environmental (including air pollution and decarbonisation metrics)
3) Economic (including NBS and data management costs, the economic benefits of improved health and employment opportunities)

The task will support the future development of the Diversity & Inclusion Green City Index (D&I GCI) and the Diversity & Inclusion Geospatial City Maps (D&IGM). This index will be defined by implementing systematic indicator frameworks which are socially, environmentally, and economically integrated, as well as geospatial approaches including data from Copernicus “Data Store”. In turn this will contribute to the definition of the Diversity & Inclusion City Certification Schemes (D&ICerS).

1.2. Definitions of impact, indicator and metric

The ways in which the terms “impact”, “indicator” and “metric” are defined and used varies widely. For the purpose of this document, we define impacts, indicators and metrics as follows:

- **Impacts** broadly define the wider societal, economic or environmental cumulative changes over a mid (2-3 years) to long term (3+ years) period of time.
- **Indicators** are defined as the measurement of an objective which needs to be met, a resource mobilised, or an effect obtained.
- A **metric** is an explicit calculated or composite measure, or value based upon two or more measures, e.g., before and after DivAirCity co-creation activities and city interventions. A single indicator may have several different, specific metrics that can potentially be used to assess its performance and impacts.

The indicators and metrics defined will be integrated into a data framework which allows us to assess the temporary and permanent living labs, the creation of inclusive activities and strategies, the actual interventions and the nature-based solutions in the cities as defined by the Cities DNAs.

1.3. Methodological approach

The methodological approach is divided into three phases:

- The first phase aimed at identifying core metrics from past EU projects and ongoing COVID-19 studies.
- Secondly a review was carried out to examine existing KPIs and to identify additional ones, in relation to the principles of social inclusion and the post-pandemic world (re. ongoing COVID-19 research). KPIs and metrics were then reviewed through the lens of gender diversity and age groups. When existing KPIs were found not to be sufficiently inclusive or contain enough depth, additional indicators were added.
- Finally, existing Census data was analysed in the cities and data gaps were identified in relation to issues of diversity and inclusion.

Within these three phases, the identification of indicators and metrics was carried out in a two-step process, which is outlined below. The targets and goals defined by each city were then translated into specific impacts to be assessed. The two steps are as follows:

Step 1:

a) Define the **impacts** to be assessed, starting from the city targets/goals.

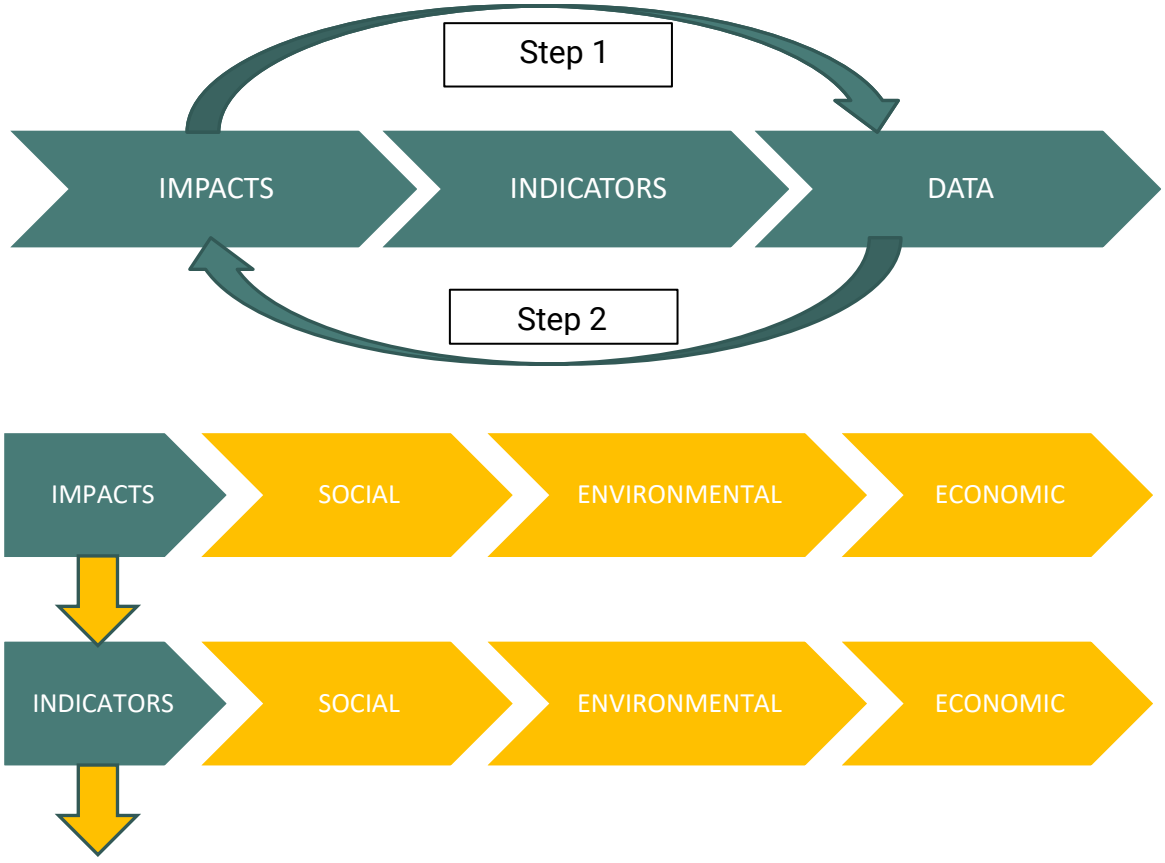
b) Identify the **indicators** that will allow us to assess the impacts.
c) Identify the **data** required to quantify the indicators.

Step 2:

a) Examine whether the data is available through existing formal sources
b) Examine whether the data can be collected during the project activities
c) Redefine the indicator or remove it completely if data cannot be gathered either from existing formal sources or via primary data collection.

1.3.1 Methodological flow

The first step began with an examination of each city's targets and goals concerning their participation in DivAirCity and the expected impacts from the interventions. Possible indicators were then researched accordingly to fit each city's co-creation and implementation processes. We then examined whether the cities would be able to measure these indicators using either existing or primary data, or a combination of the two.



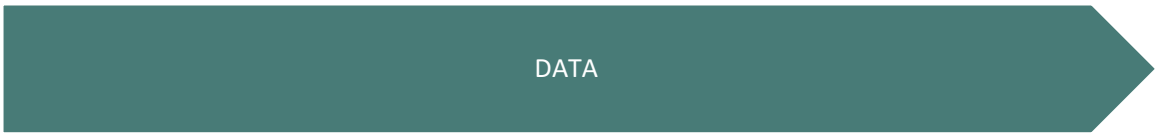


Figure 1: The methodological flow of DivAirCity

DivAirCity focuses on the social, environmental and economic impacts of interventions as these are core to the purpose and objectives of the project. The social impact covers the focus on co-creation, inclusion, and diversity. The environmental impact covers the focus on decarbonization and air quality improvement in cities. Finally, the economic impact covers the focus on all associated financial costs and benefits of interventions, as well as subsequent economic development following the introduction of city-level interventions.

The key target impacts set up by the DivAirCity project are presented in Table 1, below. All of these impacts are medium term which means they are expected to be achieved during the time frame of the project. Environmental impacts are colour coded green, social impacts are colour coded red and economic are colour coded blue. The two purple impacts relate to indices that will be cross-cutting social, economic, and environmental (Source: Grant Agreement of DivAirCity).

Table 1: Key target impacts of DivAirCity.

KPI description	Impact	KPI Description	Impact
(MT) Diversity & Inclusion Green Geo Spatial Map for cities (D&IGSM)	>5 (n)	(MT) Set of participatory activities	>10 (n)
(MT) Diversity and Inclusion Green City Index (D&IGGI)	>1 (n)	(MT) Stakeholders' engagement via co-creation	>1500 people (n)
(MT) Diversity and Inclusion Data Framework (D&IDF)	>1 (n)	(MT) Gender involvement (Women/Men)	³60%
(MT) Business models and Smart cities climate contracts (BM & SCCC)	>5 (n)	(MT) Age Representation a) under 18 years; b) 18-30 Years; c) over 60 years	a) ³25%; b) ³25%; c) ³20%
(MT) Establishment of permanent Urban Living Labs (PLL)	>5 (n)	(MT) Minorities representation in Participatory activities	>20%
(MT) Increasing of physical and creative activity	>25 %	(MT) IC - Equity in Data collection and analysis	3%
(MT) D&I Certification Scheme	>1 (n)	(MT) NMO Leveraging public-private investment	>€55 Mill

(LT) People reached by the project	>1 mill. (n)	(MT) Improving AQ – CO2 emission reduction in the targeted area.	23%
(MT) Creation of a national CoP	>5 (n)	(MT) Improving AQ – NOx emission reduction in the targeted area.	23%
(MT) Definition of one sustainable European CoP	>5 (n)	(MT) Improving AQ – PM10 emission reduction in the targeted area.	23%
(MT) Definition of innovative SCCCs	>5 (n)	(MT) BF - Creation of new jobs	>500
(MT) Creation of relational models (business, governance & other)	>5 (n)	(MT) BF – Decrease of BAME lung disease, like asthma, etc.	>20%

1.4. Summary of chapter

In the wider context of the DivAirCity project, this document sets the scene by researching the state of the art on indicators and metrics from other works and projects. This is a crucial step because in order to monitor the impacts and successes of the project, metrics firstly have to be defined and baseline values have to be collected.

Before these baseline values can be collected, a first and important step is to analyse the pre-existing indicators and metrics for the DivAirCity city co-creation activities and interventions. The process therefore involved firstly analysing indicators and metrics produced by previous projects and recent relevant scientific papers. The findings from this research can be found in the following chapters.

2 Core indicators & metrics from previous projects

The methodology for the process of compiling indicators and identifying gaps began with a thorough examination of indicators and metrics from previous projects. Since work has already been done over several months in the case of each of the projects we considered, it was prudent to consider the outcomes of this research before undertaking our own. The research therefore began with an examination of existing projects' results in terms of relevant impact assessments of nature-based solutions, diversity and inclusion. A range of projects have been identified at initial development stage and additional projects have been added to make a body of inspiration and scientifically founded practical experience.

In this section, we analyse the impact assessment methods of the identified previous projects and draw out the essential components that DivAirCity will adopt to create the

ideal indicator and metrics structure for the impact goals it wishes to reach and measure.

2.1. The Doughnut Model of Social and Planetary Boundaries

The doughnut model is the first of the past works we consider for our basis of indicators for DivAirCity. Originally introduced by Kate Raworth in 2012 through Oxfam's discussion paper "A Safe and Just Space for Humanity: Can we live within the doughnut?" (Raworth, 2012), it has since been developed in the book, Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist, in 2017. By combining the social foundation and environmental ceiling, Raworth argues that sustainable life needs to be placed within those two boundaries. The environmental ceiling consists of nine planetary boundaries, as set out by Rockstrom et al. (2009), beyond which lie unacceptable environmental degradation and potential tipping points in Earth systems. The twelve dimensions of the social foundation are derived from internationally agreed minimum social standards, as identified by the world's governments in the Sustainable Development Goals in 2015. Between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive.

Since the doughnut model's initial proposal, there have been many attempts from different cities to examine the cities performances according to the model (Malcolm and Katherine, 2015; Doughnut Economics Action Lab, 2020)

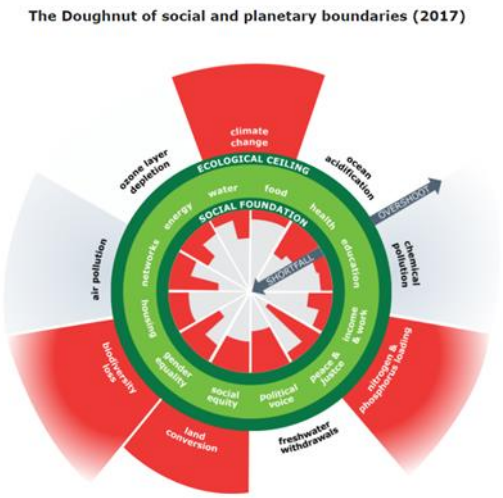


Figure 2: The Doughnut Model of Social And Planetary Boundaries (Raworth, 2012)

The Doughnut Model of Social and Planetary Boundaries provides the indicators regarding social foundation which DivAirCity needs to consider, despite the focus of the Doughnut Model being much broader than NBS or co-creation projects.

The urban indicators can be seen in **Appendix 1**, again taken from the Doughnut of Social and Planetary Boundaries. The ones highlighted are the ones which were considered as useful for DivAirCity and as such more detailed fact sheets can be found on the Wiki page, https://divairwiki.eco-wise.co.uk/ (DivAirWiki, 2022). The fact sheets in DivAirWiki are designed to be accessible online to support co-creation processes in a user-friendly manner.

2.2. UN Her City project

The UN Her City Toolbox (UN Habitat, 2022) is a joint urban development initiative by UN-Habitat (the United Nations Human Settlements Programme) and the independent think tank Global Utmaning (Global Challenge). Financed by the Swedish Innovation Agency (Vinnova) with contributions from Block by Block Foundation, White Architects, Swedish Union of Tenants and MethodKit, the toolbox has been developed in collaboration with multi-stakeholders from both the public and private sectors, research, civil society and citizens.

Her City project has a vision of involving women and girls in urban development to make the city better for everyone, in order to build more inclusive, equal and sustainable cities and communities through involvement of citizens that are rarely heard. This aim makes the toolkit directly compatible with the aims of DivAirCity.

Her City project provides a toolbox for participants to follow the process. It aims to guide urban actors to implement projects through a step-by-step methodology and provides an open and digitally accessible platform for all. The toolbox follows 9 flexible building blocks:

- BLOCK 1: Stakeholder Engagement
- BLOCK 2: City Wide Assessment
- BLOCK 3: Site Specific Assessment
- BLOCK 4: Analysing Challenges
- BLOCK 5: Designing Ideas
- BLOCK 6: Recommendations for Action
- BLOCK 7: Implementation Plans
- BLOCK 8: Sharing Results
- BLOCK 9: Implementation and Follow-up

Through this process, the Her City project generates data about the participants and site. From BLOCK 1, the data about the diversity of stakeholders, and from BLOCK 2 and 3, the data about city and site is collected. The data collection methods are participant surveys, although the indicators differ according to the BLOCKS. The

indicators gathered through participatory processes are transferrable to the Work Package 2 framework of the DivAirCity project. Particularly those indicators can contribute to fill the data gap, which is not available in the existing census, through the co-creation process which will be delivered through Work Packages 3 and 4.

Block 1 Stakeholder Engagement Indicators

The project identifies stakeholders through the census data, but the specific indicators that they used are not shared in the project outcomes. After the engagement, the project collected data of the participants to show the positions of stakeholders.

Table 2: Stakeholder engagement categories (Her City, 2021)

Dimensions	Categorisation
Types of participants	Young people Municipality Local shops Local residents
Age bands	Under 15 15-24 25-34 35-50 51-64 Over 65
Gender	Male Female

Block 2 City Wide Assessment indicators

The project uses the City-wide public space assessment toolkit (UN Habitat, 2020).

Table 3: City-wide assessment indicators

Dimension	Sub-dimension
Spatial distribution	Land allocated to public space Per capita public space Distance to public space Street connectivity Network/Distribution of public space
Governance	Finance and economy (budget for public space) Policy

Block 3 Site Specific Assessment indicators

Block 3 provides a methodology to assess and measure the quality of a selected open public space and its five minutes walking radius (equivalent to 400-meter distance). It describes a participatory and incremental process to gather and analyse information by and with girls and young women through a series of activities and tools. It is rated on a three-point scale: poor/fair/good by participants.

Table 4: Public space Her City indicators

dim	indicators
Use and users	Number and variety of users accessing the public space Number and variety of activities observed in the public space among time and space
Accessibility	Accessibility and presence of qualitative and inclusive facilities for private vehicles Accessibility and presence of qualitative and inclusive facilities for bikes Accessibility and presence of qualitative and inclusive facilities for pedestrians Accessibility and presence of qualitative and inclusive facilities for public transport
Amenities and furniture	Presence and quality of lighting Presence and quality of amenities for recreational structures Presence and quality of seating Presence and quality of waste bins Presence and quality of bike racks Presence and quality of signage and emergency items Presence and quality of water and toilet facilities
Comfort and safety	Perception of safety & level of security of the public space Quality of sensorial experience Overall comfort using the public space, through maintenance, design and ambiental conditions Presence of a public space identity, defined by cultural background and users' enjoyment
Environmental components	Quality of biodiversity and microclimate conditions in the public space Environmental and community resilience Presence of energy efficient elements in the public space

The Her City project provides an important example for DivAirCity in terms of collecting data through co-creation processes. The data about participation is crucial to provide the data to meet the expected impacts of DivAirCity. The indicators that can be generated from Her City site assessment tools can be used to diagnose the context of each city in DivAirCity.

The difference between Her City project and DivAirCity, however, is that Her City is focusing on female participants, but DivAirCity aims to include broader participants by focusing on the 6+1 elements of diversity. Therefore, throughout the data collecting processes, the consideration of 6+1 'protected categories' (as defined by the UN, please add reference), gender, age, ethnicity/race, sexual orientation, economic/social, disabilities (mental/physical) and intersectionality, needs to be included.

The indicators over the three blocks can be seen in **Appendix 2**. The ones highlighted are the ones which were considered useful for DivAirCity and more detailed fact sheets can be found on the DivAirWiki page (DivAirWiki, 2022).

2.3. Evaluating the impact of nature-based solutions: A handbook for practitioners

The European Commission Handbook on Evaluating the Impact of Nature-Based Solutions, henceforth the EU NBS handbook, is a guide to enable the development of NBS metrics which are scientifically-valid and comprehensive at all stages of the process from design to implementation. Developed by the NBS impact evaluation taskforce, the handbook provides a reference European framework for monitoring and evaluating the impact of NBS solutions in cities. It combines the efforts of 27 different EU projects which focused on NBS, and examines indicators suggested by each of these. These projects include BiodivERsA, CLEARING HOUSE, CLEVER Cities, CONNECTING Nature, EdiCitNet, EKLIPSE, GREEN SURGE, GROW GREEN, Inspiration, MAES/EnRoute, NAIAD, Nature4Cities, Naturvation, NetworkNature, OpenNESS, OPERAs, OPERANDUM, PHUSICOS, proGIreg, RECONECT, REGREEN, Think Nature, TURaS, UNaLab, URBAN GreenUP, and URBiNAT.

In order to combine the indicators from all of these projects, the EU NBS handbook provides a reference document for NBS-monitoring methodologies. To do this, indicators were categorised according to the key challenges which they address. These are as follows:

1. Climate Resilience
2. Water Management
3. Natural and Climate Hazards
4. Green Space Management
5. Biodiversity Enhancement
6. Air Quality
7. Place Regeneration
8. Knowledge and Social Capacity Building for Sustainable Urban Transformation
9. Participatory Planning and Governance
10. Social Justice and Social Cohesion
11. Health and Wellbeing
12. New Economic Opportunities and Green Jobs

The indicators from each project were examined and selected according to their importance. These are divided into 'recommended' and 'additional' indicators for each of the social challenges.

The indicators in this handbook can be seen in **Appendix 3**. The ones highlighted are the ones which were considered as useful for DivAirCity and which contain fact sheets stored on the DivAirWiki page. These factsheets contain practical information which is required for cities to collect data regarding this metric, including the data requirements and source as well as a detailed description of the metric/ indicator.

2.4. Nature4Cities H2020 project

Full title: Nature4Cities - a Nature Based Solutions knowledge diffusion and assessment platform for re-naturing cities

Nature4Cities is an EU H2020-funded project which ran from 2016 until 2020. With the objectives of improving accessibility of nature-based solutions in decision-making and integrating them into urban planning, Nature4Cities or "Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform" through new collaborative models has certain KPIs and metrics which are transferrable to the Work Package 2 framework of the DivAirCity project. Nature4Cities deliverables can be found online (Nature4Cities, 2019). Of particular interest is deliverable 2.1, which provides a list of KPIs to be used for the assessment of both urban challenges and NBS (Nature4Cities, 2019).

In particular, Nature4Cities considered eleven urban challenges, categorised under 5 broad topics, which can be seen in the below table. Within these 11 categories, a further 26 subcategories were defined.

The 110 resulting urban indicators can be seen in table 2 (**Appendix 3**). The ones highlighted are the ones which were considered as useful for DivAirCity and as such more detailed fact sheets can be found on the DivAirWiki (DivAirWiki, 2022).

Within the outlined Nature4Cities framework in table 5, a total of 110 UPIs (Urban Performance Indicators) were defined, which are listed in **Appendix 4**. This was done at three spatial scales, and for each indicator the applicable scale is indicated within the deliverable:

1. City scale
2. District/ neighbourhood scale
4. Individual / object scale.

Table 5: Nature4Cities urban challenges (Nature4Cities, 2017).

TOPICS	URBAN CHALLENGES (UC)	URBAN SUB-CHALLENGES (USC)
CLIMATE	1 | Climate issues	1.1 | Climate mitigation
		1.2 | Climate adaption
	2 | Water management and quality	2.1 | Urban water management and quality
		2.2 | Flood management
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale
		3.2 | Air quality locally
	4 | Biodiversity and urban space	4.1 | Biodiversity
		4.2 | Urban space development and regeneration
		4.3 | Urban space management
	5 | Soil management	5.1 | Soil management and quality
RESOURCE	6 | Resource efficiency	6.1 | Food, energy and water
		6.2 | Raw material
		6.3 | Waste
		6.4 | Recycling
SOCIAL	7 | Public health and well-being	7.1 | Acoustics
		7.2 | Quality of Life
		7.3 | Health
	8 | Environmental justice and social cohesion	8.1 | Environmental justice
		8.2 | Social cohesion
	9 | Urban planning and governance	9.1 | Urban planning and form
		9.2 | Governance in planning
	10 | People security	10.1 | Control of crime
		10.2 | Control of extraordinary events
ECONOMY	11 | Green economy	11.1 | Circular economy
		11.2 | Bioeconomy activities
		11.3 | Direct economic value of NBS

The list of 110 UPIs was then narrowed based on a RACER evaluation (Nature4Cities, 2017). This measures the applicability of an indicator based on 5 criteria: Relevance, Acceptability, Credibility, Easiness, and Robustness. This resulted in a scoring and a threshold was established to eliminate the indicators which did not score highly across all these criteria. A more detailed analysis of why certain indicators met this threshold whilst others did not is provided in the deliverable. For each indicator, including the ones which did not make the selection, a fact sheet including information about the calculation requirements and datasets required is provided in the annex of the

Nature4Cities deliverable 2.1 (Nature4Cities, 2017). This resulted in 52 indicators being selected for this project.

Another Nature4Cities document utilised the selected indicators of this methodology to produce a valuation scale for NBS based on quality-of-life indicators (Nature4Cities, 2019). Furthermore, its possibility to focus on NBS benefits for a particular section of the population, for example elderly citizens, can be useful for addressing the DivAirCity 6+1 categories. This will be especially useful when developing diversity and inclusion green cities index and geospatial maps.

2.5. Creating Interfaces (EN-SUGI) project

Full title: Creating Interfaces – Building capacity for integrated governance at the Food-Water-Energy-nexus in cities on the water (EN-SUGI)

The creating interfaces project focuses on improving urban governance around the food-water-energy nexus, making this urban challenge an issue which is relevant and well-understood among stakeholders. Local co-creation among citizens is a key resource which this project sought to mobilise, and from which lessons can be learned for use in the DivAirCity project.

The Citizens science open data tool (Creating Interfaces, 2022) was a method developed under the premise of addressing the food-water-energy nexus for the Creating Interfaces project, and it is used to gather local stakeholder knowledge, thoughts and opinions in the project's case studies. Importantly, this is a bottom-up co-creative approach in which the citizen is the main contributor. This tool has been developed by the Creative Interface for citizen science and offers significant potential for being fed into the monitoring and evaluation activities of DivAirCity and in the definition of the D&IGCI.

2.6. Bright Futures project (ESRC 2017-2020)

Full title: Bright Futures - Reinventing European industrial towns and challenging dominant post-industrial discourses.

Another potentially useful project which merited detailed exploration is the Bright Future project. With its specific focus on sustainable redevelopment of post-industrial towns, particularly useful was its social sustainability assessment framework. Used by the Bright Futures project, this offers important insight into how towns which were historically industrial can adapt to urban change and thrive in the future. The indicators of this project therefore included the social sustainability in cities, a clear link to the DivAirCity project. It contains four dimensions of social sustainability as depicted in the figure below. These were considered for use when developing the DivAirCity metrics and indicators.

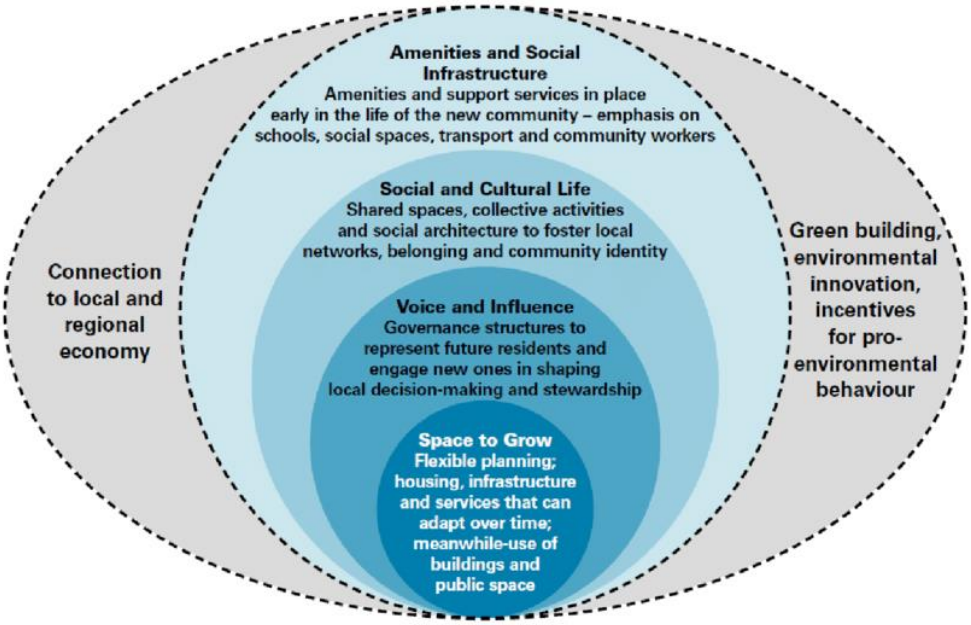


Figure 3: Four Dimensions of Social Sustainability - Illustration of Design for Social Sustainability Framework, Young Foundation Source: Woodcraft, Hackett & Caistor-Arendar (2011)

2.7. EKLIPSE H2020 project

Full title: EKLIPSE - Knowledge and Learning Mechanism on Biodiversity and Ecosystem Services

The Eklipse project has produced a very relevant publication called “An impact evaluation framework to support planning and evaluation of nature-based solutions projects”. It provides an impact evaluation framework which offers important elements for the impact assessment for the DivAirCity project. Especially the indicators related to impacts achieved from NBS implementations to addressing the following challenges are relevant:

- Climate resilience
- Water management
- Green Space management
- Air quality
- Urban Regeneration
- Participatory planning and governance
- Social justice and social cohesion
- Public health and well being
- Potential for economic opportunities and green jobs

Additional deliverables have been published by Eklipse with more specific impact assessment relevance, such as the impact of green and blue spaces on mental health and biodiversity and pandemics.

Furthermore, the Eklipse work links to the work of DivAirCity by examining the impacts, indicators and metrics of triangular cooperation where public and private stakeholders, as well as non-governmental organisations, co-create solutions to meet the SDGs (OECD 2018). The indicators considered under this project were later integrated into the handbook developed by the European Taskforce on NBS impact evaluation described in section 3.3. They are examined for use in DivAirCity and can be found integrated in the indicator list in **Appendix 3**.

2.8. URBiNAT H2020 project

Full title: URBiNAT - Urban Innovative & Inclusive Nature

URBiNAT Project has an evaluation framework assessing six dimensions:

1. co-creation and co-governance process for active involvement,
2. public space for inclusive urban regeneration,
3. culture at the heart of sustainable urban development,
4. socio-economy for inclusive urban regeneration,
5. well-being in the urban space and
6. environment resources for urban sustainability (URBiNAT, 2021).

URBiNAT, like DivAirCity, has a similar focus on social and diversity Indicators. The purpose of the URBiNAT project is to co-create healthy corridors and NBS in disadvantaged city neighbourhoods to improve quality of life for citizens. Consequently, the project is working with an impact evaluation structure consisting of the following personal indicator areas:

- Personal situation (including residential circumstances)
- Emotional, social, and mental wellbeing
- Social activity and network levels
- Physical activity and creativity levels
- Health conditions
- Environmental quality of life

The above indicators are all measured and captured through neighbourhood surveys before and after interventions. Also, the project monitors the satisfaction levels and experience of the co-creation activities in terms of real influence on the co-creation and governance processes.

In addition, URBiNAT is assessing the environmental and economic impact of the NBS and the healthy corridor co-implementations. In terms of the environmental impact indicators URBiNAT is using soil quality indicators, urban water management,

microclimate indicators, air quality indicators, landscape and biodiversity indicators, noise and landscape indicators and CO2 indicators. Especially the assessment indicators and metrics used for assessing participation and NBS impact are relevant for DivAirCity to adopt in its indicator and metrics structure.

2.9. IN-HABIT H2020 project

Full title: IN-HABIT - INclusive Health And wellBeing In small and medium size ciTies

IN-HABIT (IN-HABIT, 2021) is an EU Horizon 2020 project that aims to foster inclusive health and wellbeing (IHW) in four peripheral small and medium-sized cities (SMSCs): Cordoba (Spain), Riga (Latvia), Lucca (Italy) and Nitra (Slovakia). In each city, the project will mobilise existing undervalued resources (culture, food, human-animal bonds, and environment) to increase IHW, with a focus on gender, diversity, equity and inclusion. The integrated approach will combine technological, digital, nature-based, cultural, and social innovations in selected urban public spaces. These solutions will be co-designed, co-deployed and co-managed with and by local stakeholders.

IHW Indicators are a set of context-based key impact indicators to measure the changes produced by the IN-HABIT project on inhabitants' inclusive health and well-being in the 4 pilot cities. They are co-developed with the involvement of local inhabitants and city partners, starting from the analysis and adaptation of existing indicators on subjective well-being at European and International level (OECD, Eurostat, European Commission, UNDP/SDGs, other H2020-funded projects) in order to ensure comparability and to fill the gaps in terms of data availability on sustainable urban development for small and medium-sized cities. IHW Indicators consider both the researchers' and the inhabitants' assumptions on expected changes affecting health and well-being, with specific regard to the perspective of those people at risk of discrimination and exclusion based on different personal characteristics.

The objective of this plan is to evaluate the results of IN-HABIT's visionary and integrated solutions (VIS) on people's inclusive health and well-being by capturing the short to medium term changes affecting people's condition, with specific regard to groups at risk of discrimination by age, gender, disability, ethnicity, religion, sexual orientation and gender identity, also considering city specific minorities and intersectionality.

Table 6: IN-HABIT target groups

Cities	Target groups
Cordoba	young people
	women
	LGBTQI+ people
	people with disabilities
	families (included those with small children)

	elderly people
	ethnic and religious minorities
Riga	Young people and students
	LGBTQI+ people
	People with disabilities
	Families (including those with small children)
	Children
	Lonely and elderly people
	Ethnic minorities
Lucca	Lucca's residents of the old city center (inside the walls)
	Lucca's residents of outside the old city center
	tourists
	persons living alone
	pet owners
	persons with disabilities
	women
	children
	elderly
	ethnic minorities
Nitra	Families
	Students
	Economic Migrants
	Elderly
	Persons with disability
	Cyclists and sportsmen
	Roma community
	Women

The set of indicators is tailored and cross-checked in each participating city. Each of the cities has target groups and expected changes from both partners' perspectives and local inhabitants. Based on these expected changes and target groups, cities selected their own particular set of indicators among the lists. The full list of indicators is attached in **Appendix 6**.

The two aspects of IN-HABIT seem to be useful for DivAirCity. Firstly, the indicators are applied in cities by considering the context of the case study areas. The larger set of indicators are selected in each specific context. This context sensitivity and co-designing process of final set of applicable indicators is recommendable in the practices in cities. Secondly, diverse minority groups are considered as a main target. These target groups are also selected by considering each city's socio-cultural context. However, some indicators used in the IN-HABIT project seem to be difficult to be applicable in DivAirCity because they mainly rely on surveys to investigate subjective or perceived well-being.

2.10. GrowGreen H2020 project

Full title: GrowGreen - a partnership for greener cities to increase liveability, sustainability and business opportunities

The GrowGreen project aims to integrate nature-based solutions into city environments to act as solutions to urban challenges.

The project has defined a series of KPIs and has assessed the impact of NBS interventions in the decarbonization of the area, heat stress, human comfort, air quality, social justice and social cohesion, health, and wellbeing.

Some indicators that have been used for the NBS design during GrowGreen for the pilot projects of Valencia were the following:

- Diversity of trees and shrubs
- Diversity of vegetation strata
- Run-off coefficient in relation to precipitation quantities
- Reduction on runoff peak discharges
- Reduction on runoff volume rates
- Mean radiant temperature (Tmrt)
- Physiological Equivalent Temperature (PET)
- Carbon storage capacity
- Green area per capita
- Structural connectivity
- Accessibility to green space
- Biotop Area Factor
- Green network connectivity

Social indicators proposed for GrowGreen were as follows:

- Singular elements (informative points, monuments, or artistic interventions) in the public space
- Adaptation of basic furniture (benches, litter bins, ...)
- Adequacy of the equipment by age ranges (baby games, children's games, games for the elderly, sports areas in public spaces, etc.)
- Perception of urban green
- Number of areas perceived as insecure in public space (black points)
- Level of non-sexist representation in public space / women recognition in public space

It is evident that most of the above indicators are relevant for DivAirCity as has also been illustrated by other projects. The relevant indicators have been included in the **Appendix 3** list and where relevant integrated into the current consolidated list in Chapter 7.

2.11. Summary of project analysis

The above analysis of existing social sustainability, inclusivity, urban NBS projects and impact evaluation frameworks has been used to inform and inspire the indicator and

metrics structure of the DivAirCity project. By using relevant indicators and metrics from multiple projects and frameworks, a broad structure of indicators and metrics was developed. These were then analysed over several online workshops and prioritised based on their relevance, measurability within the project time frame and importance up against the target impacts of the DivAirCity project.

3 Open-Source data indicators & metrics

A number of open data sources are available to projects like DivAirCity. They provide regular indicators with variable data granularity and coverage to measure certain relevant impacts. We have identified a number of these sources which were found to be particularly relevant to DivAirCity as they will provide access to metric data that can supplement additional local data collections.

3.1. Copernicus

The first of these open-source data providers is Copernicus, the European Union's Earth observation programme. It offers information services that draw from satellite Earth Observation and in-situ (non-space) data. Several key indicators are derived from data which would be taken from Copernicus, and this helpfully ensures uniformity between data used across cities.

Copernicus is managed and implemented by the EC in partnership with Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.

Global data from satellites and ground-based, airborne, and seaborne measurement systems provide information to help service providers, public authorities, and other international organisations improve European citizens' quality of life and beyond. The information services provided are free and openly accessible to users.

One particularly useful data source is the European-scale air quality analyses of PM2.5, PM10, ozone, NMVOCs, carbon monoxides, nitrogen dioxide, ammonia and sulphur dioxide, which provides direct quantities of these pollutants and would be an obvious input for DivAirCity which aims to monitor this. Additionally, Copernicus provides daily forecasts of carbon dioxide provided by various models. The maps provided are only representative of large-scale phenomena, they do not describe air pollution on a local level.

This service also provides use cases in relation to urban green infrastructure, forecasts of personal allergy symptoms (PASYFO, 2022) and an ‘air quality at a glance’ service for citizens in Riga, Latvia (Copernicus, 2022a).

The VITO ATMOSYS-CAMS platform is an air quality toolbox targeted at policy support. The ecosystem of tools and web applications are designed to deliver policy-oriented information on air quality both in terms of forecasts, assessments and the evaluation of air quality plans.

DivAirCity will consider and apply these geo-spatial data sources together with the monitored air quality city data as far as it is relevant.

3.2. WHO Air Pollution Data

The second source which is particularly relevant is the World Health Organisation (WHO) which provides air pollution data.

Following the conclusions from the review of evidence on health aspects of air pollution, the WHO organized an expert consultation in Bonn between September and October 2015 as a first step for this update of the air quality guidelines. Their objective was to gather expert opinion and guidance in order to identify and discuss the latest available evidence on the health effects of air pollutants and interventions to reduce exposure to air pollution for the purpose of informing this update of the air quality guidelines.

Experts recommended that a focus of these guidelines on pollutant specific risk assessment was still appropriate and prioritized 32 air pollutants according to four categories to reflect their relative importance in the context of updating the air quality guidelines. Since reviewing the evidence systematically for all air pollutants was unfeasible considering the available resources, experts suggested prioritizing the pollutants **PM2.5, PM10, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide** for this update (World Health Organisation, 2021).

Table 7: AQEshort – Air Quality Exposure – short term health effects

Pollutant	Causality determination (reference)
$PM_{2.5}$ and PM_{10}	$PM_{2.5}$ Causal for all-cause, cardiovascular and respiratory mortality (US EPA, 2009) Causal for all-cause, respiratory and cardiovascular mortality (Health Canada, 2013) Likely causal for respiratory effects (US EPA, 2009) Causal for cardiovascular effects (US EPA, 2009) Causal for respiratory effects (Health Canada, 2013) Causal for cardiovascular effects (Health Canada, 2013) PM_{10} Supported by evidence from $PM_{2.5}$ PM (all fractions) Causal for all-cause mortality (Health Canada, 2013)
NO_2	Causal for respiratory effects (US EPA, 2016) Causal for respiratory effects (Health Canada, 2016a) Likely causal for total mortality (Health Canada, 2016a) Suggestive causality for total mortality (US EPA, 2016)

O_3	Causal for respiratory effects (US EPA, 2013) Causal for respiratory effects (Health Canada, 2013) Likely causal for total mortality (US EPA, 2013) Likely causal for total mortality (Health Canada, 2013) Likely causal for cardiovascular effects (US EPA, 2013) Suggestive causality for cardiovascular effects (Health Canada, 2013) Likely causal for cardiopulmonary mortality (Health Canada, 2013)
CO	Likely causal for cardiovascular effects (US EPA, 2010) Likely causal for cardiovascular effects (Health Canada, 2010)
SO_2	Causal for respiratory effects (US EPA, 2015) Causal in adults for respiratory effects (Health Canada, 2016b) Experimental studies demonstrate lung function decrements and respiratory symptoms at very short-term exposures (i.e., 5-10 minutes) to SO_2 in adults with asthma.

Table 8: AQElong - Air Quality Exposure – long term health effects

Pollutant	Causality determination (reference)
$PM_{2.5}$ and PM_{10}	$PM_{2.5}$ Causal for cardiovascular and respiratory mortality (US EPA, 2009) Causal for total and cardiovascular mortality (Health Canada, 2013) Likely causal for respiratory effects (US EPA, 2009) Likely causal for respiratory effects (Health Canada, 2013) PM_{10} Causal for total mortality in relation to PM (Health Canada, 2013) Group 1[b] lung cancer for PM (Straif et al., 2013) Likely causal for lung cancer mortality in relation to PM (Health Canada, 2013)
NO_2	Suggestive causality for total mortality (US EPA, 2016) Suggestive causality for total mortality (Health Canada, 2016a) Likely causal for respiratory effects (US EPA, 2016) Likely causal for respiratory effects (Health Canada, 2016a)
O_3	Suggestive causality for mortality (US EPA, 2013) Suggestive causality for respiratory mortality (Health Canada, 2013) Likely causal for respiratory effects (US EPA, 2013) Suggestive causality for respiratory effects (Health Canada, 2013)

DivAirCity will use the indicators and metrics recommended by the WHO and will apply where possible data provided by the WHO platform to supplement local data measurements.

3.3. ICOS - Integrated Carbon Observation System

ICOS ERIC (The Integrated Carbon Observation System European Research Infrastructure Consortium, or ICOS 2022) is the European environmental research infrastructure. It was created to quantify and understand the greenhouse gas balance through a network of measurement stations that continuously provide high quality data on carbon cycle and greenhouse gas emissions and their atmospheric concentration on a pan-European scale.

Currently, the ICOS ERIC observation network covers 12 countries with over 100 measurement stations and data are made available with open license through a Carbon Portal. The measurement stations are divided in atmospheric, ecosystem and marine stations. Although the primary parameters measured are the same (GHGs and meteorological ones), there are specific parameters that are measured according to the type of measuring station (see table 10). Each group of measurement stations are coordinated by a Thematic center, namely an Atmospheric an Ecosystem and Marine Center (ATC, ETC and OTC, respectively).

The Ecosystem Measurement Station covers most of the different types of vegetation present across Europe, including but not limited to forest, grassland, farmland, and wetlands. Urban measurement stations are also present in the context of the ICOS network, specifically in Finland, Italy and Poland.

Table 9: ICOS ERIC observation parameters

Parameters measured at ICOS stations	Atmospheric	Ecosystem	Marine
CO_2	Continuous	Continuous	Continuous
CH_4	Continuous	Continuous	Continuous
CO	Continuous		
N_2O	Continuous		
Radon (^{222}Rn)	Continuous		
SF6	Continuous		
H_2	Periodical		
^{13}C and ^{18}O in CO_2	Periodical		
^{14}C in CO_2	Periodical		
^{13}C and ^{2}H in CH_4	Periodical		
Air temperature	Continuous	Continuous	Continuous

Relative humidity	Continuous	Continuous	Continuous
Wind direction	Continuous	Continuous	Continuous
Wind speed	Continuous	Continuous	Continuous
Atmospheric pressure	Continuous	Continuous	
Planetary Boundary Layer Height	Continuous		
Eddy CO_2 fluxes	Continuous		
Eddy CO_2, H_2O and H fluxes		Continuous	Continuous
Eddy CH_4 and N_2O fluxes		Continuous	Continuous
H_2O		Continuous	Continuous
Short and Long Wave radiations		Continuous	Continuous
Photosynthetically active radiation		Continuous	Continuous
Precipitation		Continuous	
Snow depth		Continuous	
Soil temperature		Continuous	
Soil Water Content		Continuous	
Soil Heat Flux Density		Continuous	
Water Table Depth Measurement		Continuous	
Green Area Index		Periodical	
Aboveground Biomass		Periodical	
Litter biomass		Periodical	
Canopy height		Periodical	
Leaf mass to area ratio		Periodical	
Leaf Nutrients		Periodical	
Soil Carbon Content		Periodical	
Oxygen and pCO_2 surface concentration			Continuous
Oxygen, pCO_2 and pN_2O concentration profile			Continuous
Salinity			Continuous
Wave properties			Continuous

The ICOS network of members covers four of the five countries with participating cities in DivAirCity (excluding Romania), but where relevant DivAirCity can draw on data for those countries that can be accessed using the ICOS facility and will try to compensate with similar measurements from Romania. The lack of multiple indicator measurement data from urban areas may however limit the applicability in DivAirCity.

4 Latest research offering new KPI & metrics insights

The following section provides an overview of the literature which was consulted to find new publications which added insight to supplement that of the past projects. The literature review is organised in the three main impact and indicator domains: social, environmental, and economic. For additional literature consulted, see the annex (chapter 9).

4.1. Latest research on social and health indicators

This section summarises the review of latest research in relation to social and health impact indicators of NBS projects. The purpose of this is to better understand the inclusiveness and diversity applied in temporary or permanent living lab activities.

4.1.1 Health indicators

In table 11, below, the indicators deemed most relevant for measuring the impacts of mental and physical health consequences of activities and results are presented. Effects of green space exposure on mental and physical health has been an interesting research field in the last years, especially regarding the impact of growing cities and increased traffic. Therefore, in DivAirCity, we will further explore and identify synergistic effects of nature-based solutions on mental and physical health.

Table 10: Health indicators

TOPIC	CHALLENGES	SUB-CATEGORIES	INDICATORS
HEALTH	Mental issues	Subjective	Quality of life, mental fuctioning
		Quantitative	Vital signs (HRV, EDA, EEG)
	Physical issues	Subjective	Physical functioning
		Quantitative	Respiratory functions, physical activity, walkability

There are different health effects depending on varying space and time scales. Several studies (e.g., Mazaheri et al., 2018; Hunter et al. 2019; Reeves et al., 2019 & Sinharay et al. 2018) have been concerned with indoor or outdoor settings as well as effects of short-term or long-term exposure. These publications cover such aspects and can be further divided in outcome related to mental or physical symptoms. Especially older patients and those with chronic obstructive pulmonary disease or asthma can suffer from air pollution related symptoms.

Mental health

In terms of **mental health**, there is compelling evidence of the effects of nature on various health aspects. Most of the studies have been concerned with stress-related outcomes like decreased heart rate variability and effects on brain waves (Hunter et al., 2019). Continuously recorded data using wearable devices such as continuously recorded electroencephalographic (EEG) or heart rate seems to be good options to monitor individual symptoms in relation to green spaces (Reeves et al., 2019). Urban nature experiences reduce stress in the context of daily life. These can be linked to questionnaires and further geolocated using ecological momentary assessments.

As a consequence of these research findings, relevant DivAirCity KPIs could be:

Stress Perception (PSS), Mental Health (POMS), Recovery Effect (ROS, PRS 11), Depression and Anxiety (HADS or STAI), Vitality (SVS), Mindfulness (FFA or FFMQ), Resilience (CD-RISC), Self-Efficacy (ASKU), Exercise (IPAQ), Physical and General Complaints (B-LR), Sleep Quality (VAS)) heart rate variability (HRV), electro dermal activity (EDA), electroencephalography (EEG).

Validated questionnaires regarding those indicators will be used.

Physical health

In terms of **physical health**, recent research suggests that healthy people, as well as those with chronic cardiorespiratory disorders, should minimize walking on streets with high levels of pollution because this curtails or even reverses the cardiorespiratory benefits of exercise. Instead, walking exercise should be enjoyed in urban green space areas away from high density traffic. Patients with chronic cardiorespiratory disorders should be encouraged to use appropriate medication to mitigate the adverse effects of air pollution. Thus, current ambient levels of air pollution along busy streets are unacceptable and need to be controlled.

As a consequence of these research findings, relevant DivAirCity KPIs could be mobile spirometry: (https://www.spirometry.com). Increased walking opportunities can be assessed using walkability features.

COVID-19 and other specific health research

A recent publication found that an increase of 1 mg/m3 in the long-term average PM2.5 is associated with a statistically significant 11% (95% CI, 6 to 17%) increase in the county's COVID-19 mortality rate (Wu et al., 2020). A potential explanation of this relationship could be contributed to the damaging effect of high PM2.5 concentrations (Nor et al., 2021).

Indicators like gardening activities and non-smoking zones could be relevant for DivAirCity as well and will be included at a later stage following a first iteration with the cities.

Incidence of obesity may have connection to DivAirCity, as overweight risk groups have more severe symptoms associated with air pollution and obesity is observed more frequently in certain vulnerable citizen categories. In general, certain comorbidities are risk factors that exacerbate respiratory symptoms.

Hospital admissions would be interesting to link to air quality measures. There is a recent publication that links short term exposure to air pollution and hospital admission for pneumonia (Yee et al., 2021). However, it will be difficult for DivAirCity during the project period to measure impacts on hospital admissions of improved air quality interventions, as this will likely be a factor which changes over a longer period of time.

PH – Perceived Health

Perceived health status reflects people's overall perception of their health, including both physical and psychological dimensions. Typically ascertained through health interview surveys, respondents are asked a question such as: "How is your health in general? Is it very good, good, fair, poor, very poor?" OECD health statistics provide figures related to the proportion of people rating their health to be "good/very good" combined.

People's assessment of their health is subjective and can be affected by factors such as cultural background and national traits. Despite this, there are also large disparities in self-reported health across different socio-economic groups, as measured for instance by income level. On average across OECD countries, nearly 80% of people in the highest income quantile reports being in good health, compared with just over 60% for people in the lowest income group. These disparities may be explained by differences in living and working conditions, as well as differences in health-related lifestyles (e.g., smoking, harmful alcohol drinking, physical inactivity, and obesity problems).

HIM – Heat Induced Mortality

The heat induced mortality indicator is calculated based on the number of deaths associated with temperatures above the 75th percentile of daily mean temperature during summer months (Apr-Sep). Relative risks extracted from a European multi-city study (de' Donato et al., 2015) are used to describe the effect of high temperatures on mortality.

Calculation method: Temperature 75th percentile is calculated from Harmonie model output at the location of an official weather station and then used in the evaluation of each grid cell. The determination of the temperature 75th percentile is made separately for the historical period and for the present window of the climate scenario (for the future window of the climate scenario, the same temperature 75th percentile as calculated in the present window is used). The evaluation period for health impacts of temperatures above the 75th percentile is the full year.

Relative risks (RR) represent the risk associated with a 1°C increase in daily mean temperature. These risk coefficients were aggregated to two regions: Southern Europe (4.7% – 7.9%), Northern Europe (1.7% – 3.5%) as well as the mean for Europe (1.7%-7.9%). Each city must be classified as belonging to one of these groups.

Population data must be obtained for each city, region or country. The data on baseline mortality should come from national official sources. The interest in this indicator comes from DivAirCity cities in the southern parts of Europe where nature-based solutions may help alleviate the effects of heatwaves by installing green spaces to help cool down buildings and public spaces allowing people vulnerable to heat induced illness to seek cooler shelter. As such it is relevant for Orvieto, Castellon and Bucharest and less so for Aarhus and Potsdam.

4.1.2 Social indicators

GEN - Gentrification

Gentrification is the displacement of working-class residents of a neighborhood by wealthier professionals (Hammel, 2009). There are some historic precursors, but the process has been a feature of industrialized cities only since the mid-1960s. Over the last decades of the twentieth century, gentrification spread into smaller cities in industrialized nations and larger cities in parts of the developing world. The causes of gentrification are complex but involve both the provision of gentrified housing and the creation of a class of gentrifiers.

Studies have highlighted gentrification dynamics through the potentials of social vulnerability and environmental (in)justice were identified (Kim *et al.,* 2022). They have shown a positive correlation between social vulnerability and environmental (in)justices which exist within the gentrifying urban areas which can provide policymakers, planners, and residents with a better understanding of gentrification dynamics.

A study has assessed the impact of green spaces on gentrification (Wu & Rowe, 2022):

1. Green spaces gentrify closer areas but not when considering types and features.

2. Green space location eases the gentrification effect due to nearby disamenities.
3. Green space-triggered gentrification is stronger in marginalized areas in the case of Beijing.
4. The pre/post effects of green space openings cause stronger gentrification.

Gentrification is not included as an explicit indicator in DivAirCity. However, when we consider the future impact of the DivAirCity interventions on the gentrification issues, it is important to monitor related indicators. It is particularly important since DivAirCity is focusing on socially disadvantaged groups. While the project improves the quality of urban space and air quality, this benefit needs to be shared to the 6+1 categories. For example, the accessibility of green spaces of diverse groups and housing prices can be important aspects to monitor this future issue.

Another paper (Bockarjova et al. 2020) examines the impact of nature-based solutions on different socio-economic groups which finds that lower income groups may end up being forced to move from adjacency to nature-based solutions and being replaced by higher income groups simply because the introduction of attractive nature-based solutions also has an effect on prices of housing.

Connolly (2021) argues that three principles need to be followed and measured in order to develop just green plans and avoid green gentrification. The three principles which DivAirCity will observe and integrate in its indicator and metrics structure are: a) combined social and environmental/ecological goals; b) starting with the most vulnerable members of society; and c) work with and through the municipality/city.

Quality of Life

Quality of life is a broad concept that encompasses a number of different dimensions, by which we understand the elements or factors making up a complete entity, that can be measured through a set of sub dimensions with an associated number of indicators for each. It encompasses both objective factors and the subjective perception one has of them. For example, the objective factors can include command of material resources, health, work status, and living conditions. The latter depends significantly on citizens' priorities and needs. Measuring quality of life for different populations and countries in a comparable manner is a complex task, and a scoreboard of indicators covering a number of relevant dimensions is needed for this purpose.

Based on academic research and several initiatives, the following 8+1 dimensions / domains have been defined as an overarching framework for the measurement of well-being. Ideally, they should be considered simultaneously, because of potential trade-offs between them:

- Material and living conditions (income, consumption, and material conditions)
- Productive or main activity
- Health

- Education
- Leisure and social interactions
- Economic security and physical safety
- Governance and basic rights
- Natural and living environment
- Overall experience of life

In the calculation method, variables such us the following are used:

- conditions = Material and Living Conditions Indicator
- activity = Productive or Main Activity Indicator
- health = Health Indicator
- edu = Education Indicator
- interactions = Leisure and Social Interactions Indicator
- safety = Safety Indicator
- law = Governance and Basic Rights Indicator
- env = Natural and Living Environment Indicator

Quality of life is not included in DivAirCity as an explicit indicator, but there are a number of DivAirCity indicators which are related to these aspects. For example, the health impacts through the DivAirCity interventions can be assumed to improve quality of life in a more long-term time scale. Natural environment, jobs created from the DivAirCity projects and enhanced right to participate will also contribute to the quality of life. DivAirCity is using Maslow's pyramid – the theory that human motivation is hierarchical so people attempt to fulfil basic physiological needs before moving onto more advanced wellbeing – which will act as a basis for the co-creation activities. Behavioural motivations will be used based on the same elements that 6+1 dimensions are included in this indicator.

Social inclusion

A recent paper (Armstrong 2020) suggests Nature-based solutions have a clear potential to support social inclusion. When aligning health, well-being and social inclusion priorities, there is the potential to tackle social, cultural, environmental, economic and political exclusion.

The publication suggests three pathways and their associated stepping stones to stimulate the inclusive uptake and benefit of nature-based solutions:

Pathway 1: Broaden participation in nature-based solutions – which means for DivAirCity we require indicators and metrics on diversity of participation levels and on inclusiveness of the participation activities;

Pathway 2: Embed political commitment to social inclusion with nature-based solutions; which means DivAirCity needs to monitor indicators of political commitment to diversity and inclusion before, during and after city interventions and activities.

Pathway 3: Make public health and well-being a priority, which means DivAirCity needs indicators on diversity and inclusiveness of health and wellbeing benefits during the temporary and permanent living labs and NBS implementations.

The D-NOSES project paper (Woods, T *et al.*, 2021) details a methodology that is inclusive and diverse and therefore adds input to indicators required to measure the inclusiveness of the DivAirCity co-creation processes. The project aims to include odour pollution in policy agendas worldwide. Like DivAirCity D-NOSES is also committed to being inclusive and diverse in the citizen engagement process. This includes people from different sociocultural backgrounds, socio-economic status, literacy levels, religious affiliations, minority groups, gender, age, people with disabilities, etc. D-NOSES has developed an innovative methodology and guideline to engage citizens in the improvement of odour issues at the local level using citizen science and participatory mapping strategies. D-Noses therefore contributes a number of relevant indicators adopted by DivAirCity.

The Interlace project has produced a report providing guidance on gender, cultural, and ethics-related considerations for sustaining inclusive participatory processes when restoring urban ecosystems. As part of this publication (Øian H., Martinez G., Salmon N., Yepez G. 2021), Interlace presents a model of social and inclusion indicators totalling 20 specific indicators and recommendations in relation measuring these. DivAirCity have examined all the above input and integrated the most relevant dimensions into the consolidated DivAirCity indicators and metrics considering both understanding social circumstances when beginning activities, monitoring the inclusiveness and diversity of engagement during the project activities and finally, the social impact and access to benefits of the project at the end.

4.2. Latest research on environmental indicators

This section presents the compiled research which was carried out resulting in additional environmental indicators being discovered. Firstly, the indicators relating to air quality are defined, followed by biodiversity indicators and finally flooding indicators. The indicators which have titles coloured red are ones which were not prioritised under the task indicator selection.

4.2.1 Air quality indicators at district/city scale

CAQI – Common Air Quality Index

The CAQI (Airly, 2022) was born out of a desire to easily compare air quality across the EU and warn citizens of the dangers of exceedingly high levels of pollution. The calculation of the air quality index is as follows. It is a number on a scale from 0 to 100, and the higher the number the worse the air quality is. The index is further divided into both hourly and daily versions, and also separated depending on where measurements are being taken (“roadside” vs “background”). The two mandatory measurements for

the “roadside” CAQI are NO_2 and PM10 (particulate matter less than or equal to 10 µm in diameter), with O_3 also required for the “background” index. The five qualitative categories that correspond to the index range from “very low” for values from 0 to 25 to “very high” for values that exceed 100. **CAQI is included as one of the main indicators in the DivAirCity project (see chapter 5).**

EAQLVcity - Exceedance of air quality limit value – City scale

The EAQLVcity indicator shows the fraction of the urban population that is potentially exposed to ambient air concentrations of pollutants in excess of the EU limit value set for the protection of human health (European Environment Agency, 2014). The urban population considered is the total number of people living in cities with at least one monitoring station at a background location. The population data applied for the indicator derives from the urban audit, which is conducted at the initiative of the directorate-general for regional policy at the European Commission, in cooperation with Eurostat and the national statistical offices of the 27 current member states.

Currently, the urban audit involves more than 620 European cities in 30 EEA member countries. The urban audit contains data for over 250 indicators across nine domains (e.g., demography, social aspects, environment, travel and transport). The urban audit aims at a balanced and representative sample of cities in Europe.

To obtain such a selection, a few simple rules are applied: 1. Approximately 20% of the national population should be covered by the urban audit. 2. All capital cities were included. 3. Where possible, regional capitals were included. 4. Both large (more than 250 000 inhabitants) and medium-sized cities (minimum 50 000 and maximum 250 000 inhabitants) were included. 5. The selected cities should be geographically dispersed within each member atate. The selection of cities was prepared in close collaboration between the directorate-general for regional policy, Eurostat and the national statistical institutes.

To ensure that large and medium-sized cities are equally represented in the urban audit, in some of the larger member states not all large cities could be included. The urban audit works with three different spatial levels: the core city, the larger urban zone (LUZ) and the sub-city district (SCD). For CSI 004 only the core city level is considered, which is the most important level. To ensure that this level is directly relevant to policy makers and politicians, political boundaries were used to define the city level. In many countries these boundaries are clearly established and well-known.

As a result, for most cities the boundary used in the urban audit corresponds to the general perception of that city. Due to the highly diverse nature of political boundaries in the European Union, for some cities the political boundary does not correspond to the general perception of that city. In a few cities, Dublin for example, the political boundary of the city is narrower than the general perception of that city.

Exceedance of air quality limit values occurs when the concentration of air pollutants exceeds the limit values specified in the first Daughter Directive of the Air Quality Framework Directive for SO_2, PM_{10}, NO_2 and the target values for O_3 as specified in the third Daughter Directive. Where there are multiple limit values the indicator uses the most stringent case: Sulphur dioxide (SO_2): the daily limit value; Nitrogen dioxide (NO_2): the annual limit value; Particulate matter (PM_{10}): the daily limit value; Ozone (O_3): the target value. 'Ambient air' shall mean outdoor air in the troposphere, excluding workplaces. 'Pollutant' shall mean any substance introduced directly or indirectly by man into the ambient air and likely to have harmful effects on human health and/or the environment as a whole. 'PM_{10} ' shall mean particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 microgram aerodynamic diameter.

This indicator has not been added to the consolidated list as it is only relevant for some cities and not measuring a key impact for DivAirCity.

EAQLVlocal - Exceedance of air quality limit value – Local scale

Air quality is understood as an indicator which gives an account of the presence of substances or compounds in the air which can present a potential risk to the environment and to the health of the population exposed to them. It can be expressed by concentrations of a pollutant or as quality indices referring to a pollutant (FDES, 2013).

The statistics are measured in terms of local air quality, as these pollutants, by virtue of their source or of having a very short atmospheric lifetime, are only encountered in appreciable concentrations close to where they are emitted. This methodology sheet includes examples of target concentration levels for the air pollutants, which are those given by WHO Europe in its Air Quality Guidelines. However, national, and regional bodies may well have their own targets or legally acceptable concentration levels.

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

AAPCV - Annual amount of pollutants captured by vegetation

The regional removal of pollutants by deposition on vegetation in urban areas (Janhäll, 2015) has been calculated from reported deposition velocities and averaged concentrations, together with measured or estimated vegetation surface areas. Due to large spatial variability of both vegetation surface area and air pollutant concentrations, averaging problems are common. The main conclusion from the paper is that the vegetation effects are complex and this means that when planning urban greening, some consideration to the many possible variations have to be taken into account. The review paper ends, indeed, with a series of practical considerations about

how to plan urban greening. **Carbon storage in vegetation and in soil is included in the DivAirCity indicators.**

Air pollution in front and behind a vegetation barrier

Air pollution concentration measured in front and behind a vegetation barrier (used e.g., Ottosen & Kumar, 2020; Hagler et al. 2012 and Lin et al. 2016). This is a metric often used for studying e.g., roadside hedges, where the difference between the front and back of the barrier can be easily measured (e.g., with a low-cost sensor). The disadvantage of this method is that it is difficult to assess, which part of the difference being caused by the vegetation barrier and part of the difference being caused by the difference in distance to the road of the two sensors.

Meteorologically normalized air quality measurements

Meteorologically normalized air quality measurements are common ways to assess temporal changes in air quality (e.g., as a result of an intervention). This has been used to study the effect of COVID-19 on air quality (Ceballos-Santos et al. 2021). **There is no evidence though that this has been used for studying the effect of temporary vegetation interventions – but this would be a good argument for trying it out.**

Wearable air quality exposure

Air quality exposure measured using wearable instrumentation. This metric is particularly suitable for e.g., route-to-school studies and similar, where you assess the difference between peoples usual commuting route and an “air quality friendly” route. This has been used in e.g. Breathe London (Varaden et al. 2019). Breathe London is an air quality monitoring project that maps and monitors air pollution across London to guide citizens in appropriate behaviour and direct air quality improving investments to where it will generate the best possible effect. This is a good metric since it measures the most health relevant parameter namely “exposure”. On the other hand, this metric also requires more work in terms of recruitment of participants, ensuring ethical & privacy compliances, working with mobile equipment, etc. **A few indicators using wearable instrumentation such as ‘Concentration of particulate matter at respiration height along roads’ are selected. The detailed methodology will be devised through the consultation with citizens in co-creation process.**

4.2.2 Green Space management indicators

UGSP - Urban Green Space Proportion

Urban green space is represented by open-space areas reserved for parks and other "green spaces", including plant life, water areas and other kinds of natural environment

(WHO, 2017). Most urban open spaces are green spaces, but occasionally include other kinds of open areas. The landscape of urban open spaces can range from playing fields to highly maintained environments to relatively natural landscapes.

The European Commission has acknowledged the need for mapping and assessment of the urban ecosystems' condition and their services as matter of significance as it is estimated that almost three out of four EU citizens live in urban areas and this number will further grow (Maes et al, 2018).

The 4th Mapping and Assessment of Urban Ecosystems (MAES) report (Maes et al., 2016) of the European Commission, exclusively deals with the urban ecosystems and provides some guidelines for their mapping and assessment. This report suggests three types of indicators:

1. pressure indicators,
2. Ecosystem Condition Indicators (ECI)
3. indicators for measuring urban biodiversity.

One of the most important Ecosystem Condition Indicators being referred to also as a Structural ecosystem attribute is indicated by the Urban Green Space Proportion (UGSP) or percentage of natural area within the city boundaries. In Maes et al, 2018 it is indicated that "The share of urban green space and the percentage of natural areas are key structural indicators".

A city can be regarded as a city core and as a Larger Urban Zone (LUZ). As an example, for Bucharest, Kourdounouli, 2018, calculated an UGSP=1.66%.

Consistent negative association was found by Kondo et al, 2018, between urban green space exposure and mortality, heart rate, and violence, and positive association with attention, mood, and physical activity. Results were mixed, or no association was found, in studies of urban green space exposure and general health, weight status, depression, and stress (via cortisol concentration).

In another study, Nutsford et al, 2017, found that decreased distance to usable green space and increased proportion of green space within the larger neighbourhood were associated with decreased anxiety/mood disorder treatment counts in an urban environment. This suggests the benefits of green space on mental health may relate both to active participation in usable green spaces near to the home and observable green space in the neighbourhood environment.

An interesting review study conducted on US and Chinese literature, revealed that parks and open space and other forms of green space can also provide essential services that are critical to both urban ecological functioning and integrity (Wolch et al, 2014). Urban green space is also an environmental justice issue, given that in many cities, low-income neighbourhoods and disadvantaged communities —places where public health challenges tend to be the most critical — often have relatively poor access to safe and well – maintained parks and other types of open space. Being 'just

green enough' demands a careful balancing act. It involves collaborations between local government and disparate community groups, and a willingness of local stakeholders to contest powerful real estate interests and mainstream environmental advocates. But the active involvement of urban planners, designers, and ecologists is also essential, to articulate strategies for urban green space that explicitly advance public health, environmental equity, and social justice in urban communities.

Urban Green Space Proportion is essential indicator to monitor the accessibility of green space. **Along with the other indicators such as connectivity and accessibility, Urban Green Space Proportion is selected in DivAirCity indicators.**

Green View Index

Concerning green space and biodiversity, a (relatively) simple way to assess whether a given neighbourhood is green or grey, is the Green View Index (Li et al. 2015). This is easy to apply, since the calculations are based on Google Street View images, and thus represent what people "see" when they walk through a given neighbourhood. Regarding the visual access to green view, **the Normalised Difference Vegetation index (NDVI) and Visual access to green space indicators are selected in DivAirCity project.**

PSL - Land Use and associated impacts on biodiversity

The potential species loss (PSL) from land use represents regional species loss taking into account the effect of land occupation displacing entirely or reducing the species which would otherwise exist on that land, the relative abundance of those species within the ecoregion, and the overall global threat level for the affected species. The indicator can be applied both as a regional indicator (PSLreg), where changes in relative species abundance within the ecoregion is included, and as a global indicator (PSLglo), where also the threat level of the species on a global scale is included. The indicator covers 5 taxonomic groups: birds, mammals, reptiles, amphibians and vascular plants (Canals, 2016).

The change in land use, for example from brownfield to green areas by adding vegetated brownfield to Urban Green Infrastructure resource) and accounting for configuration like individual gardens, groups of gardens and socio-economic factors will impact on the utility of private gardens for native biodiversity conservation (Connop et al, 2020).

Land use types covered by the method include intensive forestry, extensive forestry, annual crops, permanent crops, pasture and urban land.

For the DivAirCity project we have decided to work with the Shannon Diversity Index which also allows to measure the diversity of species in a community.

Denoted as H, this index is calculated as:

$$H = -\Sigma pi * \ln(pi)$$

where:

- Σ: A Greek symbol that means “sum”
- ln: Natural log
- pi: The proportion of the entire community made up of species i

The higher the value of H, the higher the diversity of species in a particular community. The lower the value of H, the lower the diversity. A value of H = 0 indicates a community that only has one species.

Biodiversity is another important impact which the DivAirCity expect through the NBS interventions. The Shannon Diversity index is included to monitor the biodiversity.

CGS - Connectivity of green spaces

In urban planning research, the concept of green infrastructure has gained a lot of interest in the last years, especially in the context of sustainable urban development (Mell, 2017). More importantly, the idea of a planning concept for green infrastructure builds on a set of principles that define its specific differences, which diverge from open space or green belt planning. The two most highlighted principles are multifunctionality and connectivity of green spaces (Grădinaru et al, 2018; Lennon, Scott, 2014).

Connectivity of green spaces is an important part of transforming a city into an ecosystem. It is very important for conservation across a city. Connectivity is an important measure of the function of green space, both in terms of trail linkages for people, and for corridors for movement among core habitats (Sudbury, 2010).

Habitat fragmentation, or the loss of connectivity due to clearing, is one of the greatest threats to biodiversity in modern cities. Connectivity of our natural land is vital for the movement of animals, plant pollen and seeds to maintain healthy resilient populations able to adapt to threats such as climate change. Green areas can relate to a mixture of native trees, shrubs and groundcover. This will increase biodiversity, provide wildlife corridors, shade, and public access to green spaces. Conserved or restored vegetation corridors need to be large enough and undisturbed to enable species to have refuge and safely move between patches of vegetation. ‘Buffer zones’ on the edges of vegetation corridors can provide homes for wildlife and beautiful places for all our communities to enjoy. This includes riparian zones, where the land meets the river. Riparian zones are nature’s corridors and often support unique wildlife. The protection and restoration of modern cities riparian zones will ensure a greater variety of native plants, birds and other animals, and contribute to the health and wellbeing of the rivers and of the people.

Connectivity at one level can be a measure of whether a green space is physically linked to other near-by green space. It is preferred that areas to be connected where possible, especially the community, regional, natural, ecological reserve, and linear type parks (which may themselves act as connectors) (Sudbury, 2010).

Connectivity of landscapes can be evaluated in terms of: Structural connectivity – relating to the spatial configuration of patches, without considering the movement of individual organisms among these patches (Ioja et al. 2014) and Functional connectivity – relating to the ability of organisms to move among patches (Tischendorf and Fahrig 2000). Both types of connectivity can be quantified using metrics that span different ranges of scale and complexity. Structural connectivity is measured by the proximity of blue-green spaces and the infrastructure matrix that these form across a city. These are typically measured through a blue-green space mapping exercise that orientates and measures distribution and proximity on a city or regional level (Zhang et al. 2019). Typically, such mapping is done using the interrogation of satellite imagery and or land use maps. Functional connectivity is measured in relation to the ability of the landscape to support the movement of living organisms through it (Peer et al. 2011). Similarly, to biodiversity, lack of blue-green space connectivity can also present a barrier to the movement of humans through urban areas (Ioja et al. 2014), particularly in relation to the use of active transport and physical activity (Connop et al, 2020).

A comparative approach to three European city regions was carried out by Rusche et al, 2019, namely Greater Manchester, Greater Copenhagen, and the Ruhr Area. The study clearly demonstrates different perceptions of the general relationship between nature and the built environment in all three cases. Compared to the Manchester and Copenhagen areas, the Ruhr area shows a more even distribution of the connectivity of green spaces as a result of the use of greening policies and programs extensively, especially since the 1980s to change the perception of being a steel and coal mining region with structural economic problems.

Methods for measuring connectivity are based on the spatial thresholds for the group and activity of interest. The most basic method to achieve this is to use Geographical Information Systems (GIS) to apply buffer areas to mapped blue-green spaces that are known to be suitable for the target group and activity (Connop et al, 2020).

Evaluation of blue-green space structural and functional connectivity can be used to: Underpin green infrastructure and biodiversity spatial planning; Prioritise sites for interventions; Assess impacts of NBS projects on pre-existing green networks; Promote active transport initiatives (Connop et al, 2020).

The connectivity of green spaces is chosen as an important indicator for DivAirCity project. The calculation methos will be developed through the consultation with technical stakeholders along with the city participants based on this latest review on the connectivity indicator.

CED - Cumulative Energy Demand

Environmental life cycle assessment (LCA) is today an important methodology to quantify the life cycle based environmental impacts of products, services, or organisations. Since the very first LCA studies, the cumulative energy demand CED (also called 'primary energy consumption') has been one of the key indicators being addressed. Despite its popularity, there is no harmonised approach yet and the standards and guidelines define the cumulative energy demand differently. In this paper, an overview of existing and applied life cycle-based energy indicators and a unifying approach to establish characterisation factors for the cumulative energy demand indicator are provided. The CED approaches are illustrated in a building's LCA case study.

Cumulative energy demand has been used as a methodology to assess life cycle environmental impacts of commodity production since the early seventies. This article compares the cumulative energy demand of 498 commodities with the results of six frequently applied environmental life cycle impact assessment methodologies.

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

BEN - Buildings Energy needs

A great recent challenge has been to reach world climate-neutrality by 2050, and at this moment, with the buildings sector still being responsible for 40% of greenhouse gas emissions and 36% of final global energy consumption, it is clear that perspectives must change.

While the total final energy consumption of the global buildings sector remained at the same level in 2019 compared to the previous year, CO2 emissions from the operation of buildings have increased to their highest level yet at around 10 GtCO2, or 28% of total global energy-related CO2 emissions. With the inclusion of emissions from the buildings construction industry, this share increases to 38% of total global energy-related CO2 emissions. The slightly lower proportion of buildings emissions compared with the 39% seen in 2018 was due to the increases in transport and other industry emissions relative to buildings.

The indicators related to the building energy efficiency such as building ages and building energy rating have been selected for DivAirCity to tackle these aspects of energy consumption issues.

4.2.3 Water management indicators

PFvar - Peak Flow variation

Description: The peak flow is the maximum value of the flowrate due to a given rain event. It indicates how much the discharge in a river, or a stormwater network is impacted by the use of NBS.

Definition: Peak flow variation is defined by the relative error in peak flow between the peak flow of the catchment with NBS and the peak flow of a catchment without NBS (% (but flow rates are in l/s or l/s/ha (in case of different catchments comparison)).

Measurement procedure and tool: This indicator will directly assess the impact of NBS in the reduction of the flow rate, which peak flow is a characteristic value. This indicator can be calculated as the average value of a sample of peak flows deduced from a rain/runoff time series (typically one year) and may be obtained with observed runoff (if pre- and post- NBS setting is available) or simulated runoff (Nature4Cities, D2.1). It can be calculated by HYDRUS-1D/2D, URBS, and TEBHydro, models respectively at the object, neighbourhood and city scales (Nature4Cities, D2.2). Data required for the estimation of the indicator have to be calculated either from a model, or from monitoring. In case of model estimation, it requires input data provided by national meteorological services (typically rainfall and potential evapotranspiration). Once meteorological data is available, calculation makes it necessary to run the appropriate hydrological model. Then the indicator can be estimated from the model results by standard software. Nature4Cities built a simplified model for the early-stage assessment of this indicator called PFVar (Nature4Cities, D2.4). The PFVar highlights the peak flow variation between two stages with or without NBS. It is expressed in percentage and is calculated for gardens and parks, street trees and greenroofs. For the two later, the calculation needs more evaluation. Such a KPI indicates how much the discharge in a river or a stormwater network is impacted by the use of NBS based on the study of two spatial scales (catchment and city) by the mean of two different urban hydrological models. The model URBS (Rodriguez et al, 2008) was applied at the catchment scale while the model TEBHydro (Stavropulos-Lafaille et al, 2018) was applied at the City-scale. An equation is deduced from regression method for each following studied NBS: Gardens and parks; Street tree scenarios; Green Roofs. Database used to build the model is composed of data that were collected during the project VegDUD (financed by the French research agency from 2010 to 2013) and measured data from ONEVU (Nantes Urban Environment Observatory) (Nature4Cities, D2.3).

Strengths and weaknesses: This indicator will directly assess the impact of NBS in the reduction of the flowrate, which peak flow is a characteristic value.

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

WQ – Stormwater quality

The growing impact of urban stormwater on surface-water quality has illuminated the need for more accurate modelling of stormwater pollution. Water quality-based regulation and the movement towards integrated urban water management place a similar demand for improved stormwater quality model predictions. The physical, chemical, and biological processes that affect stormwater quality need to be better understood and simulated, while acknowledging the costs and benefits that such complex modelling entails. There are three approaches to stormwater quality modelling: deterministic, stochastic, and hybrid. Hybrid approaches show strong potential for reducing stormwater quality model prediction error and uncertainty. Improved stormwater quality models will have wide ranging benefits for combined sewer overflow management, total maximum daily load development, best management practice design, land-use change impact assessment, water quality trading, and integrated modelling.

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

TROvol - Total runoff volume (Runoff Coefficient – flood management)

The extent of impermeable surfaces in urban areas is continually increasing as cities develop and expand, due to the construction of buildings, roads, streets, parking lots, etc. A significant consequence is greater runoff in urban areas, which can also lead to flooding. Many factors are affecting the quantity of surface runoff, including soil 133 characteristics (whether soil has a crusty surface or acts as a sponge), land use and vegetative cover, hillslope, and storm properties such as rainfall duration, amount, and intensity (Sitterson et al. 2017).

In general, surface runoff is generated in two ways (Yang, Li, Sun & Ni, 2014): through saturation excess, where runoff is generated when the soil becomes saturated (for example after a lengthy period of rainfall); or, through infiltration excess, where runoff is generated when the rainfall intensity exceeds the infiltration rate of water into the soil, for example, during a heavy precipitation event when rain falls more rapidly than it can infiltrate the soil.

Total runoff volume is selected as the indicator in order to monitor the impact of DivAirCity interventions regarding flood management.

TRFvol Total rainfall volume – flood management

In terms of volume, with a rainfall of 10 mm, every square metre of the field receives 0.01 m, or 10 litres, of rain water. With a rainfall of 1 mm, every square metre receives

1 litre of rain water. A rainfall of 1 mm supplies 0.001 m^3, or 1 litre of water to each square metre of the field. Thus 1 ha receives 10 000 litres.

Example:

- The total amount of water received by a field of 5 ha under a rainfall of 15 mm:
- Each hectare (10 000 m^2) receives 10 000 m^2 x 0.015 m = 150 m^3 of water. Thus, the total amount of water received by the 5 hectares is: 5 x 150 m = 750 m

Rainfall is often expressed in millimetres per day (mm/day) which represents the total depth of rainwater (mm), over a period of 24 hours. **Rainfall volume in each of the DivAirCity participating cities will obviously impact on the way NBS should be designed and to what extent they should also address access to clean water and controlling stormwater/torrential rain.**

RRR - Total runoff/Total rainfall ratio

For reasons explained before, the use of runoff coefficients which have been derived for watersheds in other geographical locations should be avoided for the design of a water harvesting scheme. Also, runoff coefficients for large watersheds should not be applied to small catchment areas.

An analysis of the rainfall-runoff relationship and subsequently an assessment of relevant runoff coefficients should best be based on actual, simultaneous measurements of both rainfall and runoff in the project area.

As explained above, the runoff coefficient from an individual rainstorm is defined as runoff divided by the corresponding rainfall both expressed as depth over catchment area (mm).

Actual measurements should be carried out until a representative range is obtained. Shanan and Tadmor recommend that at least 2 years should be spent to measure rainfall and runoff data before any larger construction programme starts. Such a time span would in any case be justified bearing in mind the negative demonstration effects a water harvesting project would have if the structures were seriously damaged or destroyed already during the first rainstorm because the design was based on erroneous runoff coefficients.

When plotting the runoff coefficients against the relevant rainfall depths a satisfactory correlation is usually observed (see **Figure 4**).

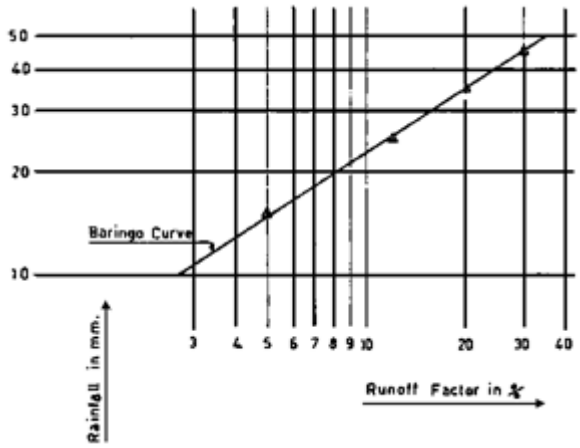


Figure 4: Rainfall-runoff relationships, Baringo, Kenya (Source: Finkel 1987)

A much better relationship would be obtained if in addition to rainfall depth the corresponding rainstorm intensity, the rainstorm duration and the antecedent soil moisture were also measured. This would allow rainstorm events to be grouped according to their average intensity and their antecedent soil moisture and to plot the runoff coefficients against the relevant rainfall durations separately for different intensities.

Rainfall intensities can be accurately measured by means of a continuously recording autographic rain gauge.

It is also possible to time the length of individual rainstorms and to calculate the average intensities by dividing the measured rainfall depths by the corresponding duration of the storms.

When analysing the measured data, it will be noted that a certain amount of rainfall is always required before any runoff occurs. This amount, usually referred to as threshold rainfall, represents the initial losses due to interception and depression storage as well as to meet the initially high infiltration losses.

The threshold rainfall depends on the physical characteristics of the area and varies from catchment to catchment. In areas with only sparse vegetation and where the land is very regularly shaped, the threshold rainfall may be only in the range of 3 mm while in other catchments this value can easily exceed 12 mm, particularly where the prevailing soils have a high infiltration capacity. The fact that the threshold rainfall has first to be surpassed explains why not every rainstorm produces runoff. This is important to know when assessing the annual runoff-coefficient of a catchment area.

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

FAV - Variation of flooded area

Flood mapping based on remote sensing is divided into three main steps: 1. The detection of the flooded area, which can be performed using a manual or a semiautomatic mapping approach: a) manual mapping which consists of the direct visual interpretation of the images (SAR amplitude or colour combinations of multispectral bands). In this case, the flooded areas were drawn manually directly on the georeferenced satellite images in QGIS software; 54 b) with the semi-automatic approach, which can help to produce an automatic flooded area map in raster format. The map can be extracted from SAR or multispectral satellite data using different methodologies such as band index, supervised classification or backscattering difference. In this step, an empirical threshold to detect flooded areas can be used; for this reason, it is not a fully automatic approach. 2. A possible improvement and refinement of manual and automatic detection which could be made using a cloud mask and permanent water body (from ancillary data or pre-flood images). Thus, additional information should be considered such as (a) water depth model derived from DEM, e.g., Shuttle Radar Topography Mission (SRTM) and ASTER, can be also used to estimate flood-prone areas (b) hillshade and aerial photos to detect the geomorphological features, and (c) ancillary data such as georeferenced photos or documents found on the web to have ground information about the flooded area extent. These data allow the creation of an improved final version of flooded area maps, manually drawn, both for the semi-automatic and manual approaches. 3. The flood map validation. This step is performed only when official flood maps or field survey maps are available. These maps should be used to evaluate the quality of the flooded area maps and in particular the performance of semi-automatic mapping (flood ratio and not flood ratio).

This indicator has not been added to the consolidated list however will be considered again in the later phases of the project.

WDT - Water Detention Time

Detention time is the length of time water is retained in a vessel or basin or the period from the time the water enters a settling basin until it flows out the other end. When calculating unit process detention times, we are calculating the length of time it takes the water to flow through that unit process. Detention times are normally calculated for the following basins or tanks:

1. Flash mix chambers (seconds)
2. Flocculation basins (minutes)
3. Sedimentation tanks or clarifiers (hours)
4. Wastewater ponds (days)
5. Oxidation ditches (hours)

To calculate the detention period of a basin, the volume of the basin must first be obtained with the formula:

$$V = L \times W \times D$$

Detention time is calculated in units of time, most commonly seconds, minutes, hours or days (MECC, 2022). The flow rate used in the calculation should have the same time frame, for example if detention time is desired in hours, then the flow rate used in the calculation should be cfh or gph.

The simplest way to calculate detention time is to divide the volume of the container by the flow rate into the container. The theoretical detention time of a container is the same as the amount of time it would take to fill the container if it were empty. For volume, the most common units used are gallons. Time units will be in whatever units are used to express the flow. For example, if the flow is in gpm, the detention time will be in days. This can be calculated using the following formula:

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} \qquad * \textit{Units must be compatible}$$

Figure 5: Detention time calculation

Detention time is included in the indicators for DivAirCity project along with total runoff volume to monitor water management impact of NBS interventions that will be implemented through DivAirCity project.

4.3. Latest research on economic indicators

In this subsection, we examine the latest research in relation to economic indicators focusing on the NBS cost and cost avoidance indicators, health economic impacts, leverage investment impact indicators of DivAirCity activities as well as potential employment benefits of DivAirCity activities.

(Amann et al. 2017) emphasize how general societal productivity can be affected by air pollution:

- Effects of short term (acute) exposure on morbidity, leading to an inability to attend work
- Effects leading to reduced performance at work (presenteeism)
- Reduction in the size of the labour force through impacts on mortality
- Inability to work through longer term health issues (e.g., associated with cardiovascular or respiratory illness)

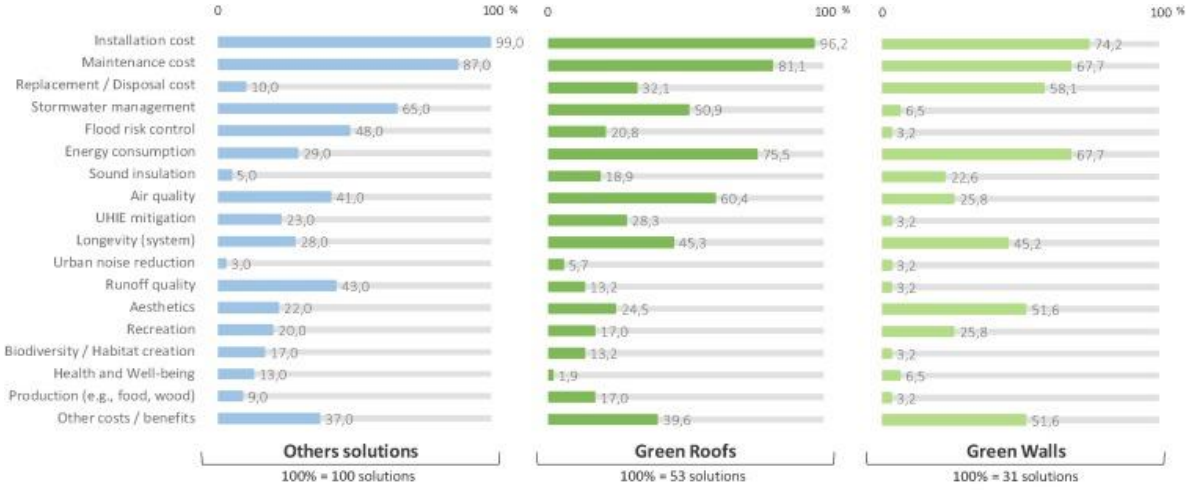
According to Amann et al. (2017) “Existing analysis for the European Commission for the CBA is limited to the first of these mechanisms.”

The consideration of spatial and temporal scale of the DivAirCity interventions will be important for the relevance of certain indicators and metrics. Most interventions will only have a minor economic impact beyond the spatial scale where they are located. It will thus be important that the relevant indicators are calculated on the same scale as the intervention. E.g., if job creation is only measured at the city scale, it will not be possible to use this indicator to measure the effect of an intervention in a specific neighbourhood or street.

This is also relevant about temporal scale, where indicators reacting slowly to changes (e.g., house prices or businesses started) will be difficult to use for an intervention happening over a shorter time scale.

The indicators need to be reconsidered and corrected in relation to other influencing factors. E.g., if a city is experiencing economic growth, new businesses will open. It will be difficult to assess how many of these new businesses result from the intervention and how many result from the general growth of the city.

In terms of literature on the costs and benefits of NBS, a good resource is a review by Teotonio et al. (2021) which is on economics of green roofs and walls, but may be applied to NBS in general (see **Figure 6**.). As can be seen from figure 6 in this study, there is no standard way to include all costs and benefits of a given NBS intervention. In the supplementary material of this paper, references to papers who evaluate the economics of air quality of NBS effects can be found.



Note: Total data = 1.102. Figure represents the costs and benefits examined in the 184 case studies.

Figure 6: Costs and benefits of NBS (Teotonio et al. 2021)

A recent study (Im et al. 2018) has examined the health and external cost impacts of air pollution with the modelled surface concentrations of O3, CO, SO2 and PM2.5 used

as input to the Economic Valuation of Air Pollution (EVA). Health impacts estimated by using concentration inputs from different chemistry–transport models (CTMs) to the EVA system may vary up to a factor of 3 in Europe (12 models examined). In Europe, the multi-model mean total number of premature deaths (acute and chronic) is calculated to be 414 000, which is in agreement with previous global and regional studies. The economic valuation of these health impacts is calculated to be EUR 145 billion in Europe. A total of 54 000 premature deaths can be avoided by a 20 % reduction of global anthropogenic emissions in Europe.

5 Consolidated structure of indicators and metrics in DivAirCity

From the literature review and review of existing project results, the consolidated impacts, indicators, and metrics structure was developed. It reflects the multi-dimensional aspects of DivAirCity by including three impact areas, co-creation phases and cities to support each co-creation stage. The resulting indicators and metrics structure is the “ideal” structure given the latest state of the art and the expected impact assessments required at project and city levels in DivAirCity.

The indicators have been suggested by technical stakeholders and city partners from both theoretical and practical viewpoints. The initial full list has been narrowed down into indicators which are presented in this section. In the selection processes, four main criteria were applied:

- the crucial indicators to provide data regarding air quality and 6+1 groups;
- the indicators contributing to inclusive governance;
- the indicators which are relevant to all five cities;
- the indicators to provide the data for target impacts (see page 9).

This initial selection process was conducted before validating the practicality based on the consultation with each city. In other words, these selected sets include both indicators that can easily be completed through the existing data and that might be challenging to collect but important. Through the future validation task, these selected sets of indicators will also contribute to identifying the data gap between the data which already exists and the data required for addressing equal access for diverse members of society to healthy air quality.

Table 11: DivAirCity data cluster structure

	Co-creation phases				
Impact areas	**A) Understanding & establishing co-creation**	**B) Define & co-designing**	**C) Materialising & co-implementing**	**D) Ensuring sustainability**	**E) Co-monitoring**
Impact area 1. Social	*Data cluster 1.1.* People and governance indicators	*Data cluster 1.2.* Participation and governance dynamic indicators			*Data cluster 1.3.* Social monitoring indicators
Impact area 2. Environmental	*Data cluster 2.1.* Urban assets & infrastructure indicators	*Data cluster 2.2.* Urban environmental dynamic indicators and metrics			*Data cluster 2.3.* Urban environmental monitoring indicators
Impact area 3. Economic	*Data cluster 3.1.* Economic indicators	*Data cluster 3.2.* Economic dynamic indicators			*Data cluster 3.3.* Economic monitoring indicators

5.1. Data cluster 1.1. People and governance indicators

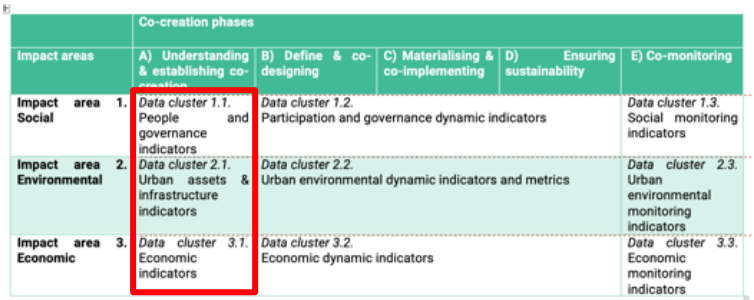


Figure 7: Data clusters in phase 1

The indicators in data cluster 1.1., 2.1., and 3.1, — in other words, the indicators in co-creation phase 1— are supporting the identifying process of current urban challenges and assets. The indicators mainly use the existing secondary data such as Census data. The unstructured public document including planning documents and national survey reports can be used.

Table 12: People and governance indicators in co-creation phase 1 (understanding & establishing co-creation)

Indicators	Metrics
Actors available	Total number and list of relevant NGOs in city/city district
	Number of schools and kindergardens in city district & just outside city district
	Number of children living in district and going to kinder garden or school inside/just outside city district and living outside district but going to school/kindergarden inside district
	Proportion of different stakeholders and population groups 6+1 participating in the discovery phase co-creation activities (measured in tick off participation – to the extent that it is impossible to identify individuals)
Participatory culture	Total number and list of existing relevant action plans in the cities (air quality action plan. Sustainable energy and climate action plan, Action plans in place Carbon emissions of the transport infrastructure and industry
	Citizens' perception of control and influence over NBS and relevant decision-making
	Citizens trust in decision-making procedure and public decision-makers
	Citizen participation/volunteering in co-governance task force/board for city DivAirCity projects (composition according to 6+1 and consistency of members)
	Existence of relevant public private partnerships to support participatory processes

	Experience with citizens science activities at city/district level – citizens having participated in citizens science; stakeholder with co-governance of citizens science projects.
Population composition	Total population in city/district
	Population density (population per square meter)
	Female/male proportion of population
	Proportion of population under 15 years of age
	Proportion of population of 60 years or older
	Proportion of population with ethnic minority background
	Breakdown of population by income brackets
	Breakdown of population by current occupation
	Breakdown of population by educational background
Digital inclusion: Access to technology	Frequency and intensity of use of technology
	Internet connection type
	Data allowance and speed
	Types of devices owned in household
Digital Inclusion: Affordability of technology	percentage of household income required to pay a standard price for a bundle of goods to ensure 'good' connection
Digital inclusion: Digital ability	Skills on a 1-10 scale at basic operational, advanced operational, information navigation, social, creative and automation processes.

5.2. Data cluster 1.2. Participation and governance dynamic indicators

Dynamic indicators cover data that emerge during the co-creation phases. While participants defining, developing, and delivering the DivAirCity activities, the data about participation and governance are collected. These data sets will help project technical stakeholders and facilitators to understand the processes. The indicators such as the per cent of participants and their perception evaluate the inclusive decision-making processes.

The define & co-designing phase is the beginning of participatory data collections. The participatory assessment on green spaces such as users and use of green spaces contribute to identifying local issues further and provide data that are not available in the large-scale statistics and public data. This process of filling the gap in the data is crucial to understanding diverse social members which the DivAirCity project aims to include.

Table 13: People and governance indicators in co-creation phase 2 (define & co-designing)

Indicators	Metrics
Target audiences for the NBS to be designed	% of target audiences engaged in the co-creation phase 2
	Representation of the target audiences in the co-creation phase 2 (Proportion and types of participating civic society organisations and related social groups)
Users and use of green spaces for diversity	Number and variety of users accessing the public space (5 Likert scale survey)
	Number and variety of activities observed in the public space among time and space (5 Likert scale survey)
Comfort and safety of green spaces for diversity	Perception of safety & level of security of the public space (5 Likert scale survey)
	Overall comfort using the public space, through maintenance, design and ambiental conditions with respect to 6+1 groups (5 Likert scale survey)
	Presence of a public space identity, defined by cultural background and users' enjoyment with respect to 6+1 groups (5 Likert scale survey)
Level of digital participation	Stats on populations digital access allowing for online participation vs actual digital participation measured during processes.
	Number of green blockchain contracts downloaded following intervention.
Accessibility of green spaces	Accessibility of urban green space assessed by participants and the demographic categories of participants (5 Likert scale survey)
	The routes taken between residential areas and schools

The data about participants in co-creation processes is collected throughout the phases. Some target impacts, for example, stakeholders' engagement via co-creation, which is mentioned on page 9 requires the data collection with participants in co-creation processes. In the materialising & co-implementing phase, the inclusive decision-making to implement the intervention in the next phase, ensuring sustainability, is crucial.

Table 14: People and governance indicators in co-creation phase 3 (materialising & co-implementing)

Indicators	Metrics
Co-governance in development of NBS	Perceived control and influence over decision-making in respect to the types of stakeholders (survey of participants)
	% of target audiences engaged in the co-creation phase 3

Target audiences for the NBS to be validated	Representation of the target audiences in the co-creation phase 3

The per cent of target audiences, 6+1 groups, is collected in the ensuring sustainability phase as well. Additionally, the evaluation of users beyond the participants in the co-governance process can be important.

Table 15: People and governance indicators in co-creation phase 4 (ensuring sustainability)

Indicators	Metrics
Target audiences for the NBS to be implemented	% of target audiences engaged in the co- creation phase 4
	Representation of the target audiences in the co- creation phase 4
	Representation of the target audiences among the users of the implemented NBS

5.3. Data cluster 1.3. Social monitoring indicators

Monitoring indicators are selected and devised to monitor the impacts of DivAirCity interventions. In the social cluster, the health and well-being impacts of city interventions are the main parts to be monitored.

Table 16: Social monitoring indicators in co-creation phase 5 (co-monitoring)

Indicators	Metrics
Green intelligence awareness	Calculated as the Quantify the number of activities, publications or campaigns focused on the enhancement of green intelligence awareness per year, related to an NBS.
Income and work	Income average and Income average of diverse groups
	% of unemployment and % of unemployment according to the 6+1 groups
Place attachment	Survey on Place Identity Scale
Visual access to green space	Self-reported amount of green space in the view from windows at home and the frequency of looking at the view
Safety and security	Crime counts in the neighbourhood
	Perceived crime level
	percentage of citizens feeling safe
Social inclusion and diversity	The number of citizens who experienced discrimination regarding ethnicity and nationality

Walkability	Normalized index indicating the degree of walkability on a scale from highly walkable to least walkable
Air quality indicators: short term health effects	Estimated number of preterm deaths due to ozone short-term exposure in urban areas (O3)
Air quality indicators: long term health effect	Estimated number of deaths in age group 30+ associated with long-term exposure to urban background levels of PM2.5 and NO2
Morbidity, Mortality and Years of Life Lost due to poor air quality	(Morbidity): Long-term (annual) incidence of chronic bronchitis due to poor air quality calculated using atmospheric NO2 and PM10 data (Mortality): Long-term (annual) incidence of mortality due to poor air quality calculated using atmospheric PM2.5, PM10, O3 and NO2 data
Level of chronic stress	Level of chronic stress (Perceived stress) measured using LEDS or STRAIN questionnaire surveys/interviews
Heat induced mortality	The Heat induced mortality indicates the number of deaths associated with temperatures above the 75th percentile of daily mean temperature during summer months (Apr-Sep).
health monitoring of diverse groups	respiratory diseases (e.g., asthma) of BAME
	Proportion of population with obesity for children measured in BMI
	Estimated change to Morbidity, Mortality and Years of Life Lost of 6+1 groups due to air quality
Health inequalities during the COVID-19 pandemic	Questionnaire responses to build a picture of why some groups are more vulnerable than others and why this may have been worsened by the pandemic.
Gender Equality in Work and COVID-19 Deaths	Different statistics regarding the gender disaggregated impact of COVID-19
Likelihood of dying from COVID-19 compared to white ethnicity	Percentage of deaths per ethnic group as a proportion of that group's incidence in the population
Perceived Health	Individuals' self-assessment of their health

5.4. Data cluster 2.1. Urban assets & infrastructure indicators

There are data to understand each city's physical built and natural environment before designing DivAirCity interventions. For example, existing green infrastructure and building quality are important to identify the areas that were less accessible to clean air, and it might be strongly linked to the residential areas where the socially disadvantaged groups inhabit. Those data such as building quality will not be subject to be continuously monitored after the interventions since they are not affected by the planned interventions differently from other indicators in data cluster 2.3. However, they can be essential contextual data to initiate co-creation.

Table 17: Urban assets & infrastructure indicators in co-creation phase 1 (understanding & establishing co-creation)

Indicators	Metrics
Building quality	Average age of buildings and composition of built environment age in the designated districts
Connectivity of green space	Calculation of connectivity of green space from GIS data from 1 (very low) to 5 (very high)
Green space management	Distribution of public green space: Per capita public space in the neighbourhood (m^2)
Residential Building quality & space	Proportion of household buildings with poor energy efficiency rating
	Correlated indoor and outdoor air quality measurements (O3, CO and PM2.5)

5.5. Data cluster 2.2. Urban environmental dynamic indicators and metrics

indicators that are collected during the co-creation phases. The information about existing NBS is collected in the first stage of the co-creation process.

Table 18: Urban assets & infrastructure dynamic indicators in co-creation phase 2 (Define & co-designing)

Indicators	Metrics
Existing NBS	CO2 absorption capacity of current tree population in city district

In Materialising & co-implementing, the data from newly implemented DivAirCity interventions are formed.

Table 19: Urban assets & infrastructure dynamic indicators in co-creation phase 3 (Materialising & co-implementing)

Indicators	Metrics
Prototypes tested in city districts	Number of constructed NBS prototypes tested in city districts of different types

After the implementation, changes to the size and distribution of green infrastructure are important data that can be generated through the co-creation process.

Table 20: Urban assets & infrastructure dynamic indicators in co-creation phase 4 (Ensuring sustainability)

Indicators	Metrics
Changes to the size and distribution of public green space	Changes to proportion of population in designated area not living within ten minutes walking from public green space (before and after the interventions)
	Changes in terms of conversion of paved area to green areas in the project areas (before and after the interventions)

5.6. Data cluster 2.3. Urban environmental monitoring indicators

The urban environmental monitoring indicators have been selected to observe the impacts of DivAirCity interventions. Those indicators include both expected direct and indirect impacts.

Table 21: Urban environmental monitoring indicators in co-creation phase 5 (co-monitoring)

Indicators	Metrics
Air pollutant levels	Removal of atmospheric pollutants by vegetation
	Change in air pollution - changes in concentrations in PM, NO2, O3, SO2
Air quality for diverse groups	Percentage of children ages 0 to 17 years living in neighbourhoods with pollutant concentrations above the

	levels of the current air quality standards (by race/ethnicity and by family income)
	Percentage of days with good, moderate, or unhealthy air quality for children ages 0 to 17 years (by race/ethnicity and by family income)
Concentration of particulate matter at respiration height along roadways and streets	The concentration of PM2.5 and PM10, respectively, per cubic metre of air (units µg m-3) at a measuring height of 1.5 m above the ground surface, or height of wheelchair users and children, to represent the air quality experienced by citizens
Avoided GHG emissions	The total amount of greenhouse gas emissions avoided as a result of implementation of NBS
Biodiversity	Number of species within defined area per Shannon Diversity Index
Carbon storage in vegetation and in soil	Increase of biomass in vegetation as tonnes of carbon stored
Common Air Quality Index	The two mandatory measurements for the 'roadside' CAQI are NO2 and PM10 (particulate matter less than or equal to 10 µm in diameter), with O3 also required for the 'background' index. The five qualitative categories that correspond to the index range from "very low" for values from 0 to 25 to "very high" for values that exceed 100.
Ecosystem Health and Integrity	Normalised Difference Vegetation index (NDVI): quantifies vegetation by measuring the difference between near-infrared and red light by using satellite images
Number of days in which air quality parameters exceed threshold values	Number of days in which air quality parameters exceed threshold values
Proportion of population exposed to ambient air pollution	Urban population exposed to air pollutant concentrations above EU standards and WHO air quality guidelines
Sustainable transport	Percentage of each mode of transportation (i.e. private, public, bicycles, pedestrians, availability of car-sharing solutions, availability of bicycles and eScooter renting services)
	Rush hour periods / traffic density periods for key roads in and out of city

Protection of water resource and environment	Total runoff volume
	Water detention time

5.7. Data cluster 3.2. Economic dynamic indicators Impact area

A few indicators are formed in the co-creation phases. For example, the initial cost and payback period according to that is important to investigate the cost and benefit of DivAirCity interventions.

Table 22: Economic dynamic indicators in co-creation phase 4 (Ensuring sustainability)

Indicators	Metrics
Initial costs of NBS implementation	Estimated initial cost (€)
Payback period for NBS	Initial Investment divided by Net Cash Flow per Period

5.8. Economic monitoring indicators

Economic indicators are mainly monitoring the direct and indirect impact of DivAirCity interventions. Valuation of DivAirCity interventions relies on the direct impacts including avoided costs from expanded green infrastructure and indirect impacts like health costs. Housing prices might be indirectly influenced by the interventions. It is also an important indicator in order to monitor potential gentrification issues.

Table 23: Economic multi-stage co-monitoring indicators (co-monitoring)

Indicators	Metrics
Avoided costs due to NBS implementation	The costs of the damages, which events could provoke without the expected intervention
	The value of each net tonne of CO2 reduced in the city districts due to DivAirCity interventions
	The value of energy use savings due to green infrastructure implementation
Maintenance costs of NBS	Cost estimates or actual cost reporting from entitles administering the NBS and sub-contractors

Valuation of NBS	Value of NBS using GI-Val toolkit. The toolkit provides a set of calculator tools and standard valuation techniques to assess the potential benefits provided by green infrastructure within a defined project area
Fluctuation of house pricing index over time	Housing price per m^2
	Potential number of properties benefiting from new green space created and green space enhanced
	Property value uplift, apportioned between new green space created and green space enhanced
Health cost as a consequence of air pollution	Using existing studies of standardised cost estimates and combining them with local air pollution data
Number of new businesses created and gross value added to local economy	Number of business created= n * Z [(nº business) (€/m2)]
	Gross value added: total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.
Number of new jobs created	Direct value on employment by zone, before and after implementation, during the established period.
Public spending on bioeconomy	Rate of Direct public spending on bioeconomy in the DivAirCity district excluding the direct funding
Energy consumption and cost of operation of blockchain	Total cost of operation of DivAirCity Smart Cities Climate Contracts against the benefit
	Total energy consumption of DivAirCity Smart Cities Climate Contracts against the energy saving through the project
	Energy consumption of DivAirCity Smart Cities Climate Contracts against the average energy consumption of blockchain

In the following chapter, this indicators and metrics structure will be validated up against the targets and requirements in each of the five cities as well as the likely feasibility of gathering the necessary data to.

6 Validation of DivAirCity city data up against system

Upon deciding the indicators which are theoretically the best for the project's purpose, it was then important to understand the feasibility and usefulness of these for each of the cities. The final step was therefore to validate the indicators against the data sources which the cities had access to, or which could feasibly be collected within the timescale of the project. This validation process will have several further iterations throughout the project. As the temporary and permanent Living Labs (WP4) and co-creation processes are initiated and developed, the feasibility and data gaps will be further identified.

This document examines the selected indicators in a linkage with the existing city visions and their expected impacts. In the initial phase of the DivAirCity project, the assessment of the infrastructure, culture and possibilities in each of the five cities are conducted. These documents, namely the City DNAs, provided an overview of existing city objectives and the contexts of cities including ecosystems and their citizens. Each city's DNAs and public data sources were therefore consulted, and later in the Data Framework process the result will be a consolidated checklist of indicators which can be provided, for each city. This chapter presents the first phase of this process, which can be summarised as an overview of each city's intervention plan and the type of indicators which they are interested in or see as useful.

6.1. Aarhus

Based on an initial understanding of the city of Aarhus's needs, the following section outlines the main targets, intervention ideas and goals. This is by no means a final assessment of the data needs for Aarhus and thus should be treated as a work in progress.

City target

Aarhus has identified 6 broad targets for the project which are:

1 A great city for everyone
2 A city of growth and a strong business environment
3 A sustainable city with great urban- and local environments
4 A city of community and citizenship
5 A city where everyone is healthy and thriving
6 A city where everyone is needed

A member of the Covenant of Mayors, Aarhus has a goal of reaching carbon neutrality by 2030

Identified DivAirCity interventions

Identified DivAirCity interventions for Aarhus are:

1) Test of therapy type-gardens including plants that are particularly efficient in absorbing CO2 and are able to grow and flourish in the Danish climate,
2) 'Benches with a green purpose'
3) Temporary Park in the City Lab area by the harbour front
4) Reduce traffic in hot-spot areas in inner city by banning the areas from cars by placing big flowerpots strategical places.

DivAirCity expected impacts

Expected impacts in Aarhus through DivAirCity project are:

Cleaner air, active citizenship with IoT, lowered CO2-emissions, greening of the city, a heightened sense of belonging and feeling safe in the streets among the citizens.

The Aarhus group of partners have considered the indicator and metrics in relation to the DNA and targets for the Aarhus DivAirCity project. The reflections are as follows:

Social

People and governance indicators

Aarhus has an integration policy specified which has the main goal of inclusive citizenship. Within this, there are 4 focus areas of intervention:

1) Inclusive citizenship and anti-discrimination
2) Education
3) Employment
4) Housing

Within this, specific initiatives include an aim for the ethnic minority employee rate to reflect the share of ethnic minority people in the total population.

Participation and governance dynamic indicators

Aarhus acknowledges that people belonging to the LGBTI community are at greater risk of vulnerability and dissatisfaction than the rest of the population; they therefore have a vision that everyone in Aarhus has access to equal opportunities to participate in society, and that no one should experience discrimination. This is evidenced in the Action Plan to Promote Security, Well-being and Equal Opportunities for LGBTI people, a 2018 document detailing a three-year plan to bring this vision to fruition.

Within this plan, there are 6 main areas of initiatives which will be addressed:

1) Advice, network and support for LGBTI people
2) Promoting openness and inclusion in the labour market
3) Combatting prejudice among young people and promoting openness in education
4) Combatting homophobia and transphobia in the public sphere and sport
5) Strengthening knowledge and advice in healthcare and elderly care.
6) International responsibility and cooperation.

6.2. Bucharest

Identified DivAirCity interventions

Bucharest city partners aim at:

1) building open streets for citizens
2) reducing the car traffic
3) enhancing social networking
4) Reconverting the green areas around the existing block of flats
5) implementing a cultural centre for the community inside a university campus.

DivAirCity expected impacts

Through these interventions, Bucharest DivAirCity interventions will put together different social communities. All the actions will involve members of the district communities leading towards a better knowledge and understanding of each other. The wellbeing of the global community will increase, the air quality will be improved when reducing car traffic and when increasing the green areas.

For Bucharest interventions, the location of existing blocks of flats and connectivity of green spaces can be important data.

6.3. Castellón

City target

Castellon city has identified these targets:

1) low-carbon society
2) Innovation in Quality of Life
3) promotion of social inclusion
4) fight against poverty

Identified DivAirCity interventions

In order to meet these targets, Castellon city partners shaped the initial ideas about DivAirCity interventions. First, they aim to improve *Marjaleria* which is a swampy land which have a problem of flooding through DivAirCity's nature-based solutions. Second, through the intervention they aim at lowering traffic in main city streets related to improving green spaces in the streets. Third, Castellon city partners plan to implement green roof in a public building.

DivAirCity expected impacts

Through these interventions, Castellon city partners expect to achieve enhanced social inclusion through innovative nature-based solution.

Castellon city partners, Castellon Living Lab, is centered around the integration of NBS in policies and innovative public procurement to solve urban challenges. With the intervention are that is located closely to the petrochemical industry which has been impacting the AQ in the area, the interventions will target urban transformation through NBS to reduce human exposure to pollution, improve AQ and decarbonisation, and increase social justice and inclusion.

Prior to the DivAirCity, Castellon developed a project which consisted in the urban transformation of one of the most important streets in Castellon. The project was focused on decarbonisation and obtained European structural funds to implement it. Bipolaire was the technical team that planned and designed the project. Bipolaire used several practical indicators that were very useful for the city and for the citizens and the city used them to explain the project and its benefits.

Castellon City is participating in UNaLab (Urban Nature Labs). The project evaluates the impact of the NBS in the UNaLab front-runner cities first involved iterative co-definition of Key Performance Indicators (KPIs) and Key Impact Indicators (KIIs) with a wide range of stakeholders.

Regarding specific indicators for decarbonization, Bipolaire have identified the following KPIs that could be measured in Castellón pilot (see **Appendix 5**). For each of the indicators, Bipolaire have introduced the data and material required and data input type, where available.

The indicators which had been used in Castellon were integrated into the DivAirCity indicators. When it comes to the indicators, the water management indicators can be important in Castellon DivAirCity interventions since they particularly aim to improve the swampy land. Some related indicators are not selected in the shortlist in chapter 5 because they are note relevant to other cities, but other potential flood management related indicators are included in longlist (see **Appendix 7**). Heat related indicators can be useful for Castellon when we consider the city context.

6.4. Orvieto

City target

Orvieto city partners aim at improving both citizen health and to limit pollutant and greenhouse gas emissions through the DivAirCity project. Nature-based solutions are expected to alleviate and mitigate these problems.

Identified DivAirCity interventions

To be more specific, Orvieto city partners aim to build a green belt by focusing on two areas, *Scalo* and *Ciconia*. Those areas are located in the valley of the Paglia river and

separated by the main national motorway and two train lines. Both areas have significant issue due to the traffic. Due to that, there have been some modifications of the car circulation with new roads connecting these two parts of the city. Moreover, along the Paglia river, following the flooding occurred in November 2012 consolidation has been performed with the aim to secure the embankments.

A green intervention along the part of the connecting roads between Orvieto Scalo and Ciconia will connect these two separated parts. The two areas of the city are currently divided by the river, the train line, and the motorway.

DivAirCity expected impacts

Through this intervention, Orvieto city partners expected to contribute to the actions already in place to restore full connection in the area. It will reduce the level of air pollution in that area interested by the main connection roads and by a quite high level of traffic and offer a more pleasant environment for citizens by improving shade effects and decreasing temperature perception in hot summer days through the intervention. Furthermore, nature-based solutions will positively impact on the local biodiversity through actions planned in the project. A reduction in the air pollution can be done by the avoidance of using cars and by planting trees. These DivAirCity activities are expected to increase awareness of the citizens toward air pollution issues, achieved by involving them in the practical measurement process.

To meet the expected impacts which are initially identified, the indicators related to the traffic might be crucial in Orvieto city interventions. For example, there are air quality indicators which are more general city level data, but more specific data collection such as 'concentration of particulate matter at respiration height along roadways and streets' can be useful in Orvieto (see page 62). The number of traffic and the correlation between the reduced cardon emission need to be monitored with a particular attention in Orvieto.

In addition, since Orvieto city interventions aim to build a long green pathway, the health impact which can be expected from the walkability is also important to monitor. Social inclusion such as enhanced accessibility to green spaces of diverse groups through this improved connectivity can be one of the expected impacts.

6.5. Potsdam

City target

City's visions and goals that are related to the DivAirCity project had been identified in the Postdam through the initial investigation, City DNAs. For example, the Potsdam Master Plan included the goal of '100% Climate Protection until 2050' (). Regarding the goal to build an inclusive city, Potsdam government established 'edict of Tolerance

for an open and tolerant city' through eight months consultation with citizens (2008). The new edict is based on the historical edict of Potsdam (1685).

Tolerance means for the people of Potsdam:

- respect and acceptance of the other
- approaching each other and getting into conversation
- being able to listen
- experiencing differences as enrichment
- to deal with conflicts in a civil manner
- to replace exclusion with integration
- combine tolerance and solidarity
- to not permit mobbing, violence, xenophobia and political extremism.

Both inclusion of diversity and climate action are recognised as important city targets in Potsdam.

Within this context, the initial ideas about DivAirCity interventions in Potsdam are shaped by Potsdam city partners. First, temporary co-curated gardens during Temporary Living Labs, can improve the air quality, biodiversity, and social inclusion. Potsdam city partners also aim at improving permanent retrofit of common outdoor areas in existing social housing districts. The goal is to establish a bottom-up network of "green-spots", based on a sharing system of facilities and local produce (e.g. urban farming products), with a strong component of social inclusion and education across all the diversity categories.

Through this intervention, Potsdam city partners expect to reduce CO2 and enhance the participation of citizens.

The Potsdam group of partners have considered the indicator and metrics in relation to the DNA and targets for the Potsdam DivAirCity project. The reflections are as follows:

Social

People and governance indicators

Possible stakeholders and the cultures of participation are very important to Potsdam with regard to the 6+1 categories. Influencing potential decisions on NBS measures and key decisions that affect their context are important building blocks for participation per se and the basis for empowerment. Participation processes are the foundation for the project and require a high level of attention.

Potsdam finds it important to expand the opportunities for participation in the participation processes through digital formats. Through digital accessibility for participants, Potsdam can make it possible for people who want to avoid social contacts or who with difficulty, for health reasons, can only participate in public or

semi-public events to be part of our project. For young people, it could make participation more attractive.

Participation and governance dynamic indicators

The proportion and composition of the target groups is an important component of the project; Potsdam has very heterogeneous users and resident structures both in the Rechenzentrum (TLL) and at Schlaatz (PLL). It is important to Potsdam to be able to reflect this diversity in the project work for phases 2, 3 and 4.

Besides the many qualities that urban green space has, the question of appropriation and use is a question of how safe and comfortable the individual users feel. Therefore, the indicators 'Overall comfort using the public' and 'Presence of public space identity' are important to Potsdam.

Social monitoring indicators

The financial and professional situation of residents and users is fundamental for drawing conclusions about possible connections in terms of air quality or access to urban green space.

Environmental

Urban Assets & Infrastructure indicators

Green spaces and their accessibility play an essential role in the area at Schlaatz (PLL) and the Rechenzentrum (TLL). Potsdam is a very green city, but the urban nature is not evenly distributed over the entire urban area.

The proportion of community gardens is interesting to Potsdam, as it could be used to make statements about the perception of the importance of the qualities of community spaces among the public and on the part of the initiators, and how much attention some areas receive.

The accessibility by public transport and motorized private transport is also fundamental. Potsdam has a good public transport structure. Nevertheless, the share of motorised individual traffic is still high.

Urban environmental dynamic indicators

Accessibility to urban green spaces plays a major role, especially in the Schlaatz district, which has a high degree of diversity among its residents. The green spaces have very large qualitative differences and could therefore appeal to or repel different users.

The amount of CO2 absorption with the help of the current stock of urban green spaces in the district would be interesting to have as a starting point for calculations of possible further CO2 absorption.

Urban environmental monitoring indicators

According to current experience and research, natural hazards will increase as a result of climate change. Finding out when and which groups of people could be affected and where dangers threaten helps to prevent these dangers.

An evaluation of the air quality in comparison to the EU standards is an important point of investigation for Potsdam. On which days and which times are there high levels of pollution and how severe is it?

Economic

Economic monitoring indicators

Prevention of high costs by NBS is an important indicator in terms of its social importance, but also in terms of its possibilities of saving costs of the city, housing cooperatives and lower burden on residents.

7 Conclusion

When considering the relevant KPIs and metrics which will be used throughout the entire DivAirCity project, it is important to consider many indicators from a wide variety of sources. This is particularly true given the project's aim of using diversity as a resource; many experts and partners were consulted to incorporate as many unique indicators as possible, on the basis that hearing as many voices as possible is an asset to the project. This document has outlined the methodologies which were used throughout this process to ensure wide participation in line with the project's objectives. The project focuses on the reduction of the effects of air pollution in an inclusive way by utilizing the diversity present in cities. In particular this is expected to benefit those with diverse starting points representing the most vulnerable groups and inclusive co-creation processes covering the four phases discover, define, develop and deliver.

As a starting point, this document focuses on the social, environmental and economic impact targets specified by the project. We have analysed the impacts expected from project activities and intervention results, by specifying indicators and metrics used to achieve the three main objectives:

- To qualify the opportunities and obstacles of each of the participating cities,
- To measure the diversity and inclusion levels through the processes, and
- To measure the impact of activities and NBS interventions on social, environmental and economic dimensions.

Indicators and metrics have been studied from existing European projects and inspiration has been taken from impact indicators summarized in the European Handbook for evaluation of NBS impact. Additionally, we have examined open-source data access opportunities that may be used to supplement other secondary and primary data within the project.

Furthermore, we have conducted a literature review which examines the latest research in relation to NBS impact evaluation, decarbonization and air quality improvement, as well as the impacts of improved diversity and inclusion in citizen engagement, participatory processes, and access to benefits of DivAirCity activities and project results.

The above analysis led to an extensive list of indicators and metrics that have been prioritized according to their relevance up against the specified impact targets as well as the likelihood of being able to measure the impact within the period of the project.

In chapter six, we have summarised the indicators and metrics considered necessary to fulfill the impact targets of the project during and after activities and interventions. On top of the short list of prioritized indicators and metrics, participating cities may

apply additional indicators and metrics according to their specific requirements and conditions. These additional impact measurements may cover potential side benefits of interventions such as the reduction of negative effects of heat waves, torrential rain and storm water.

The prioritized list of indicators and metrics are still considered to be a work in progress. The project will require further reflection as the co-creation processes begin and the city projects start developing. Further analysis of available data and possibilities of primary data gathering sources and methods may lead to a change in the currently specified indicators and metrics. Furthermore, as the project starts developing, the planned indices further indicator and metrics requirements may be identified to ensure completeness and coverage of the indices.

The current prioritized list of indicators and metrics will allow the project to measure progress up against the specified impact targets both during the co-creation processes as well as when results have been achieved.

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9 Annex: Literature review

9.1.1 Decarbonisation and inclusion/diversity

https://mdpi-res.com/d_attachment/environsciproc/environsciproc-11-00021/article_deploy/environsciproc-11-00021.pdf

- This paper presents a KPI-Driven Sustainable Evaluation Framework for Smart Cities. ed. It defines several categories under which KPIs have been identified and defined. These categories are energy and environment, mobility, urban infrastructures (including the digitalization of the city through the ICTs and urban data platform deployment), citizens, economy and governance.
- The indicators are part of the EU project My smart life which has also defined data sets used for evaluation via this deliverable: Deliverable_D5.2_M36_FINAL (mysmartlife.eu) and the baseline measurement carried out for one of three participation cities: D2.1_Baseline_report_of_Nantes_demonstration_area.pdf (mysmartlife.eu)

https://journal-buildingscities.org/articles/10.5334/bc.33/

- This paper presents carbon metrics for cities and suggests production and consumption implications for policies. It introduces a relationship analysis between three carbon accounting methods—a production-based approach (PBA), a consumption-based approach (CBA) and a community-wide infrastructure footprint approach (CIFA) – and Scopes 1–3, and the definition of functional system boundaries. An excel is made available for further analysis.

https://mdpi-res.com/d_attachment/sustainability/sustainability-13-08836/article_deploy/sustainability-13-08836.pdf

- Towards an Integrated Approach to Urban Decarbonisation in Practice: The Case of Vitoria-Gasteiz. This is not so much interesting because of the data and indicator approach but more interesting in terms of strategy and participatory intervention model.

https://enveurope.springeropen.com/articles/10.1186/s12302-020-00450-2 (March 2021)

- Urban population exposure to air pollution in Europe over the last decades. This paper reviews the progress made towards meeting the air quality standards

established by the EU Ambient Air Quality Directives (European Council Directive 2008/50/EC) and the World Health Organization (WHO) Air Quality Guidelines by estimating the trends (Mann-Kendal test) in national emissions of main air pollutants, urban population exposure to air pollution, and in mortality related to exposure to ambient fine particles (PM2.5) and tropospheric ozone (O3). It provides trends in national emissions for all EU countries for the period up until 2017 up against standards.

The impact of outdoor air pollution on COVID-19: a review of evidence from in vitro, animal, and human studies | European Respiratory Society (ersjournals.com)

- This study examines the impact of outdoor air pollution on COVID-19: a review of evidence from *in vitro*, animal, and human studies.

https://www.iied.org/can-we-reduce-urban-poverty-inequality-achieve-net-zero-cities

- An exciting new initiative with parallels to DivAirCity and partners are supporting climate actions to deliver inclusive, zero-carbon cities.
- It aims to do pilot interventions in low-income neighbourhoods which might include the use of sustainable materials and building practices that maximise natural light and airflow or more greening public spaces to combat the urban heat island effect, improve air quality and extend the social and psychological benefits of green space throughout the city.

https://www.gla.ac.uk/media/Media_758106_smxx.pdf

- This paper presents pathways to Socially Inclusive Decarbonisation. It is less relevant for KPI and metrics definition but more so for strategy and intervention.

https://mdpi-res.com/d_attachment/proceedings/proceedings-65-00020/article_deploy/proceedings-65-00020.pdf

- This paper presents lessons learned on Collaborative Approach of Positive Energy Districts from the EU Horizon2020 Smart Cities and Communities Projects. It indicates possible paths towards Energy Citizenship for a Just and Inclusive Transition.

https://urbact.eu/nine-ways-for-more-just-and-inclusive-cities

- This article introduces nine good practices for cities in relation to developing more just and inclusive cities. The nine ways are 1) Boosting social inclusion through music; 2) Encourage volunteering; 3) commit to inclusion and tolerance; 4) Celebrate local heritage through storytelling; 5) Co-manage city assets; 6) Empower neighbourhood partnerships; 7) Engage with citizens

through play and gaming; 8) Build Municipality-NGO collaboration; 9) Welcome international talent.

9.1.2 Diversity and air pollution

https://link.springer.com/chapter/10.1007/978-3-030-58278-4_14

- Inclusiveness and Diversity in Citizen Science – this paper analyses the current situation of several projects and initiatives within the Citizen Science COST Action CA15212 and the Horizon 2020 SwafS programme. It examines the data and discusses the main factors that encourage or hinder inclusiveness. It recommends ways of achieving plural participation in citizen science activities and reflect on how research is improved when diverse citizens are used as in-the-field experts. It demonstrates how research questions can be fine-tuned and how research impacts are enhanced through citizen participation, with a focus on gender representation.

https://www.mdpi.com/2071-1050/13/19/11006/htm

- This paper explores the roles and practices of collective citizen engagement in spatial planning. Drawing on a selection of core articles in planning scholarship, it investigates how citizens (re-)shape urban places by responding to perceived flaws in how spatial planning addresses societal challenges. Formal planning interventions are often spatially and socially selective, ineffective, or even non-existent due to a lack of institutional capacities and resources.

https://www.unicef.org/mena/media/8401/file/19218_MinimumQuality-Report_v07_RC_002.pdf.pdf

- This document offers minimum quality standards for community engagement covering core community engagement standards, standards for supporting implementation, supporting coordination and integration; and resource mobilization. Several of the detailed standards can be turned into qualitative indicators.

https://media.tghn.org/uploads/articles/attachments/UNICEF_Community_Engagement_Indicators_DRAFT.pdf

- This paper suggests the Community Engagement Score → Community Engagement Results & Outcomes The Community Engagement Power Index → Magnitude of Actions for Minimum Standards The Community Engagement Process Index → Community Engagement Process
- It suggests a community engagement scorecard template that DIVAIRCITY can build on and provides examples of possible indicators to use.

https://www.witpress.com/Secure/elibrary/papers/SC21/SC21024FU1.pdf

- This paper proposes evaluative framework for citizen engagement in urban planning and builds on the https://www.opengovpartnership.org/ogp-participation-co-creation-standards/ It suggests actions and indicators for each standard.

https://www.itu.int/en/ITU-D/Regional-Presence/AsiaPacific/Documents/Module%203%20Smart%20Sustainable%20Cities%20KPIs%20Draft%20H.pdf

- Key Performance Indicators (KPIs) and Standards for Smart Sustainable Cities covers several relevant factors for DIvAirCity. It covers:
- Information and Communication Technology
- Environmental sustainability
- Productivity
- Quality of life
- Equity and social inclusion
- Physical infrastructure

U4SSC-CollectionMethodologyforKPIfoSSC-2017.pdf (unece.org)

- This document details how the data is collected for the smart sustainable cities measurement up against standards and indicators.

IRIS D1.1: Report on the list of selected KPIs for each Transition Track (irissmartcities.eu)

- This report describes selected KPIs for each Transition Track" of the IRIS project (started in 2017).
- Each KPI is presented in a detailed table (KPI card) that contains the following elements: description (including justification), calculation formula, unit of measurement, measurement procedure, object(s) of assessment, involved stakeholders and responsible IRIS partner for data collection.

https://datadrivenlab.org/wp-content/uploads/2018/12/2018_UESI_Full_Report.pdf

- This interesting document details the **Urban Environment and Social Inclusion Index**. It is a project by Data-Driven Yale, in collaboration with the Samuel Center for Social Connectedness.
- It builds on SDG 11 and seeks to empower urban residents, providing tools that enable them to track their neighborhood's access to environmental benefits and burdens relative to other city districts. An open snapshot of a city's environmental performance provides a shared starting point and frame of reference for residents and policymakers as they identify environmental management priorities and develop management strategies to meet these goals.
- It introduces data at several levels from parcels via neighbourhoods to regions in cities. A four-quadrant plot examines relationship between environmental

performance (in terms of z-score for a neighborhood's average performance on the UESI indicators) and z-score of logged income.

- And it has a special focus on Air pollution and tree canopy etc. Indicators in the index are:
- NO2
- PM2.5
- PM2.5 Exceedance
- Proximity to Public Transit
- Public Transit Coverage
- Tree Cover per Capita
- Tree Cover Loss
- Urban Heat Island
- Water Stress
- Wastewater Treatment
- Climate Policy
- Distribution of income
- It uses Lorenz and concentration curves to analyze the distribution of income and environmental outcomes (Air Pollution, as measured through Average Exposure to PM2.5 and NO2; Urban Heat Island Intensity; Distance to Public Transit; and Tree Cover per capita) respectively, and for each city.

https://ensia.com/articles/urban-nature-environmental-justice-maginalized-underrepresented-communities/

https://www.frontiersin.org/articles/10.3389/frsc.2021.670190/full

- This paper examines the environmental Justice and Green Infrastructure in the Ruhr district in Germany. It compares distributive to Institutional Conceptions of Justice. It has highly relevant elements for DivAirCity but lacks important diversity and inclusion dimensions.

https://www.outdoors.org/resources/amc-outdoors/conservation-and-climate/an-unfair-burden-why-environmental-justice-means-cleaner-air-for-cities-like-chelsea-mass/

- This paper introduces the environmental justice term. It also addresses the importance of covid 19 in relation to environmental justice. It uses the EJ index made up of environmental indicators and demographic indicators. See also: https://www.epa.gov/ejscreen/what-ejscreen

https://mdpi-res.com/d_attachment/sustainability/sustainability-13-01201/article_deploy/sustainability-13-01201.pdf

- This paper develops the **just city concept** by describing and discussing key theoretical themes in a politically and justice-oriented analysis of climate change adaptation in cities. It examines case studies of climate change adaptation in three very different city contexts: Port Vila, Baltimore City, and

Karlstad. The authors conclude that the social context with its power asymmetries must be given a central position in understanding the distribution of climate risks and vulnerabilities when studying climate change adaptation in cities from a climate justice perspective.

https://www.nature.com/articles/s41467-021-24892-1

- This paper argues that while green infrastructure has the potential to decrease air pollution and provide other benefits to human health, vegetation alone cannot resolve health disparities related to air pollution injustice. it discusses how unequal access to green infrastructure can limit air quality improvements for marginalized communities and it provides strategies to move forward.

https://www.frontiersin.org/articles/10.3389/frsc.2021.728384/full

https://www.epa.gov/sciencematters/study-finds-exposure-air-pollution-higher-people-color-regardless-region-or-income

- The PICSA index measures environmental inclusiveness and the following report also points to relevant improvements:
- https://www.picsaindex.com/wp-content/uploads/2019/11/Creating-an-Inclusive-Prosperity-Cities-Index-final-PICSA-report_Nov2019.pdf

https://www.pnas.org/content/118/37/e2109249118

- This paper details Local- and regional-scale racial and ethnic disparities in air pollution determined by long-term mobile monitoring

An Evaluation Framework to Assess Multiple Benefits of NBS: Innovative Approaches and KPIs | Emerald Insight

- This is produced via the Clever project and is a relevant and interesting model. Also provides an excel sheet tool for evaluation: sustainability-13-09672-v4.pdf

D1-6_Inclusive participatory process for urban ecosystem restoration_Guidance on gender, cultural, and ethics-related considerations - INTERIM version VF.pdf (interlace-project.eu)

- The project INTERLACE has developed indicators for monitoring inclusive participatory processes for urban ecosystems.

KI0220861ENN.en.pdf and KI0420586ENN.en.pdf

- Evaluating the impact of Nature based solutions. Handbook for practitioners and Methods book. Published March 2021 by European Commission. Covers all aspects of health, economic, social and other impacts of three different categories of NBS (with different levels of eco-system integration and management requirements needed.

An overview of monitoring methods for assessing the performance of nature-based solutions against natural hazards - ScienceDirect

- This paper focuses more on natural disasters and the monitoring of impacts from introducing nature based solutions to avoid these natural disasters. The model used is good and relevant for DivAirCity.

Frontiers | Nature-Based Solutions for Co-mitigation of Air Pollution and Urban Heat in Indian Cities | Sustainable Cities (frontiersin.org)

- Specifically, nature-based solutions for mitigating air pollution in Indian cities focusing on heating issues combined with air pollution.

https://www.researchgate.net/profile/Nadja-Kabisch/publication/303733232_Nature-based_solutions_to_climate_change_mitigation_and_adaptation_in_urban_areas_Perspectives_on_indicators_knowledge_gaps_barriers_and_opportunities_for_action/links/574fda0608ae10b2ec05658f/Nature-based-solutions-to-climate-change-mitigation-and-adaptation-in-urban-areas-Perspectives-on-indicators-knowledge-gaps-barriers-and-opportunities-for-action.pdf

- Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action

Rethinking the urban physical environment for century-long lives: from age-friendly to longevity-ready cities | Nature Aging

- Indicators of age friendly cities.

How measuring different types of air pollutants creates a more holistic picture of air pollution (clarity.io)

- Measuring different types of air pollutants

10 Appendix 1. Urban Doughnut Model Indicators

social and planetary boundaries	2017 version dimensions	UK example	Amsterdam example
Social foundation	Water		Tab water quality
	Food	Adequate diet	The number of households using food banks
	Health	Years of healthy life expectancy Anxiety levels	Obesity Depression and anxiety level
	Education	Adults lacking any formal qualification	
	Income & work	Households below 60% average income -after housing costs People lacking satisfying work	The number of households who applying for the social benefits scheme Local business climate rating
	Peace & justice	Risk of victimization	The number of victims of crimes The number of victims domestic violence
	Political voice	Sense of personal political efficacy	Voter turnover
	Social equity		The sense of control over the lives in low-income neighbourhoods
	Gender equality (Equality in diversity)		The number of citizens who experienced discrimination regarding ethnicity and nationality
	Housing	Overcrowded households	The number of Homelessness The number of home seekers applying social housing City tenants unable to cover their basic needs after paying monthly rent
	Networks	People who have no internet connection due to barriers such as affordability and complexity No indicator identified	Internet access The number of citizens who experiences loneliness The sense of community in their neighbourhood

		Support from family, friends and others	
	Energy	Fuel poverty – 10% or more of income required to be spent on all energy	
Ecological ceiling	Climate change	Consumption of Co2 (MtCO2)	Greenhouse gas emission
	Ocean acidification	% of fish stocks harvested sustainably by UK vessels	
	Chemical pollution	Chemical quality of UK rivers	
	Nitrogen & phosphorus loading	Imports of manufactured nitrogen (MtN) Phosphorous loads in UK rivers	
	Freshwater withdrawals	No data	
	Land conversion	Consumption of land-use change (ha)	
	Biodiversity loss	UK farmland birds index	Total surface of green roofs
	Air pollution	Particulate concentration (PM10)	The number of deaths related to the air quality issues
	Ozone layer depletion	Ozone-depleting substances (ODS)	

11 Appendix 2. UN Her City Toolbox Indicators

	dimension	Subdimension	indicators	Data collection methods
BLOCK 1 Stakeholder Engagement Indicators		Identifying the stakeholders	N/A (not specified in the report)	Existing data (Census)
		Engagement of stakeholders	Types of participants	Survey of participants
			Age bands	Survey of participants
			Gender	Survey of participants
Block 2 City Wide Assessment indicators	Spatial distribution	Land allocated to public space	Land allocated to OPS	Municipality participation in kobo tool (https://www.kobotoolbox.org/)
			Land allocated to Streets	
			Land allocated to OPS in Public Facilities	
		Per capita public space	Per capita open public space	
			Per capita green area	
		Distance to public space	5 minutes walk to public space	
			10 minutes walk to public space	
		Street connectivity	Number of intersection per square kilometer	
			Street length per square kilometer	
			Length of bicycle lane to length of roads (excluding motorways)	
			Length of sidewalks to length of roads (excluding motorways)	
		Network/Distribution of public space	Open public space fragmentation	
			Proximity of one public space to another	
		Land cover dates	Change in green area over time (years)	
			Change in urban extent over time (years)	
			Change in average surface temperature (years)	
	Governance	Finance and Economy	Land value change around public spaces over time	
			Per cent of municipal budget allocated to public space	
		Policy	Presence of public space plans/strategies including action plans	

Block 3 Site Specific Assessment indicators	Use and users	Number and variety of **users** accessing the public space	Survey
		Number and variety of **activities** observed in the public space among time and space	Survey
	Accessibility	Accessibility and presence of qualitative and inclusive facilities for **private vehicles**	Survey
		Accessibility and presence of qualitative and inclusive facilities for **bikes**	Survey
		Accessibility and presence of qualitative and inclusive facilities for **pedestrians**	Survey
		Accessibility and presence of qualitative and inclusive facilities for **public transports**	Survey
	Amenities and furniture	Presence and quality of **lighting**	Survey
		Presence and quality of amenities for **recreational structures**	Survey
		Presence and quality of **seating**	Survey
		Presence and quality of **waste bins**	Survey
		Presence and quality of **bike racks**	Survey
		Presence and quality of **signage** and **emergency items**	Survey
		Presence and quality of water and toilets facilities	Survey
	Comfort and safety	Perception of **safety** & level of **security** of the public space	Survey
		Quality of sensorial experience	Survey
		Overall comfort using the public space, through maintenance, design and ambiental conditions	Survey
		Presence of a public space identity, defined by **cultural background and users' enjoyment**	Survey
	environmental components	Quality of **biodiversity** and **microclimate** conditions in the public space	Survey
		Environmental and community **resilience**	Survey
		Presence of **energy efficient elements** in the public space	Survey

12 Appendix 3. European Commission Handbook on Evaluating the Impact of Nature-Based Solutions Indicators

Societal Challenge	Recommended / Additional	Indicator	Sub-indicator
Climate Resilience	Recommended	1 Carbon removed or stored in vegetation and soil	
		2 Avoided greenhouse gas emissions from reduced building energy consumption	
		3 TXx, Monthly mean value of daily maximum temperature	
		4 TNn, Monthly mean value of daily minimum temperature	
		5 Heatwave Incidence	
	Additional	Carbon storage and sequestration in vegetation	
			1 Carbon storage and sequestration in vegetation per unit area per unit time
			2 Carbon storage and sequestration in vegetation – annual determination
			3 Total Leaf Area
			4 Carbon Storage Score
			5 Measured soil carbon content
			6 Modelled carbon content of the upper soil layer
			7 Soil carbon decomposition rate

		2 Energy use savings due to green infrastructure implementation	
		3 Estimated carbon emissions reduction from building energy saving - cooling	
		4 Energy and CO2 emissions savings from reduced volume of water entering sewers	
		5 Soil Temperature	
		6 Total surface area of wetlands	
		7 Surface area of restored and/or created wetlands	
		8 Aboveground tree biomass	
		9 Human Comfort	
			1 Universal Thermal Climate Index (UTCI)
			2 Thermal Comfort Score (TCS)
			3 Physiological equivalent temperature (PET)
			4 Predicted Mean Vote-Predicted Percentage Dissatisfied (PMV-PPD)
		10 Urban Heat Island Effect	
			Urban Heat Island (UHI) incidence
			Number of combined tropical nights and hot days
			3 Thermal Storage Score
			4 Thermal Load Score
		11 Estimated reduction in peak summer temperature	

		12 Maximum surface cooling	
		13 Mean or peak daytime temperature	
			1 Mean or peak daytime temperature - Direct temperature measurement
			2 Mean or peak daytime temperature - Temperature modelling
		14 Daily Temperature Range (DTR)	
		15 Cooling of ambient air	
			1 Air cooling
			2 Air temperature reduction
		16 Tree shade for local heat reduction	
		17 Rate of evapotranspiration	
		18 Land surface temperature	
		19 Surface reflectance - Albedo	
		20 Estimated carbon emissions from vehicle traffic	
Water Management	Recommended	13 Surface runoff in relation to precipitation quantity	
			1 Direct measurement
			2 Curve Number method
			3 Rational method
			4 Intensity-Duration-Frequency (IDF) curve method
			5 Process-based hydraulic modelling

		14 Water Quality – general urban	
		15 Total Suspended Solids (TSS) content	
		16 Nitrogen and phosphorus concentration or load	
		17 Metal concentration or load	
		18 Total faecal coliform bacteria	
	Additional	13 Measured infiltration rate and capacity	
		14 Calculated infiltration rate and capacity	
		15 Evapotranspiration rate	
		16 Peak flow variation	
		17 Flood peak reduction and delay	
		18 Height of flood peak and time to flood peak measurement	
		19 Flood excess volume (FEV)	
		20 Rainfall interception rate of NBS	
		21 Runoff rate for different rainfall events	
		22 Run-Off Score	
		23 Rainfall storage capacity of NBS	
		24 Quantitative status of groundwater	
		25 Depth to groundwater	
		26 Groundwater chemical status	
		27 Trend in piezometric levels (TPL)	

		28 Groundwater exploitation index (GEI)	
		29 Aquifer surface ratio with excessive nitrate	
		30 Aquifer surface ratio with excessive arsenic	
		31 Water availability for irrigation purposes	
		32 Water Exploitation Index	
		33 Water dependency for food production	
		34 Calculated drinking water provision	
		35 Net surface water availability	
		36 Volume of water removed from water treatment system	
		37 Volume of water slowed down entering sewer system	
		38 Total surface area of wetlands within a defined area	
		39 Total surface area of restored and/or created wetlands	
		40 Soil water flux	
		41 Soil water retention capacity	
		42 Stemflow rate	
		43 Percolation rate under different rainfall events	
		44 Dissolved oxygen (DO) content of NBS effluents	
		45 Eutrophication	
		46 pH of NBS effluents	
		47 Electrical conductivity of NBS effluents	

		48 Water Framework Directive: Physico-chemical quality of surface waters	
		49 Total pollutant discharge to local waterbodies	
		50 Water Quality: basic physical parameters	
		51 Total polycyclic hydrocarbon (PAH) content of NBS effluents	
		52 Total organic carbon (TOC) content of NBS effluents	
		53 General ecological status of surface waters	
		54 Ecological potential for heavily modified or artificial water bodies	
		55 Biological quality of surface waters	
		56 Total number and species richness of aquatic macroinvertebrates	
		57 Morphological Quality Index (MQI)	
		58 Hydromorphological quality of surface waters	
		59 Fluvial Functionality Index	
Natural and Climate Hazards	Recommended	13 Disaster Resilience	
		14 Disaster-risk informed development	
		15 Mean annual direct and indirect losses due to natural and climate hazards	
		16 Risk to critical urban infrastructure	

		17 Mean number of people adversely affected by natural disasters each year	
		18 Multi-hazard early warning	
	Additional	13 Potential areas exposed to risks	
			1 Urban/residential areas
			2 Productive areas
		14 Natural areas, sites of community importance and special protection areas	
		15 Potential population exposed to risks	
			1 Inhabitants
			2 Area and population exposed to flooding
			3 Other people (workers, tourists, homeless)
			4 Elderly, children, disabled
		16 Potential Population Vulnerable to Risks	
			1 Population
		17 Potential buildings exposed to risks	
			1 Housing
			2 Agricultural and industrial buildings
			3 Strategic Buildings (Hospitals, schools, etc.)
		18 Potential infrastructures exposed to risks	
			1 Roads
			2 Railways
			3 Lifelines

		19 Potential infrastructures vulnerable to risks	
			1 Buildings
			2 Transportation infrastructures and lifelines
		20 Insurance against catastrophic events	
		21 Flood hazard	
		22 Flooded area	
		23 Height of flood peak and time to flood peak	
		24 Peak flow rate	
		25 Peak flood volume	
		26 Flood excess volume	
		27 Moisture index	
		28 Flammability index	
		29 Soil Type	
		30 Soil strength	
		31 Soil temperature	
		32 Level of Groundwater Table	
		33 Shallow landslide risk – slope stability factor of safety	
		34 Landslide safety factor	
		35 Landslide risk – History of instability on site	
		36 Occurred landslide area	
		37 Landslide risk – Digital elevation/terrain modelling	
		38 Soil mass movement	
		39 Velocity of occurred landslide	
		40 Erosion risk	

		41 Total Predicted Soil Loss (RUSLE)	
		42 Days with temperature >90th percentile (TX90p)	
		43 Warm spell duration index (WSDI)	
		44 Heatwave incidence	
		45 Human comfort: Universal thermal climate index (UTCI)	
		46 Human comfort: Physiological equivalent temperature (PET)	
		47 Human comfort Predicted Mean Vote-Predicted Percentage Dissatisfied (PMV-PPD)	
		48 Urban Heat Island (UHI) incidence	
		49 Effective drought index	
		50 Standardized Precipitation Index	
		51 Groundwater level	
		52 Trend in piezometric levels (TPL)	
		53 Groundwater exploitation index	
		54 Calculated drinking water provision	
		55 Water Exploitation Index	
		56 Net surface water availability	
		57 Water availability for irrigation purposes	
		58 Avalanche Risk: Snow cover map	
Green Space Management	Recommended	1 Green space accessibility	

		2 Total green space within a defined area: Share of green urban areas	
		3 Soil organic matter	
			1 Soil Organic Matter Index
	Additional	1 Ecosystem service provision	
		2 Annual trend in vegetation cover in urban green infrastructure	
		3 Edge density	
			1 Public green space distribution (applied and EO/RS)
		5 Distribution of blue space	
		6 Effective green infrastructure in the urban-rural interface	
		7 Hot spot in peri-urban green infrastructure	
		8 Biotope Area Factor	
		9 Total vegetation cover	
			1 Woody vegetation cover
			2 Non-woody vegetation cover
			3 Total Leaf Area
		10 Diversity of green space	
		11 Stages of forest stand development -Number of class diameter	
		12 Tree regeneration	
		13 Canopy gaps	
		14 Tree biomass stock change	
		15 Soil carbon content	

			1 Measured soil carbon content
			2 Modelled carbon content of the upper soil layer
			3 Soil carbon to nitrogen ratio
			4 Soil carbon decomposition rate
		16 Soil matric potential	
		17 Soil temperature	
		18 Soil water holding capacity (field capacity)	
		19 Plant-available water	
			1 Plant available soil water
			2 Soil water available for plant uptake (SAW metric)
		20 Vegetation Wilting Point	
		21 Soil water flux and degree of soil saturation	
		22 Stemflow funnelling ratio	
		23 Soil Erodibility	
		24 Total Predicted Soil Loss (RUSLE)	
		25 Soil Ecotoxicological Factor	
		26 Soil structure	
		27 Soil chemical fertility	
		28 Flammability Index	
		29 Community garden area	
		30 Food production in urban allotments and NBS	
		31 Recreational opportunities provided by green infrastructure	
			1 ESTIMAP nature-based recreation model

			2 Number of visitors in new recreational areas
			3 Number of and reasons for visits to an NBS area
			4 Frequency of use of green and blue spaces
			5 Activities allowed in recreational areas
		33 Satisfaction with green and blue spaces	
		34 Betweenness centrality	
		35 Proportion of road network dedicated to pedestrians and/or bicyclists	
			1 New pedestrian, cycling and horse paths
			2 Sustainable transportation modes allowed
		36 New links between urban centres and NBS	
		37 Walkability	
		38 Land composition	
		39 Land use change and green space configuration	
		40 Soil sealing	
		41 Ambient pollen concentration	
Biodiversity Enhancement	Recommended	1 Structural and functional connectivity of urban green and blue spaces	
			1 Structural connectivity of green space
			2 Functional connectivity of urban green and blue spaces
		2 Number of native species	

		3 Number of non-native species introduced	
			1 Number of invasive alien species
		4 Species diversity within defined area per Shannon Diversity Index	
		5 Number of species within defined area per Shannon Evenness Index	
	Additional	1 Proportion of natural areas within a defined urban zone	
		2 Area of habitats restored	
		3 Shannon Diversity Index of habitats	
			1 Abundance of ecotones/Shannon diversity
		4 Length of ecotones	
		5 Publicly accessible green space connectivity	
		6 Ecological integrity	
		7 Proportion of protected areas	
			1 Sites of community importance and special protection areas
			2 Article17 habitat richness
		8 Number of veteran trees per unit area	
		9 Quantity of dead wood per unit area	
		10 Forest habitat fragmentation – Effective Mesh Density	
		11 Extent of habitat for native pollinator species	

		12 Polluted soils	
		13 Soil food web stability	
		14 Modelled C and N cycling in soil	
		15 Equivalent used soil	
		16 Number/proportion of conservation priority species	
		17 Article17 species richness	
		18 Number of native bird species within a defied urban area	
		19 Species diversity – general	
			1City Biodiversity Index
		20 Bird species richness	
		21 Animal species potentially at risk	
		22 Typical vegetation species cover	
		23 Pollinator species presence	
		24 Biodiversity Conservation	
		25 Metagenomic mapping	
			1Abundance of functional groups
			2 Diversity of functional groups (plants)
			3 Diversity of functional groups (animals)
Air Quality	Recommended	1 Number of days during which air quality parameters exceed threshold values	
		2 Proportion of population exposed to ambient air pollution	

		3 European Air Quality Index	
	Additional	1 Removal of atmospheric pollutants by vegetation	
		2 Total particulate matter removed by NBS vegetation	
		3 Modelled O3, SO2, NO2 and CO capture/removal by vegetation	
			1 Total Leaf Area
		4 NOX and PM in gaseous releases	
		5 Ambient pollen concentration	
		6 Trends in NOx and SOx emissions	
		7 Concentration of particulate matter (PM10 and PM2.5), NO2, and O3 in ambient air)	
		8 Concentration of particulate matter at respiration height along roads	
		9 Mean level of exposure to ambient air pollution	
		10 Morbidity, Mortality and Years of Life Lost due to poor air quality	
		11 Avoided costs for air pollution control measures	
Place Regeneration	Recommended	1 Derelict land reclaimed for NBS	
		2 Quantity of blue-green space as ratio to built form	
		3 Perceived quality of urban green, blue and blue-green spaces	
		4 Place attachment (Sense of Place): Place identity	

		5 Recreational value of public green space	
		6 Incorporation of environmental design in buildings	
		7 Preservation of cultural heritage	
	Additional	1 Share of Green Urban Areas	
		2 Land composition	
		3 Land take index	
		4 Area devoted to roads	
		5 Traditional knowledge and uses reclamation	
		6 Traditional events organised in NBS areas	
		7 Social active associations	
		8 Retail and commercial activity in proximity to green space	
		9 Number of new businesses created and gross value added to local economy	
		10 Social return on investment	
		11 Population mobility	
		12 Population growth	
		13 Proportion of elderly residents	
		14 Areal sprawl	
		15 Access to public amenities	
		16 NBS distance from urban centres and public transport	
		17 Natural and cultural sites made available	

		18 Historical and cultural meaning	
		19 Cultural value of blue-green spaces	
		20 Opportunities for tourism	
		21 Building structure – Urban form	
		22 Material used coherence	
		23 Techniques used coherence	
		24 Design for sense of place	
		25 Viewshed	
		26 Scenic sites and landmarks created	
		27 Scenic paths created	
Knowledge and Social Capacity Building for Sustainable Urban Transformation	Recommended	1 Citizen involvement in environmental education activities	
		2 Social learning regarding ecosystems and their functions/services	
		3 Pro-environmental identity	
		4 Pro-environmental behaviour	
	Additional	1 Children involved in environmental educational activities	
		2 Engagement with NBS sites/projects	
		3 Mindfulness	
		4 Proportion of schoolchildren involved in gardening	

		5 Citizens' awareness regarding urban nature and ecosystem services	
		6 Green intelligence awareness	
		7 Positive environmental attitudes motivated by contact with NBS	
		8 Urban farming educational and/or participatory activities	
Participatory Planning and Governance	Recommended	1 Openness of participatory processes	
			1 Openness of participatory processes: proportion of citizens involved
		2 Sense of empowerment: perceived control and influence over decision-making	
		3 Public-private partnerships activated	
		4 Policy learning for mainstreaming NBS	
		5 Trust in decision-making procedure and decision-makers	
	Additional	1 Community involvement in planning	
			1 Citizen involvement in co-creation/co-design of NBS
			2 Stakeholder involvement in co-creation/co-design of NBS
		2 Community involvement in implementation	
		3 Involvement of citizens from traditionally under-represented groups	

		4 Active engagement of citizens in decision-making	
		5 Consciousness of citizenship	
		6 Number of governance innovations adopted	
		7 Adoption of new forms of NBS (co-)financing	
		8 Development of a climate resilience strategy (extent)	
		9 Alignment of climate resilience strategy with UNISDR-defined elements	
		10 Adaptation of local plans and regulations to include NBS	
		11 Perceived ease of governance of NBS	
		12 Diversity of stakeholders involved	
Social Justice and Social Cohesion	Recommended	1 Bridging and bonding – quality of interactions within and between social groups	
			1 Bridging
			2 Bonding
		2 Inclusion of different social groups in NBS projects	
		3 Trust within the community	
		4 Solidarity among neighbours	
		5 Tolerance and respect	
		6 Availability and equitable distribution of blue-green space	
	Additional	1 Linking social capital	

		2 Perceived social interaction	
		3 Quantity and quality of social interaction	
		4 Perceived social support	
			1 Perception of socially supportive network
			2 Perceived social support
		5 Perceived social cohesion	
		6 Perceived ownership of space and sense of belonging to the community	
		7 Proportion of community who volunteer	
		8 Proportion of target group reached by an NBS project	
		9 Perceived personal safety	
		10 Perceived safety of neighbourhood	
		11 Number of violent incidents, nuisances and crimes per 100 000 population	
		12 Realised safety	
		13 Area easily accessible for people with disabilities	
		14 Change in properties incomes	
Health and Wellbeing	Recommended	1 Level of outdoor physical activity	
		2 Level of chronic stress (Perceived stress)	
		3 General wellbeing and happiness	
		4 Self-reported mental health and wellbeing	
		5 Cardiovascular diseases (prevalence, incidence, morbidity and mortality)	

		6 Quality of Life	
	Additional	1 Self-reported physical activity	
		2 Observed physical activity level within NBS	
		3 Encouraging a healthy lifestyle	
		4 Incidence of obesity	
		5 Heat-related discomfort: Universal Thermal Climate Index (UTCI)	
		6 Hospital admissions due to high temperature during extreme heat events	
		7 Heat-related mortality	
		8 Exposure to noise pollution	
		9 Perceived chronic loneliness	
		10 Somatisation	
		11 Mindfulness	
		12 Visual access to green space	
		13 Perceived restorativeness of public green space/ NBS	
		14 Perceived social support	
		15 Connectedness to nature	
		16 Prevalence of attention deficit/ hyperactivity disorder (ADHD)	
		17 Exploratory behaviour in children	
		18 Self-reported anxiety	
		19 Prevalence, incidence, morbidity and mortality of respiratory diseases	

		20 Morbidity, Mortality and Years of Life Lost due to poor air quality	
		21 Prevalence and incidence of autoimmune diseases	
		22 Prevalence, incidence and morbidity of chronic stress	
New Economic Opportunities and Green Jobs	Recommended	1 Valuation of NBS	
			1 Value of NBS calculated using GI-Val
			2 Economic Value of Urban Nature Index
		2 Mean land and/or property value in proximity to green space	
			1 Change in mean house prices/ rental markets
			2 Average land productivity and profitability
			3 Property betterment and visual amenity enhancement
		4 Retail and commercial activity in proximity to green space	
		5 Number of new businesses created and gross value added to local economy	
		6 Recreational monetary value	
		7 Overall economic, social and health wellbeing	

	Additional	1 New businesses established in proximity to NBS	
		2 Value of rates paid by businesses in proximity to NBS	
		3 New customers to businesses in proximity to NBS	
		4 Local economy GDP	
		5 Initial costs of NBS implementation	
		6 Maintenance costs of NBS	
		7 Replacement costs of NBS	
		8 Avoided costs due to NBS implementation	
		9 Payback period for NBS	
		10 Reduced/avoided damage costs	
		11 Social Return on Investment (SROI)	
		12 Income produced via application of green policies	
		13 Subsidies applied for private NBS measures	
		14 Private finance attracted to the NBS site	
		15 Increase in tourism	
		16 New activities in the tourism sector	
		17 Gross profit from nature-based tourism	
		18 Number of new jobs in green sector	
		19 Jobs created in NBS construction and maintenance	

		20 New employment in the tourism sector	
		21 Turnover in the green sector	
		22 Employment in agriculture	
		23 Rural Productivity Index	
		24 Economic value of productive activities vulnerable to risks	
		25 Innovation impact	
		26 Income/Disposable income per capita	
			1 Monthly disposable income
		27 Upskilling and related earnings increase	
		28 Population mobility	
		29 Avoided cost of run-off treatment	
		30 Correction Cost of Groundwater Quality	
		31 Dissuasive cost of water abstraction	
		32 Average water productivity	
		33 New areas made available for traditional productive uses	
		34 Value of food produced	
		35 Renewable energy produced	

13 Appendix 4. Nature4Cities Indicators

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO2 - Annual carbon sequestration
			1.1.2 | GHG - Avoided GHG emissions
		1.2 Climate adaption	1.2.1 | AT - Air temperature
			1.2.2 | TLO - Thermal load of outstreaming body
			1.2.3 | AC - Adaptive Comfort (indoor)
			1.2.4 | TCS - Thermal Comfort Score (outdoor)
			1.2.5 | PET - Physiological equivalent temperature
			1.2.6 | UTCI - Universal thermal climate index
			1.2.7 | MRT - Mean radiant temperature
			1.2.8 | PT - Perceived temperature
			1.2.9 | PMV - Predicted mean vote
			1.2.10 | β - Bowen ratio
	2 WATER MANAGEMENT	2.1 Urban water management and quality	2.1.1 | EPTvar - Evapotranspiration variation
			2.1.2 | SWS - Soil water storage
			2.1.3 | PFvar - Peak flow variation
			2.1.4 | WQ - Stormwater quality
		2.2 Flood management	2.2.1 | TROvol - Total runoff volume
			2.2.2 | TRFvol - Total rainfall volume
			2.2.3 | RRR - Total runoff/Total rainfall ratio
			2.2.4 | FAV - Variation of flooded area
			2.2.5 | WDT - Water Detention Time
ENVIRON-MENT	3 AIR QUALITY	3.1 Air quality at district/city scale	3.1.1 | CAQI - Common Air Quality Index

			3.1.2 | EAQLVcity - Exceedance of air quality limit value – City scale
			3.1.3 | AAPCV - Annual amount of pollutants captured by vegetation
		3.2 Air quality locally	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale
	4 GREEN SPACE AND BIODIVERSITY	4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion
			4.1.2 | SDIH – Shannon Diversity Index of Habitats
			4.1.3 | IAS - Number of invasive alien species
			4.1.4 | PALHB - Potential of areas likely to host biodiversity
			4.1.5 | RNPS - Ratio of Native Plant Species
			4.1.6 | PSL - Land Use and associated impacts on biodiversity
		4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor
			4.2.2 | CGS - Connectivity of green spaces
			4.2.3 | LUsom – Land use related to Soil organic matter changes
			4.2.4 | NDVI - Normalized Difference Vegetation Index
		4.3 Urban space Management	4.3.1 | SPI – Sustainable practices indicator
	5 URBAN REGENARATION AND SOIL	5.1 Soil management and quality	5.1.1 | Cfer - Chemical fertility of soil
			5.1.2 | EcoF - Ecotoxicology factor
			5.1.3 | SWI - Soil water infiltration
			5.1.4 | SBA - Soil biological activity
			5.1.5 | ScF - Soil classification Factor
			5.1.6 | SCr - Soil Crusting
			5.1.7 | Sct - Soil contamination

			5.1.8 | SMP - Soil macro porosity
			5.1.9 | SOM - Soil Organic Matter
			5.1.10 | SR - Soil respiration
			5.1.11 | SWR - Soil water reservoir for plants
RESOURCE	6 RESOURCE EFFICIENCY	6.1 Food, energy and water	6.1.1 | EE - Energy Efficiency
			6.1.2 | ES - Energy Security
			6.1.3 | EIWS - Energy Intensity of Water Supply
			6.1.4 | EUA - Energy use in Agriculture
			6.1.5 | PCFPV - Per Capita Food Production Variability
			6.1.6 | PCFSV - Per Capita Food Supply Variability
			6.1.7 | WS - Water Security
			6.1.8 | AWW - Agricultural water withdrawal
			6.1.9 | BEN - Buildings Energy needs
			6.1.10 | CED - Cumulative Energy Demand
			6.1.11 | WSc - Water scarcity
			6.1.12 | AWC - Absolute Water Consumption
			6.1.13 | WE - Water Efficiency
			6.1.14 | WI - Water Intensity
		6.2 Raw Material	6.2.1 | RME - Raw Material Efficiency
			6.2.2 | ARDfuels - Abiotic resource depletion – Fossil fuels
			6.2.3 | ARDmetalmineral - Abiotic resource depletion – Metal and Mineral
		6.3 Waste	6.3.1 | SWG - Specific waste generation
		6.4 Recycling	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes
			6.4.2 | ROL - Rate of landfilling
			6.4.3 | ROR - Rate of recycling

SOCIAL	7 PUBLIC HEALTH AND WELLBEING	7.1 Acoustics	7.1.1 | Lden - Day-evening-night noise level
			7.1.2 | Lnight - Night noise level
			7.1.3 | ENNH - Effects of night noise on health
			7.1.4 | PAI – Population Annoyance Index
		7.2 Quality of Life	7.2.1 | QOL - Quality of life
		7.3 Health	7.3.1 | PH - Perceived health
			7.3.2 | HIM - Heat induced mortality
			7.3.3 | AQEshort – Air quality indicators: short term health effects
			7.3.4 | AQElong – Air quality indicators: long term health effects
	8 SOCIAL JUSTICE AND COHESION	8.1 Environmental justice	8.1.1 | REC - Recognition
			8.1.1.1 | PA - Place attachment
			8.1.1.2 | BI - Bodily integrity
			8.1.1.3 | AES - Availability ES
			8.1.2 | PJ - Procedural justice
			8.1.3 | DJ - Distributional justice
			8.1.3.1 | GEN - Gentrification
			8.1.4 | CAP - Capabilities
			8.1.5 | RES - Responsibility
		8.2 Social cohesion	8.2.1 | SC - Social capital
	9 URBAN PLANNING AND GOVERNANCE	9.1 Urban planning and form	9.1.1 | AS – Areal Sprawl
			9.1.2 | BN - Betweenness
			9.1.3 | AC - Accessibility
		9.2 Governance in planning	9.2.1 | ABNC – Annual Budget of Natural Assets
			9.2.2 | SI – Segregation Index
	10 PEOPLE SECURITY	10.1 Control of crime	10.1.1 | CC - Crime counts
			10.1.2 | PC - Perceived crime

			10.1.3 | PCFS - Percentage of citizens feeling safe
			10.1.4 | PGV - Percentage of gender violence
			10.1.5 | PV - Percentage of victimization
		10.2 Control of extraordinary events	10.2.1 | DPIC - Domestic Property Insurance Claims
			10.2.2 | NDMP - Number of deaths and missing people
			10.2.3 | NPI
ECONOMY	11 GREEN ECONOMY	11.1 Circular economy	11.1.1 | C&DW - Construction and demolition waste
			11.1.2 | MCI - Material Circulatory Indicator
			11.1.3 | RRMW - Recycling rate of municipal waste
		11.2 Bioeconomy activities	11.2.1 | GVAEGS – Gross Value Added in the local Environmental Good & Services sector
			11.2.2 | LPB - Labour productivity of bioeconomy
			11.2.3 | NVATRBB - N° of VAT registered bioeconomy business
		11.3 Direct economic value of NBS	11.3.1 | ANS - Adjusted Net Saving
			11.3.2 | HPI - House Pricing Index
			11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy
			11.3.4 | PIB - Private investment on bioeconomy

14 Appendix 6: Indicators from IN-HABIT

The contents of surveys for each indicator are not yet publicly accessible.

Dimension	Sub-dimension	indicator
Social well-being	social cohesion	satisfaction with personal relationships in the neighbourhood
		Trust in others
		Social conflicts
		Social network support
		Institutional support
	crime/security and violence	sense of safety at night
		fear of road accidents
		sense of safety in green areas
		perception of crime, violence or vandalism in thieving area
	equality	Sense of being treated equally
		Equal access to digital technologies
		Access to internet from home
		Equal access to culture and leisure
		Obstacles for the access to culture and leisure
		Equal access to social care services and health services
		Equal access to pet's care services
		Obstacles for the access to social care services and health services
		Equal access to job opportunities and professional training
		Obstacles for the access to training opportunities
	discrimination	Perception of discrimination in society
		Perceived personal condition of discrimination
	social inclusion spatial well-being	Contact with others in public spaces
		Sense of inclusion
		Civil engagement
		Social engagement
		Change-making attitude
		Accessibility of local resources
		Satisfaction with urban green areas
		Satisfaction with green areas devoted to pets
		Access to green and recreational spaces
		Inclusiveness of public squares and green areas
		Air pollution perception
		Perception of noise pollution
		Sense of belonging and perception of the neighbourhood
Mental health	Positive emotions	Feeling cheerful and in good spirit
		Feeling calm and relaxed
		Feeling active and vigorous
		Feeling fresh and rested
		Feeling that one's life has been filled with things that interest oneself
	Psychological well-being	Feeling nervous
		Feeling hopeless
		Feeling restless or fidgety
		Feeling depressed
		Feeling that everything was an effort

		Feeling worthless
	Life satisfaction	Life satisfaction
Healthy lifestyles	Physical health status	Self-reported health status
	Determinants of health	Practice of physical activity
		Time spent on food preparation at home
		Self-grown fruit and vegetable consumption
		Consumption of fruits and vegetables
		Access to healthy and nutritious food
		Daily smokers
		Hazardous alcohol consumption
	Sports practice	Satisfaction with sports facilities
		Practice of sports in public green areas
		Benefits from sports
	Cultural participation	Satisfaction with cultural facilities
		Participation in cultural activities within public spaces(outdoor/indoor)
		Benefits from culture
		Cultural consumption
		Local cultural engagement
	Leisure and free time	Time devoted to leisure and personal care
		Practice of healthy leisure
		time devoted to play with one's children or grandchildren
		time spent playing, relaxing or doing sports in public green areas
		time spent in commercial spaces/areas
	Covid-19 Effects on healthy lifestyles	Persons who have changed the frequency of Playing, relaxing or doing sports in public green areas
Economic well-being	employment	Opportunity to find a job in the city
		Expected sector of occupation
	Job and skills satisfaction	Satisfaction with one's own competencies, skills
	Financial situation	Feeling that one's basic needs are met
		satisfaction with time and resources for personal care
		satisfaction with time and resources for family care
		Satisfaction with one's surroundings/living environment
		Satisfactions with one's own financial situation
	Housing	Social housing
		Being satisfied with one's own house/apartment/accommodation
		Number of rooms per household

15 Appendix 5: Indicators from Castellón-case study

	OBJECTIVES
MOBILITY	
Number of parking spaces	To mantain the same number of parking spaces
Max. distance from parking spaces to the city center desde aparcamiento a zona centro	To plan for an area of dissuassive parking with a maximum walking distance of 5'. This will increase and promote physical activity through a save itinerary.
Save itinerary (lineal m woth a pedestrian width of more than 4m)	Create a safe itinerary so that pedestrians can walk and play sports with enough space to maintain a safe distance. Also connecting and giving access to large open areas (Rafalafena Park, Basilica, Huerta Zone). What are safe itineraries? They are walking routes that guarantee a passage width of a minimum of 4 meters and that facilitate access to facilities such as markets, health centers or parks.
Bike lane (lineal m)	
Pedestrian Sport itinerary (lineal m)	
Public Road distribution	Vpub (%) = [Pedestrian road surface / Total public road surface] x 100
Pedestrian space*	% of street
Number of vehicles passing per hour	
CO2 emissions (kg CO2/day)	
ENVIRONMENT	
Number of trees	
Tree density per street section	Dtrees (trees/m)= number of trees /length (by section of street)
Biodiversity (formula)	
Vegetation strata	Yes/No
Green connectivity	
Biotic Factor	IBS=[Σ(fi xai)/At]
M2 of total surface	
m2 of sealed surface	
M2 soil surface (tree pits or gardens)	
M2 of permeable surface	
WATER	
Volume of rainwater managed sustainably	* The sustainable drainage system will be designed to manage at source, at least, the rainfall value such that 80% of the annual events have rainfall less than or equal to that value (V80). The Castellón guide indicates that V80 corresponds to 14 mm.
Water quality	

Irrigation water from reclaimed water	
Rainwater to the drainage network	
URBAN HEALTH	
Air Quality Index	
Noise	
Promotion of Physical Activity	
Connection to Nature	
Heat Stress (green cover/production of shade m2)	
SOCIAL	
Save commercial street space	
Numer of adapted furniture	
Playground spaces adapted by age	
Urban use adapted to gender	

16 Appendix 6: UNaLab Indicators (Castellón)

KPIs		UPV MONITORING	UPV INTERESTED IN
TOPIC RELATED: CLIMATE RESILIENCE			
Avoided greenhouse gas emissions from reduced building energy consumption	Data required: • National Emission factor (tCO2/ MWh) • Building energy sources and electrical energy use **Data input type**: Quantitative		**x**
TXx, Monthly mean value of daily maximum temperature TNn, Monthly mean value of daily minimum temperature	Material required: Sensors **Data input type**: Quantitative	**x**	**x**
Heatwave Incidence	Material required: Sensors **Data required:** A time series of air T° data (in ºC) Data input type: Quantitative	**x**	**x**
Energy use savings due to green infrastructure implementation	Data required: • Tons of carbon removed or stored per unit area per unit time (tCO2/m2·y) • Energy savings from reduced building consumption (kWh/y) Temperature reduction in urban areas (% energy • Reduction) Conversion factor for scaling and harmonising measurements	**x**	**x**
Estimated carbon emissions reduction from building energy saving – cooling Energy and CO2 emissions savings from reduced volume of water entering sewers	**Data from the US and UK to estimate:** energy, fuel cost and CO2 savings as a result of having trees around buildings. Toolkit free access: **https://ecosystemsknowledge.net/green-infrastructure-valuation-toolkit-gi-val** Data input type: Numeric data	**x**	**x**
Aboveground tree biomass	Depends on the calculation of carbon storage and sequestration KPIs.	To be considered if interesting	**x**
Human Comfort:	**Universal Thermal Climate Index (UTCI) -** UTCI(Ta, Tmrt, va, pa) = Ta + Offset(Ta, Tmrt, va, pa) - http://utci.org/ Thermal Comfort Score (TCS) - Rayman model Human comfort: Physiological equivalent temperature **(PET) -** Using Rayman Model (GrowGreen)	**x**	**x**

Urban Heat Island Effect	**Urban Heat Island (UHI) incidence -** urban area that is significantly warmer than its rural or undeveloped surrounding areas. Expressed and evaluated as temperature (°C). • Data required: • Material required: Quantitative	**x**	**x**
Estimated reduction in peak summer temperature	Estimated decrease in peak summer temperature experienced as a result of NBS intervention. Toolkit free access: https://www.merseyforest.org.uk/services/gi-val/ **Data input type**: Numeric data.	**x**	**x**
Maximum surface cooling	Recommended for users in North West England The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They are freely available at http://maps.merseyforest.org.uk/grabs/	**x**	**x**
Mean or peak daytime temperature	Ambient air temperature can be assessed through continuous monitoring of temperature, near the NBS intervention area, and calculation of mean and peak daytime temperature before and after NBS implementation.	**x**	**x**
Daily Temperature Range (DTR)	The range between minimum and maximum mean monthly local temperatures determined by direct measurement (°C) **Data collection:** Annually; at minimum, before and after NBS Implementation.	**x**	**x**
Tree shade for local heat reduction	thermometers/thermal cameras		**x**
Rate of evapotranspiration	In practice, ET is commonly calculated using meteorological data. Commercially-available ET monitoring stations are generally meteorological stations that calculate potential ET using monitored temperature...		**x**
Estimated carbon emissions from vehicle traffic	**Data collection:** Annually; at minimum, before and after NBS implementation	**x**	**x**
TOPIC RELATED: NATURAL AND CLIMATE HAZARDS			
Potential Population Vulnerable to Risks	Vulnerability of people is strictly connected to the vulnerability of buildings where they live.		**x**
Potential buildings exposed to risks	Potential Buildings Exposed to Risks subcriterion will assess the potential buildings exposed to risk. Housing, agricultural and industrial buildings, strategic buildings		**x**
TOPIC RELATED: GREEN SPACE MANAGEMENT			
Green space accessibility	Proportion of the population living within a 300 m maximum linear distance to the boundary of urban green spaces of at least 0.5 ha in size.		**x**
Total green space within a defined	The proportion of all vegetated areas within the city boundaries in		**x**

area: Share of green urban areas	relation to the total area of the city. https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012?tab=download https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit		
Diversity of green space	Indicates the proportion of bare turf and sparse vegetation, grassland and herbs, shrubs, trees and of built environment to the total area.		x
Proportion of natural areas within a defined urban zone	Data on zones in natural or naturalized condition in the urban area of interest from, e.g., government agencies, municipalities, nature groups, universities, etc.		x
TOPIC RELATED: AIR QUALITY			
Number of days during which air quality parameters exceed threshold values	Air pollution concentrations for regulatory compliance are based on measured pollutant concentrations (PM10 and PM2.5, O3, NO2, SO2, CO and PAHs) in ambient air. To assess differences in air quality as a result of NBS implementation, air quality monitoring should be conducted in close proximity to the NBS of interest and at an analogous reference site. Limit concentrations at doc.	x	x
Proportion of population exposed to ambient air pollution	Concentration: micrograms (mg) of pollutant per cubic metre for PM2.5, PM10, O3, NO2 and SO2. Nanograms (ng) of pollutant per cubic metre for BaP. **Urban population (POP):** number of inhabitants in the 'core city' and, from 2016 on, 'greater city' of the Urban Audit cities represented	x	x
European Air Quality Index	The Index indicates the short-term air quality situation. It does not reflect the long-term (annual) air quality situation, which may differ significantly.	x	x
Avoided costs for air pollution control measures	This KPI values green infrastructure in economic units taking into account other than conventional functionalities. https://ecosystemsknowledge.net/green-infrastructurevaluation-toolkit-gi-val	x	x

17 Appendix 7: Long list of indicators

Impact areas	Indicators	Shortlisted
Social	Actors available	X
	Participatory culture	X
	Population composition	X
	Digital inclusion	X
	Comfort and safety of green spaces for diversity	X
	Level of digital participation	X
	Accessibility of green spaces	X
	Target audiences for the NBS to be designed	X
	Users and use of green spaces for diversity	X
	Target audiences for the NBS to be validated	X
	Co-governance in development of NBS	X
	Target audiences for the NBS to be implemented	X
	health monitoring of diverse groups	X
	Gender Equality in Work and COVID-19 Deaths	X
	Income and work	X
	Health inequalities during the COVID-19 pandemic	X
	Likelihood of dying from COVID-19 compared to white ethnicity	X
	Air quality indicators: short term health effects	X
	Air quality indicators: long term health effect	X
	Morbidity, Mortality and Years of Life Lost due to poor air quality	X
	Level of chronic stress	X
	Perceived Health	X
	Safety and security	X
	Green intelligence awareness	X
	Place attachment	X
	Visual access to green space	X
	Social inclusion and diversity	X
	Walkability	X
	Heat induced mortality	X
	Social facilities	
	Co-governance in definition of problem	
	Citizens involved in environmental educational activities	
	Co-governance in management of NBS	
	Segregation index	
	COVID-19 related monitoring indicators	
	Education	
	Population health	
	Level of outdoor physical activity	
	Quality of life	
	Population annoyance Index	
	Gentrification	

	Prevalence, incidence, morbidity and mortality of respiratory diseases	
Environmental	Building quality	X
	Residential Building quality & space	X
	Connectivity of green space	X
	Green space management	X
	Existing NBS	X
	Prototypes tested in city districts	X
	Changes to the size and distribution of public green space	X
	Number of days in which air quality parameters exceed threshold values	X
	Protection of water resource and environment	X
	Air quality for diverse groups	X
	Concentration of particulate matter (PM2.5 and PM10) at respiration height along roadways and streets	X
	Avoided GHG emissions	X
	Biodiversity	X
	Ecosystem Health and Integrity	X
	Proportion of population exposed to ambient air pollution	X
	Air pollutant levels	X
	Carbon storage in vegetation and in soil	X
	Common Air Quality Index	X
	Water Detention Time	X
	Industrial & Commercial buildings	
	Sustainable transport	
	Potential building and population exposed to risks	
	The distribution of green space for diversity	
	Buildings Energy needs	
	Cumulative Energy Demand	
	Exceedance of air quality limit value	
	Flood peak reduction and delay	
	Peak Flow variation	
	Soil sealing	
	Total runoff/Total rainfall ratio	
	Variation of flooded area	
	Provision of thermal comfort, climate shield and visual and acoustic quality	
	Waste generation, treatment, and reuse	
	Biotope Area Factor	
	Particulate matter removed by NBS-vegetation by spectometry measurements	
	Heat levels	
Economic	Initial costs of NBS implementation	X
	Payback period for NBS	X
	Proportion of businesses measuring and mitigating CO2 emissions	X

	Public spending on bioeconomy	X
	Energy consumption and cost of operation of blockchain	X
	Number of new businesses created and gross value added to local economy	X
	Avoided costs due to NBS implementation	X
	Maintenance costs of NBS	X
	Valuation of NBS	X
	Fluctuation of house pricing index over time	X
	Health Cost as a consequence of air pollution	X
	Number of new jobs created	X
	Overall private investment rates	
	Private investment in bioeconomy	
	Social return of investment	
	Labour productivity of bioeconomy	
	Number of VAT registered bioeconomy business	
	Opportunities for tourism	
	Blockchain based bioeconomy start-ups	
	Blockchain based service uptake	
	Business with diversity	
	Economic activity loss as a consequence of air pollution	
	Job growth expectation	
	Perceived capability	
	Perceived opportunity	
	Proportion of vacant properties (commercial & households) before and after interventions	
	Turnover of local markets	
	Vitality rate of small firms	
	Developments of revenue in commercial businesses within walking distances of new green spaces	
	Gross Value Added in the local Environmental Good & Services sector	