Integrated NBS-based Urban Planning Methodology for Enhancing the Health and Well-being of Citizens

D4.1

Report on the multidimensional set of indicators for the assessment of NBS impacts on PH and WB as well as social sustainability aspects of the local communities (Version 1)

WP04 – Public Health and Well-being related with Social and behavioural aspects

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Executive Summary

The number of people living in urbanized areas around the globe has exponentially increased in the past decades passing the 50% mark in '00s with expected proportion to be up to 70% in 2050 (87% in developed countries). Simultaneously, health and wellbeing of citizens has been under tremendous strain, part of it being caused by challenges of living in densely populated areas, including climate changes, pollution, social challenges, changing economy, etc.

euPOLIS aims to create cities-for-healthy-people by developing a planning methodology that will provide NBS that can locally improve thermal comfort, enhance biodiversity, mitigate pollution, improve climate resilience, provide open areas that stimulate social exchange and inclusivity, and much more, all contributing to enhancing public health and wellbeing (PH&WB) of citizens.

This deliverable presents a multidimensional set of indicators that are selected as suitable for assessing different impacts NBS can have on PH&WB. Indicators are divided in five categories that correspond to impacts directly and indirectly related to PH&WB: (1) PH&WB (direct), (2) social (direct and indirect), (3) economic (indirect), (4) environmental (direct and indirect), and (5) urban development (indirect). All the indicators are selected to measure the effectiveness of NBSs, and are in line with the project objectives, demonstrating that the outcome is related to the implemented interventions.

The indicators provided support both the planning (Contextual Indicators) and the exploitation (Evaluation indicators) phases in the NBS implementation process. Contextual Indicators provide an initial site screening and site characterization, by facilitating an initial baseline assessment that will assist in gaining a better understanding of the site and its needs. The evaluation of contextual indicators is based on readily available data and sources, including national and international databases, local agencies and authorities, existing reports, questionnaires, site visits, etc. The best available data is used at the temporal and spatial resolution most appropriate for each pilot site. The list of contextual indicators presented in the document corresponds to the first version, and is to be upgraded in successive workpackage (WP8). Evaluation indicators assess NBS performance and effectiveness using appropriate data collected via monitoring and/or modelling. They are quantified prior and after the implementation of NBS and the comparison of indicator values at these two stages provides evaluation of the (positive or negative) multi-dimensional impact of the implemented NBS.

The process of selecting relevant contextual and evaluation indicators is done by working groups (that include medical doctors, sociologists, civil and environmental engineers, environmental scientists, economic experts, urban developers) gathered around each of the five categories, followed by multidisciplinary meetings between the groups, and later discussed in the entire WP4 consortium (academic and research partners, SMEs, Front runner and Follower cities).

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List of Acronyms / Abbreviations

Table 1. Acronyms

Abbreviation	Explanations
BAM	Business Activation Matrix
BGS	Blue Green Solutions
BVOC	Biogenic Volatile Organic Compounds
CD	Communicable disease
CLPP	Community level physiological profiling
CI	Contextual Indicator
EI	Evaluation indicator
ESS	Ecosystem services
FL	Follower cities
FR	Front Runner cities
GA	Grant Agreement of the euPOLIS project
GHG	Green House Gases
GIS	Geographic Information Systems
GDPM	Goal Driven Planning Matrix
HRQoL	Health Related Quality of Life
KPI	Key Performance Indicator
LTS	Leisure Time Satisfaction Measure
MF	Multi-functional
NBS	Nature-based solutions
NCD	Non-communicable disease
NDVI	Normalized Difference Vegetation Index
OEQ	Outdoor Environment Quality
PH	Public Health

SOM	Soil Organic Matter
STW	Satisfaction with Life
SUDS	Sustainable Urban Drainage Systems
Q1, Q2, Q3	Questionnaire 1, 2, 3
QoL	Quality of Life
UGS	Urban Green Space
UHI	Urban Heat Island
UTCI	Universal Thermal Climate Index
UWOT	Urban Water Optioneering Tool
WB	Well-being
WMO	World Medical Organization
WHO	World Health Organization

1 Introduction

euPOLIS' aim is to provide a planning methodology that will deliver the best services of NBS to address citizens needs for improvement of Public health and Well-being (PH&WB) in open public spaces: systematical deployment of multi-functional (MF) natural systems to simultaneously enhance PH&WB, provide resilient urban ESS, regenerate urban ecosystems, improve urban biodiversity, resilience to climate change, extreme events, water-stress, pollution, create inclusive and accessible urban spaces, etc. The extent of euPOLIS NBS interventions (Figure 1) for each of the FR cities is selected together with stakeholders (experts, local authorities, NGOs, citizens, etc.) through euPOLIS participatory processes and suited to local needs.

Figure 1 euPOLIS' overall concept, indicating NBS interventions at the demo sites of the cities and the supporting ICT-based tools

NBS Clusters/ interventions: 1. NBS-based MF pocket parks accessed by NBS locally conditioned pathways and shared spaces (1.1. -1.9), 2. Waterway with mini biotope nodes, aquatic biodiversity – feed from groundwater aquifer or purified surface runoff, 3. NBS for surface runoff quality and pluvial flood management, 4. Groundwater abstraction for water, energy, greenery nexus, 5. MF NBS canopy for socializing, „recharging electronics", or „green bus stop" etc., 6 . MF Live vegetation shaded waterfront promenade, 7. Air pollution abatement shrubs, trees and vertical green curtains, 8. Metabolic hub with MF ecotechnology demonstration/promotion, roof garden and art/cultural performance, 9. MF floating island, river water purification, 10. Coastal sea bottom marine aquatic biotope with euPOLIS-NBS, 11. MF euPOLIS Urban square/streetscape and other NBS (biotopes, sensory garden, waterfall, biodiversity & kitchen garden for socializing, recreation), 12. Space for NBS business activation and promotion

Monitoring- ICT System: A. Wearable devices for monitoring PH & WB, B. Visualization equipment, C. Renewable energy sources, D. Citizens observatories, E. Sensor network, F. Remote sensing, WS. Microclimate / wireless weather station

To test the planning methodology, euPOLIS will deploy NBS in four Front runner cities: Belgrade (Serbia), Lodz (Poland), Piraeus (Greece) and Gladsaxe (Denmark). The role of WP4 is to provide a set

of indicators for efficient monitoring and assessment of the direct and indirect impact of NBS to the PH&WB of citizens, including social and behavioral aspects, environmental and economic impacts together with required tools and methods (documented in Deliverables 4.1 and 4.2) but also guidelines for participatory processes tailored to local needs and context (documented in Deliverable 4.3).

WP4 consists of five tasks:

- Task 4.1: Development of a multidimensional set of indicators for the assessment of NBS impacts on PH and WB [M6-M18]
- Task 4.2: Methods and tools for the assessment of the social aspects of PH and WB impacts of NBS [M6-M18]
- Task 4.3: Methods and tools for the assessment of the spill-over effects of NBS on local economy [M6- M18]
- Task 4.4: Methods and tools for the assessment of the environmental impacts of NBS [M6-M18]
- Task 4.5: Development of participatory processes tailored to local needs and context through participatory research practice [M8-M24]

This deliverable summarizes the results of Task 4.1 with aim to provide a multidimensional indicator framework that will eventually allow assessing the extent of the PH&WB enhancements provided by NBSs in a limited timeframe (or short-term) and on a local scale, yet with a potential for upscaling.

1.1 euPOLIS Innovations present in WP4

Based on euPOLIS DoW the basic innovations that should be addressed through this work are the following in combination with other project WPs.

Table 2 euPOLIS Innovation potential related to WP4

IN1: Goal Driven Planning Matrix (GDPM)	Systematic interconnection of project PH and WB goals, targets, functions, concepts and solutions pre-planning analysis, secure highest quality of NBS designed to systemically enhance living conditions directly responsible for PH and WB. The result is a detailed master planning brief including well optimized and developed concepts that will be further developed into specifications for solutions, tested and approved in the demonstration projects with the potential to serve as a basis for developing a European Methodological Framework rethinking Urban Planning procedures. *Implemented through WP2, WP3, WP4, WP6*
IN2: Urban components' synergy & new planning criteria	Optimized synergic solutions are cheaper to build, have lower operation and maintenance costs and overall LCC. The euPOLIS team intention is to prove that the BG projects cost less if planned in thoroughly integrated manner. The resulted solutions will have higher value due to the fact that all technical and functional synergies are utilized and reflected through the financial impact, both in capital and running costs. EuPOLIS proposed introduction of new, compulsory planning criteria: pre-planning cost savings analytics, systematic project blend in criteria and gender related planning criteria. The business activation matrix produces implementation related benefits to every BGS project. *Implemented through WP4 (Business Activation Matrix), WP6, WP7*
IN3: Improvement of planning	If adopted, the euPOLIS' framework for planning standard improvements will result in improved city life quality and higher overall urban operational

standards	efficiency. This in particular applies to climate change induced scenarios such as extreme weather conditions. EuPOLIS proposes a new PH and WB related approval system to be introduced at a level of master planning to achieve a more controlled, target related, planning process. *Implemented through WP4, 6, 9, 10*
IN12: Innovative Social interaction	The mechanism for creating an enhanced level of understanding and mutual support of social groups is highly relevant for conflict resolution within urban developments. The method, designed to improve citizens cognitive performance and social health, will be based on the creation of specific urban spaces (as described in the section Innovation IN1: GDPM) needed for social interactions and use of web-based dynamic interactive continuing dialogue tested in the demo-cities. Further enhanced through Mikser Socio-Cultural HUB. *Implemented through WP4, WP6, WP7*

1.2 Project Work Plan and WP4 scope

The aim of WP4 is to conduct a mixed-method participatory innovation that will enable the implementation process of the euPOLIS' tailor-made interventions, as well as measuring the NBS' health, WB, social, environmental, economic and behavioral direct and indirect impacts of NBS. Figure 2 illustrates the position of WP4 in the overall project workplan, depicting also its correlations with the other WPs. Following the outcome of WP2 that channels stakeholder needs, and the findings of WP3 that sets the project requirements and potential solutions according to the needs, concerns, and available resources, WP4 expands towards developing a multidimensional indicator framework suitable for assessing the impact of the planned NBS interventions (Deliverables 4.1 and 4.2) and suggesting participatory processes tailored to the local needs and context (Deliverable 4.3).

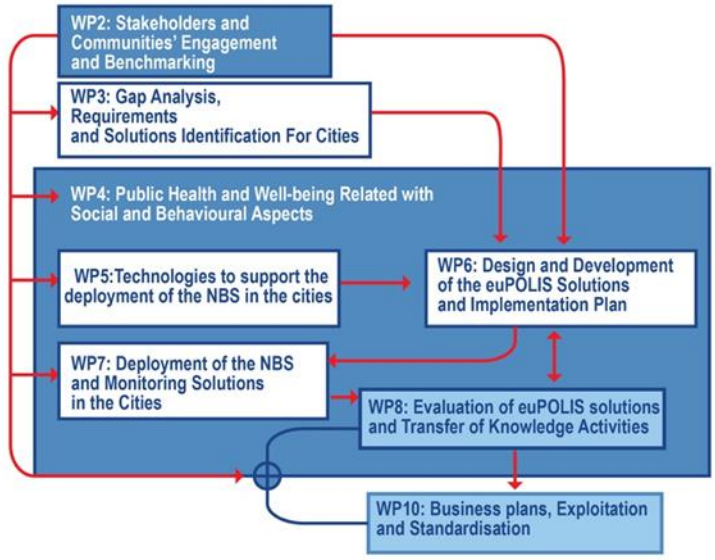

Figure 2 euPOLIS WP4 position in the project workplan

Further to the above, WP4 provides inputs for WP5 that aims at developing technologies to support the deployment of NBSs in the euPOLIS FR cities, for both the monitoring (see Figure 1 - Wearable devices for monitoring PH & WB, visualization equipment, sensor network, remote sensing, wireless weather station) and the modelling framework (UWOT). Following the successful design and development of the euPOLIS solutions (WP6), as well as their deployment together with monitoring

solutions (WP7), WP8 continues with the evaluation of such solutions (further refining and expanding the indicator framework that is set in WP4) and the transfer of knowledge.

1.3 Partners' contribution in WP4

FCEBG is the WP leader whose main role is to conduct research on NBS effects on PH&WB (including social, economic, environmental and urban development aspects), by coordinating activities toward setting the multidimensional indicator framework that will be used in all demonstrator sites for assessment (first in developing NBS set-up to maximize PH&WB benefits including its monitoring in WP7, and then for assessment in WP8). **FCEBG** contributed in selecting the appropriate indicators and instruments that cover biological, psychological, social, and psychophysiological effects on PH, as well as objective and subjective effects on WB. **FCEBG** is the leader of T4.1. responsible for developing the multidimensional framework and oversees delivering D4.1. In T4.4 **FCEBG** also contributed to environmental impact of NBSs, especially with regards to their implementation in Belgrade in terms of reduction of pollution emission, energy, and water consumption.

ISS leads Task 4.2 where methods and a project toolkit for the assessment of NBS impacts in terms of social aspects of PH and WB are developed. In Task 4.1 **ISS** used its extensive experience in the field of social sciences to develop the list of indicators describing social impact of NBS interventions. **ISS** is also responsible for preparing the methodological report describing all employed and proposed methods of measuring economic, social, environmental, and urban development impacts of NBS implementation (D4.2).

AMPHI contributed to Task 4.4 about the environmental impacts of NBS, especially with regards to their implementation to the municipality of Gladsaxe. In Task 4.1 it also had a significant contribution in developing indicators related to environmental impacts of NBS interventions.

ENPL is the leader of Task 4.3, while in Task 4.1 it assisted in developing indicators describing the effects of NBSs on local businesses and economies. In Task 3.3 **ENPL** used euPOLIS' specific Business Activation Matrix to identify locally available resources conducive to the business spill over from the implementation of NBS at each demonstration site.

ICL contributed to Task 4.1 regarding the impacts of NBS to PH and WB of the citizens from the aspect of urban development and environment.

ERCE collaborated in Task 4.1 with other partners in developing indicators related to the social and environmental aspects of PH & WB affected by NBSs and is supporting the City of Lodz in development of participatory processes. It also led a process of defining the impact of monitoring tools best indicators of the change with respect to demos' typology and assessing the system deviation from the baseline (Task 4.4).

RG assisted ENPL in the development and definition of the economic/business contextual and evaluation indicators to be used for screening the targeted urban site conditions and for assessing the spill-over effects of NBSs on the local economy, respectively. RG also provided input for defining the relation of the proposed set of business evaluation indicators to PH&WB.

GSH's role in Task 4.4 and 4.5 was to work with all partners and provide knowledge and tools for the assessment of the environmental impacts of NBSs. GSH provided assistance in T4.1 the definition of Contextual and Evaluation Indicators, with a focus on environmental challenges and themes. It is

also examining the potential of integrating Copernicus products and services, like Urban Atlas and Sentinel's satellite images, in evaluation processes but also the utilization of geospatial data as a source of evaluation indicators.

MIKS will be following the findings of Task 4.2 on locally available sets of livability indicators to understand better the community members' quality of life and local context as a prerequisite for successful community engagement in Task 4.5. **MIKS** will contribute to exploration of potentials for creation of innovative Social/Cultural/Urban hub, identify credible local partner(s) to either empower their existing efforts, or jointly develop a new hub under the euPOLIS' interventions, promoting the model of PPPPs and introducing innovation to existing sustainability models of culture/community hubs through combined financing of state and private funding, project-based and crowdfunding. (Task 4.3 and Task 4.5).

NTUA is participating in WP4 with two teams. **NTUA's** AnalyDa Lab is coordinating Task 4.5 and contributing through the development of online participatory tools available to citizens in all four FR cities. **NTUA's** UWMH Lab. is working together with other project partners on developing the multidimensional indicator framework, but also in developing tools and methods for environmental assessment, with special regards to NBS implementation in Piraeus.

CEE is a supporting partner for the City of Bogota (FL city), and is participating in developing tools and methods for environmental assessment.

1.4 Deliverable's outline

This report consists of ten (10) Sections. Section 1 provides a brief introduction, including the notion behind this deliverable, and the particular role of the involved partners. Section 2 provides background information, including literature reported relation between NBSs and PH&WB and the concept of Livability. Section 3 gives an overview of the euPOLIS indicator framework. Section 4 summarizes the Challenges and Themes of the euPOLIS indicator framework across the five considered categories (PH&WB, Social, Economy/Business, Environmental and Urban Development). Sections 5 and 6 are dedicated to the description of the Contextual and Evaluation Indicators respectively. Section 7 provides the methods and ethical principles that need to be accounted for the part of indicator evaluation that involves volunteers. Section 8 concludes the deliverable and provides insight in the future steps in the projects. Section 9 summarizes the references used from the pertinent literature, whereas section 10 is the annex to the document containing the lists of KPIs and data tables on evaluation indicators.

*The **tables of evaluation indicators** provided in the **Annex** of this document represent a **summary** of work presented in deliverables:*

- ***4.1** Report on the multidimensional set of indicators for the assessment of NBS impacts on PH and WB as well as social sustainability aspects of the local communities (set of indicators) and*
- ***4.2** Report on cultural, social, economic and environmental impacts of NBS (tools and methods).*

2 Background

2.1 Nature based systems and Public Health & Wellbeing

The definition of Nature-Based Solutions (NBS) states that they represent "solutions to societal challenges that are inspired and supported by nature", which are "cost-effective, provide environmental, social and economic benefits, and help build resilience" Such solutions give the potential for more diverse nature and natural features and processes into cities, landscapes and seascapes, through local adaptation, resource-efficient and systemic interventions (European Commission, An EKLIPSE Expert Working Group report 2017 – Raymond et al., 2017). As the consequence, they provide at the same time benefits for biodiversity and human wellbeing (Cohen-Shacham et al., 2016).

Natural environments and accessible green and blue spaces have a direct and indirect influence on health and wellbeing. NBS are supposed to improve the health and wellbeing of urban residents through the provision of **ecosystem services** provided by urban green spaces (Keniger et al., 2013). It has been already published that the urban environment significantly affects the health and wellbeing of residents (Barton and Grant, 2006). Natural environments and approachable green and blue spaces could diminish **climate change impacts** and lower the possibility of disasters. They support **active recreation** and allow places for **relaxation and consolidation from daily stress**. The lockdown consequences during COVID-19 pandemic reported in recent studies show that inhabitants of urban communities miss the opportunity of spending time in the natural environment (WHO, 2021).

A complex interaction of proximal and distal (including environmental) determinants of health in the development of **non-communicable diseases** (NCDs) is highly recognized. That implies the need for the identification of **risk factors** and highlights the opportunity of identifying domains of intervention. The provision of the access to green and blue spaces is among them (WHO, 2021).

The public health priority worldwide and in the EU is reducing the essential burden of NCDs and mental health is prominently spotlighted in that context. The third United Nations General Assembly High-level Meeting on NCDs in 2018, was dealing with the efforts in promotion of mental health and wellbeing alongside with other priority NCDs (cancers, heart and lung diseases, stroke, and diabetes) (WHO, 2021).

There is some evidence that nature-based solutions can give the positive impact on numerous **psychological** and **physiological** outcomes. Some of the investigation results include positive effects of urban green spaces on residents living in cities through **psychological relaxation of stress** (Roe et al., 2013; Ward Thompson et al., 2012) and enhanced possibilities for **physical activity** (Sugiyama and Ward Thompson, 2007). Studies found positive health effects of living in the **proximity to urban green spaces** (Maas et al., 2006) and in **viewing greenery** (Dravigne et al., 2008; Ulrich, 1984; Ulrich, 2002). Additional positive impacts include **reduced depression** (Bratman et al., 2015a) and **improved mental health** (Hartig et al., 2014; van den Berg et al., 2015; Vries et al., 2003). The pioneering study in Serbia was conducted in collaboration between the Faculty of Forestry, the Institute of Mental Health and the Botanical Garden in Belgrade, with the goal to understand how performing **horticulture therapy** during spending time in specially designed urban green environments can improve **mental health** (Vujčić M. et al, 2017). The psychiatric patients (n=30), users of the day hospital of the Institute were randomly selected for the study and the control group, assessed for depression, anxiety, and stress before and after the intervention, using a DASS21 scale. The results of the study indicated that **nature-based therapy** had a **positive influence** on the mental health and wellbeing of the participants.

Other positive health effects related to nature-based solutions include **reduced cardiovascular morbidity and mortality** (Gascon et al., 2016; Tamosiunas et al., 2014), **improved pregnancy**

outcomes, (Dadvand et al., 2012), **lower level of obesity** (Kim et al., 2014) and **diabetes** (Maas et al., 2009). Green spaces are, according to the literature, associated with **decreased mortality of natural-cause** (Gascon et al., 2016; Pereira et al., 2012; Chen et al., 2020; Rojas-Rueda et al., 2019).

WHO emphasize that **regular physical activity** provenly helps in prevention and management of noncommunicable diseases (NCDs): **heart disease**, **stroke**, **diabetes,** and several **cancers**. It is also stated that it helps in **prevention of hypertension**, maintaining **healthy body weight** and in **improving mental health**, **quality of life** and **wellbeing** (WHO, 2020). The same overview provides evidence-based public health recommendations for children, adolescents, adults, and older adults on the amount of physical activity (frequency, intensity, and duration), which are required to offer significant positive health impacts and diminish health risks. According to WHO overview, physical activity refers to all movement. Popular ways to be active include walking, cycling, wheeling, sports, active recreation, and play, and can be done "at any level of skill and for enjoyment by everybody" (WHO, 2020). The definition of physical activity by WHO is that it is "any bodily movement produced by skeletal muscles that requires energy expenditure". In adult individuals, **physical activity** gives benefits for the improved **all-cause mortality**, **cardiovascular disease**, **incident hypertension**, **incident site-specific cancers**, **incident type-2 diabetes**, **mental health** (reduced symptoms of anxiety and depression); **cognitive health**, and **sleep**; measures of adiposity might be also improved (WHO, 2020). Some researchers showed that physical activity provokes changes in the cardiovascular function of elderly with a positive effect on both the prevention and rehabilitation of serious cardiovascular diseases. Furthermore, physical activity has been referred to as a reduced **risk of obesity**, **diabetes**, and **metabolic syndrome** (Papathanasiou G. et al. 2020).

Physiological parameters, such as **heart rate**, **blood pressure**, **body temperature**, serum levels of various stress **hormones** (e.g. cortisol) and **immunological functions** (e.g. suppression of lymphocyte activity) are defined as parameters that can be used to evaluate wellbeing (Kirsten Corder K. et al., 2008; E. Jovanov et al. 2005.; Bahram M.E. et al, 2014).

The study of Misiune, I. et al. (2021) pointed out that the frequency of park visiting increases with a better quality of urban parks for "human and environmental health". They found that the most valued urban ecosystem services (ES) were the regulating services of **air quality improvement** and **noise reduction compared with** provisioning services, like **food** and **medicinal herbs**, which had the lowest mean importance values. Respondents who visited green spaces frequently (several times per week) valued ES significantly more compared to those who visited green spaces less often. Their study highlighted that the most important pull factors attracting people to the green spaces were the same for frequent and rare visitors. These pull factors included **leisure walking**, enjoying **fresh air**, **observing nature**, **relaxing**, and **recreation by physical activities**. Push factors were different among those who visited the green areas very often and seldom.

Yeh, C.T. et al. (2020) stated that improved green landscapes and their connectivity increases health benefits and decreases morbidity of diseases. In highly urbanized areas, urban green spaces (UGSs) are important **natural** and **cultural places**. Previous published studies showed some evidence of positive relationships between UGSs and human health, with a strong correlation between the spatial characteristics of UGSs and human health. Their results also revealed that living in districts with a higher area percentage of **green spaces** and **denser cover with vegetation**, as well as exposure to more convergent **and irregular-shape green spaces**, could **reduce the morbidity of diseases**.

Jabbar M. et al. (2021) reviewed previous literature regarding the significance of urban green spaces for human well-being (physical, psychological, mental, social, and subjective). The reviewed studies observed almost all population groups above 18 years old, but some studies targeted a specific group: longitudinal study of Gubbels et al. (2016) targeted adolescents and adults in the Netherlands, elders in South Korea are followed by Lee and Lee (2019), Holt et al. (2019) selected

university students in the USA, and Wang et al., (2019a, 2019b) observed adults in China. In data methods for data collection of this review paper, 89% of the study is based on primary data (cross-sectional studies), 9% of studies used secondary, whereas only 2% of the study is based on experimental data (empirical studies). They observed that most of the studies used **Landsat images** and **NDVI** to identify the study area and vegetation configuration in the data analysis section. Selmi et al. (2016) used **i-Tree Eco-model** to quantify vegetation services for the environment. It is shown that green spaces improve human physical health and wellbeing by providing space for exercise, jogging, walking, cycling, and other recreational activities. So, **human physical wellbeing and fitness** can be obtained by using mediators (exercise, jogging, cycling, and other recreational activities). Likewise, easy access to urban green spaces is one of the significant mediators for human wellbeing. Urban green spaces improve human mental and psychological health at the **old age** population by **removing social isolation and providing the space for social interaction**.

The reviewed literature outlined that **cleanliness** and a **calm environment** also improve the benefits of green spaces. Among the young population, **recreational activities** and maximum interaction enhance the **mental approach** and **academic performance**. In summary, the reviewed studies collectively highlighted the wide range of positive impacts of urban green spaces that could be obtained through mediations of easy access, daily interaction, social cohesion, physical activities such as exercise, jogging, cycling, walking and recreational and cultural activities. This review also found that even **a single view of greenery** from a window **increases work performance** and prevents adverse effects of health from stressful life situations. In summary green spaces provide a quiet space for relaxation and restoration and consecutively, for improving psychological and mental wellbeing. The natural environment works as mediation and **accelerates the restoration of stressful life effects**. Urban green spaces facilitate people of all ages. Recently, in line with previous, a new 3-30-300 rule has been proposed to improve urban forestry: “At least 3 trees in view from every #home. Every #neighborhood should have 30 percent #treecanopy (or vegetation cover). Nobody should live more than 300 meters from a larger #park or #greenspace” (van den Bosch, 2021).

Engelmann et al. (2019) show that the connectedness to green space during **childhood** is associated with **better mental health**, with supporting efforts to better integration of natural environments into urban planning and childhood life. It is observed that **prevalence of mental health** issues in elderly generally **decreased in relation to the ratio of green space** of an area (Lee and Lee, 2019).

Green spaces also promote human well-being by **regulating climate in cities**, **temperature cooling** and the **air** filtering. It has been already observed that green spaces are a necessary part of sustainable and livable cities. The role of urban planners and policymakers has become very important for planned, sustainable and balanced urbanization in the future. Availability of green spaces is crucial for human wellbeing through meditations. The most critical are daily or weekly interaction, **recreation activities**, **social interaction**, **jogging or cycling**, **quiet** environment, **cleanliness**, 5–10 min **walking distance**, and **mixed species of greenery and landscapes (**Jabbar M. et al. (2021)).

However, urban green spaces can also be linked to **negative health outcomes**, such as **allergic reactions**, or **vector-borne diseases**, as the result of increased exposure to allergenic pollen or increased amount of disease vectors in urban green environments (Bai et al., 2013; Calaza, Martinez and Iglesias-Díaz, 2016). Additionally, **physical activity** or playing in green spaces may also be associated with **increased risk of injuries,** particularly with children (Kendrick et al., 2005). These potential harmful effects may be addressed through the adequate design, maintenance and management of urban green spaces and selection of species (Lõhmus and Balbus, 2015).

The main goals of the euPOLIS project are measuring the NBS’ health, WB and social impacts. Some of the specific objectives of the WP4 are “to improve PH and WB through fostering pro-ecological

thinking, consciousness and social responsibility among community members as well as policy makers and planners/engineers and to support the creation of the livable and vibrant urban spaces through collecting voices of local communities and stakeholders and translating them into specific spatial and technical solutions". As a result, it is expected that the introduction of BGS urbanization in four European cities (Belgrade, Piraeus, Lodz and Gladsaxe), will enable new forms of outdoor activities and interactions with all positive impacts on PH and WB, based on the previous, evidence/based experiences, described in the literature (euPOLIS-Integrated NBS-based Urban Planning Methodology for Enhancing the Health and Well-being of Citizens: the euPOLIS Approach). The definition of the multi-dimensional set of indicators for the assessment of NBS impacts on PH and WB is the main task of WP 4.1.and is of great importance for the foundation of the study.

2.2 Nature based systems and social sustainability - Livability

2.2.1 Livability

Livability is a concept that embraces a set of multidimensional aspects relating to the qualities of a certain space, neighborhood or city, which are prerequisite to wellbeing and public health. Considering the multiple impacts of NBS it is necessary to identify a set of multidimensional indicators for the assessment of change in terms of livability.

There is a vast literature conceptualizing livability with numerous subjective and objective indicators applied at various levels of local management. On the one hand, Giap et al. (2014) postulated that livability is a place-based concept that contributes to the quality of life and wellbeing of residents. On the other hand, Pacione (1990) argues that livability is also a function of personal characteristics and should include people's perception of the place and whether it is suitable to their needs or not. Widespread practical approach to livability is represented by the international studies, such as the Mercer Quality of Living Survey (Mercer, 2011), or the Economist Intelligence Unit's Liveability Index (Economist Intelligence Unit, 2012), which goal is to rank cities based on their current livability. These studies cover a range of different issues such as accessibility, equity safety, comfort, available services, walkability, transit, and participation that altogether build the final livability index.

In case of euPOLIS project, the livability model will be one of the important tools of impact measurement in our pilot sites. It will synthetize various social and urban indicators to create a comprehensive measure of how the NBS influenced the livability in the neighboring community.

EuPOLIS approach of planning for people recognizes that increasing livability contributes to such important aspects of development as sustainability as well as individual and collective health and wellbeing. By linking the health- and wellbeing-related indicators and activities with specific NBS implementation in our pilot sites we aim at showing the link between reshaping public spaces in line with euPOLIS methodology and their increased livability as a direct condition for increased PH and WB.

Improved livability should result in both healthier lifestyles (enabled by NBS), as well as positive emotional attachment to the site and increased sense of responsibility or being part of the local community. euPOLIS sites are expected to contribute to local livability in terms of increasing the amount and quality of green and blue areas, ensuring safety and accessibility to diverse groups of users, introducing new attractive functions, and encouraging more intensive use of the space resulting in higher number of interactions. This requires a place-based urban planning and design approach, with innovative livability-related planning criteria, that builds upon local characteristics. In particular, it should acknowledge the preferences and needs of the local community in terms of contact with nature (close to local centers and housing estates), recognizing its primary role in supporting a community's access to healthy living, socializing opportunities, and a better living environment.

In euPOLIS, we employ the concept of livable communities and places to put people's wellbeing and health in the center of the urban equation and to shift the development patterns in urban planning, by focusing on the quality of place. As a result, livability is defined through features that create a place where people want to spend time and are happy to live in, which can be measured by factors such as safety, comfort, accessibility, walkability, and availability of community facilities, etc.
To enhance impact measurement of euPOLIS implementation as well as the process of participation in planning, we propose the theory-driven, but practice-oriented livability model, developed in line with the New European Bauhaus (European Commission, 2021) philosophy. Importantly, our approach to assessing livability is rooted in universal values, but then tailored to the local conditions and data availability. We want to consider how people actually use and perceive urban space to be able to ingrain this knowledge into design guidelines and stakeholder engagement plan.

To summarize, we treat livability as a place-related and anthropocentric concept, concerning 'here and now' of a specific place and the community of its users. Based on the common set of livability principles available in the literature, we decided to focus on those aspects that directly relate to public health and wellbeing through green space design, accessibility, available infrastructure, and services or functions. Those aspects are grouped into seven categories that directly relate to the New European Bauhaus priorities: (1) safety, (2) comfort, (3) walkability, (4) contact with nature, (5) sense of place, (6) friendliness, (7) multifunctionality.
Our euPOLIS Livability Model (see Deliverable 4.2), built on those seven major categories, is related to the direct and indirect impacts of the Blue-Green spaces designed within the framework of the project. While we perceive health and wellbeing as central areas of impact, we also point out to the desired socio-economic impacts including local civic engagement (stimulated through the use and possibilities offered by NBS as well as indirectly resulting from better health), positive place attachment (which relates to mental wellbeing as well as willingness to engage on the local level) and local economic growth (resulting from higher attractiveness of the area to people and businesses). In deliverable 4.2 we describe in detail the theoretical foundation as well as implementation methodology of euPOLIS Livability Model. We also underline its relevance to the three core dimensions of the New European Bauhaus (NEB) and current policies of the European Green Deal. The euPOLIS Livability Model is guided by three NEB values: (1) sustainability – to ensure biodiversity, circularity, and addressing the climate goals; (2) aesthetics – going beyond functionality, relating to the quality of experience in places; and (3) inclusion – to secure accessibility and affordability for all, through valorizing diversity.
For more details see deliverable D4.2.

2.2.2 Social sustainability

While livability relates to the physical context necessary for good life, social sustainability focuses on social context of community wellbeing, as well as longevity of introduced implementations and innovations. In the case of euPOLIS pilot sites, social sustainability will relate to the potential level of acceptance of planned changes, as well as potential to embrace NBS as important part of community better future.
Sustainability is commonly defined as "meeting the needs of present generations, without compromising the ability of future generations to meet their own needs." It's about ensuring that humans have what they need, now and in the future. Part of that means ensuring that their physical environment is taken care of and remains livable. However, the emphasis in social sustainability is on ensuring humans have what they need.

As one of the active social enterprises define it: 'social sustainability is a process for creating sustainable successful places that promote wellbeing, by understanding what people need from the places they live and work. Social sustainability combines design of the physical realm with design of the social world – infrastructure to support social and cultural life, social amenities, systems for citizen engagement, and space for people and places to evolve." (Social Life, 2012)
Moreover, some scholars suggest that all the domains of sustainability are social: including the environmental, economic, political and cultural sustainability. Indeed, all these domains of sustainability are dependent upon the relationship between the social and the natural, defined as human embeddedness in the environment.
In our approach we follow the findings of Vallance, Perkins and Dixon (2011), who identified the 'maintenance sustainability' – concerning ways of life that people would see maintained or improved that builds on re-humanized, context-aware concept of sustainability by highlighting why people ignore or resist change and ecological messages. The authors acknowledge the conflicts that often arise between doing what is environmentally friendly (in our case introducing Blue-Green solutions) and doing what has been always done, what is easy, or simply doing what one likes.
As advocates of sustainability, we cannot assume the facts about environmental issues will 'speak for themselves' and we have to consider why people resist change, even when there are very good arguments for introducing certain changes. The adverse impacts some eco-implementations may have on already disadvantaged groups, has to be recognized and combined with a deeper understanding of the ways in which technical aspects of Blue-Green solutions influence everyday life. These are central to ensure a smoother and equitable transition to a more sustainable future, in which the importance of social development is recognized as the central goal.
To implement the various innovations that will transform societies in the direction of environmental sustainability, it is necessary to have well-functioning societies — from a social, political and economic standpoint — that can meet the new challenges successfully. Healthy and happy individuals with a strong sense of place, identity and relations based on trust are more likely to prioritize the protection of their environment. Therefore, the empowerment of local communities and increased social sustainability is essential condition for long term grassroots, legal and political protection of the natural environment.
While environmental sustainability examines living within the limits of the natural world, likewise, social sustainability emphasizes living in ways that can be sustained because they are healthy and satisfying for people and communities. This requires providing for material, social and emotional needs, avoiding behaviors that result in poor health, emotional distress and conflict, and ensuring that we do not destroy the social structures (such as families and communities), cultural values, knowledge systems and human diversity that contribute to a vibrant and thriving human community. In other words, social sustainability means meeting the needs for human wellbeing.

In our work we focus on the universal framework for studying social sustainability proposed by Missimer, Robèrt, and Broman (2017). Building on the study of complex adaptive systems, they distinguished a unique characteristic of a sustainable social system, one that can prosper in the situation of uncertainty and change. They list five characteristics of a social system essential for achieving sustainability: diversity, common meaning, trust, capacity for learning, and capacity for self-organization.

Social Sustainability is a critical component of a community's wellbeing and longevity. Social sustainability is largely neglected in mainstream sustainability debates. Priority has been given to economic and environmental sustainability in particular in the context of planning, housing and communities, where policy and investment has focused on renewable resources, low carbon

communities and encouraging pro-environmental behaviour in households. A community is composed of people as well as the places where they live; it is as much a social environment as a physical environment. Thus, communities must not only be environmentally sustainable, they must also be socially sustainable. Social sustainability cannot be created simply through the physical design of the community but then neither can environmental sustainability be created by physical design alone. Physical design cannot ensure that individuals, families and communities will lead environmentally sustainable lifestyles, although it can help to make such environmentally sustainable choices more easy. Equally, while there is much that can be done on the "design" of the soft infrastructure of the community to ensure its social sustainability, the physical design of the community can make it either easier or more difficult for communities to be socially sustainable.
Oxford Institute for Sustainable Development[1] (OISD) has a definition for Social Sustainability:
Concerning how individuals, communities and societies live with each other and set out to achieve the objectives of development models which they have chosen for themselves, also taking into account the physical boundaries of their places and planet earth as a whole. At a more operational level, social sustainability stems from actions in key thematic areas, encompassing the social realm of individuals and societies, which ranges from capacity building and skills development to environmental and spatial inequalities. In this sense, social sustainability blends traditional social policy areas and principles, such as equity and health, with emerging issues concerning participation, needs, social capital, the economy, the environment, and more recently, with the notions of happiness, wellbeing and quality of life.

Social sustainability is explored by euPOLIS indicators, presented here and by methods presented in Deliverable 4.2.

[1] https://www.brookes.ac.uk/Research/Units/TDE/Institutes/Oxford-Institute-for-Sustainable-Development-OISD

3 euPOLIS Indicator framework overview

The euPOLIS indicator framework is being developed with the aim of evaluating the impact of NBSs in different aspects of Public Health and Well-being with special emphasis given to both time and spatial scales, by providing a list of indicators that can support time-restricted and local evaluation of NBSs, but with a potential for upscaling. The development of the *overall euPOLIS evaluation framework* (including benchmarking, normalization, and other performance assessment metrics) is the main aim/topic of Task 8.1 and is being developed in parallel to the tasks in WP4 and will continue until M24; it will be described in detail in Deliverable 8.1.
The indicator framework, besides facilitating the evaluation of implemented NBSs, also provides support for the planning of NBSs along with their monitoring during deployment and exploitation, and therefore includes two distinct levels of indicators: (1) Contextual, and (2) Evaluation Indicators. Additionally, there is a set of the ***Key Performance Indicators (KPIs)*** which aggregate data across different levels and categories of information to provide an overall project evaluation (see Table 12 in Section 7.1 - Annex).

Contextual Indicators (CIs) are used during the ***planning phase*** to provide an initial site screening and site characterization, by facilitating an initial baseline assessment that will assist in gaining a better understanding of the site and its needs. The evaluation of CIs is based on readily available data and sources, including national and international databases, local agencies and authorities, existing reports, questionnaires, site visits, etc. The best available data is used at the temporal and spatial resolution most appropriate for each pilot site. It is quite common that the resolution of the available sources may differ between the different data categories (social, environmental, etc.), as well as among different countries.
CIs together with various euPOLIS urban planning tools and methodologies (e.g., GDPM) are then used to identify, select and design appropriate NBSs that will target specific issues, as these are represented by Challenges and Themes (see Section 4), of the location at which their implementation is planned. Specifically, by quantifying CIs it is possible to identify the specific needs, trends, and pressures of each site, which subsequently in conjunction with the GDPM and urban planning participatory processes (e.g. recording of stakeholders' concerns) allow for the selection of potential interventions/NBSs to address these site needs according to the euPOLIS project aims and focus. The initial baseline assessment of FR cities and the resulting gap analysis of the demo-sites, as well as project requirements are included in Deliverable 3.2 (Baseline status and indicators identification) and Deliverable 3.3 (euPOLIS Project Requirements).

Since CIs provide a wider context of the site, they could also be used in the future for analyzing more in depth the NBS evaluation results through EIs and possibly provide a path for upscaling of solutions. This will be investigated within the work of WP8. CIs, including their definitions and use, will be described in detail in D8.1 together with the overall euPOLIS evaluation framework and methodology. The list of CIs as defined until this point (version 1.0) that has been used for the initial FR cities baseline assessment (Deliverable 3.3), is included in Section 0.

Evaluation indicators (EIs) are used during the ***exploitation phase*** of NBSs to assess their performance and effectiveness using appropriate data collected via monitoring and/or modelling. EIs are quantified prior and after the implementation of NBSs and the comparison of indicator values at these two stages provides evaluation of the (positive or negative) multi-dimensional impact of the implemented NBS. The development of appropriate EIs is a core element of the work within WP4 and they are described in detail in Section 6 of this report.

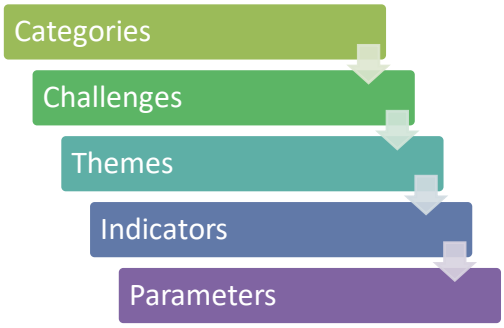

Figure 3 Hierarchy of euPOLIS terms in the Indicator framework

The euPOLIS indicator framework uses the following terminology (Figure 3):

1. **Categories** – there is a total of five categories in which indicators are developed: Public Health and Wellbeing (PH&WB), Social (S), Environmental (E), Economy/Business (B), and Urban Development (U).
2. **Challenges** – Challenges are identified under each of the Categories and are targeting main problems that are to be addressed by NBSs.
3. **Themes** – are recognized as sub-challenges that serve to identify various aspects of a challenge that should be addressed by NBSs. In most cases, Themes are used for defining Indicators (both Contextual and Evaluation). However, sometimes the spatial or temporal scale are inadequate (too small) to evaluate a theme, in which case Indicators are designed to evaluate multiple Themes at once or a whole Challenge.
   The purpose of Themes goes beyond the Indicator framework, as they provide a connection with the euPOLIS planning system – the GDPM (Figure 5).
4. **Indicators –** are metrics used to evaluate the context of the area (CIs) or the change of state for each Theme/Group of themes/Challenge addressed at the site – before and after the NBS implementation (EIs). The metrics are calculated using parameter data – that is collected via monitoring or calculated via modelling.
5. **Parameters** – are the most basic component of Indicators and represent the "raw" monitored/measured data that can be used to quantify Indicators.

The main planning system of euPOLIS is the Goal Driven Planning Matrix (GDPM) (Figure 4), that represents a systematic process for defining developer's goals, identifying available resources, and ensuring full participation of relevant stakeholders (see Deliverables 3.2 and 6.1 for more details). Indicators in euPOLIS are an integral part of this planning methodology (Figure 5) – features of the GDPM are closely related to the indicator framework structures.

1. euPOLIS KPIs represent a source (together with stakeholders' inputs) for both GDPM's Goals and Indicator framework's Challenges.
2. Challenges develop into Themes, while GDPM's Goals develop into Sub-goals used to set Targets.
3. Interventions (Concepts, Solutions) serve to fulfill the Targets, and Evaluation Indicators are a metric used to assess the intervention efficiency.

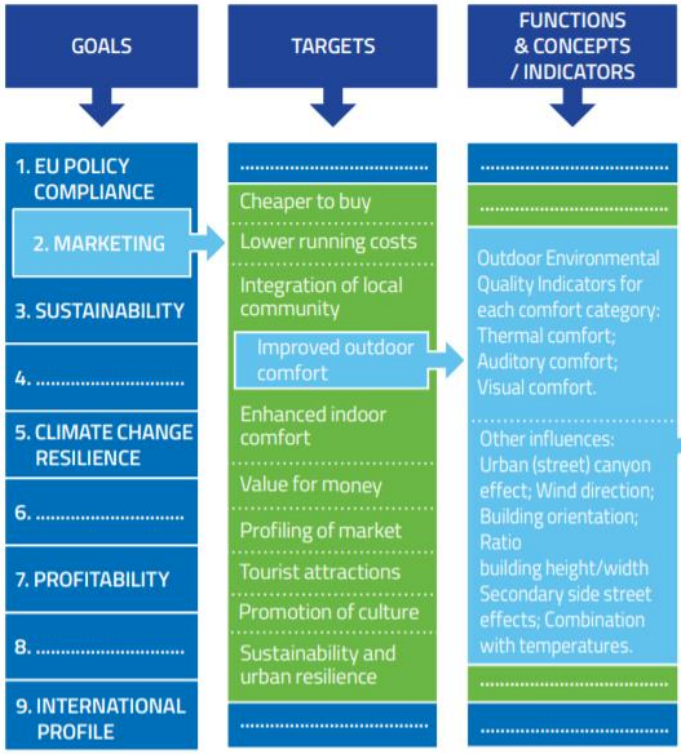

Figure 4 GDPM sample - figure taken from Bozovic et al., 2017

The processes of developing sets of challenges and themes, and goals, subgoals and targets is iterative, and performed until participants are satisfied with the outcome. Once CIs are developed, they become additional input for the GDPM, as quantified values of CIs indicate needs and trends and pressures that exist at the location, that should be addressed by concepts/interventions. The process of how CIs feed into the GDPM is presented in Deliverable 3.2, while actual outputs of combined quantified CIs and provisional GDPM for setting project requirements is presented in Deliverable 3.3.

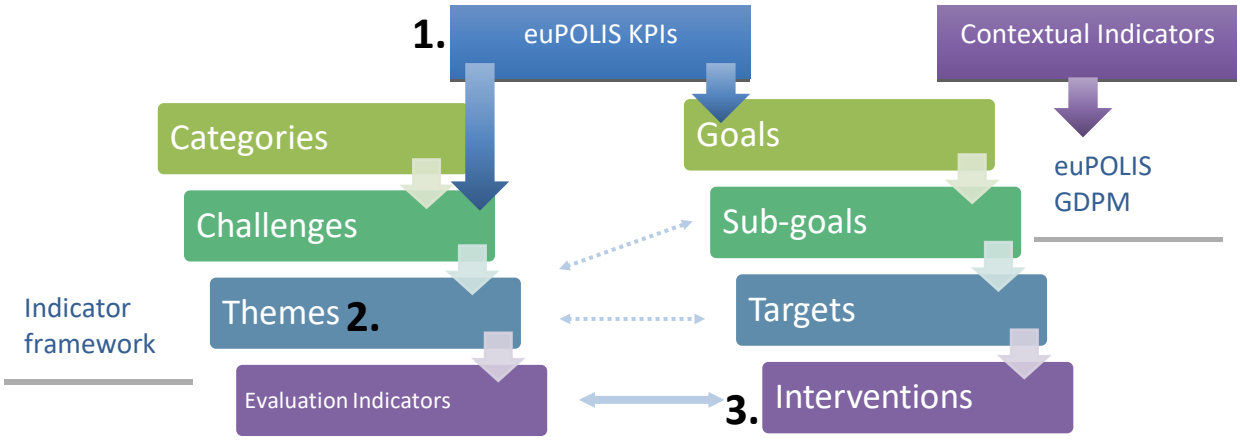

Figure 5 euPOLIS Indicator framework and GDPM

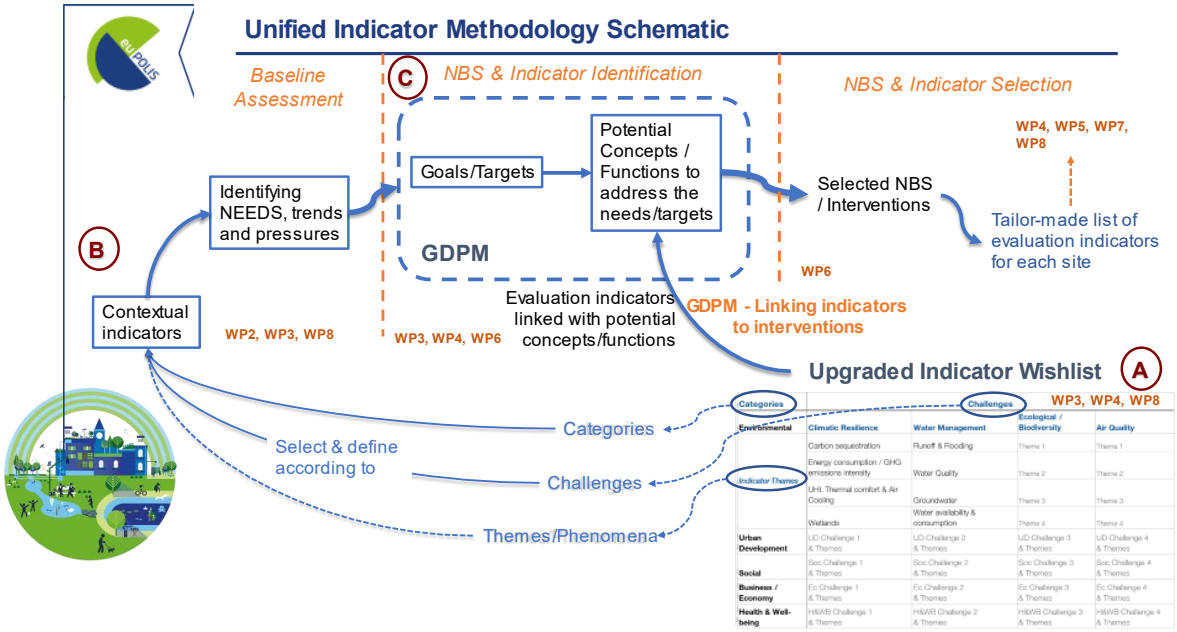

Figure 6 euPOLIS overall Indicator methodology schematic

Figure 6 presents an overall euPOLIS unified indicator methodology schematic, showing how the individual methodological components, A, B and C, could link together creating a coherent methodology across the different WPs. ***"Indicator Wishlist"*** **(A)**, is a pool of indicators, developed throughout the project – starts in WP3, continues in WP4 and finishes in WP8. Indicators are selected from this list according to site needs and selected NBS (within component **C**).

The steps in the process are following:

Indicator wishlist **(A)**

1. Define main indicator ***Categories*** i) Public Health & Wellbeing ii) Social iii) Economic/Business, iv) Environmental, v) Urban development
2. Identify main ***Challenges*** within each category in line with project objectives (e.g. climate resilience, air quality, water management, physical activity, involvement in participatory processes, etc.)
3. Identify sub-challenges i.e. ***Themes*** (relate to ***Sub-goals*** and ***Targets***) and potential suitable ***Indicators*** within each Theme, as well as possible needs for future indicator additions
   Possible ***sources*** for Challenges & Themes: Project KPIs, NBS Indicator Handbook, professional expertise, stakeholders' inputs, etc.
   Possible ***sources*** for Indicators: Existing indicators from literature, existing own indicators (models, etc.), new for development / definition, participatory process
4. Produce an NBS evaluation indicator ***Wishlist*** (started in WP3, refined in WP4, to be further refined in WP8)

Baseline assessment **(B)** (performed in Deliverables 3.2 and 3.3)

Further develop and refine ***Baseline assessment*** **(B)** methodology inline also with Task 8.1 by including ***Contextual indicators & Trends and Pressures***

1. Main ***purpose***: to gain a good understanding of demo locations (site characterization), identify main challenges and needs, pinpoint potential NBS types for implementation

2. Identify important ***Contextual indicators & Trends and Pressures*** under each indicator *Category, Challenge and maybe Theme*, where appropriate. Trends and Pressures could include information on issues such as urbanization, population aging, climate change, etc.
3. ***Sources*** where to extract relevant information for each site from: Questionnaires (WP2), statistical, climatic, other data from local agencies/authorities and national/international databases (OECD, Eurostat, Urban Atlas, etc.). Included data will be at variable spatial scales, according to availability (site, neighborhood, city, (region)).
4. Need to finalize this as the agreed contextual indicators could further inform the information asked from the pilots (questionnaires, etc.)

NBS and evaluation indicator identification **(C)**

The ***GDPM*** methodology is central to the indicator methodology and NBS planning/design as it is used for identifying and designing appropriate NBS interventions/functions and identifying the relevant NBS evaluation indicators.

1. The GDPM uses the outputs of the Baseline Assessment **(B)** (issues and needs) to identify appropriate Goals for each site
2. Extract ***Goals/Sub-goals/Targets*** from project KPIs
3. For each ***Target*** identify possible ***Functions*** (a.k.a. Interventions / Solutions)
4. For each intervention identify from the refined Wishlist the relevant ***evaluation indicators*** (at appropriate spatial and temporal scale) that will be used for the evaluation of NBS **(A)**. Only indicators linked to selected interventions / NBS are going to be evaluated / monitored / modelled at each site.

The main output of this process would be a tailor-made list of evaluation indicators for each site. This indicator list will inform:

- WP4 for the refinement and final definition of selected indicators, as well as inform the requirements of the models included in this WP
- WP5 for the modelling and monitoring requirements included in this WP
- WP7 for the monitoring requirements
- WP8 for the overall assessment methodology & site assessment

The process of selecting relevant Challenges and Themes, followed by contextual and evaluation indicators, is done by working groups (WGs) gathered around each of the five categories, followed by multidisciplinary meetings between the groups, and later discussed in the entire WP4 consortium (academic and research partners, SMEs, Front runner and Follower cities). The following are the partners participating in each of the WGs:

1. PH&WB: FCEBG, NTUA, Imperial
2. Social: UNIWARSAW, FCEBG, NTUA
3. Business: EnPlus, RG, NTUA
4. Environmental: ERCE PAN, FCEBG, NTUA, AMPHI, GEOSYSTEMS, UNIANDES, Imperial
5. Urban Development: Imperial, GEOSYSTEMS, Mikser, Byspektrum

Following steps in developing indicators (beyond this deliverable) will be to include inputs from citizens to customize existing and come with new tailor-made indicators suited to local needs. This action will be undertaken through participatory processes, and results will be contained in Deliverable 8.3 (Report on Evaluation and Validation Assessment).

4 euPOLIS Challenges and Themes

There is a total of five categories in which indicators are developed: Public Health and Wellbeing (PH&WB), Social (S), Environmental (E), Business/Economy (B), and Urban Development (U). In each of the Categories, a series of Challenges is identified using euPOLIS Key Performance Indicators (KPIs), project partners' experience and knowledge, literature review (Section 2) and stakeholders' wishes (Table 3). Table 14 in Section 10.1 (Annex) contains euPOLIS preliminary KPIs, where #1-9 are relevant for the Indicators' framework.

Table 3 List of Challenges identified under five Categories: Public Health and Wellbeing, Social, Environmental, Business and Urban Development

Public Health and Wellbeing	Social	Environmental	Economy/ Business	Urban Development
Physical activity	Sense of safety	Climatic Resilience	Creation of livable and vibrant urban spaces conducive to business activation	Multifunctionality
Mental health	Friendliness	Water Management	Site related business initiatives - opportunities for businesses	Accessibility
Risks for Respiratory Diseases	Social Cohesion	Circular economy	City providing financial support to private start-ups and NBS-related businesses (primarily those enhancing WB)	Safety
Risks for Cardiovascular diseases, Diabetes type 2, Obesity	Diversity	Integrity (or Biodiversity loss/habitat fragmentation)	Comprehensive positive impact from the business activity on the neighborhood	Identity
Risks for Communicable Diseases	Comfort of use	(environmental) Pollution	Engagement of nearby companies into the NBS paradigm; support and enhancement of existing business with NBS interventions	Impact
Wellbeing	Sense of place	Access to ecosystem services	Increase of neighborhood value - surrounding property value	Density
	Willingness to participate			Demography
	Activation in participatory process			Blue-Green Systems Planning Approach
	Strengthening local community ties			
	Environmental awareness			

4.1 Public Health and Wellbeing Category

The selection of relevant Public Health challenges is in line with euPOLIS KPIs and is based on two criteria: (1) the burden of disease and disabilities analysis as well as risk factor analyses, and (2) the expected impact of implemented interventions/NBSs in all demo-sites limited by available project time. Based on the latest burden of disease studies, the leading causes of morbidity, mortality, and disability worldwide as well as in Europe are **cardiovascular diseases**, malignant diseases, **respiratory**, metabolic (**diabetes**, hyperlipidemia), **mental** and **communicable diseases** with six most important risk factors dietary risks, high systolic blood pressure, tobacco, air pollution, and **high body mass index** (a measure of body fat) (GBD 2019 Viewpoint Collaborators, 2020). Due to limited available project time, malignant diseases are excluded since prolonged effects of NBSs are needed to assess this influence. Additionally, given the multicausality of the most relevant **noncommunicable diseases** present nowadays, there is an overlap among the risk factors and these diseases.

Table 4 Themes/Phenomena for each of the PH&WB Categories

Physical activity	Mental health	Risks for Respiratory Diseases	Risks for Cardiovascular diseases, Diabetes type 2, Obesity	Risks for Communicable Diseases	Wellbeing
Walking, running, cycling (individual activities)	Sensory effects of the environment	Presence of allergens*	Physical activity (cross-cutting challenge)	Water quality*	Interaction between people and nature
Collective sports	Safe and secure environment	Air Quality*	Work therapy (e.g. gardening)	Waste management*	Engagement in the local activities**
Work therapy (e.g. gardening)	Socialization / Social cohesion**	Physical activity (cross-cutting challenge)	Education on a healthy lifestyle***	Sanitation & urban drainage*	Feeling of responsibility
Cultural events		Education on a healthy lifestyle***	Outdoor environment control*	Education on a healthy lifestyle***	Place attachment**
					Positive emotions
					Positive relationships
					Feeling of meaning and accomplishments

* These overlap with the Environmental Category
** These overlap with the Social Category
*** This is not evaluated through indicators, but is promoted throughout project activities

Physical activity is selected as an independent cross cutting challenge, because it is recognized as the stimulant for good health and wellbeing. According to the literature data, the physical activity requirements are the same as 400,000 years ago for the people living today (Leonard, 2010). Physical activity plays an essential role at all periods of life in the prevention of non-communicable diseases. It is proved that physical activity has positive impacts for the people of all ages in

improving mental health, self-confidence, sleep, increasing energy and reducing the risk of chronic diseases. (Leonard and Robertson, 1992). Regular physical activity aids in reducing the risk of stroke, heart disease, cancers, high blood pressure, and osteoporosis (Saqib et al., 2020). The type, level and duration of physical activity have an impact on physiological parameters.

The heart rate is usually described as a total number of times that heart beats in a minute. The heart rate is higher in persons, who practice more intensive physical activities, although aerobically fit people have lower heart rate at any stage of activity. The average number of heart beats for a normal individual is 60−100 times per minute, but for a trained person the number of heart beats is 40−60 times per minute. The results of research studies point out that the higher ambient heart rate during sitting or relaxing correlates with the higher risk of heart diseases. Analogously, the lower ambient heart rate usually manifests better health condition. Heart rates are usually measured using external hardware (sensors, cardiac monitors, chest belts, wrist for pulse counting and more recently, modern smartphones with heart rate monitoring application (Chaudhry, 2016). It is obviously shown that the exercise has long-term advantage on cardiovascular system, which comprises decreased resting heart rate, improved ability of deeper breathing, reduced resting blood pressure and lowering risk of heart disease, increased burning of calories which helps in maintaining healthy body weight (Papathanasiou et al., 2020). During the exercise, human body produces more carbon dioxide and needs additional levels of oxygen. To manage with this extra demand, breathing in individuals during exercise must increase from around 15 times a minute at resting, to about 40−60 times a minute during exercise. Lungs in healthy persons keep a large reserve of breathing. Persons with reduced lung function may use a large part of their breathing reserve (Your lungs and exercise, 2016). Furthermore, physical activity has supportive effects in lowering stress and in improving general wellbeing by enhancing energy levels. Lack of Physical activity has become a challenge due to the rising burden of non-communicable diseases.

Improving **wellbeing** is another project core objective and compared with PH it is a more multidimensional feature. The World Health Organization (WHO) defines positive mental health as “a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community” (WHO, 2001). Good health is, therefore, one part of the wellbeing, but so are the economic security (GDP, poverty, employment, etc.), social and behavioral aspects (literacy, education, social involvement and activity, lifestyle, living conditions, etc.) and environmental conditions (pollution, climate change, environmental safety, etc.) (How is life?, 2013). Even some subjective features make personal wellbeing: positive emotions, place attachment, social engagement, positive relationships, feelings of meaning and accomplishment. Therefore, Wellbeing as a challenge, is spread across four categories (PH&WB, Social, Economy/Business, Environmental), with the subjective side mostly being in the PH&WB category.

PH&WB is closely related to euPOLIS KPIs 1, 2, 3 and 5. The Category is covered by 6 Challenges: Physical activity, Mental health, Risks for respiratory diseases, Risks for cardiovascular diseases, diabetes type 2 and obesity, Risks for communicable diseases and Wellbeing, all identified in the literature as the most probable features of PH&WB that will have positive effects from NBSs.

Physical activity is a Challenge related to KPI_2, that is to be evaluated through improvements (duration and diversity) of individual activities (walking, running, cycling) and collective sports, but also through activities that can result from engagement into working around NBSs (e.g. urban

gardening/horticulture) or participating in NBS related cultural events (e.g. concerts, plays, performances, exhibits, etc.).

Mental health is a Challenge derived from KPI_1, that depends on the sensory effects of the environment (noise, visual, olfactory, etc.), sense about the safety and security of the environment, and the extent of socialization. There is a strong connection between mental health (stress, anxiety, depression, etc.) and psychological well-being with biodiversity, which is why this is a standalone Challenge in the Environmental category (see Section 4.4).

Risks for Respiratory Diseases, **Cardiovascular Diseases, Diabetes type 2, Obesity** and **Communicable Diseases** are all related to KPI_3 – where it is expected that the improvements of the local conditions such as maintaining lower levels of noise, air pollution, moderate air temperature, water quality, exposure to waste, etc. should substantially decrease the risks for both NCDs and CDs. Additionally, moderate physical activities and education on a healthy lifestyle both can contribute to the decrease of the risks for both NCDs and CDs.

The part of **Wellbeing** found under this category is related to KPI_5, which focuses on how wellbeing is improved through interaction between people and nature, engagement in the local activities, feeling of responsibility, place attachment, positive emotions and relationships, and a feeling of meaning and accomplishments.

4.2 Social Category

Table 5 and Table 6 show the list of Social challenges selected to be addressed through euPOLIS project, along with their Themes. Social challenges are selected to be relevant to the variety of PH and WB aspects, while also including livability and social sustainability issues.

The selection of relevant Social challenges, is built upon euPOLIS KPIs, as well as an extensive literature review on the topic and experiences of previous European Commission funded projects (like CLIC[2] or WILCO[3]). The selection was based on two criteria: (1) the relevance of potential challenges to euPOLIS objectives and methods, and (2) the expected impact of implemented NBSs in demo-sites limited by project period.

Sense of safety – remain a basic prerequisite of quality of life and a condition of the willingness to use public space for health and wellbeing. Sense of safety and fear of crime have established causal relationships with a multitude of health and wellbeing outcomes, including mental health (Stafford et al., 2007), self-rated health (Chandola, 2001), and physical functioning (Ross and Mirowsky, 2001). Potential indicators include safety for the general population and for specific subgroups (e.g., children, women), safety while walking alone and provision of safe public spaces for people to meet (Honey-Ray and Enns, 2009), and perceptions of safety in public spaces, (Community Indicators Victoria, 2013).

[2] https://www.clicproject.eu/

[3] http://www.wilcoproject.eu/

Table 5 Themes/Phenomena for each of the Social Categories - first part

Sense Safety	Friendliness	Social Cohesion	Diversity	Comfort of use
Making the space safe for women and girls walking alone	Friendliness for women and girls	Sense of belonging	The space is used by people of all genders and age	The space is well-connected in terms of public transport
Making the space safe for kids and teenagers	Friendliness for kids and teenagers	Trust within community	The space is used by minorities and newcomers	There is a space for kids of all ages
Making the space safe for seniors	Friendliness for seniors and people with disabilities	Community efficacy	The space is used by people of various incomes and social status	The space is accessible for seniors and people with disabilities
Making the space safe for people from minorities and newcomers	Friendliness for minorities and newcomers	Trust towards other space users	Non-discrimination practices	The space is walkable and bikeable
Space maintenance signaling that the place is taken care of	Friendliness for low-income users	Involvement of residents in local activities	Opportunities for self-expression for all	Access for trolleys and wheelchairs

Table 6 Themes/Phenomena for each of the Social Categories - second part

Sense of place	Willingness to participate	Activation in participatory process	Strengthening local community ties	Environmental awareness
Positive place attachment	Proportion of residents interested in the project	Participatory activities tailored to the specificity of the local area	Implementation's potential to create new community ties and strengthening the existing ones	Increased responsibility for the natural environment
Sense of ownership of the space	Proportion of residents involved in longitudinal studies	A wide information and promotion campaign about the project, tailored to diverse groups of users	Increased positive interactions between various groups of users	Increased knowledge about the importance of NBS for PH and WB
Sense of pride in being part of the local community	Drop-out rate of participants in longitudinal study	A significant number of local inhabitants (target > 200) taking part in project activities	Enabling trust and solidarity among the community members	Increased expectations in terms of energy and water conservation
Recognizing NBS as part of the common good	Trust towards decision makers and local municipality	Engagement in the local activities	Enabling tolerance for diversity, and mutual respect among users	Increased experience in participatory processes

Friendliness – addresses the issue of openness of a given place to all people, signaled by the space design as well as diversity of functions and access options. Blue-Green Spaces in urban areas are often lacking in terms of child-friendly or elderly-friendly standards (e.g., Yuniastuti and Hasibuan, 2019). Good public space create harmony in urban areas, especially inducing pleasant feelings in different groups of users causing a sense of attachment and willingness to stay in a given space (Devi 2018). Blue-Green Spaces are essential to provide ecosystem services that reduce the social stress levels of people living in densely populated urban areas. They need to address the needs of the community interaction and joint activities. Space also serves as a place of active play for children and adults, as well as passive relaxing space for adults affording aesthetics, social and psychological benefits (Haq, 2001).

Social cohesion – refers to the strength of relationships and the sense of solidarity among the members of a community, including the sense of collective commitment to carry the 'costs' (financial, social, emotional, or otherwise) to assist others (Prainsack and Buyx, 2012). Social cohesion also signals tolerance and respect – attitudes paramount to overcoming conflict. As a result, it plays an important role in shaping local environments and the lives of the people within them as they are responsible for the empowerment and engagement of community members in planning, implementation, and delivery of services, infrastructure, and policies. Therefore, it is important for reducing social and health inequalities (Campbell, 2010) and can lead to greater confidence and competence among individual citizens, and empower whole communities (Schuller et al., 2004). Related community efficacy, grounded in mutual trust, describes a community's ability to create change and exercise informal social control (i.e., influence behavior through social norms) (Cohen et al., 2008). Collective efficacy is associated with better self-rated health, lower rates of neighborhood violence, and better access to health-enhancing resources, and as such an important euPOLIS focus.

Diversity – is the first aspect of the adaptive capability of social systems (Norberg and Cumming, 2008). It can be understood as a diversity of knowledge, skills, opinions, beliefs, and values. Anything that adds to the variety of a community helps to prepare it for the unknown (Folke et al., 2005). A monolithic society, in case of external shocks, often lack the right resources allowing for smooth adaptation to a new situation (Ostrom, 2009). The diversity can be understood as a latent resource of the community from which it can draw whenever the need emerges. The diversity or heterogeneity of agents is also often mentioned in the context of innovation (Lane, 2016). The heterogeneity, which leads to the creative tension and forces people to think out of the box, is believed to facilitate innovation. Confrontation with heterogeneity helps to understand reality and plurality of opinions and meanings.

Comfort of use – comfort in urban public spaces has become increasingly important for improving environmental quality and encouraging people to spend more time in outdoor activities (Peng 2021). Main approaches to understand comfort perception are based on the rational indices. However, a more comprehensive understanding of comfort by considering a wider range of influential factors from both individual and environmental perspectives is necessary. Those include the overall quality of experience deriving from presence of different stimuli (or lack of thereof) in the given space. Comfort of use is therefore a challenge that must address the quality of greenery and water infrastructure, outdoor furniture, amount of noise, presence of diverse smells and colors, brightness of lightning and amount of shade as well as general harmony of design. The outdoor Blues-Green spaces role in facilitating the adaptation to the increased heat stress is also important, evolving into a contribution to the energy efficiency of the surrounding buildings (Yang et al., 2014).

Sense of place – relates to the emotional, cognitive, and behavioral bond that people develop with the place (Lewicka, 2011). Sense of place is defined as the meanings of and the attachment to a place held by an individual or a community (Semken, 2005). It refers to the emotive bonds and attachments people develop or experience in particular locations and environments, at scales ranging from the home or neighborhood to city or country. Sense of place is also used to describe the distinctiveness or unique character of specific localities. It relates to positive bonds of comfort, safety, and wellbeing engendered by place, as well as negative feelings of fear, dysphoria, and placelessness (Foote and Azaryahu, 2009). It is linked with the consciousness of responsibility and ownership for the neighborhood, and a sense of belonging to the community (Pierceet al., 1992)

Willingness to participate – a common barrier to implementation processes, the willingness to participate remains one of the main challenges in euPOLIS. It strongly correlates with the perceived trustworthiness of decision-making and decision-makers, based on three dimensions: (1) perceived competence: perception of government organization as capable, effective, skillful, and professional; (2) perceived benevolences: perception of government organization as caring about the welfare of the public and motivated to act in the public interest; (3) perceived integrity: perception of government organization as sincere, truthful, and fulfilling its promises.

Activation in participatory processes – addresses the need to ensure the representativeness of participatory processes within the euPOLIS project. It will estimate the proportion of residents involved in the public participation processes in a given municipality per e.g. 100 000 residents. Degrees of participation will be also considered, including following types: information, consultation, collaboration, co-decision, and empowerment (Arnstein, 1969). The extent to which citizens and other stakeholders have been involved in the planning phase of a given project will include the indicator defined as the mix of stakeholders involved in a co-production process, based on their backgrounds and sectoral logics. Special attention should be given to the extent to which the NBS project has led to increased participation by groups of people who are typically not well represented in a society.

Strengthening of local community ties – one of the important aspects of strengthening the community ties is trust. When people trust each other, they focus on potentials, not threats, neither they lose time and effort on the verification of others' trustworthiness (Nowak et al., 2019). Instead of securing themselves against potential mistrust, they can concentrate on the elaboration of shared meaning and development of solutions. A high level of trust facilitates open-minded interaction of people and exchange of opinions that can form a base for self-organization. Capacity for self-organization is the last aspect of a resilient social system that Missimer et al. (2017) highlighted. In order to react fast and adequately to the changing environment, communities have to have potential for self-organization on different levels and scopes (Levin, 1998).

Environmental awareness – is an important aspect of ensuring sustainability of BGS solutions. It requires a collective meaning making process that leads to the common meaning, which is the ability of people to make sense of their situation and actions (Cacioppo et al., 2005). It helps to set the goals, rules of conduct, and values that the community collectively agrees on. Therefore, the alignment of understanding is a crucial step in the emergence of common meaning (Missimer et al., 2017). In the context of environmental sustainability, the existence of common meaning may enable the transition but only when the shared understanding of a community does not contradict the understanding of a whole system proclaimed by NBS approach. If a local community perceives its

environment as an unlimited resource (what can be their common meaning) they might be reluctant to invest extra time and money in maintaining the facilities, recycling, or reusing. In such circumstances, the probability of social sustainability is very low.

4.3 Economy/Business Category

This category deals with assessing the spill-over effects on the local economy, stemming from the implementation of NBSs, via considering the relevant Challenges and Themes presented in Table 3. The actual impact assessment is performed by quantifying a multitude of economic indicators (presented in this document) and also by creating the so-called Business-Activation-Matrix – essentially an interdisciplinary approach based on the "develop business around NBSs" strategy, that first defines and then combines the resources created by each potential NBS (business opportunities) with the existing site resources (for more details about this methodology the interested reader should refer to Deliverable 4.2).
The Challenges and Themes of the Economy/Business category relate to the KPI_9 (as per the euPOLIS GA), namely "List of activated/implemented business models. The Economy/Business challenges were selected so as to address a spectrum of PH and WB aspects, while also promoting economic and financial sustainability.

Creation of livable and vibrant urban spaces conducive to business activation – New economic opportunities are created following the implementation of NBSs primarily due to their social attractiveness (that lead to an increase in the number of site visitors) and the added site restoration value (European Commission, 2021). This challenge addresses the need to consider those NBS-related business activation values as well as the need to scan the targeted site for potential issues hampering the business activation process (e.g., unfavorable regulatory framework, space restrictions, absence of fiscal instruments for NBS-related business opportunities).

Site related business initiatives - opportunities for SMEs and individual businesses – This challenge addresses the potential of the upscaled site to deliver business opportunities for new and existing private owned or SMEs companies, new product and services, new jobs etc.

City providing financial support to private start-ups and NBS-related businesses (primarily those enhancing PH&WB) – Among the barriers prohibiting the NBS uptake are the lack of public or blended (i.e. public and private) financial instruments (Coles et al., 2019) and well as the lack of appropriate policy and regulation tools to promote private-sector NBS-related initiatives. Lowering the initial investment is a key driver to business activation. On the other hand, presenting the value proposition of NBSs in financial terms along with the provision of promoting city in-house expertise to handle issues related to their deployment could persuade the decision makers considering and consequently investing in NBSs as opposed to the gray infrastructure.

Comprehensive positive impact from the business activity on the neighborhood – Business activities could result in neighborhood economic growth in several different ways such as, increase the number of locally available jobs, increase local tax money being fed to the local economy, promote the local economic cycle, further encourage entrepreneurship, lower city maintenance infrastructure costs.

Engagement of nearby companies into the NBS paradigm; support and enhancement of existing business with NBS interventions – The perception of what constitutes an acceptable risk level, when investing to NBSs or the engagement of the local companies to the NBS paradigm could be increased by expressing their direct and indirect benefits in quantifiable terms. The over-reliance to gray infrastructure is often just a byproduct of the inherent resistance to change, company brand-related concerns and overall lack of information on the long-term performance of NBSs.

Table 7 Themes/Phenomena for each of the Business Categories

Creation of the livable and vibrant urban spaces conducive to business activation	Site related business initiatives - opportunities for small SME + individual business	City providing financial support to private start-ups and NBS related businesses (primarily the ones enhancing PH&WB)	Comprehensive positive impact from business on neighbourhood	Engagement of neighbouring companies into the NBS paradigm; support and enhancement of existing business with NBS's	Increase of neighbourhood value - surrounding property value
Space availability (for any type of small business)	Identified opportunities	Adaptable existing city polices	Positive impact on PH&WB	Local companies mapping and interviews	Gentrification risk
Financing availability	Existing site related businesses New marketable product & services Creation of new jobs	Proposal development for the city	Any other positive impact (reduction of unemployment rate)		Citizens benefit due to higher property values

Increase of neighborhood value - surrounding property value – This is a twofold challenge to tackle with potentially positive and negative consequences. The increase in the site attractiveness could result in an overall increase in the land property prices at the vicinity of the NBS upscaled site. This increase could be of low to moderate intensity and could be also concentrated just around the urban blue area, hence not affecting substantially the overall neighborhood. In some other cases though, the property prices around the upscaled site increase at a much higher rate compared to the household income while also are encountered at a much broader range. If this trend is persistent over a long period then it could give rise to the so-called “green gentrification” risk (Bockarjova et al, 2020) i.e., displacement of low-income residents from the neighborhood that is nearby the NBS upscaled site.

4.4 Environmental Category

Table 8 shows the list of Environmental Challenges selected to be addressed through this project, along with their Themes. Environmental Challenges are selected to be relevant to the aspects of PH&WB, but also to include some of the side-objectives of the project, most importantly environmental sustainability (and circularity).

Table 8 Themes/Phenomena for each of the Environmental Challenges

Climatic Resilience	Water Management	Circular economy	Integrity (or Biodiversity loss/habitat fragmentation)	(Environmental) Pollution	Access to ecosystem services
UHI, Thermal comfort & Air Cooling	Runoff & Flooding / Urban Drainage	Biomass used on place	Soil vitality	Air Quality	Green space availability
Energy consumption / GHG emissions	Water availability (surface & GW) & consumption	Water reuse	Species diversity	Water quality	Green space accessibility
Carbon sequestration	Sanitation / Wastewater Treatment	Energy recovery	Habitat connectivity and reduced fragmentation	Noise pollution	Formal / informal greenery
		Waste/Material reuse	Habitat type creation and restoration		BGI & human activities (or service functions)*

* This overlaps with the Urban Development Category

Climatic resilience – This Challenge is directly linked to KPI_7 and KPI_8 (improvement of local microclimate conditions and habitat quality), which drives KPI_1 in terms of reduction of stress, e.g. caused by unfavorable physical conditions (heat, wind) and KPI_3 dealing with reduce of risk factors that enable communicable and non-communicable diseases.

As emphasized in many studies, progressive urbanization accelerates the effect of the Urban Heat Island (UHI), causing air temperatures in highly urbanized areas to rise by several degrees higher compared to the surrounding green/rural areas, during both day and night (reduced cooling) as well as the disruption of air flows. In addition to direct heat-related health effects (dehydration, heat strokes, fainting, etc.), urbanization and UHI interfere with the water cycle and impact nature and its services: drop of air and soil humidity accelerates air pollution effect on humans and animals, supports spread of allergens, hence contribute to worsening of existing medical problems (asthma, allergies, cardiovascular disorders) (WHO, 2004). Decrease of biodiversity, caused by the both, favors harmful invasive and nonnative species, of which spectacular case is Sosnowsky's hogweed, but also contracted food-borne or vector-borne diseases (as heat helps growth of disease-causing organisms and vectors).

As similar anthropogenic activities lead to both increased pollution and heat production (transport, industry, etc.), and excessive heat additionally contributes to chemistry cycles leading to enhanced ground-level ozone production, higher emission of biogenic hydrocarbons (BVOCs) and higher evaporation of synthetic VOCs from vehicle engines (Ulpiani, 2021), thus UHI is almost always coexisting with Urban Pollution Island (UPI) (Crutzen, 2004).

Some of the strategies to reduce UHI effects include mitigating air pollution, providing adequate landscape and increasing the albedo of surfaces (Shahmohamadi et al., 2011), all to which NBSs can contribute. NBSs can reduce the UHI effect by imitating pre-urbanized microclimate conditions that are much more convenient for humans and many animal species. They can also enable coming back or existence of species efficiently supporting air purification (e.g. white poplar, mulberry), phytoremediation (e.g. willow species, common wheat, ragweed) (Bolan et al. 2011; Utmazian et al. 2007) or reduction of CO_2 emission / increase of carbon sequestration (e.g. all tree species, wetland systems) (Malak et al. 2021, Rogerson et al. 2021). Therefore, through implementation of NBSs it is expected to observe the improvement of microclimate conditions per se, as well as their effects on Public Health and Wellbeing. The effect in this category will be evaluated through assessment of recovery of relevant ecosystem functions.

Energy consumption and GHG emissions is another critical aspect of the Climatic Resilience Challenge. For example, the implementation of NBSs could result in both in energy savings (e.g., building heating and cooling, energy for the urban water cycle UWC - upstream or downstream, etc.) or additional energy consumption (e.g., for on-site water purification, water supply, illumination, etc.), which needs to be taken into account to estimate the net energy spendings or savings, as well as those of the associated GHG emissions. Clearly, if spendings are significantly higher than savings, the system will not be sustainable in terms of that aspect and this will need to be taken into account in the overall NBS assessment when weighing all the diverse benefits and trade-offs. not provide benefits on the long-term scale. Therefore, such aspects need to be considered during the design phase to ultimately propose and implement sustainable NBS systems.

Water Management – Besides microclimate, intensive urbanization has extremely negative effects on urban water management and the urban water cycle. For decades water has been perceived as a hazard to both infrastructure (flooding risk) and human health (as a consequence of severe surface and groundwater pollution). In consequence, the only aim of water management was to increase outflow from the city, and to isolate polluted water from direct contact with people. The most common effects of urbanization are: extreme peak flows and hydrological stress to urban rivers associated with rainfalls, general drop of groundwater table (sometimes with fast raise after rainfalls), limited recharge and link of groundwater and rivers, disruption of ecological flows in rivers, etc. (Scott 2016, Heidari et al. 2021), all having also impact on wetlands.

Another aspect of water management are issues related to existing infrastructure and its malfunctions. The existing stormwater systems in many highly urbanized areas have been designed for more “moderate” predictions of urbanization, and hence they can no longer support expansion of big cities. In many old cites the combined systems are still in operation, which results in subsequent overflows of sewage treatment plants, and creates hazards to human health and water resources with each flooding event. The challenge is therefore to switch from the rigid, conventional water management system to adaptable one, built upon nature. This is the main role of NBS and refers to reduction of the load on the sewer system by retaining and slowly releasing rainwater, which is particularly important during highly intensive rainfall events predicted as being more and more frequent under climate change. On the other hand, the urban infrastructure must be adjusted to meet water demand of natural systems and NBS in cities, and to sustain their efficiency under rainy and dry conditions (Wagner, Krauze 2014). The combination of both allows also for improvement of urban water quality, providing safe water for irrigation purposes, securing good ecological status of recipient water bodies, removing and blocking hazardous substances, like PCBs

(Urbaniak et al, 2016), enabling recycling of water and sludge (Urbaniak et al., 2017). It should be mentioned, that inadequate management of stormwater runoff increases non-point source pollution which can be a major threat to water quality of both water supplies and recreational waters, threatening thus directly human health (Gaffield et al., 2003). Furthermore, it can also lead to pooling of stormwater increasing therefore the breeding grounds for disease vectors, like mosquitos. The provision of adequate sanitation services, both in terms of quantities and treatment levels, is of outmost importance for preventing the transmission of various diseases, such as cholera, diarrhoea, dysentery, hepatitis A, typhoid, and polio (Freeman et al., 2017; WHO, 2019). Additionally, according to the WHO (2019) poor sanitation has also a negative impact on human well-being, as well as on social and economic development. Hence, the provision of adequate stormwater management and sanitation services decreasing wastewater quantities and improving its quality can directly affect public health.

EuPOLIS NBS are to facilitate those different aspects of water management, therefore evaluating indicators assess the level of enabling water resources for other uses and reduce water-related risks before and after implementations.

Circular Economy – In order to create a resilient system with various NBS interventions, it is important to make sure it has high level of autonomy in terms of water and energy requirements. For example, the implementation of NBSs could result both in energy savings (e.g. heating and cooling, energy for the UWC - upstream or downstream, etc.) or additional energy consumption (e.g., on-site water purification, water supply, illumination, etc.), which needs to be taken into account to estimate the net energy spending or savings. Clearly, if spendings are higher than savings, the system is not sustainable in the long-term, and independently of offered benefits may be considered as a burden to the community (maintenance costs). What is equally important is ecological impact of resource reuse, e.g. in many locations all over Europe grass cutting and removal exposes soil to wind and water erosion, drought, and thus decrease of fertility, water retention capacity and vitality. This affects resilience of ecosystems and their ability to provide any services. Reuse of biomass on site may increase soil formation processes, carbon sequestration, water retention and creation of habitats. Resource recovery through NBS is gaining popularity and is being explored as a viable option worldwide and as a means of moving away from the business-as-usual linear economic model towards a circular economy paradigm, in which resource flows are utilized and not considered waste (Kisser et al., 2020; Carvalho et al., 2022). Re-use of material during construction phase of the EuPOLIS demos reduces water and carbon footprint and is considered as an asset. The circularity of different resources is described by means of different Indicators within this Challenge.

Integrity (or Biodiversity loss/habitat fragmentation) – EuPOLIS has an ambition to create sites according to ecosystem approach, where nature recovers its self-regulating potential, and urban system sustains the function of ecosystem service transfer along natural capital gradient (Krauze, Wagner, 2019). In fact many KPIs make use of regulatory functions of ecosystems, which can be delivered only when releasing nature from permanent stress (water availability, temperature, noise, pollution, trampling, invasions). Otherwise, blue-green infrastructure struggles for existence (e.g. young tree mortality due to water stress in the City of Łódź reaches 60%) instead of efficiently providing shading, pollution release, disease and pest control etc. The critical factor and the best indicator of nature's health is biodiversity. Therefore, the main goal of NBS is enhancement of biodiversity and in consequence improvement of life quality in urban areas, that can be achieved in

well planned cities, which demonstrate to act as an ultimate habitat source for highly endangered species e.g. pollinators (Hall et al. 2017). Nevertheless, urban areas provide great opportunity for humans to come closer to nature and improve their health and well-being through interaction with a variety of flora and fauna species. Specifically, there is evidence that mental health (anxiety, stress levels) and psychological wellbeing may benefit from plant species richness (Fuller et al., 2007), animal species richness (Dallimer et al., 2012) and soil biodiversity (Wall et al., 2015). Furthermore, it has been shown that soil organisms, through their roles in controlling soil-borne pathogens and pests (soil vitality) lessen the prevalence of allergic diseases (Wall et al. 2015). Replacing or restoring the soil, regulation of water conditions, enabling plant species diversity - especially native ones, can substantially increase soil biodiversity leading to recovery of the natural soil food web, so the pathogen risk would be minimized with respect to communicable and non-communicable diseases (Crump et al., 2021).

In the long-term, newly established diversity of habitats and species can be maintained at relatively low costs through sustaining beta diversity – diversity between communities of the same species. The way is to re-create connectivity between habitats / blue-green areas through multiplication of NBS implementations. In macroscale also the size of blue-green areas matter – the bigger is area, the smaller is the so-called “edge effect” and the ability of the ecosystem to maintain its characteristics are higher, including climate regulation. The critical size has been defined for 1ha (Stülpnagel et al., 1990), and in densely populated areas it needs to be compensated by increased number of small green spaces, their compactness, and the density of green corridors.

The indicators within this challenge, as well as KPI_8, are formulated to secure that above conditions are met or the progress towards reaching them is done.

(Environmental) Pollution (Air Quality, Water Quality, Noise Pollution) – is probably the most straightforward environmental challenge group related to PH&WB. It is described through KPI_3. It is related to mental health, risks of respiratory diseases, cardiovascular diseases, diabetes, obesity, and NCDs and CDs. The extent of physical activity also is influenced by the levels of pollution.

There is plethora of studies that demonstrate the connections between air quality and worsening of different health conditions (respiratory, cardiovascular, metabolic, etc.), as air pollution has an impact on most of the organs and systems of the human body. Major outdoor air pollutants related to detrimental health effects include particulates (especially PM2.5) and gases NO_2, SO_2 and O_3 (Carey et al., 2013). PM2.5 can accumulate in the respiratory system, causing respiratory problems (asthma, COPD) (Guarnieri & Balmes ,2014), induce extensive immune response (allergies) (Bartra et al., 2007), and in combination with ozone trigger cardiovascular problems (including stroke and cardiac arrest) (Al-Kindi et al, 2020). Effects of the combination of PMs and gases are reported to have an effect even on diabetes, neurodevelopment, cognitive functions, birth outcomes, etc. (Kelley and Fussell, 2015). Long-term ambient air pollution exposure is reported to increase all-cause mortality (Carey et al., 2013). In relation to PH&WB challenges of this project – air quality is a major risk for respiratory and cardiovascular diseases, along with diabetes and obesity. The challenge here is to select indicators which enable recognition of NBS impact on air quality improvement while spread of air pollution is an uncontrollable factor.

When referring to water quality in the extent of this project, and its relation to human health, it is dependent on the type of interaction that exists between humans and water. Relevant interactions

include recreational purposes, but also possible contact between humans, especially children, and NBS, possible contaminated water vapor used for evaporative cooling, and water used for irrigation in urban gardens. Bad water quality in all these cases can induce CDs (pathogens) or NCDs – poisoning through various dangerous substances/pollutants (heavy metals, pesticides, emerging pollutants, toxins, etc.), which in the long-term can induce many system diseases. The role of NBS in reduction of both is already well documented, therefore EuPOLIS solutions are aimed to do the best use of this knowledge. With respect to N and P loads a particular care needs to be given to NBS which have a (semi)permanent pool of water, to prevent eutrophication with possible algal blooms leading to accumulation and release of toxins (either in water or in air), but also accumulation of sediments which reduce efficiency of the NBS in long term.

Noise pollution is recognized as a stressor to the autonomic nervous system and the endocrine system (Geravandi et al., 2015), leading to worsening of sleep quality, nervousness, and mental health, but also immune system problems (Zhang et al., 2021), cardiovascular diseases, increased hypertension, heart rate and possibility of cardiac arrest or stroke (Davies and Kamp, 2012). Densely populated urban areas are notorious for elevated noise levels, due to intensive anthropogenic noise-inducing activities (most importantly transport), but also due to the abundance of surface materials that cannot damp and absorb some of the sound waves (manmade materials and plain surfaces). On the contrary sounds of nature are believed to support rehabilitation (Cerwén et al. 2016). Potentially the effect of NBS – even the small scale ones - on noise pollution can be the most detectable.

Access to ecosystem services – Recently, there is an increasing scientific interest and investigation in the inter-relationship between NBS and ecosystem services (Babí Almenar et al., 2021; Castellar et al., 2021). There are two aspects of blue-green infrastructure and NBS – accessibility of green areas and accessibility of ecosystem services. Although those two don't necessarily have to go together to use the full potential of NBS and to emphasize their positive impact on the environment and human health, it is necessary to provide not only good access to its services, but also enable in-person contact with nature. Makropoulos et al. (2018) highlight the importance of striving to create diverse ecosystem services and focus on the investigation of water-enhanced ecosystem services by using recycled water. In terms of access, it is crucial to pick appropriate locations for NBS so they attract the attention of both visitors and residents, and are free of physical and mental barriers. From this perspective important aspect is to avoid eco-gentrification when improving the aesthetics and multifunctionality of green spaces and consider profiles of potential users. In planning sense, the longer the distance between NBSs and user's residence location lower the frequency of green space use and hence lower the impact on PH & WB (Coombes et al., 2010). Also, it is quite important to secure structural and functional connectivity between different NBSs (NBS Handbook, 2021), thus encouraging the movement of users and different animal species between different green elements. That way not only human physical activity is amplified, but also biodiversity of animal species. This challenge relates to KPI_8.

4.5 Urban Development Category

Urban development group has identified a series of Challenges and Themes (Table 9, Table 10), based on the main euPOLIS KPIs, focused on the main purpose of the project – enhancing health & well-being of citizens, and the general characteristics of an open urban space, able to guarantee vibrancy, liveability and the safety of urban residents (Kashef, 2016). Those Challenges include, among others, the main features of the

contemporary open space, privately or publicly owned, such as multifunctionality, accessibility, identity, impact, and an overall strengthening of the BGS in a planning approach.

Every Challenge was further developed in several Themes. Most of the Themes are specific for its on Challenge, and other Themes are repeated in different Challenges, such as sustainability, materials, interactivity, visibility, and universal accessibility. This horizontal presence of certain thematic issues was necessary to bond the euPOLIS project vision to the goals of sustainable development of inclusive places, able to improve health, reduce inequality and incentive socio-economic prosperity.

This initial list of the project Challenges and Themes forms the basis for the definition of the contextual indicators list (Table 15) and subsequently establishes a clear pathway for a list of evaluation indicators for the implementation of the project. The contextual indicators for the urban development category, together with the work performed in the WP3 on the local conditions, constitute a comprehensive knowledge about the specific features of the euPOLIS demo-sites.

Table 9 Themes/Phenomena for each of the Urban Development Categories - first part

Multifunctionality	Accessibility	Safety	Identity
Blue-Green Spaces	Public transport	Urban lighting	Heritage
Sustainability	Private vehicles	Visibility	Unique spatial elements
Land Use efficiency	Pedestrians	Protections	Visibility
Amenities	Bicycles	Universal accessibility	Esthetics
Flexibility	Personal transport	Orientation	Sustainability
Interactivity	Universal accessibility	Maintenance	Materials
Gender-related criteria	Sustainability	Materials	

Table 10 Themes/Phenomena for each of the Urban Development Categories - second part

Impact	Density	Demography	BGS Planning Approach
Scalability	Intensity	Ageing	Vision
Connectivity	Frequency	Population mobility	Participation
Direct/indirect effects	Sustainability	Different age groups	Implementation
Interactivity	Seasonability		Management
Urban Spillover	Diurnal/nocturnal		

5 Contextual indicators

CIs, as mentioned in Section 3, have a dual purpose: (1) to quantify the present state of the location via identifying local needs, trends and pressures (and consequently using GDPM and participatory processes identify a set of suitable NBS interventions), and (2) to provide input for undertaking a deeper analysis of results obtained from EIs and possible upscaling of solutions (later on in the project).

CIs are evaluated in the planning phase of the project using existing (National and International databases, existing reports, etc.) best-available data: the longest timeframe available that has similar features with the present state of the site and at the smallest spatial resolution closest to the location where the NBSs will be implemented. These vague criteria for selecting temporal and spatial scales actually make these indicators not fully uniform across different categories (e.g. environmental databases are usually more frequently populated with fresh data compared to social, economic or health databases), different cities, counties and countries (depending on the national / local standards for collecting different types of data).

CIs are mostly selected as standardized measures that can easily be found or calculated from the data most commonly collected by local authorities and are related to euPOLIS Challenges. Indicators from the Economy/Business and Urban development categories are custom made for euPOLIS sites and in line with the project objectives, therefore their evaluation is done through data supplied by the FR cities and the citizens in the euPOLIS questionnaires: Q1, Q2, and Q3 (Deliverable 2.2 Report on the local site analysis report and list of relevant issues problems and resources).

By quantifying CIs it is possible to specify an initial baseline for the site of interest, that together with the stakeholder concerns (found in Q1, Q2, Q3) and the original project description will be fed into the GDPM to perform a gap analysis of the demo-sites, set the project requirements (Deliverable 3.3) and identify the potential NBS interventions that serve the scope of meeting the set targets and goals (Deliverable 3.2).

The selection of contextual indicators is an iterative process performed between working groups (WP4) – partners selecting indicators that relate to particular challenges and/or themes per each category, and FR cities' representatives and cities' supporting partners (Belgrade - FCEBG, Mikser, Enplus; Piraeus - NTUA, GEOSYSTEMS with help from RG; Lodz - ERCE PAN, UNIWARSAW; Gladsaxe - AMPHI, Byspektrum) searching and providing available data sources (FL cities following the process). The final list of contextual indicators, known as Version 1.0, that was evaluated in all FR cities is provided in Table 15 (Annex). Deliverable 8.1 will provide further insight and upgrade of the CIs along with standardization metrics. CI values can be found in Deliverable 3.3 as part of the analysis of demo-sites.

6 Evaluation indicators

EIs, as mentioned in Section 3, are used during the ***exploitation phase*** of NBSs to assess their performance and effectiveness using data collected via monitoring and/or modelling. EIs are quantified prior and after the implementation of NBSs, where the comparison of values at these two stages provides the evaluation of the (positive or negative) impacts of those NBSs.

The process of identifying EIs depends on the:

1. Selection of Challenges and Themes
2. Potential interventions to be implemented on the site (GDPM)
3. Spatial scale at which the assessment is carried out (site, neighborhood, city, etc.)
4. Temporal scale within which the results will be analyzed.

The following are the main sources of data/parameters used for quantifying EIs:

1. Monitoring site-users/volunteers with two types of wearables
2. Monitoring site-users/volunteers with surveys, questionnaires, interviews, focus groups, etc.
3. Environmental monitoring with a network of permanent sensors (see Deliverable 5.1)
4. Environmental modelling with selected simulation tools (e.g., UWOT)
5. Remote sensing data
6. Maps, 3D surface models, photographs, videos, etc.
7. Inputs from experts, local authorities, small businesses
8. Livability model (see Deliverable 4.2)

There is a total of three groups of people that will be surveyed to estimate some of the evaluation indicators:

- Group A - people who will be visitors to the site and will wear wearables (MyFeel by Sentio and/or smart-bracelets compatible with the online platform provided by BioAssist) and will provide data on their physiological and psychological state along with answers to surveys that will be implemented in the BioAssist platform (PH&WB indicators).
- Group B – people who will be visitors to the site and will only provide answers to related surveys through BioAssist's online platform, or through an analog (paper) survey, however not requiring from experts to provide help for their answers.
- Group C – people who will be visitors to the site and will provide their inputs through interviews, focus groups, workshops, etc.; expert assistance will be required to provide meaningful answers (mostly for social indicators).

Groups A, B and C may or may not overlap to some extent. In addition, some of the indicators, including some of the social, business, and urban development indicators, need to be evaluated by data provided by local experts or local authorities.

Table 11 lists the indicators selected up to this point of the project (month 18) for the evaluation of euPOLIS interventions as developed within WP4, that:

- Cover the Challenges and Themes within the five categories as identified and described in Section 4,

- Are found to be relevant at each pilot site following the baseline assessment performed through the quantification of contextual indicators (WP3) and
- Are relevant to the list of potential euPOLIS interventions (provisional GDPM, Deliverables 3.2 and 6.1).

Section 10.3 contains details related to each of the indicators listed in Table 11, including definition, description and use, relation to PH&WB, spatial and temporal scale at which it should be evaluated, units, method of assessment, method of calculation and data requirements.

Next steps of the project will include intensive participatory processes of the wider community (experts, citizens, local authorities, etc.) to select and design NBSs (WP6). It is expected that in this process some of the indicators might be modified, or new tailor-made indicators will be developed to suite local needs. Additionally, the development of new compound indicators will be investigated following also the analysis of the data collected from the monitoring systems (wearables for PH&WB assessment, network of permanent sensors, etc.) and/or supplied from the modelling tools (e.g., once correlations between different categories of data are demonstrated); these will be additionally included in the evaluation and validation activities of WP8.

Table 11 List of euPOLIS Evaluation indicators (M18)

Category		Evaluation Indicator	Challenge
Public Health & Wellbeing	1	Physiological Indicators for physical activities *1a Physical Activity; 1b Heartrate; 1c Blood Oxygen Saturation; 1d Sleep quality; 1e Stress levels*	Physical activity, Risks for Respiratory Diseases, Risks for Cardiovascular diseases, Diabetes type 2, Obesity
	2	Emotional events	Mental health
	3	Level of outdoor physical activity	Physical activity
	4	Level of depression, anxiety and stress	Mental health
	5	Visual access to green space	Mental health
	6	Prevalence of allergic respiratory diseases	Risk for Respiratory Diseases
	7	Prevalence of smoking and prevalence of exposure to secondhand smoke	Risk for Respiratory Diseases
	8	Prevalence of hypertension	Risks for Cardiovascular diseases, Diabetes type 2, Obesity
	9	Prevalence of diabetes	Risks for Cardiovascular diseases, Diabetes type 2, Obesity
	10	Prevalence of obesity	Risks for Cardiovascular diseases, Diabetes type 2, Obesity
	11	Prevalence of arrhythmias	Risks for Cardiovascular diseases, Diabetes type 2, Obesity
	12	Quality of life	Wellbeing
	13	Healthy lifestyle	Wellbeing
	14	Satisfaction with Life (SWL)	Wellbeing
	15	Health Related Quality of Life (HRQoL)	Wellbeing
	16	Connectedness to nature	Wellbeing; Environmental awareness (S)

Category		Evaluation Indicator	Challenge
Social	17	Perceived loneliness	Friendliness; Social Cohesion
	18	Leisure Time Satisfaction Measure (LTS)	Friendliness; Social Cohesion; Willingness to participate
	19	Perceived safety of the neighborhood (feeling)	Safety
	20	Perceived safety of the neighborhood (experience)	Safety
	21	Friendliness	Friendliness
	22	Walkability	Accessibility
	23	Perceived quality of space and its maintenance	Friendliness; Safety
	24	Place attachment	Sense of place; Friendliness
	25	Perceived ownership of space and sense of belonging to the community	Sense of place; Social Cohesion
	26	Collective efficacy	Social Cohesion
	27	Community social cohesion	Sense of place; Safety
	28	Involvement of citizens in participatory process	Willingness to participate; Activation in participatory process
	29	Diversity of stakeholders involved in the project	Willingness to participate; Activation in participatory process
	30	Involvement of citizens from traditionally excluded groups	Willingness to participate; Activation in participatory process
	31	Trust in the decision-making procedures and decision-makers	Strengthening local community ties; Friendliness
	32	Sustainability consciousness	PH & WB, Environmental, Social
Economy/ Business	33	Number of new jobs	Site related business initiatives - opportunities for businesses
	34	Percentage of new jobs addressing unprivileged social groups	Site related business initiatives - opportunities for businesses
	35	Change in the residential / business property sale prices in the proximity of the demonstration site	Comprehensive positive impact from business activity on neighborhood; NBS's which contribute to the increased neighborhood value - surrounding property value
	36	Number of new businesses established in proximity to demonstration site	Site related business initiatives - opportunities for businesses; Comprehensive positive impact from business on neighborhood
	37	Change in the number of visitors at the demonstration site	Creation of the livable and vibrant urban spaces conducive to business activation; Comprehensive positive impact from business activity on

Category		Evaluation Indicator	Challenge
			neighborhood
	38	Value of food / plants produced at the demonstration site	Comprehensive positive impact from business activity on neighborhood; NBS's which contribute to the increased neighborhood value - surrounding property value
	39	Private financing attracted to the demonstration site	Site related business initiatives - opportunities for businesses; City providing financial support to private start-ups and NBS-related businesses (primarily those enhancing WB)
	40	Annual maintenance savings from biomass reusage	Circular Economy (E)
	41	Annual maintenance savings from rainwater harvesting and / or grey water treatment and reusage	Circular Economy (E)
Environmental	42	Air Temperature Reduction / Air Cooling	Climatic Resilience
	43	Universal Thermal Climate Index (UTCI)	Climatic Resilience
	44	Avoided or additional net energy consumption (or GHG emissions)	Climatic Resilience
	45	Site Water Autonomy for NBS	Water Management, Circular Economy
	46	Potable water savings / Water reuse	Water Management, Circular Economy
	47	(Additional) Wastewater Treatment Coverage	Water Management
	48	Wastewater (and stormwater) managed on site	Circular Economy
	49	Flood risk factor (FRF)	Water Management
	50	Runoff coefficient	Water Management
	51	Mitigation of the urban runoff peak	Water Management
	52	Delay of the urban runoff peak	Water Management
	53	Water quality - general	Water Management, (Environmental) Pollution
	54	Exposure to noise pollution	(Environmental) Pollution
	55	European Air Quality Index	(Environmental) Pollution
	56	Average NDVI values	Access to ecosystem services
	57	Biologically active space (de-sealed area)	Access to ecosystem services
	58	Community level physiological profiling (CLPP)	Soil vitality
	59	% of biomass reuse on site	Circular economy
	60	Plant & animal richness of selected native indicator species	Integrity (or Biodiversity loss/habitat fragmentation)

Category		Evaluation Indicator	Challenge
	61	Changes in habitat quality	Integrity (or Biodiversity loss/habitat fragmentation)
	62	Blue space availability	Integrity (or Biodiversity loss/habitat fragmentation)
	63	Connectivity of urban green spaces	Integrity (or Biodiversity loss/habitat fragmentation)
	64	Green space accessibility	Access to ecosystem services
	65	Changes in Habitat Diversity (Habitat Unit diversity)	Integrity (or Biodiversity loss/habitat fragmentation)
Urban Development	66	Derelict land reclaimed for NBS	Multifunctionality; Safety
	67	Quantity of blue-green space as ratio to built form	Multifunctionality; BGS Planning Approach
	68	Perceived quality of urban green, blue and blue-green spaces	Multifunctionality; Accessibility; Safety; Identity; BGS Planning Approach; Density
	69	Recreational value of green space	Multifunctionality; Accessibility; Safety; Identity; BGS Planning Approach; Density
	70	Material used coherence (Amount of sustainable materials used for interventions within the demo-site)	Multifunctionality; Accessibility; Safety; Identity; BGS Planning Approach;
	71	Multifunctionality and flexibility of functional use of open space	Multifunctionality; Accessibility; Safety; Identity; BGS Planning Approach;
	72	Interaction between building's street level and open spaces	Multifunctionality; Accessibility; Safety; Identity;
	73	Access to public amenities and ease of reaching (and interacting with) destinations or activities distributed in the proximity to the demo-site	Multifunctionality; Accessibility; Safety; Identity; Demography
	74	Demo-site area devoted to roads	Multifunctionality; Accessibility; Safety;
	75	Demo-site area devoted to clean transport	Multifunctionality; Accessibility; Safety;
	76	Sustainable urban (street) lighting (multifunctionality day and night) at the demo-site	Multifunctionality; Safety;
	77	Obstacles in the use of the open space	Safety; Accessibility; Demography
	78	Urban furniture equipment at the demo site	Safety; Identity; Impact
	79	Preservation of cultural heritage and presence of unique spatial elements	Identity; Safety; Impact
	80	Scenic sites and landmarks created	Multifunctionality; Accessibility; Safety; Identity; Impact

6.1 Public Health and Wellbeing Indicators

6.1.1 Indicators based on bio-signals

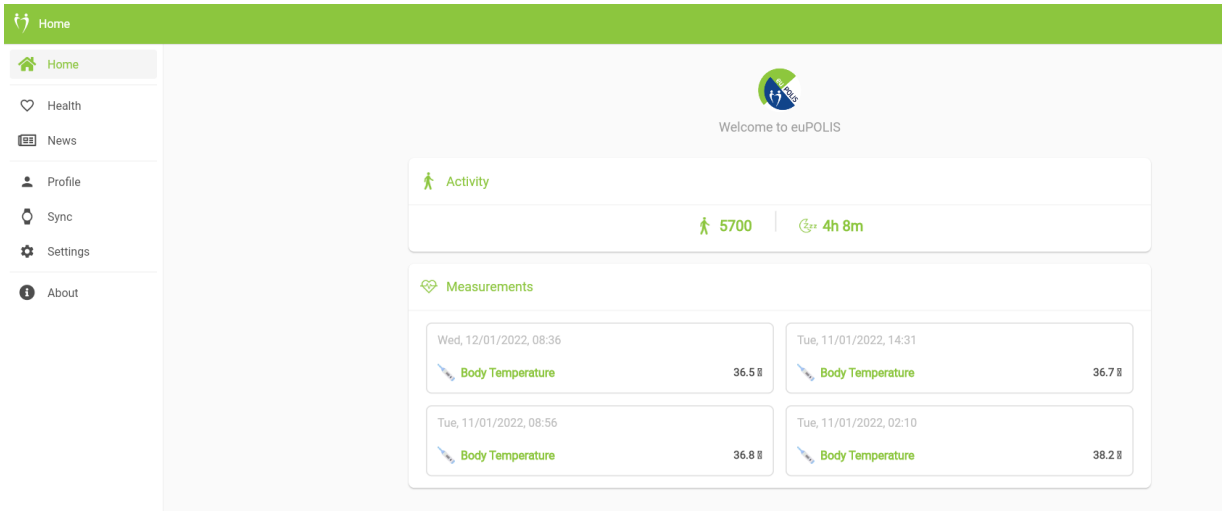

Figure 7 "euPOLIS by BioAssist" user interface – Intro

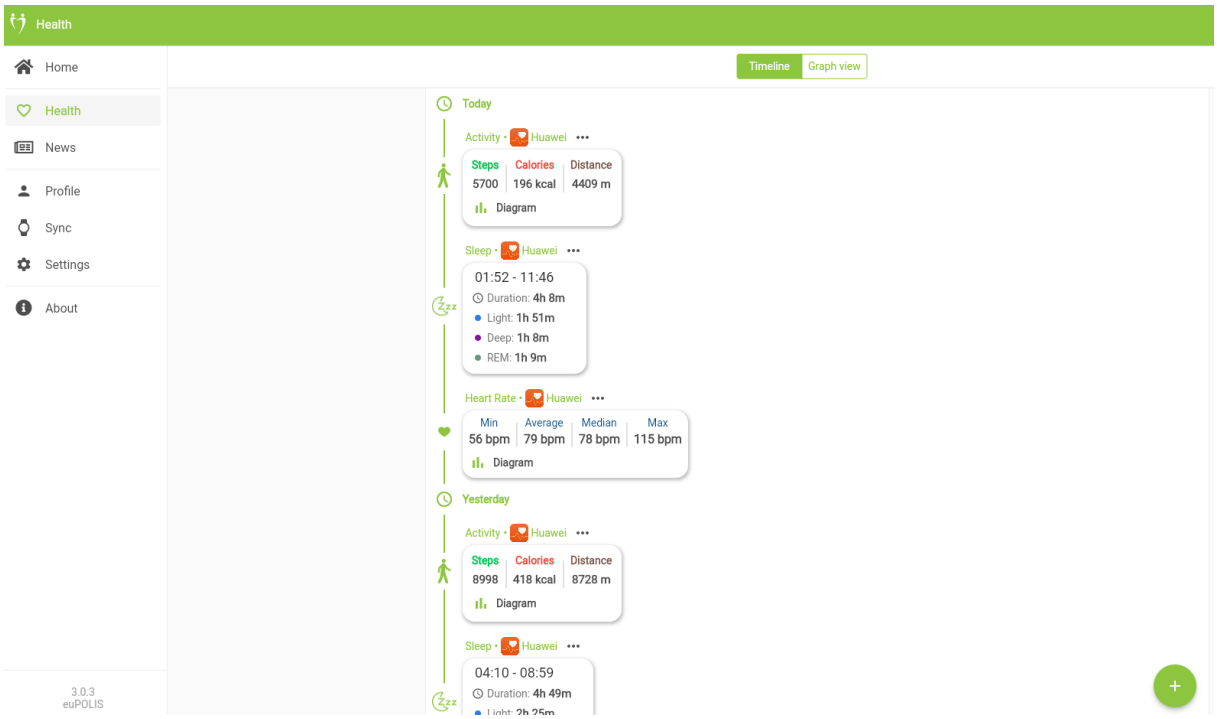

Figure 8 "euPOLIS by BioAssist" user interface – Timeline

The euPOLIS project uses new digital techniques i.e. smart bracelets and interactive platforms, to engage citizens in performing extensive monitoring of the impact NBSs may have in terms of PH&WB.

"euPOLIS by BioAssist" is an interactive health-centric platform being developed in the project, that is compatible with multiple commercial smart bracelets that provides accurate recordings of physiological parameters (skin temperature, pulse, oxygenation and/or respiration), levels of physical activity (intensity and duration), sleep quality and user interactive feedback. These bio-signals/vital signs and physical activity represent parameters used for determining "Physiological Indicators for physical activities" (Table 12).

This type of data is collected from a diverse group of volunteers defined as group A (see introduction in Section 6). Data is collected before and after the implementation of NBSs, with a sub daily timestep, and statistically analyzed for peaks, trends and inconsistencies to showcase the impact of NBS. Expected positive effects of NBSs include increase in the outdoor physical activity of the site visitors and with-it related decrease in the average resting heart rate, increase in the average daily oxygenation and better sleep quality (prolonged deep sleep periods). Skin temperature data does not have one positive outcome, as increase in physical activities can both increase (high intensity anaerobic) and decrease (low intensity aerobic) these values (Neves et al, 2015), and thus those measurements are to be analyzed in combination with heartrate and/or oxygenation to define the type of physical activity that takes place.

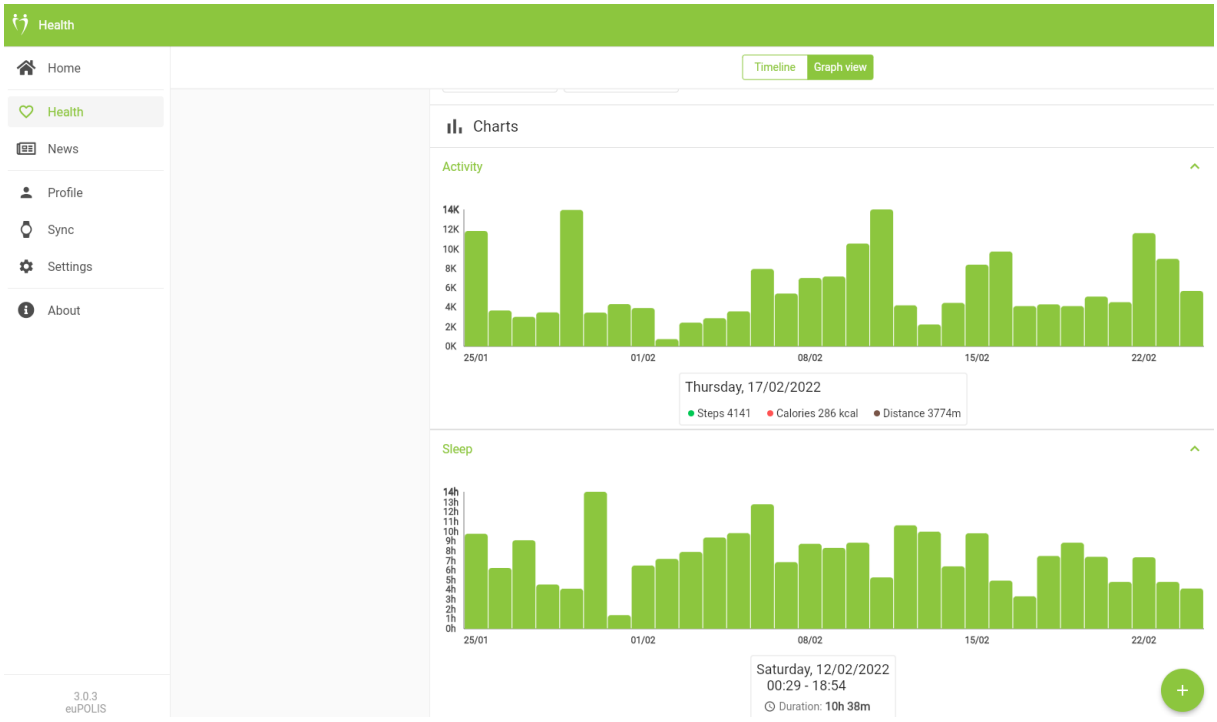

Figure 9 "euPOLIS by BioAssist" user interface - Charts

The Feel wristband, along with MyFeel platform, for monitoring and assessment of the emotional status, emotional events and stress/anxiety levels, is another source of biosignal data that feeds into the "Emotional states" Indicator (Table 12). The Feel Emotion Sensor is a wristband that has integrated bio-sensors, which monitor a variety of end user physiological signals throughout the day, while in the background, proprietary algorithms analyze these signals to recognize the wearer's emotions. Sentio Labs has designed and produced an advanced biosensor (Galvanic Skin Response

sensor) integrated in the only wristband that can continuously measure two additional bio-signals (Heart Rate Variability and Skin Temperature), along with additional signals (i.e. ambient temperature, ambient humidity).

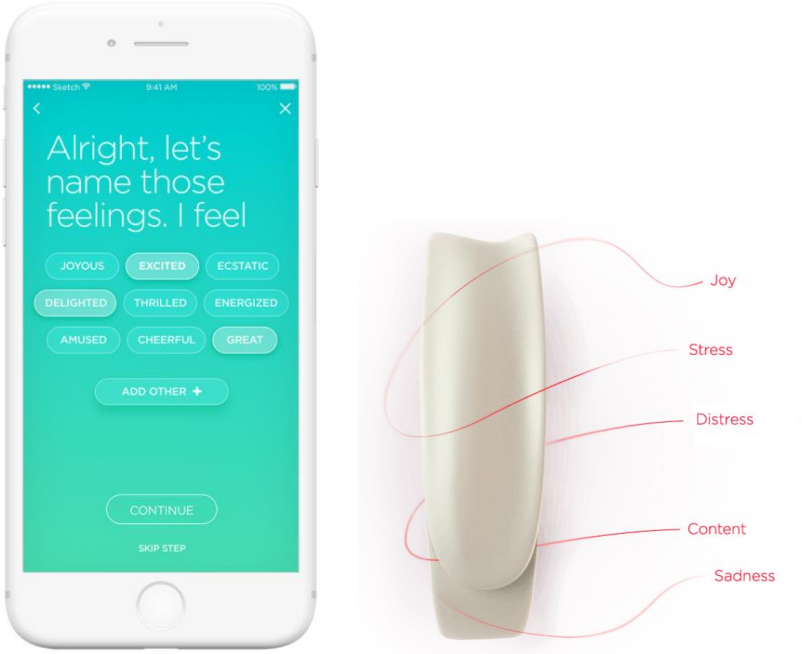

Figure 10 MyFeel application with emotion tags and MyFeel sensor

When MyFeel detects an emotion, the participant that wears the Feel Emotion Sensor is notified through the Feel mobile application and then can log the detected emotion along with providing a variety of supplementary information, to the Feel Mobile Application that is connected to the wristband, such as the feelings that were experienced, the emotion intensity, the emotion trigger, her thoughts, physical sensations. The participant can access any logged emotion journal at any time. The Feel monitoring platform will be used in euPOLIS to collect, process and assess data related to the individuals' emotional status and mental wellbeing.

Table 12 List of PH Evaluation Indicators based on bio-signals

No	Evaluation indicator	Description	Relation to PH&WB
1	Physiological Indicators for physical activities *1a Physical Activity* *1b Heartrate* *1c Blood Oxygen Saturation* *1d Sleep quality* *1e Stress levels*	A group of physiological parameters is measured using biosensors and collected via "euPOLIS by BioAssist" platform. Physical activity (number of steps, daily exercise, walking/running, etc.), continuous heartrate and SpO_2 monitoring, sleep quality and stress levels	Mental health, Wellbeing, Non-communicable diseases (Cardiovascular health, Respiratory health)

2	Emotional events	Significant emotional events that a user experiences. More specifically, the type (e.g., happy, joyous, distressed, sad), the duration, time, and intensity of the event as well as the intensity and what triggered the user to experience such an event along with the thoughts and physical sensations after the event.	Mental health, Wellbeing

This type of data is collected from a diverse group of volunteers defined as group A (see introduction in Section 6). Data is collected before and after the implementation of NBSs, with a sub daily timestep, with expected log of 3-5 emotions per day. Expected positive effects of NBSs include increase in the average number of positive emotions per day, showing improvements in mental state, decrease in stress and improved wellbeing of the wearers.

The data for both platforms is collected continuously for at least three (preferably 12) months before and three (preferably 12) months after the NBS implementation and fed into the euPOLIS Data Management System (following all protocols to secure anonymity of the data and in accordance with the euPOLIS D11.3 Data Management Plan). The actual outputs will not be related to a particular NBS, but to the demo-site as a whole. More details on selection of participants can be found in Section 7.

6.1.2 Indicators based on survey/questionnaire data

PH&WB indicators #3 to #17 (Table 11) will be determined from answers to questionnaires collected via the "euPOLIS by BioAssist" platform or paper survey (to ensure inclusivity of all groups, including those who cannot provide digital answers due to poor economic status, digital illiteracy, disabilities, etc.) both completed by visitors to the demo site (online platform follows the location of the device). The actual process of including all the diverse group of visitors will be presented in Deliverable 4.3.
Indicators in this category are directly related to either PH or WB (or both), as the challenge to which they are related indicates (Table 11). Some of the proposed evaluation indicators are similar to contextual, namely the prevalence for different diseases or risk factors (indicators #6-11), however, they are evaluated at a smaller spatial scale (with visitors to the demo-site) than contextual (neighborhood, municipality, city, country), providing a local evaluation. It should be noted that due to the limitation of the project duration i.e. only 12 months available for monitoring after the NBS implementation, it is highly probable that this set (indicators #6-11) will show little or no change. It is expected that indicators #3-5 and 17 will show the most evident change.
The data will be collected at least twice: once before and once after the NBS implementation, although preferable it will be collected three times after NBS implementation: (1) just after, (2) 6 months and (3) 12 months after the implementation. Indicator values will not be related to a particular NBS, but to the demo-site as a whole. More details on selection of participants can be found in Section 7.

6.2 Social Indicators

The data collection necessary for estimating the social indicators will be collected through different methods to ensure better understanding of the euPOLIS impact on local community, the livability of the neighborhood as well as social sustainability. Based on the existing data, many of the indicators

will be difficult to estimate on the local level of the demonstration site, therefore additional data collection may be needed. Social indicators' role will be to estimate changes that could be observed before and shortly after the implementation of the NBSs at the pilot site. However, in terms of social impact, the long-term effect is more probable, yet may not be necessarily observable within the project timeframe. Few indicators were defined to assess the long-term social impacts of the NBSs and the data collection was expanded in some cases beyond the demonstration site boundaries.

To understand the specificity of Blue-Green spaces that are going to be changed during the project, first, we will gather information about the neighborhood in which the BGS/NBS is located. We will collect data about the local community − people who live nearby and activities one could perform there. This kind of data, mainly based on desk research conducted by cities, will allow us to understand how the BGS is used and by whom. For example, information about socio-economic status, age, and gender distributions of the local community would allow for better mapping of citizens needs and preferences. Moreover, we also gather information about the NBS site regarding its aesthetics, functions, and history of construction works there.

The proposed social indicators measurement includes both desk research and longitudinal design study. it will allow for measuring not only the social benefits of using blue-green spaces but also to understand whether, and if so how, the characteristics of both local community and place itself interact with the upgrading of the BGS and consequently how they improve the social aspects of PH and WB impacts of BGS.

We will use indicators on two separate levels: community / site level and individual level. The latter will be used for the assessment of the effects of the upgrading/ building NBS in euPOLIS sites on the social aspects of residents' life. In the case of individual-level indicators, we divide them further into two groups. The first group includes demographic variables that will allow for a better understanding of the characteristics of the sample drawn from the population. The second group of the individual level indicators will be used for the evaluation of the social aspects of PH and WB impacts of BGS. We will use their operationalizations in social study. Therefore, following the longitudinal design, we will strive to ask participants to complete a questionnaire at least twice − before the beginning of the NBS site construction and after it is fully finished. That strategy will enable tracking the dynamics of these indicators and assessing whether BGS construction has a positive effect on the social aspects of users' lives.

6.3 Economy/Business Indicators

The data collection/monitoring needed for estimating the defined economic indicators is mostly restricted to the realm of the demonstration site and accounts for changes that could be observed before and shortly after the implementation of the NBSs at the site of interest, yet not necessarily fully appreciable within the project timeframe (i.e., number of new jobs, number of new on-site businesses, increase in the number of visitors, value of food/plants produced at the demonstration site, annual maintenance savings). A few other indicators were defined to assess the long-term economic impacts of the NBSs (i.e., changes in the property sale prices and new businesses in the surrounding neighborhood, attracted private financing) and the collection of the needed data should be expanded in some cases beyond the demonstration site boundaries.

NBSs could **create new jobs** at the demonstration site. This is for the benefit of the community and the nearby region (e.g. by promoting local employment). Reducing the unemployment rate improves

the WB of the citizens (via poverty reduction) but could also have a positive impact on their mental health (e.g., Wilson and Finch, 2021). Additionally, NBSs could **create new jobs** at the demonstration site for **unprivileged social groups**. Apart from the direct benefits stemming from the reduction of the unemployment rate, the creation of jobs for unprivileged groups could enhance their motivation and self-confidence and in general improve their mental health.

The existence of well-maintained NBSs is often associated with **increases in the nearby property prices** (e.g. Luttic, 2000; Ichihara and Cohen, 2011) since they constitute a positive location factor (e.g. due to more recreation opportunities, appealing landscape, increased living standards). Nevertheless, if this increase is high (e.g. household income increase not in pace with a short-term increase in the housing prices) it could have a negative impact on the lower socioeconomic groups living in the neighborhood [e.g. by preventing house tenure, that is also often linked to health issues (Ellaway *et al*, 2013) or by resulting in the displacement of the poorer residents (Bockarjova *et al*, 2020)]. This element should also be considered when planning green regeneration for a certain city location.
NBSs could also stimulate economic growth and consequently enhance citizens WB. The **number of new businesses** can be assessed only after euPOLIS interventions have been implemented and their effect established. Demonstrating this effect of NBSs could well become the base for: (a) the city to reconsider any regulations limiting business activation and (b) the individuals to consider investing in NBS-related businesses.

Change in the number of visitors at the demonstration site due to NBSs, could have positive impacts on WB due to the increased consumer spending in the demonstration site and the overall neighborhood area. Additionally, pertinent positive impacts may be extended towards the PH dimension (e.g. Kabisch *et al*, 2017) due to the increased number of people becoming more physically and socially active and being exposed to an aesthetically superior landscape as well as to reduced air pollution, noise and heat.
Value of food / plants produced at the demonstration site may impact economic growth and social interaction and hence improve PH&WB.
Private financing attracted to the demonstration site through different business drivers (see Deliverable 4.2) due to NBSs stimulating economic growth (as positive impacts of euPOLIS interventions) and consequently enhance citizens WB.

Biomass reusage (and consequent **annual maintenance savings coming from them**) that is directly related to the reduction of waste and the use of sustainable fertilizers -produced from the biomass waste-, could have a positive impact on PH. It also contributes to both environmental and economic sustainability by creating additional employment.
Rainwater harvesting and / or grey water treatment and reusage (and **annual maintenance savings coming from them**) may mitigate the risks of floods and consequently protect citizens lives and reduce asset losses; hence could have a positive impact on WB. Additionally, it may reduce discharge rate of pollutants into rivers and/or groundwater and thus having a direct positive impact on PH.

6.4 Environmental Indicators

The environmental impact of NBSs is probably their most studied feature – just to illustrate the EC Indicator Handbook (EC, 2021) has 7 out of 12 societal challenges dedicated to environmental indicators. However, this set of indicators in principle describes the ability of nature to provide regulatory services which are of the highest importance for human health, but also feedback health

of nature, and cultural ones, important for mental conditions. Having in mind the specific aim of the project, which is to explore the extent at which NBSs influence the PH&WB, environmental indicators are filtered in a way to select those: (1) related to PH&WB, (2) well document status quo and its changes, (3) are measurable within project lifespan and its budget. Additional aim is to secure sustainability in the implemented solutions, which was used as another criteria for filtering. The actual selection of relevant indicators was performed through collaborative work of environmental (environmental scientists, environmental and civil engineers) and PH&WB (medical doctors) working groups, having in mind the available monitoring and modelling methods available in the consortium.

Annex contains indicator tables where a special section is dedicated to indicator relation to PH&WB (for each EI from Table 11), while in the following text only several EIs are described as representatives of different sub-groups related to thermal comfort, quality of air/water/soil, urban flooding, representation of blue/green spaces, and biodiversity.

NBSs are affecting microclimate mainly through **Air Temperature Reduction / Air Cooling** (EC HandBook, 2021**)** that has direct impact on PH&WB as it protects humans from heat stress. It is particularly important in hot climates and areas with high heat risk. NBSs affect not only air temperature, but also human comfort that can be described by means of so called **Universal Thermal**
Climate Index (UTCI) − see EC HandBook (2021), Błażejczyk et al. (2010), etc. This index is the reference environmental temperature causing strain, which besides the actual air temperature also depends on wind speed, relative humidity and mean radiant temperature. In the near vicinity of NBSs there can be deviation between the UTCI value and the actual air temperature, indicating better thermal comfort that allows people to do outdoor physical activities even at higher air temperatures.

NBSs have strong impact on the quality of air, water, and soil, which is directly related to PH & WB. For example, **European Air Quality Index (EAQI -** see EC HandBook (2021), https://airindex.eea.europa.eu/Map/AQI/), which corresponds to the poorest level for any of five key pollutants (particulate matter PM10, fine particulate matter PM2.5, ozone O_3, nitrogen dioxide NO_2, sulphur dioxide SO_2) is also influenced by NBSs. The index is directly related to PH & WB since each of the key pollutants can affect human health causing different respiratory problems. ***Allergen concentration****, as one of the possible air pollutants closely connected to detrimental health effects, was considered but eventually* ***not selected****, as a result of a cost-benefit analysis: multiple types of allergens throughout the blooming season, and difficulty in concluding the influence of implemented NBS on allergen concentration due to the limits in site size.* **Water Quality** of rainwater and grey water can be improved by means of NBSs, allowing its further use for irrigation or recreational purposes, which otherwise would not be possible due to risk of spreading communicable diseases. For soils, **Community level physiological profiling (CLPP)** indicates changes in microbial communities (Garland & Mills, 1991; Grządziel et al., 2018; Jałowiecki et al., 2016; Zak et al., 1994) that are often a precursor to changes in the health and viability of the environment as a whole. Microbial activity influences processes like decomposition, soil formation, degradation of toxic substances, and in general impacts soil water capacity and survival of greenery. This indicator is the measure of environmental security in terms of contaminants in soils, which is in direct correlation with PH & WB, but it may also help to reduce costs of greenery maintenance through navigation of adequate NBS actions.

One of the main "technical" purposes of NBSs is prevention from urban flooding, i.e. provision of environment resilient to weather extremes. Indicators such as **Runoff Coefficient**, and **Mitigation and Delay of the urban runoff peak** are used to describe the amount of rainwater that NBSs can retain and postpone its release to sewer system with reduced outflow peak by forcing water to infiltrate through the porous medium (Asleson et al., 2009; De-Ville et al., 2018; Versini et al., 2020). Also, **Flood Factor** is used to calculate the risk from fluvial flooding to properties, which can be reduced through implementation of NBSs. Besides their technical purposes, mentioned indicators related to flooding in urban areas have direct impact on PH & WB through creating hazards to health (pollution, habitats for diseases), but also through deterioration of living conditions (damage of infrastructure, moisture - microbial development).

It has been proved the increase in green / blue spaces has positive impact on PH & WB. With respect to that, **the average NDVI** value[4] has been selected as a relevant indicator describing the vegetation health/status, since vegetation is the one ameliorating the environmental conditions delivering health benefits. Higher NDVI values are related to more greenery (values above zero indicate photosynthetically active surface), while lower values indicate its lacking. In case of mental health, it has been shown the increase in percentage of blue spaces (**Blue space availability** - De Vries et al., 2018) in the near vicinity of visitors' houses has positive impact in reducing anxiety and mood disorders, and in improving self-reported mental health. Also, research has shown that visitors living closer to green areas (**Green space accessibility** − Coombes et al., 2010) are less likely to be obese.

Biodiversity is another important benefit of NBSs. For example, **Plant and animal richness of selected native species** (Fuller, 2007; Luck, 2011; Dallimer, 2012) is an indicator providing an overview of the species diversity which has direct impact on psychological wellbeing because people, in general, demonstrate a greater aesthetic appreciation for more-diverse plant communities, and therefore report a higher well-being when visiting diverse green spaces. However, to secure sustainable diversity of plant and animal species, it is necessary to secure both structural and functional **Connectivity of urban green spaces** (EC HandBook, 2021; Saura & Torné, 2009) related to spatial configuration of green areas and ability of organisms to move among them, respectively. This indicator is indirectly related to PH & WB since a well-connected and functional network of urban greenspaces enhances the delivery of ecosystem services, and therefore the benefits to citizens.

6.5 Urban Development Indicators

The key result of the contextual indicators for the urban development category and activities specified under the T3.3 has confirmed that the euPOLIS FR cities demo-sites are very different and complementary and have specific characteristics. There are certainly several common features relevant to all FR cities demo-sites, such as lack of active green spaces, but there is a different range of the size and the scale of demo sites with various spatial characteristics and urban development heritage.

Analysis of local conditions through baseline statuses, literature review (e.g. EC Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods, 2021) and the definition of

[4] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/normalized-difference-vegetation-index

contextual indicators has helped to identify the list of evaluation indicators for supportive measures of the potentials and benefits of euPOLIS project's implementation. The newly introduced NBS has gear around support in what is needed for the demonstration of the benefits, that will be performed in forthcoming WPs. CI have demonstrated the specific local values, but it has also shown great potential to upgrade value by BGS/NBS with the main design criteria for enhancing health and well-being of citizens that are reflected in the list of evaluation indicators to estimate the effects of the euPOLIS interventions.

These urban development evaluation indicators (Table 11) are supporting BGS planning approach while at the same time putting emphasis on promoting improvements in PH&WB. Urban Development Indicators include 15 items focused on the blue-green infrastructure, multifunctionality and safety of open spaces, level of accessibility, as well as the urban identity and preservation of cultural heritage.

Due to the specificity of Urban Development category, most of the evaluation indicators have an indirect impact on public health, but they all can be viewed as an indicator of improvement of wellbeing and quality of life, as for example, landmarks and the access to public amenities and ease of reaching and interacting with destinations or activities distributed in the proximity to the demo-site. Some NBS implementation could contribute to enhance landscape enjoyment increasing the amount of perceivable scenic sites that could represent new elements of visibility, orientation, and local identity (Davoudi and Brooks, 2019). Other indicators, such as quantity of blue-green spaces as ratio to built form and recreational value of green space have a direct impact on public health and well-being. Use of this indicator is to evaluate the benefits of open spaces relate to both their materials and functions for increased vegetation and soil permeability and water retention, as well as the potential increased social benefits of open meeting spaces, areas for recreation, sports and relaxation (WHO, 2016).

The list of evaluation indicators gives a clear overview on the potential of the planning of BGS interventions, relevant for the existing specific demo-sites, but also the future locations in their cities with potential for extrapolation to the other national cities or internationally.

7 Methods for collecting data from volunteers/study participants for direct evaluation of PH&WB

The research in project euPOLIS will be performed utilizing a mixed method composed of quantitative and qualitative parts. The quantitative part of the study will be designed according to the type of panel study, which is a combination of cohort and cross-sectional study. The first cross-sectional study will be conducted before the implementation of the NBSs for a period of at least three (preferably 12) months. A second cross-sectional study will be performed after the implementation of the NBS interventions for a period of at least three (preferably 12) months. A period of 12 months is preferred as it covers all seasons.

The main aims of the present study are to:

1. Examine the socio-demographic and epidemiological characteristics of the study participants.
2. Determine the predictive significance of the implemented NBSs on the level of physical activity of the study participants.
3. Determine the predictive significance of the implemented NBSs on the mental health of the study participants.
4. Determine the predictive significance of the implemented NBSs on the risks for non-communicable diseases (respiratory diseases, cardiovascular diseases, diabetes type 2 and obesity) of the study participants.
5. Determine the predictive significance of the implemented NBSs on the wellbeing of the study participants.

Study hypotheses:

1. There is a statistically significant association between the implementation of NBSs and the increased level of physical activity of the study participants.
2. There is a statistically significant association between the implementation of NBSs and the improvement of mental health of the study participants.
3. There is a statistically significant association between the implementation of NBSs and the reduction of the risks and the burden of non-communicable diseases (obesity, respiratory diseases, cardiovascular diseases, diabetes type) among the study participants.
4. There is a statistically significant association between the implementation of NBSs and the improvement of wellbeing of the study participants.

Ethical principles (in addition to Deliverable 1.1 and in reference to CIOMS, 2017 and WMO, 2013)

In accordance with the basic ethical principles, attention will be paid to:

1. Protection of the WB of all those who participate in the research, both the researchers and their assistants and especially the subjects of the research and the community in which the research is realized. Research cannot and must not harm anyone involved.
2. Minimizing the risks and maximize the benefits for the respondents/study participants.
   - The intended type of research could be characterized as "without or with minimal risk".
3. Respecting the basic human rights of persons participating in research. Ethics of justice, fair relations, not exposing the subjects to any inconveniences during the research, not making any demands that are not related to the research.
4. Respecting the personality and integrity of the research subjects. This includes the dignity of each respondent and her/his right to self-determination.

5. Respecting participant autonomy.
6. Ensuring confidentiality and anonymity. The principle of anonymity is provided through non-entry of names or other recognizable information, use of codes, incoherence of information (from various sources) with the participant, handling, and storage of information by authorized persons and institutions. (see Deliverable 1.1)
7. Volunteering. The most important ethical principle of research and the only one that is regulated in a special, formal way - Consent after information, which is a form in which a person confirms his decision to participate in research. Consent is not only a form, but also an opportunity to build the trust of researchers and participants, because:
    - consent can be given only by a legally competent person;
    - the procedure for obtaining consent / consent implies two phases: the conversation between the researcher and the potential participant and the signing of the Consent / consent;
    - it is necessary that the information is communicated to the participant in an understandable and acceptable manner.

8. The information related to the research that is necessary for the respondent to receive is:
    - Purpose of the study
    - The way in which the study is realized
    - Role of the participant: benefits and possible damages;
    - Participant's rights (anonymity, confidentiality, possibility to withdraw, requesting additional information);
    - How to use the data (for whom, from whom, storage);
    - Contact addresses and telephone numbers for complaints and grievances of any irregularities, for seeking additional assistance or information.

Target population

Residents of Belgrade, Lodz, Piraeus and Gladsaxe aged 18-64 of both sexes using sites where NBSs are implemented. Minors (<18) and elders (65+) may participate, although they are not accounted for in calculation of the minimum required sample (see section *Sample (sample type, sample frame, sample design and sample size)*).

Criteria for inclusion of respondents in the research:

- Mental ability of the respondents to understand the goals and procedure of the study.
- Permanent residence in either Belgrade, Lodz, Piraeus and Gladsaxe for easier monitoring.
- At least middle level of computer literacy to use the on-line tools for data collection.
- Internet access/data availability: Ideally, users should have access to the Internet on their mobile phone throughout the day (through WiFi or a suitable mobile data plan), so that the application can communicate to Sentio back-end systems and data from the MyFeel Emotion Sensor and the app can be transferred and processed in real time. Similarly, internet connection is needed for connection between “euPOLIS by BioAssist” and euPOLIS Data Management System.
- The minimum operating system requirements are:
    Android: > Android 5.0
    iOS: > iOS 11.0

Criteria for exclusion of respondents from the survey:

- Mental inability of the respondents to understand the goals and procedure of the research.
- Not providing a written consent for their participation in the project research activities

7.1 Sample (sample type, sample frame, sample design and sample size)

Table 13 provides an overview of populations and unofficial estimates on the number of visitors to demo-site(s) in the four FR cities. When the target population size is known, a representative sample is usually selected as 10-20% of that size. However, the limited resources of the project (finances, time, digital platform limits, etc.) do not allow for such elaborate sample sizes (e.g., 30,000 people in Belgrade), therefore, a more reasonable estimate is based on a statistical analysis that provides reliable conclusions.

Table 13 Population and expected number of visitors to the FR cities' demo-sites

	Population	Expected number of visitors to the demo site(s)*
Belgrade	1,374,000	50,000-300,000+
Lodz	696,708	2,000-5,000+
Piraeus	163,688	5,000-50,000+
Gladsaxe	69,450	1700 (demo-site is a private area, this is number of inhabitants that have access to it)

* Unofficial estimates

The minimum sample size is based on targeting the adult population of ages between 18 and 64, where the expected variation of results in the age group (there are 5 age groups: 18-24, 25-34, 35-44, 45-54, 55-64) is acceptable. Minors (age<18) may participate in the study if their legal guardians provide a written consent, and if this data is collected it will be split into at least two groups: "child" (pre-puberty) and "adolescent". People 65+ (elders) are more than welcome to participate, although they are more likely to suffer from chronic illnesses, resulting in greater variation of results in the group, diminishing the statistical strength of conclusions.

To evaluate the effect of NBS on PH&WB, it is necessary to have at least two measurements: (1) one before and (2) one after the NBS implementation.

Targeting 5 age groups (18-64, see the above paragraph) with 2 repeated measurements (before and after the NBS implementation) and selecting a medium effect size of 0.25 in the analysis of the variance (statistical significance 0.05, statistical strength 0.95), results in a minimum sample size of 302 respondents obtained by means of the program G-power 3.1.6.[5]. Assuming there is a loss or exit of participants during the study duration of about 20%, the final minimum sample size is 363 respondents per demonstration site.

The sample size of 363 might be too large for some of the sites (e.g. Lodz, Gladsaxe). In that case, a more intuitive – rule of thumb approach may be used to determine the minimum sample size (although that will result in diminished statistical strength of conclusions). Roscoe (1975) suggests a 30 sample per category, allowing the sample size to vary between 30 (single category, no age groups – 1x30 = 30) and 300 participants (5 age groups, male and female subgroups – 5x2x30 = 300). For

[5] https://www.psychologie.hhu.de/arbeitsgruppen/allgemeine-psychologie-und-arbeitspsychologie/gpower

groups with increased variations inside the group (minors, elderly), it is suggested to have at least 40 participants.

For measurements performed by wearables, the limit is the number of wearables planned per FR city: 100 MyFeel wearables and 100 wearables compatible with "euPOLIS by BioAssist" platform, resulting in 100-200 participants per FR city (depending on the option of one participant wearing one or two devices).

7.2 Research instruments

The collection of socio-demographic and epidemiological characteristics will be carried out using structured questionnaires consisting of closed and open-ended questions, covering the following topics:
- Socio-demographic characteristics of the respondents including anthropometric measures.
- Habits and behaviors.
- Concomitant diseases.

Data related to level of physical activity, mental health, risks for non-communicable diseases (respiratory diseases, cardiovascular diseases, diabetes type 2) and wellbeing of the study participants will be collected using standardized tools - questionnaires and by objective measurements using various types of equipment (wearables with sensors).
The survey will take place using online applications (for participants that cannot complete online, an analog survey will be provided). Completing the questionnaires will take up to 30 minutes or less.

Place of research
The research will be conducted at the FR cities: Belgrade (Park Usce, Linijski Park), Piraeus (Akti Dilaveri, Mikrolimano, Ralleio school), Lodz and Gladsaxe.

Field research team
Volunteers and other colleagues involved in the field research.

Field training
All participants in the field research team are required to complete training before starting the field research. Training includes:
1. General part - purpose and goals, research method, ethical issues;
2. Specific part for study instruments.
3. Organizational rules of research - detailed acquaintance with all procedures at the place of research and communication.

Field work instructions
As part of the training, all participants will be provided with questionnaires, additional forms and detailed written instructions on the procedures for proper study implementation.

Data entry and processing
After receiving the completed questionnaires data will be entered into specially prepared applications. Depending on the type of variables and the normality of the distribution, the quantitative data description will be shown as n (%), arithmetic mean ± standard deviation or median (range, min - max). From the methods for testing statistical hypotheses, the following will be used: t-test, Mann-Whitney test, chi-square test, Fisher's test of exact probability, ANOVA and Kruskal-Wallis test. ANOVA of repeated measurements and a linear model of mixed effects (or

MLVA) will be used to model the influence of NBS solutions as dependent variables with potential predictors. Statistical hypotheses will be tested at the level of statistical significance (alpha level) of 0.05.

8 Conclusions

This report outlines the indicator framework that was developed by the euPOLIS multidisciplinary team, which engages several different disciplines, e.g., medical doctors, environmental scientists, social scientists, civil and environmental engineers, managers, and city representatives. The framework is developed to evaluate, among others, the impact of NBSs in different aspects of Public Health and Well-being with special emphasis given to both time and spatial scales, providing a list of indicators that can support very time limited and local evaluation of NBSs, but with a potential for upscaling.

The indicators provided support both the planning (Contextual Indicators) and the exploitation (Evaluation indicators) phases in the NBS implementation process. The indicators included in this report are suitable for assessing the direct (categories of PH&WB, social) and indirect (categories of environmental, economic, urban development) impacts of NBSs on PH&WB. All of them are selected to measure the effectiveness of NBSs, and in line with the project objectives, demonstrating that the outcome is related to the implemented interventions.

The next project steps will include intensive participatory processes of the wider community (experts, citizens, local authorities, etc.) to consequently select and design the NBSs (WP6). It is expected that through this process some of the indicators might be modified, refined or new will be defined to suite the local needs. WP5 and WP7 that will develop and deploy, respectively, the monitoring system, might additionally influence the selection of indicators. It is also anticipated that the analysis of the data collected from the monitoring system (wearables for PH&WB assessment, network of permanent sensors, etc.) and/or supplied to modelling tools will produce new compound indicators (e.g. once correlations between different categories of data are demonstrated) that will additionally be included in the evaluation and validation activities of WP8.

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10 Annexes

10.1 List of KPIs

Table 14 euPOLIS preliminary Key Performance Indicators and corresponding Indicator Category

KPI definitions	Indicator Category
KPI_1 – Psychological and physiological responses, psycho-emotional states: Optimization of relevant psychophysiological parameters among users of re-designed public space, including the reduction of stress, depression, and anxiety levels;	PH&WB
KPI_2 – Health indicators related to physical activity (leisure activities including e.g. walking, running, cycling, skateboarding) 1: New activities related to an intervention, e.g., running in the new park, strolling along the new pedestrian street, etc.; Increased number and share of people involved in physical activity in the re-designed space, duration and diversity of indoor/outdoor physical activities;	PH&WB
KPI_3 – Health indicators related to improvements of local conditions: Reducing the risk factors and number of incidence of non-communicable diseases (NCDs) and/or communicable diseases (CDs) through maintaining lower levels of noise and air pollution, moderate air temperature, and offer exposure to a microflora in physiological range;	PH&WB, E
KPI_4 – Enhancement of social cohesion and cultural particularity through ensuring sense of security and inclusion for all (with focus on gender and age equality as well as newcomers integration) allowing for the strengthening of exploratory and socializing/culture behaviors among users: Increased use of public space – both during the day and in the evenings; Increased presence of women, children, senior citizens and disabled persons as well as newcomers/migrants; Higher generational, gender and ethnic diversity visible in public spaces; New group activities engaging previously non-active community members; Significant number of local inhabitants (target > 200) taking part in project activities; Increased engagement of citizens and local authorities during the participatory processes;	S
KPI_5 – Sense of place and place attachment among users: Data from quantitative and qualitative studies showing an increased positive emotional attachment to the neighborhood as well as re-designed public space; Increase feeling of responsibility and ownership among community members; Increased sense of pride of being part of local community;	S
KPI_6 – Density and strength of local community ties: Higher trust in local community members; New forms of neighborly exchange, neighborhood engagement and cooperation; Emergence of local leaders and social entrepreneurs; Increased feeling of community efficacy;	S
KPI_7 – Number of planned natural systems: Quantified improvements of local conditions by implemented NBS such as microclimate control (measurable improvements in local outdoor microclimate conditions; # of kWh of energy saved through HI effect reduction);	E
KPI_8 – Significant improvement of habitat, biodiversity, resilience, EcoSystems (ES) in case studies: The list of Regenerated ES and resulting effects; 30% improvement of ecological status at each case study; The list of resilience measures and their expected results, € savings in case of weather extremes;	E
KPI_9 – List of activated/implemented business models: Number of new marketable products and/or new business initiatives, such as urban farms, food coops, social entrepreneurships, start-ups (>5 new products and >3 new	B

businesses); Number of businesses that master and adopt new BGS paradigm and tools (>5 new trained);	
KPI_10 – Deployed communication/dissemination activities: Number of other cities or corporations involved through technology adoption and implementation alliance in "paradigm shift" capacity building (>3 additional cities in Europe and >5 international); Number of people involved in participatory processes; Size of audience of project-related meetings, conference panels; Number of website visits and downloads of prepared guides and reports.	NA

10.2 List of Contextual Indicators

Table 15 List of euPOLIS contextual indicators – version 1.0

Category		Contextual Indicator	Challenge
Public health and Wellbeing	c1	Prevalence of allergic respiratory diseases	Risks for respiratory diseases
	c2	Prevalence of smoking	Risk for respiratory diseases; Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c3	Incidence of chronic respiratory diseases (chronic obstructive pulmonary disease- COPD and asthma)	Risks for respiratory diseases
	c4	Mortality from chronic respiratory diseases (chronic obstructive pulmonary disease- COPD and asthma)	Risk for respiratory diseases
	c5	Incidence of cardiovascular diseases	Risks for cardiovascular diseases; Wellbeing
	c6	Mortality from cardiovascular diseases	Risks for cardiovascular diseases; Wellbeing
	c7	Prevalence of hypertension	Risks for cardiovascular diseases
	c8	Incidence of diabetes	Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c9	Mortality from diabetes	Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c10	Prevalence of diabetes	Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c11	Prevalence of obesity	Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c12	Prevalence of arrhythmias	Risk for cardiovascular, diabetes type 2, obesity; Wellbeing
	c13	Health related quality of life	Wellbeing
	c14	Prevalence of depression	Mental health, Wellbeing
	c15	Prevalence of physical activity	Physical activity; Mental health; Risks for respiratory diseases; Risks for cardiovascular, diabetes type 2, obesity; Wellbeing
	c16	Incidence of alimentary infections	Risks for communicable diseases; Wellbeing
	c17	Incidence of vector-borne diseases	Risks for communicable diseases; Wellbeing
	c18	Incidence of zoonoses	Risks for communicable diseases; Wellbeing
Social	c19	Age and gender distribution in the neighbourhood	Friendliness of the space; Diversity
	c20	Social status	Friendliness of the space; Diversity
	c21	Education level	Citizen's willingness to participate; Environmental awareness

Category		Contextual Indicator	Challenge
	c22	Quality of education	Citizen's willingness to participate; Environmental awareness
	c23	Unemployment	Friendliness of the space; Diversity
	c24	Sectors of the employment	Friendliness of the space; Diversity
	c25	Economic situation of households (average income of the household)	Friendliness of the space; Diversity
	c26	Type of housing arrangement (type of residency)	Friendliness of the space; Diversity
	c27	Life expectancy	NA
	c28	Racial, ethnic, and religious diversity	Friendliness of the space; Diversity
	c29	Number of children in foster care	NA
	c30	Number of families receiving social benefits	Friendliness of the space; Diversity
	c31	Poverty	Friendliness of the space; Diversity
	c32	Voter turnout in the last election	Citizen's willingness to participate
	c33	Number of community-based organizations	Social cohesion
	c34	Access to culture	Friendliness, Sense of safety
	c35	Access to sport facilities	Friendliness, Sense of safety
	c36	Crime rate	Sense of safety
	c37	Population change rate	NA
	c38	Local government expenditure on similar projects	NA
	c39	Things to enjoy in the existing space	Comfort of use, Friendliness
	c40	Functions of the existing space	Comfort of use, Friendliness
	c41	Aesthetic of the space	Comfort of use, Friendliness
	c42	Type of users	Friendliness; Social cohesion; Activation in participatory processes
Economy / Business	c43	Existing regulations restricting or allowing only specific business activities	Creation of the livable and vibrant urban spaces conducive to business activation
	c44	Existing businesses related to the site (i.e. interacting with euPOLIS interventions e.g. restaurants, cafes)	Site related business initiatives - opportunities businesses
	c45	Surrounding [comparative] property value (a. Offices b. Residential, c. Commercial)	Increase of neighborhood value - surrounding property value
	c46	Neighbourhood people acceptance/satisfaction on the site's impact on PH&WB (current condition)	Creation of the livable and vibrant urban spaces conducive to business activation, Comprehensive positive impact from business activity on the neighborhood

Category		Contextual Indicator	Challenge
	c47	Unemployment rate	City providing financial support to private start-ups and NBS related businesses (primarily the ones enhancing WB), Comprehensive positive impact from business activity on the neighborhood
	c48	Local companies' interest in supporting euPOLIS vision	Engagement of nearby companies into NBS paradigm and support and enhancement of existing business with NBS
	c49	Municipality budgeting for NBS interventions at the demonstration site	Creation of the livable and vibrant urban spaces conducive to business activation, Increase of neighborhood value - surrounding property value
Environmental	c50	Heat Risk (Number of combined tropical nights (>20 °C) and hot days (>35 °C))	Climatic resilience / UHI, Thermal comfort & Air Cooling
	c51	Freshwater scarcity (EEA WEI+)	Water Management / Water availability (surface & GW) & consumption
	c52	Groundwater scarcity (EEA WEI+)	Water Management / Water availability (surface & GW) & consumption
	c53	Groundwater salinization / Seawater intrusion	Water Management / Water availability (surface & GW) & consumption
	c54	River & sea floods (% of the area that would flood for a specific return period)	Water Management / Runoff & Flooding
	c55	Urban Drainage Flooding (% of impervious area)	Water Management / Runoff & Flooding
	c56	Surface water quality	Environmental Pollution / Water Quality
	c57	Groundwater quality	Environmental Pollution / Water Quality
	c58	Climate change adaptation (existence of environmental policies in general)	Climatic resilience
	c59	Wastewater treatment coverage	Water Management / Sanitation/Wastewater Treatment
	c60	Level of wastewater treatment	Water Management / Sanitation/Wastewater Treatment
	c61	Air Quality	Environmental Pollution / Air Quality
	c62	Water reuse (on-site)	Circular economy / Water Reuse
	c63	Land surface temperature	Climatic Resilience / UHI, Thermal comfort & Air Cooling
	c64	Waste Management	Circular economy / Waste/Material reuse?
	c65	Area of greenery (formal / informal)	Access to ecosystem services / Green space availability or Formal / informal greenery

Category		Contextual Indicator	Challenge
	c66	Share of green urban areas	Access to ecosystem services / Green space availability
	c67	Ecological Connectivity	Integrity-Biodiversity / Habitat connectivity and reduced fragmentation
	c68	Quality (BD, tree condition, soil viability)	Integrity-Biodiversity
	c69	Greenery use (intensity, type)	Access to ecosystem services
	c70	Public green space distribution	Access to E.S. / Green space accessibility
	c71	Level of recycling of resources	Circular economy
	c72	NDVI	Green space availability
Urban Development	c73	Surface area of demo-site	Land use efficiency/BGS Planning Approach
	c74	Average green space per inhabitant	Blue-green spaces /Sustainability/Maintenance/Identity/ Density/Impact
	c75	Number of houses	Density/Intensity/Impact
	c76	Multifunctionality	Flexibility/Interactivity/Demography
	c77	Pedestrian accessibility	Accessibility/Safety/Pedestrians
	c78	Parking facilities for different private transport	Accessibility/Safety
	c79	Frequency of public transport service	Accessibility/Safety/Demography
	c80	Available urban open space	Blue/Green Spaces/Sustainability/Land use efficiency/flexibility
	c81	Presence of obstacles in the use of the public space	Safety/Demography/Accessibility
	c82	Presence of unique spatial elements (sculptures, monuments etc.)	Identity/Safety/Visibility/Esthetics

10.3 Tables of Evaluation Indicators

<table>
<tr><td>1</td><td colspan="2">Indicator name
Physiological Indicators for physical activities</td><td>Tags
PH & WB, Digital</td></tr>
<tr><td colspan="4">Definition
Physiological measurement involves the direct or indirect observation of variables attributable to normative functioning of system and subsystems in the human body. This includes phenomena such as heart rate, number of steps, blood pressure, skin temperature and number of respirations.</td></tr>
<tr><td colspan="4">Description & use
There are several methods to distinguish the intensity of an aerobic activity. They are measured by heart rate. The higher the intensity, the higher the heart rate will be. Normal vital signs range for the average healthy adult while resting are: Blood pressure: 90/80mm Hg to 120/80mm Hg. Breathing: 12 to 18 breaths per minute. Pulse:60 to 100 beats per minute. Skin temperature overactive muscles increase during high intensity anaerobic exercise, decreases slowly after exercise and increases again in the days after the exercise. On the other hand, during low intensity aerobic exercise, skin temperature overactive muscles decrease, returning to normal values a few minutes after it and present a small rise in the following days.</td></tr>
<tr><td colspan="4">Relation to PH & WB
Mental health, Wellbeing, non-communicable diseases (Cardiovascular health, Respiratory health)</td></tr>
<tr><td colspan="2">Scale</td><td>site</td><td>Twice, once before the implementation of the nature-based solutions and once after.</td></tr>
<tr><td colspan="2">Units</td><td colspan="2">Continuous variables</td></tr>
<tr><td colspan="4">Method for assessment
Direct measurement with devices using the “euPOLIS by BioAssist” mHealth app (see Section 6.1.1 in the main text)</td></tr>
<tr><td colspan="4">How it is calculated
output will be provided automatically</td></tr>
<tr><td colspan="2">Data needed</td><td colspan="2">Heart rate, blood pressure (measured by the wearables), skin temperature (measured by the wearables), oxygenation (measured by the wearables) and number of respirations (recorded by manually entry by the user).</td></tr>
</table>

References	- https://znnhs.zdnorte.net/wp-content/uploads/2020/11/PEH3-M4.pdf - https://pubmed.ncbi.nlm.nih.gov/35062191/ - www.bioassist.eu

<table>
<tr><td>2</td><td colspan="2">Indicator name
Emotional events</td><td>Tags
PH & WB, Digital</td></tr>
<tr><td colspan="4">Definition
Significant emotional events that a user experience. More specifically, the type (e.g. happy/sad), the duration, time and intensity of the event as well as the intensity and what triggered the user to experience such an event along with the thoughts and physical sensations after the event.</td></tr>
<tr><td colspan="4">Description & use
Several correlations can be used to determine if and how the emotional responses of the citizens change upon an NBS. An example could be to compare the number of negative emotions before and after the introduction of the NBS.</td></tr>
<tr><td colspan="4">Relation to PH & WB
Mental health, Wellbeing</td></tr>
<tr><td>Scale</td><td colspan="2">Spatial scale cannot be specified because both residents and frequent visitors of the vicinity of demo-site will be included in the research</td><td>Twice, once before the implementation of the nature-based solutions and once after.</td></tr>
<tr><td>Units</td><td colspan="3">Continuous variables</td></tr>
<tr><td colspan="4">Method for assessment
Direct measurement with devices</td></tr>
<tr><td colspan="4">How it is calculated
output will be provided from devices</td></tr>
<tr><td>Data needed</td><td colspan="3">Sentio platform provides an output with respect to the significant emotional events that a user experiences. More specifically, the platform can provide the type (e.g. happy/sad), the duration, time and intensity of the event as well as the intensity and what triggered the user to experience such an event along with the thoughts and physical sensations after the event. intensity of the detected emotion on a scale 1-10.</td></tr>
<tr><td>References</td><td colspan="3">https://www.myfeel.co/research-studies</td></tr>
</table>

3	***Indicator name*** Level of outdoor physical activity	***Tags*** PH&WB
Definition Outdoor Physical activity as self-reported participation in organized or unorganized sport or exercise, outdoors, at least once a week.		
Description & use "Solid empirical evidence as to relationship between physical and mental health, and wellbeing, and physical activity in nature and urban green space (parks, playgrounds, and residential greenery). Robust empirical evidence for the role of physical activity in cardiovascular disease and obesity."		
Relation to PH & WB Mental health, and wellbeing, prevention of cardiovascular disease and obesity.		
Scale	site	Twice; once before the implementation of the nature-based solutions and once after.
Units	text - ordinal	
Method for assessment International Physical Activity Questionnaire (long - 27 items or short form - 7 items), available at: https://sites.google.com/site/theipaq/questionnaire_links		
How it is calculated Hours per week a person spends for different kinds of physical activities		
Data needed	Survey data	
References	https://www.who.int/publications/i/item/9789240015128; Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

4	***Indicator name*** Level of depression, anxiety, and stress	***Tags*** PH & WB
Definition Measure of the negative emotional states of depression, anxiety and stress		
Description & use The Depression Anxiety Stress Scale (DASS) has been shown to be a valid and reliable measure of the dimensions of depression, anxiety, and stress separately but also taps into a more general dimension of psychological distress]. The DASS is available in two forms: the DASS-21 and the DASS-42.		
Relation to PH & WB Mental health, Wellbeing		
Scale	site	Twice, once before the implementation of the nature-based solutions and once after.
Units	text – ordinal	
Method for assessment Depression, anxiety and stress scale - DASS (21 or 42 items)		
How it is calculated Scoring Guide available at: https://www.healthfocuspsychology.com.au/tools/dass-42/ and https://maic.qld.gov.au/wp-content/uploads/2016/07/DASS-21.pdf		
Data needed	Survey data	
References	https://www.healthfocuspsychology.com.au/tools/dass-42/	

5	***Indicator name*** Visual access to green space	***Tags*** PH & WB, Environmental, Urban development
Definition Self-reported amount of green space in the view from windows at home and the frequency of looking at the view		
Description & use Visual access to green space is an indicator of exposure to green spaces. Previous experimental studies have shown short-term looking at green spaces could have mental health benefits such as reducing stress, restoring attention, and improving mood. An emerging body of evidence is also suggestive of the health benefits of the long-term visual exposure to green spaces		
Relation to PH & WB Mental health, Wellbeing		
Scale	site	Twice; once before the implementation of the nature-based solutions and once after.
Units	Continuous variables	
Method for assessment "The indicator is obtained using a survey which is taken by a sample of the general population. The survey includes a section with the following questions: “At home, how much green space (trees, grasses, flowers, etc.) can you see through the following window(s)?” with possible answers on a scale from 0 (no green space/no window) to 4 (all of the view completely filled green space) “How often (during the day) do you look out through the following window(s)?” with possible answers on a scale from 0 (no window/never) to 3 (often) This survey is repeated before and after the implementations of NBS in order to observe a potential change in visual exposure to green and blue spaces."		
How it is calculated Average renormalized score of the Likert scales described in “Method for assessment”		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

6	***Indicator name*** Prevalence of allergic respiratory diseases	***Tags*** PH & WB
Definition Prevalence is a measure of the burden of allergic respiratory diseases in a population in a given location and at a particular time, as represented in a count of the number of people affected.		
Description & use The rising trend in prevalence of allergic respiratory disease and bronchial asthma, observed over the last decades, can be explained by changes occurring in the environment, with increasing presence of biologic, such as allergens, and chemical atmospheric trigger factors able to stimulate the sensitization and symptoms of these diseases.		
Relation to PH & WB Respiratory diseases and risk factors		
Scale	site	Twice, once before the implementation of the nature-based solutions and once after.
Units	%	
Method for assessment Questionnaire		
How it is calculated Number of people diagnosed with allergic respiratory diseases among the population of the site in particular time		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

<table>
<tr><td>7</td><td>Indicator name
Prevalence of smoking and prevalence of exposure to secondhand smoke</td><td>Tags
PH & WB</td></tr>
<tr><td colspan="3">Definition
Prevalence is a measure of the burden of smoking in a
population in a given location and at a particular time, as represented in a count of the number of people affected.</td></tr>
<tr><td colspan="3">Description & use
Smoking leads to disease and disability and harms nearly every organ of the body.
More than 16 million Americans are living with a disease caused by smoking. For every person who dies because of smoking, at least 30 people live with a serious smoking-related illness. Smoking causes cancer, heart disease, stroke, lung diseases, diabetes, and chronic obstructive pulmonary disease (COPD), which includes emphysema and chronic bronchitis. Smoking also increases risk for tuberculosis, certain eye diseases, and problems of the immune system, including rheumatoid arthritis.
Secondhand smoke exposure contributes to approximately 41,000 deaths among nonsmoking adults and 400 deaths in infants each year. Secondhand smoke causes stroke, lung cancer, and coronary heart disease in adults. Children who are exposed to secondhand smoke are at increased risk for sudden infant death syndrome, acute respiratory infections, middle ear disease, more severe asthma, respiratory symptoms, and slowed lung growth.</td></tr>
<tr><td colspan="3">Relation to PH & WB
All noncommunicable diseases and risk factors</td></tr>
<tr><td>Scale</td><td>site</td><td>Twice, once before the implementation of the nature-based solutions and once after.</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
Questionnaire</td></tr>
<tr><td colspan="3">How it is calculated
Number of smokers among the population of the site in particular time, Number of persons exposed to secondhand smoke among the population of the site in particular time</td></tr>
<tr><td>Data needed</td><td colspan="2">Survey data</td></tr>
<tr><td>References</td><td colspan="2">Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.</td></tr>
</table>

8	***Indicator name*** Prevalence of hypertension	***Tags*** PH & WB
Definition Prevalence is a measure of the burden of hypertension in a population in a given location and at a particular time, as represented in a count of the number of people affected.		
Description & use Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on urban residents through reduced cardiovascular morbidity and mortality (Gascon et al., 2016; Tamosiunas et al., 2014)		
Relation to PH & WB Cardiovascular diseases and risk factors		
Scale	site	Twice, once before the implementation of the nature-based solutions and once after.
Units	%	
Method for assessment Questionnaire. Data will be obtained using assessment of health status from National Health Survey 2019, with the permission of the authorities		
How it is calculated Number of people with hypertension among the population of the location in particular time		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

9	***Indicator name*** Prevalence of diabetes	***Tags*** PH & WB
Definition Prevalence is a measure of the burden of diabetes in a population in a given location and at a particular time, as represented in a count of the number of people affected.		
Description & use Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on reduced obesity (Kim et al., 2014) and diabetes (Maas et al., 2009).		
Relation to PH & WB Cardiovascular diseases and risk factors		
Scale	site	Twice, once before the implementation of the nature-based solutions and once after.
Units	%	
Method for assessment Questionnaire. Data will be obtained using assessment of health status from National Health Survey 2019, with the permission of the authorities		
How it is calculated Number of people diagnosed with diabetes among the population of the location in particular time		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

<table>
<tr><td>10</td><td>Indicator name
Prevalence of obesity</td><td>Tags
PH & WB</td></tr>
<tr><td colspan="3">Definition
Prevalence is a measure of the burden of obesity in a population in a given location and at a particular time, as represented in a count of the number of people affected.</td></tr>
<tr><td colspan="3">Description & use
Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on reduced obesity (Kim et al., 2014) and diabetes (Maas et al., 2009). In adults, obesity is associated with increasing risk of cardiovascular disease, type 2 diabetes, and all-cause mortality. Most of the associated mortality and morbidity is mediated through major chronic diseases related to obesity, such as cardiovascular disease, diabetes, and cancer (Bhrem & D'Alession, 2014).</td></tr>
<tr><td colspan="3">Relation to PH & WB
Cardiovascular diseases, diabetes and risk factors</td></tr>
<tr><td>Scale</td><td>site</td><td>Twice; once before the implementation of the nature-based solutions and once after.</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
Questionnaire. Data will be obtained using assessment of health status from National Health Survey 2019, with the permission of the authorities</td></tr>
<tr><td colspan="3">How it is calculated
Number of people diagnosed with obesity among the population of the location in particular time</td></tr>
<tr><td>Data needed</td><td colspan="2">Survey data</td></tr>
<tr><td>References</td><td colspan="2">Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.</td></tr>
</table>

<table>
<tr><td>11</td><td colspan="2">Indicator name
Prevalence of arrhythmias</td><td>Tags
PH & WB</td></tr>
<tr><td colspan="4">Definition
Prevalence is a measure of the burden of arrhythmias in a population in a given location and at a particular time, as represented in a count of the number of people affected.</td></tr>
<tr><td colspan="4">Description & use
Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on urban residents through reduced cardiovascular morbidity and mortality (Gascon et al., 2016; Tamosiunas et al., 2014)</td></tr>
<tr><td colspan="4">Relation to PH & WB
Cardiovascular diseases and risk factors</td></tr>
<tr><td colspan="2">Scale</td><td>site</td><td>Twice; once before the implementation of the nature-based solutions and once after.</td></tr>
<tr><td colspan="2">Units</td><td colspan="2">%</td></tr>
<tr><td colspan="4">Method for assessment
Questionnaire. Data will be obtained using assessment of health status from National Health Survey 2019, with the permission of the authorities</td></tr>
<tr><td colspan="4">How it is calculated
Number of people diagnosed with arrhythmias among the population of the location in particular time</td></tr>
<tr><td colspan="2">Data needed</td><td colspan="2">Survey data</td></tr>
<tr><td colspan="2">References</td><td colspan="2">https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/ks-01-20-253</td></tr>
</table>

12	***Indicator name*** Quality of life (QoL)	***Tags*** PH & WB, Social
Definition WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment (WHO, 1995). QoL refers to a person's cognitive assessment of their overall standard of living, or their 'personal assessment of life satisfaction' (Price and Harding 2004). WHO underlines the importance of culture and value systems for the individual's perception of QoL, in relation to their needs, goals, expectations, standards and concerns. QoL is affected by the person's physical health, psychological state, personal beliefs, social relationships and relationship to the environment (WHO 1995).		
Description & use The Quality of Life indicator indicates the global level of perceived quality of Life. It is capable to describe initial planning problems like perceived health in urban areas). Environmental quality of life is a multidimensional concept and considers the benefits of environment on physical, psychological and social dimensions (WHO, 1998), as well as multiple aspects of interactions between individuals and their environment (thermal comfort, noise, air quality, ambience, etc.)		
Relation to PH & WB Wellbeing		
Scale	site	Twice; once before the implementation of the nature-based solutions and once after.
Units	text - ordinal	
Method for assessment The Environmental Quality of Life (EQoL) scale developed in Nature4Cities, or QoL scale		
How it is calculated https://www.nature4cities.eu/post/eqol-scale-operational-tool-to-assess-nbs-benefits-on-quality-of-life		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2021.	

13	***Indicator name*** Healthy lifestyle	***Tags*** PH & WB, Social

Definition
Extent to which the NBS project and associated activities serve to promote a healthy lifestyle among local residents

Description & use
A core co-benefit of NBS is the encouragement of healthy lifestyles for urban residents. Many different measures can be employed to encouraging a healthy lifestyle, such as:
- Increasing bicycling opportunities in the neighborhood - network of bicycle paths covering an area between residences and businesses/services
- Increasing walking opportunities in the neighborhood - network of pedestrian walkways covering an area between residences and businesses/services
- Increasing the number, diversity or accessibility public sports facilities
- Increasing the extent or accessibility of community gardening facilities
- Designating public areas as non-smoking zones

Relation to PH & WB
Wellbeing

Scale	site	Twice; once before the implementation of the nature-based solutions and once after.
Units	Continuous variables	

Method for assessment
The overall process of NBS co-creation, co-implementation and co-management with stakeholders provides ample opportunity to specifically target NBS interventions that provide opportunities for local citizens to adopt healthier lifestyles. The extent to which this is considered during NBS planning and implementation is assessed qualitatively using a five-point Likert scale from not at all (1, no encouragement of healthy lifestyles) to excellent (extensive online and offline encouragement):

Not at all – 1 – 2 – 3 – 4 – 5 – Excellent 1. Not at all: no measures were taken to encourage a healthy lifestyle. 2. Poor: there was little encouragement of a healthy lifestyle. 3. Somewhat: there was some encouragement of a healthy lifestyle with the implementation of some measures. 4. Good: a sufficient encouragement of a healthy lifestyle was translated into several offline (biking facilities, public sports facilities) and online (i.e., reminder app) initiatives. 5. Excellent: a healthy lifestyle was extensively encouraged offline (biking facilities, public sports facilities, pedestrian networks) and online (i.e., exercise apps) **Other methods:** Survey, self-reported frequency of healthy behavior in-door and out-door **On-site observations:** number of people cycling, running, exercising	
How it is calculated Average (probably renormalized) score obtained based on the 5-point Liker scale	
Data needed	Survey data
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2019.

14	***Indicator name*** Satisfaction with Life (SWL)	***Tags*** PH & WB, Social

Definition

Life satisfaction (Diener, Emmons, Larsen, & Griffin, 1985) is a cognitive, judgmental process based on a comparison of one's current state of affair with a standard that each individual sets for him or herself (i.e., not externally imposed). Diener et al. (1985) developed the Satisfaction with Life Scale (SWLS) around the idea that one musk ask subjects for an overall judgment of their life in order to measure the concept. Life satisfaction belongs to the category of evaluative subjective WB, as organized by current literature (Dolan & Metcalfe, 2012; MacKerron & Maurato, 2013)

Description & use

Cross-disciplinary literature operates with a variety of concepts to delineate general wellbeing (WB) and happiness, such as (subjective) wellbeing (SWB), happiness, life satisfaction (LS), experienced utility, and quality of life (Larson, Jennings, & Coutier, 2016; MacKerron & Mourato, 2013). Cervinka, Röderer, and Hefler (2012) categorize WB as an umbrella-term that includes experiences of positive emotional states and processes ranging from short-term to long-term, from current positive feelings (positive affect) to habitual dispositions (personality-factors), and that encompasses pleasurable affect as well as general life satisfaction. A growing body of empirical evidence documents the otherwise intuitive notion that people who are more connected with nature and engage in nature's beauty (i.e., experience positive emotional responses when witnessing nature's beauty) report more subjective well-being (Frumkin, Bratman, Breslow, Cochran, Kahn Jr., Lawler, Levin, Tandon, Varanasi, Wolf, & Wood, 2017; ; Howell, Dopko, Passmore, & Buro, 2011; Howell & Passmore, 2013; Larson et al., 2016; Pritchard, Richardson, Sheffield, & McEwan, 2019; Zhang, Howell, & Iyer, 2014). MacKerron and Maurato (2013) document theoretical and empirical evidence for at least three reasons for thinking that experiences of natural environments will be positively related to health, wellbeing and happiness: 1. the existence of direct pathways by which such experiences affect the nervous system, bringing about stress reduction and restoration of attention; 2. natural environments may be lower in environmental 'bads' that have significant negative impacts on physical and mental wellbeing, which in turn could affect happiness; 3. natural environments might increase happiness by facilitating and encouraging − for practical, cultural and/or psychological reasons − behaviours that are physically and mentally beneficial, including physical exercise, recreation and social interaction.

Relation to PH & WB

Wellbeing

Scale	site	Twice; once before the implementation of the nature-based solutions and once after.

Units	Continuous variables
Method for assessment Satisfaction with Life Scale (SWLS − Diener et al., 1985)	
How it is calculated Scoring available at: https://fetzer.org/sites/default/files/images/stories/pdf/selfmeasures/SATISFACTION-SatisfactionWithLife.pdf	
Data needed	Survey data
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2019.

15	***Indicator name*** Health Related Quality of Life (HRQoL)	***Tags*** PH & WB

Definition

HRQoL refers to the cognitive appraisal which a respondent makes about the impact their health has on their daily life (Yin 2016).

Description & use

Health-related quality of life (HRQOL) is an individual's or a group's perceived physical and mental health over time.

- On the individual level, HRQOL includes physical and mental health perceptions (e.g., energy level, mood) and their correlates—including health risks and conditions, functional status, social support, and socioeconomic status.
- On the community level, HRQOL includes community-level resources, conditions, policies, and practices that influence a population's health perceptions and functional status.

HRQOL questions have become an important component of public health surveillance and are generally considered valid indicators of unmet needs and intervention outcomes. Self-assessed health status is also a more powerful predictor of mortality and morbidity than many objective measures of health. HRQOL measures make it possible to demonstrate scientifically the impact of health on quality of life, going well beyond the old paradigm that was limited to what can be seen under a microscope. (CDC website)

Relation to PH & WB

Indirect - Additional measure of PH

Scale	Neighborhood level	Twice; once before the implementation of the nature-based solutions and once after.
Units	Continuous variables	

Method for assessment

HRQoL scale, eg. CDC set of questions called the "Healthy Days Measures."

- Would you say that in general your health is excellent, very good, good, fair or poor?
- Now thinking about your physical health, which includes physical illness and injury, how many days during the past 30 days was your physical health not good?
- Now thinking about your mental health, which includes stress, depression, and problems with emotions, how many days during the past 30 days was your mental health not good?
- During the past 30 days, approximately how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?

How it is calculated

Examples available here: https://www.cdc.gov/hrqol/methods.htm

Data needed	Survey data
References	https://www.cdc.gov/hrqol/methods.htm

16	***Indicator name*** Connectedness to nature	***Tags*** PH & WB, Environmental
Definition Sense of connectedness and oneness to nature.		
Description & use This indicator is a measure of individuals' trait levels of feeling emotionally connected to the natural world. Previous studies confirmed that connectedness to nature predicts the self-reported well-being and life satisfaction.		
Relation to PH & WB Wellbeing		
Scale	site	Twice, once before the implementation of the nature-based solutions and once after.
Units	Continuous variables	
Method for assessment Questionnaire. Data obtained using a validated scale named "Connectedness to Nature Scale" (CNS - Mayer, 2004)- 14 items before and after NBS		
How it is calculated Average (probably renormalized) score obtained from 5-point Likert scale which includes 14 items		
Data needed	Survey data	
References	Evaluating the Impact of Nature-based Solutions: Appendix of Methods. EUROPEAN COMMISSION. 2019.	

17	***Indicator name*** Perceived loneliness	***Tags*** Social, Loneliness

Definition
Loneliness, or social isolation, can be defined as disengagement from social ties, institutional connections, or community participation. A substantial body of evidence demonstrates that loneliness and social isolation presents a major risk for premature mortality, comparable to other risk factors such as high blood pressure, smoking, or obesity.

Description & use
Three-Item Loneliness Scale:
The next questions are about how you feel about different aspects of your life. Please rate on a scale from 1 to 5, where 1 -- None of the time and 5 -- All the time.
1. First, how often do you feel that you lack companionship?
2. How often do you feel left out?
3. How often do you feel isolated from others?

Berkman–Syme Social Network Index:
- In a typical week, how many times do you talk on the telephone with family, friends, or neighbors?
- How often do you get together with friends or relatives?
- How often do you attend church or religious services?
- How often do you attend meetings of the clubs or organizations you belong to?

Relation to PH & WB
Supportive indicator

Scale	Demo site	Before and after NBS implementation
Units	5-points Likert scale	

Method for assessment
Monitoring

How it is calculated
Average (probably renormalized) score obtained from Three-Item Loneliness Scale (Hughes et al., 2004). Index calculated based on Berkman–Syme Social Network scale (Berkman and Syme, 1979)

Data needed	Survey data
References	Seeman, T. E. (1996). Social ties and health: The benefits of social integration. Annals of Epidemiology, 6(5), 442-451. Hughes, M. E., Waite, L. J., Hawkley, L. C., & Cacioppo, J. T. (2004). A short scale for measuring loneliness in large surveys: Results from two population-based studies. Research on Aging, 26(6), 655-672. See also: https://www.nap.edu/read/25663/chapter/8#110

18	***Indicator name*** Leisure Time Satisfaction Measure	***Tags*** Social, Leisure time
Definition The Leisure Time Satisfaction (LTS) can be defined as subjective assessment of the quality of leisure time (Francken and Van Raaij 1981).		
Description & use Please answer the following questions on a scale from 1 to 5, where 1 -- Very unsatisfied and 5 -- Very satisfied Over past month how satisfied you with the amount of time are you have been able to spend: 1. In quite time by yourself? 2. Attending church or going to other meetings or organizations? 3. Taking part in hobbies or other interests? 4. Going out for meals or other social activities? 5. Doing fun things with other people? 6. Visiting with family and friends?		
Relation to PH & WB Supportive indicator		
Scale	Demo site	Before and after NBS implementation
Units	5-points Likert scale	
Method for assessment Monitoring		
How it is calculated Average (probably renormalized) score obtained from the 5-point Likert scale		
Data needed	Survey data	
References	A. B. Stevens Director , D. Coon , S. Wisniewski , D. Vance , S. Arguelles , S. Belle , A. Mendelsohn , M. Ory & W. Haley (2004) Measurement of leisure time satisfaction in family caregivers, Aging & Mental Health, 8:5, 450-459, DOI: 10.1080/13607860410001709737	

<table>
<tr><td>19</td><td>Indicator name
Perceived safety of the neighborhood (self-reported feeling)</td><td>Tags
Social, Crime</td></tr>
<tr><td colspan="3">Definition
Self-reported perceptions of neighborhood/community crime and safety.</td></tr>
<tr><td colspan="3">Description & use
Please rate on 5-points Likert scale, where 1 -- very violent and 5 -- very peaceful.
1. In your opinion, is your neighborhood generally peaceful or marked by violence?
2. In general, how safe from crime and violence do you feel when you are alone at home?
3. How safe do you feel when walking down the street alone after dark?

Please rate on 5-points Like scale, where 1 -- very fearful and 5 -- not at all fearful
6. How fearful are you about crime in your neighborhood?
7. How fearful are you about crime in your city?</td></tr>
<tr><td colspan="3">Relation to PH & WB
Expected positive indirect impact</td></tr>
<tr><td>Scale</td><td>Neighborhood vs city level</td><td>Before and after (if possible the same group of people)</td></tr>
<tr><td>Units</td><td colspan="2">5-points Likert scale</td></tr>
<tr><td colspan="3">Method for assessment
Monitoring</td></tr>
<tr><td colspan="3">How it is calculated
Sum of all answers</td></tr>
<tr><td>Data needed</td><td colspan="2">Survey data</td></tr>
<tr><td>References</td><td colspan="2">- Grootaert, C., Narayan, D., Jones, V.N., & Woolcock, M. (2004). Measuring Social Capital: An Integrated Questionnaire. World Bank Working Paper 18. Washington D.C.: World Bank. Retrieved from http://documents.worldbank.org/curated/en/515261 4687403 92133/Measuring-social-capital-an-integrated-questionnaire
- Smith, S.K., Steadman, G.W., Minton, T.D., & Townsend, M. (1999). Criminal victimization and perceptions of community safety in 12 cities, 1998. Washington, DC: Bureau of Justice Statistics and Office of Community Oriented Policing Services, U.S. Department of Justice. Retrieved from</td></tr>
</table>

	https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=17 3940

20	***Indicator name*** Perceived safety of the neighborhood (self-reported experience)	***Tags*** Social, Crime
Definition Self-reported experience of being a victim of a crime, traffic accident, or violence in the neighborhood.		
Description & use 1. In the past 12 months, have you or anyone in your household been the victim of a violent crime, such as assault or mugging? 1 -- Yes; 2 -- No; If yes, how many times? 2. In the past 12 months, has your house been burglarized or vandalized? 1 -- Yes; 2 -- No; If yes, how many times?		
Relation to PH & WB Expected positive indirect impact		
Scale	Neighborhood level	Before and after the implementation of NBS.
Units	Number of people who has been a victim of a crime in the last 12 months.	
Method for assessment Monitoring		
How it is calculated Number of times a person was a victim of each category of crime		
Data needed	Survey data	
References	- Alfredo J. Velasquez, Jason A. Douglas, Fangqi Guo, Jennifer W. Robinette, (2021). What predicts how safe people feel in their neighborhoods and does it depend on functional status?, SSM – Population Health, Volume 16, 2021 - Beenackers, M. A., Kamphuis, C. B., Mackenbach, J. P., Burdorf, A., & van Lenthe, F. J. (2013). Why some walk and others don't: exploring interactions of perceived safety and social neighborhood factors with psychosocial cognitions. Health education research, 28(2), 220-233.	

21	***Indicator name*** Friendliness	***Tags*** Social
Definition Presence of different age, gender and minority groups, presence of people with disabilities, low-income and high-income users.		
Description & use Public space can be referred as friendly space when it is freely accessible to everyone (Peters and Haan, 2010), open, non-discriminatory and shared by diversity of people every day. By spending time in public spaces people not only utilize their leisure time and meet diversity of people (Jacobs, 1992; Peters and Haan, 2010) but also manifest public space to be democratic. In public space, people can learn to live together, display their culture and identities; it also provides opportunities for children and young people to meet, play or simply 'hang out'. Carr et al. (1992) points out that convivial space are the heart of democratic living, a place to have good time, where difference encountered teaches understanding and tolerance towards other people. All these have important benefits and help to create place attachments, and community relations (Worpole and Knox, 2007).		
Relation to PH & WB Direct - Main measure of Livability		
Scale	Demo site	Before and after the implementation of NBS.
Units	1-5 based on qualitative data	
Method for assessment **On-site observations:** the presence of different age, gender and minority groups, people with disabilities **Alternatively we can use survey data:** - perception of the friendliness of the site - opportunities for families to spend time locally - opportunities to socialize - opportunities for sports/recreation **Additional data can be collected through interviews with local leaders**		
How it is calculated Qualitative measure, will be presented on the scale 1 to 5		
Data needed	Observation data Survey questions concerning perception of the friendliness and opportunities for different activities	
References	S Shrestha, 2011. THE VITALITY OF PUBLIC SPACE: CONSIDERING 'DIVERSITY' (Master thesis): https://edepot.wur.nl/176717 Ouf, A. S. E. D., & El-Zafarany, N. A. (2018). DIVERSITY AND INCLUSION IN THE PUBLIC SPACE AS ASPECTS OF HAPPINESS AND WELLBEING. Journal of Urban Research, 28(1), 109-129.	

22	***Indicator name*** Walkability	***Tags*** Social
Definition Easiness of reaching the NBS place on foot, by bike or public transport (Lo 2009).		
Description & use People living in more ‘‘walkable’’ and ‘‘bikeable’’ neighborhoods with homes in proximity to non-residential destinations are less likely to be overweight or obese than people living in neighborhoods that require motorized transportation. Improving the built environment to make it easier for people to be physically active, in part through more active transportation, is an essential component of increasing physical activity.16–19		
Relation to PH & WB Direct – Main measure of Livability		
Scale	Demo site	Before and after the implementation of NBS.
Units	Qualitative measure on scale 1 to 5	
Method for assessment **On-site observations:** - the presence of walkers and bikers, styles of commuting **Spatial audit:** - evaluation of accessible entry points, public transport stops, functions encouraging walking and cycling - access for trolleys and wheelchair - the quality of walking paths and biking route		
How it is calculated Based on observation sheet and spatial audit results an average score will be calculated.		
Data needed	Observation data	
References	- Lo, R. H. (2009). Walkability: what is it?. Journal of Urbanism, 2(2), 145-166. - Frank, L. D., Sallis, J. F., Saelens, B. E., Leary, L., Cain, K., Conway, T. L., & Hess, P. M. (2009). The development of a walkability index: application to the Neighborhood Quality of Life Study. British Journal of Sports Medicine, 44(13), 924–933. doi:10.1136/bjsm.2009.058701	

23	***Indicator name*** Perceived quality of space and its maintenance	***Tags*** Social, Maintenance
Definition Self-reported perception of maintenance of the space.		
Description & use How would you rate the space on the following dimensions: Cleanness, where 1 -- usually very dirty and 5 -- Usually very clean Lightning, where 1 -- very poor lightning during the evenings and night and 5 -- very good lightning during the evenings and nights The usefulness of the urban furniture, i.e. benches, bike racks, where 1 -- very unuseful and 5 -- very useful		
Relation to PH & WB Expected positive indirect impact		
Scale	Demo site	Before and after NBS implementation
Units	5-points Liker scale	
Method for assessment Monitoring		
How it is calculated Sum of all answers		
Data needed	Survey data	
References	The City of Ellensburg (2015). Parks and Recreation Questionnaire Results Summary. https://www.ci.ellensburg.wa.us/DocumentCenter/View/4511/Online-Survey---Final-Summary?bidId=	

24	***Indicator name*** Place attachment	***Tags*** Social, Place Attachment
Definition The emotional, cognitive and behavioral bond that people develop with places. Intangible qualities of the place measured by intrinsic value, perceived essentialism and anti-essentialism are important predictors shaping the response to change (Roszczynska-Kurasińska et al. 2021). They capture the site's perceived historic value, inherent value (uniqueness and importance of the place) and (anti-)essentialist character of a place.		
Description & use Please rate on a scale from 1 to 5 whether you agree with the following statements, where 1 -- strongly disagree; 5 -- strongly agree. 1. I miss the space when I am not here. 2. I feel foreign here. (r) 3. I feel safe here. 4. I am proud of this place. 5. This place is part of me. 6. I would like to move out of this place. (r) 7. I want to be engaged in its affairs. 8. I am rooted here. 9. I would like my friends and family to live here in the future.		
Relation to PH & WB Expected positive direct impact		
Scale	Demo site	Before and after NBS implementation
Units	5-points Likert scale	
Method for assessment Monitoring		
How it is calculated Sum of all answers (statements with r should be recoded so 5 becomes 1 and 4 becomes 2 etc.)		
Data needed	Survey data	
References	- Lewicka, M. (2011). On the varieties of people's relationships with places: Hummon's typology revisited. Environment and Behavior, 43(5), 676-709. - Roszczyńska-Kurasińska, M., Domaradzka, A., Wnuk, A., & Oleksy, T. (2021). Intrinsic value and perceived essentialism of culture heritage sites as tools for planning interventions. Sustainability, 13(9), 5078.	

25	***Indicator name*** Perceived ownership of space and sense of belonging to the community	***Tags*** Social, Ownership

Definition
The extent to which the NBS project has contributed to increasing consciousness of citizenship. The consciousness of responsibility and ownership for the neighborhood, and a sense of belonging to the community (Pierce, Van Dyne and Cummings 1992).
Civic consciousness can be described as an individual's awareness of their community, civic rights and responsibilities and their relationship with the community (Ng 2015).

Description & use (taken from "Evaluating the impact of Nature-Based Solutions – Appendix of methods", 2021)

Consciousness of citizenship can be described as an individual's awareness of their community, civic rights and responsibilities and their relationship with the community, state or nation. An individual with consciousness of citizenship is aware of how the community functions and their respective role in the community. As such, consciousness of citizenship contributes to a sense of community. According to Ng (2015), civic consciousness includes the following elements:
• Personal identity and citizenship: characteristics such as personal awareness, pride, obedience to the law, and a sense of equality
• National identity: respect for national authorities, belief in the legitimacy of the current political system, sense of the nation as a cohesive whole
• Moral consciousness: upholding family and social normative values in public and in private, willingness to promote public welfare
• Ecological consciousness: awareness of the finite nature of natural resources, consideration of the environmental consequences of personal actions
• Global citizenship: actively concerned with others at home and abroad

Relation to PH & WB
Expected positive direct impact

Scale	Neighborhood scale	Before and after the implementation of NBSs
Units	5-point Likert scale	

Method for assessment
The extent to which an NBS project seeks to contribute to the local consciousness of citizenship can be qualitatively rated on a five-point Likert scale, from no effort to substantial effort.
1 -- None: The NBS project has made no effort to increase civic consciousness;
2 -- Little: The NBS project has developed some initiatives to increase civic consciousness;
3 -- Somewhat: The NBS project has developed some initiatives to increase civic consciousness;
4 -- Significant: The NBS project has executed several activities to increase civic consciousness
5 -- High: increasing civic consciousness was (one of) the main goals of the NBS project and substantial effort has been made to enhance civic consciousness In addition a single-question survey can be used to assess citizens' feeling of belonging. Please rate on scale Before the

COVID-19 crisis, how strongly do you feel you belong to your immediate neighborhood/local area. Please think of the areas within a few minutes' walking distance from your home.	
How it is calculated Average (probably renormalized) score obtained from the 5-point Likert scale	
Data needed	Observation and Survey data
References	- "Evaluating the impact of Nature-Based Solutions – Appendix of methods", 2021 - Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. (2017). CITYkeys indicators for smart city projects and smart cities. CITYkeys D1.4. Retrieved from http://nws.eurocities.eu/MediaShell/media/CITYkeysD14Indic atorsforsmartcityprojectsandsmartcities.pdf - Herranz-Pascual et al. (2020) CLEVER Social Survey Questionnaire (CLEVER-SSQn) In Zorita et al. D4.3 Monitoring strategy in the FR interventions. Deliverable 4.3, CLEVER Cities Project, 6th July 2020. - Ng, J.A.I. (2015). Scale on Civic Consciousness (SCC) for the National Service Training Program. International Journal of Humanities and Management Sciences, 3(3), 161-165.

26	***Indicator name*** Collective efficacy	***Tags*** Social
Definition Grounded in mutual trust, describes community's ability to create change and exercise informal social control (i.e., influence behavior through social norms) (Cohen, Inagami and Finch 2008). Collective efficacy is associated with better self-rated health, lower rates of neighborhood violence, and better access to health-enhancing resources.		
Description & use Collective efficacy, i.e., perception of mutual trust and willingness to help each other, is a measure of neighborhood social capital and has been associated with positive health outcomes including lower rates of assaults, homicide, premature mortality, and asthma. Collective efficacy (Sampson et al., 1997) is a standardized and well-tested aggregate measure of individual perceptions of "social cohesion among neighbors combined with the willingness to intervene on behalf of the common good".		
Relation to PH & WB Indirect - Additional measure of Social Sustainability		
Scale	Neighborhood scale	Before and after the intervention
Units	5-point Likert scale	
Method for assessment An informal social control in a neighborhood (three or five items) Neighbors can be counted on to intervene in various ways if (i) children were skipping school and hanging out on a street corner, (ii) children were spray-painting graffiti on a local building, (iii) children were showing disrespect to an adult, (iv) a fight broke out in front of their house, (v) the fire station closest to their home was threatened with budget cuts.		
How it is calculated Average score		
Data needed	Survey data	
References	- Zaccaro, S. J., Blair, V., Peterson, C., & Zazanis, M. (1995). Collective efficacy. In Self-efficacy, adaptation, and adjustment (pp. 305-328). Springer, Boston, MA. - R.J. Sampson, S.W. Raudenbush, F.	

	Earls. Neighborhoods and violent crime: a multilevel study of collective efficacy, Science, 277 (5328) (1997), pp. 918-924 - Cohen, D. A., Inagami, S., & Finch, B. (2008). The built environment and collective efficacy. Health & place, 14(2), 198-208.

<table>
<tr><td>27</td><td>Indicator name
Community Social Cohesion</td><td>Tags
Social, Social Cohesion</td></tr>
<tr><td colspan="3">Definition
Refers to the strength of relationships and the sense of solidarity among members of a community – the sense of collective commitment to carry ‘costs’ (financial, social, emotional, or otherwise) to assist others (Prainsack and Buyx 2012). Includes tolerance and respect - attitudes paramount to overcoming conflict.</td></tr>
<tr><td colspan="3">Description & use
Please rate on a scale from 1 to 5 whether you agree with the following statements, where 1 -- strongly disagree; 5 -- strongly agree

Factors related to individual perception of social cohesion (five items)

This is a close-knit neighborhood
People generally do not get along
People are willing to help neighbors
People do not share same values
People can be trusted</td></tr>
<tr><td colspan="3">Relation to PH & WB
Expected positive indirect impact</td></tr>
<tr><td>Scale</td><td>Demo site</td><td>Before and after NBS implementation</td></tr>
<tr><td>Units</td><td colspan="2">5-points Likert scale</td></tr>
<tr><td colspan="3">Method for assessment
Monitoring</td></tr>
<tr><td colspan="3">How it is calculated
Sum of all answers or average – to be analyzed together with collective efficacy</td></tr>
<tr><td>Data needed</td><td colspan="2">Survey data</td></tr>
<tr><td>References</td><td colspan="2">- Stafford, M., Bartley, M., Sacker, A., Marmot, M., Wilkinson, R., Boreham, R., & Thomas, R. (2003). Measuring the Social Environment: Social Cohesion and Material Deprivation in English and Scottish Neighborhoods. Environment and Planning A: Economy and Space, 35(8), 1459–1475. doi:10.1068/a35257
- Prainsack, B., & Buyx, A. (2012). Solidarity In Contemporary Bioethics - Towards A New Approach,</td></tr>
</table>

	Bioethics, 26(7), pp. 343-350, doi:10.1111/j.1467-8519.2012.01987.x

28	***Indicator name*** Involvement of citizens in participatory process	***Tags*** Social, participation
Definition The proportion of residents involved in the public participation processes in a given municipality per 100 000 residents per year.		
Description & use Number of people participating in each category of participation actions in the project: Information, Consultation, Collaboration, Co-decision, and Empowerment.		
Relation to PH & WB Supporting indicator		
Scale	Neighborhood level	Over the course of the project
Units	Number of people	
Method for assessment Monitoring		
How it is calculated Number of people		
Data needed (taken from "Evaluating the impact of Nature-Based Solutions – Appendix of methods", 2021)	Data are usually collected from the municipality participatory actions annually. Participatory actions with the scientific community per year (#/month, #/year, n º attendees). This includes scientists, university students and scholars. - Participatory actions with Other stakeholders (individuals and organized citizenship such as civic center's board and neighborhoods' associations, as well as Local entities) per year (#/month, #/year, n º attendees). - Participatory actions with economic agents per year. Economic agents involved such as technicians, specialists, consultants, enterprises, companies and others (#/month, #/year, nº attendees).	
References	References can be found in "Evaluating the impact of Nature-Based Solutions – Appendix of methods", 2021	

29	***Indicator name*** Diversity of stakeholders involved in the project	***Tags*** Social, Equality
Definition The indicator is defined in terms of the mix of stakeholders involved in a co-production process, based on the backgrounds and sectoral logics.		
Description & use At the beginning of the meetings organized during a coproduction/participatory process, stakeholders should be invited to sign a timesheet. The indicator will be equal to the whole number of stakeholders involved during these meetings. In a second step, the stakeholders are categorized based on the role/position they took in the process. There are two options to categories the diversity of stakeholders: Multi-Actor Perspective (MAP): - State: policymakers, politicians, bureaucrats - Community: residents, users - Market: firm, entrepreneurs - Third sector: activists, volunteer, researcher Quintuple Helix: - Education system: academia, higher education, schools, kindergartens - Economic system: industry, firms, services, banks, entrepreneurs - Political system: national/local governments, policymakers, law makers, politicians - Civil society and media: local communities, community groups, NGO's, mainstream and local media, environmental media - Natural environments of society: NBS experts form NGO's, policy makers, political bodies, experts and opinion leaders on NBS In a third step, the numbers per category are added up and the proportion of each groups is calculated. What is considered a good spread across the different groups often depends on the type of participations process.		
Relation to PH & WB Supporting indicator - related to the planning process. In general, we expect the number of Community members or Third sector involvement to increase.		
Scale	This should be calculated on the demo site level	Over the course of the whole project. During meetings organized by cities.
Units	% in categories	
Method for assessment Monitoring		
How it is calculated % of people in each category		
Data needed	Timesheet from the meetings.	

References	- Carayannis, E.G., Barth, T.D., Campbell, D.F.J. (2012) The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. Journal of Innovation and Entrepreneurship, 1:2. DOI: 10.1186/2192-5372-1-2 - Avelino, F. and Wittmayer, J.M. (2016). Shifting Power Relations in Sustainability Transitions: A Multi-actor Perspective. Journal of Environmental Policy & Planning, 18(5): 628-649. DOI: 10.1080/1523908X.2015.1112259.

30	***Indicator name*** Involvement of citizens from traditionally excluded groups	***Tags*** Social, Equality
Definition The extent to which the NBS project has led to increased participation by groups of people who are typically not well represented in society.		
Description & use Definitions of vulnerable and under-represented groups in society vary somewhat, but in general, the following groups can be considered vulnerable to discrimination and/or under-represented: Women and girls; Children; Refugees; Internally displaced persons; Stateless persons; National minorities; Indigenous peoples; Migrant workers; people with disabilities; Elderly persons; HIV positive persons and those suffering from AIDS; Roma/Gypsies/Sinti; Lesbian, gay, bisexual, transgender, queer, and differently gendered people (LGBTQ+)		
Relation to PH & WB Expected positive indirect impact		
Scale	District to metropolitan scale	Before and after
Units	The participation of vulnerable or traditionally under-represented groups in NBS projects or specific NBS project activities can be qualitatively assessed using a five-point Liker scale: 1 -- not at all: the project has not increased the participation of groups not well represented in the society. 2 -- poor: the project has somewhat increased the participation of groups not well represented in society. 3 -- fair: the project has somewhat increased the participation of groups not well represented in society. 4 -- good: the project has significantly increased the participation of groups not well represented in society. 5 -- excellent: participation of groups not well represented in the society has clearly been hugely improved due to the project.	
Method for assessment Information used to evaluate the performance of a particular NBS project with regard to the participation of vulnerable or traditionally under-represented groups can be obtained from project documentation and/or interviews with the project leaders and stakeholders (including representatives of the groups targeted).		
How it is calculated Average (probably renormalized) score obtained from the 5-point Likert scale		

Data needed	- Number of vulnerable or traditionally under-represented groups in NBS project or specific NBS project activities
References	Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.-M., Airaksinen, M., & Huovila, A. (2017). CITYkeys indicators for smart city projects and smart cities. CITYkeys D1.4. Retrieved from http://nws.eurocities.eu/MediaShell/media/CITYkeys D14Indicatorsforsmartcityprojectsandsmartcities.pdf

<table>
<tr><td>31</td><td>Indicator name
Trust in the decision-making procedures and decision-makers</td><td>Tags
Social, Trust</td></tr>
<tr><td colspan="3">Definition
The political trust comprises evaluations of the trustworthiness of governmental decision-making and decision-makers, based on three dimensions:
1) perceived competence: the extent to which a citizen perceives a government organization to be capable, effective, skillful, and professional;
2) perceived benevolences: the extent to which a citizen perceives a government organization to care about the welfare of the public and to be motivated to act in the public interest;
3) perceived integrity: the extent to which a citizen perceives a government organization to be sincere, to tell the truth, and to fulfill its promises.</td></tr>
<tr><td colspan="3">Description & use
Please rate on a scale from 1 to 5 whether you agree with the following statements, where 1 -- strongly disagree: 5 -- strongly agree.

Perceived competence:
1. The municipality of XX is capable.
2. The municipality of XX wastes a lot of public money (r)
3. Local politicians generally know what they are doing

Perceived benevolence:
4. Local politicians act in the interest of citizens.
5. The municipality of XX carries out its duty very well.
6. Local politicians keep their commitments.

Perceived integrity
7. In the main, local politicians tell the truth.
8. Governmental officials (e.g. civil servants) tell us a little about what get up to as they can.
9. When things go wrong, local politicians admit their mistakes.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Supporting indicator</td></tr>
<tr><td>Scale</td><td>Municipality level</td><td>Before and after NBS implementation</td></tr>
<tr><td>Units</td><td colspan="2">5-point Likert scale</td></tr>
<tr><td colspan="3">Method for assessment
Monitoring</td></tr>
<tr><td colspan="3">How it is calculated
Sum of all answers (statements with r should be recoded so 5 becomes 1 and 4 becomes 2 etc.)</td></tr>
</table>

Data needed	Survey data
References	- Seyd, B. (2016) How should we measure political trust? Paper for PSA annual conference, Brighton March 21-23, 2016. https://www.psa.ac.uk/sites/default/files/conference/papers/2016/P aper .v2.pdf - Grimmelkhuijsen, S., Knies, E. (2017) Validating a scale for citizen trust in government organizations. International Review of Administrative Sciences, 83(3): 583-601. DOI: 10.1177/0020852315585950

32	***Indicator name*** Sustainability consciousness	***Tags*** PH & WB, Environmental, Social
Definition Environmental awareness is commonly described as an awareness of environmental issues. In, detail, it is an experience and awareness of sustainable development. The construct as a whole consists of three dimensions: knowingness (information and knowledge), attitudes (personal attitudes), and behaviour (pro-environmental behaviour).		
Description & use This indicator is a measure of individuals' attitudes towards the environment, more specifically towards sustainable development. It tries to capture three components of attitudes: cognitive, affective, and behavioral. That is why we employ both questionnaire and observation methods to collect data.		
Relation to PH & WB Well-being		
Scale	site	Twice, once before the implementation of the Nature-Based Solutions and once after.
Units	Continuous variable	
Method for assessment Questionnaire. Data obtained using a validated scale named "Sustainability Consciousness Questionnaire". We are going to use a short version that includes 27 items. Moreover, we are going to also observe the behaviour in the demo locations to track signs of environmental consciousness.		
How it is calculated The average (probably normalized) score obtained from the 5-point Liker scale supported by the behaviours' observation at the demo location.		
Data needed	Survey data and observation data	
References	Gericke, N., Boeve-de Pauw, J., Berglund, T., & Olsson, D. (2019). The Sustainability Consciousness Questionnaire: The theoretical development and empirical validation of an evaluation instrument for stakeholders working with sustainable development. *Sustainable Development*, *27*(1), pp. 35-49.	

33	***Indicator name*** Number of new jobs	***Tags*** Social, Business
Definition The number of new jobs created at the demonstration site (e.g. in site maintenance, security, businesses operating at the demonstration site) after the NBS implementation		
Description & use This indicator will evaluate number of new jobs related to changed circumstances at the site, deriving from the individual small businesses and / or additional activities from the surrounding companied caused by improved site attractiveness and usability		
Relation to PH & WB NBSs could create new jobs at the demonstration site. This is for the benefit of the community and the potentially economically disadvantaged nearby region (e.g. by promoting local employment). Reducing the unemployment rate improves the WB of the citizens (via poverty reduction) but could also have a positive impact on their mental health (e.g., Wilson and Finch, 2021)		
Scale	Demonstration site	After NBS implementation
Units	Number of new jobs	
Method for assessment Questionaries results from city, NGOs and other local community organizations, before the NBS implementation and 6 to 12 months after NBS implementation		
How it is calculated Total number of new jobs created at the demonstration site (and potentially its near vicinity) due to implementation of NBSs.		
Data needed	Number of new jobs created at the demonstration site	
References	Wilson H, Finch D. Unemployment and mental health. The Health Foundation; 2021 (https://www.health.org.uk/publications/long-reads/unemployment-and-mental-health)	

34	***Indicator name*** Percentage of new jobs addressing unprivileged social groups	***Tags*** Social, Business
Definition Percentage of new jobs created at the demonstration site after the NBS implementation that address unprivileged social groups		
Description & use This indicator evaluates demo site contribution to the unprivileged communities that have regular, direct contact with the site, through its impact on their income, which converts into wellbeing of these groups.		
Relation to PH & WB NBS could create new jobs at the demonstration site for unprivileged social groups. Apart from the direct benefits stemming from the reduction of the unemployment rate, the creation of jobs for unprivileged groups could enhance their motivation and self-confidence and in general improve their mental health.		
Scale	Demonstration site	After NBS implementation
Units	% of new jobs, within unprivileged community, related from the demo site activities	
Method for assessment Questionaries results from city, NGOs and other local community organizations, before the NBS implementation and 6 to 12 months after NBS implementation		
How it is calculated 100*(No of new jobs addressing unprivileged social groups / No of new jobs)		
Data needed	Number of new jobs created at the demonstration site addressing unprivileged social groups, Number of new jobs created at the demonstration site	
References	N/A	

35	***Indicator name*** Change in the residential / business property sale prices in the proximity of the demonstration site	***Tags*** Business & Economy, Urban development
Definition The percentage change in the residential property sale prices in the proximity of the demonstration site. The percentage change in the business property sale prices in the proximity of the demonstration site		
Description & use This indicator will analyze medium term property prices in the vicinity of the demo site and make estimate of potential for the property prices increase due to the introduction of NBSs at the demo site. The probable, actual increases In property values will materialize years after project completion, but these estimates could be useful for the discovery of protentional gentrification risks, thus enabling authorities to address that issue timely.		
Relation to PH & WB NBS are often associated with increases in the nearby property prices (e.g. Luttic, 2000; Ichihara and Cohen, 2011) since they constitute a positive location factor (e.g. due to more recreation opportunities, appealing landscape, increased living standards). Nevertheless, if this increase is high (e.g. income increase not in pace with a short-term increase in the housing prices) it could have a negative impact on the lower socioeconomic groups living in the neighborhood [e.g. by preventing house tenure, that is also often linked to health issues (Ellaway et al, 2013) or by resulting in the displacement of poorer residents (Bockarjova et al, 2020)].		
Scale	Neighborhood around the demonstration site	Before and after NBS implementation
Units	% increase in property sales and renting costs	
Method for assessment Survey results from real estate agents before NBS implementation with their estimate of price increase within 2 to 5 years. The appropriate results will not be available during the euPOLIS project duration		
How it is calculated 100* (sale price after - sale price before) / (sale price before)		
Data needed	Property sale prices (residential and business in Euros/m^2) in proximity to the demonstration site	
References	- Luttik, J. The value of trees, water and open space as reflected by house prices in the Netherlands. Landscape and urban planning, 48(3): 161-167;2000. https://doi.org/10.1016/S0169-2046(00)00039-6 - Ichihara K, Cohen JP. New York City property values: what is the impact of green roofs on rental pricing?	

	Letters in Spatial and Resource Sciences, 4: 21–30; 2011. https://doi.org/10.1007/s12076-010-0046-4 - Ellaway A, Macdonald L, Kearns A. Are housing tenure and car access still associated with health? A repeat cross-sectional study of UK adults over a 13-year period, BMJ Open; 2016. http://dx.doi.org/10.1136/bmjopen-2016-012268 - Bockarjova M, Botzen WJW, van Schie MHm Koetse MJ. Property price effects of green interventions in cities: A meta-analysis and implications for gentrification. Environmental Science and Policy, 112: 293-304; 2020. https://doi.org/10.1016/j.envsci.2020.06.024

36	***Indicator name*** Number of new businesses established in proximity to the demonstration site	***Tags*** Business & Economy
Definition The impact assessment of the implementation of NBS in terms of new business creation and improvement on business rates.		
Description & use The number of new businesses created around the demonstration site as a result of recognition, by surrounding businesses, that the Improved number of visitors or enhanced environment could offer new business opportunities.		
Relation to PH & WB NBS could stimulate economic growth and consequently enhance citizens WB. The number of new businesses can be assessed only after euPOLIS interventions have been implemented and their effect established. That will be the base for: City to reconsider any limiting regulations and individuals to consider potential business activation.		
Scale	Neighborhood around the demonstration site	After NBS implementation
Units	Number of new businesses	
Method for assessment Available data, surveys results and city economy experts' elicitation		
How it is calculated Total number of new businesses established in the near vicinity of demo site because of the construction of NBSs.		
Data needed	City official data, city platforms, questionnaires, small-medium enterprise account (Related to de NBS investment zone).	
References	Evaluating the impact of Nature-Based Solutions − Appendix of methods, 2021	

<table>
<tr><td>37</td><td>Indicator name
Change in the number of visitors at the demonstration site</td><td>Tags
Business & Economy</td></tr>
<tr><td colspan="3">Definition
The percentage change in the number of visitors at the demonstration site</td></tr>
<tr><td colspan="3">Description & use
This indicator will evaluate the additional number and gender groups typology of demo site visitors expected there as a result of new site attractiveness, socializing opportunities and chance for longer exposure to the nature. The results will be used as a very important component of euPOLIS project, as a proof of NBSs impact on society.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Positive impacts on WB due to the increased consumer spending in the demonstration site and the neighborhood area. Positive impacts on PH (e.g. Kabisch et al, 2017) due to the increased number of people becoming more physically and socially active and being exposed to an aesthetically superior landscape as well as to reduced air pollution, noise and heat.</td></tr>
<tr><td>Scale</td><td>Demonstration site</td><td>No if the data are obtained via estimations / Yes if the data are obtained via monitoring, before and after NBS implementation</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
Monitoring data (if any) and informed estimates from municipality experts, from city management, NGOs and other local community organizations, before the NBS implementation and 6 to 12 months after NBS implementation</td></tr>
<tr><td colspan="3">How it is calculated
100* (annual number of visitors after -annual number of visitors before) / (annual number of visitors before)</td></tr>
<tr><td>Data needed</td><td colspan="2">The annual number of visitors at the demonstration site</td></tr>
<tr><td>References</td><td colspan="2">Kabisch N, van den Bosch M, Lafortezza R. The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review. Environmental Research, 159: 362-373; 2017. https://doi.org/10.1016/j.envres.2017.08.004</td></tr>
</table>

38	***Indicator name*** Value of food / plants produced at the demonstration site	***Tags*** Business & Economy
Definition This will be the indicator of demo site urban agriculture potential impact on local economy		
Description & use This will be the evaluation of demo site urban agriculture potential impact on local economy and will be used to demonstrate potential for the extrapolation of these / similar activities throughout the city. Therefore, this indicator will evaluate the benefit obtained from the production of food in some of the NBS. The food produced in some cases may be sold but other methods of distribution may also be possible (self-consumption, donation, etc.).		
Relation to PH & WB Food and plant production at the demonstration site could impact economic growth and social interaction and hence improve PH&WB.		
Scale	Demonstration site	After NBS implementation
Units	Euros / year	
Method for assessment Survey of food and / or other plants production operation to establish the amount of money produced at the site. Monitoring the number of socializing events before and after NBS implementation		
How it is calculated Regular monthly surveys of products monetary conversion		
Data needed	The annual value of foods / plants produced at the demonstration site	
References	N/A	

39	***Indicator name*** Private financing attracted to the demonstration site	***Tags*** Economy & Business
Definition Private financing available either on demo site or on any other city site		
Description & use Private financers realizing advantages for their business if they either finance into additional NBSs at demo site or, with information from euPOLIS demo site, finance NBSs at any other city available site and with that promote their commitment to achievements demonstrated by euPOLIS project.		
Relation to PH & WB NBS could stimulate economic growth (as positive impacts of euPOLIS interventions might trigger activation of business drivers) and consequently enhance citizens WB.		
Scale	Demonstration site	After NBS implementation
Units	Euros / year + number of companies	
Method for assessment Collecting city data on the amount of money from the businesses financing additional NBSs at the demo site and other sites in the city		
How it is calculated Collecting of projects financing data from city public sources		
Data needed	The amount invested into NBSs at the demo site and elsewhere	
References	N/A	

40	***Indicator name*** Annual maintenance savings from biomass reusage	***Tags*** Business & Economy, Environmental, Sustainability
Definition Evaluation on city savings from biomass recycling		
Description & use Biomass can be considered as a waste generated by green areas, which can be used as an alternative source of energy and/or fertilizer, and hence for covering (at least partially) maintenance costs of NBSs.		
Relation to PH & WB Reducing waste and using sustainable fertilizers produced from biomass waste has a positive impact on PH.		
Scale	Demonstration site	No, after NBS implementation
Units	Euros / year	
Method for assessment Monitoring of data, with relevant organizations, on biomass usage, expressed in value terms		
How it is calculated In actual city maintenance costs against relevant Income from biomass recycling		
Data needed	Annual amount of biomass produced; annual amount of biomass reused; annual costs of maintenance	
References	N/A	

41	***Indicator name*** Annual maintenance savings from rainwater harvesting and / or grey water treatment and re-usage	***Tags*** Economy & Business, Sustainability, Environmental

Definition
Evaluation of capital and running costs savings produced by rainwater harvesting and grey water recycling.

Description & use
Sustaining greenery as well as applied NBS requires water. Conventionally city nature was either left unmaintained or was watered with tap water, what involved costs of water supply. Circular economy and water shortages in many places reinforce solutions with low water footprint. The method is to collect rainwater in-site (in/by NBS) and use when needed, in broader sense rainwater and grey water can be treated by different kinds of NBSs (biofilters, green walls, etc.), then collected and used for irrigation purposes. In this case NBS perform additional role of reducing the health risk.

Relation to PH & WB
Direct to WB as it economizes solutions and makes them affordable. The improvement of life quality happens without running extra maintenance costs. To PH directly through reduction of health hazards or indirectly through reduction of flood risk when water surplus is efficiently stored by NBS.

Scale	Demonstration site	After NBS implementation
Units	Euros / year	

Method for assessment
Monitoring of data, with relevant organizations, on recycled water benefits, expressed in value terms

How it is calculated
(Annual amount, in m3, of reused wastewater) x (cost of water per m3 - cost of water treatment / harvesting per m3)

Data needed	Annual amount (in m3) of reused wastewater, cost of water per m3, any costs per m3 related to the water treatment / harvesting
References	Wagner, I., Krauze, K., Zalewski, M., 2014. Blue aspects of green infrastructure. W: Bergier, T., Kronenberg, J., Lisicki, P. (eds.): Sustainable Development Applications Journal 4/2013 (Nature in the city - solutions)

42	***Indicator name*** Air Temperature Reduction / Air Cooling	***Tags*** Environmental, PH&WB, Digital
Definition The cooling effect/air temperature reduction caused by an NBS due to an increase in evapotranspiration and/or shading.		
Description & use This indicator measures the difference in air temperature caused by the implementation of NBS through evapotranspiration and/or shading. This indicator is important in terms of mitigating UHI effects, as well as climate change impacts and weather extremes, especially in hot climates.		
Relation to PH & WB Strongly related as a reduction in air temperature could protect from temperature extremes and heat stress. It is particularly important in hot climates and areas with high heat risk (Contextual Indicator).		
Scale	Site Level	Hourly or less to get adequate temperature variations and peaks (to be specified further). Additionally, before and after the NBS implementation.
Units	°C	
Method for assessment The indicator can be estimated in different ways, through **on-site monitoring**, **remote sensing**, or **modelling**. However, the most appropriate method depends on characteristics of the applications (e.g., scale), as well as the objectives of the analysis. **Direct measurements** provide generally higher accuracy/confidence, especially for small-scale applications, therefore local monitoring would be more appropriate in this case. **EO/RS methods** are mostly used for larger areas and meso-scales and would probably not be appropriate for small-scale applications. **Modelling tools** for micro-climatic analysis are mostly suited for planning purposes (planning stage) for the comparison of different scenarios. It is suggested however, that the reliability of simulation results decreases with the scale of the NBS intervention. (Information from Connecting Nature project) The distance from the NBS within which there is a cooling effect, differs with the various NBS types. Literature gives different ranges, these are also listed by Naturvation project, which also assigns a custom scoring system through normalization (could also be used for euPolis). An appropriate **monitoring scheme** needs to be designed/set-up according to available information/literature, preferably with sensors at increasing distances from the NBS to capture and quantify the distance effect (temperature cooling distance). A **monitoring scheme** needs to be designed/set up according to available information/literature. If feasible, sensors should be installed at increasing distance from the NBS to capture and quantify the distance effect.		

How it is calculated Air Temperature (Ta)	
Data needed	Air Temperature (Ta) (Most probable, but other approaches for measuring the cooling effect of NBS via additional data/measurements besides Ta could be considered, such as apparent temperature based on additional measurements of relative humidity and wind speed, land surface temperature (LST), mean radiant temperature (Tmrt), (Physiological Equivalent Temperature (PET).)
References	- Cheng, C. Y., Cheung, K. K. S., & Chu, L. M. (2010). Thermal performance of a vegetated cladding system on facade walls. Building and Environment, 45(8), pp. 1779-1787. - Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management, 146, pp. 107-115.

43	***Indicator name*** Universal Thermal Climate Index (UTCI)	***Tags*** Environmental, PH &WB
Definition UTCI provides a human-based representation of the environment temperature. In other words, it is an estimate of the apparent temperature that our body feels under certain environmental conditions (as specified by air temperature T_a, wind speed, humidity and radiation). UTCI is based on the UTCI-Fiala model (Fiala et al., 2012), which combines a dynamic thermoregulation model of the human body together with a temperature-varying clothing insulation model, both describing distinct states depending on different ambient factors (https://utci.lobelia.earth/what-is-utci).		
Description & use A good example describing the importance of UTCI can be found at https://utci.lobelia.earth/what-is-utci where graphics show how UTCI values vary in different climatic zones. For example, in Barcelona UTCI values during summer are significantly higher than the actual temperatures (it feels warmer than it is) due to high humidity which is a consequence of the vicinity of the Mediterranean Sea. On the contrary, in London UTCI values during winter are significantly lower than the actual temperatures (it feels colder than it is) because of the wind, and cloudy weather.		
Relation to PH & WB Directly related. UTCI is more important for PH & WB than the actual air temperature, and the main goal of NBS is to secure more pleasant environmental conditions in its near vicinity, meaning UTCI < Ta during summer, and potentially UTCI > Ta during winter.		
Scale	Site scale	Depends on the frequency of measured meteorological data
Units	$^{\circ}$ C	
Method for assessment UTCI is determined based on the previously mentioned meteorological data that are measured in the near vicinity of the NBS or the demo site.		
How it is calculated $UTCI(T_a, T_{mrt}, v_a, p_a) = T_a + Offset(T_a, T_{mrt}, v_a, p_a)$ where Ta is measured air temperature, Tmrt is mean radiant temperature, pa is water vapour pressure that can be substituted with relative humidity rH (%), and va is wind speed at 10 m height. An online UTCI calculator is available at http://utci.org. After calculating the UTCI value, its relationship with physiological stress can be estimated according to the table proposed by Błażejczyk et al. (2010).		
Data needed	Air temperature, Ta ($^{\circ}$ C) Mean radiant temperature, Tmrt (degrees Kelvin) Water vapour pressure (hPa) / Relative humidity (%)	

	Wind speed at a height of 10 m (m/s)
References	- Fiala D, Havenith G, Bröde P, Kampmann B, Jendritzky G. UTCI-Fiala multi-node model of human heat transfer and temperature regulation. Int J Biometeorol. 2012 May;56(3):429-41. doi: 10.1007/s00484-011-0424-7. - Błażejczyk, K., Broede, P., Fiala, D., Havenith, G., Holmér, I., Jendritzky, G., Kampmann, B. & Kunert, A. (2010). Principles of the new Universal Thermal Climate Index (UTCI) and its application to bioclimatic research in European scale. Miscellanea Geographica, 14, 91-102 - Evaluating the impact of Nature-Based Solutions – Appendix of methods, 2021 - https://utci.lobelia.earth/what-is-utci

<table>
<tr><td>44</td><td>Indicator name
Avoided or additional net energy consumption (or GHG emissions)</td><td>Tags
Environmental, Sustainability</td></tr>
<tr><td colspan="3">Definition
The avoided or additional net energy consumption (or associated GHG emissions) due to NBS implementation</td></tr>
<tr><td colspan="3">Description & use
The implementation of NBS could result to energy savings (e.g. heating and cooling, energy for the UWC - upstream or downstream, etc.) or additional energy consumption (e.g., on-site water purification, water supply, illumination, etc.). These elements need to be taken into account to estimate the net energy spending or savings (or associated GHG emissions based on the corresponding emission factors) resulting from NBS implementation to assess the environmental sustainability of the intervention.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Very weak connection (through Climate Resilience), but important for the environmental sustainability of the proposed/implemented NBS Intervention and creating standards for blue-green investments</td></tr>
<tr><td>Scale</td><td>Site Level</td><td>Data modelled/estimated for at least 1 year. (If some elements are modelled, a daily time-step or bigger would be sufficient.)</td></tr>
<tr><td>Units</td><td colspan="2">kWh/y (or kg CO2/y)</td></tr>
<tr><td colspan="3">Method for assessment
Estimation, monitoring, modelling
The water-related energy can be estimated through simulations of the Urban Water Optioneering Tool (UWOT) (Rozos and Makropoulos, 2013; Baki and Makropoulos, 2014)</td></tr>
<tr><td colspan="3">How it is calculated
Σ ESi - Σ ECi

ESi: Energy Saving due to NBS
ECi: Additional energy consumption due to NBS</td></tr>
<tr><td>Data needed</td><td colspan="2">Relevant energy consumption components for the site (water/wastewater, heating/cooling, illumination, etc., where relevant), emission factors of electrical grid</td></tr>
<tr><td>References</td><td colspan="2">- McPherson, E.G., Nowak, D., Heisler, G., Grimmond S., Souch C., Rowntree R., 1997. Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. Urban Ecosystems 1: 49–61;
- ESMAP. 2020. Primer for Cool Cities: Reducing Excessive Urban Heat. Energy Sector Management</td></tr>
</table>

	Assistance Program (ESMAP) Knowledge Series 031/20. Washington, DC: World Bank. - Rozos, E., Makropoulos, C., 2013. Source to tap urban water cycle modelling. Environ. Model. Softw. 41, 139−150. https://doi.org/10.1016/j.envsoft.2012.11.015 - Baki, S., Makropoulos, C., 2014. Tools for Energy Footprint Assessment in Urban Water Systems. Procedia Engineering, 16th Water Distribution System Analysis Conference, WDSA2014: Urban Water Hydroinformatics and Strategic Planning 89, 548−556. https://doi.org/10.1016/j.proeng.2014.11.477

<table>
<tr><td>45</td><td>Indicator name
Site Water Autonomy for NBS</td><td>Tags
Environmental, Sustainability, (Digital)</td></tr>
<tr><td colspan="3">Definition
Percentage of locally sourced water (rainwater, recycled water, etc.) to cover the irrigation needs of the NBS</td></tr>
<tr><td colspan="3">Description & use
A measure of how autonomous / self-sustained an NBS is in terms of covering its water needs. The aim is minimizing the need for potable water that creates an environmental pressure on water resources and hence providing environmentally sustainable solutions. This especially important for water scarce areas.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Very weak connection (through Water Availability), but important for the environmental sustainability of the proposed/implemented NBS / Intervention</td></tr>
<tr><td>Scale</td><td>Site Level</td><td>Data estimated or modelled for at least 1 year. If the Urban Water Cycle (UWC) is modelled a daily time-step would be sufficient.</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
Estimation, monitoring, modelling
The urban water cycle within the site and the use of alternative water sources can be simulated through the Urban Water Optioneering Tool (UWOT) (Rozos and Makropoulos, 2013; Bouziotas et al., 2019).</td></tr>
<tr><td colspan="3">How it is calculated
Locally sourced water (alternative sources of water) / Total water required for NBS x 100</td></tr>
<tr><td>Data needed</td><td colspan="2">Water requirements for NBS, Locally sourced water supplied, Potable water supplied</td></tr>
<tr><td>References</td><td colspan="2">- Wagner, I., Krauze, K., Zalewski, M., 2014. Blue aspects of green infrastructure. W: Bergier, T., Kronenberg, J., Lisicki, P. (eds.): Sustainable Development Applications Journal 4/2013 (Nature in the city - solutions)
- Rozos, E., Makropoulos, C., 2013. Source to tap urban water cycle modelling. Environ. Model. Softw. 41, 139–150. https://doi.org/10.1016/j.envsoft.2012.11.015
- Bouziotas, D., van Duuren, D., van Alphen, H.-J., Frijns, J., Nikolopoulos, D., Makropoulos, C., 2019. Towards</td></tr>
</table>

	Circular Water Neighborhoods: Simulation-Based Decision Support for Integrated Decentralized Urban Water Systems. Water 11, 1227. https://doi.org/10.3390/w11061227

<table>
<tr><td>46</td><td>Indicator name
Potable water savings / Water reuse</td><td>Tags
Environmental, Sustainability</td></tr>
<tr><td colspan="3">Definition
(Potable) water savings due to NBS implementation</td></tr>
<tr><td colspan="3">Description & use
Besides the water autonomy of the NBS, implemented water reuse interventions and NBSs could result in additional (potable) water savings, decreasing the pre-existing water demand of the site (irrigation, domestic/commercial water demand).</td></tr>
<tr><td colspan="3">Relation to PH & WB
Very weak connection (through Water Availability), but important for the environmental sustainability of the proposed/implemented NBS / Intervention</td></tr>
<tr><td>Scale</td><td>Site Level</td><td>Data modelled/estimated. If the UWC is modelled a daily time-step would be sufficient. Should be calculated/estimated for at least 1 year</td></tr>
<tr><td>Units</td><td colspan="2">m3/year</td></tr>
<tr><td colspan="3">Method for assessment
Estimation, monitoring, modelling
The urban water cycle within the site and the use of alternative water sources can be simulated through the Urban Water Optioneering Tool (UWOT) (Rozos and Makropoulos, 2013; Bouziotas et al., 2019).</td></tr>
<tr><td colspan="3">How it is calculated
Annual potable water savings</td></tr>
<tr><td>Data needed</td><td colspan="2">Baseline water consumption of the site (irrigation, domestic/commercial, other), potable water savings</td></tr>
<tr><td>References</td><td colspan="2">- Rozos, E., Makropoulos, C., 2013. Source to tap urban water cycle modelling. Environ. Model. Softw. 41, 139−150. https://doi.org/10.1016/j.envsoft.2012.11.015
- Bouziotas, D., van Duuren, D., van Alphen, H.-J., Frijns, J., Nikolopoulos, D., Makropoulos, C., 2019. Towards Circular Water Neighborhoods: Simulation-Based Decision Support for Integrated Decentralized Urban Water Systems. Water 11, 1227. https://doi.org/10.3390/w11061227</td></tr>
</table>

<table>
<tr><td>47</td><td>Indicator name
(Additional) Wastewater Treatment Coverage</td><td>Tags
Environmental, PH&WB, Sustainability</td></tr>
<tr><td colspan="3">Definition
Volume of wastewater treatment accomplished by NBS.</td></tr>
<tr><td colspan="3">Description & use
This indicator measures the additional wastewater treatment accomplished through the implementation of a relevant NBS. Particularly important in areas with low wastewater treatment coverage and/or degraded environmental status.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Strong connection to Risks for Communicable Diseases/Sanitation & urban drainage as well as risk related to chemical pollution</td></tr>
<tr><td>Scale</td><td>Site Level / Urban Water Zone</td><td>Data modelled or measured. Should be calculated/estimated for at least 1 year</td></tr>
<tr><td>Units</td><td colspan="2">Volume of treated wastewater [m^3].</td></tr>
<tr><td colspan="3">Method for assessment
Estimation, monitoring, modelling</td></tr>
<tr><td colspan="3">How it is calculated
Wastewater treated / Total wastewater x 100</td></tr>
<tr><td>Data needed</td><td colspan="2">Wastewater volume treated by NBS</td></tr>
<tr><td>References</td><td colspan="2">N/A</td></tr>
</table>

48	***Indicator name*** Wastewater (and stormwater) managed on site	***Tags*** Environmental, Sustainability, (Digital)
Definition Percentage of wastewater (and stormwater) managed locally instead of centrally		
Description & use This indicator measures the amount of wastewater and stormwater managed on site (e.g. for irrigation) instead of entering the main wastewater / stormwater treatment		
Relation to PH & WB No connection, but important for the **Circularity / Environmental Sustainability** of the solution		
Scale	Site Level	Should be calculated/estimated for at least 1 year
Units	%	
Method for assessment Estimation, modelling The urban water cycle within the site with all the different flows (potable, greywater stormwater, wastewater) can be simulated through the Urban Water Optioneering Tool (UWOT) (Rozos and Makropoulos, 2013; Bouziotas et al., 2019)		
How it is calculated Wastewater & Stormwater used on site / Total wastewater & Stormwater generated x 100		
Data needed	Wastewater (and stormwater) managed on site	
References	- Rozos, E., Makropoulos, C., 2013. Source to tap urban water cycle modelling. Environ. Model. Softw. 41, 139−150. https://doi.org/10.1016/j.envsoft.2012.11.015 - Bouziotas, D., van Duuren, D., van Alphen, H.-J., Frijns, J., Nikolopoulos, D., Makropoulos, C., 2019. Towards Circular Water Neighborhoods: Simulation-Based Decision Support for Integrated Decentralized Urban Water Systems. Water 11, 1227. https://doi.org/10.3390/w11061227	

<table>
<tr><td>49</td><td>Indicator name
Flood risk factor (FRF)</td><td>Tags
Environmental, urban development, PH&WB</td></tr>
<tr><td colspan="3">Definition
Decrease of probability and severity of flooding caused by implementation of NBS</td></tr>
<tr><td colspan="3">Description & use
Flood Factor is determined by the likelihood of flooding and the potential depth of that flood. Flood factor is used to calculate the risk to properties related with flooding. Thus, it is a core variable for many insurance companies, and sometimes can be retrieved from statistical data. NBS interfere between the runoff area and runoff recipient, reducing the flood risk through capturing part of the water. FRF is critical for more complex systems involving e.g. urban drainage.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Direct through creating hazards to health (pollution, habitats for diseases) indirect through deterioration of living conditions (damage of infrastructure, moisture - microbial development)</td></tr>
<tr><td>Scale</td><td>site level, neighborhood, city, catchment</td><td>NA - models are run based on long-term data and remained valid until the context changes</td></tr>
<tr><td>Units</td><td colspan="2">%, probability, frequency, m3</td></tr>
<tr><td colspan="3">Method for assessment
modelling</td></tr>
<tr><td colspan="3">How it is calculated
Flood frequency analysis is a technique used by hydrologists to predict flow values corresponding to specific return periods or probabilities. In case of fluvial flooding, it is calculated based on the flood frequency curve. Using annual peak flow data that is available for a number of years, flood frequency analysis is used to calculate statistical information such as mean, standard deviation and skewness which is further used to create frequency distribution graphs. The best frequency distribution is chosen from the existing statistical distributions i.e., Gumbel, Normal, Log-normal, etc. After choosing the probability distribution that best fits the annual maxima data, flood frequency curves are plotted. The return period is calculated as the likelihood of any event in one year. The flood frequency curve is used to relate flood discharge values to return periods to provide an estimate of the intensity of a flood event.
For pluvial flooding a return period of the rainfall is taken and the comparisons between rainfall and rainfall response are considered. The recorded intense rainfall data are statistically analyzed with either of two statistical approaches: the series of annual maximum values for various durations from 5 min to 24 h or the values above a given threshold. Results are presented using intensity-duration-frequency curves for given area. The assessment involves modelling that links maximum flood depth and rainfall intensity in given location.</td></tr>
<tr><td>Data needed</td><td colspan="2">Fluvial flooding: historical peak discharge dataset
Pluvial flooding: historical rainfall dataset, threshold value</td></tr>
</table>

	defined as the exceedance of a given runoff flow to the drainage system, duration values, terrain model;
References	• https://assets.firststreet.org/uploads/2020/06/FSF_Flood_Model_Technical_Documentation.pdf • Mailhot, A., & Duchesne, S. (2010). Design Criteria of Urban Drainage Infrastructures under Climate Change. Journal of Water Resources Planning and Management, 136(2), 201–208. • Tuyls, D. M., Thorndahl, S., & Rasmussen, M. R. (2018). Return period assessment of urban pluvial floods through modelling of rainfall–flood response. Journal of Hydroinformatics, 20(4), 829–845.

50	***Indicator name*** Runoff coefficient	***Tags*** Environmental, Digital, Sustainability, Resilience
Definition Ratio between the water volume drained from the NBS and the volume of precipitation		
Description & use This indicator takes values between zero and 1, and it describes the water retention capacity of the NBS (the higher the value the lower the retention capacity is, and vice versa)		
Relation to PH & WB Indirect relation – Decrease in runoff coefficient values means more water is stored in NBSs and less water enters the sewer system. Hence, the occurrence of urban flooding caused by overloading of sewer system decreases. This reduces the chances for collapse of the traffic system in urban areas due to excess water on the streets (relation to wellbeing), but also reduces the chances for spreading communicable diseases (relation to public health) due to wastewater that can be found on streets during flooding (in case of combined sewer systems).		
Scale	Demo site level and the NBS level	Continuously during at least one year
Units	Unitless, or in percentages	
Method for assessment This indicator can be determined based on both monitoring and modelling data. From monitoring data, the runoff coefficient can be determined based on the monitored precipitation data, measured discharge drained from NBSs, and known area covered by NBSs. From modelling data, the runoff coefficient is estimated by using the monitored precipitation data that serve as an input for rainfall-runoff model which calculates drained discharge. Note that for continuous simulations it is necessary to account for evapotranspiration process as well. There are different complexity levels of rainfall-runoff models, where physically based ones are more accurate, but also more time consuming and require more input parameters (numerical models that solve Richards equation), while simpler models are more efficient but provide less reliable results (SCS-CN method, Green-Ampt, Linear and Non-linear reservoir, etc.).		
How it is calculated RC = Vd/Vp, where Vd is the water volume drained from NBSs [L3] during a defined time interval, while Vp is the volume of precipitation for the same period [L3].		
Data needed	Data needed for calculation are time series of rainfall intensity and evapotranspiration rate (or meteorological data necessary for its estimation), as well as computed / monitored time series of discharge drained from the relevant NBSs.	
References	- Versini P.-A., Stanić, F., Gires, A., Scherzer, D., Tchiguirinskaia, I., 2020. Measurements of the water balance components of a large green roof in the	

	greater Paris area, Earth Syst. Sci. Data, 12, 1–11. https://doi.org/10.5194/essd-12-1-2020 - Evaluating the impact of Nature-Based Solutions – Appendix of methods, 2021 - https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/513.pdf (accessed 8.02.22)

<table>
<tr><td>51</td><td>Indicator name
Mitigation of the urban runoff peak</td><td>Tags
Environmental, Digital, Sustainability, Resilience</td></tr>
<tr><td colspan="3">Definition
Relative difference between the inflow peak (rainfall intensity peak multiplied by NBS area) and drained discharge peak.</td></tr>
<tr><td colspan="3">Description & use
NBSs serve as a buffer that forces rainwater to infiltrate through the porous media, mitigating that way the runoff peak and preventing it from coinciding with outflows from impervious areas that can lead to overload of sewer system. This indicator describes how much the NBS affects the reduction of the runoff peak by forcing water to infiltrate through the porous medium.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Indirect relation – as in the case of Runoff Coefficient.</td></tr>
<tr><td>Scale</td><td>It can be applied both on the site level and the NBS level</td><td>Continuously during at least one year</td></tr>
<tr><td>Units</td><td colspan="2">In percentages (or unitless) or in absolute values [L^3/T]</td></tr>
<tr><td colspan="3">Method for assessment
As in case of Runoff Coefficient, this indicator can be determined based on both monitoring and modelling data.</td></tr>
<tr><td colspan="3">How it is calculated
MRP = (max(Qp)-max(Qd))/max(Qp), where Qp is the precipitation rate multiplied by NBS area [L3/T], while Qd is the discharge drained from the same NBS [L3/T].</td></tr>
<tr><td>Data needed</td><td colspan="2">Same as for the Runoff coefficient</td></tr>
<tr><td>References</td><td colspan="2">- Asleson, B.C., Nestingen, R.S., Gulliver, J.S., Hozalski, R.M., Nieber, J.L., 2009. Performance Assessment of Rain Gardens. JAWRA Journal of the American Water Resources Association, 45, 1019–1031.
- De-Ville, S., Menon, M., Stovin, V., 2018. Temporal variations in the potential hydrological performance of extensive green roof systems. Journal of Hydrology, 558, 564-578.
- Versini P.-A., Stanić, F., Gires, A., Scherzer, D., Tchiguirinskaia, I., 2020. Measurements of the water balance components of a large green roof in the greater Paris area, Earth Syst. Sci. Data, 12, 1–11. https://doi.org/10.5194/essd-12-1-2020
- Evaluating the impact of Nature-Based Solutions − Appendix of methods, 2021</td></tr>
</table>

52	***Indicator name*** Delay of the urban runoff peak	***Tags*** Environmental, Digital, Sustainability, Resilience
Definition Relative difference between the time when the inflow peak occurs and the time when discharge peak occurs		
Description & use This indicator describes how much the NBS postpones the occurrence of the runoff peak by forcing water to infiltrate through the porous medium.		
Relation to PH & WB Indirect relation – as in the case of Runoff Coefficient.		
Scale	It can be applied both on the site level and the NBS level	Continuously during at least one year
Units	In percentages (or unitless) or in absolute values [T]	
Method for assessment As in the case of Runoff Coefficient, this indicator can be determined based on both monitoring and modelling data.		
How it is calculated DRP = (td,max - tp,max)/tp,max, where td,max is the time when the drained discharge peak occurs [T], while tp,max is the time when the precipitation rate peak occurs [T].		
Data needed	Same as for the Runoff coefficient	
References	- Asleson, B.C., Nestingen, R.S., Gulliver, J.S., Hozalski, R.M., Nieber, J.L., 2009. Performance Assessment of Rain Gardens. JAWRA Journal of the American Water Resources Association, 45, 1019–1031. - De-Ville, S., Menon, M., Stovin, V., 2018. Temporal variations in the potential hydrological performance of extensive green roof systems. Journal of Hydrology, 558, 564-578. - Versini P.-A., Stanić, F., Gires, A., Scherzer, D., Tchiguirinskaia, I., 2020. Measurements of the water balance components of a large green roof in the greater Paris area, Earth Syst. Sci. Data, 12, 1–11. https://doi.org/10.5194/essd-12-1-2020 - Evaluating the impact of Nature-Based Solutions − Appendix of methods, 2021	

53	***Indicator name*** Water quality - general	***Tags*** Environmental, PH&WB
Definition WQI of freshwater streams, or compound index for stormwater. Must be decided on-site, depends on the actual needs and NBS/intervention. Includes: TSS, N, P, TOC, COD, BOD, heavy metals, DO, pH, EC, temperature, turbidity		
Description & use Water quality depends on its chemical status, biochemical parameters and pathogen content. NBS are proved to contribute to removal up to 90% of P and N compounds, reduce heavy metal content through processes generally called phytoremediation, and reduce pathogen content, e.g. E. coli up to 70%.		
Relation to PH & WB Unless NBS is used for recreational purposes, for drinking, and/or irrigation - this is a supporting indicator (technical). Otherwise, it has a direct relation to health - related to communicable and non-communicable diseases.		
Scale	Site, water body, NBS	Regularly at least monthly and after rainfall / flooding events, for at least one year
Units	Various (mg/L, %, pH, mS, degree C)	
Method for assessment Depending on the parameter either In-situ with mobile devices or fixed loggers e.g. DO, COD, pH, temp. or with laboratory methods, e.g. heavy metals, COD, BOD.		
How it is calculated Direct measurements either with devices or with laboratory analyses.		
Data needed	Water samples	
References	N/A	

<table>
<tr><td>54</td><td>Indicator name
Exposure to noise pollution</td><td>Tags
Environmental, PH&WB, Digital</td></tr>
<tr><td colspan="3">Definition
Exposure to noise pollution is the proportion (%) of population exposed to noise levels (L_{DEN}) above 55 dB, before and after NBS implementation.
L_{DEN} is a combination of equivalent sound pressure levels A - pondered on 3 periods of the 24h day (day, evening, night).</td></tr>
<tr><td colspan="3">Description & use
This indicator shows the effect of NBS on noise pollution.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Noise pollution is recognized as a stressor to the autonomic nervous system and the endocrine system (Geravandi et al., 2015), leading to worsening of sleep quality, nervousness, and mental health, but also immune system problems (Zhang et al., 2021), cardiovascular diseases, increased hypertension, heart rate and possibility of cardiac arrest or stroke (Davies and Kamp, 2012). Densely populated urban areas are notorious for elevated noise levels, due to intensive anthropogenic noise-inducing activities (most importantly transport), but also due to the abundance of surface materials that cannot damp and absorb some of the sound waves (manmade materials and plain surfaces). NBS may absorb some of the noise.</td></tr>
<tr><td>Scale</td><td>Site</td><td>Data modelled or measured. Should be calculated/ estimated for at least 1 year</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
Noise levels can be measured or modelled, both of which are A-weighted long-term averages: day – 6-18h, evening (penalty 5dB) 18-22h, night (penalty 10dB) 22-6h.</td></tr>
<tr><td colspan="3">How it is calculated
$$L_{DEN} = 10log_{10}\frac{1}{24}\left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening}+5}{10}} + 8 \cdot 10^{\frac{L_{night+10}}{10}}\right)$$
Where L_{day}, $L_{evening}$ and L_{night} are A-pondered long term measured averages of day, evening, and night noise levels (see above for definition).
L_{DEN} can be simulated e.g. open-source tool “NoiseModelling” http://noise-planet.org/noisemodelling.html (EC Handbook, 2021)</td></tr>
<tr><td>Data needed</td><td colspan="2">- Noise levels (in dB(A)) measured and aggregated on a 24h period as per formula above.
- Simulated L_{DEN} (numerical predictions): acoustic simulation (in dB(A)) on hourly periods (depending on input data, e.g., road traffic characterization, built-up implementation through</td></tr>
</table>

	GIS, etc.), gathered on 3 periods (Day, Evening, Night) and next aggregated on 24h. - Number of inhabitants exposed to noise, and total number of inhabitants
References	- Geravandi S, Takdastan A, Zallaghi E, Vousoghi Niri M, Mohammadi M J, Saki H, Naiemabadi A., 2015. Noise Pollution and Health Effects. Jundishapur J Health Sci. 7(1):e60312. doi: 10.5812/jjhs.25357 - EC Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods, 2021

<table>
<tr><td>55</td><td>Indicator name
European Air Quality Index</td><td>Tags
Environmental, PH&WB, Digital</td></tr>
<tr><td colspan="3">Definition
Concentrations values for up to five key pollutants determine the index level that reflects air quality at each monitoring station. The index corresponds to the poorest level for any of five pollutants.</td></tr>
<tr><td colspan="3">Description & use

The Index is based on concentration values for up to five key pollutants, including:
- Particulate matter (PM10);
- Fine particulate matter (PM2.5);
- Ozone (O3);
- Nitrogen dioxide (NO2);
- Sulphur dioxide (SO2).
It reflects the potential impact of air quality on health, driven by the pollutant for which concentrations are poorest due to associated health impacts.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Direct relation since concentration of different pollutants in the air directly affect human health</td></tr>
<tr><td>Scale</td><td>Site Level</td><td>Continuously (hourly or daily)</td></tr>
<tr><td>Units</td><td colspan="2">Likert scale (Good, Fair, Moderate, Poor, Very Poor, Extremely Poor)</td></tr>
<tr><td colspan="3">Method for assessment
Measurements</td></tr>
<tr><td colspan="3">How it is calculated
Directly based on measuring devices.</td></tr>
<tr><td>Data needed</td><td colspan="2">Five key pollutants. PM2.5, PM10, NO2, O3, SO2</td></tr>
<tr><td>References</td><td colspan="2">- https://airindex.eea.europa.eu/Map/AQI/Viewer/
- Directorate-General for Research and Innovation (European Commission), & Arnbjerg-Nielsen, K. (2021). Evaluating the impact of nature-based solutions: Appendix of methods. European Union. https://doi.org/10.2777/11361</td></tr>
</table>

56	***Indicator name*** Average NDVI values	***Tags*** Environmental, PH&WB, Digital
Definition The NDVI is an indicator of greenness based on the land surface reflection of visible (red) and near-infrared parts of the spectrum.		
Description & use NDVI is used to assess the greenness level of a specified area or distance. Higher values of NDVI indicate more greenness, and more specifically values above 0 indicate presence of green biomass (photosynthetically active surface).		
Relation to PH & WB **INDIRECT** - NDVI indicates vegetation health/status, and this vegetation is the one ameliorating the environmental conditions delivering health benefits. *From the literature: Higher NDVI value has been shown to be related to higher birth weight, less depression, better mental health and reduced mortality. Also ADHD symptoms have been found to be related to NDVI indicators.*		
Scale	Site / Neighborhood scale	Average BEFORE and average AFTER implementation
Units	Unitless (values from -1 to +1)	
Method for assessment Based on Remote Sensing measurements		
How it is calculated **NDVI = (NIR — VIS)/(NIR + VIS)**: near-infrared radiation minus visible radiation divided by near-infrared radiation plus visible radiation		
Data needed	Satellite images for NDVI Calculation - as much resolution as possible (as we are dealing with very local scales in some demo-sites (e.g. Gladsaxe)	
References	Sources: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/normalized-difference-vegetation-index https://www.sciencedirect.com/science/article/abs/pii/S0169204616301153 https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1205244 https://ehp.niehs.nih.gov/doi/10.1289/ehp.1308049 https://jech.bmj.com/content/69/6/523 https://www.mdpi.com/1660-4601/11/3/3453 https://www.sciencedirect.com/science/article/abs/pii/S0013935112000862 BREATH PROJECT https://ehp.niehs.nih.gov/doi/10.1289/ehp.1408215	

57	***Indicator name*** Biologically active space (de-sealed area)	***Tags*** Environmental, Urban Development
Definition A surface arranged in a manner providing natural plant vegetation and/or rainwater infiltration and retention, and maintaining soil vitality.		
Description & use Share of area inside of demonstration site not covered with impermeable surfaces, therefore active in terms of water infiltration and retention, supporting evapotranspiration, maintaining habitats and biodiversity, decomposition and soil formation, water purification, etc. The share of BAS indicates the level of reversing impact of urbanization and recovery potential of the space.		
Relation to PH & WB Indirectly through increasing potential for recovery of regulatory services of ecosystems.		
Scale	site	Before and after intervention
Units	%	
Method for assessment GIS / Measurements		
How it is calculated Biologically active space = Ncon / Area × 100%, where: Ncon is the area inside of the park covered without concrete.		
Data needed	orthophoto map	
References	- Maienza, Ungaro, F., Baronti, S., Colzi, I., Giagnoni, L., Gonnelli, C., Renella, G., Ugolini, F., & Calzolari, C. (2021). Biological Restoration of Urban Soils after De-Sealing Interventions. Agriculture, 11(3), 190. https://doi.org/10.3390/agriculture11030190 - https://adriadapt.eu/adaptation-options/reduction-of-soil-consumption-and-surface-unsealing-in-urban-areas/ (accessed 8.02.22)	

58	***Indicator name*** Community level physiological profiling (CLPP)	***Tags*** Environmental, Sustainability, Resilience
Definition A rapid screening method used to characterize microbial communities of different habitats, ranging between sediments to seawater and between oligotrophic groundwater to soil and fertilizers.		
Description & use Microorganisms are present in virtually all environments and are typically the first organisms to react to chemical and physical changes in the environment. Changes in microbial communities are often a precursor to changes in the health and viability of the environment as a whole. Microbial activity influences a number of processes critical for such processes like decomposition, soil formation, degradation of toxic substances, and in general impacts soil water capacity and survival of greenery.		
Relation to PH & WB Influences environmental security in relation to contaminants, may help to reduce costs of greenery maintenance through navigation of NBS actions		
Scale	Site level, NBS level	Seasonally: spring. summer, autumn before and after implementation
Units	The results were expressed as average well color development (AWCD), % of the total carbon source utilization, and the Shannon-Weaver (H), substrate richness (S) and substrate evenness (E) indices	
Method for assessment Soil sampling and laboratory measurements. The CLPP measures the metabolism of 31 carbon sources. The results are read every 24h on the Microplate Spectrophotometer. The reduction the colorless tetrazolium chloride to red formazan (λ=590 nm) is used to determine to what extent carbon sources were used by growth substrate microbial community. The CLPP is a simple, fast and robust tool that bases on colorimetric readout. It is readable with any microplate reader. Microbial communities provide useful information about environmental change.		
How it is calculated AWCD-OD590 nm; Richness (S) is the number of utilized carbon substrates calculated using OD values of 0.250 as threshold for positive response; Shannon's diversity index is related to the number of carbo substrates the bacterial community is able to degrade and it is calculated as follows: (H')=H'=-Σpi(ln pi) where pi is ci divided by the sum of all ci values; the Evenness index (E) is the evenness of ci values across all utilized substrates according the formula: E=H'/ln S		
Data needed	fresh soil samples (1 g per one repetition)	
References	Weber, K. P., & Legge, R. L. (2009). Community-Level Physiological Profiling. Bioremediation, 263–281;	

	doi:10.1007/978-1-60761-439-5_16; https://www.biolog.com/wp-content/uploads/2020/04/Sigler_Von_Sigler_LEPR_Protocols_files_CLPP.pdf

59	***Indicator name*** % of biomass reuse on site	***Tags*** Economic-business; Environmental
Definition Re-use of biomass / nutrients / sediments obtained from the site as a side effect of its maintenance.		
Description & use Biomass can be considered as a waste generated by blue and green areas (thus generating maintenance costs) or as a resource and a sustainability factor, when it contributes to in-situ soil formation, production of fertilizer, habitat formation.		
Relation to PH & WB Direct to WB as it decreases maintenance costs, or income sources (compost production, biofuel), indirectly through creating more diverse communities of plants and animals, better controlling e.g. pest or diseases		
Scale	site / NBS	annually
Units	%	
Method for assessment statistics		
How it is calculated % of biomass produced on the place which stays there as a source of carbon and habitat		
Data needed	Amount of biomass produced and removed	
References	https://iwaponline.com/bgs/article/2/1/138/72076/A-review-of-nature-based-solutions-for-resource (accessed 8.02.22	

<table>
<tr><td>60</td><td>Indicator name
Plant & animal richness of selected native indicator species</td><td>Tags
Environmental, biodiversity, habitat quality, well-being, native species</td></tr>
<tr><td colspan="3">Definition
Provides an overview of the species diversity, with distinctions able to be made across taxonomic groups if multiple groups can be covered. Defined species can also serve as an indirect "indicator" for the habitat quality. In addition, the total number of plant species and bird species has been correlated to a higher self-reported well-being.</td></tr>
<tr><td colspan="3">Description & use
The total number of native species within a defined area (site/neighborhood/ region/city). This can compromise one or more of the following taxonomic groups (it should be specified which groups are covered): a. Plants, b. Birds, c. Butterflies, d. Invertebrates, e. Mammals . These biodiversity proxies could be used to assess whether the increase on species richness has a direct effect on the self-reported well-being of users.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Psychological well-being - reflection (ability to think and gain perspective); distinct identity (degree of feeling unique or different through association with a particular place); continuity with past (extent to which sense of identity is linked to greenspace through continuity across time); and attachment (degree of emotional ties with the greenspace). People, in general, demonstrate a greater aesthetic appreciation for more-diverse plant communities, and therefore report a higher well-being when visiting diverse greenspaces</td></tr>
<tr><td>Scale</td><td>NBS / site level /neighborhood / city (establish a buffer zone of impact)</td><td>Monitoring frequency: flora & fauna surveys before the NBS implementation and after. Interviews also carried out before and after to be able to compare the results.</td></tr>
<tr><td>Units</td><td colspan="2">Number and type of species in the defined area</td></tr>
<tr><td colspan="3">Method for assessment
Species inventory (seasons will differ depending on the selected species). In the literature, parcels 10x10m were used to asses flora and transects were used to acquire data on bird richness (see references). In case of insects yellow traps are commonly applied. In order to correlate the biodiversity data with self-reported well-being, semi-structured interviews in situ can be used.</td></tr>
<tr><td colspan="3">How it is calculated
Species richness (number of species), Evenness (Pielou Index) habitat diversity (Shannon diversity index), Psychological well-being (interviews/questionnaire).</td></tr>
<tr><td>Data needed</td><td colspan="2">Species survey / inventory before and after the NBS implementation. Species counting, GIS coordinates. Self-reported well-being of users before and after.</td></tr>
</table>

References	- Dallimer, M., Irvine, K. N., Skinner, A. M. J., Davies, Z. G., Rouquette, J. R., Maltby, L. L., … Gaston, K. J. (2012). Biodiversity and the Feel-Good Factor: Understanding Associations between Self-Reported Human Well-being and Species Richness. BioScience, 62(1), 47–55. - Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. Biology Letters, 3(4), 390–394. - Directorate-General for Research and Innovation (European Commission), & Arnbjerg-Nielsen, K. (2021). Evaluating the impact of nature-based solutions: Appendix of methods. European Union. https://data.europa.eu/doi/10.2777/11361

61	***Indicator name*** Changes in habitat quality	***Tags*** Environmental, biodiversity, habitat quality, well-being,
Definition Urban sites are usually degraded in terms of water cycle and soil conditions, what is an obstacle to natural succession and a barrier to return of native fauna and flora. NBS create an enabling conditions reducing imperviousness, protect undeveloped landscapes or increasing green spaces, fertility and vitality of soils, and often restore or create riparian and wetland habitats for wildlife		
Description & use Impervious or other paved surfaces can be turned into habitat for biodiversity, and consequently deliver all the related benefits. An assessment of the proportion of impervious / paved area that is turned into habitat for biodiversity can be calculated and used as an indicator of change in habitat quality.		
Relation to PH & WB **Indirectly related**. A higher proportion of high-quality habitats may provide significant benefits related to pollution reduction, amenity opportunities, mental health restorativness, reduced temperature due to evapotranspiration...		
Scale	Site level	Mapping before and after NBS implementation
Units	% / ha	
Method for assessment Mapping of habitats before the NBS implementation and after (GIS). Comparison of the area designed to deliver high quality habitat for biodiversity. The assessment of habitat quality may need expert field assessment using indices for specific species (e.g. Habitat Suitability Index).		
How it is calculated Area covered by high quality habitats / total area of the site (calculate the percentage before and after NBS implementation).		
Data needed	Reference land-cover maps of the demo sites before the NBS construction. High resolution satellite images.	
References	Jessup, Parker, S. S., Randall, J. M., Cohen, B. S., Roderick-Jones, R., Ganguly, S., & Sourial, J. (2021). Planting Stormwater Solutions: A methodology for siting nature-based solutions for pollution capture, habitat enhancement, and multiple health benefits. Urban Forestry & Urban Greening, 64, 127300. https://doi.org/10.1016/j.ufug.2021.127300	

<table>
<tr><td>62</td><td>Indicator name
Blue space availability</td><td>Tags
Environmental, Digital, Blue space</td></tr>
<tr><td colspan="3">Definition
Amount (%) of blue space (water elements such as ponds, basins, creeks, streams, lakes, wetlands...) within 1 km of the participant’s home</td></tr>
<tr><td colspan="3">Description & use
The % of blue space available within 1km of the participant home has been related to effects on self-reported mental and general health, as well as on anxiety and mood disorders.</td></tr>
<tr><td colspan="3">Relation to PH & WB
Mental health : anxiety and mood disorders were correlated negatively with the increase of % in blue spaces. Self-reported mental health correlated positively with increase of % in blue space.</td></tr>
<tr><td>Scale</td><td>NBD and/or site level</td><td>Measure once before NBS implementation and once after NBS implementation.</td></tr>
<tr><td>Units</td><td colspan="2">%</td></tr>
<tr><td colspan="3">Method for assessment
With remote sensing high resolution images, or drones, Calculating the % of area covered by blue spaces using GIS interface.</td></tr>
<tr><td colspan="3">How it is calculated
% of the total area studied (1km radius from demo site or user's residence) covered by blue spaces</td></tr>
<tr><td>Data needed</td><td colspan="2">Satellite images or up-to-date land-use maps.</td></tr>
<tr><td>References</td><td colspan="2">- De Vries, S., ten Have, M., van Dorsselaer, S., van Wezep, M., Hermans, T., & de Graaf, R. (2016). Local availability of green and blue space and prevalence of common mental disorders in the Netherlands. BJPsych Open, 2(6), 366–372.
- Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. Journal of Epidemiology & Community Health, 63(12), 967–973.</td></tr>
</table>

<table>
<tr><td>63</td><td>Indicator name
Connectivity of urban green spaces</td><td>Tags
Environmental, Digital, Biodiversity, Connectivity</td></tr>
<tr><td colspan="3">Definition
Connectedness of habitat patches for humans and other species. Connectivity reflects the integrity of green and blue areas so it opposites fragmentation.</td></tr>
<tr><td colspan="3">Description & use
Connectivity can evaluated in terms of structural connectivity relating to the spatial configuration of patches, without considering the movement of individual organisms among these patches and functional connectivity relating to the ability of organisms to move among patches. Structural connectivity is more straight-forward to measure than functional connectivity.</td></tr>
<tr><td colspan="3">Relation to PH & WB
A well-connected and functional network of urban greenspaces enhances the delivery of ecosystem services, and therefore the benefits to citizens (cultural ecosystem services). It also facilitates walking and biking through the cities thus promotes physical activity.</td></tr>
<tr><td>Scale</td><td>Site level in relation to the neighborhood/city available green spaces</td><td>Assess before, and after the NBS implementation</td></tr>
<tr><td>Units</td><td colspan="2">unitless</td></tr>
<tr><td colspan="3">Method for assessment
Structural connectivity is measured by the proximity of bluegreen spaces and the infrastructure matrix that these form across a city. CONEFOR Software can be used to assess connectivity http://www.conefor.org/index.html Participatory processes are also possible using internet-based public participation GIS (PPGIS) surveys to map functional aspects of urban blue-green space. Two indexes that have been successfully used : integral index of connectivity (IIC) and the probability of connectivity (PC)</td></tr>
<tr><td colspan="3">How it is calculated
Usually calculated by modelling with a broad set of models, which use graph theory.</td></tr>
<tr><td>Data needed</td><td colspan="2">Land cover, land use</td></tr>
<tr><td>References</td><td colspan="2">- McRae, B. H. 2006. Isolation by resistance. Evolution 60:1551 1561
- Directorate-General for Research and Innovation (European Commission), & Arnbjerg-Nielsen, K. (2021). Evaluating the impact of nature-based solutions: Appendix of methods. European Union. https://doi.org/10.2777/11361 Indicator Nr.9.1 Structural and functional connectivity of urban green and blue spaces:</td></tr>
</table>

	https://ec.europa.eu/info/news/evaluating-impact-nature-based-solutions-handbook-practitioners-2021-may-06_en Article regarding Conefor Software: https://www.sciencedirect.com/science/article/abs/pii/S1364815208000959

64	***Indicator name*** Green space accessibility	***Tags*** Environmental, Digital, Green Space, Accessibility

Definition
The ability to reach and access green spaces determined by the distribution of green spaces (walking distance to nearest green space (meters)) and easiness of their access

Description & use
With increasing distance to an accessible green space, and the number of barriers / obstacles, either physical or mental, the frequency of green space use declined and therefore the health benefits provided by physical presence in the green space as well. This indicator could be used to assess if the NBS intervention shortens the distance to nearest green space (from the users residency location) and increases a number of users being able to access the space.

Relation to PH & WB
Physical health and **Mental health**: users being able to physically enter green spaces and make the active use of them are less likely to be overweight or obese, and less prone to mental disorders.

Scale	Site level in relation to NBS / green space availability around users residency	Before and after NBS implementation.
Units	Meters, supplementary a number of socially excluded people due to poverty, disabilities, age, gender entering the site	

Method for assessment
GIS Approach -The GIS database needs to be cross referenced with a high resolution aerial photography of the site to ensure that no spaces are omitted or erroneously included in the assessment.
Alternatively, through structured interviews and questionnaires indicating the closest accessible green areas, and marking obstacles and barriers to reaching the others; interactive maps and citizen science.

How it is calculated
The measure of green space accessibility computed in the GIS was the distance by road from the residential location of each respondent to the nearest green space of each type considered. Several network analysis plug-ins of QGIS can be utilized.

Data needed	GIS database of neighborhood and green space characteristics. Road network, city blocks and buildings can be acquired freely from Open Street Map (OSM) as a shapefile.
References	- Coombes, E., Jones, A. P., & Hillsdon, M. (2010). The relationship of physical activity and overweight to objectively measured green space accessibility and use. Social Science & Medicine, 70(6), 816–822.

65	***Indicator name*** Changes in Habitat Diversity (Habitat Unit diversity)	***Tags*** Environmental, biodiversity, habitat quality, well-being,
Definition Hermys & Cornelis (2000) provided a list of "habitat units" for (sub)urban parks, that can be extrapolated to habitat types in the demo sites. Habitat diversity refers to how many different habitat units a certain landscape has.		
Description & use The change of habitat unit diversity, before and after NBS implementation could be assessed, in order to explore whether NBS can diversify the landscape.		
Relation to PH & WB **Indirectly related**. A higher proportion of high-quality habitats, and also a higher diversity of habitats, may provide significant benefits related to pollution reduction, amenity opportunities, mental health restorativness, reduced temperature due to evapotranspiration...		
Scale	Demo site scale	Before and after NBS implementation.
Units	N/A	
Method for assessment With GIS calculate the proportion (%) of each type of the habitat in the demo site. Then apply the Shannon-Wiener diversity index (H).		
How it is calculated See Shannon Wiener diversity index formula in the reference		
Data needed	GIS database of neighborhood and classified following the typology provided by the reference	
References	Hermy & Cornellis (200): https://www.sciencedirect.com/science/article/abs/pii/S016920460000061X	

66	***Indicator name*** Derelict land reclaimed for NBS	***Tags*** Urban development, Digital
Definition Reclamation of derelict and/or contaminated land (brownfields)		
Description & use Conversion of a piece of land's use by obsolete use (industry/infrastructure) from one purpose to another, related to NBS		
Relation to PH & WB Indirect		
Scale	Site scale	Yearly and the percentage change in the area is reported, as well as the actual area remaining.
Units	Expressed as total area (ha)	
Method for assessment Proportion of derelict land of the site redeveloped over the four year for productive use via implementation of NBS, and the total area of identified brownfield remaining		
How it is calculated Surface area is calculated using maps.		
Data needed	Total area	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

67	***Indicator name*** Quantity of blue-green space as ratio to built form	***Tags*** Urban Development, Environmental, (Digital)
Definition Proportion of the area of blue-green spaces, including open space, public space, urban greenery, ponds and public park to the built area at the demo-site.		
Description & use Use of this indicator is to evaluate the benefits of open spaces relate to both their materials and functions for increased vegetation and soil permeability and water retention, as well as the potential increased social benefits of open meeting spaces, areas for recreation, sports and relaxation (WHO, 2016).		
Relation to PH & WB Direct		
Scale	Site scale	Annually
Units	Ratio of the total demo-site land (blue and green km2/total km2 of total land). Ratio of open spaces to built form within a demo-site area	
Method for assessment Calculate the green space of demo-site area, based on hard impermeable surfaces as built and soft permeable surfaces as green areas. The total area covered by buildings is calculated from maps, and consequently the ratio of the open area to the building area is calculated.		
How it is calculated Amount of green spaces, buildings and other infrastructure assets in the demo-site		
Data needed	Ratio of the total area	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

68	***Indicator name*** Perceived quality of urban green, blue and blue-green spaces	***Tags*** Urban development
Definition This indicator reports perceptions of space quality of NBS - attractiveness of the area for a specific use.		
Description & use Perceived quality of space is one of the factors to influence the successfulness of open space, especially in terms of engaging users in activities (Fongar et al., 2019).		
Relation to PH & WB Indirect		
Scale	Site scale	Before NBS implementation and aligned with timing of targeted objectives at the end of the project
Units	Qualitative description (questionnaires or interviews) of the place attractiveness in terms of stimulation for gardening / social interaction / relaxation / physical activity 1 Yes, it's attractive 2 No, it's unattractive	
Method for assessment Qualitative description through questionnaires, semi-structured interviews		
How it is calculated Qualitative description		
Data needed	Qualitative description	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

69	***Indicator name*** Recreational value of green space	***Tags*** Urban development
Definition This indicator represents a quantification of the number of demo-site users, visitors or recreational activities within an open, greenspace or blue-green space in order to evaluate an increase in recreational benefits as a result of NBS.		
Description & use The most basic measure for this indicator is increase/decrease in the number of visitors to a blue-green space before and after a change in how it is designed or managed.		
Relation to PH & WB Direct		
Scale	Analysis is performed on a single site scale and can comprise sites ranging from very large parks and open spaces to micro-scale pocket parks.	Data collection frequency will be depend on selected method. It could be before and after the NBS implementation.
Units	Number of visitors/recreational activities within a greenspace or blue-green space of the demo-site	
Method for assessment Questionnaires - the most typical practice for assessing the causal link for recreational value of blue-green spaces is through generating direct feedback from demo-site users.		
How it is calculated Data input types will be depend on selected methods		
Data needed	Number of visitors (quantity)	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

70	***Indicator name*** Material used coherence (Amount of sustainable materials used for interventions within the demo-site)	***Tags*** Urban development, Sustainability
Definition It assesses whether the construction materials used currently and after interventions are coherent or not with local climate conditions and natural materials and if they produce negative impacts on landscape perception.		
Description & use Assessment of the coherence of used material and techniques with local materials and climate conditions.		
Relation to PH & WB Indirect		
Scale	Site scale	Before NBS implementation and at the end of the project
Units	Dichotomic (Yes/No) or % of used materials	
Method for assessment Questionnaires, demo-site surveys		
How it is calculated Qualitative description of surveys results		
Data needed	Information about used materials.	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

71	***Indicator name*** Multifunctionality and flexibility of functional use of open space	***Tags*** Urban development
Definition It assesses whether the open spaces (public and private) at the demo-site have the flexibility of changing its functional use.		
Description & use Flexibility of functional uses is an added value of an open space in terms of its engagement capacity, seasonability and sustainability.		
Relation to PH & WB Indirect		
Scale	Site scale	Before NBS implementation and at the end of the project
Units	<2; 3-5; 6>	
Method for assessment Maps, questionnaires and demo-site surveys		
How it is calculated Quantifying functional uses		
Data needed	Number of functional uses	
References	Zivkonic et al. (2019) Multifunctional public open spaces for sustainable cities. Facta universitatis – series Architecture and Civil Engineering 17	

72	***Indicator name*** Interaction between building's street level and open spaces	***Tags*** Urban development
Definition It assesses whether the interaction between the building's at the street level and open spaces of the demo-site		
Description & use NBS implementation can lead to an increase of interactivity at the demo-site and improve the engagement capacity, connectivity and safety of space		
Relation to PH & WB Indirect		
Scale	Site scale	Before NBS implementation and at the end of the project
Units	High/medium/low	
Method for assessment Maps, plans and questionnaires		
How it is calculated Qualitative description		
Data needed	Qualitative description	
References	Carmona, M. (2018) Principles for public space design, planning to do better	

73	***Indicator name*** Access to public amenities and ease of reaching (and interacting with) destinations or activities distributed in the proximity to the demo-site	***Tags*** Urban development
Definition Share of population (% of people) with improved access to at least one type of public amenity within 500m.		
Description & use NBS implementation can facilitate an increase of accessibility to local services/facilities and reduce transport distances and vehicle use. It can also be viewed as an indicator of health/wellbeing and quality of life.		
Relation to PH & WB It can be viewed as an indirect indicator of health/wellbeing and quality of life.		
Scale	City scale	Data collection frequency will depend on selected methods
Units	% of people	
Method for assessment From workshops and public participation techniques through to earth observation/remote sensing approaches		
How it is calculated Quantifying the results from observation/remote sensing approaches		
Data needed	Required data will depend on selected methods	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

74	***Indicator name*** Demo-site area devoted to roads	***Tags*** Urban development, Digital
Definition Total proportion of a defined area of the demo site devoted to roadways for motorized vehicle use only (ratio or fraction)		
Description & use NBS implementation can decrease the area of hard non-permeable roads, and improve multifunctionality and increase the permeability of the total surface.		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Km2 or %	
Method for assessment Maps, plans		
How it is calculated The total area covered by grey roads for cars is calculated from maps or estimated from appropriate sources, and the ratio to the total area is calculated		
Data needed	Initial required data from demo-sites municipality	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

75	***Indicator name*** Demo-site area devoted to clean transport	***Tags*** Urban development, Digital
Definition Total proportion of a defined urban area devoted to bike lines or other clean vehicle use only (ratio or fraction)		
Description & use Demo-sites NBS interventions will aim to including the areas devoted to clean transport reducing the space devoted to only motorized vehicles use.		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Km2 or %	
Method for assessment Maps, plans		
How it is calculated The total area covered by clean transport is calculated from maps or estimated from appropriate sources, and the ratio to the total area is calculated		
Data needed	Initial required data from demo-sites municipality	
References	Steamer K (2003) Energy and the City: density, buildings and transport. https://doi.org/10.1016/S0378-7788(02)00075-0	

76	***Indicator name*** Sustainable urban (street) lighting (multifunctionality day and night) at the demo-site	***Tags*** Urban development, Sustainability
Definition Presence of urban lighting elements at the demo-site		
Description & use Urban lighting impacts the spatial perception of the demo-site and therefore affects the use of open space.		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Lux	
Method for assessment Demo-site survey		
How it is calculated Geographical information system (GIS)-based informative system integrated with lighting data		
Data needed	Local data	
References	- Tagliabue, L; Cecconi, F; Moretti, N; Rinaldi, S; Bellagente, P; Ciribini, A; (2020) Security Assessment of Urban Areas through a GIS-Based Analysis of Lighting Data Generated by IoT Sensors - Dwimirnani, P; Karimi, K; Palaiologou, G; (2017) Space after dark: Measuring the impact of public lighting at night on visibility, movement, and spatial configuration in urban parks.	

77	***Indicator name*** Obstacles in the use of the open space	***Tags*** Urban development, Digital
Definition Presence of obstacles in the use of the open spaces in the area of demo-sites		
Description & use NBS implementation can remove the obstacles in the use of open spaces and thus improve its engagement capacity and potential health and wellbeing co-benefits.		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Absence - Presence (N°)	
Method for assessment Maps, plans, photos, videos		
How it is calculated Counting number of obstacles		
Data needed	Number - quantity	
References	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904439/Improving_access_to_greenspace_2020_review.pdf	

78	***Indicator name*** Urban furniture equipment at the demo site	***Tags*** Urban development, Digital
Definition Presence of urban furniture and elements for protection from adverse sensations and from transport accidents		
Description & use Urban furniture can link with the NBS implementation and improve the comfort by protecting from adverse sensations (wind, rain/snow, cold/heat, dust, bright light, noise) and transport accidents in the roads in vicinity of the demo-sites		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Present - Nonexistent	
Method for assessment Maps, plans, photos, videos		
How it is calculated Counting number of urban furniture equipment		
Data needed	Number - quantity	
References	Pranov, S. (2017) Street furniture in high-density urban areas: Geometry, Ergonomic, and CNC Production. DOI: 10.13140/RG.2.2.20396.26242/1	

79	***Indicator name*** Preservation of cultural heritage and presence of unique spatial elements	***Tags*** Social, Urban development, Digital
Definition This indicator assesses the extent to which preservation of local cultural heritage is considered during NBS interventions on the demo-site		
Description & use NBS implementation by enhancing relationship between culture and sustainable development linked to issues such as social equity and social justice, participation and engaged governance, social cohesion, and social capital (Soini & Birkeland, 2014), (UNESCO, 2001; UNESCO, 2005).		
Relation to PH & WB Indirect. It enhances or connects to the existing character of the place.		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Not at all — 1 — 2 — 3 — 4 — 5 — Very much 1. Not at all 2. Fair 3. Moderate 4. Much 5. Very much	
Method for assessment Maps, plans, photos, videos		
How it is calculated Qualitative description		
Data needed	Qualitative description	
References	EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods	

80	***Indicator name*** Scenic sites and landmarks created	***Tags*** Urban development, Digital, Social
Definition A scenic site or a landmark - viewpoint where it is possible to enjoy the view of the area of demo-site or the area surrounding demo-site valued.		
Description & use Some NBS implementation could contribute to enhance landscape enjoyment increasing the amount of perceivable scenic sites and creating new landmarks that could represent new elements of visibility, orientation and local identity.		
Relation to PH & WB Indirect		
Scale	Site scale	Before and after the interventions at the demo-site
Units	Number of scenic sites and landmarks	
Method for assessment Maps, plans, photos, videos		
How it is calculated Counting number of scenic sites and landmarks		
Data needed	Number of scenic sites and landmarks created by the project.	
References	- EC (2021). Indicators Handbook: Evaluating the Impact of Nature-based Solutions: Appendix of Methods - Davoudi, S., Brooks E., 2019. Landscape quality: A rapid review of the evidence. Defra Science Advisory Council	

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