URBAN GreenUP

D5.3: City Diagnosis and Monitoring Procedures

WP 5 , T 5.3

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Authors: 15 (GMV), 1 (CAR), 2 (VAL), 7 (LIV), 8 (CFT), 9 (UOL), 10 (IZM), 11 (DEM), 12 (EGE), 13 (IZT), 14 (BIT)

URBAN GreenUP

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[1] PU = Public
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0 Executive summary

Following the previous tasks in Work Package (WP) 5, this deliverable aims to continue the definition of the Key Performance Indicators selected for the project URBAN GreenUP. It shall define the set of KPIs (Key Performance Indicators) selected, that will be used to assess the methodology defined in Work Package 1 (WP1): renaturing city methodology and also in each demonstration city diagnosis and baselines being developed (WP2, Valladolid; WP3, Liverpool; WP4, Izmir), where the projected NBS (Nature Based Solutions) are related to both a challenge (below) and to KPIs.

In this document the methodology for the monitoring of different NBS and a global perspective, shall be approached by outlining the main challenges and focused on goals that have been drawn directly from the Eklipse Mechanism; a self-sustained mechanism under the umbrella of the European Union's Horizon 2020.

The KPIs are based on the Eklipse mechanism framework, where a robust set of KPIs shall be selected and established by challenges that relate to NBS. These challenges are:

- Climate mitigation & adaptation
- Water Management
- Coastal Resilience
- Green Space Management
- Air Quality
- Urban Regeneration
- Participatory Planning and Governance
- Social Justice and Social Cohesion
- Public Health and Well-being
- Potential of economic opportunities and green jobs
- Other challenge/s

In Task 5.1: Technical KPIs definition provided a detailed definition of calculation formulas and indices in order to measure and evaluate the accuracy and quality of the Key Performance Indicators. Now, Task 5.3. City Diagnosis and monitoring procedures regarding climate and water resilience and Deliverable 5.3: City diagnosis monitoring procedures will focus on the description of the KPIs defined previously, aiming to amend and add information that was not available, while giving a high level description of the indicators to follow for baseline monitoring and future performance of the NBS and the project.

1 Introduction

1.1 Project Overview

Currently, 54% of the world's population lives in towns and cities, and it is projected to increase to nearly 70% by the middle of the century[2]. Therefore, the creation and maintenance of sustainable urban environments is vital.

In fact, the European Environmental Action Programme[3] states that by 2020: *"…a majority of cities in the Union are implementing policies for sustainable urban planning and design…"* and that the Commission should develop: *"…a set of criteria to assess the environmental performance of cities, taking into account economic, social and territorial impacts"*.

While the conservation and sustainable development community considers Nature-Based Solutions (NBS) to be a strong method of addressing climate change and its associated challenges in urban environments, there is still a tendency to implement mainly traditional engineering and architectural solutions. Normally, authorities promote changes in patterns of mobility, expansions of cities or major infrastructure projects to combat floods and other effects of climate change.

Nature-Based Solutions can improve air quality, minimize heatwaves, act as carbon stores, help to mitigate climate change, reduce flooding disasters overcome adaptation to climate change and be an important habitat for wildlife. Furthermore, they can also provide a multitude of benefits that impact on human health, lifestyle and well-being[4] Worldwide[5] [6], and at EU level[7] [8].

In line with those statements, in 2008 EC the Annual European Green Capital Award (EGCA)[9], which recognizes and rewards cities efforts. Moreover, EC is currently working on the definition of an urban environment self-assessment tool that will be used by cities, as a basis for assessing their environmental performance and aiming to find innovative ways to meet urban environmental and sustainability policy targets[10].

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[2] United Nations. World Urbanization Prospects: The 2014 Reviion, Highlights (ST/ESA/ SER.A/352). (2014).

[3] http://ec.europa.eu/environment/action-programme/ [Accessed 15/06/2018]

[4] Final Report of the Horizon 2020 Expert Group on "Nature-Based Solutions and Re-naturing Cities" (2015).

[5] IUCN. Ecosystem Based Adaptation: Knowledge Gaps in Making an Economic Case for Investing in NBS for CC. (April 2015).

[6] Green Infrastructure: Sustainable Solutions in 11 Cities across the United States. Columbia University Water Centre (April 2014).

[7] EEA Technical report Nª 2/2014. Spatial analysis of Green infrastructure in Europe. ISSN 1725-2237

[8] EEA Technical report Nº12/2015. Exploring nature-based solutions. ISSN 1725-2237

[9] http://ec.europa.eu/environment/europeangreencapital/ [Accessed 15/06/2018]

[10] http://ec.europa.eu/environment/urban/tool.htm[Accessed 31/08/2016]

Despite these initiatives, there is a lack of tools to associate improvements of cities environmental problems with natural-based solutions. Plans and actions involving green areas of the city are often kept separate from the urban development plans and the key issue is that existing guidelines usually do not incorporate NBS to fight against and adapt to climate change.

In order to address in depth the aforementioned needs and demonstrate the potential of the NBS to contribute to the main cities' challenges, URBAN GreenUP aims at obtaining a tailored methodology: 1) To support the co-development of Renaturing Urban Plans (RUPs) focused on climate change mitigation and adaptation and efficient water management, and; 2) to assist in the implementation of NBS in an effective way.

NBS classification and parametrization will be addressed (WP1) and some resources to support decision making will be established. A large scale and fully replicable demonstration action of NBS accompanied by innovative business models will provide evidence about the benefits of NBS contributing to the creation of new market opportunities for European companies, and fostering citizen insight and awareness about environmental problems. Three European cities will deliver the demos as front runner cities (Valladolid, Liverpool and Izmir), and another two European cities will act as followers to strengthen the replication potential of the results (Ludwigsburg and Mantova) and finally three non-European cities (Medellin, Chengdu and Quy Nhon) will help to identify the market opportunities for European companies out of Europe and foster the European leadership in NBS implementation at a global level.

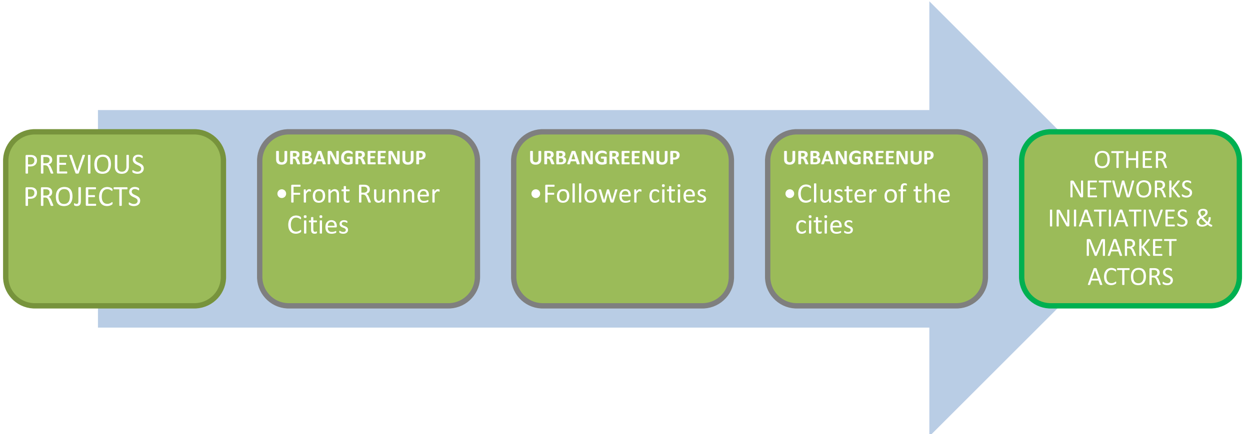

Figure 1.1 Growth of impact and market uptake of URBAN GreenUP

URBAN GreenUP aims to create a Renaturing Methodology as a specific part of the Sustainable Urban Plan focused on Climate Change Mitigation (CCM) and water resilience on the basis of NBS implementation. WP1 is devoted to achieve these targets following a concept based on co-creation and social acceptance strategies. The use of Social Sciences and Humanities (SSH) will be strongly embedded. The core of the work plan is the set of demonstration work packages (WP2-Valladolid, WP3-Liverpool and WP4-Izmir). Each front-runner city has planned their specific actions following similar schemes (baseline assessment, green urbanization, water interventions, singular green infrastructures and non-technical actions) but integrating specificities in order to manage all the foreseen interventions.

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Several partners will act in a cross-cutting way, coordinating common actions. Each demonstration WP is led by the front-runner cities (Valladolid, Liverpool and Izmir). WP5 is dedicated to establish the monitoring and evaluation strategy, WP6 to deploy a deep replication strategy together with coaching, mentoring and staff exchange actions among follower cities (Mantova and Ludwigsburg in Europe, and Medellin, Chengdu and Quy Nhon outside Europe) and front-runners. WP6 will address a cluster to foster replicability and links with other projects.

WP7 addresses tasks related with the exploitation and market deployment of the results, deploying the exploitation strategy, analysing the most promising business cases for NBS and renaturing implementation, fostering the leadership of European companies in the implementation of NBS to fight against climate change and improving the water management and use both in Europe and outside Europe (for this ambitious challenge, three cities, two in Asia and one in South America are full members of the consortium acting as followers as previously mentioned, Medellin, Chengdu and Quy Nhon). Finally WP8 aims to deploy a strong communication and dissemination strategy and WP9 is committed to the coordination actions.

WP5, where this task falls, is fully devoted to monitoring and assessment of the results, will address issues from the diagnosis, challenge identification the definition of baselines and the selection of the main Key Performance Indicators (KPIs). As can be seen in 1.3.1, section C, a rigorous set of KPIs will be selected, from the more technical to those related with social acceptance assessment and economic analysis. There is where this document aims to establish a robust set of indicators that will help the Project and the NBS to be weighted, incorporate lessons learnt and to effectively use the results for replication.

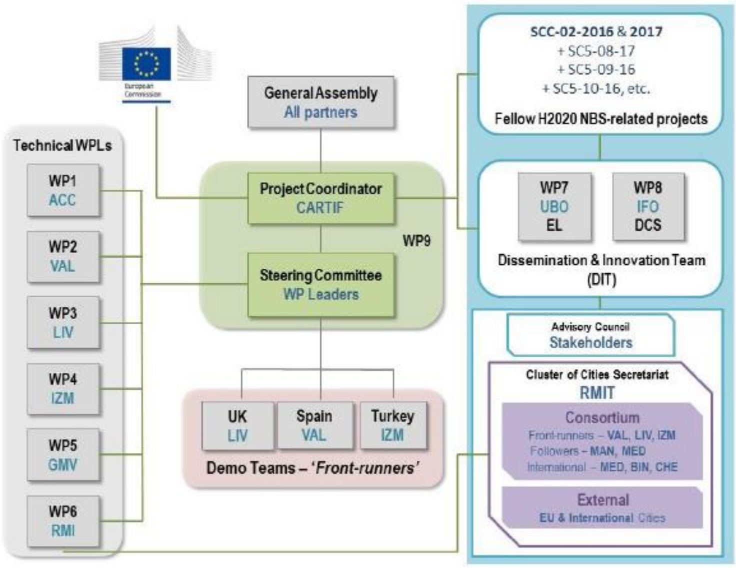

Figure 1.2: Project management and decision making structure

1.2 Scope of the task

The aim of this document is to present URBAN GreenUP project KPIs and a methodological approach that will be followed at later stages of the Project.

The monitoring description in this document and the description of the KPIs can be utilized by:

- Demo Cities and municipal administrations, enabling them to develop strategies based on the progress of the NBS.
- City residents and non –profit citizen organizations enabling them to understand the development and the baseline of the city.
- Follower cities, in order to learn from the use and application of the NBS and the improvement on the cities.
- Other professionals of urban planning, geographers, architects and landscape professionals.

The intention is to list a robust set of indicators that will evaluate and monitor the progress and the application of the NBS at each of the demo cities. It is desirable that each city can continuously quantify according to each goal for KPIs and their Challenges.

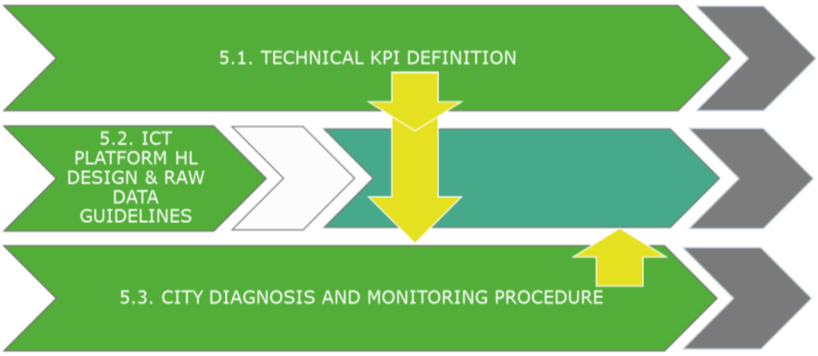

Figure 1.3: Interoperability amid the WP5

1.3 Aims and principles of a green infrastructure monitoring program

The key aim is to quantify the impacts of having GI. GI is hypothesised to have multiple benefits, so we want to measure multiple axes.

Principles: effective, repeatable and reasonable cost.

1.4 Issues in when and where to monitor - the ideal and practical workarounds

When: ideally before and after and allowing time for slow-acting effects. Frequency ideally tailored to natural range of variability (e.g. no need to monitor every day if change slow; no need to monitor in winter if summer is when effects occur. However, monitoring before and after intervention should use the same time schedule). Workarounds might include using different baseline data sources.

Where: at relevant NBS and/or close to relevant NBS where effects are hypothesised to reach; Sampling and representativeness; ideally sample control sites in BACI design. Workarounds might include taking an arbitrary sample instead of a random sample (e.g. a bus route).

2 PROTOCOLS FOR MEASURING KEY PERFORMANCE INDICATORS

Each KPI requires a clear and simple protocol, in order to arrive at an effective and comparable monitoring program. By protocol we mean every step from recording raw data (or obtaining it from publicly available sources), through any data processing and modelling that may be necessary, to the final KPI which can be reported. In the rest of this section, each KPI will have its own entry either under its *Eklipse Challenges* (for Core KPIs), or under the city adopting it (for city specific KPIs).

Each protocol will typically include:

- Whether the KPI is directly measured or modelled based on e.g. A map
- The choice of sensor or measuring instrument and why that was chosen (if needed)
- Which NBS the KPI is relevant to (although in some cases some KPIs are best measured across a whole demo area or whole city and not attributable to individual NBS interventions)
- When (frequency and duration) and where (extent and placement relative to NBS) measurements are made
- Method to be followed by the measurer, if not automated
- Method for data post-processing and modelling if relevant, including GIS methods

For core KPIs, we will also contrast *minimum* standards for the protocol and *desirable* standards which would lead to better data if time and resources allow.

2.1 Core KPIs

A set of Key Performance Indicators (KPI) were selected based on the Eklipse mechanism that show how the proposed actions and NBS will tackle the challenges that the project and each demonstration city is facing. These challenges and KPIs are specified in a summary below. Each epigraph is named after a challenge where the 29 related KPIs are fitted in.

The Core KPI are divided by challenges : Challenge 1, climate mitigation & adaptation; Challenge 2, water management; Challenge 3, coastal resilience – there are no NBS planned to face this challenge in city demos, therefore it is not considered to be Core–; Challenge 4, green space management; Challenge 5, air quality; Challenge 6, urban regeneration; Challenge 7, participatory planning and governance; Challenge 8, social justice and social; Challenge 9: public health and well-being; Challenge 10, potential of economic opportunities and green jobs.

CH	TYPE OF INDICATOR	KPI DEFINITION
1	Environmental, Chemical	**Tonnes of carbon removed or stored per unit area per unit time**
		Total amount of carbon stored in vegetation
	Environmental, Physical	**Decrease in mean or peak daytime local temperatures**
		Heatwave risks
	Others	**Use of *Star tools* to calculate projected maximum surface temperature reduction**
2	Physical indicators	**Run-off coefficient in relation to precipitation quantities**
		Absorption capacity of green surfaces, bioretention structures and single trees
		Temperature reduction in urban areas
		Areas (Ha) and population (inhab) exposed to flooding
	Chemical indicators (water quality)	**Drinking water provision**
		Water for irrigations purposes
	Economic indicators (benefits)	**Volume of water removed from water treatment system**
		Volume of water slowed down entering sewer system
3	N.A	**Not selected**
4	Social indicators (benefits)	**Accessibility (measured as distance or time) of urban green spaces for population**
		Weighted recreation opportunities provided by Urban Green Infrastructure
	Environmental (biological)	**Production of food**
		Increased connectivity to existing GI
		Pollinator species increase
5	Environmental (chemical)	**Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities concentration recorded ug/m3**
		Trends in emissions NOX, SOX
	Economic	**Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. use of GI Val to calculate the value of air quality improvements**
	Social (physiological	**Air quality parameters NOx, VOC, PM etc.**
6	Urban green indicators (environmental, biological)	**Accessibility: distribution, configuration, and diversity of green space and land use changes (multi-scale ;). - Green spaces quantity**
	Socio-cultural indicators	**Savings in energy use due to improved GI**
7	Social	**Perceptions of citizens on urban nature - Green spaces quality**
8	Social Cohesion	**Green intelligence awareness.**
9	Psychological indicators	**Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit**
	Health indicators related to ecosystem service provision	**Increase in walking and cycling in and around areas of interventions**
10	Economic	**Number of jobs created; gross value added**

Table 2.1: Core KPI table

2.1.1 CHALLENGE 1: CLIMATE MITIGATION & ADAPTATION MONITORING PROCEDURE (CAR)

Climate resilience is based on two interacting concepts: “adaptation”, that is the capacity to react and respond to an external stimulus or stress such as climate change, and “mitigation”, that is the potential of improving the current status of a parameter or driver through active or passive behaviour, in this case through reducing greenhouse gas emissions or sequestering carbon. In the case of NBS, which involve elements of ecosystems, the two concepts are closely linked as any adaptation of an ecosystem can further influence the mitigation potentials (e.g. by sequestering carbon in vegetation), with an overall dramatic effect on climate resilience.

This challenge is subdivided by following types:

Environmental indicator regarding chemical and biological aspects
- Tonnes of carbon removed or stored per unit area per unit time
- Total amount of carbon stored in vegetation

Environmental indicator regarding physical aspects
- Decrease in mean or peak daytime local temperatures
- Heatwave risks (number of combined tropical nights and hot days

Others climate mitigation and adaptation indicators
- Use of STAR Tools to calculate projected maximum surface temperature reduction

- **KPI-1: TONNES OF CARBON REMOVED OR STORED PER UNIT AREA PER UNIT TIME**

RATIONALE

Urban vegetation has an important role in offsetting CO_2 concentration by acting as a sink for atmospheric CO_2 via photosynthesis and by storing carbon through the growth process [1].

A proportion of the CO_2 that is sent into the atmosphere is reabsorbed. The concentration of the gas would otherwise increase exponentially, and would undoubtedly be irreversible. Natural systems are responsible for part of this absorption. They have a limited capacity which can also change the effects of climate change or how different ecosystems are used. Most natural systems have stored carbon, and the amount that is stored at any given time is called a carbon reservoir or carbon stock. If the amount in this system naturally increases over time, then it is described as a sink, which helps reduce the concentration of CO_2 the atmosphere. This process is called carbon sequestration. However, if the amount of carbon in the system declines, this is a CO_2 emission source [2].

Carbon sinks can be addressed at two spatial scales: within the city and at the urban regional level. Within a city park, green areas and tree plantings can function as carbon sinks, although urban vegetation only sequestrates a small part of annual CO_2 emissions of a city. In fact, urban parks can function as carbon sources because management and the use of parks produce multiple amounts of CO_2 emissions compared to the carbon sequestration capacity of a green area. Although urban carbon sinks do not necessarily have a significant impact on the global carbon balance, urban green areas can have local importance as carbon sinks [3]. This KPI is selected by Izmir and Valladolid.

RELATED NBS

Vertical and horizontal green infrastructure, tree related actions, SuDs /raingarden, urban carbon sink, vertical green interventions, new green cycle lane and re-naturing existing bike lanes: green cycle lane; green resting areas; cycle-pedestrian green paths.

METHODOLOGY

This KPI can be estimated as carbon sequestration and it is defined as the process of increasing the carbon content of a reservoir or pool other than the atmosphere. When plants grow, they capture CO_2 from the atmosphere therefore the choice of plant species for urban areas may be set out taking into account their own air amelioration capability. Maximizing the net sequestration of carbon through species selection and management practices will be the aim.

In this KPI, total amount of carbon (tonnes) stored in vegetation will be calculated and used to assess the impact of the NBS. This KPI includes the measurement and calculation of area of new woodland created to complete the study.

In the case of Izmir demo, based on different land covers, different formulas are employed for calculating the amount of carbon stored in vegetation at the level of the related demo sites. The carbon storage capacity of the existing land covers are calculated separately based on the methods and formulas employed by Rowntree and Nowak, 1991 [5]. It is executed in the scale of demo sites (kg/year) before the interventions and will be executed again using the same formulas and equations after NBSs are implemented in order to make a before and after comparison (kg/year).

DATA SAMPLING

Datasets should be identified to know:

• Area of new woodland created,

• Type of species,

• Number of species.

Different data sources will be consulted to estimate this KPI, mainly the Spanish National Forest Inventory (SNFI) and the Spanish Forest Map. The selection of species present at these inventories will be prioritised.

DATA PROCESSING

KPI calculation will be based on CO_2 removals per planted specimen, to subsequently apply this data to the entire project, depending on the number of specimens expected at the end of the period of project development.

Plant structure in each technology will be analysed regarding type of plant species and total number of species. The choice of plant species for each action shall be specific set out within the project development, taking into account their own air amelioration capability [4].

Total t CO_2, removed thanks to each NBS detailed before shall be calculated as follows:

$$\frac{tCO_{2,removed}}{yr * ha} = \left[\frac{tCO_{2,sequestred}}{specie * n_{years}}\right]_{[4]} * n_{years} * \frac{Number_{species} \text{to be planted within the NBS}}{\text{Total ha of species}}$$

RESULTS

- ton CO_2/year
- ton CO_2/year * ha

The amount of carbon stored in biomass (leaves, stems, trunk, roots and soil organic matter) to assess the tonnes of carbon removed or stored per unit area per unit time shall be obtained at the end of the process for this KPI.

REFERENCES

[1] Gratani L. et al. Carbon sequestration of four urban parks in Rome. Urban Forestry & Urban Greening 19 (2016) 184–193.

[2] CLIMATE CHANGE IN CATALONIA Executive summary of the Third Report on Climate Change in Catalonia, ISBN 978-84-9965-317-4 (2017).

[3] Niemelä J. et al. Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodiversity and October 2010, Volume 19, Issue 11, pp 3225–3243.

[4] Guide to estimate carbon dioxide absorptions (in Spanish) Spanish Office of Climate Change. Ministry of Agriculture, Food and Environment.

[5]Rowntree and Nowak, 1991; Vleeshouwers and Verhagen, 2002; Bandarnayake et al., 2003; Tratalos et al., 2007; Townsend-Small and Czimczik, 2010; Davies et al., 2011; Beaumont et al., 2014.

- **KPI-2: TOTAL AMOUNT OF CARBON STORED IN VEGETATION (Nº2)**

This KPI is selected by Liverpool and Izmir.

Rationale

Vegetation sequesters and stores carbon from the atmosphere, thus helping to mitigate climate change. GI-Val tool 1.7 can be used to estimate the amount of carbon sequestered by trees as they grow, and tool 1.8 can estimate the amount of carbon sequestered as a result of various other land use changes.

Related NBS

Vertical and horizontal green infrastructure, Tree related actions, Suds/raingarden, Urban carbon sink, Vertical green interventions, New green cycle lane and re-naturing existing bike lanes: green cycle lane; green resting areas; cycle-pedestrian green paths

Method

The areas of each type of new vegetation planted will be entered into GI-Val (https://www.merseyforest.org.uk/services/gi-val/).

- **KPI-7: DECREASE IN MEAN OR PEAK DAYTIME LOCAL TEMPERATURES**

RATIONALE

Green urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapotranspiration, which leads to two benefits: improved thermal comfort and reduced energy use. We address the thermal comfort and reduced energy benefits via physical indicators such as ambient temperature, turbulent fluxes and energy savings.

In this KPI, mean and peak daytime local temperatures will be calculated and used to assess the impact of the NBS. This KPI includes the measurement and calculation of mean and daytime local relative humidity to complete the study.

NBS TYPES

Green Shady structures, shade tree, cooling trees, green façade, and green parking pavements.

METHOD: BACI (BEFORE, AFTER, CONTROL, IMPACT)

Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously.

Field measurements will be done at the micro scale by using fixed sensors placed on site in representative locations and regularly measuring variables of interest. The meteorological data gathered from demo sites before and after the application will be compared and the impacts of the NBS on demo sites will be evaluated.

As a previous work, temporal series of temperature and relative humidity will be studied in order to define peak times and values and mean values of historical data (at night and daytime) for the city in the *Red de Control de la Contaminación Atmosférica del Ayuntamiento de Valladolid* (RCCAVA) areas (According its characteristics). This study will serve to stablish a general baseline for the city. On the other hand, RCCAVA measurements will be used as additional references of non-intervention areas.

NULL HYPOTHESIS

There is no difference in air temperatures and relative humidity between samples in stretches of street where green shady structures, street trees/green walls, etc. are present, and samples or measurements taken in stretches of streets without the NBS.

MONITORING EQUIPMENT

Wireless samplers to hang from street lamps or other urban furniture without carrying out works (low weight and low visual impact).

EXAMPLES

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity (Sensirion), solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

http://www.libelium.com/uploads/2013/02/agriculture-sensor-board_2.0_eng.pdf

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Elitech RC-5 USB Temperature Data Logger LCD Display Temperature Recorder 32000 Points High Accuracy Reusable.

MEASUREMENTS

Air temperature and relative humidity, wind velocity and direction will be measured and recorded hourly (at least).

UNIT OF MEASUREMENT

Temperature in ºC and Relative Humidity in % and wind velocity in m/s

CALIBRATION / VERIFICATION

Calibration at laboratory.

STUDY SITES

a) Stretches of street where street shady structures or tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of street (street of similar width and with comparable building heights to intervention site and **orientation**) where street tree/green wall interventions are not proposed (**control study sites**). Control sites should be a sufficient distance away from intervention sites for the observations made to be considered independent from the effects of NBS.

NUMBER OF SAMPLES

At each study site and control site, a set of sensors will be installed at fixed height (between 1.5m, human height, and 3.5m, height to avoid vandalism) in different locations (same number in right and left side of the street) and avoiding estrange elements which can modify air conditions like exhaust part of an air conditioning or a shop door. This range of sampling point distances from proposed NBS reflects the scale at which measurable impacts are predicted relative to the size of street tree/green wall interventions proposed for Liverpool.

SAMPLING METHOD

Both intervention and matched control study sites should be monitor with the same schema during the same time (although with a lower number of sensor points). Each fixed sampling location at a study site should be sampled hourly (at least) for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

DATA PROCESSING

Calculation of dairy, weekly, monthly and annual mean levels (night and day) of temperature and relative humidity at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site before and after of the interventions.

Calculations for comparison purposes must be done using comparable periods of time before and after the interventions (i.e. if measurement period before of the intervention goes from nov18-oct19, measurement period must be from nov19-oct21 at least and processing can be done for either years or yearly).

SPATIAL ANALYSIS

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 latest stable version or QGIS 3 early release[11]). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

RESULTS

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\textbf{\textit{Temperature impact}} = \left(\frac{NBS\ Temp.average\ after\ intervent. - NBS\ Expected\ Temp.average\ after\ intervent.}{NBS\ Expected\ Temp.average\ after\ intervent.}\right) \times 100$$

Where *temperatures average after intervent.* Is the average value of measurements after interventions and *Expected temperature value after intervent.* (But supposing that interventions had not been done) is:

[11] Accessed: 18 Jun. 18

$$\textit{Temperature Expected average after intervent.} = \left(\frac{\textit{Ref.Temp.average after intervent.}}{\textit{Ref.Temp.average before intervent.}}\right) \times \textit{NBS Temp.average before intervent.}$$

Positive or null temperature impact values indicate negative or no impact of the NBS on average temperatures for that implementation. A negative value indicates a positive impact of that NBS on temperatures (and/or humidity, same procedure).

REFERENCES

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V.T. Ca, T. Asaeda, E.M. Abu, Reductions in air conditioning energy caused by a nearby park, Energy and Buildings 29 (1998) 83–92.

- **KPI-9: HEATWAVE RISKS NUMBER OF COMBINED TROPICAL NIGHTS AND HOT DAYS**

This indicator takes into account the number of combined tropical nights and hot days per city. Physical measurements of air temperature shall be performed. Comparison of risk with nearby areas of similar form with low/no NBS.

Considering different metrics per city, in the case of Liverpool (53°25’00”N 3°00’00”O), the metrics to follow are:

- 3 days >25Cº at day
- 3 days >18Cº at night

And in Valladolid (41°39’07”N 4°43’43”O) and Izmir (38°26’00”N 27°09’00”E) demonstrations the metrics are:

- 3 days >35Cº at day
- 3 days >20Cº at night

The unit proposed are ˚C per number of days and nights. An assessment of reduction of risk due to GI interventions, also modelled in GI-Val.

SENSOR

Air temperature sensor and external data source UK –Met office–

RELATED NBS

Tree related actions, Vertical green interventions, Green noise barriers, Green vertical mobile garden, and Green facade.

RATIONALE

Urban heat island (UHI) effect refers to the increased temperatures of urban areas compared to surrounding rural areas under a range of meteorological conditions. Temperatures of sealed urban surfaces such as roads and pavements can be significantly higher than air temperature due to the higher capacity of construction materials to absorb and retain heat, releasing it during the night. The UHI effect can exacerbate summer heatwave conditions, with a detrimental effect on human health. Vegetation is well known to mitigate the effects of UHI through the process of evaporative cooling; where leaf stomata open at periods of intense heat to release moisture into the air. Trees additionally contribute to reducing temperatures by providing shade, making public space and travelling routes more comfortable for people on summer days when temperatures in urban areas are high. We propose to a) evaluate the local impact of a number of individual NBS on air and surface temperatures and, b) assess the potential impact of NBS on heatwave risk at the sub-demo scale by modelling using GI-Val.

NBS TYPES

Green shady structures, Shade Trees, Cooling trees, Green Façade, and Green parking pavements.

MONITORING METHOD

1. Air temperature measurement

Physical air temperature measurements at GI locations and control sites without GI pre- and post-intervention can be obtained using a portable anemometer or standard outdoor thermometer. This is a cheap and simple method suitable for monitoring multiple fixed survey points over time.

2. Surface temperature

Thermal imaging camera to capture surface temperatures at GI locations and control sites without GI pre- and post-intervention. Thermograms should be taken under consistent emissivity settings and displayed using a consistent temperature scale. Relative contribution of different urban surfaces to the UHI effect may be inferred from difference in surface temperatures during hottest summer days. This is a relatively simple method suitable for comparing surface temperatures at multiple fixed survey points over time.

3. Reference data: air temperature

- A continuous air temperature data logger will be installed in each of the sub-demo areas to provide background data for air temperature in the shade.
- Air temperature data from the nearest Meteorological Office weather station.

DATA PROCESSING

Calculation of the number of tropical nights and heatwaves monthly (summertime) and yearly assessing hourly mean values of temperature at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site.

DATA ANALYSIS

1. Evaluate the local impact of individual NBS by comparing *a)* air temperatures and *b)* surface temperatures on hottest summer days at fixed sampling points at each NBS site selected for monitoring with those recorded at equivalent fixed sampling points at its matched control site; both pre- and post-NBS intervention. Temperature measurements at sampling points for each NBS should be taken on the same date and at similar times of day as measurements for its matched control site. Compare temperature values measured at NBS and matched control sites to background data for the same date and time from the nearest continuous temperature data logger (one situated in each sub-demo area), and to local Meteorological Office weather station temperature data.

2. Evaluate impact of NBS at a sub-demo or city-scale by using a model (STAR Tools) to estimate reduction in peak summer temperatures. Input: pre-intervention proportion of green space in the demo area and post-intervention increase in proportion of green space. The output of the model will be the predicted reduction in peak summer temperatures in the demo area modelled. From the modelled output, the potential impact of NBS on hypothetical heatwave conditions in the demo area modelled can be inferred.

The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They were created by The Mersey Forest and The University of Manchester, and can be found at https://maps.merseyforest.org.uk/grabs

REFERENCES

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- **KPI-13: USE OF STAR TOOLS TO CALCULATE PROJECTED MAXIMUM SURFACE TEMPERATURE REDUCTION (°C)**

The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They are freely available at http://maps.merseyforest.org.uk/grabs/. The surface temperature tool can be used to model the maximum surface temperature expected in a neighbourhood, taking into account the evaporative cooling effect of the vegetation. Since the implementation of nature-based solutions will usually result in an increase in vegetation cover, we should be able to see a decrease in the modelled maximum surface temperature under each climate change scenario (including the baseline).

The STAR Tools underlying models were used by The University of Manchester in the ASCCUE project where they were applied to Greater Manchester (Gill, 2006; Gill et al, 2007). They had previously been developed and used in Merseyside (Whitford et al, 2001). As part of the GRaBS project the surface temperature model was also used in Catania, Italy (Cuvato & Ianni, 2011). The surface temperature model was developed from an urban climate model used in Kuala Lumpur, Malaysia (Tso et al, 1991; 1990).

The following maps are an example of how the outputs from the surface temperature tool can be used. In Urban GreenUP, however, the areas of interest will likely be much smaller, and since the model is not well suited to very small areas, the number of subdivisions is likely to be much smaller as well.

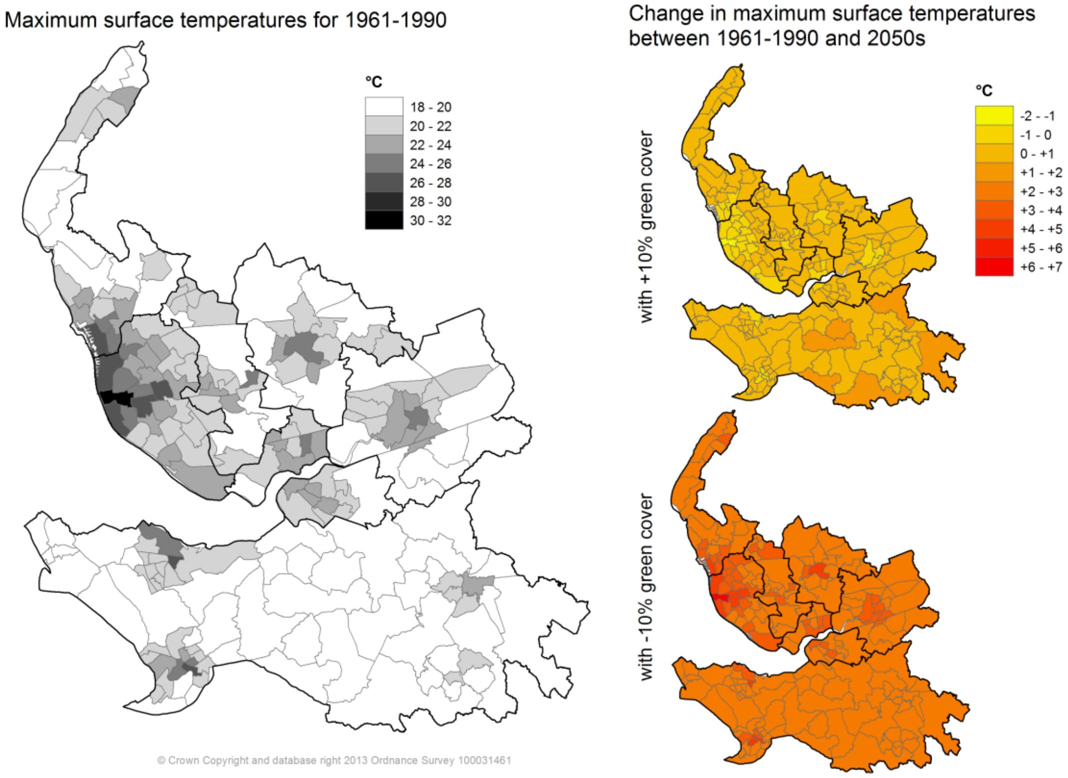

Figure 2.1: Example of a representation into a map of the KPI-13

RELATED NBS

All

METHOD

In the case of the Liverpool demo the sub-demo areas will be divided into study areas where groups of interventions have been made, and for each study area the pre- and post-intervention land cover will be calculated. The primary inputs for these calculations will be Ordnance Survey's MasterMap[12] and the landscape architects' drawings. The default temperature scenarios and other parameters will be used, as these are appropriate to North West England. Valladolid and Izmir demo shall adapt the methodology to their specific case.

2.1.2 CHALLENGE 2: WATER MANAGEMENT MONITORING PROCEDURES (VAL; LIV; IZM)

This challenge is subdivided by following types:

- Run-off coefficient in relation to precipitation quantities
- Absorption capacity of green surfaces, bio-retention structures and single trees
- Temperature reduction in urban areas
- Areas and population exposed to flooding
- Decrease in mean or peak daytime local temperatures
- Heatwave risks (number of combined tropical nights and hot days
- Use of STAR Tools to calculate projected maximum surface temperature reduction

- **KPI-16: RUN-OFF COEFFICIENT IN RELATION TO PRECIPITATION QUANTITIES**

In Valladolid demo, the KPI will be calculated based in a hydraulic model.

In the case of Liverpool, the use of Star Tools will be considered to model projected reduction in surface water run-off in demo areas as a result of NBS under various precipitation scenarios.

The metrics will be run off coefficient in terms of water volume or percentage (%).

RATIONALE

The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They are freely available at http://maps.merseyforest.org.uk/grabs/. The surface runoff tool can be used to model the volume and percentage of rainfall that will be converted to runoff in a neighbourhood, taking into account the various effects of the vegetation (interception, infiltration and storage). Since the implementation of nature-based solutions will usually result in an increase in vegetation cover, we should be able to see a decrease in the modelled surface water runoff under each precipitation scenario (including the baseline).

The STAR Tools underlying models were used by The University of Manchester in the ASCCUE project where they were applied to Greater Manchester (Gill, 2006; Gill et al, 2007). They had previously been developed and used in Merseyside (Whitford et al, 2001). The surface runoff

[12] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

model is based upon the US Soil Conservation Service approach (Soil Conservation Service, 1972).

RELATED NBS

SUDs, Natural Wastewater Treatment Plan, Rain Gardens, Floodable park, Green Parking pavements.

SENSOR/SOFTWARE

No sensor is required. Data are acquired by statistic and rainfall and soil available information in each intervention. The runoff reduction will be compared before and after the installation of the NBS to know if the intervention has influenced the study area. Spreadsheet software can be required.

METHODOLOGY

This is an estimated KPI using a cost-effective hydrologic model based on the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*).

The SCS-CN model is able to estimate the volume of runoff reduction by urban green spaces in each of the different sites where NBS´s will be allocated. The SCS-CN method has been used for a wide range of watershed areas, ranging from 0.25 ha to 1000 km^2, applied to various climatic zones and functions well both in natural or urban areas. *(Boughton, 1989; Ebrahimian et al., 2012; El-Hames, 2012; Baker and Miller, 2013).*

This model is based on empirical studies of ungauged watersheds to estimate runoff from rainfall events (*NRCS, 1986*). Minimal input data are needed to simulate direct surface runoff. Specifically, the calculations require only rainfall abstraction, without considering other complex factors such as groundwater recharge and baseflow (*Yao et al., 2015*).

Three parameters are used to calculate surface runoff: rainfall depth, initial abstraction of the rainfall, and the potential maximum storage of the soil (*Boughton, 1989*).

Daily rainfall data from each intervention site are needed to calculate runoff. In case of the interventions developed in Spain, rainfall data can be obtained from the *AEMET* Service.

In the case of Liverpool the approach will be focused in the sub-demo areas and will be divided into study areas where groups of interventions have been made, and for each study area the pre- and post-intervention land cover will be calculated. The primary inputs for these calculations will be Ordnance Survey's MasterMap[13] and the landscape architects' drawings. The hydrological soil types will be derived from data from the National Soil Resources Institute at Cranfield University[14]. The default precipitation scenarios and other parameters will be used, as these are appropriate to North West England.

RUNOFF REDUCTION CALCULATION

[13] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

[14] www.landis.org.uk/data/index.cfm

Since the reduction of surface runoff is achieved by replacing fully impervious surfaces with urban green spaces, two variables have been defined to evaluate the potential hydrologic benefits of runoff reduction: the total amount of runoff reduction due to urban green spaces (ΔV) and the runoff reduction coefficient (Cr).

- **DV**, as defined by *Zhang et al., 2012*, is used to represent differences in total runoff reduction volume and characterize the general benefit provided by URBAN GreenUP interventions in terms of reducing rainfall-runoff.

- **Cr** is similar to the runoff coefficient (runoff depth/rainfall depth) (*Weng, 2001; Costa et al., 2003*) and is generated by dividing DV by the total amount of rainfall in a specific area. Unlike DV, Cr represents differences in runoff reduction efficiency.

- **KPI-20: ABSORPTION CAPACITY OF GREEN SURFACES, BIO-RETENTION STRUCTURES AND SINGLE TREES**

RATIONALE

The use of urban greenspace, in particular urban forests, is increasingly being identified as a tool to reduce runoff and so mitigate the negative effects of urbanization upon the hydrology of urban areas (Bartens *et al*., 2008). Rainwater which lands on trees either evaporates to the air or drips down to the ground below, where it can soak into the soil. Surface water from nearby areas can also flow into the permeable area around the trees, which further increases the amount of water that can soak away and reduces demand on stormwater drains.

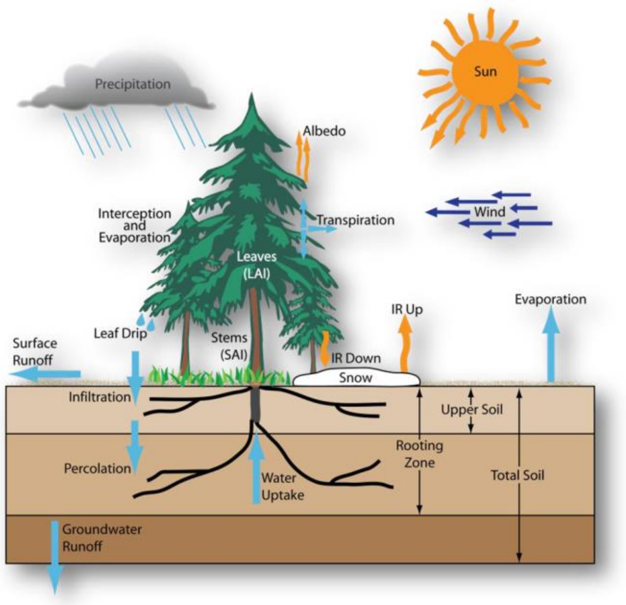

Figure 2.2: Water balance in green areas (Source: USGS)

The absorption capacity of a green area /NBS is then related to the soil infiltration and retention capability and the interception of the rainfall and evapotranspiration by the vegetation.

This indicator can be applied at urban/street/building scale depending on the scale of intervention of the NBS to be assessed.

NBS TYPES

Natural wastewater treatment, Floodable Park, tree related actions, green filter area, rain garden, SUDs, Green parking pavements, electrowetland.

SENSOR/SOFTWARE

No sensor is required. Data are acquired by statistic and rainfall and soil available information in each intervention. The runoff reduction will be compared before and after the installation of the NBS to know if the intervention has influenced the study area. Spreadsheet software can be required.

METHODOLOGY

This is an estimated KPI using the water balance approach to calculate the absorption capacity of the NBS by comparing precipitation and runoff data for watersheds. Concretely, the difference between the rainfall in a storm event (mm/m^2) and the runoff produced (mm/m^2) is the water retained by the green/vegetated area. This KPI is directly related to KPI 16 *RUN-OFF COEFFICIENT IN RELATION TO PRECIPITATION QUANTITIES* as the estimation of the runoff is based on the on the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*). This common methodology facilitates the evaluation of the efficiency of the NBS implemented (after and before).

Meteorological data (daily rainfall and temperature) can be obtained directly from the Spanish Meteorological Agency- *AEMET*. Rainfall rate and rainfall event timings shall be recorded, if possible. Temperature will also be recorded. If data is not available from the official network of meteorological stations of the National Agency, then a simple meteorological station will be place in the surroundings of the NBS to be monitored.

As mentioned above, the surface runoff is calculated according to the Soil Conservation Service Curve Number (SCS-CN) method (*NRCS, 1986*). The runoff curve number is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area.

The runoff curve number is based on the area's hydrologic soil group, land use, treatment and hydrologic condition. Three parameters are used to calculate surface runoff: rainfall depth, initial abstraction of the rainfall, and the potential maximum storage of the soil (*Boughton, 1989*). The equations for the SCS-CN model are as follows (*NRCS, 1986*):

$$Q = \begin{cases} (P - I_a)^2/(P - I_a + S), & P \geq I_a \\ 0, & P < I_a \end{cases}$$

$$S = \frac{25,400}{CN} - 254$$

$$I_a = \lambda \cdot S$$

Where:

- Q: the runoff depth (mm).
- P: the rainfall depth (mm).
- I_a: the initial abstraction of the rainfall (mm).
- S: represents potential maximum soil−water capacity.
- λ: The initial abstraction coefficient which is a constant, usually defined as 0.2 (*El-Hames, 2012; Kadam et al., 2012; Singh et al., 2013*).
- CN: is a dimensionless parameter, ranging from 0 to 100. The US Natural Resources Conservation Service (NRCS) has developed CN values for various land-cover categories based on their hydrologic characteristics. The lower the curve number, the more permeable the soil is.

As can be seen in the curve number equation, runoff cannot begin until the initial abstraction has been met. It is important to note that the curve number methodology is an event-based calculation, and should not be used for a single annual rainfall value, as this will incorrectly miss the effects of antecedent moisture and the necessity of an initial abstraction threshold.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting.

Cover description: Cover type and hydrologic condition	Average percent impervious area [2]	Curve numbers for hydrologic soil group: A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1] Average runoff condition, and $I_a = 0.2S$.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2.2: Runoff curve numbers for urban areas (NRCS, 1986)

NRCS classified the antecedent moisture condition –AMC- as “dry conditions” (AMC I), “moderate/normal conditions” (AMC II), and “wet conditions” (AMC III) to represent the relative moisture of the pervious surfaces prior to the rainfall event (*NRCS, 1986*). Therefore, the determination of the AMC of each rainfall event will depend on rainfall amount during the previous 5 days and the season.

The **absorption capacity** of the NBS /green area will be then calculated as the difference between the rainfall and the subsequent surface runoff in a specific storm event.

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- **KPI-22: TEMPERATURE REDUCTION IN URBAN AREAS**

RATIONALE

Green and blue urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapotranspiration, which leads to two benefits: improved thermal comfort and reduced energy use. We address the thermal comfort and reduced energy benefits via physical indicators such as ambient temperature, turbulent fluxes and energy savings.

This indicator can be applied at street/building, neighbourhood or city scale depending on the scale of intervention of the NBS to be assessed. Monitoring schemes will depend on the scale of the intervention.

In this KPI, mean and peak daytime local temperatures will be calculated and used to assess the impact of the NBS. This KPI includes the measurement and calculation of mean and daytime local relative humidity to complete the study.

RELATED NBS

Natural wastewater treatment, Floodable Park, Urban catchment forestry, Green filter area.

METHOD

BACI (Before, After, Control, Impact)

Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously.

As previous work, temporal series of temperature and relative humidity will be studied in order to define peak times and values and mean values of historical data (at night and daytime) for the city in the RCCAVA areas (According its characteristics). This study will serve to stablish a general baseline for the city. On the other hand, RCCAVA measurements will be used as additional references of non-intervention areas.

NULL HYPOTHESIS

There is no difference in air temperatures and relative humidity between samples in stretches of street where green shady structures, street trees/green walls, etc. are present, and samples or measurements taken in stretches of streets without the NBS.

SENSOR / SOFTWARE

Monitoring equipment. Wireless samplers to hang from street lamps or other urban furniture without carrying out works (low weight and low visual impact).

EXAMPLES

The Smart Agriculture models allow to monitor multiple environmental parameters involving a wide range of applications. It has been provided with sensors for air and soil temperature and humidity, solar visible radiation, wind speed and direction, rainfall, atmospheric pressure, etc.

http://www.libelium.com/uploads/2013/02/agriculture-sensor-board_2.0_eng.pdf

Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Price around 1.500€.

Elitech RC-5 USB Temperature Data Logger LCD Display Temperature Recorder 32000 Points High Accuracy Reusable.

https://www.elitechonline.co.uk/RC-5

Price around 25€ (amazon)

Measurements

Air temperature and relative humidity will be measured and recorded hourly (at least).

Unit of measurement

Temperature in ºC and Relative Humidity in %.

Calibration / Verification

Calibration/verification at laboratory.

Study sites

a) Stretches of street where street shady structures or tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of street (street of similar width and with comparable building heights to intervention site and **orientation**) where street tree/green wall interventions are not proposed (**control study sites**). Control sites should be a sufficient distance away from intervention sites for the observations made to be considered independent from the effects of NBS.

Number of study sites

This is to be discuss at this stage.

Number of samples

At each study site and control site, a set of sensors will be installed at fixed height (between 1.5m, human height, and 3.5m, height to avoid vandalism) in different locations (same number in right and left side of the street) and avoiding estrange elements which can modify air conditions like exhaust part of an air conditioning or a shop door. This range of sampling point distances from proposed NBS reflects the scale at which measurable impacts are predicted relative to the size of street tree/green wall interventions proposed for Liverpool.

DATA SAMPLING

Both intervention and matched control study sites should be monitor with the same schema during the same time (although with a lower number of sensor points). Each fixed sampling location at a study site should be sampled hourly (at least) for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

DATA PROCESSING

Calculation of dairy, weekly, monthly and annual mean levels (night and day) of temperature and relative humidity at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site before and after of the interventions.

Calculations for comparison purposes must be done using comparable periods of time before and after the interventions (i.e. if measurement period before of the intervention goes from nov18-oct19, measurement period must be from nov19-oct21 at least and processing can be done for either years or yearly).

Spatial Analysis software

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

RESULTS

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections. Quantitative assessment will be done by using the following expression:

$$\textbf{Temperature impact} = \left(\frac{NBS\ Temp.average\ after\ intervent. - NBS\ Expected\ Temp.average\ after\ intervent.}{NBS\ Expected\ Temp.average\ after\ intervent.}\right) \times 100$$

Where *temperatures average after intervent.* is the average value of measurements after interventions and *Expected temperature value after intervent.* (but supposing that interventions had not been done) is:

$$\textbf{Temperature Expected average after intervent.} = \left(\frac{Ref.Temp.average\ after\ intervent.}{Ref.Temp.average\ before\ intervent.}\right) \times NBS\ Temp.average\ before\ intervent.$$

Positive or null temperature impact values indicate negative or no impact of the NBS on average temperatures for that implementation. A negative value indicates a positive impact of that NBS on temperatures (and/or humidity, same procedure).

REFERENCES

EKLIPSE Report.

Demuzere et al., 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management 146, 107-115

Yu, C., Hien, W., 2006. Thermal benefits of city parks. Energy Build. 38 (2), 105-120.

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- **KPI-29: AREAS AND POPULATION EXPOSED TO FLOODING**

This KPI can evaluate the increasing on green areas and its relation with the flooding risks. This indicator has been mainly defined for the floodable park but it could also be applied to scale the impact of other types of NBS on areas and population exposed to flooding.

RELATED NBS

This KPI affects NBS involving horizontal green infrastructures, especially the floodable park.

SENSOR/SOFTWARE

No sensor is required.

Data needed to assess this KPI will be acquired though rainfall information provided by *AEMET*; digital land cover maps from *CORINE* land *cover project;* demographic data from the municipality of Valladolid; and size and topography from digital elevation models (DEM) of each intervention.

The areas and population exposed to flooding will be compared before and after the installation of the NBS to know if the intervention has influence in mitigating effects from flood risks.

In order to estimate this KPI, the use of a numerical model for simulation of turbulent free surface unsteady flow and environmental processes in river hydraulics is proposed.

It is in this regard that Iber software (version 2.4.3) is seen as a good option to achieve the pretended output results of this KPI.

Iber is a free software whose range of application covers river hydrodynamics, dam-break simulation, flood inundation modelling, sediment transport calculation and tidal currents in estuaries.

Furthermore, at European level, the European Commission approved in November 2007 the Directive 2007/60/EC on the assessment and management of flood risks. Basically, the aim of this European Directive is to reduce and manage the risks that floods involve to human health, the environment, cultural heritage and economic activity. These regulations require Member States to conduct a series of steps which are briefly explained in the lines below:

In the first place, Member States would have carried out a Preliminary flood risk assessment by 22 December 2011. It is essential that action will only be taken in areas where potential significant flood risks exist or are reasonably foreseeable in the future. For that purpose, based on available or readily derivable information, such as records and studies on long term developments, in particular impacts of climate change on the occurrence of floods, a preliminary flood risk assessment shall be undertaken by Member States in order to provide an assessment of potential risks. The city of Valladolid is among one of those areas due to the influence of the rivers Pisuerga and Esgueva.

Secondly, Member States would have also prepared flood hazard maps and flood risk maps, at the most appropriate scale for those areas identified in the preliminary flood risk assessment by 22 December 2013.

These flood hazard maps and flood risk maps were developed in order to increase public awareness; support the process of prioritizing, justifying and targeting investments and developing sustainable policies and strategies; and support flood risk management plans, spatial planning and emergency plans.

Flood hazard maps cover the geographical areas which could be flooded according to the following scenarios:

- Floods with a low probability, or extreme event scenarios (return period = 500 years).
- Floods with a medium probability (likely return period ≥ 100 years).
- Floods with a high probability (return period = 10 years), where appropriate.

For each scenario studied the following elements shall be taken into account:

- The flood extent.
- Water depths or water level, as appropriate.
- The flow velocity or the relevant water flow, where appropriate.

On the other hand, flood risk maps show the potential adverse consequences associated with flood scenarios referred to potential significant flood risks areas and expressed in terms of the following:

- The indicative number of inhabitants potentially affected.
- Type of economic activity of the area potentially affected.
- Installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (1) which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC.
- Other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

In this regard, and for those NBS located in the city of Valladolid, flood hazard maps and flood risk maps of Pisuerga and Esgueva rivers as they flow through Valladolid for a 10 and 100 years return period flooding would be used to assess and quantify this KPI for the initial situation prior to the implementation of the NBS considered.

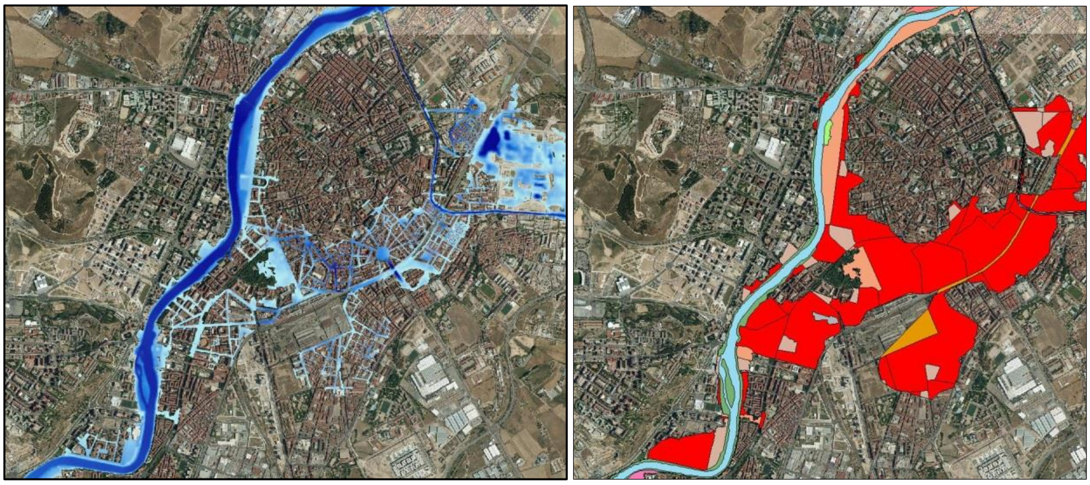

Figure 2.3: Flood hazard map and flood risk map, respectively, of Pisuerga and Esgueva rivers as they flow through the city of Valladolid for a 100 years return period flood.

The SNCZI, promoted by the Ministry of Agriculture and Fisheries, Food and Environment, compiles all these flood hazard maps and flood risk maps already carried out and those which will be prepared in the future in order to implement a tool to facilitate its consultation and management.

METHODOLOGY

As explained in the previous paragraphs, a numerical model for hydraulic simulations will be applied to assess this KPI for the situation after the implementation of the NBS that is pretended to be studied. Main steps to build and run a hydraulic simulation in Iber software is shown below (extracted from *Iber user´s manual*) and *Bladé et al. (2014)*:

1. **Create or import a geometry of the study Area:** The study area of the NBS that is pretended to be assessed is the entire land area draining to the stream reach or sewer point of interest. Iber presents a user interface in which geometries can be created from scratch, drawing points (directly in the screen or entering coordinates), lines and surfaces. At the same time, different standard geometry formats can be imported (.dxf, .shp, among others). Finally, digital terrain models can be imported from Arc Info ASCII format files.

2. **Assign a series of input parameters:** Bed roughness, turbulence model and other hydraulic parameters are needed at this step to create the numerical model. Also, boundary and initial conditions need to be assigned.

3. **Build a numerical mesh:** The numerical mesh is a key element in order to obtain good results from the computation. In Iber there are various ways of getting a good computational mesh. Depending on the characteristics of the problem, the choice of a specific mesh type can produce better results and reduce the computational time. Iber can work with triangular or quadrilateral elements, or with mixed meshes. The

computational meshes can be regular or irregular, as well as structured or non-structured.

4. **Run the computation:** To launch a computation, all the input computation parameters must be set beforehand. At this step, it is also necessary to set the problem data (time of calculation, numerical scheme parameters, and additional modules requirements, among others).

5. **Results visualization:** Once the computation is over, or even during the simulation process, the post-process interface can be accessed in order to visualize and analyze the results. Moreover, Iber allows exporting the results in Arc Info ASCII grid format.

RESULTS

Flood hazard maps and flood risk maps will be developed and then compared quantitatively in two scenarios (before and after the installation of the NBS) for each intervention.

As explained in previous lines, data according to the initial situation prior to the implementation of the NBS located in the city of Valladolid are already available at the *SNCZI* website (http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI) for both 10 and 100 years return period flooding.

In this website, there are different layers which show flood extent, water depths, number of inhabitants potentially affected or type of economic activity of the area potentially affected, among others, for potential floods with different return periods. These data are useful to assess the current status of the area.

The following table shows the results extracted from SNCZI regarding the assessment of this KPI for the initial situation before the implementation of the NBS located in the city of Valladolid:

KPI description	Data values (initial situation)
Area (Ha) and population (inhab) exposed to flooding in the city of Valladolid.	340 Ha and 54.424 inhabitants (10 years return period flood) 620 Ha and 99.312 inhabitants (100 years return period flood) 1.497 Ha and 239.672 inhabitants (500 years return period flood)

Table 2.3: Area (Ha) and population (inhab) exposed to flooding in the city of Valladolid before the development of the NBS´s.

For the evaluation of this KPI after the implementation of the NBS´s located in Valladolid, different maps, tables and graphs extracted from the post-process interface of Iber software as well as demographic data from the municipality of Valladolid will be the base to develop flood hazard maps and flood risk maps and thus, obtain the following data:

Area (ha) exposed to flooding: This value represents the surface of land expressed in hectares (ha) that is flooded for the different scenarios considered (10, 100 and 500 years return period).

Population (inhab) exposed to flooding: This value represents the number of citizens living in parts of land that are flooded for the different scenarios considered (10, 100 and 500 years return period).

Finally, the higher decrease in both area (ha) and population (inhab) exposed to flooding when comparing the values prior and after to the implementation of the NBS considered, the greater potential benefits in mitigating flood risks will be achieved.

REFERENCE

- AEMET (Agencia Estatal de Meteorología): http://www.aemet.es/es/portada.
- Bladé, E., Cea, L., Corestein, G., Escolano, E., Puertas, J., Vázquez-Cendón, E., Dolz, J., Coll, A., 2014. Iber: herramienta de simulación numérica del flujo en ríos. Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería, Volume 30, Issue 1, 2014, Pages 1-10, ISSN 0213-1315, DOI: 10.1016/j.rimni.2012.07.004
- Iber user´s manual: http://iberaula.es/space/54/downloads
- SNCZI (Sistema Nacional de Cartografía de Zonas Inundables): http://sig.mapama.es/snczi/visor.html?herramienta=DPHZI

- **KPI-33: DRINKING WATER PROVISION**

Measurement method for the drinking water supplied to the consumers is direct measurement with the help of water meters. Each consumer has their own meters so, it is possible to measure the provision in terms of amount of water per flat, building and/or any other facilities. With this detailed monitoring consumption of the water can be calculated as $m^3 * ha^{-1} * year^{-1}$. The image and technical specifications of the water flow meter can be seen below:

Figure 2.4: Image of the water flow meter

Nominal diameter	mm	15	20
Nominal flow rate	m^3/h	2.5	4
Maximum flow rate	m^3/h	3.125	5
Minimum flow rate	l/h	15.6	25
Maximum operation pressure	bar	16	16

Pressure loss	bar	0.63	0.63
Maximum water temperature	°C	50	50
Total length of meter	mm	190	190

Table 2.4: Technical Specifications of water flow meter

Apart from supplied water, volume of available drinking water is calculated with the measurement of height of water in dams and water wells. Dimensions of the dams and wells are known and the height of water gives the current volume and occupancy rate of dams. The volume and the occupancy rate can be monitored on the website of Izmir Water and Sewerage Administration.

RELATED NBS

Tree related actions; SUDs; NWTP; Rain Gardens; Floodable park; Green Parking pavements; Electro wetland

REFERENCES

1- IZSU 2017 Activity Report
http://www.izsu.gov.tr/siteitems/documents/FaaliyetRaporlari/2017YiliFaaliyetRaporu.pdf

2- http://www.teksan.com.tr/tv.html

3- http://www.izsu.gov.tr/Pages/DamStatusBsd.aspx

- **KPI-34: WATER FOR IRRIGATION PURPOSES**

Some NBS are able to treat wastewater at the time other ecosystem services are provided. As a function of the effluent quality, several uses for the regenerated wastewater can be considered, one of which is for irrigation purposes.

Every country has its own specific law regarding the water quality limits that must be fulfilled depending on the final use of the treated wastewater.

Considering the nature of the NBS implemented and the potential uses of the treated wastewater generated, some of the uses considered in the Spanish law were selected and summarized in the Table below in Valladolid demo. Mainly, agricultural, industrial and environmental uses were rejected while urban uses considered the most probable.

URBAN USES
WATER QUALITY 1.2: SERVICES a) Green urban areas irrigation (parks, sports camps and similar areas). [1] b) Street washing [1] c) Fire extinction systems [1]

[1] *When exists a water use that can imply water aerosolisation, it is cumpolsory to follow the usage conditions established, in each case, by the sanitary authority. Without the compliance of those conditions, the esmented water use will not be authorised.*

Table 2.5: Table with properties of the new variable obtained

METHOD

BACI (Before, After, Control, Impact)

Treated wastewater will be reused to irrigate the surrounding gardens. Reclaimed wastewater flow will be quantified by means of flowmeters placed at the effluent of the treatment line. Volumes of reused wastewater for irrigation purposes will be compared to the irrigation volumes of tap water used before for that aim. The surface irrigated with reclaimed water will be also measured. Required water quality parameters will be analysed from samples of treated wastewater to guarantee legislation fulfilment.

NULL HYPOTHESIS

Treated wastewater does not fulfil the legislation limits established for water reutilization for irrigations purposes (Table 2).

WATER VOLUME SENSOR

Monitoring equipment: two different flowmeters permanently installed at the influent and the effluent of the treatment line.

DATA

Data sampling

Continuous monitoring (sensors and water samples) at the outflow and the inflow of the NWWTP.

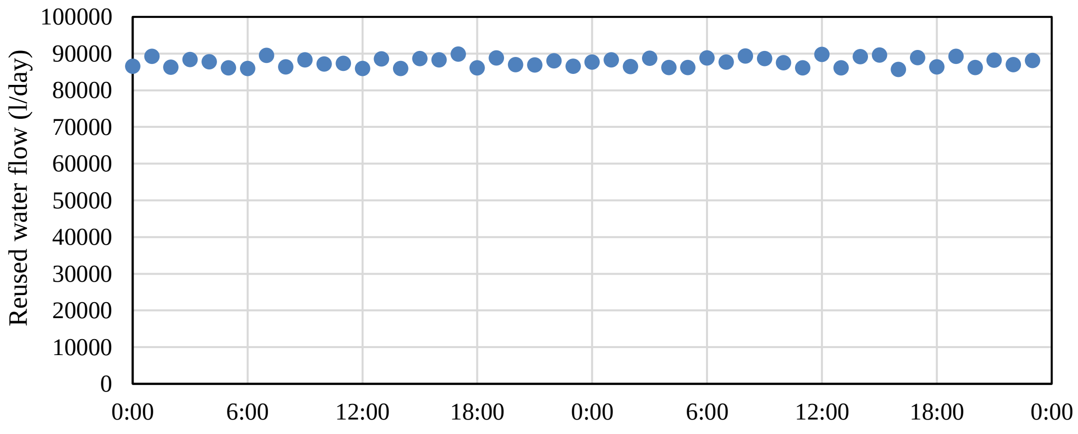

Figure 2.5: data example of reused water flow

Data processing

Calculation of (weekly, monthly and/or yearly) mean levels of reused water volumes.

Volumes of reused wastewater will be normalized to the NBS surface in order to make the KPI comparable to other NBS which also generate reused wastewater for irrigation purposes.

RESULTS

At the location where NWWTP will be located there was no reused wastewater generation before the intervention. Therefore, this KPI constitutes an absolute value of volume of reused wastewater.

REFERENCES

Greyline (2017). Precision Flow Measurement. Available at: http://www.greyline.com

REAL DECRETO 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas

RELATED NBS

The Natural Wastewater Plant Treatment is a NBS based on the concept of the Waterharmonica in its design.

- **KPI-38: VOLUME OF WATER REMOVED FROM WATER TREATMENT SYSTEM**

RATIONALE

Green infrastructure can prevent rainfall from entering the water treatment system by allowing it to soak into the soil or to evaporate back into the air. GI-Val tool 2.1 can be used to model the volume and percentage of rainfall that is affected in these ways, and to put a monetary value on part of the benefit: the energy and carbon emission savings.

In the case of Valladolid, storm water, domestic sewage and industrial wastewater are collected through a combined sewers system which transports all the wastewater to a sewage treatment plant. The wastewater treatment plant (WWTP) of Valladolid has a treatment capacity for 570,000 population equivalent (future extension up to 750,000 pe) and a maximum flow rate 3 m^3/s. The foreseen reduction in the surface runoff by the implementation of the different NBS in Valladolid city will reduce the total volume of wastewater collected though the sewers system and, therefore, the volume of water to be treated at the WWTP. Thus, will suppose an important economic savings.

MEASURED METHOD

Direct measurement of water flow pre and post intervention. Create local urban catchment hydrograph for demonstration site. Model projected savings (Euro) using GI-Val. Discharge data for storm water (m^3) from United Utilities.

RELATED NBS

Smarts soils as substrate, SUDS and raingardens, tree related actions, GI horizontal, Floodable Park.

METHOD

There are two options here: either directly measure changes in flow, convert them to changes to the runoff volume/percentage, enter them into GI-Val, or use GI-Val solely to estimate the monetary value; or model the changes to the runoff volume/percentage in GI-Val as well, thus reducing the need for direct measurements and their conversion.

If the second option is pursued, the sub-demo areas will be divided into study areas where groups of interventions have been made, and for each study area the pre- and post-intervention land cover will be calculated. In the specific case of Liverpool demo the primary inputs for these calculations will be Ordnance Survey's MasterMap[15] and the landscape architects' drawings. The hydrological soil types will be derived from data from the National Soil Resources Institute at Cranfield University[16]. Precipitation data will be sourced from the Met Office[17].

In the case of Valladolid, the volume of water retained by the NBS will be estimated through KPI 16 and 20. Then, this volume of water (m^3/ year; m^3/month), which is not diverted to the sewer system, will be multiplied by the annual costs of water treatment (€/m^3 of wastewater treated). The actual costs of the water treatment will be provided by AQUAVALL (the public company which manages the urban water cycle in Valladolid).

- **KPI-39: VOLUME OF WATER SLOWED DOWN ENTERING SEWER SYSTEM**

This KPI is principally based on investigating rate change in runoff production at field or plot scale. The parameters under principle investigation are discharge (m^3 sec^{-1}) and flow velocity (m sec^{-1}), which when plotted on a storm-hydrograph, ought to demonstrate the following changes between the baseline and post GI scenario:

i) An increased lag-time (L), the time of peak rainfall to peak discharge and,
ii) Reduced peak discharge (Q_p)

KPI SCOPE

Evapotranspiration (ET) (mm sec^{-1}) and interception rates will not be directly observed under this KPI, through various processes, both are implicit in reducing inflow rates into sewers. ET represent system losses of groundwater, potentially lowering wetted fringe and water table that is hypothesised to reduce soil moisture and increase infiltration – a useful GI service if permeable paving is installed.[18]

KPI METHOD

I) Source local tipping bucket rainfall data (P), from Liverpool University weather observatory, scale P rates to study site area.

[15] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

[16] www.landis.org.uk/data/index.cfm

[17] http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html

[18] Hankin B, Craigen I, Chappell NA et al. (2016) Strategic Investigation of Natural Flood Management in Cumbria. Jeremy Benn Associates, Skipton, UK. See http://naturalcourse.co.uk/uploads/2017/04/2016s4667-Rivers-Trust-Life-IP-NFM-Opportunities-Technical-Report-v8.0.pdf (accessed 02/02/2018).

II) Determine inflow and outflow points to a given locality of GI interventions, established from surface water flood mapping (Environment Agency RoSWFM/JFLOW[19]) and overland flow routing model[20]

III) Apportion percentage inflow and outflow to the boundary of the plot or field-scale site under investigation.

IV) At the area of largest or principle inflow and outflow, install a gauging station, with one or more mid-point gauging stations along the overland flow-pathway and proposed GI corridor, to augment boundary observations, creating a longitudinal chain of continuous discharge observation.

V) Conduct continuous discharge monitoring through the baseline and post-intervention scenario to tests the effects of GI on increased lag-time and reduced Q_p.

APPARATUS

Open Pipe

I) V-notch gauging station weir with stilling well and spot discharge measurement to establish stage-discharge relationship, and therefore continuous discharge, extrapolated from 5 minute water-level (stage).

II) Non-contact flow measurement – Particle Image Velocity [21]and infa-red height sensors to continually monitor height and velocity, over a known cross sectional area. Together these observations can combine to create a continuous discharge data-series.

Closed Pipe

i) Ultrasonic Flow Meters, see example here: http://www.rshydro.co.uk/liquid-pipe-flowmeters/

RELATED NBS

Tree related actions; SUDs; horizontal GI, Tree related actions, SuDs /Raingarden, Horizontal green interventions, natural flood management techniques.

2.1.3 CHALLENGE 4: GREEN SPACE MANAGEMENT MONITORING PROCEDURES

This challenge is subdivided by following types:

Social indicators

- Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014).
- Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al. 2015)

Environmental indicators related to biological aspects

[19] https://www.gov.uk/government/publications/flood-risk-maps-for-surface-water-how-to-use-the-map

[20] http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/stream-order.htm

[21] http://meetingorganizer.copernicus.org/EGU2015/EGU2015-8582.pdf

- Production of food (ton/Ha/year)
- Increased connectivity to existing GI
- Pollinator species increase (number)

- **KPI-53: ACCESSIBILITY OF URBAN GREEN SPACES FOR POPULATION**

KPI DEFINITION

Calculation of the shortest distance (linear) between the population in the NBS (line type), and the NBS location centroid. This social indicator evaluates the accessibility of urban green spaces for population in terms of total distance or time.

RELATED NBS

This KPI affects NBS involving green infrastructures, either horizontal or vertical, such as:

New green cycle lane and re-naturing existing bike lanes: Green cycle lane; Green resting areas; Cycle-pedestrian green paths. Vertical green interventions. Horizontal green interventions. Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock. Educational activities: Educational paths (A, C); Urban farming educational activities. Tree related actions for Liverpool

TOOL/SENSOR

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. QGIS is the GIS software proposed to be used, due to it being an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA).

METHOD

Data processing using QGIS has been designed to obtain one KPI value for the whole city. In addition, a neighbourhood level study is also recommended in order to find deficient areas.

The first step is obtain a shape file in which each Entryway is linked to its nearest GI, throughout the tool Distance to the nearest hub. As a result, a new shape-file is obtained with an attribute field containing the measured distance in meters.

In order to obtain this KPI in terms of time, Field calculator tool can be used. A conversion factor has to be set to measure a pedestrian walking speed. Bosina et al (2017) sets the average for pedestrian speed walking in Spain were 1.59 m/s, which means 95.4 m/min. So the distance value in minutes can be obtained dividing by this value.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
Distance to nearest GI.	Entryways linked to its nearest Green infrastructures (line).	m	Shapefile – Polyline	Derived variable obtained by GIS processing.
Time to nearest GI.	Entryways linked to its nearest Green infrastructures (line).	min	Shapefile – Polyline	Derived variable obtained by GIS processing.

Table 2.6: Table with properties of the new variable obtained

Overall statistics can also be calculated by a QGIS tool called Basic statistics for numeric fields. The result of this tool is a table (not GIS data), with resume figures of both terms of the KPI, including minimum and maximum values, range, mean and median value, standard deviation and coefficient of variation.

VARIABLE	DESCRIPTION	UNIT	SOURCE TYPE	NOTES
KPI 053 (1)	Accessibility (measured as distance) of urban green spaces for population.	m	table	Derived variable obtained by GIS processing.
KPI 053 (2)	Accessibility (measured as time) of urban green spaces for population.	min	table	Derived variable obtained by GIS processing.

Table 2.7: Inputs provided for the KPIs calculation

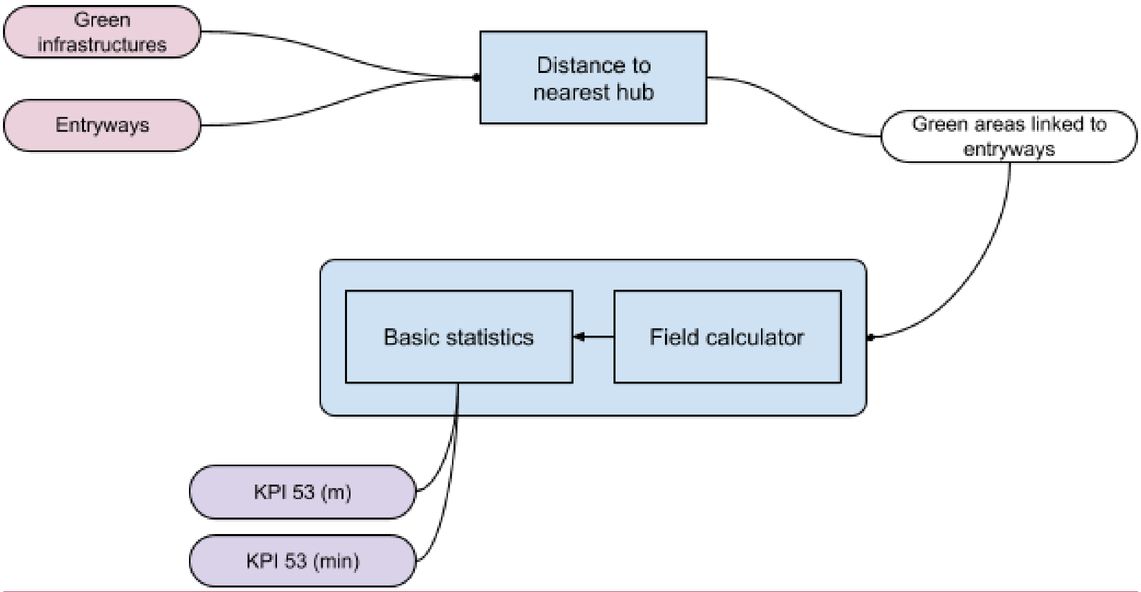

Figure 2.6 Algorithm for this described process

RESULTS

Two final figures are obtained at the end of the process for this KPI. One of them shows the accessibility for green areas in terms of total distance (m), and the other shows the accessibility for green areas in terms of total time (min).

Tamosiunas et al (2014) classifies the accessibility to green parks using a tertiles method. As a result, they obtained 3 categories showed in the table below. A tertiles distribution is also proposed to use in this case.

CATEGORY	HIGH	MODERATE	LOW
Distance	≤347.8 m	347.81–629.6 m	≥629.61 m

Table 2.8: Tamosiunas et al (2014) classification of the accessibility to green parks

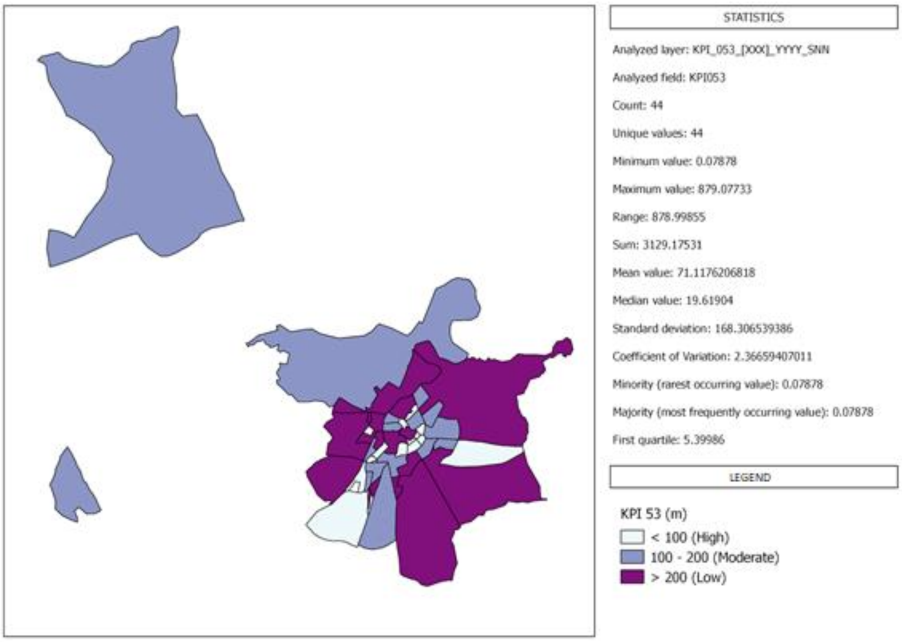

Figure 2.7: Example of classification in a map

REFERENCES

QGIS 3 – Userguide. https://www.qgis.org/en/site/

Spatial Reference - Howard Butler, Christopher Schmidt, Dane Springmeyer, and Josh Livni http://spatialreference.org/

Inspire Knowledge Base - https://inspire.ec.europa.eu/

Tamosiunas, A., Grazuleviciene, R., Luksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., Vencloviene, J., Bernotiene, G., Radisauskas, R., Malinauskiene, V., Milinaviciene, E., Bobak, M., Peasey, A., Nieuwenhuijsen, M.J., 2014. Accessibility and use of urban green spaces, and cardiovascular health: Findings from a Kaunas cohort study. Environ. Heal. 13, 20. doi:10.1186/1476-069X-13-20

Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L. and Calfapietra, C. (2017) An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom

- **KPI-60: WEIGHTED RECREATION OPPORTUNITIES PROVIDED BY URBAN GREEN INFRASTRUCTURE**

This KPI aims to measure the increase of opportunities related to green infrastructures (Derkzen et al. 2015), being valued for recreation, social interaction, education and supporting healthy living (satisfaction).

Recreation opportunities are based on the different types of urban green infrastructure's degree of naturalness, aesthetics-scenic beauty, and presence of water. A score or weight (in the 0–5 range Likert-scale) assigned to these factors standing for their relative importance or impact in terms of recreation potential. The definition of scores was based on a consultation process via focus group. Alternatively, In case of no consensus for a specific score, a compromise value can be agreed (e.g., average value of suggested scores or sum of voting scores).

Baseline and post-intervention measurements of engagement with NBS through walking and cycling, types of activity undertaken in/with NBS (other than walking and cycling), frequency of interaction with NBS. Reported as frequency count data (interactions/week) (number of visitors, number of recreational activities) (Number of cultural events, people involved, and children in educational activities) value (Kabiisch and Haase 2014).

Surface measurements shall be calculated with Geographical Information Systems (GIS). A Social Survey shall be calculated with the measurement of a questionnaire through standard software (Excel or SPSS). The units to have into account shall be: for the Green corridor distance, km); Users, number; Satisfaction, through surveys; Cycle lane, green corridor distance in meters; Number of people who use green corridor, number of users.

RELATED NBS

Tree related actions; Green cycle lane/pedestrian route/road traffic junction improvements. Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock. Educational activities: Educational paths (A, C); urban farming educational activities.

- **KPI-73: PRODUCTION OF FOOD**

Production of food in urban orchards (agriculture, eggs, etc.). Measurement of the amount of food produced. The production of food will be measured by tones/Ha per year.

RELATED NBS

Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock

METHODOLOGY

Measurement of the amount of food produced. If it cannot be measured, an estimate of the amount generated will be made.

Users will be asked directly using surveys.

MONITORING EQUIPMENT / SOFTWARE

Online surveys.

DATA PROCESSING

Sum of the KG per user in yearly bases.

RESULTS

Kg/Ha year: Kg produced per Ha of the orchard yearly.

REFERENCES

Ecological orchards of Valladolid (2016-2017)
http://www.valladolid.es/es/actualidad/noticias/huertos-ecologicos-2016-2017

- **KPI-76: INCREASED CONNECTIVITY TO EXISTING GI**

This indicator is included in the list of indicators for Challenge 4. Green Space Management. This environmental (biological) indicator evaluates the increases of connectivity related to existing green infrastructures.

In Liverpool demo case, the calculation of the cycle lane distance that has been increased by the green corridor, with respect to the total bike lane. Use of GIS to calculate % change in GI parameters (including maximum distance between areas of GI; extent and type of GI within each demo area; distance from existing large urban GI e.g. parks) before vs after GI interventions. Input data: Project delivery records; OS Map datasets; high resolution imagery pre and post intervention. GIS Analysis (m) (%)

RELATED NBS

New green cycle lane and re-naturing existing bike lanes: Green cycle lane; Green resting areas; Cycle-pedestrian green paths.

CODE	ACTION	SUB-DEMO	CATHEGORY	SUB-CATHEGORY
VAc1	New green cycle lane and re-naturing existing bike lanes	A	Re-naturing Urbanization	Green route
VAc2	Planting 1,000 trees	A	Re-naturing Urbanization	Arboreal interventions
VAc3	Tree shady places (500 trees)	A	Re-naturing Urbanization	Arboreal interventions
VAc4	Shade and cooling trees (600 trees)	B	Re-naturing Urbanization	Arboreal interventions
VAc5	Re-naturing parking trees (250)	C1	Re-naturing Urbanization	Arboreal interventions
VAc6	Installation of 3 Green Resting Areas	A	Re-naturing Urbanization	Resting areas
VAc7	Urban Carbon Sink	C3	Re-naturing Urbanization	Carbon capture
VAc15	Cycle-pedestrian green paths	A	Singular GI	Cycle-pedestrian infrastructure

VAc22	Green noise barriers	A	Singular GI	Vertical GI
VAc23	Green noise barriers	B	Singular GI	Vertical GI
VAc24	Green Vertical mobile garden	B	Singular GI	Vertical GI
VAc25	Green Façade	B	Singular GI	Vertical GI
VAc26	Electro wetland	B	Singular GI	Horizontal GI
VAc27	Green Covering Shelter	B	Singular GI	Horizontal GI
VAc28	Green Roof	B	Singular GI	Horizontal GI
VAc29	Green Shady Structures	B	Singular GI	Horizontal GI

Table 2.9: complete list of NBS Types that can be measurable with this KPI

RATIONALE

The extent and spatial arrangement of accessible green space within each sub-demo area may have an important influence on public health and wellbeing; as well as having the potential to increase biodiversity. Vegetated areas provide cooling on hot days through evapotranspiration; and trees reduce radiant heat by shading, making public space and travelling routes more comfortable for people on days when temperatures in urban areas are high. This KPI will focus on public accessible greenspace, therefore residential gardens will not be considered here.

METHOD

Typology map data representing areas of GI both before and after NBS GI interventions will be analysed using a Geographic Information System (GIS) to calculate change in each sub-demo area in *a)* the proportion of the sub-demo area represented by GI, *b)* distance between areas of GI, and *c)* the number of street trees

BASELINE HABITAT INPUT DATA

In the case of Liverpool, a baseline GI typology maps [Figure 38, D3.2 Mersey Forest] were produced in 2017 using OS Mastermap Green infrastructure typology (MasterMap Topography Layer and Greenspace Layer) and tree canopy data from Bluesky's National Tree Map. If the Mersey Forest maps are updated to reflect any update in OS MasterMap Topography/Greenspace Layers/Bluesky National Tree Map before interventions start in the demo areas this updated version will be used.

POST-INTERVENTION HABITAT INPUT DATA

From project delivery records detailing the extent, location and type of each GI intervention, shapefiles will be created and added to the baseline typology map to create a new map layer representing the extent and type of new NBS GI habitat post-intervention.

CALCULATIONS

Use of GIS to calculate % change in the following parameters in each sub-demo area following NBS GI interventions:

1. The extent of accessible GI. Calculate the proportion of the sub-demo area occupied by GI (select all GI types in typology layer except residential gardens) pre- and post- GI interventions.
2. The distance between each accessible GI patch and its nearest accessible GI neighbour within the sub-demo area. If *d* is the nearest-neighbour (Euclidean) distance from accessible GI patch *i* to accessible GI patch *j*; calculate the mean nearest-neighbour distance over all patches, both pre- and post-intervention (FRAGSTATS, 2015)
3. The distance to the nearest accessible green infrastructure everywhere (for every raster cell) calculated using a raster nearest neighbour approach
4. the number of street trees

HABITAT MAP DATA SOURCES

For example in Liverpool:

- OS Mastermap Topography and Greenspace Layers[22][23]
- Bluesky National Tree Map[24]

SPATIAL ANALYSIS SOFTWARE

QGIS is free, open source software. The current version is QGIS 2.18.16 'Las Palmas' and was released on 19.01.2018. QGIS is available[25] on Windows, MacOS X, Linux and Android... QGIS 2.18 user guide is available at the same page[26].

CALCULATION OF LANDSCAPE METRICS IN QGIS

QGIS Landscape Ecology Plugin LecoS[27] is based on metrics taken from FRAGSTATS[28] for calculation of landscape metrics using raster and vector layers.

REFERENCES AND SOURCES OF FURTHER INFORMATION

D3.2 Baseline Document for Liverpool 2017. Urban Green UP Project Deliverable

FRAGSTATS, 2015 McGarigal, K. fragstats.help.4.2.pdf

http://www.umass.edu/landeco/research/fragstats/fragstats.html.

LecoS2.0.7 http://plugins.qgis.org/plugins/LecoS/

QGIS Development Team 2013. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.osgeo.org

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[22] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

[23] http://digimap.edina.ac.uk/

[24] https://www.blueskymapshop.com/products/national-tree-map

[25] https://www.qgis.org/en/site/forusers/download.html#

[26] https://docs.qgis.org/2.18/en/docs/user_manual/

[27] http://plugins.qgis.org/plugins/LecoS/

[28] http://www.umass.edu/landeco/research/fragstats/fragstats.html.

- **KPI-77: POLLINATOR SPECIES INCREASE**

Ecological surveys of selected taxa at NBS pre-intervention and year 1 and 2 post intervention. Comparison of pollinator species richness/abundance/seasonal spread at NBS pre and post intervention. Analysis of survey data using standard software (Excel/R).

RELATED NBS

SuDs /Raingarden; Horizontal green interventions; Vertical green interventions; Pollinator verges and spaces Pollinator (houses) modules.

In the case of Izmir, the pollinator study has been conducted at two locations determined in Karşıyaka-Mavişehir and Çiğli- Sasalı regions. The study has been carried out two days in every month in each locality for 6 months from March to August 2018. These localities were determined on the basis of NBSs where pollinator species are aimed to be observed and recorded (please see Report 4.2). Sample areas with a 10 X 10 m stable quadrat are determined in the localities and observations of pollination have been executed to record the species of insects (species count) that visit plant species throughout the day. Simultaneously, microclimatic variables (air temperature and wind speed) of the observation areas (using by data logger) have been recorded. In the locality in Karşıyaka-Mavişehir, majority of the plant cover is composed of exotic shrubs and trees, and there is not much plant diversity based on the initial observations. Therefore, a 10 x 10 m stable quadrat serves our purpose very well to represent the entire area. Other study area in the Sasali region is treated in a similar fashion in terms of quadrat size and observation intervals. It is a semi-natural area that contains native annuals and some invasive Eucalyptus trees. In addition to these observations in 10 x 10 m quadrat, since flying pollinating insects are highly mobile, in the vicinity of the quadrats, additional one-day/month observation has been made in the monitoring period. It is hoped that at the end of the observation period, two different insect lists will be prepared per locality.

The same procedure will be repeated after the NBSs are implemented in the project area to see if there is an increase in number of pollinator insects visiting NBS. All the observations are being photographed as well.

RATIONALE: POLLINATORS AS ECOLOGICAL INDICATORS

The presence of pollinating insects such as bees, hoverflies, butterflies and moths visiting flowers is indicative of pollination (ecosystem service). Increased habitat for pollinators in NBS GI may contribute to increased abundance of pollinators in the wider urban area and provide stepping stones or corridors of habitat from a source site such as an urban park to another urban GI site. Flying pollinating insects are an appropriate indicator of pollination and biodiversity in new NBS GI as these taxa are likely to be already present in source sites such as urban parks within normal foraging range of the new NBS. Flying pollinating insects are highly-mobile, and therefore, considered to have the potential to reach the NBS sites within the project monitoring period.

NBS TYPE

Monitoring focus for this KPI will be NBS sites with herbaceous or shrub vegetation including floral resources (not trees). The NBS types proposed in this category are: pollinator verges and spaces, pollinator walls, SUDs (including rain garden) and pollinator roofs. For example, in the case of Liverpool the NBS types proposed in this category are:

Sub-demo A (Baltic)

- Pollinator verges
- Pollinator walls vertical
- SUDs (Rain garden)

Sub-demo B (BID)

- Pollinator roofs
- Pollinator walls vertical
- Moving gardens

Sub-demo C (Jericho)

- Pollinator verges
- Pollinator walls vertical
- SUDs (open water)

STUDY SITES

STUDY SITES(i) Pollinator NBS sites with herbaceous vegetation (i.e. not tree interventions); **(ii)** paired control sites within the same demo area and of a similar size to NBS match site; **(iii)** a matching number of randomly selected UGI sites (with public access) within each demo area; **(iv)** a matching number of homogenous areas of herbaceous vegetation in large source sites (with public access - parks etc.) within or close to each demo site.

NUMBER OF STUDY SITES

In the case of Liverpool demo, for each of the three Liverpool demo areas the following study sites will be selected:

- Pollinator NBS GI - depending on the spatial arrangement and design of NBS within the demo sites: either 2 study sites (each with 3x 1x1m pollinator samples) or 3 study sites (each with 2x 1x1m pollinator samples) tbc when NBS locations, size, number and type are confirmed.

- For each pollinator NBS study site selected for monitoring; a control study site will also be selected.

SIZE OF SAMPLING UNIT (Liverpool specific)

1x1m quadrats are selected as appropriate to observe and record flower visits by pollinating insects. In the case of green walls, a 1x1m area will be selected estimated using ground measurements (with the centre of the plot at head height if possible, or if the entire wall is above head height, sampled using binoculars). The position of the plot along the length of the wall will be determined by random number.

NUMBER OF SAMPLES

An equal number of random samples should be carried out for each study site, although study site size may vary. Comparing sites of continuous homogenous vegetation and sites with scattered floral resources (the floral element of an urban 'mosaic' community)

In a study site comprised mainly of impermeable surfaces no herbaceous vegetation or only scattered flowering plants (e.g. pre-intervention NBS and control sites) where the total area (m^2) of vegetation supporting floral resources is lower than the area required to support the total number of 1x1m pollinator samples required per site; each of the scattered areas of flowering plants will be sampled using 1x1m quadrats, after which additional samples without vegetation - up to the total number of samples required per site - will be recorded as zero pollinator-flower visits.

- **Repeated sampling & detectability of focal taxon**

Each study site will be sampled (with sample locations selected at random on each occasion to ensure observations are independent) once every 4 weeks between May and September (selected as an optimal seasonal time window for recording pollinator foraging activity) over three years (pre-intervention 2018; plus 2 years post-intervention). Pollinator observations will be carried out between 10 and 4pm, in appropriate weather conditions (see below) for detecting pollinator visits to floral resources.

LOCATION OF SAMPLES

Sampling locations will be selected at random at every visit. To select random location, in advance of the survey a 1m grid produced in QGIS will be overlaid on a map of each study site and random numbers for x and y co-ordinates used to determine location of the required number of pollinator 1x1m quadrats. The co-ordinates generated from the random selection process will be located at the study site using Garmin e-trex GPS (to a 3m accuracy limit of the e-trex device). If there are no open flowers at the point selected at random, then the surveyor should walk to the nearest flower seen and place the quadrat there.

- **Floral resources samples**

For each study site, a nectar index will be obtained by sampling at random (using random walk with distance and direction determined by random numbers from each pollinator quadrat location) 5x the number of pollinator plots sampled at the study site. Count the number of flowers open in a 1x1m quadrat.

- **Pollinator samples**

At each plot vegetation, variables below will be recorded and pollinator visits to flowers within the plot will then be observed for a continuous period of 15 minutes. The observer should stand in a position that does not shade the plot. Close focus binoculars will be used, together with compact close focus camera to aid species ID. Collecting containers/net may be used to aid insect ID if necessary but all pollinators will be released immediately at the study site.

- **Weather conditions**

National Pollinator Monitoring Scheme guidance: pollinator observation count surveys should be carried out when the weather is warm and dry. If the sky is clear (less than half cloud) the minimum temperature for a count is 13°C. If the sky is cloudy (half cloud or more) the minimum temperature for a count is 15°C. (www.ceh.ac.uk/our-science/projects/pollinator-monitoring)

EQUIPMENT

In the case of Liverpool demo, the equipment to be used shall be: Garmin e-trex GPS, compass, lightweight 1x1m quadrat, binoculars, camera, ID guides, and temperature logger.

VARIABLES TO BE RECORDED AT EACH POLLINATOR SAMPLING PLOT (1X1M)

- Date
- Time
- Temperature (air and surface)
- Weather e.g. full sun, breeze, overcast etc.
- Aspect – if sloped or vertical
- List of each plant species and estimated abundance % cover
- Substrate type
- Number of flowers open (nectar source/pollen source)
- % plot shaded
- % plot bare ground
- Number of visits by pollinating insects – landing on an open flower: record taxonomic group of each pollinating insect, to species level where possible. Alternatively, higher level pollinator groups can be used: bumblebees, solitary bees, hoverflies, butterflies, moths.
- Plant species of flower visited by each pollinating insect recorded
- Photograph of insect or plant species if required for ID.

NOTE

It is possible that the same insect may be recorded more than once if it leaves and returns to the plot during sampling).

ADDITIONAL INFORMATION REQUIRED

- Locations and design of NBS
- Selection of control/UGI and source sites (once NBS locations and design known)
- Access permissions – particularly to pollinator roof and control roof

2.1.4 CHALLENGE 5: AIR QUALITY MONITORING PROCEDURES

Environmental indicators related to chemical aspects

- Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration recorded ug/m3
- Trends in emissions NOX, SOX

Economic indicators

- Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. Use of GI-Val to calculate the value of air quality improvements.

Social indicators related to physiological aspects

- Air quality parameters NOx, VOC, PM, etc.

- **KPI-83: ANNUAL MEAN LEVELS OF FINE PARTICULATE MATTER IN CITIES CONCENTRATION RECORDED**

RATIONALE

Road transport and construction operations are identified as major sources of air pollutants in cities. Airborne particulate matter is associated with harmful effects on human cardiovascular and respiratory health. Particles ≤ 10 microns (PM10), and particularly the finer particles ≤ 2.5 microns (PM2.5) associated with road transport vehicles, are of concern due to their small size; (a micron, or micrometre = one-millionth of a meter: 0.001 millimetre). Green walls (or screens) in urban streets may act as barriers to direct dispersal of pollutants from combustion engine vehicles to pedestrian areas. Particulates may be deposited on the leaf surface of trees or taken up into the leaf surface wax layer, reducing atmospheric particulate concentrations. Monitoring of air quality parameters is complex; involving many potentially interacting variables. Variation in weather conditions; prevailing wind direction and speed; tree species, density, location and structure; and the configuration of built urban infrastructure are among factors which may affect the trajectory and rate of dispersal of particulate pollutants. We aim to compare outdoor air concentrations of PM10 and PM2.5 at child and adult head heights at locations with and without street trees or green walls to evaluate whether these NBS are associated with reduced local concentrations of airborne PM10 and PM2.5.

NBS TYPES

Street trees and green walls (or screens), Urban Garden BioFilter, Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas, Green Façade, Green shady structures, Green fences.

METHOD

BACI (Before, After, Control, Impact)

Measure air concentrations of PM2.5 and PM10 at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of road without street trees/green wall at a similar time of day on the same dates.

NULL HYPOTHESIS

There is no difference in concentrations of PM2.5 or PM10 between samples in stretches of road where street trees/green walls are present, and samples taken in stretches of road without street trees/green walls.

MONITORING EQUIPMENT

A portable photometric sampler designed to measure ambient PM2.5 and PM10 concentrations: for example, the Aeroqual Series 500 Portable PM Monitor. A laser and optical sensor are fitted to the sensor head of the monitor to measure light scattered from particles passing through a laser beam. The scattered light is transformed to electrical signals to provide mass measurements of PM2.5 and PM10. (https://www.aeroqual.com/product/portable-particulate-monitor). Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

MEASUREMENTS

Concentrations of airborne particulate matter are measured by recording PM mass per cubic metre of air.

UNIT OF MEASUREMENT

Micrograms (mcg) per cubic metre, µg m^{-3}. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

CALIBRATION

Comparison of the readings from the portable PM monitor against those from the static PM monitoring equipment at the Liverpool local government AQ monitoring station at Speke to inform reliability of measurements (http://www.airqualityengland.co.uk/local-authority/?la_id=183).

STUDY SITES

a) Stretches of road where street tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where street tree/green wall interventions are not proposed (control study sites). Control sites should be a sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

NUMBER OF SAMPLES

At each study site and control site, depending on the width between road and street buildings, a sample will be taken at pre-determined locations: ***a)*** at the roadside, ***b)*** 3-5m from the road (where street trees/green walls have been installed the NBS should be situated between this sampling point and the road) ***c)*** 6-10m from the road; with additional measurements at intervals at greater distances from the road for study sites where urban infrastructure constraints allow. This range of sampling point distances from proposed NBS reflects the scale at which measurable impacts are predicted relative to the size of street tree/green wall interventions proposed for Liverpool.

SAMPLING METHOD

Both intervention and matched control study sites should be sampled on the same occasion during each round of samples (i.e. an intervention site and matched control should be sampled on the same date and at as close a time of day as possible). Each pre-determined sampling location at a study site should be repeat sampled every 4 weeks for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022). At each sampling point two readings should be taken: at heights estimated to represent ***a)*** child and ***b)*** adult head heights.

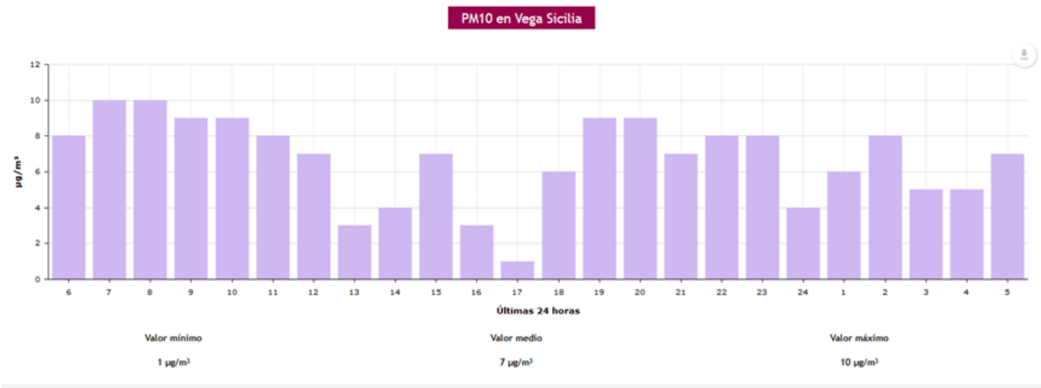


Figure 2.8: Example of data sampling by hour. Source: Valladolid City Council

DATA PROCESSING

Calculation of annual and monthly mean levels of NO_2, O_3, PM10 and PM2.5 at each station location.

There are three main types of stations for city domains (excepting industrial sites that are no considered for this KPI).

- Road traffic
- Urban background
- Peri-urban background

According to this classification, it can be obtained average values for road traffic areas, urban areas and peri-urban areas. Then, using a GIS software, a model of the city can be built that classifies all locations/streets/areas of the city in those categories.

DATA ANALYSIS

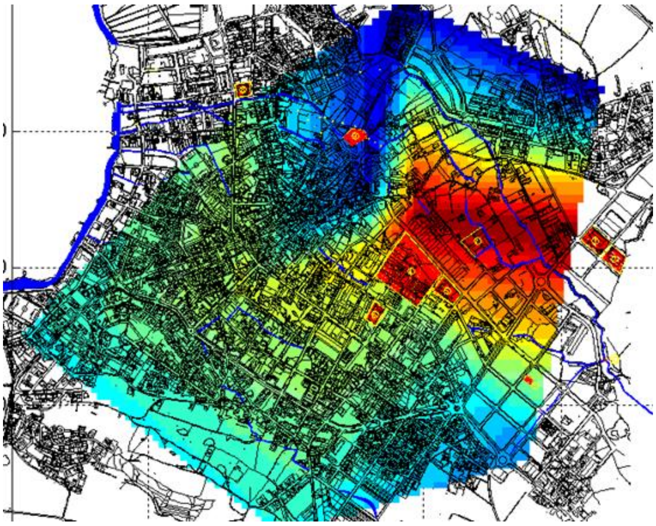
Data to be downloaded to PC from Aeroqual PM monitor using bundled software and exported to Excel (xlsx or csv file). Calculation of annual mean levels of PM10 and PM2.5 at each sampling location. Comparison of annual mean values for NBS intervention and control sample locations at each study site.

SPATIAL ANALYSIS SOFTWARE

QGIS is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one and QGIS 3). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

RESULTS

The main result of this KPI is a city map where can be shown air quality average levels for the city. This outcome can be used to define population exposition levels and to highlight buildings used by vulnerable groups such as schools or residences for the elderly.



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https://qgis.org/en/site/

- **KPI-84: TRENDS IN EMISSIONS NO_x AND SO_x**

RATIONALE

It is estimated that in the UK air pollution reduces overall life expectancy by seven to eight months, with estimated annual health costs of up to £20 billion. The impacts are higher on the most vulnerable, including lifelong impact on children.

The predominant source of NO_x in Britain is road transport and it is thought that half of emissions in Europe originate from this source; certainly the highest concentrations of NO_2 are generally found close to busy roads in urban areas In keeping with other local authorities across England and Wales, Liverpool and the wider city region is close to failing to meet the European Union (EU) air quality standard for Nitrogen Dioxide (NO_2) which is measured as an annual mean of 40µg/m^3. High levels of NO_2 have a health impact on the local population; in particular those suffering from existing heart related conditions, asthma and Chronic Obstructive Pulmonary Disease. Whilst air pollution from NO_2 cannot be said to be the single direct causal effect upon hospital emissions, it does contribute. NO_2 pollution levels within the Liverpool City region follow a similar pattern with the majority of NO_x emissions being road transport related. Commercial, industrial and domestic sources also make a small contribution to background.

The main source of SO_2 is fossil fuel combustion. And SO_x emissions in the UK have decreased substantially since 1992, due to reductions in the use of coal, gas and oil, and also to reductions in the sulphur content of fuel oils and DERV (diesel fuel used for road vehicles). The decrease in emissions over time is the continuation of an on-going trend partly due to the decline of the UK's heavy industry. Although the city has made great strides in reducing levels of sulphur dioxide over recent years it remains an important atmospheric pollutant.

We aim to compare outdoor air concentrations of NO_x and SO_x according to the established practices currently operated by Liverpool City Council to ensure that data remains comparable to our historical citywide baseline. We intend to mount the diffusion tubes on street furniture owned by the city council such as lamp posts or other street furniture at a monitoring height of roughly 3m or 10 feet. The height of the diffusion tube placement is a little higher than adult head height but is necessary in a public place to reduce unauthorised removal of tubes and disruption to the experiment. The diffusion tubes will remain in situ for a month and then be removed and replaced. Usually two people are required to remove and replace tubes and a litter picker can be used to retrieve and replace tubes. Retrieved diffusion tubes will be sent away for analysis. At present the analysis is carried out for existing city air quality diffusion tubes by a laboratory called Gradko who use an analytical method of 20% TEA in water. It is proposed that diffusion tube analysis for the URBAN GreenUP project will also be carried out by the same laboratory to provide consistency in comparability of data collected historically and elsewhere across the city.

NBS TYPES

Street trees and green walls (or screens), improved highway improvements

METHOD

BACI (BEFORE, AFTER, CONTROL, IMPACT)

Measure air concentrations of NO_x and SO_x at identified sampling points close to planned nature-based interventions and highway improvement schemes both pre- and post-intervention. Compare this data for differences and also compare this data to historical city wide data and trends.

NULL HYPOTHESIS

There is no difference in concentrations of NO_x and SO_x between sampling locations with or without nature based ort highway interventions.

MONITORING EQUIPMENT

Diffusion tubes designed to measure dissolved gaseous emissions of NO_x and SO_x will be used throughout the study. Diffusion tubes are a type of passive sampler; that is, they absorb the pollutant to be monitored directly from the surrounding air and need no power supply. Passive samplers are easy to use and relatively inexpensive, so they can be deployed in large numbers over a wide area, giving good spatial coverage. This has made them a popular choice for Local Authorities, who often use diffusive samplers to complement more expensive automatic monitoring techniques, or at locations where it would not be feasible to install an automatic monitor.

It should be noted that diffusion tubes have two limitations. Firstly, they are an *indicative* monitoring technique. Whilst ideal for screening surveys, or for identifying locations where NO_2 concentrations are highest, they do not provide the same level of accuracy as automatic monitoring techniques. Secondly, as the exposure period is typically several weeks, the results cannot be compared with air quality standards and objectives based on shorter averaging periods such as hourly means. Diffusion tube samplers operate on the principle of molecular diffusion, with molecules of a gas diffusing from a region of high concentration (open end of the sampler) to a region of low concentration (absorbent end of the sampler). Their use is recognised by DEFRA.

MEASUREMENTS

Concentrations of NO_x and SO_x (units) will be provided following laboratory analysis.

CALIBRATION

Comparison of the readings from the diffusion tubes for NO_x and SO_x can be compared against those from the static PM monitoring equipment at the Liverpool local government AQ monitoring station at Speke to inform reliability of measurements (http://www.airqualityengland.co.uk/local-authority/?la_id=183). Analysis at the same laboratory, using the same techniques for the city's existing diffusion tubes will help to ensure consistency and comparability between historical and citywide air quality data.

STUDY SITES

- ***a)*** At suitable locations tbc in the Baltic corridor.
- ***b)*** At suitable locations tbc in the Business Improvement District in the city centre
- ***c)*** At suitable locations tbc in the Jericho Lane/Otterspool corridor.

Control sampling will be considered for some key sites according to the available budget. There are 88 diffusion tubes across the city at 86 locations, which are prepared and analysed by Gradko (2017).

NUMBER OF STUDY SITES

There are 3 sub demo areas but the number of individual study sites within each of the sub demo areas has yet to be determined and will be guided by the final position of the Nature Based Solutions.

NUMBER OF SAMPLES

It is estimated that the budget could potentially allow for something in the region of 100 diffusion tubes; spread across the 3 demo areas, 2 different air quality parameters over a 3 year period. The location and nature of the various NBS interventions will however dictate the final positioning and type of diffusion tube and they will not necessarily be spread equally between the demo areas or the different air quality parameters being recorded. An option exists to consider some limited replication at key sites and to utilise any current data from existing diffusion tube sampling at appropriate locations. Budget costs dedicated to other essential monitoring equipment will determine the final number of diffusion tube sampling locations that can be supported throughout the duration of the project.

SAMPLING METHOD

Both intervention and the control study site should be sampled on the same occasion. Each fixed sampling location at a study site should be sampled every month for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

DATA ANALYSIS

Data analysis will be carried out by a third party to enable calculation of NO_x and SO_x at each location. Data can be compared with available historical data across the city.

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- **KPI-88: MONETARY VALUES: VALUE OF AIR POLLUTION REDUCTION; TOTAL MONETARY VALUE OF URBAN FORESTS INCLUDING AIR QUALITY, RUN-OFF MITIGATION, ENERGY SAVINGS, AND INCREASE IN PROPERTY VALUES**

GI-Val is The Mersey Forest's green infrastructure valuation toolkit. The current prototype is free and open source, and can be downloaded from http://www.merseyforest.org.uk/services/gi-val/. It takes the form of a spreadsheet calculator and a user manual. One of the tools, Tool 4.6, can estimate the impact of nature-based solutions on various air pollutants, in tonnes per year, and from those quantities it can estimate the avoided costs of other air pollution control measures. It uses a benefit transfer method, based upon the Chicago Urban Forest Climate Study by the USDA Forest Service (Nowak et al, 1994).

It is possible that monitoring in some cities will provide more accurate figures for the removal of air pollutants – if so, the tool can simply be used to put a monetary value on these.

4.6 Avoided cost of air pollution control measures

This tool uses currency exchange rates. To update these, right-click the table at the bottom of this sheet and click refresh.

What type of location is the project in?	*Sub-urban*	*Select*			
What is the existing land use type?	*Vacant*	*Select*			
Input existing area of tree cover (ha)	0	*Ha OR*	~~Number of trees~~	~~0~~	*Tool uses Ha as default, using values entered in the Project Data sheet.*
Proposed increased tree cover (ha)	36.00391967	*Ha OR*	~~Number of trees~~	~~0~~	*If using Number of Trees, reduce C22 and C23 to Zero.*

CURRENT LAND COVER - POLLUTANT REMOVAL	Tonnes/ha/yr	Tonnes/tree/yr	Gross removal (tonnes/yr)	Cost savings	
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.00	£0.00	*Auto calculation cells*
Sulphur Dioxideremoved (tonnes / year)	0.0028	1.3E-04	0.00	£0.00	*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.00	£0.00	*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.00	£0.00	*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.00	£0.00	*Auto calculation cells*

PROPOSED NEW ADDITIONAL LAND COVER - POLLUTANT REMOVAL				Cost savings	Net impact of scheme on pollutants removal (tonnes/yr)		
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.03	£36.49	*CO t/yr*	0.03	*Auto calculation cells*
Sulphur Dioxide removed (tonnes / year)	0.0028	1.3E-04	0.10	£226.84	*SO2 t/yr*	0.10	*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.09	£546.89	*NO2 t/yr*	0.09	*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.23	£408.37	*PM10 t/yr*	0.23	*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.26	£172.47	*O3 t/yr*	0.26	*Auto calculation cells*

Tool 4.6 output	33,770	*£ NPV Discounting over 50 yrs already built in the worksheet below*

Figure 2.9: Example of GI-Val toolkit

Improvements to or replacement of this tool is planned, as more robust methods are likely available.

RELATED NBS

Primarily trees, but also, to a lesser extent, other vegetation.

METHOD

The location type (urban) and the pre- and post-intervention tree canopy cover will be entered into GI-Val. In the case of Liverpool demo the tree canopy cover will be measured using the colour infrared imagery and height data available under the Aerial Photography for Great Britain agreement[29] and the landscape architects' drawings.

If the GI-Val tool is substantially changed, as planned, the method will also change somewhat.

- **KPI-92: AIR QUALITY PARAMETERS NOX, VOC, PM ETC.**

This indicator is included in the list of indicators for Challenge 5. Air Quality. See table below with the total set of KPIs related to Air Quality (AQ) Challenge.

Other indicators are defined to assess a general impact of a NBS on AQ at building, district or city scale. However, this indicator is focused on the impact of specific NBS on a polluted gaseous stream before being released into the urban atmosphere.

This indicator has been mainly defined for Urban Garden BioFilter but in future can be used for other NBS to be installed in outdoor pipes to capture pollutants.

RELATED NBS

Urban Garden BioFilter.

[29] https://www.apgb.co.uk/

METHOD

This KPI is calculated from measured data using a methodology defined by URBAN GreenUP Project.

BACI (BEFORE, AFTER, CONTROL, IMPACT)

Measure air concentrations of NO_2, PM2.5 and PM10 at sampling points at a range of radii from NBS location both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without NBS at a similar time of day on the same dates.

NULL HYPOTHESIS

There is no difference in concentrations of NO_2, PM2.5 or PM10 between samples in stretches of road where street trees/green walls are present, and samples taken in stretches of road without street trees/green walls.

MEASUREMENTS

Concentrations of NO_2 and airborne particulate matter are measured by recording PM mass per cubic metre of air (PM2.5 and PM10).

UNIT OF MEASUREMENT

PM - Micrograms (mcg) per cubic metre, $\mu g/m^3$. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

NO_2 – ppb (parts per billion). Parts per billion (ppb) is the number of units of mass of a contaminant per 1000 million units of total mass.

NUMBER OF SAMPLES

Continuous monitoring in the selected points each ten minutes.

DATA SAMPLING

Continuous monitoring in the selected points each ten minutes.

Figure 2.10: Data example of the KPI

DATA PROCESSING

Calculation of (weekly, monthly and/or yearly) mean levels of NO_2, PM10 and PM2.5 at each sampling location as the average value of the all the measurements done before and after of the interventions. Comparison of mean values for NBS intervention and control sample locations in the implementation area.

Data comparison before and after of the intervention using the reference to assess possible meteorological or other factors influence.

RESULTS

The calculated values will be compared qualitatively and quantitatively for the periods before and after the interventions in the NBS and reference sections.

2.1.5 CHALLENGE 6: URBAN REGENERATION MONITORING PROCEDURES

Urban green indicators related to environmental and biological aspects

- Accessibility: distribution, configuration, and diversity of green space and land use changes (multi-scale ;). - Green spaces quantity

Socio-cultural indicators

- Savings in energy use due to improved GI

- **KPI-95: ACCESSIBILITY: DISTRIBUTION, CONFIGURATION, AND DIVERSITY OF GREEN SPACE AND LAND USE CHANGES**

This index means to evaluate the performance of various NBS among the cities. In this particular case the scope of the KPI has different related NBS, for example: new green cycle lanes and re-naturing existing bike lanes; Green resting areas; Cycle-pedestrian green paths; also Vertical green interventions and Horizontal green interventions; Urban farming promotion as the Urban orchard, Community composting and Small-scale urban livestock; among educational activities as Educational paths and Urban farming educational activities and the tree related actions. That's why this KPI tackles the implementation of the project at an urban scale.

There are two measured methods for this index. One is based on calculation of the shortest distance (linear distance) between access of the population to the NBS (line type), and the NBS location centroid. The results obtained shall be in distance (m) and time (min). This KPI will be calculated using Geographic Information Systems. The sources used will be population number, provided by each city council. The other measurement method to be used is based also on GIS analysis of distance of the NBS site but in this case to homes, schools, and businesses. Land use cover will also add to the analysis in GIS to show what each area is comprised of, what different NBS are located within each site, and what socio-economic amenities can be identified.

RELATED NBS

Tree related actions. New green cycle lane and re-naturing existing bike lanes: Green cycle lane; Green resting areas; urban orchard; Community composting; Small-scale urban livestock.

- **KPI-110: SAVINGS IN ENERGY USE DUE TO IMPROVED GI**

The energy sector is the largest single source of global greenhouse gas emissions, and is responsible for over a quarter of all EU greenhouse gas emissions (European Comission). Green Infrastructure can play a role in reducing the negative impacts of the energy sector, by: (1) reducing energy consumption; (2) providing bioenergy; and (3) providing carbon uptake and storage.

The KPI presented aims at quantifying both the energy savings and the bioenergy generated by all the NBS implemented in Valladolid. This KPI will be calculated converting into energy savings the benefits already considered by means of other KPIs. Therefore, in this KPI, all the NBS that provide an ecosystem service which has a direct link to an energy saving or the ones that generate electricity themselves will be considered.

RELATED NBS

Planting 1,000 trees, Tree shady places (500 trees), Shade and cooling trees (600 trees), Re-naturing parking trees (250), Urban Carbon Sink, Floodable park, Natural Wastewater Treatment Plant, Electro wetland, Green Roof and Green Shady Structures.

METHOD

This KPI is calculated from measured data using a methodology defined by URBAN GreenUP Project.

Energy savings due to improved Green Infrastructure (ESGI) will be calculated by converting other KPIS (BASE KPIS, with other units of measurement) into its associated energy saving. Accordingly, from the complete list of KPIs measured at Valladolid DEMOSITE, the ones that imply an energy saving will be considered. Selected BASE KPIs and their corresponding units of measurement are defined in Table 1.

Furthermore, there are NBS able to generate bioenergy themselves, such as Electrowetland. This bioenergy, which will be used to power temperature and humidity sensors, will be also considered as an energy saving and therefore added to the ESGI KPI.

BACI (Before, After, Control, Impact)

Energy savings will be calculated according to the KPIs established in Table 1. Each BASE KPI has its own control methods and baselines and therefore, no specific control is required for this KPI.

NULL HYPOTHESIS

None of the KPI in which the ESGI KPI is based (Table 1) generate any quantifiable benefit.

DATA PROCESSING

The initial step is the conversion of all the BASE KPIs considered in the Table 1 to the same timescale (referred to the same period of time). According to this factor, most of the BASE KPIs are quantified during yearly periods. However, if they are provided at other timescales values should be harmonized. This harmonization will be conducted considering constant values along the time (either if the time should be extended or reduced) as indicated in the Table 2.9.

	BASE KPI	CONVERSION	TIMESCALE CONVERTED KPI	Date
EXTENSION	m^3/month	BASE KPI x 12 months	m^3/year	m^3/month
REDUCTION	m^3/5 years	BASE KPI/5	m^3/year	m^3/5 years

Table 2.10: Examples of timescale harmonization

Once all the BASE KPIs have the same timescale, the energy savings which they are linked to will be calculated. Each one of the BASE KPIs considered for this calculation is given in different primary units. Therefore, for the calculation of their associated energy savings, when required they will be converted into energy units by means of specific conversion factors.

2.1.6 CHALLENGE 7: Participatory Planning and Governance

Social indicators

- Perceptions of citizens on urban nature - Green spaces quality

- **KPI-117:PERCEPTIONS OF CITIZENS ON URBAN NATURE - GREEN SPACES QUALITY**

INTRODUCTION

Public and stakeholder perceptions of urban nature, and specifically the quality or functionality of nature, are critical to our understanding of the “value” people place on local environments. This KPI will reflect on how people assess change in their local environments in terms of quantity and quality of green space at a site, neighbourhood and city scale.

METHOD

Periodic surveys can be performed in person via a social survey of via the smartphone application. The perceptions of green space will be assessed via a combination of qualitative questions reflecting on the composition, function and utility of green space and quantitative questions using a scaled responses and pre-determined asset/value lists to assess the perceived greenness and quality. Both will assess the socio-cultural values of green spaces, its perceived ecological value, and any economic benefits they respondents personally or communally derive from interactions with NBS. The % of satisfaction can be determined with the number of participants above a threshold. In addition satisfaction with NBS investment and changes in environmental quality will be recorded. Reported perception of NBS and value to social, economic and ecological landscape. Social Survey - Calculated with questionnaire and standard software (Excel or SPSS).

RELATED NBS

Vertical and horizontal green infrastructure; tree related actions; promotion of NBS at citizen scale: Engagement Portal for citizen; Promotion of ecological reasoning and intelligent; Single desk for RUP deployment; City mentoring strategy (Staff Exchange activities).

2.1.7 CHALLENGE 8: SOCIAL JUSTICE AND SOCIAL MONITORING PROCEDURES Social indicators

- Green intelligence awareness

- **KPI-127: GREEN INTELLIGENCE AWARENESS**

INTRODUCTION

Changes in behavior and human attitudes are fundamental to achieve a more sustainable world, so that, it is very interesting to analyze the potential of an activity or intervention to increase the green intelligence awareness of a population.

There is enormous opportunity for nature based solutions to promote understanding of sustainability in ways that positively influence citizen behavior. There are numerous available resources to learn and understand the fragility of our environmental and the responsibility of humans to protect, preserve and respect the world. Therefore, this KPI aims to reflect how the intervention is used for educational purposes and enhancement of public awareness.

NBS TYPES

Non-technical interventions: Educational activities: Educational paths (A, C); Urban farming educational activities.

METHODOLOGY

Quantify the number of activities, publications or campaigns focused on the enhancement of green intelligence awareness per year, related to a NBS:

1) Activities:
- Number of guided tours.
- Number of educational meetings: courses, conferences, lectures, workshops, seminars, and symposia.
- Civil participation through competition activities raising public awareness about environmental protection.

2) Publications
- Articles, texts, photographs or videos published in magazines, newspapers, books with technical and educational content.
- Online social networks campaigns (YouTube, Twitter, Facebook…) with technical and educational content.
- Distribution of brochures.

SENSOR/SOFTWARE

No sensor is needed

DATA PROCESSING

Sum of the educational activities per year, and sum of the publications with educational content per year, separately, because the concept and magnitude of each result are different.

RESULTS

2 numbers: Number of activities per year and number of publications per year.

The result can be expressed as: nº a/nºp. Per example, 12a/6p means 12 activities and 6 publications per year related to a NBS in particular.

REFERENCES

"Educating for a Sustainable Future: a Transdisciplinary Vision for Concerted Action". UNESCO, November 1997.

2.1.8 CHALLENGE 9: PUBLIC HEALTH AND WELL-BEING MONITORING PROCEDURES

Psychological indicators

- Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit

Health indicators related to ecosystem service provision

- Increase in walking and cycling in and around areas of interventions

- **KPI-128: NOISE REDUCTION RATES APPLIED TO UGI WITHIN A DEFINED ROAD BUFFER DB(A) M-2 VEGETATION UNIT**

Noise pollution by traffic, construction works, etc. is a common city problem. Nuisance from noise is detrimental to neighbourhood liveability, living comfort and work environments, and can increase risk of serious health problems such as hearing loss and cardiovascular disease.

Urban ecosystems provide noise reduction services by serving as a natural sound buffer. Vegetation provides both a direct and an indirect barrier to environmental noise. Starting with its direct functions, green belts attenuate noise by absorption, dispersal, and destructive interference of sound waves, though sound levels can intensify locally if measured right below tree crowns. Indirect noise reduction effects are generated by lessened wind speeds and the absorptive capacity of pervious soils. UGS also proved to offer noise reducing services via psychological effects: just observing the presence of a green wall can lead people to perceive less noise nuisance or alter the perception of noise as sounds such as flowing water, bird singing, and leaves rustling in the wind mask disturbing background noise.

On the other hand, the methodology proposed for this KPI is based and uses the methodology and tools proposed by the European Commission Working Group Assessment of Exposure to Noise (WG-AEN).

The Environmental Noise Directive (END) requires two main indicators to be applied in the assessment and management of environmental noise. The first indicator (Lden) is the noise level for the day, evening and night periods and is designed to measure 'annoyance'. The END defines an Lden threshold of 55 dB. The second indicator (Lnight) is the noise level for night-time periods and is designed to assess sleep disturbance. The END defines an Lnight threshold of 50 dB. Member States must report the numbers of people who are exposed to noise levels above both thresholds for each noise source (e.g. roads, railways, airports, industry).

NBS TYPES

This KPI is related to NBS involving **vertical green infrastructures**, such as green noise barriers, green façade or green fences.

Green Noise Barriers, Green Façade, Green shady structures, Green fences, Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas, Green roof, Green covering shelters.

METHOD

This KPI is calculated from measured data using a methodology defined by URBAN GreenUP Project.

It is accounted for two factors that influence noise reduction services: vegetation (NBS) characteristics and distance to the noise source. The analysis is focused on road traffic noise as this is a constant source and most disturbing to people.

BACI (BEFORE, AFTER, CONTROL, IMPACT)

Measure noise levels at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention (with or without) to serve as input to model simulations and to create a noise map. The measurements before and after the intervention have to be made on similar dates, same day of the week and hour. Simulations with and without NBS will be assessed to define the impact of the NBS.

A strategic noise map[30] is the presentation of data on one of the following aspects:

- A noise situation in terms of the noise indicators L_{den} and L_{night};

- The exceeding of a limit value;

- The estimated number of dwellings that are exposed to specific values of a noise indicator;

- The estimated number of people exposed to noise.

Values of L_{den} and L_{night} can be determined either by computation or by measurement (at the assessment positions) and that for prediction, only computation is applicable.

- **KPI-139: INCREASE IN WALKING AND CYCLING IN AND AROUND AREAS OF INTERVENTIONS**

INTRODUCTION

This is a social indicator, which links to human health and well-being, as walking and cycling in nature has been shown to improve both physical health and psychological well-being. This KPI measures how NBS interventions can increase engagement of citizens specifically related to walking and cycling inside the interventions and in close proximity. NBS, and specifically green infrastructure, interventions, is thought to increase street attractiveness, which leads to increased engagement with active transport (Adkins, 2012; Tzoulas et al. 2007).

NBS TYPES

This KPI is related to NBS involving **green infrastructures**, such as green corridor, new green cycle lane, horizontal green interventions, floodable park, etc.

METHOD

[30] 'strategic noise map' shall mean a map designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area;

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. Surveys may be done as well, in order to know the walking use of the walking zones. These surveys can involve local residents, users and businesses of their perceived and actual use of NBS for walking, cycling and other activities pre and post-investment.

In Liverpool, this KPI will be measured qualitatively through direct observation and as an item in the questionnaire, as above. If budget allows, this qualitative data will be complemented by quantitative data from walking and cycling counters.

MEASUREMENTS

L_{den} and L_{night}. (In situ measurements and modelled values by software assistance)

Frequency counts from both qualitative data and sensors

UNIT OF MEASUREMENT

L_{den} and L_{night} in decibel (dB).

Number of users and trips (estimated)

CALIBRATION / VERIFICATION

Where noise-related interventions are proposed, calibration of the sound level meter will be used for in situ measurements following standard procedures (EN 61672-2:2013/A1:2017, EN 61672-2:2013, EN 61672-1:2013, EN 61672-3:2013).

STUDY SITES

In Valladolid, study sites will be:

a) Stretches of road where noise barriers or other interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) A matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where NBS interventions are not proposed (control study sites). Control sites should be a sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

In Liverpool, study sites will be focused around in and around the areas of the NBS interventions designed to enhance walking and cycling.

DATA PROCESSING

QGIS is the GIS software proposed to be used in Valladolid, as it is an open source and multiplatform software distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA). We recommend to use the last long-term release repository, most stable (QGIS 2.18 is currently the last one). Data processing involved in this KPI can be done with the standard version and the standard toolbox.

Data are acquired by statistic and GIS processing, so **no sensor is required**. This data can involve new subscriptions to the bicycle loan system. Using the smartphone application we can promote walking and cycling at the intervention sites, and also measure its use by using the GPS or other types of validation (QR code reading).

Survey data will be analysed in standard software (Excel and SPSS), to determine if there is a statistical difference between walking and cycling pre- and post-intervention for residents and users in the sub-demo areas.

RESULTS

Results can be displayed throughout maps and/or tables.

Figure 2.11: Example of results displayed in maps

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2.1.9 CHALLENGE 10: POTENTIAL OF ECONOMIC OPPORTUNITIES AND GREEN JOBS MONITORING PROCEDURES

Economic indicators

- Number of jobs created; gross value added

Following the methodology on creation and maintenance of sustainable urban environments, and the final impact the technology implementation may have, the economic aspects are be taken into account from the early beginning of the NBS integration process. The economic KPIs, together with the social and territorial ones, are those that decide at the end about the accuracy of the interventions proposed to the city, city area, and region.

Climate Change has significant impacts on ecosystem functioning (pollution, climate and water disturbs and depletion of natural resources), well-being of people and economy. Climate projections indicate that climate-related extremes will increase in the future, and the economic costs of Climate Change can be very high. In order to balance the negative economic impacts arising from Climate Change, it is imperative to adopt measures that contribute to Climate Change adaptation and mitigation. Sustainable development and integration of green infrastructure offers an attractive economic Return On Investment (ROI) and a range of other benefits to society (de Roo, 2011; Kabisch et al., 2017; Wamsler et al., 2017).

The concept of Economic Sustainability must be considered as the result of a process that has taken into account the costs involved in the implementation of the Sustainable City, and its subsequent management. "Environmental sustainability" must be considered as one of the factors that are part of the "enonomic production" process of cities and for this it is necessary to be able to quantify in monetary terms the economic value of "environmental sustainability".

These "environmental values" or "sustainability" depends on subjective elements of difficult quantification, but one can resort to the Real Estate Valuation Techniques that turn out to be the only feasible way to objectify the market values.

Producing strong evidence on NBS for Climate Change adaptation and mitigation and raising awareness of their multiple benefits is decisive for the development of new economic opportunities. NBS have the potential to facilitate cooperation between sectors and contribute to a more holistic approach to the development of green jobs. The engagement of citizens is also a crucial aspect in this process, as it allows the implementation of more effective environmental regimes that address societal challenges and needs (van Ham & Klimmek, 2017, Wamsler et al., 2017).

Summary on possible indicators needed for KPIs calculation as listed briefly below:

- Number of new jobs created related to NBS (gardening, maintenance, etc).
- Increase in the property value or land value in the NBS area.
- Number of people who find a job and leave the urban orchard.

- Compost production (t/year) and sales (€).
- Number of employees (maintenance, parks and gardens). Property value / Land value evolution.
- Change in number of jobs located in areas in NBS investment and reporting and changes in income/composition of company post-investment. Nº of jobs created. Economic increase (€) in business returns. Social Survey - Calculated with questionnaire and standard software (Excel or SPSS)

Concept on Land Value

We can define the value of "environmental sustainability" of a use located in a sustainable environment as the increase in value that this use experiences as a consequence of the higher environmental quality obtained in its "soil/land" for this concept.

The value of the land is calculated as the difference between the market value of the use and the expenses necessary for its execution, including the business benefits and the infrastructure costs it supports.

If we take into account that the new value of the land must include the value of its "environmental quality", then the "real estate" value of the land must group at least the following values:

- The initial basic value of the land (an intrinsic basic value of the soil)
- Value of "centrality" for the intended use (which refers to the quality of its location in Human Systems)
- Value of the "environmental quality" of the place, within which it is necessary to include the value generated by a "sustainable environment" (due to the fact that the "sustainable" environment increases the value of "environmental quality" and therefore the value of the soil)

Concept on New Jobs creation

The market of green jobs has been constantly monitoring trends that show a market increasing in quantity and quality. In this context, various initiatives have been developed to deepen multi-stakeholder partnerships, private sector leadership and citizen engagement, which have supported the expansion of economic opportunities and green jobs (Droste et al., 2017; Enzi et. al., 2017; van Ham & Klimmek, 2017).

The market of green jobs is increasing in a consistent way, which leads to the provision of long-term, secure and sustainable new jobs and opportunities (Enzi et. al., 2017).

The investment in NBS in urban areas represents an investment in ecosystems and society, with a high financial return. The economic values attached to NBS can be classified as use values and non-use values. Use values are divided into direct use value, indirect use value and option use value. The direct use value includes consumptive values (market-priced products that derive from green infrastructure, such as timber and urban agriculture) and non-consuptive values (social benefits derived from a pleasant landscape, as well as recreational activies) (Tyrvainen et al., 2005; de Roo, 2011; Kabisch et al., 2017).

The indirect use value include protection functions, such as mitigation of urban climate, reduction of heat island effect, regulation of urban hydrology, reduction of pollution and increase of resiliency to extreme climate conditions related to Climate Change. These values represent a high economic return, reducing costs related to buildings' heating and cooling, associated with artificial reduction of pollution, related to artificial urban drainage systems, linked to health disorders that arise from climate extreme events, among other savings. The option use value includes the willingness to ensure the personal use of green infrastructure (Tyrvainen *et al*., 2005; de Roo, 2011).

The non-use values include request values (e.g. willingness to ensure use of green infrastructure by future generations, and nature, cultural and historic preservation values), as well as existence values (e.g. preserving urban biodiversity). Existence values include the Willingness to Accept Compensation (WTA) for the availability or loss of ecosystem services. In addition, the implementation of NBS in urban areas increases tourism and real estate values, which benefits both society and the urban development (Tyrvainen *et al*., 2005; de Roo, 2011). In conclusion, the integration of NBS in urban areas generates several economic co-benefits and contributes to Climate Change mitigation and adaptation.

NBS represents an opportunity not only to protect the environment, but also to improve business prospects and the position of the EU in international markets (Kronenberg *et al*., 2017). According to the Amoeba model (AtKisson, 2009), the implementation of NBS possesses several crucial stakeholders (Kronenberg *et al*., 2017), as forthwith indicated:

- Change agents: Non-governmental organizations, universities, pioneering investors, designers and architects.;
- Transformers: European Union, selected municipal departments, mainstream media, significant developers and investors;
- Controllers: Ministries, top city authorities responsible for construction regulation and governmental institutions;
- Mainstreamers: Private investors, architects and designers, construction companies and developers, residents, city officers (urban planning, local development, municipal investments, etc.);
- Laggards: Construction companies and developers.

In conclusion, NBS implementation creates several economic opportunities and builds a solid range of green jobs. Collaboration between different NBS stakeholders can improve their technical capacity, competitiveness and business opportunities (Kronenberg *et al*., 2017). The multifunctionality of NBS promises high economic return on investments, and in order to encourage diffusion of NBS, policy instruments must be developed. These instruments can include information systems, fostering cooperation, planning procedures and setting incentives (Droste et al., 2017)

- **KPI-141: Number of jobs created; gross value added**

INTRODUCTION

This KPI, related to economic aspects measurements, evaluates how NBS interventions can increase the attraction of businesses, or how to increase the value of the existing ones. This value, evaluated through the measurements of number of jobs created and the percentage of the gross value added, will reflect the economic opportunities and potential of NBS solutions.

Green jobs should contribute to environmental benefits. They should be strive for minimisation of resources, create decent employment opportunities and build low-carbon sustainable societies. International Labour Organization (ILO) has methodology to estimate green jobs. According to ILO's various country-wide studies, primary green activities (i.e.organic agriculture, sustainable forestry), secondary activities (i.e.renewable energy, clean industry, sustainable construction) and tertiary activities (i.e. recycling, sustainable tourism, sustainable transport) are defined.

RELATED NBS

This KPI is related to NBS involving: Vertical green interventions, Horizontal green interventions, Urban farming promotion: Urban orchard; Community composting; Small-scale urban livestock, Sponsoring activities; Support to citizen project of NBS, Non-technical actions, Natural waste water treatment

METHOD

The KPI-141 value comes from the measured data using a methodology defined by URBAN GreenUP Project.

BACI (Before, After, Control, Impact)

Essentially a 'before-after' indicator which captures the part of the employment increase that is (a) direct consequence of NBS implementation (workers employed to implement the NBS project should not be directly counted). The positions needs to be filled (vacant posts are not counted) and increase the total number of jobs in the enterprise. If total employment in the enterprise does not increase, the value is zero – it is regarded as realignment, not increase. Safeguarded etc. jobs are not included.

Gross: Not counting the origin of the jobholder as long as it directly contributes to the increase of total jobs in the organisation. The indicator should be used if the employment increase can plausibly be attributed to the support.

Full-time equivalent: Jobs can be full time, part time or seasonal. Seasonal and part time jobs are to be converted to FTE using ILO/statistical/other standards.

Durability: Jobs are expected to be permanent, i.e. last for a reasonably long period depending on industrial-technological characteristics; seasonal jobs should be recurring. Figures of enterprises that went bankrupt are registered as a zero employment increase.

Timing: Data is collected before the project starts and after it finishes; the NBS holders are free to specify the exact timing (depending on the NBS time needed to get the profit). Using average employment, based on 6 months or a year, is preferred to employment figures on certain dates.

MEASUREMENT INSTRUMENTS

SENSORS / SOFTWARE EXAMPLES:

City official data, city platforms, questionnaires, small-medium enterprise accounts… (Related to de NBS investment zone)

UNIT OF MEASUREMENT

(nº jobs) (€/m^2)

(nº jobs or nº users) (kg/year) (€/year)

CALIBRATION / VERIFICATION (Standards)

The following factors should be considered in correct calibration:

- Each climate resilience challenge area can be addressed by multiple individual actions, and indicators can be used to assess the effectiveness of individual actions in addressing each climate resilience challenge
- Indicators for assessing specific types of NBS impacts of NBS across aspects of multiple systems, including socio-economic, socio-cultural and ecosystems, although geographic and temporal scale may be relevant to the interactions
- The applicability of indicators can vary across geographic scales, highlighting of considering regional, metropolitan, urban, street/neighborhood and building impacts separately
- There is a need for assessing the impacts of NBS over the short, medium and long-term, and thus mechanisms are needed for monitoring NBS effectiveness beyond the end of the project
- Synergies and trade-offs can be associated with NBS impacts, including across elements of the ecosystem and socio-cultural system. NBS impacts are, therefore, likely to be multi-directional and complex

- Investment in NBS can maximize the benefits for provision of environmental, socio-cultural and economic services if multiple challenge areas are considered concurrently and the different stakeholder are involved in the planning and implementation process.

STUDY SITES (Position)

R/ M/ U

DATA PROCESSING

Monitoring systems need to be improved with systematic quality checks in order to ensure that data collected are reliable and there needs to be effective coordination between regional/ area authorities, and MAs generally, to ensure that the data reported are consistent and comparable. The guidelines, spelling out the frequency of checks, the concept used, the methods for carrying them out and so on should be provided for each NBS by specific region.

RESULTS

- **Number of jobs created (Direct employment)**

Direct value on employment by zone, before and after implementation, during the established period.

Number of jobs created= n * Z [(nº jobs) (€/m2)]

Where n is referring to the direct full time employment in during the time defined (directly related to the each particular NBS); Z- affected zone/area in reference to the NBS (should depend on NBS the definition of the area)

- **Gross value added (GVA)**

Defined as the difference between the value of goods and services produced and the cost of raw materials and other non-labour inputs, which are used up in production. The research should conclude what is the total contribution of NBS in % of the total GVA to the region/area economy in Euro/ by year.

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2.2 Optional, city-specific KPIs

2.2.1 VALLADOLID NBS Optional KPIs

Valladolid is monitoring 21/29 Core KPIs selected for URBAN GreenUP. In the following table you can see the Valladolid KPIs compared with the Core KPIs. You can check the report *D2.4. Monitoring program to Valladolid*, for further references. Optional KPIs have been highlighted in bold letters.

CHALLENGES	TYPE OF INDICATORS	KPI	VALLADOLID	ESA core KPIs	NBS
CHALLENGE 1: Climate mitigation & adaptation	Carbon savings per unit area Carbon storage and sequestration	1. Tonnes of carbon removed or stored per unit area per unit time	x	1	Tree related actions; Carbon sink
	Temperature reduction (environmental, physical)	7. Decrease in mean or peak daytime local temperatures (°C)	x	1	Vertical & Horizontal Infrastructure; Tree related actions
		9. Heatwave risks (nº of combined tropical nights (>20 °C) and hot days (>35 °C)	x	1	
	Energy and carbon savings	10. kWh/y and t C/y saved	x		NBS in buildings (green façade, green roof, green shady structures)
CHALLENGE 2: Water Management	Physical indicators	16. Run-off coefficient in relation to precipitation quantities (mm/%)	x	1	Tree related actions; SUDs; Natural Wastewater Treatment Plan; Rain Gardens; Floodable park; Green Parking pavements; Electro wetland
		17. Flood peak reduction. Increase in time to peak (%).	x		
		18. Reduction of drought risk (probability).	x		
		20. Absorption capacity of green surfaces, bioretention structures and single trees (m3/m2) (m3/tree)	x	1	
		22. Temperature reduction in urban areas (°C, % of energy reduction for cooling).	x	1	
		26. Intercepted rainfall (m3 year-1)	x		
		27. Share of green areas in zones in danger of floods (%)	x		
		28. Population exposed to flood risk (% per unit area)	x		
		29. Areas (Ha) and population (inhab) exposed to flooding	x	1	
	Chemical indicators (water quality)	**30. Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals, COD; BOD; SST (mg/l)**	x		Tree related actions; SUDs; Natural Wastewater Treatment Plan; Rain

CHALLENGES	TYPE OF INDICATORS	KPI	VALLADOLID	ESA core KPIs	NBS
		34. Water for irrigations purposes (m3 ha-1year-1)	x	1	Gardens; Floodable park; Green Parking pavements; Electro wetland
	Economic indicators (benefits)	38. Volume of water removed from water treatment system	x	1	Floodable park;
CHALLENGE 4: Green Space Management	Social indicators (benefits)	**52. Distribution of public green space – total surface or per capita.**	x		Green cycle lane; Tree related actions; All NBS
		53. Accessibility (measured as distance or time) of urban green spaces for population.	x	1	
		54. Recreational or cultural value.	x		Non-technical actions;
	Environmental (biological)	73. Production of food (ton/Ha/year)	x	1	Urban orchards;
		74. Sustainability of green areas	x		Green cycle lane; Tree related actions; Vertical and horizontal interventions; Floodable park, NWTP
		75. Quality of life for elderly people	x		
		76. Increased connectivity to existing GI	x	1	
		77. Pollinator species increase (number)	x	1	Pollinator's modules
		78. Perceptions of connectivity and mobility	x		All NBS
CHALLENGE 5: Air Quality	Environmental (chemical)	83. Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration	x	1	Green cycle lane; Tree related actions; Smarts soils as substrate; Urban garden bio-filter; Vertical green interventions; Horizontal green interventions;
		86. Mean levels of exposure to ambient air pollution (population weighted)	x		
	Economic	88. Monetary values of NBS	x	1	All NBS (Monetary issues)
	Social (physiological)	92. Air quality parameters NOx, VOC, PM	x	1	Urban garden bio-filter;
CH6	Socio-cultural indicators	**109. Assessment of typology, functionality and benefits provided pre and post interventions**	x		All NBS (Global indicator)
		110. Savings in energy use due to improved GI	x	1	All NBS (Energy issues)
CH7	Social	**111. Openness of participatory processes.**	x		Non-technical actions;
		112. Legitimacy of knowledge in participatory processes.	x		

CHALLENGES	TYPE OF INDICATORS	KPI	VALLADOLID	ESA core KPIs	NBS
CH 8: Social	Social justice	**123. Crime reduction through police reports and local authority data**	x		All NBS
	Social cohesion	127. Green intelligence awareness	x	1	Non-technical actions;
CHALLENGE 9: Public Health and Well-being	Psychological indicators	128. Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit	x	1	Noise barriers; Vertical & Horizontal green interventions
	Health indicators	139. Increase in walking and cycling in and around areas of interventions	x	1	Green cycle lane; Vertical green interventions; Horizontal green interventions; Floodable park; NWTP
CHALLENGE 10: Economic opportunities and green jobs	Economic	**140. Number of subsidies or tax reductions applied for (private) NBS measures**	x		Vertical & Horizontal interventions; Natural Wastewater Treatment Plant; Green filter area; Floodable park; Green parking pavements; Non-technical actions;
		141. Number of jobs created; gross value added	x	1	
		143. New businesses attracted and additional business rates	x		
		150. Consumption benefits: property betterment and visual amenity enhancement resulting from NBS.	x		
	TOTAL NUMBER OF KPIs		**41**	**21/29**	

Table 2.11: Additional KPIs of the city of Valladolid

Local optional KPIs are listed below – refer to D3.4 for a more detailed information. This section collect a general description of each KPI.

- **KPI-17: FLOOD PEAK REDUCTION. INCREASE IN TIME TO PEAK (%).**

To be collected from Deli 2.4

- **KPI-18: REDUCTION OF DROUGHT RISK (PROBABILITY).**

To be collected from Deli 2.4

- **KPI-26: INTERCEPTED RAINFALL (M3 YEAR-1)**

To be collected from Deli 2.4

- **KPI-27: SHARE OF GREEN AREAS IN ZONES IN DANGER OF FLOODS (%)**

To be collected from Deli 2.4

- **KPI-28: POPULATION EXPOSED TO FLOOD RISK (% PER UNIT AREA)**

To be collected from Deli 2.4

- **KPI-30: NUTRIENT ABATEMENT, ABATEMENT OF POLLUTANTS (%, NUTRIENT LOAD, HEAVY METALS) (CHEMICAL OXYGEN DEMAND (COD) (MG/L); BIOCHEMICAL OXYGEN DEMAND (BOD) (MG/L); TOTAL SOLIDS (SST) (MG/L))**

To be collected from Deli 2.4

- **KPI-52: DISTRIBUTION OF PUBLIC GREEN SPACE – TOTAL SURFACE OR PER CAPITA.**

INTRODUCTION

This indicator evaluates how green spaces are increasing in the cities related to total surface or habitants. Its relative character can absorb the effect of the population dynamics and expansive processes of the city.

This KPI is related to NBS involving **green infrastructures**, either horizontal or vertical, such as green corridor, NWTP, green façade, etc.

METHOD

This KPI can be measured throughout specific software, such as GIS software and spreadsheet software. **QGIS** is the GIS software proposed to be used, due to it is an open source and multiplatform software and it is distributed under Creative Commons Attribution-Share Alike 3.0 licence (CC BY-SA).

Data are acquired by statistic and GIS processing, so none sensor is required.

RESULTS

The main result of this KPI is a city map where can be shown relative green surface average levels for the city. For instance, this outcome can be used to define areas with a low level of green areas in terms of population. Resume statistics can be displayed also in this map.

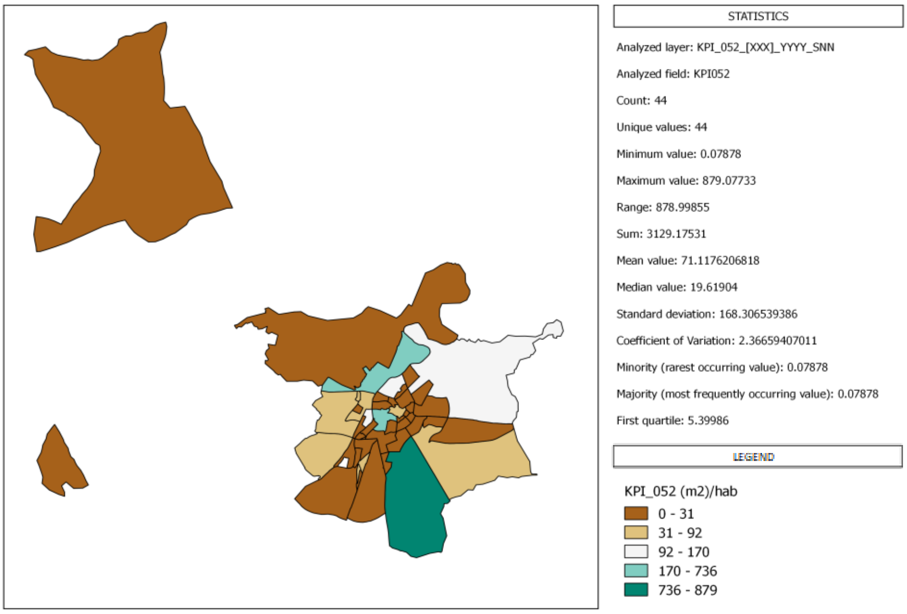

Figure 2.12: Example of results displayed in maps

- **KPI-54: RECREATIONAL (NUMBER OF VISITORS, NUMBER OF RECREATIONAL ACTIVITIES) OR CULTURAL (NUMBER OF CULTURALEVENTS, PEOPLE INVOLVED, CHILDREN IN EDUCATIONAL ACTIVITIES) VALUE.**

INTRODUCTION

This indicator evaluates the ways in which people are engaging with the existing landscape and enhanced NBS provision. The KPI will integrate information regarding the number and types of activities and events that people attend, and whether this is influenced by socio-demographic, geographical or other factors.

The KPI relates to investments in neighbourhood and larger-scale investments in NBS that have the capacity to hold events and activities, which can be formally assessed/monitored. Smaller site interventions that do not or cannot provide spaces for formal activities will not be assessed.

To be collected from Deli 2.4

METHOD

The KPI will be measured through a social survey with participants on-site and with local residents within a 500m radius of the NBS investments.

The data collected will be quantitative in nature highlighting the types, number of and access to events from participants. Additional socio-demographic data will be collected to highlight whether different societal groups engage with specific events, activities or NBS more frequently.

RESULTS

The KPI will provide evidence of the number, location and types of events that different demographic groups engage with. It will also provide data on what factors promote engagement with NBS and what the barriers to use are.

- **KPI-74: SUSTAINABILITY OF GREEN AREAS**

INTRODUCTION

This indicator evaluates the sustainability of green areas in ecological, social and economic terms.

This KPI is related to NBS involving both horizontal and **vertical green infrastructures**, such as new green cycle lane and re-naturing existing bike lanes: Green cycle lane; Green resting areas; Cycle-pedestrian green paths, etc.

METHOD

This KPI can be measured throughout specific software, such as GIS software and/or spreadsheet software.

Data are acquired by statistic and GIS processing, so none sensor is required. Some data can be obtained by another KPIs results.

RESULTS

The main result of this KPI is a city map where each neighbourhood is classified by ranges of sustainability of its green areas. In addition, a table can be elaborated with the sustainability value of each green area, with an average value at a city-scale.

- **KPI-75: QUALITY OF LIFE FOR ELDERLY PEOPLE**

To be collected from Deli 2.4

- **KPI-78: PERCEPTIONS OF CONNECTIVITY AND MOBILITY**

To be collected from Deli 2.4

- **KPI-86: MEAN LEVELS OF EXPOSURE TO AMBIENT AIR POLLUTION (POPULATION WEIGHTED) (PROPOSED INDICATOR FOR SDG TARGET 3.9)**

INTRODUCTION

This KPI is useful to assess the level of population exposed to low air quality levels in the city and the importance of this challenge for the city. Further analysis could be developed using public health or hospital admission data to correlate the importance or green infrastructure on air quality levels.

METHOD

This KPIs is calculated from ground measurements by the official Air Quality monitoring networks in cities applying a methodology defined by URBAN GreenUP Project adapted from different sources. Additionally, information on the type of the zone (road traffic, city background, industrial, etc.) has been assigned to the different areas/streets of the city to weight population.

RESULTS

The main result of this KPI is a city map where can be shown air quality average levels for the city. This outcome can be used to define population exposition levels and to highlight buildings used by vulnerable groups such as schools or residences for the elderly.

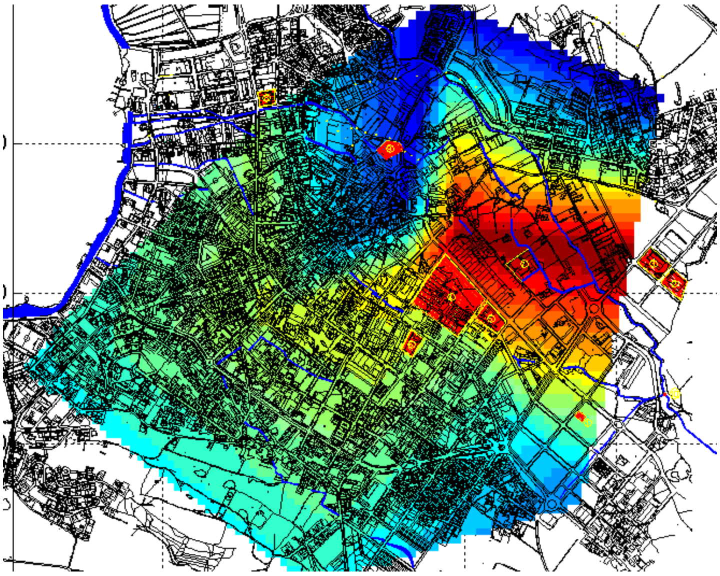

Figure 2.13: Example of results displayed in maps

- **KPI-109: ASSESSMENT OF TYPOLOGY, FUNCTIONALITY AND BENEFITS PROVIDED PRE AND POST INTERVENTIONS**

To be collected from Deli 2.4

- **KPI-111: OPENNESS OF PARTICIPATORY PROCESSES.**

To be collected from Deli 2.4

- **KPI-112: LEGITIMACY OF KNOWLEDGE IN PARTICIPATORY PROCESSES.**

To be collected from Deli 2.4

- **KPI-123: CRIME REDUCTION THROUGH POLICE REPORTS AND LOCAL AUTHORITY DATA**

INTRODUCTION

This KPI measures how NBS can contribute to crime reduction in those places, which have invested in NBS or non-technical interventions. This KPI evaluates the relationship between local urban context, locations and frequency of crime activities and the potential of physcoal landscape improvements in NBS to mitigate criminal activity. This is linked to the literature on frequency of use, perceived value and inclusivity of green space, and localised centres/hot spots of crime.

METHOD

This KPI requires statistical data based in surveys, regarding the number of acts of vandalism or unintentional actions or/and number of urban furniture damages. This will be obtained from publicly available information collected and reported by local police and the city council, and will be mapped via GIS to assess where and how often criminal activities occur, and whether the intervention of NBS has led to a change in frequency. Crime will be assessed around the location of the NBS (with 300m buffer) to assess whether increased landscaping has an impact in criminal behaviour.

RESULTS

The main result of this KPI will be a GIS mapping exercise illustrating where criminal activity has historically taken place and the frequency of activity post-intervention in NBS. The results of the mapping exercise will be cross-referenced to KPIs 109 and 123.

- **KPI-140: NUMBER OF SUBSIDIES OR TAX REDUCTIONS APPLIED FOR (PRIVATE) NBS MEASURES (MEULEN ET AL., 2013).**

To be collected from Deli 2.4

- **KPI-143: NEW BUSINESSES ATTRACTED AND ADDITIONAL BUSINESS RATES (EFTEC, 2013). LIV WORDING: INCREASED RETURNS OF BUSINESS RATES WITH NBS**

To be collected from Deli 2.4

- **KPI-150: CONSUMPTION BENEFITS: PROPERTY BETTERMENT AND VISUAL AMENITY ENHANCEMENT (TYLER ET AL., 2013) RESULTING FROM NBS.**

To be collected from Deli 2.4

2.2.2 LIVERPOOL NBS Optional KPIs

Liverpool is monitoring 20/29 Core KPIs selected for URBAN GreenUP. The following table shows the Liverpool KPIs compared with the Core KPIs. These are also listed in section D3.4, Monitoring programme for Liverpool.

- Purple text = ESA KPI for Liverpool (18 indicators)
- Red text = Local KPI for Liverpool (15 indicators)
- Black text = ESA KPI not being monitored by Liverpool

CHALLENGES	TYPE OF INDICATORS	KPI	LIVERPOOL	ESA core KPIs	NBS
CHALLENGE 1: Climate mitigation & adaptation	Carbon savings per unit area Carbon storage and sequestration	Tonnes of carbon removed or stored per unit area per unit time	X	1	Tree related actions; vertical and horizontal green infrastructure; SUDs and raingardens; Urban Carbon sink
	Temperature reduction (environmental, physical)	Decrease in mean or peak daytime local temperatures (°C)		1	Vertical & Horizontal Infrastructure; Tree related actions
		Heatwave risks (nº of combined tropical nights (>18 °C) and hot days (>20 °C)	X (amended)	1	
	Carbon sequestration	Economic value of carbon sequestration by vegetation as a result of NBS over 25 years	X		Tree related actions; vertical and horizontal green infrastructure; SUDs and raingardens; Urban Carbon sink
		use of Star tools to calculate projected maximum surface temperature reduction	X	1	Tree related actions; Urban Carbon sink; horizontal GI
		Increased opportunity for species movement in response to climate change as a result of NBS	X		Tree related actions; pollinator verges and spaces; Urban Carbon sink; horizontal and vertical GI
CHALLENGE 2: Water Management	Physical indicators	Run-off coefficient in relation to precipitation quantities (mm/%)	X	1	Tree related actions; SUDs and raingardens; Urban Carbon sink; horizontal GI

CHALLENGES	TYPE OF INDICATORS	KPI	LIVERPOOL	ESA core KPIs	NBS
		Absorption capacity of green surfaces, bioretention structures and single trees (m3/m2) (m3/tree)		1	
		Temperature reduction in urban areas (°C, % of energy reduction for cooling)		1	
		Areas (Ha) and population (inhab) exposed to flooding		1	
	Chemical indicators (water quality)	Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals, COD; BOD; SST (mg/l)	X		SUDs and raingardens; Green filter area; smart soils, natural waste water treatment
		Drinking Water provision (m3/ha/yr)		1	
		Water for irrigations purposes (m3 ha-1year-1)		1	
	Economic indicators (benefits)	Volume of water removed from water treatment system	X	1	SUDs and raingardens; tree related GI; horizontal GI, smart soils
		volume of water slowed down entering sewer system	X	1	
		Economic benefit of reduction of stormwater to be treated in public sewerage system (€) (Deng et al., 2013; Soares et al., 2011; Xiao and McPherson, 2002)	x		Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Challenge 4: Green Space Management		Accessibility (measured as distance or time) of urban green spaces for population and total green space m2/distribution (Tamosiunas et al., 2014).	X	1	Vertical & Horizontal Infrastructure; Tree related actions
		assessment of typology, functionality and benefits provided pre and post interventions	X		Non-technical actions;
	Environmental (biological)	Production of food (ton/Ha/year)		1	
		Increase in density and seasonal spread of floral resources for pollinators	X		Pollinator verges and spaces; horizontal green interventions; vertical green interventions; SUDs and raingardens
		Increase in plant species richness and functional diversity as a result of NBS	X		
		Increase in Insectivore (e.g. bat) abundance and use of corridors for movement as a result of NBS	X		

CHALLENGES	TYPE OF INDICATORS	KPI	LIVERPOOL	ESA core KPIs	NBS
		Increased connectivity to existing GI	X	1	Tree related GI; horizontal green interventions; Vertical and horizontal green interventions; SUDs and raingardens
		Pollinator species increase (number)	X	1	Pollinator verges and spaces; horizontal green interventions; vertical green interventions; SUDs and raingardens
CHALLENGE 5: Air Quality	Environmental (chemical)	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration	X	1	Green cycle lane; Tree related actions; green filter area, vertical GI
		Trends in emissions (actual levels) NOX, SOX	X	1	
	Economic	Monetary values: value of air pollution reduction (Manes et al., 2016); total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values (Soares et al., 2011). use of GI val to calculate the value of air quality improvements	X	1	Tree related actions; Smarts soils as substrate; green filter area, vertical GI
	Social (physiological)	Air quality parameters NOx, VOC, PM		1	
CH6 Urban Regeneration	Socio-cultural indicators	Accessibility (Schipperijn et al., 2010): distribution, configuration, and diversity of green space and land use changes (multi-scale; Goddard et al., 2010). LIV WORDING: Accessibility: distribution, distance, spatial configuration to NBS and green spaces. Diversity of NBS (land use and functionality).	X (amended)	1	Green cycle lane; Tree related actions;
		Savings in energy use due to improved GI	X	1	Vertical GI, Tree related actions, Horizontal GI
CH7 Participatory planning and governance	Social	Social learning concerning urban ecosystems and their functions/services (Colding and Barthel, 2013).	X		Tree related GI; horizontal green interventions; Vertical and horizontal green interventions
		Perceptions of citizens on urban nature- green spaces quality (Buchel and Frantzeskaki, 2015; Colding and	X	1	

CHALLENGES	TYPE OF INDICATORS	KPI	LIVERPOOL	ESA core KPIs	NBS
		Barthel, 2013; Gerstenberg and Hofmann, 2016; Scholte et al., 2015; Vierikko and Niemelä, 2016).			Non-technical actions;
		Citizen participation in the development and delivery of interventions. LIV WORDING: Engagement with NBS (sites/projects)	X		
CH 8: Social Justice and social cohesion	Social justice	Crime reduction through police reports and local authority data	X		Non-technical actions; vertical and horizontal GI, vertical GI, Horizontal GI, Tree related actions, SUDs and raingardens, pollinator verges and spaces
CHALLENGE 9: Public Health and Well-being	Psychological indicators	Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit		1	
		Perceptions of health and quality of life	X		Green cycle lane; Vertical green interventions; Horzontal green interventions, open water SUDs
	Health indicators	Increase in walking and cycling in and around areas of interventions	X	1	Green cycle lane; Vertical green interventions; Horizontal green interventions; raingarden
CHALLENGE 10: Economic opportunities and green jobs	Economic	Change in mean or median land and property prices (Forestry Commission, 2005). LIV WORDING: Changes in mean house prices/rental markets	X		Tree related actions; Natural Wastewater Treatment Plan; Green filter area; SUDs and raingardens; Non-technical actions
		Number of jobs created; gross value added	X	1	
		New businesses attracted and additional business rates	X		
		Job creation, increased footfall and spend in the areas of interventions if appropriate	X		
	TOTAL NUMBER OF KPIs		**32**	**17/29**	

Table 2.12: Additional KPIs of the city of Liverpool

Local optional KPIs are listed below – refer to D3.4 for details

Climate Change Challenge

KPI-6: MEASUREMENTS OF GROSS AND NET CARBON SEQUESTRATION OF URBAN TREES BASED ON CALCULATION OF THE BIOMASS OF EACH MEASURED TREE (I-TREE ECO MODEL), TRANSLATED INTO AVOIDED SOCIAL COSTS OF CO_2 EMISSIONS (USD T-1 CARBON). LIV WORDING: ECONOMIC VALUE OF CARBON SEQUESTRATION BY VEGETATION AS A RESULT OF NBS OVER 25 YEARS

Modelled using GIVal to calculate the projected economic value of carbon stored in vegetation as a result of NBS over 25 years. Input data: project delivery records

INCREASED OPPORTUNITY FOR SPECIES MOVEMENT IN RESPONSE TO CLIMATE CHANGE AS A RESULT OF NBS

Use of Condatis model to quantify increased long-distance range-shift potential for selected taxa as a result of GI interventions.

Water Management Challenge

KPI-30: NUTRIENT ABATEMENT, ABATEMENT OF POLLUTANTS (%, NUTRIENT LOAD, HEAVY METALS) (CHEMICAL OXYGEN DEMAND (COD) (MG/L); BIOCHEMICAL OXYGEN DEMAND (BOD) (MG/L); TOTAL SOLIDS (SST) (MG/L))

% change in key water quality indicators between baseline measurement and years 1 and 2 post intervention.

KPI-35: ECONOMIC BENEFIT OF REDUCTION OF STORMWATER TO BE TREATED IN PUBLIC SEWERAGE SYSTEM (€) (DENG ET AL., 2013; SOARES ET AL., 2011; XIAO AND MCPHERSON, 2002)

Measure by applying discharge cost/m3 stormwater at baseline and then post intervention.

Coastal Challenge

Not considered relevant for Liverpool sites.

Air Quality Challenge

No local indicators

Green Space Management Challenge

KPI-109: ASSESSMENT OF TYPOLOGY, FUNCTIONALITY AND BENEFITS PROVIDED PRE AND POST INTERVENTIONS

Social surveys will be used to evaluate the added-value that NBS can provide within local communities, businesses and other stakeholders in Liverpool. The KPI will be evaluated through engagement with users, formal friends of/community groups and local businesses to investigate their ex-ante and ex-post understanding of the local landscape, and the potential benefits that could be provided by investment in NBS. This will reflect upon whether specific types of NBS, i.e. street trees, SUDS, enhanced public space, are deemed to be more appropriate and functional in different locations and to different communities of interest. The survey will also examine the perceptions of functionality pre and post intervention. This will be achieved through an engagement with participants and discussions with them regarding the proximity, use and socio-economic and perceived ecological functionality of NBS. Socio-demographic data, geographical location and local environmental context will all be taken into account to structure the discussions.

INCREASE IN DENSITY AND SESONAL SPREAD OF FLORAL RESOURCES FOR POLLINATORS

Ecological surveys of selected taxa at NBS locations pre-intervention and at 1 and 2 years post intervention

INCREASE IN PLANT RICHNESS AND FUNCTIONAL DIVERSITY AS A RESULT OF NBS

Ecological surveys of selected taxa at NBS locations pre-intervention and at 1 and 2 years post intervention

INCREASE IN INSECTIVORE (E.G. BAT) ABUNDANCE AND USE OF CORRIDORS FOR MOVEMENT AS A RESULT OF NBS

Bat survey transects including NBS locations pre-intervention and at 1 and 2 years post intervention; using Batlogger M real-time, full spectrum detector to record bat species echolocation calls.

Urban Regeneration challenge

None

Participatory planning and governance Challenge

KPI-115: SOCIAL LEARNING CONCERNING URBAN ECOSYSTEMS AND THEIR FUNCTIONS/SERVICES (COLDING AND BARTHEL, 2013).

Using a mixed methods case study, we will be measuring social learning. Social learning has long been established as essential to policy change, and thus is essential to mainstreaming NBS. To monitor social learning, it is essential to examine how policies and processes have actually changed. Such changes can encompass adoption of new interventions, techniques, policy, and processes in response to past experience and new information (Hall, 1993). Semi-structured interviews, participant observation, and content analysis will all be used as part of baseline monitoring and throughout the project to understand how decision makers, policy makers and practitioners are incorporating new knowledge about NBS into their processes, discussions, and documents. This KPI will focus on a particular form of social learning known as policy learning. In both baseline and post-intervention monitoring, monitoring for this KPI will include structured content analysis on key policy documents relevant to the study area will be undertaken, using a range of techniques including word-frequency counting, key-word-in-context listings, concordances, classification of words into content categories, content category counts, and retrievals based on content categories and co-occurrences (Druckman 2005; Weber 1990).

In addition, using purposive, non-probability sampling, baseline and post-intervention monitoring will includes interviews key individuals involved in making relevant policies and making decisions with respect to green infrastructure and NBS in the City of Liverpool, with data being collected until saturation (Minichiello et al. 2008). Sometimes these adjustments will require small, incremental changes, and sometimes they will require radical shifts in approach, and it may also require time for changes to be made on paper, so interviews will allow access to the most up-to-date thinking and information. To ensure consistency in data collection, an interview guide based on the key theoretical elements of policy learning (Suškevičs et al. 2017; Dovers and Hussey 2013) will be used to analyse baseline knowledge of NBS, examine current processes and implementation of policy, and identify adjustments to processes and policies. At the same time, participant observation will be used to analyse decision-making in real-time and evaluate how it evolves over the course of four years. Two levels of policy learning will be assessed: 10 how policy problems are constructed and how solving the problem should be approached (i.e. scope of policy and its goals), and 2) instrumental learning, where lessons about policy design and knowledge about when a particular policy instrument is appropriate or viable (May 1992).

Data from all methods will be analysed using Nvivo, using a combination of deduction and induction, using a priori codes from theory (Creswell 2013), followed by a second level of analysis where emergent themes were identified from coding patterns in the data (Miles and Huberman 1994). A selection of interviews will also be blindly coded by another researcher to check intercoder reliability is at least 85%.

CITIZEN PARTICIPATION IN THE DEVELOPMENT AND DELIVERY OF INTERVENTIONS. LIV WORDING: ENGAGEMENT WITH NBS SITES.

This KPI will be measured primarily via participant observation and record keeping on community consultation and the governance and implementation of each intervention, wherein descriptive statistics of the organisations and individuals involved, and their demographic characteristics, will be kept. To complement this data and provide a richer source of data on how citizens and community groups are participating in the development and delivery of interventions, targeted interviews with a sample of participants will be undertaken to better understand the reasons for their involvement and how they have been involved, and analysed in conjunction with survey data to assess how this changes over time.

Social Justice and Social Cohesion Challenge

KPI-123: CRIME REDUCTION THROUGH POLICE REPORTS AND LOCAL AUTHORITY DATA

Crime will be assessed around the location of the NBS (with 300m buffer) to assess whether increased landscaping has an impact in criminal behaviour. This data will be collected from publicly available information collected and reported by local police and the city council.

Public Health and Wellbeing Challenge

PERCEPTIONS OF HEALTH AND QUALITY OF LIFE

Survey of local residents to understand perceptions of general, physical, and mental health, as well as general, individual, and communal well-being. This will be measured primarily via questionnaires administered in person and online. Residents will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Perceptions of general, physical, and mental health and well-being will be measured on 5-point Likert scales and analysed statistically in standard software (Excel and SPSS), and will examine perceptions of urban nature more generally and specifically in their neighbourhoods. Perceptions of quality and social values will also be analysed alongside other survey data using cluster analysis to identify variation within the population. Using a stratified probability sampling technique, the researchers will aim for a minimum of a 95% confidence interval and a sample that is representative of the broader target populations that live near the interventions and those who use the sites.

Economic Opportunities and Green Jobs Challenge

KPI-142: CHANGE IN MEAN OR MEDIAN LAND AND PROPERTY PRICES (FORESTRY COMMISSION, 2005). LIV WORDING: CHANGES IN MEAN HOUSE PRICES/RENTAL MARKETS

Change in house/rental prices in NBS intervention areas will be measured primarily using secondary analysis of property market data. A full database of property market value will be collected prior to the interventions, and then monitored for a period of 2 years afterward, then analysed to determine if significant change in property values near the interventions has occurred. All data will be corrected for standard market growth in comparable areas of the city. This data will also be complemented by GVal calculations.

NEW BUSINESSES ATTRACTED AND ADDITIONAL BUSINESS RATES (EFTEC, 2013). LIV WORDING: INCREASED RETURNS OF BUSINESS RATES WITH NBS

Change in revenue from businesses in the NBS intervention areas, as self-reported via questionnaires administered in person and online. Businesses in the local catchment areas of the interventions will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Data will be collected on both perceptions (using 5-point Likert scales) and economic data from businesses on increases in business rates collected by the council. This data will be analysed in standard software (Excel and SPSS), to determine if there is a statistical difference between dwell time and sales pre- and post-intervention for businesses in the immediate vicinity. Given the relatively small number of businesses, the researchers will aim for a census or at least of minimum of a 95% confidence interval and a sample that is representative of the business communities that operate near the interventions.

KPI-151: JOB CREATION, INCREASED FOOTFALL AND SPEND IN THE AREAS OF INTERVENTIONS IF APPROPRIATE

Change in number of jobs located in areas in NBS investment and reporting and changes in income/composition of company post-investment will be measured via questionnaires administered in person and online. Businesses in the local catchment areas of the interventions will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Data will be collected on both perceptions (using 5-point Likert scales) of footfall and self-reported increases in jobs, will be collected directly from businesses and analysed in standard software

(Excel and SPSS), to determine if there is a statistical difference between dwell time and sales pre- and post-intervention for businesses in the immediate vicinity. Given the relatively small number of businesses, the researchers will aim for a census or at least of minimum of a 95% confidence interval and a sample that is representative of the business communities that operate near the interventions. This perception and self-reported economic data will be checked against footfall data collected during the baseline monitoring period and after the interventions are implemented as a means of triangulation, if budgets allow for the purchase of this monitoring equipment.

2.2.3 IZMIR NBS Optional KPIs

Purple text = Optional KPI for İzmir

Green text= Additional KPI for İzmir

CHALLENGES	TYPE OF INDICATORS	KPI	İZMİR	ESA core KPIs	NBS
CHALLENGE 1: Climate mitigation & adaptation	**Carbon savings per unit area** (environmental, chemical) **Carbon storage and sequestration in vegetation and soil**	Tonnes of carbon removed or stored per unit area per unit time (ton CO2/Ha) (ton CO2/year).	x	1	
		Total amount of carbon (tonnes) stored in vegetation	x		
	Temperature reduction (environmental, physical)	Decrease in mean or peak daytime local temperatures (oC)	x	1	
		Measures of human comfort e.g. ENVIMET PET — Personal Equivalent Temperature, or PMV — Predicted Mean Vote.	x		
		Heatwave risks (number of combined tropical nights (>20oC) and hot days (>35oC) following Fischer, Schär, 2010, cited by Baró et al. (2015)	x	1	
	Energy and carbon saving	Energy and carbon savings from reduced building energy consumption	x		
	add	Tonnes of stored per unit area per unit time (ton CO2/ha) (ton CO2/year). Total amount of carbon stored in soil (smart soil)			
	add	Energy, water and carbon reduction via urban farming (Climate-smart Greenhouse)			
	add	Increase in shadow surface (m2)			
CHALLENGE 2: Water Management	Physical indicators	Drinking water provision (m3 ha-1year-1)	x		
		Water for irrigations purposes (m3 ha-1year-1)	x		
	add	Runoff volume calculation			
	add	Peak runoff rate calculation			

CHALLENGE4: Green Space Management	Social indicators (benefits)	Distribution of public green space – total surface or per capita	x		
		Accessibility (measured as distance or time) of urban green spaces for population	x	1	
		Weighted recreation opportunities provided by Urban Green Infrastructure	x		
	Environmental (biological)	Production of food (ton ha-1 year-1)	x		
		Increased connectivity to existing GI	x	1	
		Pollinator species increase	x	1	
	add	Urban green spaces per capita			
CHALLENGE 5: Air Quality	Environmental (chemical) and Social(physiological)	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) oncentration recorded ug/m3	x	1	
		Air quality parameters and trends in emissions NOx, SOx, PM10 etc	x		
		Pollutants removed by vegetation (in leaves, stems and roots) (kg ha-1 year-1)	x		
CH6 Urban Regeneration	Socio-cultural indicators	Accessibility: (Connectivity - add.) distribution, configuration, and diversity of green space and land use changes (multi-scale;). - Green spaces quantity	x		
CH7 Participatory Planning and Governance	Social	Perceptions of citizens on urban nature - Green spaces quality	x		
	add	Urban Farming Educative/ participate activities, Learning for producers			
CH 8: Social Justice and Social Cohesion	Social cohesion	Green intelligence awareness	x	1	
CHALLENGE 9: Public Health and Well-being	Health indicators related to ecosystem service provision	Increase in walking and cycling in and around areas of interventions	x	1	

CHALLENGE 10: Potential of economic opportunities and green jobs	Economic	Number of jobs created	x	1	
	TOTAL NUMBER OF KPIs				

- **KPI-8: MEASURES OF HUMAN COMFORT E.G. ENVIMET PET — PERSONAL EQUIVALENT TEMPERATURE, OR PMV — PREDICTED MEAN VOTE.**
- **KPI-10: ENERGY AND CARBON SAVINGS FROM REDUCED BUILDING ENERGY CONSUMPTION (kWh/y, ton C/y saved)**
- **KPI-52: DISTRIBUTION OF PUBLIC GREEN SPACE – TOTAL SURFACE OR PER CAPITA.**
- **KPI-87: POLLUTANTS REMOVED BY VEGETATION (IN LEAVES, STEMS AND ROOTS) (KG HA-1 YEAR-1)**

Added ones:

- Tonnes of stored per unit area per unit time (ton CO2/ha) (ton CO2/year). Total amount of carbon stored in soil (smart soil)
- Energy, water and carbon reduction via urban farming (Climate-smart Greenhouse)
- Increase in shadow surface (m2)
- Runoff volume calculation
- Peak runoff rate calculation
- Urban green spaces per capita
- Urban Farming Educative/ participate activities, Learning for producers

- **KPI-87: Pollutant's removed by vegetation (in leaves, stems and roots)**

RATIONALE

Road transport and construction operations are identified as major sources of air pollutants in cities. Airborne particulate matter is associated with harmful effects on human cardiovascular and respiratory health. Particles ≤ 10 microns (PM10), and particularly the finer particles ≤ 2.5 microns (PM2.5) associated with road transport vehicles, are of concern due to their small size; (a micron, or micrometre = one-millionth of a meter: 0.001 millimetre). Green walls (or screens) in urban streets may act as barriers to direct dispersal of pollutants from combustion engine vehicles to pedestrian areas. Particulates may be deposited on the leaf surface of trees or taken up into the leaf surface wax layer, reducing atmospheric particulate concentrations. Airborne particles and gas molecules can be deposited when they pass close to a surface. Most plants have a large surface area per unit volume that increases the probability of deposition compared to the smooth surfaces present in urban areas (Roupsard et al., 2013).

Monitoring of air quality parameters is complex; involving many potentially interacting variables. Variation in weather conditions; prevailing wind direction and speed; tree species, density, location and structure; and the configuration of built urban infrastructure are among factors which may affect the trajectory and rate of dispersal of particulate pollutants. We aim to compare outdoor air concentrations of PM10 and PM2.5 at child and adult head heights at locations with and without street trees or green walls to evaluate whether these NBS are associated with reduced local concentrations of airborne PM10 and PM2.5.

With this KPI the main aim is to calculate the pollutions removed by vegetation (in stem, leaves and roots) (kg ha -1 year -1) using formulas and equations in order to asses the impact of the NBS.

Related NBS: *Green Parklets, Urban Carbon Sink: Planting New Trees, Green fences/green walls, Shade and cooling trees*

METHODOLOGY

Air pollutant removal capacity of trees is estimated based on dry deposition that is considered as the rate of air pollutants removed from the atmosphere (Lovett, 1994; McPherson et al., 1998; Scott et al., 1998). Pollutants are removed on leaf surfaces primarily in two ways: through leaf stomata uptake of gaseous pollutants and leaf interception of particulate matter (Nowak et al., 2006). The first one leads to the diffusion of pollutant into the inner part of leaves. Gases may also be absorbed or react with plant surfaces; while removal through the letter process may be reduced by the re-suspension of intercepted particles from the leaf surfaces through wind action (Selmi et al., 2016). As this research focused on the ES of trees, air pollutant deposition on other vegetation cover (such as shrubs, grass) and land cover types (like water bodies, and buildings) are not included in the calculation.

The pollutant flux (Fi) is calculated as the product of the deposition velocity (Vd) and the concentration of air pollutant i (Ci), Eq.(3):

$$F_i = Vd\ (cm/sn) \times C(g/m^3) \qquad (3)$$

Total flux into urban trees of air pollutant i (Fit) can be estimated through multiplying Fi by tree cover (A) in a time period (T), Eq.(4):

$$F_{it} = F_i \times A \times T \qquad (4)$$

The amount of air pollutants removed by trees (F) could be quantified by Eq.(5);

$$F = \sum_{i=1}^{3} F_{it} \qquad (5)$$

It is calculated in demo sites in Izmir before the interventions and will be executed again after NBSs are implemented in order to make a before and after comparison.

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KPI: Urban green spaces per capita

RATIONALE

Green spaces are useful ingredients for spatial planners in achieving a sustainable urban landscape. They can provide elements characterizing the heritage and aesthetics of the area (Madureira et al., 2011; Niemelä, 2014), as well as being valued for recreation (Fors et al., 2015), social interaction (Kaźmierczak, 2013), education (Krasny et al., 2013) and supporting healthy living (Carrus et al., 2015). Green spaces are also important for urban biodiversity (Bennett et al., 2015) as they provide habitats for various species (Niemelä, 2014). However, size, distribution and configuration of urban green spaces are always problematic in urban landscapes. In other words, their configuration is highly fragmented and they show absence of the necessary qualities and quantities and evenly distribution (Hepcan, 2013).

This KPI calculates existing urban green spaces per capita (m^2/people) in the urban development zone of two cities: Karşıyaka and Çiğli where all the NBSs are located in Izmir to evaluate the impact of the NBS that will increase the amount of green areas up to some extent.

Related NBS: *Grassed swales and water retentions ponds, Green covering shelter, Shade and cooling trees, New green cycle lane and re-naturing existing bike lane, Urban Carbon Sink: Planting Trees*

METHODOLOGY

The proposed new green corridor that starts in Çiğli and ends in Karşıyaka acts as a green connecter between two districts. It is important to indicate that the urban zones of two districts are already spatially connected. Therefore, calculation for urban green and public green spaces was based on confluence of the urban development zone of two urban districts. Urban green spaces are composed of private gardens, roadside vegetation, natural vegetation cover (shrublands, wetlands etc.), and vacant lands with little or no vegetation, agricultural areas and olive groves.

The ultimate purpose is to calculate amount of urban green spaces per capita. Of course the figure of urban green spaces per capita does not make a lot of sense or give the big picture of green spaces in an urban landscape unless quality, connectivity and accessibility aspects are addressed in a sustainable way.

Calculation for urban green spaces was based on confluence of the urban development zone of two urban districts; Karşıyaka and Çiğli. In the study area, green spaces/total surface per capita is calculated by dividing the sum of all green spaces in the urban development zones by the total urban population in ArcGIS10. The land use/cover map was derived from WorldView2 satellite images dated 2014 and the population number was provided by 2016 consensus data (TurkStat, 2016).

It is measured at neighbourhood and city scale in the project before NBSs are implemented and will be repeated again in a similar fashion after the implementations to make a comparison or evaluate the performance of NBSs.

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KPI: Distribution of public green spaces/total surface per capita

RATIONALE

Urban green spaces include all the green spaces such as private gardens, roadside vegetation, natural vegetation cover, vacant lands with little or no vegetation and agricultural areas. On the other hand, public green spaces are limited with publicly owned green spaces that are accessible to all city dwellers. Public green spaces are dominated by urban parks (including the coastal promenade), play grounds, sport facilities, and cemeteries in the case of Izmir. They are actively used spaces throughout the city and having a quantitative picture would be helpful in addressing other aspects such as strengthening and/or providing connectivity, increasing quality and accessibility and ecosystem services they provide.

This KPI measures the distribution of public green spaces per capita (m^2/people) in the urban development zone of two cities: Karşıyaka and Çiğli where all the NBSs are located in Izmir to evaluate the impact of the NBS that will increase the amount of green areas up to some extent.

Related NBS: *Grassed swales and water retentions ponds, Green covering shelter, Shade and cooling trees, New green cycle lane and re-naturing existing bike lane, Urban Carbon Sink: Planting Trees*

METHODOLOGY

In the case of Izmir, public green spaces/total surface per capita is calculated by dividing the sum of all green spaces in the urban development zones by the total urban population in ArcGIS10. The land use/cover map was derived from WorldView2 satellite images dated 2014 and the population number is provided by 2016 consensus data (TurkStat, 2016). Calculation for public green spaces was based on confluence of the urban development zone of two urban districts; Karşıyaka and Çiğli.

It is measured at neighbourhood and city scale in the project before NBSs are implemented and will be repeated again in a similar fashion after the implementations to make a comparison or evaluate the performance of NBSs.

- **KPI-: RUN-OFF VOLUME CALCULATION**

RATIONALE

Urbanisation produces numerous changes in the natural environments it replaces. The impacts include the quality and quantity of the stormwater runoff, and result in changes to hydrological systems as well. The hydrological impacts of urbanisation originate from the reduction of the perviousness of urban areas compared to rural and natural land uses. Impervious surfaces such as buildings, roads and other paved areas reduce rainwater infiltration and increase stormwater runoff (Jacobson, 2011).

With this KPI the main aim is to calculate the volume of runoff before and after the implementation to evaluate the effect of the NBS in demo area in means of runoff quantity.

The KPI will be estimated by a simple and most commonly used hydrological model dealing with small and ungauged watersheds basically from rainfall data. The metric will be volume (m^3)

RELATED NBS

Grassed swales and water retentions ponds around Bio-Boulevard

SENSOR/SOFTWARE

No sensor is required. ArcMap 10.3 will be used for digitizing the topographic, soil, and land use maps besides generating final maps.

DATA SAMPLING

Data needed to be obtained:

- Location information
- Rainfall data
- Land use/cover information
- Soil type information

Rainfall data will be obtained from Turkish State Meteorological Service database. Soil information will be derived from topographic maps that will be obtained from General Command of mapping database. Land use/cover information will be digitized from Worldview2 satellite images.

METHODOLOGY

The most common method of predicting runoff is the curve number (CN) method developed by the USDA (United States Department of Agriculture) Natural Resources Conservation Service (NRCS) formerly the Soil Conservation Service (SCS) (Jacobson, 2011) will be used to predict runoff in demo site where NBS will be allocated.

The runoff curve number (CN) is used to predict runoff based on the amount of impervious area, soil group, land cover type, hydrological condition, and antecedent runoff (USDA NRCS, 1986).

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- **KPI-: PEAK RUNOFF RATE CALCULATION**

RATIONALE

Urbanization itself obviously increases impervious surface area within a watershed that cause decreasing infiltration of precipitation. Runoff increases in proportion to the cover of impervious surface in a watershed (Arnold and Gibbons, 1996), and the increased storm runoff increases peak discharges and flood magnitudes according to Dunne and Leopold (1978) (White and Greer, 2006).

Within this KPI the main purpose is to calculate peak runoff rate for design of storm water management structures by a method called Rational Method widely used around the world for peak flow estimation of small drainage basins. The metric will be volume (m^3/s).

RELATED NBS

Grassed swales and water retentions ponds around Bio-Boulevard

SENSOR/SOFTWARE

No sensor or software is required.

DATA SAMPLING

Data needed to be obtained:

- Location information (Drainage area detection)
- Land use/cover information
- Intensity-duration-frequency graph

Location information to detect the drainage area will be derived from topographic maps that will be obtained from General Command of Mapping database. Land use/cover information will be digitized from Worldview2 satellite images.

METHODOLOGY

The rational method will be used to calculate the peak runoff rate in demo site where NBS will be allocated. The method developed by Mulvaney, 1851, Kuichling, 1889, is rational in the sense that it relates runoff peak discharge to rainfall intensity as opposed to purely empirical techniques that correlate peak discharge to catchment characteristics. models compute the peak flow rate at the outlet of a catchment for a given rainfall intensity (Crobeddu et al., 2007).

Values for the runoff coefficient, drainage area, time of concentration and design return period are needed for the calculation.

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KPI-8: MEASURES OF HUMAN COMFORT E.G. ENVIMET PET — PERSONAL EQUIVALENT TEMPERATURE, OR PMV — PREDICTED MEAN VOTE.

RATIONALE

Climate change is often discussed in terms of changes in air temperature, cloud, wind, etc. However, in order to evaluate its impact on people's thermal perception and wellbeing, it is definitely necessary to analyse their combined effect (Mayer, H. and Höppe, P., 1987). Human thermal comfort can be defined as a condition of mind that shows satisfaction with the surrounding environment. High temperatures and humidity naturally result in discomfort sensations and dissatisfaction (Abdel-Ghany et al., 2013).

The degree of human or thermal comfort that people experience in open and green spaces is one of the key factors, especially in areas with extreme climatic conditions. There is a wide range of indices in the literature on this matter, such as THI, PE, TS, PMV, PET, mPET and COMFA (Matzarakis et al., 1999, Ruiz & Correa, 2014, Xuea & Xiao, 2016).

The main goal of this KPI is to calculate outdoor thermal comfort after measuring micro-climate conditions in demo sites before and after implementation of the NBS.

RELATED NBS

Green Shady structures, shade tree, cooling trees, green façade, and green parking pavements

SENSOR/SOFTWARE

The RayMan Pro (Matzarakis et al., 2007) version 2.1 Software will be used to calculate the values of outdoor thermal comfort indices using the measured air temperature and relative humidity data for KPI 7.

METHODOLOGY

The method is composed of two parts;

(1) collecting air temperature and relative humidity, and surface temperature data (measured for KPI 7),

(2) calculating and analyzing of human thermal comfort conditions by collected data according to the Physiological Equivalent Temperature or PET index and mean radiant temperature.

The measurements will be analysed and interpreted according to the Physiological Equivalent Temperature (PET) index and mean radiant temperature (T_{mrt}) by RayMan software model.

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KPI-10: ENERGY AND CARBON SAVINGS FROM REDUCED BUILDING ENERGY CONSUMPTION (kWh/y and ton C/year SAVED)

Energy and carbon savings from reduced building energy consumption is included in *Challenge 1. Climate mitigation and adaptation.*

RATIONALE

Climate change can cause overheating in city centers, especially through the "heat island effect". Green urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapo-transpiration, which leads to energy and carbon savings from reduced building energy consumption especially in summer (Akbari, 2002). On the other hand, insulating effect of plants reduces heating energy consumption and associated carbon emissions in winter (Alexandri and Jones, 2008; Zinzi and Agnoli, 2011).

NBSs in Izmir do not have any building level interventions such as green roof and green façade. Green shady structures will be implemented in car parks which has no connection with buildings. Therefore, energy and carbon savings from reduced building energy consumption will be obtained using a dynamic building energy performance software, Design Builder (v.4.7) (Design Builder, 2018). The buildings in NBS locations will be classified such as residential, commercial, etc. and one example from each class will be modelled. The models will be simulated by air temperature and relative humidity, and surface temperature values which will be obtained from KPI-7 "Decrease in mean or peak daytime local temperatures (°C)". The difference between energy consumption values of pre- and post-intervention will give energy savings. Then, corresponding carbon savings from reduced energy consumption will be calculated by conversion factors given by the Building Energy Performance Regulation (BEP, 2017). Finally, the study will be extended to all buildings at NBS locations.

SENSOR/SOFTWARE

Design Builder (v.4.7) (Design Builder, 2018) Software will be used to model the buildings and simulate the model to obtain energy consumption data based on measured air temperature and relative humidity, and surface temperature data for KPI 7.

RELATED NBS

Green Shady structures, shade tree, cooling trees, green façade, and green parking pavements

METHODOLOGY

The methodology consists of measurements, modelling and simulations. The steps of the methodology are;

(1) collecting air temperature and relative humidity, and surface temperature data (measured for KPI 7) from NBS locations both pre- and post-intervention,

(2) classifying the buildings at NBS locations and modelling one building for each class,

(3) simulating the building models to obtain energy consumption values,

(4) converting the energy consumption values to primary energy consumption value using conversion factors provided by the Building Energy Performance Regulation (BEP, 2017),

(5) converting the energy consumption values into CO_2 by means of conversions factors provided by the Building Energy Performance Regulation (BEP, 2017),

(6) obtaining energy and carbon savings by comparing pre- and post-intervention primary energy consumptions and CO_2 emissions at NBS locations,

(5) extending the study to all buildings at NBS locations.

If modelling is not possible, a city specific mean heat gain/loss correlation can be obtained from the literature. Based on the decrease in air temperature by interventions, decrease in energy consumption will be calculated by the correlation. Finally, corresponding carbon savings from reduced energy consumption will be calculated.

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3 Climate and water resilience assessment procedures

3.1 Summary of interventions

A large scale demonstration is being carried out in the three front-runner cities, Valladolid, Liverpool and Izmir. Each city has general objectives to solve specific problems previously identified and a different baseline as current situation, related with the climate change and the water management. For that reason, the interventions that are being implemented in each front-runner city are not exactly the same, but they are comparable and transferable

Each city will address three different areas (SUBDEMOS) to mitigate a set of challenges, by means of the integration of several complementary NBS. The demonstration consists in a real implementation of several NBS integrated in the three front-runners. Those NBS of URBAN GreenUP are classified into 4 categories according to their nature, which are complemented with other subcategories:

1) NBS devoted to renaturing urbanization.
2) NBS related with water interventions.
3) Green singular infrastructures.
4) Non-technical interventions.

The following table lists, on the basis of this scheme, all the NBS to be implemented in each front-runner city. It is noticed that this table has been updated with respect to the initial planning.

	RE-NATURING URB.	WATER INTERV.	SINGULAR GREEN INFRASTRUCT.	NON TECHNICAL INTERVENTIONS
	Green route	SUDSs	Smart soils	Educational activity
VAL	**VAc1**-New green cycle lane and re-naturing existing bike lanes	**VAc8**-SUDs for green bike lane/ **VAc9**-SUDs for re-naturing parking/ **VAc10**-Rain gardens	**VAc16,17,18**-Smarts soil/substrate **Cycle-pedestrian infrast.** **VAc15**-Cycle-pedestrian green paths	**VAc34**: Educational path in NWTP area/ **VAc35**: Educational path in floodable park area/ **VAc36**-Urban Farming educational activities
LIV	**LAc1**-New green cycle route/ LAc2- Green travel route/ LAc3- Road junction pedestrian improvements	**LAc8**-SUDs	**Smart soils** **LAc11**-Enhanced nutrient managing and releasing soil	**LAc18**-Wood allotments/ **LAc19**-GI for Education (School and community groups)/ **LAc20**-Forest School
I			**Smart soils**	

	RE-NATURING URB.	WATER INTERV.	SINGULAR GREEN INFRASTRUCT.	NON TECHNICAL INTERVENTIONS
	IAc1-Cycle and pedestrian route in new Green Corridor	**IAc6**-Grassed swales and Water Retention Pounds	**IAc9**-Smart soil production in climate-smart urban farming precinct/ **IAc10**-Smart soil into green shady structures	**IAc19**-Industrial Heritage Route/ **IAc20**-The Bio-boulevard/ **IAc21**-Education for the Food-smart Future of Izmir/ **IAc22**-Urban Farming Educative/participate Activities
	Arboreal Interventions	**Flood actions**	**Pollinators**	**Engagement**
VAL	**VAc2**-Planting 1,000 trees/**VAc3**-Tree shady places /**VAc4**-Shade&cooling trees/ **VAc5**-Re-naturing parking trees	**VAc11**-Floodable Park	**VAc19, VAc21**-Natural pollinator's modules/ **VAc20**-Compacted Pollinator's modules	**VAc37**-Engagement Portal for citizen/ **VAc38**-Sponsoring activities
LIV	**LAc5**-Shade trees. Species to spread canopies/**LAc6**-Cooling trees.	**LAc4**-Urban Catchment forestry/ **LAc9**-Hard drainage (flood prevention)	**LAc12**-Pollinator verges/ **LAc13**-Pollinator walls/vertical/ **LAc14**-Pollinator roofs	**LAc21**-Engagement Portal for citizens/ **LAc22**-Green Art/engagement/ **LAc23**-Forest Church/ **LAc24**-BioApp/**LAc25**-GI for Physical health/ **LAc26**-GI for Mental health
IZM	**IAc2**-Planting 4,800 trees/ **IAc3**-Arboreal areas around Ege Park Green Car Park	**IAc7**-Culvert works for Peynircioğlu River	**IAc11**-Natural pollinator's modules	**IAc23**- Engagement portal for citizens/ **IAc24**-Municipality Enabled Urban Farming/ **IAc25**-Women Cooperative Community Agriculture/ **IAc26**-Bio-Blitz/open platform
	Resting areas	**Water treatment**	**Vertical GI**	**City coaching**
VAL	**VAc6**-Installation of 3 Green Resting areas	**VAc12**-Green filter area/**VAc13**-Natural Wastewater Treatment Plant	**VAc22-VAc23**-Green noise barriers/ **VAc24**-Green Vertical mobile garden/ **VAc25**-Green Façade	**VAc39**-Promotion of ecological reasoning/intelligent
LIV			**LAc15**-Mobile gardens	**LAc27**- Ecological reasoning/ intelligent
IZM	**IAC4**- Parklets Installation		**IAc12**-Green fences/ **IAc13**-Establishment of fruit walls	**IAc27**-Ecological reasoning and intelligent/ **IAc28**-Izmir bio-diversity Atlas
	Carbon capture	**Green Pavements**	**Horizontal GI**	**Support activity**
LIV	**LAc7**-Urban Carbon Sink	**LAc10**-Hard drainage pavements	**LAc16**-Floating gardens **Pollutants filter** **LAc17**-Green filter area large urban trees	**LAc28**-Single window/desk for RUP deploy/ **LAc29**-Support to citizen project of NBS/ **LAc30**-City mentoring strategy

	RE-NATURING URB.	WATER INTERV.	SINGULAR GREEN INFRASTRUCT.	NON TECHNICAL INTERVENTIONS
VAL	**VAc7**-Urban Carbon Sink	**VAc14**-Green Parking Pavements	**Horizontal GI** **VAc26**-Electro wetland/ **VAc27**-Green Covering Shelter/ **VAc28**-Green Roof/ **VAc29**-Green Shady Structures **Pollutants filter** **VAc30**-Urban Garden Bio-Filter **Urban farming** **VAc31**-Urban orchard/ **VAc32**-Compost.	**VAc40**-Single desk for RUP deployment/ **VAc41**-Support to citizen project of NBS/ **VAc42**-City mentoring strategy
IZM	**IAc5**-Urban carbon sink	**IAc8**-Green pavements for Peynircioğlu River	**Horizontal GI** **IAc14**-Green Car park Covering Shelter in Ege Park/ **IAc15**-Cool pavement/ **IAc16**-Green Shady Structures **Urban farming** **IAc17**-Climate-smart Greenhouses/ **IAc18**-Improving Overall Efficiency of urban waste water treatment	**IAc29**-Single window/desk for RUP deployment/ **LAc30**-Support to citizen project of NBS/ **LAc30**-Support to citizen project of NBS

Table 3.1: List of NBS implemented in each front-runner city

3.2 Climate and resilience measurement and verification protocol definition

The project shall stablish a verification protocol related to the previous indexes (KPIs).

3.2.1 Baseline definition

In the URBAN GreenUP project it is necessary to evaluate the impact of the interventions that will be carried out about Nature Based Solutions in the three demonstration cities, Valladolid, Liverpool and Izmir, as an essential part of the monitoring result-oriented process. For that reason, it is proper to know the starting situation ("baseline") with which to compare the obtained results.

As a starting point for URBAN GreenUP, during the first phases of the project there was defined a systematic procedure that allowed to get a detailed city diagnosis in respect of the climate change challenge. As a result, there was obtained a process that helped to the easy evaluation of the city current situation, as well as, the impact in the city of a RUP or specific NBS implementation.

Therefore the work started firstly with the definition of a city/area diagnosis. Every front- runner city from URBAN GreenUP, defined a detailed diagnosis following the climate change challenges identified, following the ESA (Ecosystem Services Approach), MAES (Mapping and Assessment of Ecosystems and their Services) and EKLIPSE (EKLIPSE project).

In the initial diagnosis there was identified KPI`s that allow evaluate the current situation of the city/area, on respect of the climate change challenge, focusing on these which could be resolved through the implementation of NBS. The initial KPI's were classified considering the parameterization of ten challenges under EKLIPSE.

The diagnosis results were reflected in the Report on the diagnosis of the front-runner cities (Deliverables D2.1, D3.1 and D4.1. for Valladolid, Liverpool and Izmir).

After the initial diagnosis, there was identified the baseline of the cities/areas, where there was taken into account the KPIs developed in the diagnosis. This procedure allowed to get a baseline, but also, to make a diagnosis of the current situation which will allowed to detect the NBS that could be able to solve or mitigate the problems identified, and generate RUP`s for the follower cities. On the other hand this procedure will allow comparing the baseline with different RUP scenarios for the follower-cities, or the introduction of a specific NBS informing on its impact.

The baselines were reflected in the Reports on baseline documents to the front-runner cities (Deliverables D2.2, D3.2 and D4.2. for Valladolid, Liverpool and Izmir).

3.2.2 Expected results

URBAN GreenUP will monitor and evaluate the effectiveness of the project actions and interventions as compared to the initial situation and the objectives and expected results through a full monitoring methodology that will allow data collection even after the end of the project. A robust monitoring and evaluation protocols are being developed through the KPIs calculation, which will measure the NBS performance level.

Furthermore, URBAN GreenUP will achieve a big set of impacts, most of them related with environmental effects and socio-economic aspects, like the demonstration of very technical NBS, the creation of new market opportunities to the European companies even outside of the European framework and specific achievements related with social integration of a wide set of collectives.

It is remarkable that the re-naturing methodology that is being carried out and validated, will foster the development of very ambitious re-naturing urban planning (RUP) to address climate change challenges. It will combine a big set of well proven and properly characterized NBS (in the front-runner cities) with a collaborative framework for the definition of both planning and further NBS implementation.

In detail, the expected results of URBAN GreenUP are:

1) Promote the creation of a European reference framework and the establishment of EU leadership in a new global market for NBS.
2) Increase awareness of the benefits of re-naturing cities, through the creation of 'communities of practice' under the research and demonstration of nature based solutions.
3) Enhance stakeholder and citizen involvement in participatory, trans-disciplinary and multi-stakeholder consultation processes for codesign, co-development and co-implementation of visionary urban planning.
4) Increase the international cooperation and global market opportunities through replication in non-EU countries, fostering the staff exchange among local policy makers to promote knowledge transfer.
5) Enhance the implementation of EU environmental policies of the Sustainable Development Goals and UN conventions.
6) Foster the creation by 2020 of healthier and greener cities, increasing resilience to climate change.
7) Improve biodiversity and living conditions for the citizens (such as mobility or urban farming).
8) Deploy innovative, replicable and integrated NBS and the accompanying business models.
9) Trigger the creation of new green jobs through newly emerging businesses, transforming the local economy.

4 How to use KPIs once they have been calculated

4.1 Using KPIs within cities for reporting

4.1.1 Post intervention measurements and collecting sources

4.1.2 Monitoring responsibilities (partners/third parties …)

GMV is working intensively in the different front runners' demonstrations (WP2, WP3 and WP4) with the delivery of their monitoring programs, ensuring technological harmonization among the different front-runners cities. Front-runners cities (Valladolid, Liverpool and Izmir) are supported by several local partners creating a group of stakeholders to lead the city transition, that assures the solutions implementation and monitoring success.

The following diagram shows the relation between the global Monitoring and Evaluation Plan, between the corresponding local monitoring programs of the front-runner cities. Local partners of each city have defined the evaluation protocols and KPIs for monitoring the NBS that they are implementing, according to their knowledge and experience.

Local partners' responsibility will be data capture of and KPIs calculation. The data sources will be provided by the municipal entities (Valladolid, Liverpool and Izmir city councils), from external sources or from the URBAN GreenUP monitoring systems such as sensors, drones, satellite image or others.

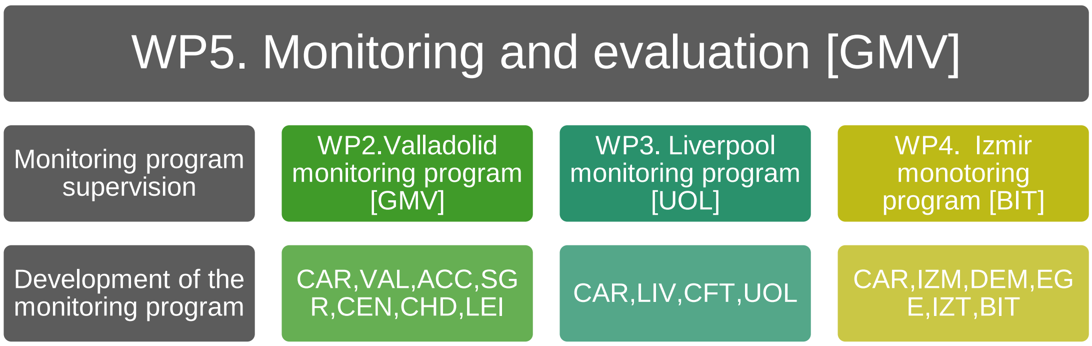

Figure 4.1: Relationship between monitoring programs and responsible partners.

4.1.3 Reporting periods

URBAN GreenUP will launch a two year monitoring period to collect a complete set of data and achieve maximum accuracy in the evaluation process. Data collection periodicity will be variable according to the KPI nature and its data source. Thus, there are daily data, such as air quality, regular data or punctual data.

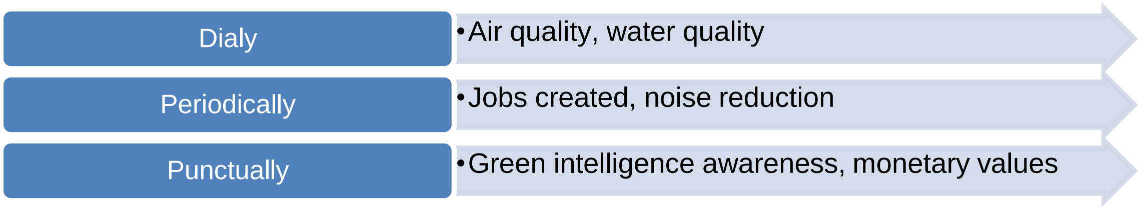

Figure 4.2: Different data collection periods and some examples.

However, the following reporting periodicity is proposed for the KPIs calculation:

- **Quarterly reporting**: The values of the KPIs calculated/measured should be uploaded to the monitoring platform quarterly. It is noted that some indicators will not show quarterly variations. Leader: Monitoring program supervisor (GMV for Valladolid, UOL for Liverpool and BIT for Izmir).
- **Annual reporting**: Grouped global KPI calculation will be submitted annually. Leader: Monitoring program supervisor (GMV for Valladolid, UOL for Liverpool and BIT for Izmir) with the supervision of local entities, WP2, WP3 and WP4 leaders.

Figure 4.3: Reporting periods' proposal.

4.1.4 Report format (reporting tables)

The calculated indicators should be presented in a homologated table format consistent with the database language. The final format will be provided by the URBAN GreenUP database manager, GMV, as part of the WP5.

The table will have a standard format that will match with the current KPI definition table for each city/area. The Core KPIs will be identified, as well as if the indicator is specific for each city/area.

Database field	Description	Example
Eklipse challenge	Classification of the indicator in 10 Challenges of the Eklipse project.	CHALLENGE 5: Air Quality
Type of indicator	Sub-classification.	Environmental (chemical)
KPI Definition	Indicator description according to the metric.	Air quality parameters NOx and PM
KPI unit	Unit of measurement for the indicator value.	$\mu g/m^3$
Core / DemoSite	Identify with an 'X' if it is a Core KPI. Identify the city which is calculating this KPI. This field allows identifying	ESA core KPIs (X) Valladolid (X) Liverpool ( ) Izmir ( )

	if the KPI is Core or is calculated specifically by a city.	
NBS	Contains the intervention to which the indicator applies to monitor its effectiveness	Urban Garden BioFilter
Value	Value of the indicator for the corresponding quarter. There will be four quarterly values and an annual value.	XX % of reduction in PM or NOX concentration in the area after the intervention.

Table 4.1: Content of the indicator monitoring standard reporting table

4.2 Intended use of KPIs within the URBAN GreenUp global ICT platform

The global Urban Greenup ICT platform is based on the city KPI calculation platforms enabled and or developed for the different types of KPIs received from the respective partner cities' data and or model of systems and platforms. By intending use of KPIs, global platform serves as a scientific tool for developers of climate solutions for urban cities and provides a model that enable smart usage of data for “green” status. The global platform provides an effective and sustainable framework and architecture to produce the necessary visualization of the KPIs. The KPIs are basically reported and collected from a combination of guidelines provided for raw data, KPI calculation processes and user’s engagement at different cities of concerns. The platform is not just for raw data collection of calculated KPI input and output but also for visualization, scientific storage, scientific visor, decision making processes, and additionally provides an engagement platform for users from scientific communities, and, municipalities to interact and make proactive “green” solutions for cities at large. The task T5.2 of WP5 explains how KPIs from partner cities, data, and ICT capabilities to produce a digital model for cities that fulfils the goal of using necessary data as required to measure or track changes with respect to defined KPIs or baselines.

The KPIs input and output are one of the elements for any of the local ICT platforms. The URBAN GreenUp global ICT platform shall be scalable so that calculations from local platform can be presented with dashboards. The URBAN GreenUp city to web based access and Global API (UGCoG API) will use its services to model the KPIs and KPI input raw data with respect to required baselines and city. The KPIs are the visualization’s object and parameters that will be used as flash cards. The URBAN GreenUp ICT platform will model with other parameters, whether the KPIs is for an environment parameter or specific for a city. Similarly, more data may wind up accessible to administration. This in turn does encourage the possibilities of revealing new KPIs that gives a more profound comprehension of the business. It may also help in determining a change for a current KPI.

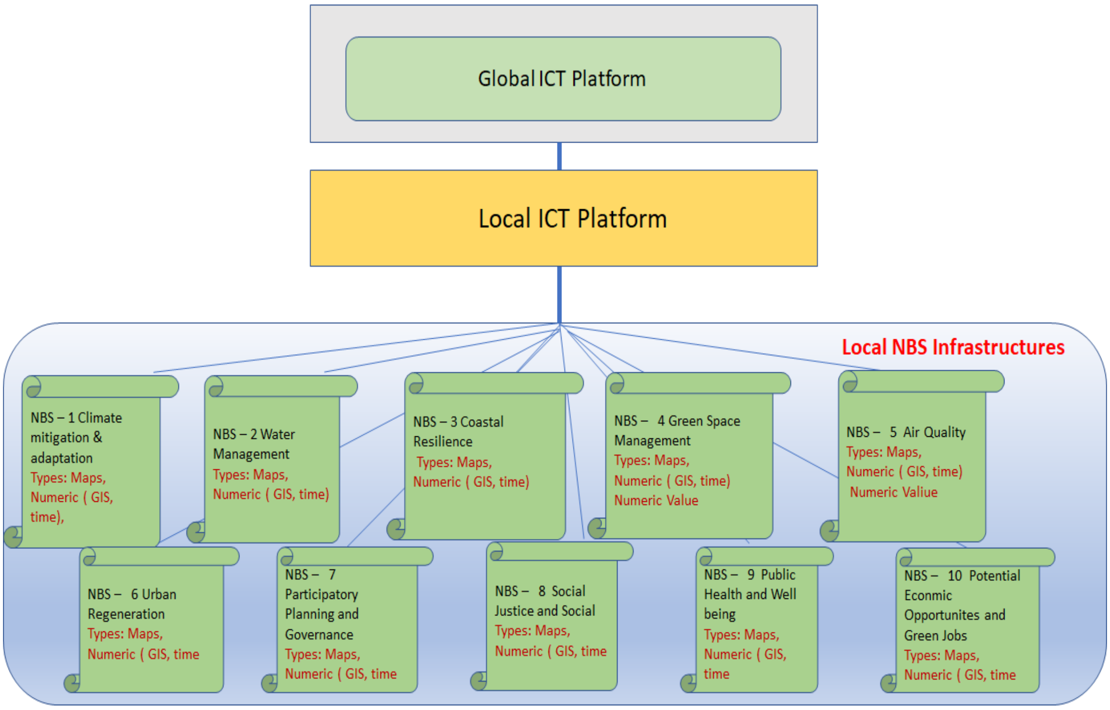

Figure 4.4: ICT platform diagram I

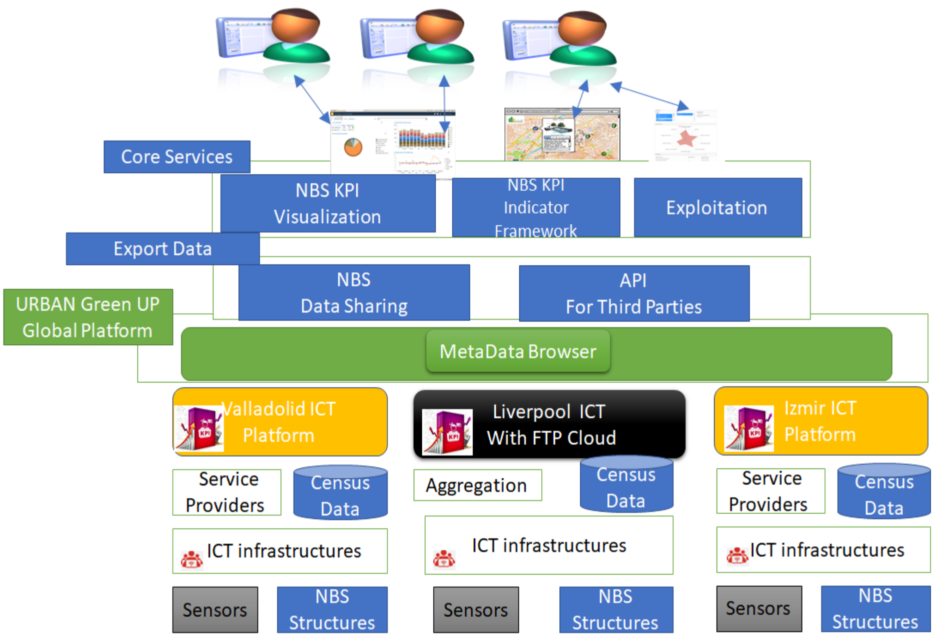

Figure 4.5: ICT platform diagram II

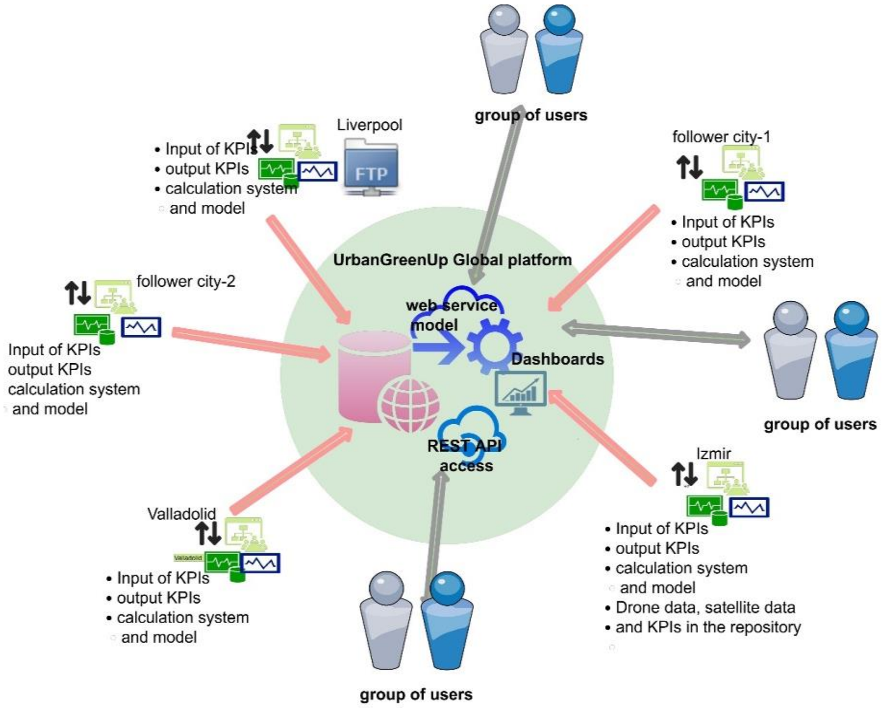

Figure 4.6: Example of interaction

KPIs are quantities that depict the condition of a NBS model and are utilized as input or output to condense data about the state of URBAN GreenUp system. They lessen dimensionality of information, disentangle understandings, and encourage correspondence amongst specialists and non-specialists. In this way, KPIs could be utilized as measurements for key data concerning community-based solution structure, and administrations. Scientific KPIs can consolidate quantifiable attributes of structure [1]. For example, natural surroundings or green space designs, with inalienable environment capacities and administrations. Besides, a KPI shows the overall calculations with specific to the benefits and effects to the system. The KPIs to the URBAN GreenUp is to do visualized data about conditions and may demonstrate drifts and give a superior comprehension of the reasonability of cities' framework [2]. The KPIs used are generally describing:

- Which ecosystem/environment function is providing a service and how much
- How much of that service or input can be used in a sustainable way

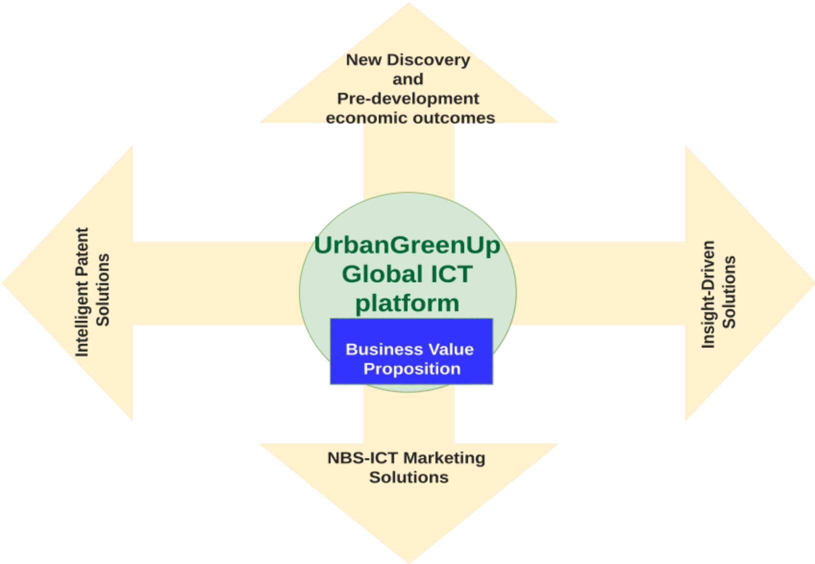

Figure 4.7: KPI-enabled Global ICT Platform: Business model, actions and future

The KPIs will be a substantial function of parameter to present a model of visualization that can be used in urban ecosystem. It enables the visualization of functions to provide services that increases the "green" capacities of our environment. The URBAN GreenUp ICT platform will enable services that use the KPIs to do performance analysis for various "green" environment solutions in steps as:

- Evaluate the weight as related to other corresponding parameters such as KPI input data
- Do benchmarking, certification with respect to other cities and projects
- Do replication development for other "green-enabled" citizens' related project

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4.3 Combining KPIs to give aggregated indicators

According to Eklipse 2017 report, in many cases, the measurement of impacts may not be reasonable or even feasible at an urban scale because the change caused by a single measure is too small. While the amount of pollutants captured by vegetation may be important at the micro scale, a single project will hardly affect the quantity of pollutants at the meso level. The same holds for water quality, the urban heat island effect and the carbon storage capacity, as the impacts of spatially limited individual NBS projects (or actions) may be very small, but in aggregate they can make a difference.

Examples of the possible range of co-benefits and costs as identified in the challenges taken for Urban GreenUP team are given in table below. For example, temperature reduction actions are likely to have co-benefits for air quality and green space management, but also for public health and wellbeing. Increasing the ground water quality, will benefit green space. There are also opportunities for urban regeneration and social justice and social cohesion from actions aimed at increasing the water quality. In contrast, increases in property prices stemming from actions to improve economic opportunities and green jobs in urban areas may adversely affect social justice and social cohesion by displacing groups of socioeconomically disadvantaged residents. Nevertheless, as potential costs, benefits and trade-offs need to be assessed in the specific local context, this table can only indicate some of the interactions between the challenges, including opportunities to build synergies.

In order to compare, and evaluate different options for NBS or alternative investments, Net Present Value (NPV) of each option needs to be evaluated. So most common form of aggregation of KPIs can be based on economic (monetary) assessment methods which aggregate all monetary costs and expected benefits of the investment. This is called Cost and Benefit Approach (CBA) either considers costs and benefits directly connected to single (or a group of) investors (e.g. a local authority or utility), the Social Costs and Benefits Approach (SCBA) includes wider societal costs and benefits in the assessment, such as tax revenues, subsidies, increased real estate values, etc.

Many of the environmental and social benefits and costs connected to the impacts of NBS actions are measured in terms of physical parameters or qualitative judgements of individual and aggregated preferences, which can only partly be translated into monetary terms (e.g. pollution-related health effects) and are thus difficult to aggregate. Therefore, researchers need to take in to account different types of qualification, quantification, aggregation and standardisation. Multi-criteria analysis allows for the representation of different outcomes of the assessment process according to different group (or individual) preferences. Rather than producing a single result indicating the “optimal” solution, these approaches allow for visualising the impact of different preferences on the assessment results.

			CORE	CHALLENGE 1: Climate mitigation & adaptation	CHALLENGE 2: Water Management	CHALLENGE 4: Green Space Management	CHALLENGE 5: Air Quality	CHALLENGE 6: Urban Regeneration	CHALLENGE 7: Participatory Planning and Governance	CHALLENGE 8: Social Justice and Social Cohesion	CHALLENGE 9: Public Health and Well-being	CHALLENGE 10: Potential of economic opportunities and green jobs
CHALLENGE 1: Climate mitigation & adaptation	1	Tonnes of carbon removed or stored per unit area per unit time (Zhang et al., 2013)	X	*	+	+	+	+	o	o	o	
	2	Total amount of carbon (tonnes) stored in vegetation	X	*	+	+	+	+	o	o	o	
	6	Measured of gross and net carbon sequestration of urban trees based on calculation of the biomass of each measured tree (i-Tree Eco model), translated into avoided social costs of CO2 emissions (USD t-1 carbon). UVSWORKING: Economic value of carbon sequestration by vegetation as a result of NBS over 25 years		*	+	+	+	+	o	o	o	
	7	Decrease in mean or peak daytime local temperature (oC) (Demuzere et al., 2014)	X	*		+	+				+	
	8	Measures of human comfort e.g ENVIMET PET - Personal Equivalent Temperature, or PMV - Predicted Mean Vote.		*		+	+				+	
	9	Heatwave risks (number of combined tropical nights (>20oC) and hot days (>35oC) following Fischer, Schär, 2010, cited by Bartel et al. (2015). UVSWORKING: no metric: # days >35oC day and 20oC night	X	*		+	+				+	+
	10	Energy and carbon savings from reduced building energy consumption (kW/h and ton C/year saved)		*	+	+	+	+	o	o	+	+
	13	Use of Star tools to calculate projected maximum surface temperature reduction	X	*		+	+				+	+
CHALLENGE 2: Water Management	16	Run-off coefficient in relation to precipitation quantities (mm/%)	X	+	*	+						
	17	Flood peak reduction. Increase in time to peak (%)		+	*	+		o	o	o		+
	18	Reduction of drought risk (probability).		+	*	+	+	o	o	o	+	+
	20	Absorption capacity of green surfaces, bioretention structures and single trees (m3/m2) (m3/tree)	X		*	+					o	
	22	Temperature reduction in urban areas (oC, % of energy reduction for cooling)	X	+	*	+	+	+	o	o	+	+
	26	Intercepted rainfall (m3 year-1)		+	*							
	27	Share of green areas in zones in danger of floods (%)			*	+						
	28	Population exposed to flood risk (% per unit area)			*			+	+	+		
	29	Areas (ha) and population (inhab) exposed to flooding	X		*			+	+	+		
	30	Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals) Chemical Oxygen Demand (COD) (mg/l); Biochemical Oxygen Demand (BOD) (mg/l); Total Solids (SST) (mg/l)		o	*		o				+	
	33	Drinking water provision (m3 ha-1 year-1)	X		*							
	34	Water for irrigation purposes (m3 ha-1 year-1)	X	+	*	o	o	+	o	o	o	
	35	Economic benefit of reduction of stormwater to be treated in public sewerage system € (Deng et al., 2013; Soares et al., 2011; Xiao and McPherson, 2002)			*							+
	38	Volume of water removed from water treatment system	X		*							
	39	Volume of water slowed down entering sewer system	X		*							
CHALLENGE 4: Green Space Management	52	Distribution of public green space - total surface or per capita.		+	o	*	+	o	o	o	o	o
	53	Accessibility (measured as distance or time) of urban green spaces for population.	X	+	o	*	+	o	o	o	o	o
	54	Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.				*			+	+		
	55	Percentage of people living within 300m of green urban areas of any size in inner city				*		+	+	+	o	
	56	Accessibility to public parks, gardens and play-grounds (more than 50 ha) - (inhabitants within 10 km from a park)				*				+		
	60	Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al., 2015)	X			*						
	73	Production of food (ton/ha/year)	X	+	o	*	+	+	o	o	+	
	74	Sustainability of green areas				*						
	75	Quality of life for elderly people				*					+	
	76	Increased connectivity to existing GI	X	+	+	*	+	o	o	o	o	o
	77	Pollinator species increase (number)	X	+	+	*	+	o	o	o	o	o
	78	Perceptions of connectivity and mobility				*						
CHALLENGE 5: Air Quality	82	Spatial indicators: pollutant fluxes per m2 per year (Manes et al., 2016; Tallis et al., 2011)		+	+		*				+	
	83	Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration recorded ug/m3	X	+	+		*				+	
	84	Trends in emission NOX, SOX	X	+	+		*				+	
	86	Mean levels of exposure to ambient air pollution (population weighted) (proposed indicator for SDG target 3.9)		+	+		*				+	
	87	Pollutants removed by vegetation (in leaves, stems and roots) (kg-ha-1 year-1)		+	+	+	*				+	
	88	Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. Use of GI valt to calculate the value of air quality improvements	X		+		*					+
	90	Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9)	X	+	+	+	*				+	+
	92	Air quality parameters NOX, VOC, PM etc	X	+	+		*				+	
CHALLENGE 6: Urban Regeneration	95	Accessibility: distribution, distance, spatial configuration to NBS and green spaces. Diversity of NBS (land use and functionality)	X	+	+	*	+	o	o	o	o	o
	100	Incorporation of environmental design: percentage of total building stock		o		o		*		o		
	101	Land devoted to roads: percentage of site area occupied by roads		o		o	o	*				o
	109	Assessment of typology, functionality and benefits provided pre and post interventions.						*				
	110	Saving in energy use due to improved GI	X	o			o	*				
CHALLENGE 7: Participatory Planning and Governance	111	Openness of participatory processes.							*			
	112	Legitimacy of knowledge in participatory processes.							*			
	113	Saving in energy use due to improved GI		+					*			+
	115	Social learning concerning urban ecosystems and their functions/services (Colding and Barthel, 2013)							*			
	117	Perceptions of citizens on urban nature - green space quality (Buchel and Frantzeskaki, 2015; Colding and Barthel, 2013; Gerstenberg and Hofmann, 2016; Scholte et al., 2015; Vierikko and Niemelä, 2016)	X						*		+	
CHALLENGE 8: Social Justice and Social Cohesion	123	Crime reduction through police reports and local authority data								*		
	127	Green intelligence awareness	X	o		o				*		
CHALLENGE 9: Public Health and Well-being	128	Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit	X	o		o	o				*	
	139	Increase in walking and cycling in and around areas of interventions	X	+			o	+		o	*	
	add	Perceptions of health and quality of life								+	*	
CHALLENGE 10: Potential of economic opportunities and green jobs	140	Number of subsidies or tax reductions applied for (private) NBS measures (Meulen et al., 2013).		+	o	+	+			+		*
	141	Number of jobs created (Forestry Commission, 2005); gross value added (Forestry Commission, 2005).	X	o		o				o		*
	142	Change in mean or median land and property prices (Forestry Commission, 2005). UVSWORKING: Changes in mean house prices/rental markets				+						*
	143	New businesses attracted and additional business rates (Ettec, 2013). UVSWORKING: increased return of business rates with NBS		o		o				o		*
	150	Consumption benefits: property betterment and visual amenity enhancement (Tyler et al., 2013) resulting from NBS		o		o				o	o	*
	151	Job creation, increased footfall and spend in the areas of interventions if appropriate.		o		o				o		*

Key: Ch = challenge; * Main challenge addressed; + Co-benefits that will follow; O **Opportunities that could be taken; - Potentially negative impacts or disservices**

Table 4.2: Examples for indicators of potential co-benefits and negative impacts across the challenges (modified from Table 25 (EKLIPSE, 2017)).

4.4 Results analysis

Results will be collected and analysed in WP5 framework during Task 5.4 (*Data collection and ICT platforms implementation supervision*) and Task 5.5. (*Global Evaluation and conclusions/recommendations*). Task 5.4 will supervise remotely the raw data collection and the implementation of the monitoring procedures on each city to ensure a compliance with the given guidelines and established schedule. On time and right. In Task 5.5 an overall performance of the KPIs weights shall be defined. These weights will depend on social, meteorological or other local aspects to any NBS. Each city will obtain a global evaluation as a function of the KPIs with their associated weights after its NBS implementation is finished. The overall conclusion and the data analysis will be derived into recommendations for the follower cities, guidelines and also knowledge that may be marketable for both front-runner and follower cities.

5 Quality assurance

The aim of this section is to describe the methodology that will be followed in the Urban Green Up project to assess the validity of the set of indicators selected for each of the intervention sites in order to evaluate the performance of the Nature Based Solutions deployed in the scope of the project.

If the previous sections of the document work on top of the impact assessment framework of the EKLIPSE Expert Working Group Report of the EC to select a set of indicators and describe the implementation of the indicators themselves, this section aims to define a set of tests to study the relevance, cross interference and sensitivity of the indicators as defined in previous sections, trying to provide insight on the usefulness of these indicators both to measure the cost-effectiveness of NBS individually, but also to compare across different NBS projects.

Different tests will be carried out to understand if the indexes are well designed and respond to changes as expected and also to compare the proposed methodologies for the construction of the indexes (particularly where the implementation between different sites is different). These tests should lead to the selection of the most suitable calculation and aggregation methods and also highlight areas for improvement in the selected indicators.

5.1 Validation of the evaluation strategy

Given that NBS seek to address societal challenges, they need, by definition, to address economic, environmental and social challenges. There are a range of potential actions that can be taken and indicators are an important means of assessing the potential performance and the actual effectiveness of particular NBS actions (European Commission, 2016).

Each climate resilience challenge area can be addressed by multiple individual actions, and indicators can be used to assess the effectiveness of individual actions in addressing each climate resilience challenge. However, there is potential for interactions between NBS actions which require consideration in NBS assessments.

Indicators for assessing specific types of NBS impacts can be relevant to multiple climate resilience challenges. It is, therefore, important to assess the impacts of NBS across aspects of multiple systems, including socio-economic, socio-cultural and ecosystems, although geographic and temporal scale may be relevant to the interactions.

The selection of appropriate indicator(s) will depend on a number of factors including:

- Objective of the action — which challenge(s) it is seeking to address;
- Type of action — all NBS will involve some element of biodiversity, but will differ in their attributes and thus appropriate methods for measurement;
- Potential expected impacts, both direct and indirect, and both positive (synergies) and negative (trade-offs or disservices);
- Resources and skills available for measurement of the impacts;
- Scale of analysis, which influences the availability and relevance of data for specific indicators

The objective of the evaluation strategy is to determine the robustness and sensitivity of the selected indicators to changes and assure that the impact of the Nature based Solutions adopted in the scope of the project is correctly reflected in the changes of the different KPIs.

The evaluation strategy should assess the methodology selected to calculate the different indicators: aggregation (or single impacts), thresholds, baseline definition, stipulations, models, calculation formulas, statistical data sources, robustness against missing data, etc.

Finally, the evaluation strategy will try to provide insight on the cross-effects between NBS actions, synergies and interactions among the different indicators (although issues of scale, implementation and local context may hide said synergies or trade-offs).

5.2 Indicators tests

The purpose of the indicators tests is to check if the calculated indicators respond to changes as it is expected to happen with the variations introduced in the value of the actual measurements and to compare the methodologies proposed. Thus, the following indicators tests are defined:

- Extreme values. Minimum and maximum values.
- Variation of values. Minimum and significant variations.
- Missing values. Minimum, maximum and mean values.

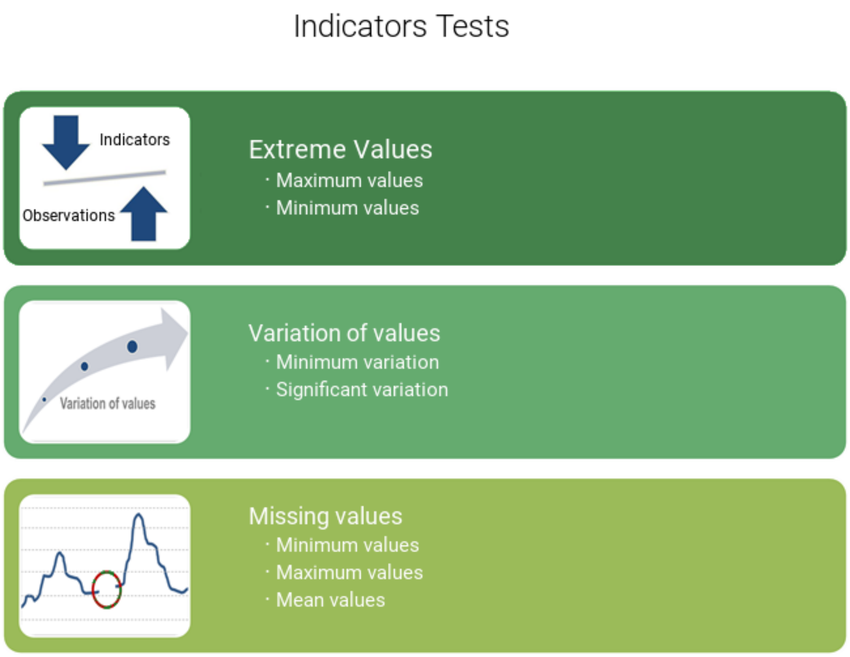

Figure 5.1: Indicators examples

5.2.1 Reference scenarios

5.2.2 Behaviour under extreme values. Minimum and maximum values

The purpose of these tests is to check that the indicators can reach the expected minimum and maximum values, that is, if the KPI is calculated by transforming an observation of a physical magnitude (in time or multiple locations) or a combination of observations of multiple magnitudes, or replies to surveys, when all the observations take the minimum value or all the observations take the maximum value (limited by the sensitivity of the measurement equipment /sample limitations).

This means that the indicators can reach their maximum value when all the observations have maximum values, and likewise will reach the lowest possible value when the observations have minimum values. This means that the calculation formulas will be evaluated when:

- All the observations take the maximum value.
- All the observations take the minimum value.

Inability to reach said values may indicate that it is necessary to normalize the indicator or modify the calculation procedure so that it reaches the expected values.

5.2.3 Variation of values. Minimum and significant values

The purpose of these tests is to understand the sensitivity of the indicators to minimum and significant variations of the value of the measured observations in the final value of the indicators. Since there are different proposed methodologies for weighting and aggregation, these tests are also defined to compare the sensitivities of the different methods to these variations in the final indicator values. Thus, the following variations are defined to test the indicator behaviour:

- Variation of 5% of the value of all the observations (multiple spatial/time samples or multiple observations if they are combined for a single indicator) at the same time.
- Variation of 50% of the value of all the observation at the same time.
- Variation of 5% of the value of all the magnitudes, one at the time.

Variation of 50% of the value of all the magnitudes one at the time.

5.2.4 Resilience to missing values, minimum and mean values

Due to multiple reasons, such as malfunction of a sensor, impossibility to perform a field survey, lack of samples in a particular area, or lack of statistical information from a particular source, it is likely to have missing values for some of the observations used for the indicator calculation.

The purpose of these tests is to determinate the sensitivity of the indicators to missing observations in order to compare which method is the most appropriate to use in the final configuration of the indicators. Thus, the following tests are defined:

- Variation of the value of each magnitude to the mean value of the interval

- Variation of the value of each magnitude to the minimum value of the interval
- Variation of the value of each observation to the maximum of the interval

This should allow determining which the most suitable substitution value is for each of the indicators.

5.3 Data sources validation

The basis for all observational studies is the availability of appropriate data of high quality. Data may be collected specifically for the research purpose in question (what is often referred as “primary data”), but data collected for other purposes (so-called “secondary data”) is also useful in research. Data validation is intended to provide certain well-defined guarantees for fitness, accuracy, and consistency for any of various kinds of input data.

Although high accuracy and precision are desirable, a high degree of trust and knowledge about their maximum and minimum level and additional metadata of the data sources (collection method, availability, transformations, etc.) is often as much or even more valuable to achieve correct and unbiased results.

Primary data is mostly validated through proper screening, by using various descriptive statistical methods. Secondary data validation is more complex, and often relies on trust in the sources, combining data from multiple sources, two-stage sampling and aggregated methods.

5.4 Reference data sets

Reference datasets provide statistically accurate data that can be used to evaluate the measurements (primary source data) performed on the NBS sites and other datasets used for the calculation of the KPI. Such data may come from statistics institutes, public administrations, or previous similar studies. In any case, it is necessary to validate the data to a degree according to the rest of the project (usually by comparing to real data or previous publications).

It may also be necessary to convert the datasource information due to differences in representation, sampling, units or accuracy. Thus, not only the reference data source needs to be validated but also the transformation applied to the reference data.

All datasources used for the calculation of the indicators need to be listed and validated, on one hand, to verify that the data is applicable, and also to prepare a dataset for further studies that will allow to evaluate the methodology and as a future reference for additional research and to compare between different NBS and demonstration sites.

Reference datasets can also be used to evaluate the calculation methods for the indicators. By entering the reference dataset in the KPI calculation algorithms, we should obtain the range of typical values for the indicator, to compare the results with the expected scenarios.

Finally, having a reference data set to compare with allows detecting deviation or malfunction in primary data collection during operation (e.g. a sensor malfunctioning or an error in data transmission/encoding) by comparison with the expected range of values.

6 Data management and data privacy (CAR)

6.1 Introduction

Data Management Plans (DMPs) have been introduced in the Horizon2020 Work Programme for 2014-15. Since the main purpose of the DMP is to provide an analysis of the main elements of the data management policy that will be used in the scope of the project with regard to all the datasets that will be managed to carry out the related activities. The scope of the DMP is not only the development of the project, but also after it is completed.

A DMP has to describe the data management life cycle for the data sets that will be collected, processed and/or generated in the scope of the project, and even after it is completed. Processes regarding data collection, processing and generation should be outlined, including methodologies, standards, data access and how this data will be curated and preserved.

According to the EC guideline, the DMP needs to be updated at least by the mid-term and final review of the project, it is not a fixed document; it evolves and will be updated during the lifespan of the project. In this case, updates of the DMP will be developed in M24 and at the end of the project.

6.2 Data Management Plan in the scope of the URBAN GreenUP project

Once the purpose of a DMP has been described, the main elements of the DMP of the URBAN GreenUP project have to be detailed.

Confidentiality issues must be taken into account, but also the dissemination ones, because it is in the interest of some partners to disseminate the results achieved in the scope of the project. As a result, it is important to take into account that the DMP is closely related to the Dissemination Plan, so a compromise must be found between confidentiality and dissemination of the achieved results.

As detailed in picture below, two different types of datasets will be created: the ones containing gathered data and the ones containing the Key Performance Indicators (KPIs) calculated using the aforementioned data. Restricted access will be given to raw data sets, and the calculated KPIs will be free to access and use. The data gathered will be available by ftp (secured using login/password), and the KPIs will be published in the project website[31].

[31] http://www.urbangreenup.eu/

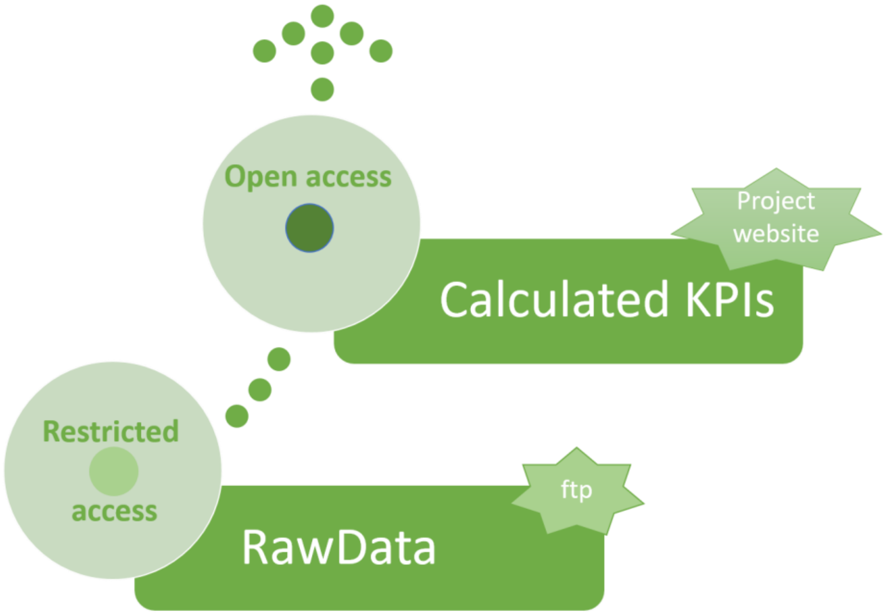

Figure 6.1: Data relation

Concerning the data gathering, and if needed (if personal data will be gathered/processed), all the issues related to the GDPR (General Data Protection Regulation) will be implemented.

As the GDPR is a new regulation, the main differences with the previous directive 95/46/EC regarding the data subject rights are pointed below:

- The conditions for consent have been reinforced for the sake of clarity and intelligibility of the legal terms and conditions, and also making easy the processes of withdraw.
- Breach notification that should be done within 72 hours after the notification.
- Right to access. The data subjects now have the right to get, from the data controller, confirmation that the data is being processed and the purpose of that process.
- Right to be forgotten. The data subject has de right to oblige the data controller to erase the data, cease dissemination and halt processing of the data from third parties.
- Data portability. The data user, once he has received its personal data in a legible digital format from one controller, can send them to another one.
- The territorial scope has been increased, and now the regulation applies to all companies processing data of subjects residing in the EU, independently from the location of the company.

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