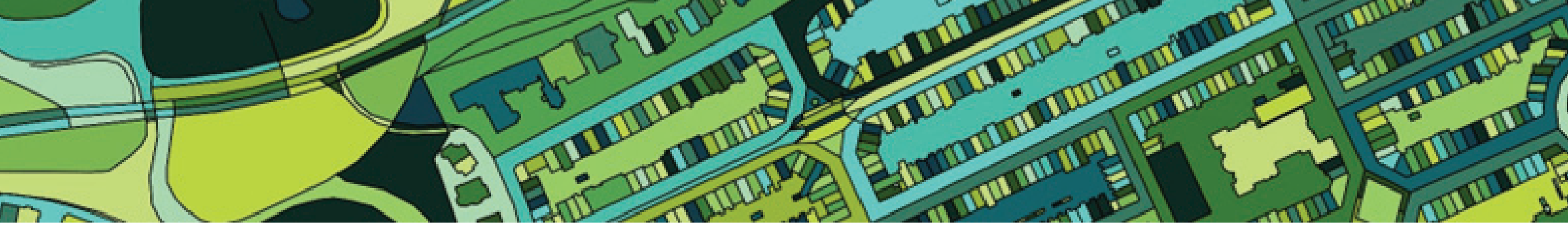

City-centered approach to catalyze nature-based solutions through the EU Regenerative - Urban Lighthouse for pollution alleviation and regenerative development

Quick Guide for monitoring Nature Based Solutions

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101003818.

Imagine a city where lush green areas, vibrant parks, and thriving urban forests combine seamlessly with contemporary infrastructure, producing a harmonious environment that not only improves quality of life but also combats climate change and aids in the resolution of modern city concerns. This can be accomplished by effectively implementing and monitoring nature-based solutions (NbS).

This document is intended to help municipalities navigate the process of implementing adequate monitoring systems for evaluating their NbS. Knowing what measures to take and which technologies to rely on is the only way to realize NbS's full promise for creating resilient, sustainable, and liveable urban settings.

Municipal planners, policymakers and urban development professionals will find here practical insights and ideas to support your efforts in the implementation and monitoring of NbS in your city for maximising the benefits for both people and nature.

This guide is developed in the context of the EU Project UPSURGE. The main objective of this initiative is to help cities use proven Nature-Based Solutions (NbS) to effectively tackle various urban challenges.

https://www.upsurge-project.eu/

1. URBAN NATURE BASED SOLUTIONS (NBS)

The official definition of NbS by the International Union for the Conservation of Nature (IUCN) is *"Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal changes effectively and adaptatively, simultaneously providing human well-being and biodiversity benefits"*.

NbS embraces nature conservation principles and can be implemented alone or integrated with other solutions (e.g. technology and engineering) giving answer to societal challenges.

NbS' are applied at landscape scale and the context where the action takes place plays a major role in determining its characteristics (natural and cultural specificity). It is an inherent feature of this concept that the societal benefits produced must be fair and equitable.

For the specific case of cities, five important principles to support the identification and integration

MAIN ENVIRONMENTAL AND SOCIAL CHALLENGES IN CITIES

- **Spatial conflicts, how urban systems fir together**
- **Unique city biodiversity, fragmented habitats, and changed environments.**
- **Value plurality, many stakeholders and unfair environmental impacts.**
- **Historical and cultural influences affecting current planning.**
- **Misconception of cities as disconnected from nature**

WANT TO KNOW MORE?
Check the article "Planning nature-based solutions: Principles, steps, and insights" by C. Albert in AMBIO.

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of the solutions are to be considered:

- Assess the functions, benefits, costs, and suitability considerations of NbS
- Use a combined (integrated) method to apply Nature-Based Solutions (NbS) for making cities more resilient.
- Consider the principles of ecosystem conservation by adopting a hierarchy of ecosystem-based approaches
- Consider the integration of NbS across a range of spatial scales
- Adopt a multistakeholder and interdisciplinary approach

Most urban NbS are designed to support the adaptation to climate change and can be classified as per the following categories:

- Urban heat island effect (UHI) reduction
- Stormwater runoff reduction
- Noise reduction
- Ait purification
- Carbon capture
- Aesthetics
- Recreation

SIX STEPS FOR NbS PLANNING

1. **Co-define setting**
2. **Understand challenges**
3. **Create visions and scenarios**
4. **Assess potential impacts**
5. **Develop solution strategies**
6. **Realize and monitor**

WANT TO KNOW MORE?
Check the UN Environmental Programme FORESIGHT BRIEF #23, on Nature-Based Solutions for Urban Challenges.

WANT TO KNOW MORE?
Check the report "Catalogue of Nature Based Solutions for urban resilience" by the GFDRR and the World Bank; and the article "Principles for Urban Nature-Based Solutions" by N. Kabisch in AMBIO.

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2. DEVELOPING A MONITORING STRATEGY

Monitoring for Nature-Based Solutions (NbS) has evolved significantly, focusing on measuring outcomes for people and nature. A good monitoring ensures that NbS projects deliver benefits such as carbon sequestration, flood protection, and biodiversity enhancement. Local governments often face challenges in adopting these protocols. Common issues include limited resources, lack of standardized methodologies, and difficulties in interpreting data. The complexity of urban environments and the multi-stakeholder collaboration complicate the implementation of robust monitoring systems.

This is the key part of this guide, and its objective is to help you design the impact assessment strategy for your NbS. In order to develop a robust and reliable monitoring strategy, we recommend following the step-by-step approach advised by the European Commission.

STEPS FOR DEVELOPING A MONITORING STRATEGY	
STEP 1	Constructing a theory of change: – Engage in structured reflection on key local context challenges and NbS objectives – Involve the appropriate stakeholders and foster a sense of belonging to the process
STEP 2	Developing a results chain to outline the theory of change
STEP 3	Specifying the evaluation question(s)
STEP 4	Selecting indicators and data gathering: – Select appropriate indicators – Choose an appropriate impact evaluation method – Identify and collect the data needed to assess selected indicators – Developing a local monitoring and data collection plan
STEP 5	Implementing the impact evaluation
STEP 6	Disseminating results and achieving policy impact

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Defining a monitoring strategy requires significant technical and scientific expertise. However, involving the community through collaborative and co-production approaches can greatly enhance the process. Gaining citizen acceptance and approval early on is crucial for the success of these strategies. The definition of a monitoring strategy should benefit from collaborative and co-production approaches. Citizen acceptance and approval is critical for the success of monitoring strategies and considering this at the design stage improves cost-efficiency and mitigates perception-related issues in the future.

STAGES OF THE CO-CREATION PROCESS:

1. Define the goals and create space
2. Identify and reach the actors to be involved, ideally the scientific community, the economic system, the political system, the media and the natural environment should be represented.
3. Planning of the activities and tools
4. Reflect on the co-production process and results
5. Communicate about the co-production process

COCREATION APPLIED TO NbS MONITORING:

1. Co-planning the conditions - setting the scene and engaging citizens.
2. Self-projection - motivating and empowering citizens.
3. Projection - sharing purpose & scenario development.
4. Design/ideate - conceptualising, diverging then converging.
5. Discuss and validate - counterpointing, dialoguing and consensus building.
6. Prototyping - experimenting and testing in place.
7. Systematise - preparing for future iterations and next stages.

WANT TO KNOW MORE?
Check the handbook "Evaluating the impact of Nature-Based Solutions" by the European Commission.

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3. CHOOSING THE INDICATORS FOR MONITORING MY NbS

A useful approach aligned with widely implemented EU methods would be to combine a Co-creation process with the RACER method, for definition of indicators that are relevant to the stakeholders involved of high quality.

To the extent that this is feasible (which inter alia depends on the nature of the proposed intervention) all indicators should be 'RACER', i.e.

- relevant, i.e. closely linked to the objectives to be reached
- accepted (e.g. by staff, stakeholders)
- credible for non-experts, unambiguous and easy to interpret
- easy to monitor (e.g. data collection should be possible at low cost)
- robust against manipulation.

The next chart will help you make the right questions towards the selection of the proper indicators for the monitoring strategy defined.

For the monitoring activities	
What will be monitored?	• Expected outcomes • Chosen indicators
Where will the monitoring take place?	• Location of tools and data collection
Who will do the monitoring?	• Responsible for each type
When will the monitoring take place?	• Schedule • Times • Frequency

For the data collection and storage plan	
Which type of data will be collected?	• Type • Target population
Who will analyse the data?	• Responsible for the analysis
Who will store the data?	• Responsible/owner of data platform or base
How will the data be presented?	• Presentation towards policy makers, citizens, and decision-making processes

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4. BASIC INDICATOR CATALOGUE

The following tables include a list of widely used indicators for NbS monitoring, for each type, a list of related NbS is provided.

CLIMATE VULNERABILITY	
INDICATOR	**UNITS**
Total carbon removed or stored in vegetation and soil per unit area per unit time	kg/ha/y
Avoided greenhouse gas emissions from reduced building energy consumption	t CO_2e/y
Monthly mean value of daily maximum temperature (TX_x)	°C
Monthly mean value of daily minimum temperature (TN_n)	°C
Heatwave incidence: Days with temperature >90th percentile, TX90p	No./y
Potential areas exposed to flood risks: Urban/residential areas	Ha
Flooded area	Ha
Effective Drought Index	EDI scale
Soil temperature	°C
Soil sealing	% area
Days with maximum temperature >90th percentile	No. of days
Days with minimum temperature <10th percentile	No. of days
Area struck by destructive windstorms	Ha
Area struck by wildfire events	Ha
Relative humidity	%
Maximum surface temperature reduction	°C
Mean annual direct and indirect losses due to natural and climate hazards	€
Risk to critical urban infrastructure	%
Number of people adversely affected by natural disasters each year	No. of people

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AIR QUALITY	
INDICATOR	**UNITS**
Number of days during which ambient air pollution concentrations in the proximity of the NbS ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO and/or PAHs expressed as concentration of benzo[a]pyrene) exceeded threshold values during the preceding 12 months	No. of days
Proportion of population exposed to ambient air pollution ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, CO and/or PAHs expressed as concentration of benzo[a]pyrene) in excess of threshold values during the preceding 12 months	%
European Air Quality Index	Good, Fair, Moderate, Poor, Very Poor, Extremely Poor
Annual O_3, SO_2, NO_2, CO, and $PM_{2.5}$ capture/removal by vegetation	t CO_2e
Ambient pollen concentration	Grains/m^3
Avoided greenhouse gas emissions from reduced building energy consumption	t CO_2e

WATER MANAGEMENT	
INDICATOR	**UNITS**
Surface runoff in relation to precipitation quantity	mm/%
Water quality: general urban (pH, temperature, EC, DO, flow rate)	Several
Water quality: TSS content	mg/L
Nitrogen and phosphorus concentration or load	%
Metal concentration or load	%
Water quality: total faecal coliform bacteria content of NbS effluents	No.
Pollutant discharge to local waterbodies	mg/L
Eutrophication	Transparency, µg/L clorophyll
Infiltration capacity	mm/hr

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WATER MANAGEMENT	
INDICATOR	**UNITS**
Volume of water slowed down	m^3
Rainwater or greywater use for irrigation purposes	m^3
Water Exploitation Index	%

SOIL QUALITY	
INDICATOR	**UNITS**
Soil organic matter index	%
Concentration or load	mg/L
Measured soil carbon content	g/kg
Soil carbon to nitrogen ratio	Ratio
Soil water retention capacity	g/g
Soil Available Water (SAW)	cm/cm
Surface area of restored and/or created wetlands	ha
Erosion risk (soil loss estimate)	tons/ha/year
Polluted soils	mg/kg
Derelict land reclaimed for NbS	ha
CH pollution level of soil	mg/kg
Heavy metal pollution levels of soil	µg/kg
Pesticide levels of soil	µg/kg

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BIODIVERSITY ENHANCEMENT	
INDICATOR	**UNITS**
Structural connectivity of urban green and blue spaces	Several
Functional connectivity of urban green and blue spaces	Several
Number of native species	Number
Number of nonnative species introduced	Number
Number of invasive alien species	Number
Species diversity within a defined area	Number
Number of species within a defined area	Number
BAF - Biotope Area Factor	Area ratio
Percentage of protected natural areas	%
Percentage of tree canopy cover	%
City Biodiversity Index	Own scoring system
Pollinator species presence	Number
Density and seasonal spread of floral resources for pollinators	No./area
Percentage of private green areas in the city area	%
Number of veteran trees per unit area	trees/ha

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GREEN SPACE MANAGEMENT	
INDICATOR	**UNITS**
Green space accessibility	%
Share of green urban areas	%
Soil organic matter content	%
Soil organic matter index	Number (0-1)
Ratio of open spaces to build form	Ratio
Benefits provided pre and post interventions	No.
Edge density of Green Urban Areas (GUAs)	m/ha
Distribution of blue space	%
Effective green	%
Infrastructure at the urban-rural interface	Several

PLACE REGENERATION	
INDICATOR	**UNITS**
Derelict land reclaimed for NbS	ha
Quantity of bluegreen space (as a ratio to built form)	Ratio
Perceived quality of urban blue-green spaces (accessibility, amenities, natural features, incivilities and recreational facilities)	various
Place attachment: Place identity or "sense of place"	Several
Recreational value of public green space	Several
NbS incorporated in building design / incorporation of environmental design in buildings	map
Cultural heritage protection	map
Community garden area	ha
Total vegetation cover	ha

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KNOWLEDGE AND SOCIAL CAPACITY BUILDING FOR SUSTAINABLE URBAN TRANSFORMATION	
INDICATOR	**UNITS**
Citizen involvement in environmental education activities	No. of people
Social learning regarding ecosystems and their functions	Qualitative data (dimensionless)
Pro-environmental identity	Qualitative data (dimensionless)
Pro-environmental behaviour	Qualitative data (dimensionless)

PARTICIPATORY PLANNING AND GOVERNANCE	
INDICATOR	**UNITS**
Openness of participatory processes	Qualitative data (dimensionless)
Proportion of citizens involved in participatory processes	%
Sense of empowerment: perceived control and influence over decision-making	Qualitative data (dimensionless)
Adoption of new forms of participatory governance: PPPs activated	No.
Policy learning for mainstreaming NbS: Number of new policies instituted	No.
Trust in decision making procedure and decision-makers	%

SOCIAL JUSTICE AND SOCIAL COHESION	
INDICATOR	**UNITS**
Bridging (between groups)– quality of interactions within and between social groups	Qualitative data (dimensionless)
Bonding (within groups) – quality of interactions within and between social groups	Qualitative data (dimensionless)
Inclusion of different social groups in NbS co-co-co processes	Qualitative data (dimensionless)

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SOCIAL JUSTICE AND SOCIAL COHESION	
INDICATOR	**UNITS**
Trust within the community	Qualitative data (dimensionless)
Solidarity among neighbours	Qualitative data (dimensionless)
Tolerance and respect	Qualitative data (dimensionless)
Availability and equitable distribution of blue-green space	map

HEALTH AND WELLBEING	
INDICATOR	**UNITS**
Level of outdoor physical activity	Qualitative data (dimensionless)
Level of chronic stress (perceived stress)	Qualitative data (dimensionless)
General wellbeing and happiness	Qualitative data (dimensionless)
Self-reported mental health and wellbeing	Qualitative data (dimensionless)
Prevalence of cardiovascular disease	%
Incidence of cardiovascular disease	% per year
Quality of life	Several indexes
Prevalence of attention deficit/ hyperactivity disorder (ADHD)	%

NEW ECONOMIC OPPORTUNITIES AND GREEN JOBS	
INDICATOR	**UNITS**
Valuation of NbS: Value of NbS calculated using GI-Val	€
Economic value of urban nature	€
Mean land and/ or property value in proximity to green space	€

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NEW ECONOMIC OPPORTUNITIES AND GREEN JOBS	
INDICATOR	**UNITS**
Change in mean house prices/ rental markets	€
Average land productivity and profitability	€/ha
Property betterment and visual amenity enhancement	€/m^2
Direct economic activity: Number of new jobs created	€/year
Direct economic activity: Retail and commercial activity in proximity to green space	%
Direct economic activity: Gross value added to local economy from new business creation	%/year
Recreational monetary value	€/year
Overall economic, social and health well-being	Human Dev. Index

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5. CASE STUDIES IN UPSURGE

In this section the monitoring strategies of the 5 demonstrator cities in UPSURGE are discussed (Belfast, Breda, Budapest, Katowice and Maribor) with the aim of serving as examples and paving the way for future green cities. These monitoring systems are designed for verification of the NbS'.

When implementing my NbS...	
CHALLENGES **(What difficulties will I face?)**	**OPPORTUNITIES** **(What benefits can I expect?)**
• Lack of public awareness • Political and regulatory obstacles • Financial and resource limitations • Collaborative coordination among stakeholders	• Improvement of ecosystem services (water purification, carbon storage, pollination) • Adaptation and mitigation of Climate Change • Social and Economic benefits • Environmental risk reduction and mitigation

6. BELFAST

The Belfast Resilience Strategy highlighted in 2020 several potential sources of stress for the city, including the climate change or the risk of carbon-intensive systems.

NbS is located south of the city in an area that belongs to the Botanic Gardens, adjacent to Queen's Conservation Area. The UPSURGE demonstrator site is known locally as Lower Botanic and runs along the Stranmillis Embankment facing into the River Lagan to the east.

ACTIONS

- Research garden for testing carbon sequestration approaches and sustainable food growing
- **Agroecology community garden and community education space, providing opportunities for citizens to participate on the site.**
- Habitat Enhancement Works by creating species-rich grassland and 'wetland scrapes'
- Climate Resilience Garden as a growing space, encouraging the development of horticultural skills

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7. BREDA

Breda is a diverse landscape municipality, home to greenhouses, forests and natural areas. This variety of environments is home to a rich variety of plant and animal species. The local government is committed to preserve this biodiversity and focusing its efforts on climate resilience and environmental protection.

The site is located between railways and the Northern ring road of the city. There are challenges due to a lack of environmental education and awareness in the city.

ACTIONS

- **Green parking spaces: Replacement of concrete pavement with permeable grass pavers**
- Swammerdamplein Square is targeted as a recreational area **and Vuchstraat Park is being developed as a toddler playground**
- **Green facades: Covering over 450 m² implemented with residents and housing company**
- Jan VD Heijdenplein Square will be planted with flowery perennial plants and the implementation of raingardens
- **Infiltration areas to capture rainwater: Implementation of areas with deep-rooted vegetation for storage and infiltration**

8. BUDAPEST

Budapest, the capital city of Hungary, consists of 23 districts. Budapest's 18th District is the fourth largest district in Budapest and the one hosting the NbS.

Even if it is characterized by relatively many green spaces, significant air pollution can be detected along the three main roads linking the district with other parts of the city, due to increased traffic load coming from the commuting residents and the transit traffic from Liszt Ferenc International Airport. Besides, urban flash floods stemming from sealed soil surface and climate change are increasingly affecting the areas such as it has been facing severe submergence cases in recent years. BP18 plans to implement various NbS across the district on public and on private land.

ACTIONS

- Raingarden and parking lot with biodiverse lawn.
- Green walls covering 200 m² at the Municipality.
- Tree trenches for over 600 m for improved infiltration and evapotranspiration.
- New small raingardens dispersed in the district (25 in private spaces, 25 in public).

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9. KATOWICE

Katowice is a city in southern Poland with approximately 300,000 inhabitants living within 164 km^2. For most of its existence, there were mines and heavy industry plants in the city, but this has been recently substituted for high-tech and creative companies.

ACTIONS

- **Greenery solutions for bus stops (roof, soil restoration for water retention, flowerbeds)**
- **Greenery solutions in urban areas (unsealing concrete areas, green plants in pots, climbers, shrubs and perennial plants).**

The challenges Katowice faces include reducing heat islands, reducing particulate matter levels, improving water retention and overall citizen comfort. Key strategies include unsealing ground surfaces, and implementing greenery solutions (roofs, bus stops).

10. MARIBOR

Maribor (Marburg) has a total population of 112,838 and is the second largest city in Slovenia, and is located in the north-east of the country, east of the Alps, at an altitude of 270 meters (900 feet). The city is surrounded by wine hills and Pohorje mountain.

ACTIONS

- **Pekrski Potok green corridor (500 m) with stream bank regulation (100 m). Tree Species and design selected to target air pollution and water retention against flash flooding.**
- **Three pocket parks – green observatory as an outdoor educational space, outdoor health for fitness and green oasis for mental health**

To further improve the living conditions in the city, Maribor's UPSURGE demonstration site will establish a biophilic-designed network of nature-based spaces throughout the waterway of Pekrski Potok, creating a seemingly free-flowing continuity of natural environments leading to a climate-resilient neighbourhood.

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MONITORING STRATEGIES SELECTED FOR UPSURGE USE CASES						
TYPE	**MONITORING STRATEGY /INDICATORS SELECTED**	**Belfast**	**Breda**	**Budapest**	**Katowice**	**Maribor**
Air quality	Air quality: Measuring of air concentrations (PM_{10}, $PM_{2.5}$, NO_2, O_3, CO, CO_2).	✓	✓	✓	✓	✓
	Bee monitoring: Analysis of pollen collected by bees, giving qualitative and quantitative information on plans species, biodiversity, and indirect info on other parameters for air- and soil pollution (plant diversity, pesticides, heavy metals, PAH).	✓	✓	✓	✓	✓
UHI Effect	Weather: Measuring the following parameters: Air temperature, air relative humidity, wind speed, wind direction, solar radiation, rain gauge, atmospheric pressure	✓	✓	✓	✓	✓
	Urban heat island effect: Will be measured by comparing temperature and humidity between areas	✓	✓	✓	✓	✓
Noise	Noise: will be analysed and recorded	✓	✓	✓	✓	✓
Water	Soil measurings: Water content, temperature, infiltration capacity, soil conductivity	-	-	✓	-	-
	Water level control: Surface and groundwater level	-	-	✓	-	-

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11. CONCLUSIONS AND RECOMMENDATIONS

This guide addresses the third step of the sequence Definition of the problem – Definition of the solution – Setting of indicators for follow-up. Before using it, you should already know your city and the specific solutions you will be working with. Once you are there, you can make use of the step-by-step processes in this guide for the success of your monitoring strategy, select the proper KPIs from its catalogue, and get inspired by the solutions others found for their cities.

Here are some recommendations you might find useful for the design of your monitoring scheme:

- Select the proper metrics for your KPIs: Informative, feasible, affordable and durable.
- Use standardized methodologies if possible: If your data is compatible with that form other cities, a wider analysis, comparison and exchange of experiences is possible.
- Check on those who did it before you: Many cities have implemented NbS through the years and a lot of information is available, take advantage of previous experiences from others.
- Make sure everyone is on-board: From the co-creation process to the benefits from them, the success of an NbS depends on the stakeholders around it, especially the citizenship.

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