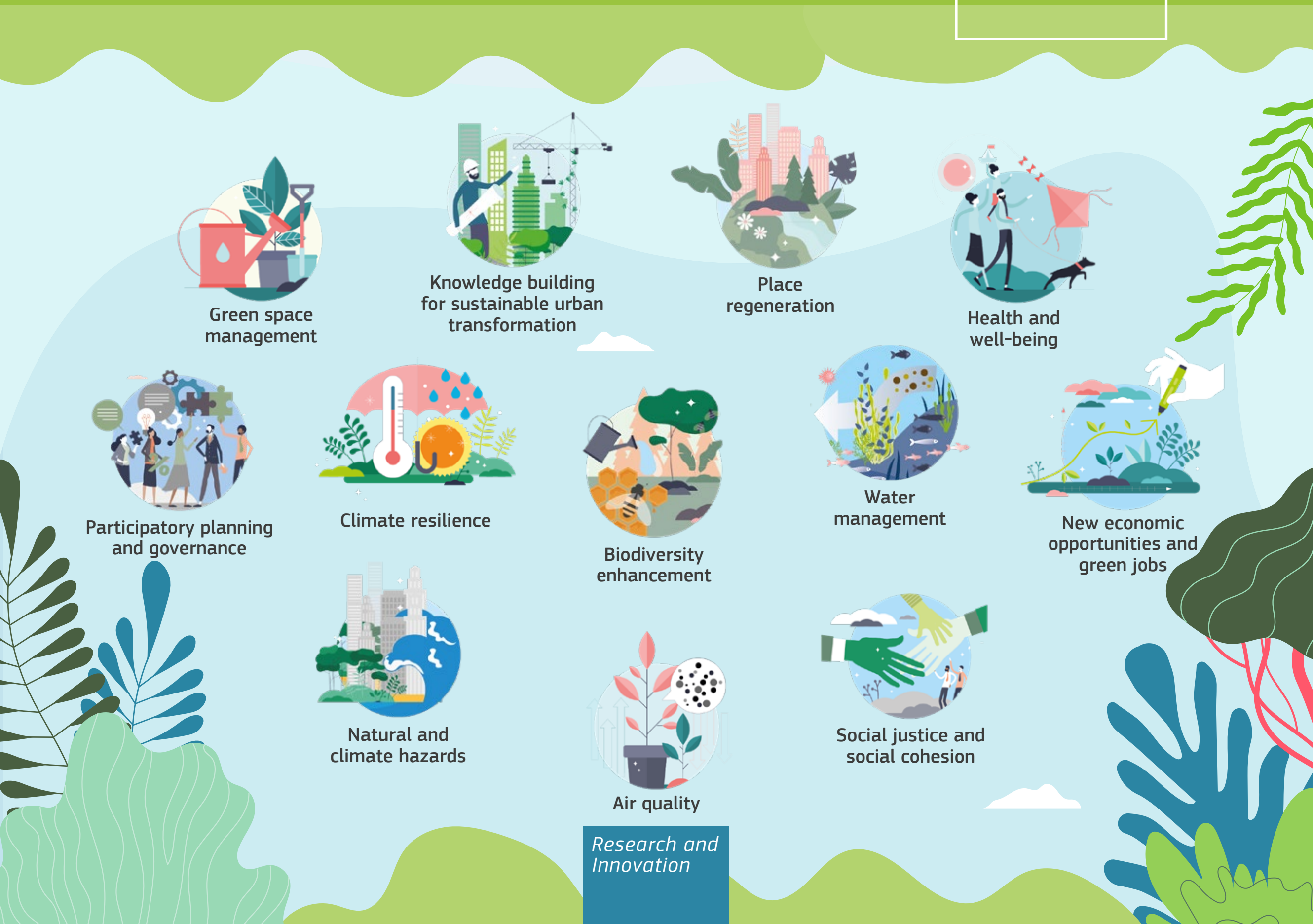
European Commission

EVALUATING THE IMPACT OF

NATURE-BASED SOLUTIONS

A Handbook for Practitioners

Independent Expert Report



Research and Innovation

Evaluating the Impact of Nature-based Solutions: A Handbook for Practitioners

European Commission
Directorate-General for Research and Innovation
Directorate C — Healthy Planet
Unit C3 — Climate and Planetary Boundaries

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EVALUATING THE IMPACT OF NATURE-BASED SOLUTIONS

A Handbook for Practitioners

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Directorate-General for Research and Innovation
Healthy Planet - Climate and Planetary Boundaries

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FOREWORD

Urban expansion and densification brings both opportunities and challenges. Regeneration of urban areas is therefore a significant priority, which needs to take into account environmental quality, social justice and sustainable development. Transforming cities and regions into vibrant, sustainable and resilient living places has become a key global priority. This is reflected in numerous policy initiatives at local, region al and national scale, and internationally through the UN Sustainable Development Goals (particularly SDG 11). Together these are part of a global call to rethink and redesign urban environments through innovative solutions that address multiple issues.

The EU Research and Innovation policy agenda on Nature-based Solutions and Re-naturing Cities defines nature-based solutions to societal challenges as "*solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*"[1]. Nature-based solutions (NBS) intrinsically provide biodiversity benefits and support the delivery of ecosystem services; however, there is increasing recognition of the multitude of environmental, social and economic co-benefits delivered by NBS.

The objective of this handbook is to support the adoption of common indicators and methods for assessing the performance and impact of diverse types of NBS. The handbook is designed to be relevant for NBS implemented across a wide geographic area and at a multitude of scales. The integrated NBS assessment framework presented in the handbook has been developed with the three-fold objective of:

- Serving as a reference for relevant EU policies and activities;
- Orienting urban practitioners in developing robust impact evaluation frameworks for nature-based solutions at different scales; and,
- Providing a comprehensive set of indicators and methodologies.

This handbook is intended to serve as a guide to the development and implementation of scientifically-valid monitoring and evaluation plans for the evaluation of NBS impacts (Figure 1). We begin by defining NBS in the context of global challenges and key policy instruments (Chapter 1). Subsequent chapters guide the reader through the development and execution of robust NBS monitoring and evaluation plans (Chapter 2 and Chapter 3), the selection (Chapter 4 and Appendix of Methods) and application (Chapter 5) of impact indicators, the use of NBS in Disaster Risk Reduction (DRR; Chapter 6), and the acquisition and management of relevant data (Chapter 7).

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[1] https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en

Why do we need a coordinated approach to NBS impact monitoring? **Chapter 1** describes how the development of robust monitoring and evaluation frameworks to assess NBS impacts enables cities and regions to assess the strengths and weaknesses of specific interventions in achieving strategic goals, understand the realised benefits and trade-offs, and sustainably manage NBS in the long term. Chapter 1 also describes how monitoring and evaluation can help to build the case for investments in NBS.

How do monitoring and evaluation contribute to evidence-based policy-making and policy learning? Monitoring and evaluation tells us whether an NBS functions as desired by providing evidence of its ability to achieve specific outcomes. **Chapter 2** describes the principles that guide NBS performance and impact evaluation to support the development of an appropriate, scientifically robust NBS monitoring and evaluation plan. The chapter presents general steps along with advice on how these steps can be tailored to suit a specific NBS context.

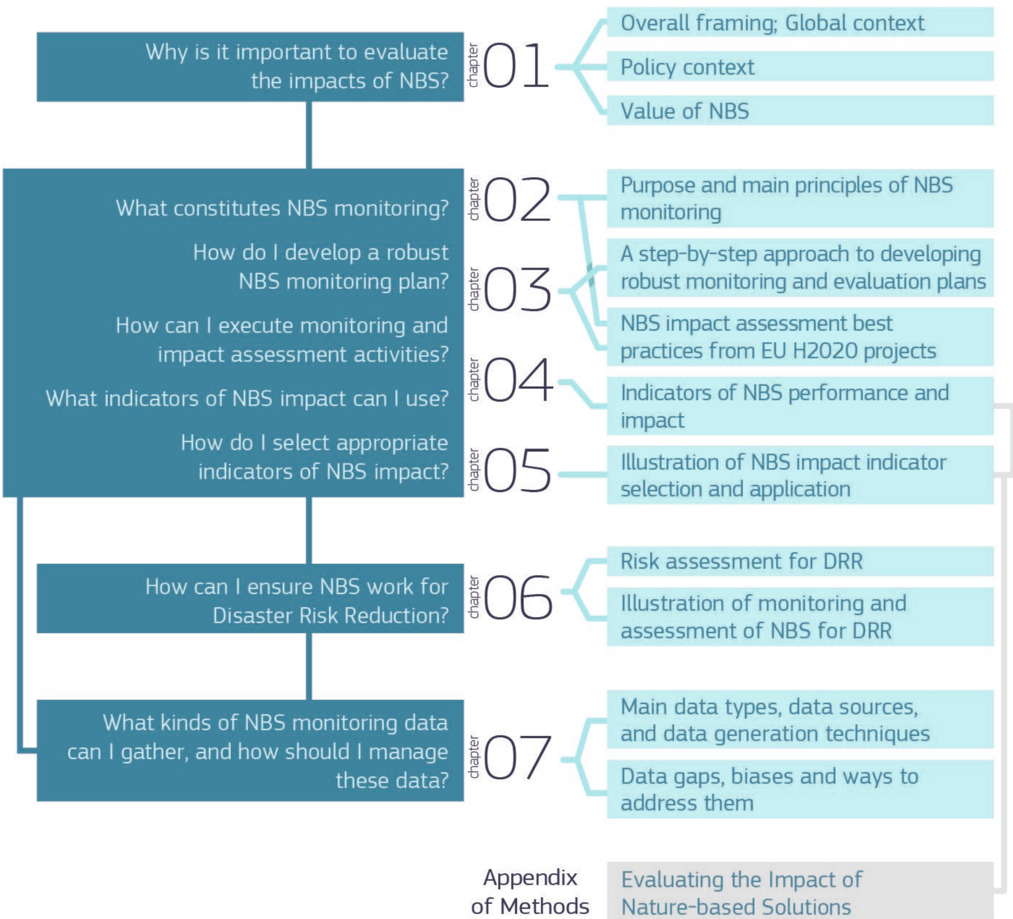

Figure1. Overall structure and content of this handbook.

Chapter 3 further elaborates the steps in the development of monitoring and evaluation plans. The development of local NBS monitoring and evaluation strategies are illustrated by a series of case studies from several EU H2020 projects. In particular, Chapter 3 emphasises the connection between NBS evaluation and monitoring plans and the processes of knowledge co-production and NBS co-management.

How is impact measured? The impacts of NBS can be assessed quantitatively and/or qualitatively by adopting indicators, a set of variables providing the means to assess particular attributes to meet an explicit objective. Identification and selection of specific indicators to evaluate NBS can seem a daunting prospect due the vast selection of potential indicators and their specific metrics. The buffet-style overview of indicators in this handbook helps the reader select the appropriate indicators. The handbook builds upon and expands the EKLIPSE Expert Working Group Impact evaluation framework. **Chapter 4** presents a suite of Recommended and Additional indicators to evaluate NBS impact across the following 12 societal challenge areas:

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

In addition to the identification and classification of NBS impact indicators across each of the 12 identified societal challenge areas, a range of methodological approaches are presented in the accompanying *Evaluating the Impact of Nature-based Solutions: Appendix of Methods*. The **Appendix of Methods** provides a brief description of each indicator determination method, along with guidance for end-users about the appropriateness, advantages and drawbacks of each method in different contexts.

How does it all fit together? **Chapter 5** presents a number of different case studies to further illustrate the selection and application of indicators for impact evaluation of different types of NBS implemented across a range of scales and in diverse environments. The examples display how indicators can be used together to address specific issues with the aim to inspire other cities and regions in developing robust monitoring and evaluation frameworks and facilitate evidence-based urban policy-making for NBS.

Chapter 6 details the use of NBS in ecosystem-based disaster risk reduction (Eco-DRR) schemes, outlining the components of risk and the potential impacts of NBS on risks due to natural phenomena. The use of NBS for DRR is illustrated by a series of case studies focused on large-scale hydro-meteorological risk reduction.

Chapter 7 provides an overview of data types, sources and techniques for the generation of data to monitor and assess the impacts of NBS. An understanding of different types of data, their sources and use is core to the development of robust monitoring and evaluation plans.

The handbook supports practitioners to independently design and implement NBS impact evaluation schemes. The indicators and methods of NBS impact assessment presented reflect the state of the art in scientific research on impacts of nature-based solutions and are valid and standardised methods of assessment. The selection is not exhaustive, but acts as a European reference framework on NBS impact evaluation and monitoring. The handbook synthesises information concerning the current state of play in the implementation of evaluation frameworks, as fostered by the European agenda on climate change adaptation and disaster risk reduction, including the re-naturing of cities and urban transformation towards sustainable, liveable, healthy and just cities.

This handbook was collaboratively developed by the NBS Impact Evaluation Taskforce, a clustering initiative by the EU Commission to capitalise on synergies between H2020 funded projects relating to NBS. The handbook expands on the pioneering work of the EKLIPSE Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas.

These Horizon2020 funded projects and collaborating institutions contributed to the NBS Impact Evaluation Taskforce that prepared this handbook (in alphabetical order): CLEARING HOUSE; CLEVER Cities; CONNECTING Nature; EdiCitNet; EEA; GROW GREEN; JRC; MAES/EnRoute; NAIAD; Nature4Cities; Naturvation; OPERANDUM; PHUSICOS; proGIreg; RECONECT; REGREEN; Think Nature; UNaLab; URBAN GreenUP; and, URBiNAT. The taskforce has relied on the input of more than 150 European researchers and over 60 European cities and regions involved in these projects. We thank all authors, lead authors and coordinating lead authors for their hard work and commitment to developing the handbook, and the European Commission for their support throughout the development of this work.

We hope that this handbook is helpful to those who make the difference in the field - practitioners, planners and decision-makers who implement NBS. Let this handbook inspire your work.

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LIST OF ABBREVIATIONS

ABM	Agent-based model
ADCIRC	Advanced circulation model
ADHD	Attention deficit hyperactivity disorder
ANK	Atlas of Natural Capital
API	Application programming interface
AQP	Air quality pollutant
ARIES	Artificial Intelligence for Ecosystem Services
ART	Attention Restoration Theory
AVHRR	Advanced very high-resolution radiometer
B£ST	Benefits Estimation Tool
BC	Black carbon
BI	Blue infrastructure
BGI	Blue-green infrastructure
BISE	Biodiversity Information System for Europe
BMI	Body mass index
BMPs	Best management practices
bVOC	Biogenic volatile organic compound
CA	Cellular automata
CBA	Cost-benefit analysis
CCA	Climate change adaptation
CH_4	Methane
CIF	Common Implementation Framework
CNS	Connectedness to nature scale
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CORDEX	Coordinated Regional Climate Downscaling Experiment
CVD	Cardiovascular disease
DEM	Discrete element method
DRMKC	Disaster Risk Management Knowledge Centre
DRR	Disaster risk reduction
EbA	Ecosystem-based adaptation

Eco-DRR	Ecosystem-based disaster risk reduction
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECS	Edible City Solutions
ECV	Essential climate variable
EE	Ecological engineering
EEA	European Environment Agency
EO	Earth observation
ERA40	Re-analysis of meteorological data from September 1957 to August 2002 produced by ECMWF
ESA	European Space Agency
ESM	European Settlement Map
ESS	Ecosystem services
ESTIMAP	Ecosystem Services Mapping tool
EU	European Union
Eurostat	Statistical Office of the European Union
FAIR	Findability, accessibility, interoperability and reusability of data
FEV	Flood excess volume
FRAME	Fine Resolution Atmospheric Multi-species Exchange model
FRC	Front-runner city
FUA	Functional urban area
GCM	General circulation model
GDPR	General Data Protection Regulation
GEE	Google Earth engine
GHG	Greenhouse gas
GHSL	Global Human Settlement Layer
GI	Green infrastructure
GIS	Geographic Information System
GLEON	Global Lake Ecological Observatory Network
GVA	Gross value added
H2020	Horizon 2020 framework programme
HEC	Hydrologic Engineering Center
HEE	Hydrological extreme event

HFA	Hyogo Framework for Action
HMR	Hydro-meteorological risk
IACS	Integrated Agriculture and Control System
ICOS	Integrated Carbon Observation System
ILO	International Labour Organization
INSPIRE	Infrastructure for Spatial Information in Europe
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
IPAQ	International physical activity questionnaire
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for the Conservation of Nature
IVR	Immersive virtual reality
JRC	Joint Research Centre
KIP INCA	Integrated system of Natural Capital and Ecosystem Services accounting
KPI	Key performance indicator
LAI	Leaf area index
LID	Low-impact development
LiDAR	Light detection and ranging
LL	Living Lab
LM	Landscape mosaic
LUCI	Land Utilisation Capability Indicator
LUE	Land Use Efficiency
LUISA	Land Use-based Integrated Sustainability Assessment
LULC	Land use and land cover
LUT	Look-up tables
M&E	Monitoring and evaluation
MAES	Mapping and Assessment on Ecosystems and their Services
MCDA	Multicriteria decision analysis
MODIS	Moderate resolution imaging spectroradiometer
NBS	Nature-based solution
NC	Natural capital
NDVI	Normalised Difference Vegetation Index

NGO	Non-governmental organisation
NO_2	Nitrogen dioxide
NO_3-N	Nitrate-nitrogen
NO_x	Nitrogen oxides
NUTS	Nomenclature of Territorial Units for Statistics
NWRM	Natural Water Retention Measures
O_3	Ozone
OAL	Open Air Laboratory
OECD	Organisation for Economic Cooperation and Development
OGC	Open Geospatial Consortium
OS	Opportunity spectrum
OSGeo	Open Source Geospatial Foundation
OSM	Open Street Map
PAH	Polycyclic aromatic hydrocarbon
PLS	Partial least square
PM	Particulate matter
$PM_{2.5}$	Particulate matter <2.5 μm in diameter
PM_{10}	Particulate matter <10 μm in diameter
PPGIS	Public participation geographic information system
PPP	Public-private partnership
ROI	Return on investment
RP	Recreation potential
ROS	Recreation Opportunity Spectrum
RS	Remote sensing
RUP	Re-naturing Urban Plan
SAR	Synthetic aperture radar
SCI	Site of community importance
SD	System dynamics
SDG	Sustainable Development Goal
SEA	Strategic environmental assessment
SEDAC	Socioeconomic Data and Applications Centre
SES	Social-ecological systems
SFDRR	Sendai Framework for Disaster Risk Reduction

SMART	Specific, Measurable, Attributable, Realistic, Targeted
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SolVES	Social Values for Ecosystem Services
SOPARC	System for Observing Play and Recreation in Communities
SPA	Special protection area
SRA	Strategic Research Agenda
SROI	Social return on investment
SRT	Stress Recovery Theory
SuDs	Sustainable urban drainage systems
SWAN	Simulative Waves Nearshore model
SWAT	Soil Water Assessment Tool
SWMM	Storm Water Management Model
TC	Technical Committee
TEEB	The Economics of Ecosystems and Biodiversity
TESSA	Toolkit for Ecosystem Service Site-based Assessment
TF	Taskforce
TOPHEE	Approach combining indicators for technical, physical, organizational, environmental, social/human and economic features
TSS	Total suspended solids
UCDB	Urban Centres Database
UCM	Urban canopy model
UCS	Urban Carbon Sink
UF	Urban forestry
UGI	Urban green infrastructure
UHI	Urban Heat Island
ULL	Urban Living Lab
UN	United Nations
UNA	Urban Nature Atlas
UNEP	United Nations Environment Programme
UNISDR	United Nations International Strategy for Disaster Reduction
UTCI	Universal Thermal Comfort Index

VGI	Volunteered geographic information
VOC	Volatile organic compound
WCDRR	World Conference on Disaster Risk Reduction
WEAP	Water Evaluation and Planning model
WHO	World Health Organisation
WMO	World Meteorological Organization
WSN	Wireless sensor network
WSUD	Water-sensitive urban design
WRF	Weather Research and Forecasting Model
YoLL	Years of life lost

02

What constitutes NBS monitoring?

How do I develop a robust NBS monitoring plan?

How can I execute monitoring and impact assessment activities?

What indicators of NBS impact can I use?

How do I select appropriate indicators of NBS impact?

Purpose and main principles of NBS monitoring

NBS impact assessment best practices from EU H2020 projects

Why is it important to evaluate the impacts of NBS?

How can I ensure NBS work for Disaster Risk Reduction?

What kinds of NBS monitoring data can I gather, and how should I manage these data?

2 Principles guiding NBS performance and impact evaluation

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Summary

What *is this chapter about?*

In this chapter, you will learn the main principles guiding NBS performance and impact evaluation. Good evaluation can be the basis for effective NBS implementation, enable evidence-based policymaking, support policy learning and facilitate flexible decision-making, via adaptive management, to ensure the sustainable performance of NBS over time. Credible and appropriate impact evaluation is based on scientific evidence and end-user experiences, is properly scaled and is linked to policy directives.

First, we explain key terms such as performance, impact, monitoring and evaluation (Section 2.1). Then, in Section 2.2, we describe the critical role of performance and impact evaluation in supporting decision-making. In section 2.3 we respond the question: "How do you develop a credible and appropriate impact evaluation?" We propose a set of general steps and principles necessary to develop an NBS impact monitoring and evaluation (M&E) plan, and explain how to tailor this plan to the specific type and size of an NBS in your local context. Finally, we synthesise the issues related to the design of M&E plans based on practitioners' feedback from existing H2020 projects and provide several examples.

How *can I use this chapter in my work with NBS?*

This chapter provides an overview of the general steps and principles that are necessary to develop a credible impact monitoring and evaluation plan. The challenges and knowledge gaps that may arise during the definition of a monitoring and evaluation strategy are also explored in this chapter.

When *should I use this knowledge in my work with NBS?*

Chapter 2 should be used at the beginning of the planning process for NBS monitoring and impact assessment. Timely planning enables allocation of the necessary time and resources to develop and implement the impact evaluation plan, identify potential data gaps, and address funding constraints. These principles can be revisited after initiating NBS monitoring to ensure that all relevant and applicable steps of the process are being deployed.

How *does this chapter link with the other parts of the handbook?*

Chapter 2 introduces practical steps and principles for impact evaluation of NBS measures in urban and rural settings. The individual impact monitoring steps are further elaborated in Chapter 3.

2.1 Introduction and definitions

Impact evaluation is part of a broader agenda of evidence-based policy-making and is essential to building knowledge about the effectiveness of interventions by highlighting what does and does not work to achieve desired change (Morton 2009). To achieve this, impact evaluation systematically and empirically examines the causal effects of the change in the built or natural environment associated with the NBS intervention. These effects can be grouped into 12 societal challenges[32] and often impact simultaneously across multiple dimensions (e.g., Place regeneration and Health and Wellbeing). Thus, impact evaluation is related to the interpretation of indicators selected to assess NBS performance

[32] Climate resilience, water management, natural and climate hazards, green space management, biodiversity enhancement, air quality, place regeneration, knowledge and social capacity building for sustainable urban transformation, participatory planning and governance, social justice and social cohesion, health and wellbeing, new economic opportunities and green jobs (see Chapter 4).

and effectiveness in addressing challenges and fulfilling objectives. The main aim of the impact evaluation is to answer a particular cause-and-effect question:

What is the impact (or causal effect) of an NBS intervention on an outcome of interest?

It is therefore essential to define in advance what impacts (or effects) an NBS intervention is expected to have, so that appropriate data at the appropriate scale (e.g., spatial and temporal) may be collected (Morton, 2009). Meaningful impact evaluation appropriately represents the NBS intervention in question and its context. It should be valid in all respects (e.g., providing for both internal and external validity[33]) and provide useful information that can help inform future directions. In order to understand why aspects of an intervention worked or did not work, additional information on characteristics of NBS intervention are necessary to understand the reasons for effectiveness (Morton, 2009) and the conditions necessary for replicating the results in different context. In that sense, significant support from monitoring is essential to complement the impact evaluation.

The main characteristics of monitoring and evaluation are described in the following paragraphs to enable differentiation between different approaches suitable for NBS impact assessment.

Monitoring is a continuous process that tracks:

- The *implementation* process in order to determine what takes place and when, during a project. The collected data are used to inform project implementation, day-to-day management (adaptive management, management of risk) and decisions related to effective implementation processes and governance, and addressing challenges associated with these processes.

- *NBS performance* against expected results (related to 12 societal challenges[3]) and compared with measurements of a reference situation (baseline). NBS performance is defined as the degree to which NBS address an identified challenge[3] and/or fulfil a specified objective in a specific place (territory), time and socio-economic context (Raymond et al., 2017). It measures:

1. Change towards certain targets* (in this case performance thresholds must be set - targets bring an additional challenge relating to how they are selected /set); or ,

2. The change in relation to the Baseline/Reference; or,

3. A combination of numbers 1 and 2.

[33] Internal validity refers to study design (factors like selection bias, spillovers, etc. should be addressed) and external validity refers to generalizability (applicability of lessons-learned to another context or conditions)

Performance can be assessed by comparing against results from before the intervention, from different NBS interventions or from alternative non-NBS interventions, and may also analyse trends over time. The collected (qualitative and quantitative) data is used to assess Key Performance Indicators (KPIs) needed in impact evaluations.

Monitoring is therefore a critical source of information about NBS performance (e.g., in terms of effectiveness, see Figure 2-1), including implementation and costs, which supports the evidence base for both new and existing NBS. Monitoring is used to reflect the reference situation before/without NBS and the situation after/with the NBS implementation. In order to generate the most relevant data from this process, monitoring should be conducted at an appropriate scale taking into consideration urban morphology and regional characteristics. A range of stakeholders may be involved in the local monitoring teams, in different forms of participation - from informative to co-monitoring activities.

Establishing a common standard for key indicators is important for comparing NBS effectiveness across cities or regions. This helps to make results transferable and thus support decision-makers in demonstrably effective and evidence-based design of interventions in the built environment as well as in the natural environment.

Evaluation is periodic, objective (un-biased, well-documented) assessment of a planned, ongoing, or completed NBS project used selectively to answer specific questions related to design, implementation, and results. It should be conducted at the appropriate scale (e.g., spatial and temporal) according to different decision-making contexts. In general, evaluations can address three types of questions (Morra Imas and Rist, 2009):

- Descriptive questions explore what is taking place related to conditions, processes and stakeholder views;
- Normative rating questions assess 'what is' taking place in comparison to 'what should be' taking place and apply to inputs, activities and outputs;
- Cause-and-effect questions explore what difference the NBS intervention makes to outcomes.

Impact evaluation mostly addresses the cause-and-effect questions. The basic evaluation question - what is the causal effect (impact) of an NBS intervention on an outcome of interest? – can be applied to different contexts. For example, what is the impact of the NBS on the mitigation of the adverse effects of hydro-meteorological risks (that at the same time deliver socio-economic and well-being benefits)? What is the impact of the residents' participation in the NBS co-creation on the use of the NBS, social cohesion and human health and well-being aspects? How can broadening the scope of the evaluation of NBS projects engage diverse funding sources necessary for city-wide implementation of NBS?

In that sense, impact evaluation focuses on the attribution and causality. To be able to establish the causal effect and to attribute it to the NBS intervention different methods can be used. These methods should estimate what the outcome would have been for the area and for its users (residents, people working in that area, etc.) if the NBS had not been developed (Morton, 2009). Alternatively, is a given NBS intervention effective compared to the absence of the intervention or to alternative, traditional engineering or planning solution? According to the causality view, **X** (NBS intervention) causes **Y** (an outcome, e.g., alters microclimate or social cohesion) and without **X**, **Y** would not exist.

Why are measurements needed in reference areas with no intervention?

Impact evaluation should use appropriate methods to prove that an NBS intervention (X), rather than other changes in environment, society, etc. - has caused a specific outcome (Y). However, NBS full development and changes in the built environment usually take a longer period of time, during which other factors may change as well. Thus, a whole range of effects can occur in the meantime, that may change the behaviour and perception of the population but have nothing to do with the original NBS intervention. This can be a global crisis (such as the Corona pandemic), but also local events (such as particularly mild weather for a longer period of time or a good score in sports events) that may change the feeling of happiness of the population independently of the original intervention.

One of the methods to filter out these effects, to prove the causality (Morton, 2009) and be able to attribute the outcome to the NBS intervention is a comparison[34] of the *treated area* (NBS implemented) with a *control area* that has not received a treatment (no NBS implemented). If an outcome of interest, e.g. microclimate or social cohesion, has improved in both areas it means that there were other factors that caused that change, rather than the NBS intervention. In cases where an outcome of interest, microclimate or social cohesion, has improved only in the treated area, then that change can be attributed to the NBS intervention.

Treated and control area are assessed before (pre) and after (post-) -the NBS intervention. The main challenge is to identify a control area and construct population group that is as similar as possible to the treated area/group and be in time before the participation and implementation process begins. In that sense, timely planning of impact evaluation will enable allocation of the necessary time and resources, and minimise funding constraints.

The definition of suitable "control area/group" or "before/after status" may not be applicable in all cases, for example, where NBS are designed to mitigate hydro-meteorological risks with relatively long (>10 years) return periods, such as floods and droughts (see Chapter 6). Under such a scenario, modelling could be an option, or evaluation of the impact of NBS on less severe (and more frequent) events.

[34] Example of a comparison to determine the impact of a programme or policy https://ec.europa.eu/jrc/en/research-topic/counterfactual-impact-evaluation

For certain impact assessments of large-scale NBS, finding a suitable control area can be challenging. Ideally, the control area should have similar environmental and socio-economic conditions as the treated area but be located far enough to be unaffected by the NBS intervention (to avoid spillover effect). If no suitable control area can be identified, an alternative approach may be to predict what the situation would be in the project area without implementation of the NBS. This would become the reference situation to which post-NBS monitoring data could be compared to assess the impact of NBS.

2.1.1 The concept of effectiveness

NBS effectiveness is defined as:

> *the degree to which objectives are achieved and the extent to which targeted problems are solved. In contrast to efficiency, effectiveness is determined without reference to costs (Raymond et al., 2017, p. vi).*

For example (based on Raymond et al., 2017):

- *Does the NBS lead to enhanced climate resilience in the urban area?*
- *Does the NBS lead to environmental benefits?*
- *Does the NBS lead to social benefits?*
- *Does the NBS lead to economic benefits?*
- *Does the NBS lead to biodiversity benefits?*

In cases when NBS interventions combine solutions to achieve different impacts, it is important to ensure that the impacts and its cumulative effects are integrated throughout the process rather than simply synthesised at the end (Morton 2009). This makes the whole analysis of their effects and impacts complex, increasing uncertainty with respect to data collection.

A functional analysis using safety and reliability analysis concepts (Figure 2-1) can help identifying the different system's components, their functions, their objectives and therefore their effectiveness. This methodology, classically used for technological systems is innovative and helpful to model the whole system and the interactions, as well as to break down the protected system into components with given functions. The concept of components' function and corresponding objectives identification is key to design and choose the best indicators for each application context. For example, a soakaway designed to divert road drainage can also be planted with shrubs and other plants to support pollinators. In that case, it is necessary to not only select indicators that measure the quantity of drainage waters diverted or extent of flooding avoided, but also indicators related to numbers of pollinators visiting flowers, etc. However, it is essential to avoid overlapping indicators in the projects' framework. Clustering of indicators can be handy for NBS effectiveness comparisons across cities or regions and help decision-makers to move towards better solutions.

Based on the project objectives the assessment of the performance and the effectiveness of a particular NBS intervention should take into account spatial and temporal scale as well as specific target groups. Important part of impact evaluations is an assessment of cost-benefit or cost-effectiveness. **Knowing which NBS interventions are effective and at what cost is crucial for informing decisions about whether an intervention could be scaled up and replicated.**

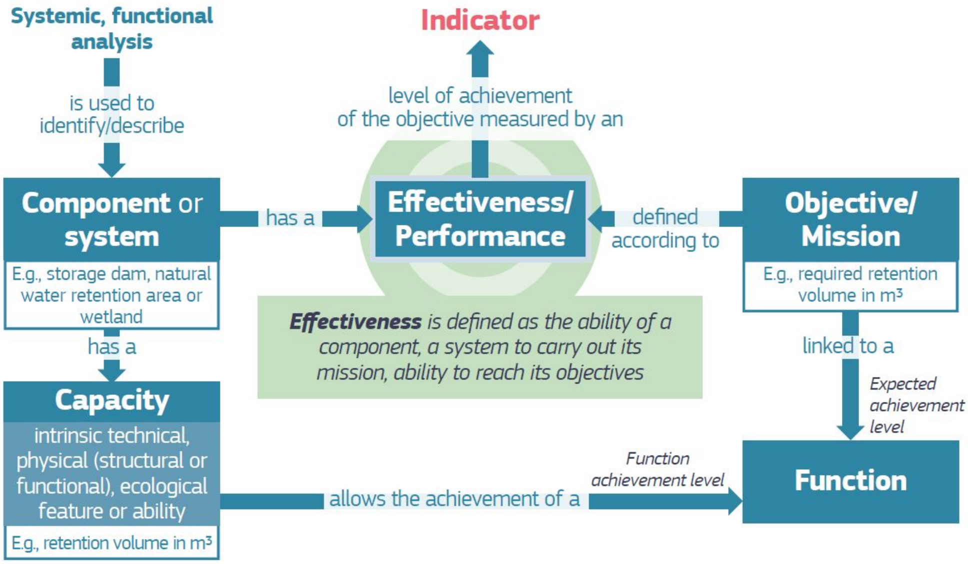

Figure 2-1. Effectiveness indicators are designed to measure the extent to which NBS capacity reaches the objective linked to an explicitly identified function (adapted from Tacnet et al., 2021*)*

Since benefits do not only refer to the physical sphere but include social/individual, economic, and ecological/environmental benefits as well, the complementary use of several evaluation approaches such as *ex ante simulations, mixed method analysis* (drawing on both qualitative and quantitative data)*, modelling* and *process evaluations* can complement impact evaluations. It is therefore important to note that there are always alternative approaches to assess benefits, including those, which are non-monetisable. For a customised impact assessment, it may therefore be helpful to adapt methods to one another (e.g., by adding other dimensions to an already planned questionnaire) in order to arrive at an effective impact assessment. In addition, integrating assessment methods such as multi-criteria analysis or natural capital evaluation methods can be adopted.

2.2 Decision-making context and impact evaluations: from needs to indicators

This section provides a broad vision of decision-making contexts explaining why NBS impact evaluations are needed. The aim is to identify and describe the evaluation needs in general, independent of a specific project or objective.

Impact evaluation focuses on results of NBS interventions and provides a set of tools that stakeholders can use to verify and improve the quality, efficiency, and effectiveness of the interventions at various stages of implementation. Although impact evaluation is a core driver of decision-making, since it is resource (time and expertise) demanding it can remain a marginal activity. In that sense, *it is important that impact evaluation is designed at the early planning phases of an NBS intervention*, in order to allocate necessary resources, develop the stakeholder engagement strategy and, where possible, integrate citizen science in the design of the evaluation. Additionally, it is important that its value is thoroughly communicated in order to support appropriate mainstreaming and management.

In general, there are two main approaches to NBS impact evaluation:

1. NBS has already been developed in the past and the main aim is to determine whether the NBS intervention is effective (*retrospective impact evaluation, i.e., ex-post evaluation*). If NBS is already there and baseline data was not collected before the NBS was implemented, it is difficult to analyse whether the NBS is successfully implemented and whether the envisioned outcomes are achieved (challenges related to the selection of appropriate treated and control groups before the implementation). However, this can be done for specific indicators using data that was collected during the monitoring of the NBS and data collected for other purposes (e.g., regional statistics of city administration data).

2. NBS has to be chosen during the planning phase (in comparison to alternative solutions or business-as-usual, i.e., ex-ante evaluation including screening) and implemented. Impact evaluations are developed at the same time as the NBS intervention is being planned and are integrated into the NBS implementation (*prospective impact evaluation,* i.e., ex-ante evaluation including screening). Baseline data are collected before the NBS intervention is implemented for both the area and/or group receiving the intervention (the treated area/group) and the area/group used for comparison that is not receiving the intervention (the control area/group).

In both cases, the robust evidence generated by impact evaluations is important for greater accountability, innovation, and learning in a decision-making context. Learning and innovation demand a willingness to take risks and experiment. Interdisciplinary nature of impact evaluation can contribute to busting departmental silos and understanding broader benefits and co-benefits of NBS. The accountability is crucial when it comes to reporting to funders, influencing decision-makers and engaging novel funding streams (Gertler et al., 2016).

In that sense impact evaluations should provide credible evidence on performance of the NBS and on whether a particular NBS intervention has achieved or is achieving its envisioned outcomes. Impact evaluations require the interpretation of those indicators that have been chosen to assess the benefits and co-benefits over a period of time. In this respect, an important challenge is how to look at the different indicators as a whole, considering their variation at different time scales. It is also necessary to decide in advance how large an effect is desirable and establish thresholds of impact. This is required in order to design an evaluation with the appropriate degree of statistical power to be able to detect an effect of the size expected. However, it is important to avoid a situation whereby even a smallest change is interpreted as a success or failure of the NBS (Gertler et al., 2016).

The question concerning uncertainty and more generally information imperfection is very important here. Information imperfection (including uncertainty) can apply to data features (e.g., resolution, coverage/spatial extent, etc.) and come from type and reliability of sources (number of monitoring locations, experts) and also from the evaluation procedure, measurement method or model themselves. This is an important aspect as it carries the weight and reliability of recommendations that will come from the monitoring and evaluation work. In that sense, it is recommended to assess and propagate information quality during the process of evaluation. The risk of failure of the monitoring system requires the development of protocols to adopt mitigation measures in case a failure in the monitoring system is detected.

In the decision-making context, the ability to replicate results is fundamental to questions about the broader effectiveness and scalability of a particular NBS. In addition to assessing the effectiveness of NBS in terms of desirable outcomes, it is important to carefully trace a theory of change[35] that explains the process through which NBS intervention has achieved the final outcome (benefits, co-benefits, but also unintended negative effects). As illustrated in Figure 2-2, the process begins with determining the desired long-term impacts related to the project objectives/challenges (vision). Proceeding from the identification of the existing conditions (reality), the necessary inputs and outputs are identified to achieve short-term as well as intermediate outcomes, which themselves lead to the desired long-term impact (vision). Assumptions identify the locally specific risks and conditions that are present in the project's context and attempt to manage these risks by identifying what conditions must hold true for change to occur. Understanding the process through which the changes have been implemented enables the identification of causal pathways (Morton, 2009), explaining:

- how the development of NBS functions in producing outputs, and
- how the process of producing outputs influences the final outcome.

[35] A theory of change is a description of how an intervention is intended to deliver the desired results. It describes the causal logic of how and why a particular program or intervention will reach its intended outcomes. A theory of change is a key underpinning of any impact evaluation, given the cause-and-effect focus of the research (Gertler et al., 2016, p. 32).

Figure 2-2. Example of the Theory of Change
(simplified adapted from The Young Foundation, CLEVER Cities project - D4.3/ WP4, pp. 18)

In order to gain a full picture of results, it is necessary to combine impact evaluations with monitoring and complementary evaluation approaches (i.e., to determine was the NBS implemented as planned, to provide context and explanations to quantitative analysis – qualitative data and mixed methods[36]). Moreover, in the decision-making context a long-term, transdisciplinary studies that focus on comparisons between NBS and non-NBS alternatives are very valuable to policy-makers (Dick et al., 2020).

NBS are always implemented to fulfil a range of specified functions (e.g., reducing floods, reducing air temperature, etc.), which can relate either to a quantifiable parameters (e.g., water storage volume) or to a qualitative metric such as an index to assess the well-being of a population.

In practice, assessing NBS' effectiveness can be seen as several decision-making problems:

a) Choosing - what is the most effective NBS?

b) Sorting - to which category of effectiveness or impact (low, medium, or high) does the NBS belong?

c) Ranking - what is the effectiveness of NBS ranking from the worst to the best (or vice versa)?

Multi-criteria decision analysis (MCDA)[37] is a way to gather any kind of qualitative and quantitative criteria, which correspond to NBS impacts (Figure 2-3; see Langemeyer et al., 2020; Harrison et al., 2017).

[36] Mixed methods – an expert or a team of experts from different disciplines seeks to integrate quantitative and qualitative approaches to theory, data collection, data analysis and interpretation. The purpose is to strengthen the reliability of data, validity of the findings and recommendations, and to broaden and deepen our understanding of the processes through which program outcomes and impacts are achieved, and how these are affected by the local context. (Bamberger, 2012)

[37] More information on multi-criteria decision analysis (MCDA), PP.129-139

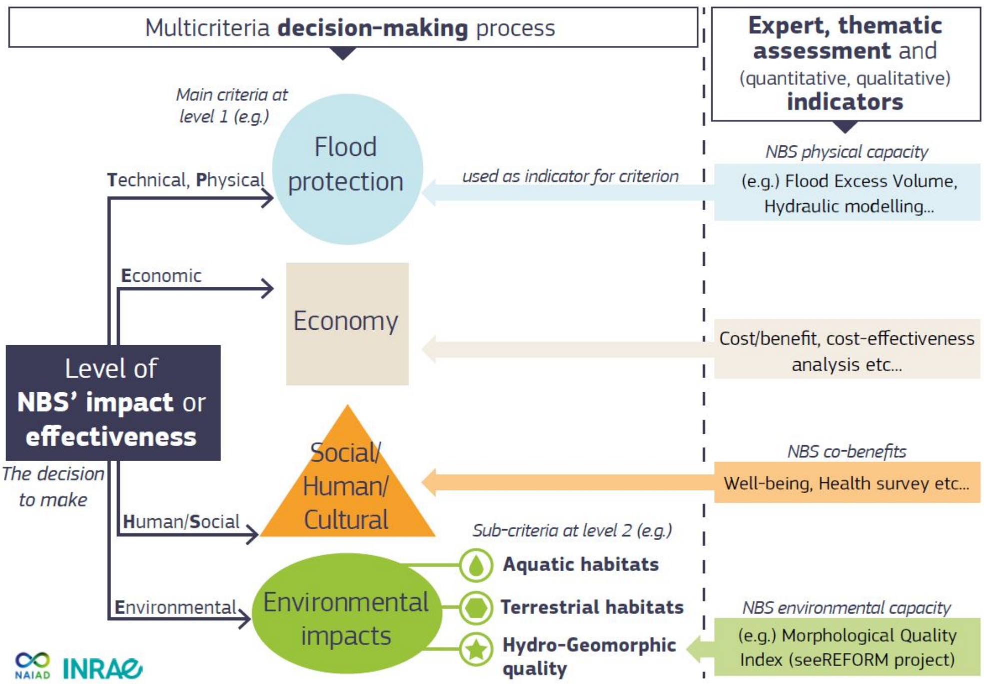

Figure 2-3. The analysis of the effectiveness or impact of NBS can be done through a combination of decision-aiding approaches and thematic, expert analysis and indicators. Features related to impact (effects) of NBS are combined in a multicriteria decision-making framework including technical (T), organisational (O) – not represented, physical (P), human (H), economic (E) and Environmental (E) considerations (TOPHEE framework) (Tacnet et al., 2021, based on the NAIAD project D5.4).

In practice, those criteria can be linked to measurable indicators coming from thematic, expert analysis. An interesting point is that it is a multidisciplinary framework, which can easily link deterministic, physical assessments and a global aggregated model as shown in Figure 2-3. In addition, this allows differentiation between factual, objective assessment and more subjective evaluation based on decision-makers' preferences.

Planning frameworks move proactively towards adaptive planning and management models, as a response to uncertainty and as an option to effectively harness resilience (adapted from IUCN, 2020[38]). In this context, it is imperative that NBS implementation includes provisions to enable this adaptive planning and management, generating evidence-base provided by regular monitoring and evaluation, drawing on local knowledge as well as on scientific understanding. NBS effectiveness and continuous performance evaluation are relevant throughout the life-cycle of the intervention for identifying deviations, maximizing synergies and total impacts, assessing and mitigating potential trade-offs, and minimizing stranded investments.

[38] https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard-nbs

2.3 Principles for the development of impact monitoring and evaluation plans

Since evaluation plans are developed to evaluate benefits, co-benefits, and negative effects as well as to evaluate performance of NBS in achieving predefined objectives, this may require combining results of several impact evaluations (each requiring its individual impact evaluation plan). The first section lists general steps in designing and implementing an impact evaluation plan (Figure 2-4). The second section presents main principles that should be followed when developing steps of impact evaluations plans (Figure 2-4).

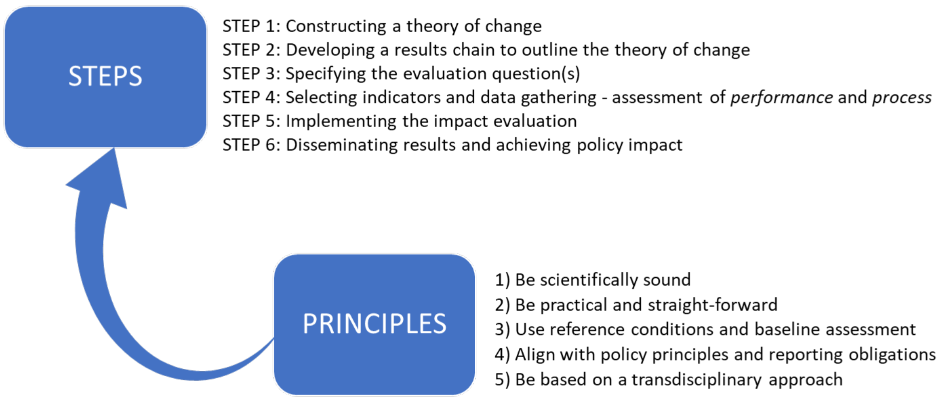

Figure 2-4. General steps and main principles involved in the development and implementation of an impact evaluation plan.

2.3.1 Steps

The design of an impact evaluation plan is a multi-faceted process. Based on the literature review and existing NBS projects we list six steps for developing impact monitoring and evaluation plans. This is a general overview that will be explained in more detail in Chapter 3.

STEP 1: Constructing and adopting a theory of change (Figure 2-2), which helps to identify objectives and challenges, as well as outlining the process for achieving the intended outcomes and impacts.

STEP 2: Developing a results chain to outline the theory of change – this covers both the implementation process and the results outcomes.

STEP 3: Specifying the evaluation question(s), the basic impact evaluation question is 'What is the impact (or causal effect) of an NBS intervention on an outcome of interest?' The focus is on the Impact - the changes directly attributable to an NBS intervention.

STEP 4: Selecting indicators and gathering data that answer the evaluation question(s) and that allow the assessment of *performance* and *process*: 'Does NBS operate as designed and is it consistent with the planned theory of change?' Critical selection of indicators that will be used to measure success/effectiveness of the NBS intervention, as well as cause-and-effect indicators should focus the evaluation, establish link to interventions well-defined objectives and assure that outcome is attributable to the NBS.

STEP 5: Implementing the impact evaluation, evaluating positive/negative features of NBS impacts related to the different challenges[39], analysing and interpreting the findings.

STEP 6: Disseminating results and achieving policy impact

2.3.2 Principles

A proper assessment and evaluation of the targeted impacts is needed in a way that is relevant and useful firstly to immediate end users and secondly to inform broader policy processes. Therefore, development of impact monitoring and evaluation plans should consider a few universal principles. Impact evaluation plans and its indicators must:

1. Be scientifically sound,
2. Be practical and straight-forward,
3. Use reference conditions and baseline assessment,
4. Align with policy principles and reporting obligations,
5. Be based on a transdisciplinary approach.

These principles are explained below. Examples of the implementation of these principles can be found in the selected NBS project example boxes between each chapter.

[39] In this Handbook impacts of nature-based solutions are assessed across 12 societal challenge areas: Climate Resilience; Water Management; Natural and Climate Hazards; Green Space Management; Biodiversity; Air Quality; Place Regeneration; Knowledge and Social Capacity Building for Sustainable Urban Transformation; Participatory Planning and Governance; Social Justice and Social Cohesion; Health and Well-being; New Economic Opportunities and Green Jobs – see Chapter 4

1) Impact evaluation should be scientifically sound

Since impact evaluations measure the change in an outcome that is attributable to a defined NBS intervention, it is based on models of cause-and-effect. It requires a credible and rigorously defined study design to control for factors other than the intervention. However, cause-effects are not necessarily the only model. In cases when the purpose of impact evaluation is raising awareness of the impact of the NBS, the crucial factor is engagement of communities and decision-makers. In that case, attribution may be replaced with contribution analysis[40]. Ideally, in a Theory of Change, aspects such as 'community engagement' can also be assessed to demonstrate success of the project.

Measuring the impact of an NBS intervention should follow a concrete selection of appropriate methodology that is capable of assessing the Key Performance Indicators (or KPIs). Quantification and assessment of indicators is needed for every challenge (environmental, economic, social or other[4]). But how to select or develop indicators to be scientifically sound? This handbook provides an extended list of scientifically sound indicators (Chapter 4) and examples of their application (Chapter 5). The accompanying Appendix of Methods provides full descriptions of each indicator and provides a brief methodology for each.

In case further indicators are necessary, based on a scientific literature the following criteria can be used for their development (Figure 2-5):

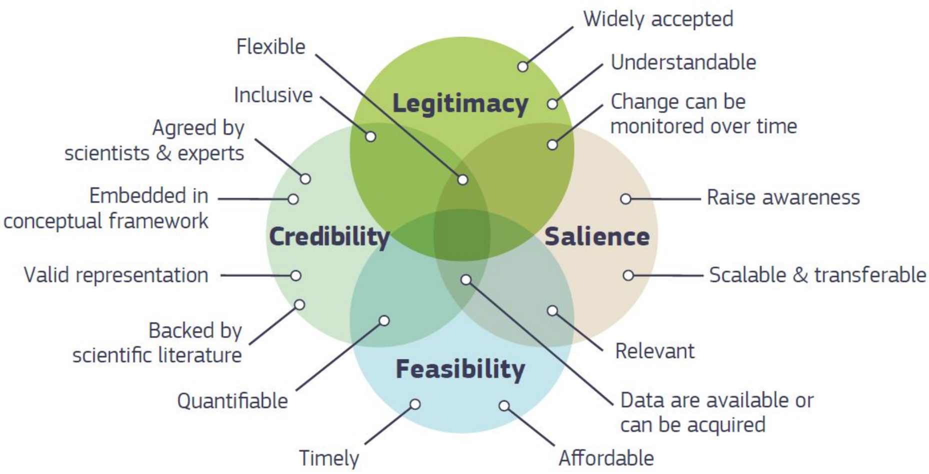

Figure 2-5. Criteria for developing ecosystem service indicators
(adapted from Van Oudenhoven et al., 2018)

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[40] Contribution Analysis is a structured approach that enables assessing real-world challenges. It consists of a step-wise, iterative process of refining Theory of Change. It does not seek to conclusively prove whether, or how far, a development intervention has contributed to a change. Instead it seeks to reduce uncertainty (https://www.intrac.org/wpcms/wp-content/uploads/2017/01/Contribution-analysis.pdf).

1. *Credibility:* the process of indicator development should be based on a review of existing literature and on an external review by experts, controlled path of production, elaboration, validation and monitoring of data according to scientific protocols and methodologies: scientific selection methods, validation, integration into methodology, triangulation of data.

2. *Salience:* relates to the capacity of indicators to convey useful and relevant information for decision makers about specific objectives as perceived by potential end-users and stakeholders. It is important to use effective means to present and translate scientific indicators in a way that it is easy to communicate to non-experts: easy to read, understandable and not generating misunderstanding (visualisation, modelling and simulation tools: such as graphical, GIS, tabular, model animations, landscape design drawings, etc.). Indicators should be temporary explicit to have the potential to monitor change and assess progress over time. Moreover, indicators should be scalable and transferable.

3. *Legitimacy:* selection on the basis of relevant indicators to meet the scopes of monitoring process (for example, SMART[41]): the selection of the most appropriate model of impact evaluation will depend mainly on vision and outcomes of interest in the project, scale of implementation, desired co-benefits and available resources allocated to monitoring work and time. The impact monitoring and evaluation plans need to be iterated and co-produced with the relevant stakeholders and experts from different disciplines (see principle 5 on transdisciplinarity) and not be a one-way communication or design. In addition, indicators should be the outcome of a shared process, to meet the expectations of a wide number of stakeholders and, where possible, to express the engagement of communities in decision-making and raise the awareness.

4. *Feasibility:* relates to the sufficiency of data, time and resources to assess and monitor indicators (simple indicators are easy to acquire, easy to elaborate, assess, and monitor over time). Another crucial aspect to the scientific appropriateness of impact evaluation models is checking beforehand the availability of baseline data, as well as, the (economic, temporal, ethical) feasibility of measuring new data or collecting new information throughout the monitoring process to get down the road.

2) Impact evaluation should be practical and straightforward but fulfil technical requirements

Impact evaluation has to be practical and straightforward, including when planned by scientists and conducted by experts. This implies that many barriers should be overcome in communicating (and making aware of) the final aim of the monitoring activity, to assure it is successful and well conducted.

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[41] SMART Specific, Measurable, Attributable, Realistic, and Timely or Time-bound, see Chapter 3

Since every NBS project is unique, measuring of impact/outcome needs to be adjusted to that specific project and context. Although no universal framework can be proposed, some basic requirements for a successful monitoring activity are listed below.

- A high level, cooperative dialogue among practitioners, local or regional authorities, stakeholders and scientists should occur from the beginning of developing the monitoring and impact evaluation plans (see point 5) on transdisciplinarity)

  This will help practitioners, local or regional authorities and stakeholders to be more aware about the critical aspects of a scientifically robust assessment, as well as help scientists to focus more on the challenges that really need to be tackled by the NBS intervention.

- Definition of the scope in which effects of the intervention are expected

- Definition of the site of investigation and/or target groups

  The site of investigation can be the NBS site, its neighbourhood, its district, the whole city or region. The target group is located within this spatial limit and it should be as statistically representative as possible (see Chapter 3 and Chapter 7).

- Choice of a control area/group (when applicable)

  In many cases outside factors may influence outcome of the NBS intervention. In order to validate the monitoring results and correlate them with the NBS intervention realized, a parallel, twin, monitoring activity should be performed elsewhere, by identifying the so-called "control area/group". It should be as identical as possible to the actual treated area/group. This usually means that it should be located in the same neighbourhood/district/city/region (depending on the scale at which effects are expected, by scaling a level up the spatial scale) in order to take local conditions (e.g., climatic conditions or cultural ones) into account. For instance: if NBS effects are expected at the district level, the control area/group should be chosen within the same city or region but in a different district.

- Choice of a reliable and feasible frequency of data collection

  Reliable frequency of the data collection should ensure the impact evaluation on a temporal scale, which is adapted to the type of intervention and/or of the challenge to be faced. However, data collection frequency should be also feasible (see Figure 2-5), since regional authorities, municipalities or stakeholders generally have limited budget/persons to do this.

3) Impact evaluations should clearly state and use reference conditions and baseline assessment

Baseline data are important for measuring pre-intervention outcomes (reference conditions) that are used later in the assessment process for the before-and-after comparison. Chapter 7 of this handbook discusses how baseline data are established and used operationally. In this section we list the following key points:

- Ensure that the method for establishing baseline data is repeatable
- Differentiate between process and outcome
- Chose standardized ways of assessing certain outcomes to allow for the accumulation of evidence and comparability; striking a balance between common indicators and highly specific ones;
- Assure clear link between challenges addressed and indicators selected
- Establish baseline and control area/group or reference values for comparison in order to determine change(s) attributable to NBS implementation

4) Impact evaluation should align with policy principles and reporting obligations.

The expected outcomes based on objectives of an NBS intervention are important for the impact evaluation. However, it is also important to identify and include unexpected outcomes. Considering the time-frame of the project and the time necessary for outcomes to be 'visible', some impacts may occur more quickly than others.

In that sense, short-term immediately visible improvements are initial outcomes that can be assessed immediately after the intervention (green quality, aesthetic, amenities, etc.). Intermediate outcomes are assessable after some period of time during the project (use and function of NBS, individual status and perception, social environment) while long-term health outcomes (mortality rates, life expectancy, cardiovascular disease, obesity, etc.) are often difficult to assess; either because there is no long-term monitoring institutionalized, but also because these outcomes are influenced by many interweaving factors. Moreover, achieved positive impacts might change over time (depending on management, succession, changing climate, etc.).

To assure relevance for policy-makers, it is also important to seek alignment with key policy objectives. This can be done through a strategic review of policy alignment between local/regional/national strategic objectives and potential NBS benefits. The desired impact from the NBS implementation process can then feed into the local administration, urban or regional policies (e.g., green roofs mitigation and adaptation measure).

This should also provide connection to the local, national and EU-based policies and requirements. For example, NATURA 2000 may require from all member states to use certain indicators in the assessment of their natural areas. Similarly, Floods Directive will specify those indicators that are related to flood risk assessment. Water Framework Directive demands certain water quality standards and indicators. Similarly, the LIFE programme[42], the EU's funding instrument for the environment and climate action, has developed a KPI framework that can be seen as embedding element for measuring the impact of a NBS. However, indicators in this Handbook (Chapter 4) are based on H2020 Projects involving EU and non-EU cities and regions and are thus applicable globally.

5) Impact evaluation should be based on a transdisciplinary[43] approach.

Impact evaluation of NBS interventions relates to a whole range of different societal challenges. It is unlikely that the knowledge required for such broad evaluation sits with a single individual. As such, monitoring and evaluation teams should engage societal actors and experts from across relevant disciplines in a transdisciplinary approach. A transdisciplinary approach enables combining knowledge from societal actors with knowledge and methods from different disciplines (e.g., engineering, public health, social sciences, etc.) (Schneider et al., 2019). To achieve transdisciplinarity, monitoring and evaluation plans should be co-produced in collaborative actions to achieve the best balance between local needs, values and knowledge, and scientific interdisciplinary knowledge and requirements. Local authorities and practitioners, who are aware of real conditions as well as administrative and technical barriers, should drive collaborative actions. However, they should also involve additional expertise, for example from the civic sector (to identify local needs and raise the awareness about the benefits related to NBS), industry (to contribute to feasibility), and scientists.

The co-production process should start with identifying a joint vision (Theory of Change, Figure 2-2) and establishing desired outcomes collaboratively from the beginning. By approaching co-production this way, it will be easier to relate outcomes to the planned NBS, to expected results, and to the indicators that will be used to measure the expected impact. Support from the local community is crucial as this not only to improves the quality of information and trust in the results of the impact evaluation itself, but also raises awareness and increases sense of stewardship and caring. Likewise, partnerships and collaborations among actors that are normally not in contact with each other can be generated. Allowing different partners to get involved in participatory decision-making will generate a sense of ownership of the solutions to be implemented (see also Mahmoud and Morello, 2021).Their involvement will bring diverse perspectives in defining outcomes, selecting indicators, collecting and analysing data.

Support from the scientific community or other experts is desirable when deciding what methods or research designs will be considered credible for the impact evaluation. This handbook is already driven by scientific principles and should

[42] The LIFE Programme

[43] Transdisciplinarity – problem-driven, cross-disciplinary, cooperative approach including scientists, practitioners, stakeholders.

facilitate selection of suitable monitoring tools and protocols that can be adapted to the local needs.

In that sense, it would be desirable that local administrations and practitioners in collaboration with stakeholders and scientists interested in the implementation and monitoring of a NBS:

- Tailor the monitoring protocols, while preserving the scientific robustness;
- Choose the needed experimental setup according to the required resolution and disciplines; and,
- Follow up regarding the process during short and long-terms implementation processes.

2.4 Capitalising on existing experiences and remaining critical concerns

Impact evaluation of NBS interventions requires joint effort of different actors to be able to assess wide range of outcomes and identify trade-offs before, during and after the NBS implementation. A high-quality impact evaluation depends on skills of team members conducting the study. However, even with a skilled team, evaluation processes may face different challenges. In the following sections, we describe challenges and gaps from H2020 projects and conclude with key messages based on existing experiences from these projects.

2.4.1 Challenges and gaps in current monitoring and evaluation efforts

Impact evaluation is related to the interpretation of indicators selected to assess NBS performance and effectiveness in addressing challenges and fulfilling objectives. A number of common challenges and gaps in monitoring and evaluation efforts are emerging from the existing NBS projects. These challenges are analysed from four perspectives: practitioner, scientific, citizen/user and private sector.

From a practitioner perspective main challenges are identified from project work with stakeholders in cities and regions. They include a lack of expertise in evaluation and data collection, in the critical selection of indicators that address the predefined impacts; short time frames; dispersed and siloed data within different agencies; lack of implementation monitoring vs. performance monitoring (which could lead to the missing of important data afterwards, such as for the accounting of the cost-benefit and cost-effectiveness); etc. Problems of dispersed and siloed data can partly be solved with transdisciplinary approach, which enables the effective gathering of data from many different disciplines (health, air quality, biodiversity, water management, economics, etc.) and effective communication with those who hold those data.

The use of indicators themselves has following practical issues:

- Indicators exist but it is difficult to use them due to the lack of understanding (e.g., understanding the logic behind the models), data unavailability, data not available for use at fine scale (e.g., detailed census data may be available at household level but cannot be released), etc.

- Lack of resources, lack of ownership, lack of requirement from funders, lack of interest once NBS has been installed, lack of expertise, change in personnel

- Issues related to the complexity of cities and regions, as a system of systems with several layers of networks constantly interacting with each other, which makes it difficult to identify causal chains (especially when people and their behaviour are the target of interest)

- The multiplicity of decision-making contexts and processes cannot be captured by a universal and versatile set of indicators: each decision requires the selection of ad-hoc indicators from among an extended set. Formalisation of all those decisions is not always fully understood by the different stakeholders who may expect easy ready-to–use methods working in any conditions.

- Feasibility based on the available expertise (e.g., biomonitoring).

From a scientific perspective, (see section 2.3.2) the main gaps in the monitoring process are:

- Lack of differentiation between the process and outcome, the gaps in the monitoring methodology and implementation stages (micro-, meso-, macro-, etc. scales of interventions) and longer-time frame of effects measurement.

- Lack of longer-term evaluations to assess effects over time and guaranteeing continuity of monitoring measurements: often models of monitoring impacts lack the continuity of measurement from the pre-greening to the long-term effects in the post-greening phase, they are also influenced by the complexity and feasibility of the monitoring itself. The ideal impact monitoring methodologies are the ones with the minimum specialised equipment and time efforts, or relying on ready-to-run and consolidated data acquisition protocols, possibly managed by the public authority. Involving citizens and local stakeholders in the co-monitoring of NBS interventions, often requires simplification, which is challenging for some complex impacts.

- Difficulties in communicating to non-scientific partners in a less -technical language. Engaging stakeholders in the process of data collection and monitoring is challenging. However, scientists should translate indicators to be simple and capable of immediate representation, easy to understand and, connected to people‘s priority interests and concerns.

- Ability to express levels of uncertainty associated with evaluation outcomes. Decision-makers want to know what is the relative level of certainty or uncertainty associated with evaluation work. For example, speaking in practical terms, if the likely chance of an NBS achieving its intended impact is 80% then decision-makers may be very willing to up-scale such an NBS intervention elsewhere, as opposed to their willingness to upscale if the likelihood of achieving the desired impact is only 20%.

- Indicators exist but they may not be relevant to the studied NBS in a place-based context. The way indicators are assessed (quantitative, qualitative, traceability/justification of hypothesis) is essential.

- Any set of indicators will always remain contextual and correspond to the knowledge level at a given moment: it is therefore interesting to provide lists of indicators but also methodologies to build new ones in a dynamic way if needed.

- Measurability of intangible impacts (e.g., aesthetic enjoyment) and spillovers (impact of NBS intervention may spread beyond the treated area or group) as well as accounting for trade-offs is challenging, particularly because of the diverse perspectives of stakeholder valuing NBS, the multiple time scales of assessment and influence of other programs and factors.

- The assessment of NBS effectiveness or impacts is a multi-scale and multi-temporal problem. Indicators for urban scales and issues may not be relevant for wider scale such as catchment basin scale for example when dealing with flood risk reduction.

- Indicators related to NBS effectiveness require the use of multi-disciplinary approaches able to combine physical, environmental, social, human and economic features. New paradigms are needed to integrate this different kind of knowledge and related methods.

From citizens/users perspective: experience with citizen monitoring is limited and collected data about the impacts of NBS is often not presented in a user-friendly format and/or made available to the public. Need for scientific and intercultural translation, lack of appropriation and adequate tools for co-diagnostic, co-evaluation and co-monitoring that involve citizens as active actors in the evaluation processes. Adoption of tools that include: the perception of citizens, the translation and adaptation of content, the validation of monitoring results by citizens. To consider people's voices, is to recognize the plurality and open paths for effective co-production of knowledge, see section 2.3.2.

From a private sector perspective: in some cases, NBS are elaborated in collaboration with industries and partners from the private sector. This is particularly true when the NBS implementation includes regeneration of previously productive sites and/or includes the implementation of innovation technologies. In all these cases, to have valuable inputs, beyond the non-monetisable benefits, is a real challenge.

In addition to the four perspectives, we identify three types of issues in NBS implementation of monitoring and evaluation plans: technical, physical and social. Some NBS which have been selected through the previous steps of building a theory of change and which encompass an evaluation model (e.g., SMART) have encountered a variety of hindrances in their actual implementation contexts, such as:

- Technical issues: some NBS in place require a specific sophisticated technical knowledge that is not necessarily available in project competences.

- Physical issues: some NBS in place have shown physical constraints or drawbacks that might obstruct the implementation in reality or induce unexpected side effects (e.g., a riparian forest causing woody debris and bridges' section reduction or even closure, see NAIAD project, La Brague demonstration site).

- Social issues: a social acceptance factor towards implementation is needed for any NBS impact model evaluation to measure an increase in openness, awareness, citizen engagement and to assess management efficiency, accountability, sharing, transparency, and communication. That is why a transdisciplinary approach is needed in order to facilitate the co-production of monitoring and evaluation plans with stakeholders.

In these cases, where the foreseen monitoring and evaluation plans cannot be implemented, mitigation measures have to be applied.

2.4.2 Key messages from existing projects

NBS performance and impact evaluations should provide answers to policy questions that affect people's daily lives. In H2020 projects questions such as 'Does an NBS intervention influence air quality, enable climate adaptation, regulate microclimate, increase biodiversity or contribute to social cohesion and well-being?' are related to societal challenges. Key messages from these projects are listed below.

Three core elements of well-designed NBS performance and impact evaluation are:

1. A concrete assessment *question* related to an outcome of interest developed in a theory of change that can be answered with the impact evaluation.

2. A robust *methodology* that balances understanding of the complexity of diverse NBS outcomes, as well as trade-offs, with feasibility in relation to the specific socio-economic context and available resources.

3. A well-formed evaluation *team* that functions as a transdisciplinary partnership between different sectors (public, private, civil society) and various knowledge disciplines depending on the type of NBS and outcomes of interest.

It is important to have a practical focus and adapt these very general steps and principles to local context and develop tailor-made monitoring and evaluation plans. Moreover, don't be afraid to start small and begin with evaluation indicators that are more manageable and understandable. This can represent a good foundation for the development of a transdisciplinary evaluation plan.

When developing such bespoke plans, although local practitioners and the local population are crucial for plan development, it is also necessary to engage experts from different disciplines to ensure that various benefits and co-benefits as well-as unintended negative effects of NBS interventions are assessed and evaluated. Although impact evaluations are complex processes with dynamic parts, they are a worthwhile investment and collaboration can be the most effective way to maximise the return on this investment.

Participants in the NBS impact evaluation should be included in the dissemination efforts. Since they have invested their time and energy in planning and implementing monitoring and evaluation plans, it is essential to ensure that they have access to and remain informed about the evaluation results. This small effort can contribute to their continued interest and willingness to participate in future NBS evaluations.

On the following pages and between chapters there are different case studies illustrating main characteristics and challenges of monitoring and evaluation plans from different H2020 projects. Chapter 3 explains step-by-step the process of development of monitoring and evaluation plans, which complements the general overview provided in this chapter.

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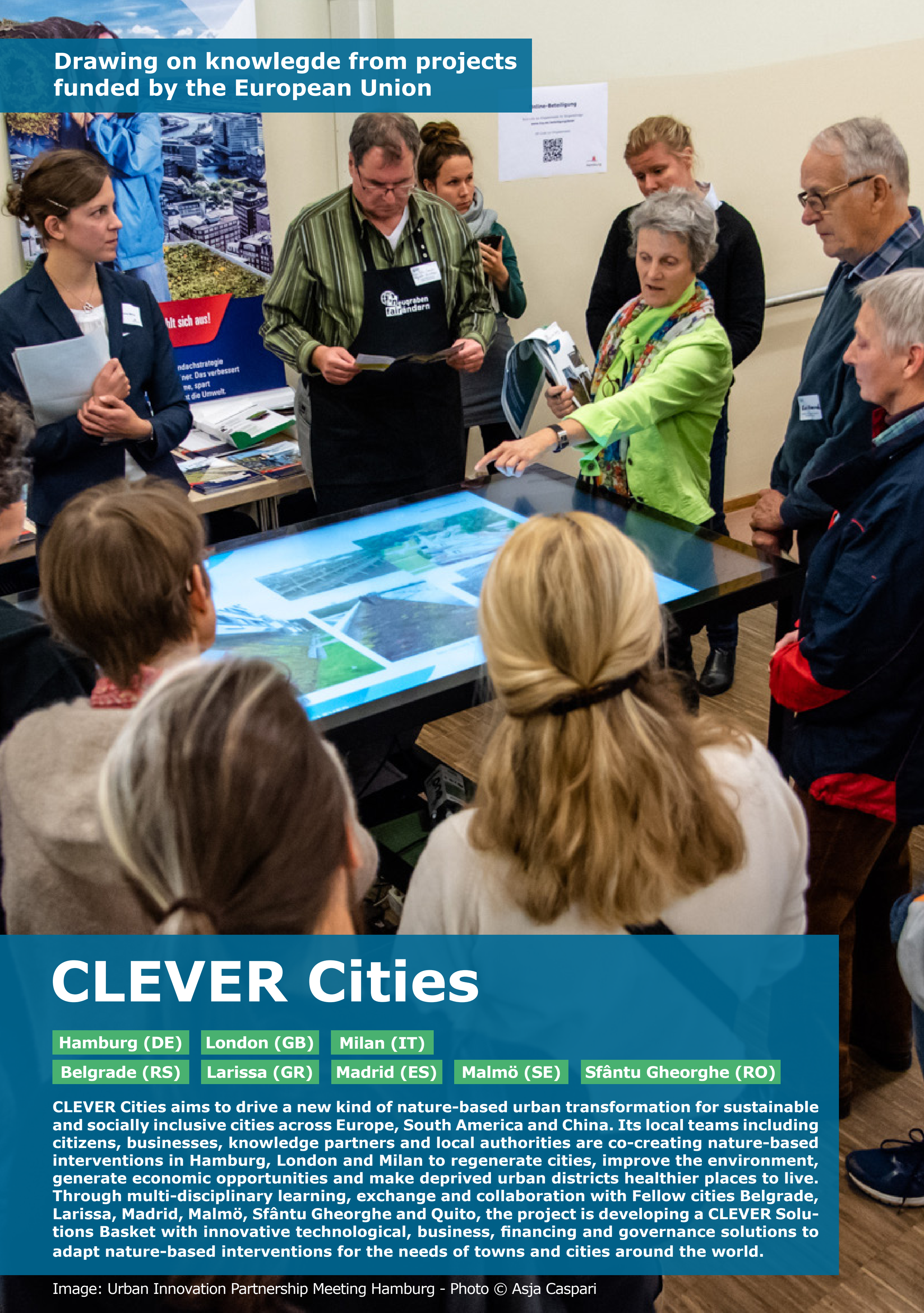
Drawing on knowlegde from projects funded by the European Union



CLEVER Cities

Hamburg (DE) | London (GB) | Milan (IT)

Belgrade (RS) | Larissa (GR) | Madrid (ES) | Malmö (SE) | Sfântu Gheorghe (RO)

CLEVER Cities aims to drive a new kind of nature-based urban transformation for sustainable and socially inclusive cities across Europe, South America and China. Its local teams including citizens, businesses, knowledge partners and local authorities are co-creating nature-based interventions in Hamburg, London and Milan to regenerate cities, improve the environment, generate economic opportunities and make deprived urban districts healthier places to live. Through multi-disciplinary learning, exchange and collaboration with Fellow cities Belgrade, Larissa, Madrid, Malmö, Sfântu Gheorghe and Quito, the project is developing a CLEVER Solutions Basket with innovative technological, business, financing and governance solutions to adapt nature-based interventions for the needs of towns and cities around the world.

Image: Urban Innovation Partnership Meeting Hamburg - Photo © Asja Caspari

Approach to Impact Assessment

The decision-making process for the development of the project's monitoring framework was iterative and collaboratively designed with Front-runner cities and stakeholders involved in their local Urban Innovation Partnerships (UIPs). A first framework to guide local impact assessment processes was developed using a Theory of Change model. The second phase involved cross-comparing the Theory of Change model against the baseline data of each city, then conducting a SMART model analysis in order to prioritize the most salient themes for impact monitoring. Afterwards, Local Monitoring Plans were developed for each city based on four macro-areas of indicators, namely: environmental, human health and well-being, safety and security, and economic prosperity. For each thematic area, a performance model was developed for identifying who is doing what, how, with which tools and at what point of the project's lifetime.

Involved Stakeholders and roles

All relevant stakeholders are integrated in the process of co-defining the monitoring KPIs, including strategic leads, operational leads, technical and academic advisors and community members. A highly collaborative approach was developed between thematic experts in the project and local monitoring teams to coordinate the KPIs co-development and data gathering. By emphasizing the importance of community building, the project has created the necessary conditions for potential co-management of NBS by citizens.

- **Municipal Administrations**
- **Regional/national statistics authority**
- **Citizen**
- **Scientists / Academia**
- **NGOs**
- **Schools and Kindergartens**
- **Housing Associations**

Main Challenges addressed

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

Lessons learned

In order to apply Theory of Change models to monitoring processes, technical support is needed to help cities identify the outcomes and impacts that they expect from NBS. The project team found it challenging to define monitoring KPIs, especially those related to social outcomes such as health and wellbeing or social cohesion. Iterative feedback from thematic experts was required to help cities overcome this challenge. This highlights the need of including a robust scientific methodology in the process of co-defining KPIs. For urban regeneration projects that expect to monitor NBS co-benefits to well-being and health, it is key to create community-driven processes and consider stakeholders' different expectations.

Learn more
www.clevercities.eu

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The Handbook aims to provide decision-makers with a comprehensive NBS impact assessment framework, and a robust set of indicators and methodologies to assess impacts of nature-based solutions across 12 societal challenge areas: Climate Resilience; Water Management; Natural and Climate Hazards; Green Space Management; Biodiversity; Air Quality; Place Regeneration; Knowledge and Social Capacity Building for Sustainable Urban Transformation; Participatory Planning and Governance; Social Justice and Social Cohesion; Health and Well-being; New Economic Opportunities and Green Jobs.

Indicators have been developed collaboratively by representatives of 17 individual EU-funded NBS projects and collaborating institutions such as the EEA and JRC, as part of the European Taskforce for NBS Impact Assessment, with the four-fold objective of: serving as a reference for relevant EU policies and activities; orient urban practitioners in developing robust impact evaluation frameworks for nature-based solutions at different scales; expand upon the pioneering work of the EKLIPSE framework by providing a comprehensive set of indicators and methodologies; and build the European evidence base regarding NBS impacts. They reflect the state of the art in current scientific research on impacts of nature-based solutions and valid and standardized methods of assessment, as well as the state of play in urban implementation of evaluation frameworks.

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