REGREEN
NATURE-BASED SOLUTIONS

FOSTERING NATURE-BASED SOLUTIONS FOR SMART, GREEN AND HEALTHY URBAN TRANSITIONS IN EUROPE AND CHINA

Deliverable **N°2.4.**

Guidance on development of the toolkit for exploring options and potential benefits of NBS design

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WP N°2 Challenges and nature-based solutions

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EXECUTIVE SUMMARY

This report results from REGREEN Task 2.5 'Informing Solutions' and aims to 1) understand the links between different tools developed in REGREEN, their timing, and how they can contribute to the decision-making tool in WP8 'Innovation and Impact Creation'; 2) discuss factors relevant for NBS choices and their role; and 3) provides step-wise guidance for NBS planners.

The report discusses NBS scopes including the systemic impacts that NBS may have as well their multiple benefits. It outlines ex-ante comprehensive conceptual frameworks in order to ensure that NBS evaluation accounts for all positive and negative impacts of NBS implementation. The report furthermore addresses the trade-offs between the production of a few immediate economic benefits and future options for the delivery of the full range of ecosystem services. It also considers scalability and replicability and the contextual factors that play a role such as technological, ecological or political, and institutional factors.

The report presents a matrix of NBS interventions within ULLs and assesses their applicability to other situations, working closely with WP7 'Urban Living Labs'. This will allow a strategic assessment of individual NBS across the ULLs and will ensure that the project can capture the multi-functional benefits within and across NBS interventions, which typically only become apparent when assessed at larger scales and through integrated analysis and interpretation. The report was developed in close collaboration with the ULLs to understand their needs and synthesises the findings in providing a stepwise guide for NBS planners and developers, which aspects to consider, when to select and to implement NBS projects.

Glossary

DPSIR: Driver-Pressure-State-Impact-Response
DSS: Decision support system
NBS: Nature-based Solutions
SME: Small and Medium-sized enterprise
ULL: Urban Living Lab

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1 INTRODUCTION

1.1 Purpose of the document

The document aims to provide guidance for the toolkits developed in REGREEN and explores options and potential benefits of NBS design. The documents address several key issues to be considered when implementing, and deploying NBS projects by policymakers, planners, or investors. The report gives insights into the possible scale and scope of NBS, and what to consider when combining NBS in urban areas with relevant factors to scale-up and replicate NBS.

1.1.1 Objective

This deliverable provides a set of guidelines to inform policy and business-focused developments of NBS solutions and the development of decision support toolkits in WP8. Key activities will be to:

i) Set the scope and boundaries for upscaling and valuation of NBS cases,
ii) Help to develop a set of coherent combinations of NBS interventions to inform and underpin the development of a decision-support toolkit in WP8,
iii) Provide an understanding of short and long term trade-offs of policy choices and their impacts

1.1.2 Relation with other project activies/tasks/deliverables

These recommendations will inform the design and scope of modelling and valuation of ecosystem services and their benefits in WP3 and WP4, NBS activities within WP7, and design of decision support toolkits in WP8.

In particular, Task 2.5:

i) will build upon previous tasks within WP2 and related deliverables D2.1 Drivers and pressures and challenges, in urban living labs, D2.2 NBS Knowledge Base Collective Report, and D2.3 Report on the cost-effectiveness of existing NBS and key recommendations for NBS design in REGREEN)
ii) is important for the scope and boundaries for upscaling and valuating NBS in WP3 and WP4 that will feed inputs to WP8
iii) underpin the development of the decision-support toolkit in WP8 a combination of interventions and NBS will be developed with Task 3.3.
iv) will inform the development of a matrix of NBS interventions within WP7
v) will point to issues to be considered in policy design (WP6)

1.1.3 Partners' contributions

The basic structure of the report was provided by JR. In a workshop in August 2021 with all REGREEN partners, questions of scalability and replicability were discussed and a tailor-made approach for REGREEN was drafted. Finally, a core team of JR and UKCEH provided additional analytical work and developed guidance and conclusions.

1.2 Scope of the document

1.2.1 Boundary conditions

This report identifies the appropriate boundary conditions for the scale and scope of different types of NBS interventions to enable realistic incorporation in a decision-support framework. For example:

- How big an intervention do we consider (single tree to ULL-area to the whole city)?
- What is the impact of different types of NBS?
- How do we upscale that information, or make it transferable to other settings?

Working closely with the other WPs identifies business and policy needs, urban population demand for the NBS ecosystem services, the ability of different type of NBS to deliver these services, cost-effectiveness of interventions, and any constraints on implementation.

1.2.2 Coherent combination of NBS interventions

This report also informs the development of a matrix of NBS interventions within ULLs and assess their applicability to other situations, working closely with WP7. This will allow a strategic assessment of individual NBS across the ULLs, and will ensure that the project can capture the multi-functional benefits within and across NBS interventions, which typically only become apparent when assessed at larger scales and through integrated analysis and interpretation.

Currently, there is a lack of a clear approach for a coherent city-scale NBS uptake that would take into account urban drivers and pressures, needs of citizens, social groups, public and private companies, and the availability of financial and regulatory support. There is a lack of clarity on when to make the approach standardized, when to include it in city-scale planning and when to leave space for more investor-driven projects letting other organisations decide where and how to establish it. Understanding what multifunctional ecosystem services each NBS can deliver, at what cost, and with what potential side-effects is crucial for decision making on city-scale level, and choosing the appropriate approach for NBS delivery.

1.3 Structure of the document

The report first describes the interlinkages of Task 2.5 with other WPs (chapter 2), then it discusses major elements to be considered for choosing NBS or coherent NBS combinations (chapter 3), explains factors influencing scalability and replicability (chapter 4), and finally provides step-wise guidance for NBS choice and design (chapter 5).

2 DECISION SUPPORT TOOLS IN REGREEN

2.1 Decision support as a crosscutting issue

The report is part of Task 2.5 'Informing Solutions' that is highly interactive with other WPs and tasks, in particular with WP3 'Mapping and Modelling Ecosystem services' that includes guidance for mapping and modeling of NBS and the services they provide, WP4 'Wellbeing Assessments and Valuing Benefits of NBS' that assess multiple benefits, and WP7 that runs the Urban Living Labs. There is also a close interaction with WP6 'Governance including planning systems' as NBS needs to be integrated within urban strategies or environmental wider policies. The report will also guide WP8 'Innovation and Impact Creation' where a decision support system (DSS) will be designed that partly integrates or at least links to the other tools.

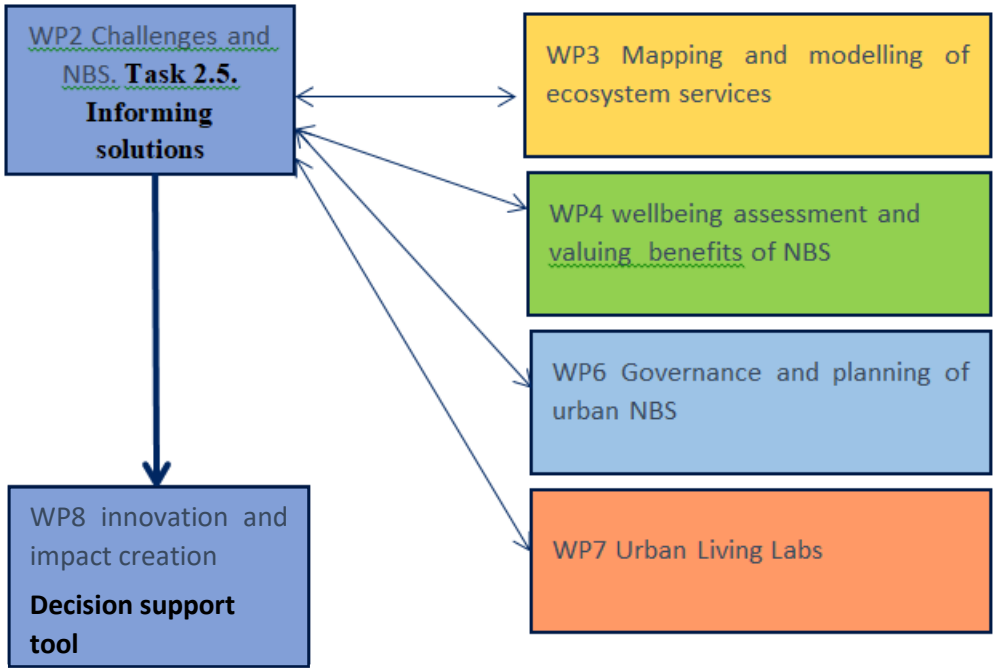

Fig 1 Interlinkages of T2.5 and other Workpackages

WP3 (T3.3) will establish a framework to combine quantitative and qualitative data that explain the urban demand of NBS from multifunctional green infrastructure by exploring their benefits and values. In this framework, the spatially explicit urban drivers (WP2) and pressures (WP3) will be collectively analyzed with qualitative values of residential perception and responses gathered in WP4. This mixed methodology will take account of the complex interactions between drivers, pressures and perceived valuation at the most appropriate scales. The outcome will serve as a synthesis to identify the most appropriate locations of future NBS interventions in a case sensitive way. Task 3.4 will provide a well-founded contribution for further valuation in WP4, support urban governance in WP6, and feed into WP8. WP4 will inform about multiple benefits and aims to quantify them as well as possible. In WP7 finally the needs of ULL are understood that feedback into the tool development.

2.2 The REGREEN Decision support tool

Task 2.5 has a strong linkage to WP8 connecting other WPs activities to feed the D8.5 Decision support tool with a set of guidelines to inform business-focused developments of NBS solutions. The task of the REGEEN digital platform will also include a web-based decision support tool that will be designed to help all stakeholders build, implement and deliver effective and meaningful NBS. The

Figure 1 Interlinkages of T2.5 and other Work packages

tool will be split into user groups - SMEs, communities, local authorities and other stakeholders can use the tool in the way best suited to specific needs.

The decision support tool will absorb tasks outputs of this report and broader results of the WPs and tasks mentioned above. To do so partners will logically describe their work in form of a "fact sheet" addressing questions of users, needs to be covered by their activity, potential benefits brought, describe innovative potential if any, what type of activity partners have carried out, try to estimate potential resources needed, what type of NBS they tackle and at what locations is it possible to apply activity.

Each fact sheet will be in form of a short manual or guidance with an aim of explaining in layman English Regreen activities:

- Why should users repeat the Regreen activity?
- What is individual Regreen activity about what NBS or NBS combinations?
- Who is needed to complete the activity?
- Where and when can be activity replicated?

The online tool will allow the users to choose their user group: SMEs, communities, local authorities and other stakeholders. Based on their choice users will receive a download link to relevant documents (fact sheet that will contain information on developments of Regreen activities).

The online decision tool fact sheet will be built upon output O.2.1 Developing evidence and toolkits to design and plan NBS, O.2.2 Co-creation in ULLS, Task 2.5 Informing solutions, Task 3.4 Develop tools and guidelines for mapping and modeling ES and possibly Task 6.1 while content for the fact sheets will be sourced from all relevant tasks within Regreen.

3 CHOICE OF NBS INTERVENTION

A precondition for urban NBS design and implementation is that cities should have data on their referent state of the urban drivers and pressures (air pollution levels, urban heat island location, lack of accessible public open space, noise levels, flooding events, and water quality, potential future urban expansion, and change in morphology). Also, they should have an overview on how significant pressure is, periods of occurrence, locations, impacts on the wider public, and have an assessment on prospects of occurrence of such urban drivers and pressures. To do so cities should have a multidisciplinary approach while conducting their strategic documents, action plans, and implementing individual measures to mitigate those pressures. Maps and datasets of those challenges can be made with constant monitoring stations that prove to be useful in the planning of NBS alongside with analysis of existing NBS on urban/peri-urban areas. Urban planning is challenging now more than ever with rising pressures and it should be done in collaboration with various stakeholders. For example, specific cultural heritage sites and significant landscapes should be taken into account with the possibility of turning grey infrastructure to blue, hybrid, or green. Based on this knowledge cities can choose NBS or a coherent combination of different sizes and scopes, as well as impacts. This is why a systemic approach is needed in choosing the individual NBS interventions with an outlook on a specific local area.

3.1 Scale and scope of each type of NBS intervention

The integration of environmental policies and concepts (such as NBS) occurs at multiple scales. This includes integration at the level of comprehensive planning (visionary focus, longer time horizon,

large scale), detailed planning and implementation projects (practical focus, shorter time horizon, smaller scale), for example through the use of supportive tools (Wickenberg et al, 2020). Implementation cases in the urban context, on the other hand, typically take place at the scale of neighborhood or real estate level through specific, and directed projects, experimentation and detailed planning (Wamsler et al., 2020). Therefore, the actual implementation of NBS seems to a large degree dependent on how planning and development is organized at the micro-scale, which relates to e.g. local governance structures, how knowledge co-creation is organized and facilitated, and methods for handling tensions and negotiating trade-offs (Wickenberg et al, 2020).

Thus, conceptual NBS principles and frameworks, which are indeed needed to foster systemic knowledge of NBS, might be too general for operationalizing NBS at the local scale. They need to be carefully translated, or adapted, to how processes of urban planning and policy are organised to address the challenges at the appropriate scale. A challenge here is that the organisation of planning and urban development differ between local contexts, e.g. municipalities' level of capacity, influence and leadership, the ratio between private and public land, as well as level of collaborative forms of governance (Wickenberg et al, 2020).

When discussing the scale of a project not only the geographical geographic size should be considered but also the size and scope of the impact. Small scale NBS may have a large impact on the surrounding socioeconomic systems, but only if they are sited in the correct location to address both pressures and user needs (see also Fletcher et al. (2020), Deliverable 2.1). Benefits from NBS illustrate complex scale-dependent relationships, depending on the nature of the urban pressure, the type of NBS, and where beneficiaries are located (Hutchins et al. 2021). These factors also need to be taken into account in the planning and development of NBS for particular solutions. In the context of the Green Deal and circular economy, the function of NBS for wider services to cities are being discussed and investigated. NBS are considered to become part of a greater system that solves one or more challenges (Atanasova *et al,* 2021).

3.2 Synergies with other types of interventions where necessary to meet societal needs

The Green Deal aims for a circular economy. Nature-based solutions still need to find their role in new and circular value chains addressing specific demands of different sectors, such as the building sector. From a policy perspective, stimulating demand and supply is not a simple proposition and requires consideration of the complexity of this market sector. Demand-led policies must take into account the nature of NBS not only as private goods and their services (e.g. green buildings primarily paid for by the private sector but which may create public benefits such as urban cooling), but public goods and services, which can benefit many (Andersson *et al*, 2021). Synergies with other types of interventions should be searched for when NBS can help to meet societal needs. NBS are embedded in ecosystems and the services they provide, but NBS can also be complemented by other types of solutions (e.g. technological and engineering) increasing the likelihood of effectively addressing the societal needs (IUCN, 2021). Where the NBS does not have sufficient capacity or leverage to promote mainstreaming in policy or regulatory frameworks on its own, synergies should be made with other measures connected to public goods that could support NBS from a business and policy perspective. The successful implementation of NBS implementation can also drive the creation of new environmental and sustainability objectives and NBS should promote these where possible (IUCN, 2021).

3.3 Impacts of NBS interventions

Nature-based solutions (NBS) often receive criticism on the basis of a narrow, discipline or domain-focused, viewpoint. For instance, the removal of air pollution using vegetation is considered by some researchers and practitioners as only making marginal contributions to improving air quality in urban areas. A common denominator of such criticisms is a lack of understanding of the multiple benefits that NBS has over some technical solutions. At the same time, by focusing (solely) on the benefits NBS can yield, not accounting for potential intended or unintended consequences may skew the basis for decision-making.

In order to ensure that NBS evaluation accounts for all (within a pre-defined system) positive and negative impacts of NBS implementation ex-ante, a comprehensive conceptual framework for evaluations is essential. Such frameworks exist e.g. in the the Driver-Pressure-State-Impact-Response (DPSIR) framework (see box below) which was originally conceived by the European Environment Agency as an extension of the pressure-state-response model developed by OECD, and is widely applied e.g. by EEA, EU, FAO, OECD etc.

> The Driver-Pressure-State-Impact-Response (DPSIR) Framework provides a structure within which to present the indicators needed to enable feedback to policymakers on environmental quality and the resulting impact of the political choices made or to be made in the future. The DPSIR framework assumes a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical, and biological) and 'impacts' on ecosystems, human health, and functions, eventually leading to political 'responses' (prioritisation, target setting, indicators). Establishing a DPSIR framework for a particular setting is a complex task as all the various cause-effect relationships have to be carefully described and environmental changes can rarely be attributed to a single cause.
>
> Source: FAO (https://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1026561/)

Recognising the lack of contextual aspects in DPSIR, Morris *et al.* (2006) created the DPSEEA (mDPSEEA) model, which already expanded DPSIR to explicitly recognise the way Exposure and Effect could substantially differ due to external and internal factors, to incorporate social, economic, etc. context. Building on this work, Reis *et al.* (2015) proposed a further expansion of this conceptual model to account for the different pathways how human health and well-being could be influenced, either through direct exposure, or through modification of ecosystem services and their functions supporting human health and well-being. This conceptual model is referred to as the ecosystem-enriched DPSEEA model (in short eDPSEEA, see Fig. 2). While eDPSEEA explicitly accounts for different pathways through which exposure (in the widest sense, including both negative and positive effects) can impact on human health and well-being, it can be applied as well to deliberate the proximal and distal effects as demonstrated by Morris et al. (2015) on the example of climate change and health effects.

Such conceptual models are both suitable as 'Tools to Think With' (McIntosh *et al*, 2007) in exploring the complex relationships between drivers and environmental state, exposure, effects and the way (policy) interventions can shape the response, recognising the need for an iterative process. Morris *et al.* (2019) have applied this to creating healthy sustainable cities, for instance, and other applications in interdisciplinary workshops have focused on a wide range of settings and challenges.

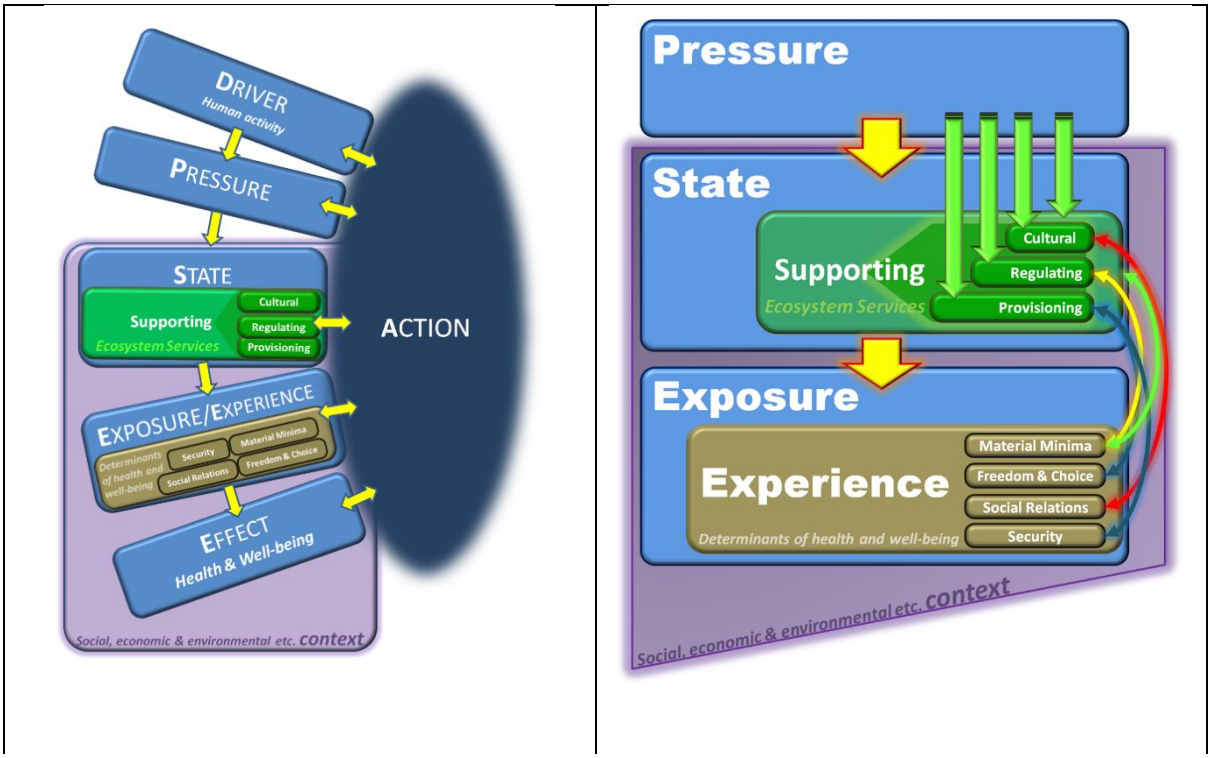

Figure 2 eDPSEEA conceptual model structure

3.4 Coherent combinations of NBS

3.4.1 Conceptual frameworks for the integrated assessment of NBS

This chapter aims to illustrate the systemic impacts that NBS can have. Raymond *et al.* (2017) introduced a framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. This frame framework has been designed for assessing the co-benefits (and costs) of NBS within and across ten challenge areas and the study highlights that "benefits in one challenge area can have co-benefits, costs or neutral effects in other challenge areas", thus recognising the need for cross-disciplinary approaches. The framework comprises a 7-stage cyclic process for implementing NBS informs a cross-sectoral approach to environmental policy and planning (Fig. 3).

With a focus on water, the RainSolutions project[3] aims to develop an integrated framework of methodologies to assess NBS for the restoration and rehabilitation of urban water resources systems. One specific objective is to "create a NBS planning and design framework supported by machine learning to generate recommendations addressing challenges associated with climate resilience and well-being in urban areas", thus explicitly recognising the need for assessing multiple parameters.

Calliari *et al.* (2019) postulate that assessment frameworks should evaluate NBS' effectiveness under future climate conditions. They propose an assessment framework based on systems analysis and back casting, which can be applied to support the choice between NBS and traditional interventions.

[3] https://www.researchgate.net/project/Research-based-Assessment-of-Integrated-approaches-to-Nature-based-SOLUTIONS-RainSolutions

The framework explicitly factors in NBS' multifunctionality and assesses (in)direct benefits/costs, as well as a 'ecosystem disservices' as co-costs.

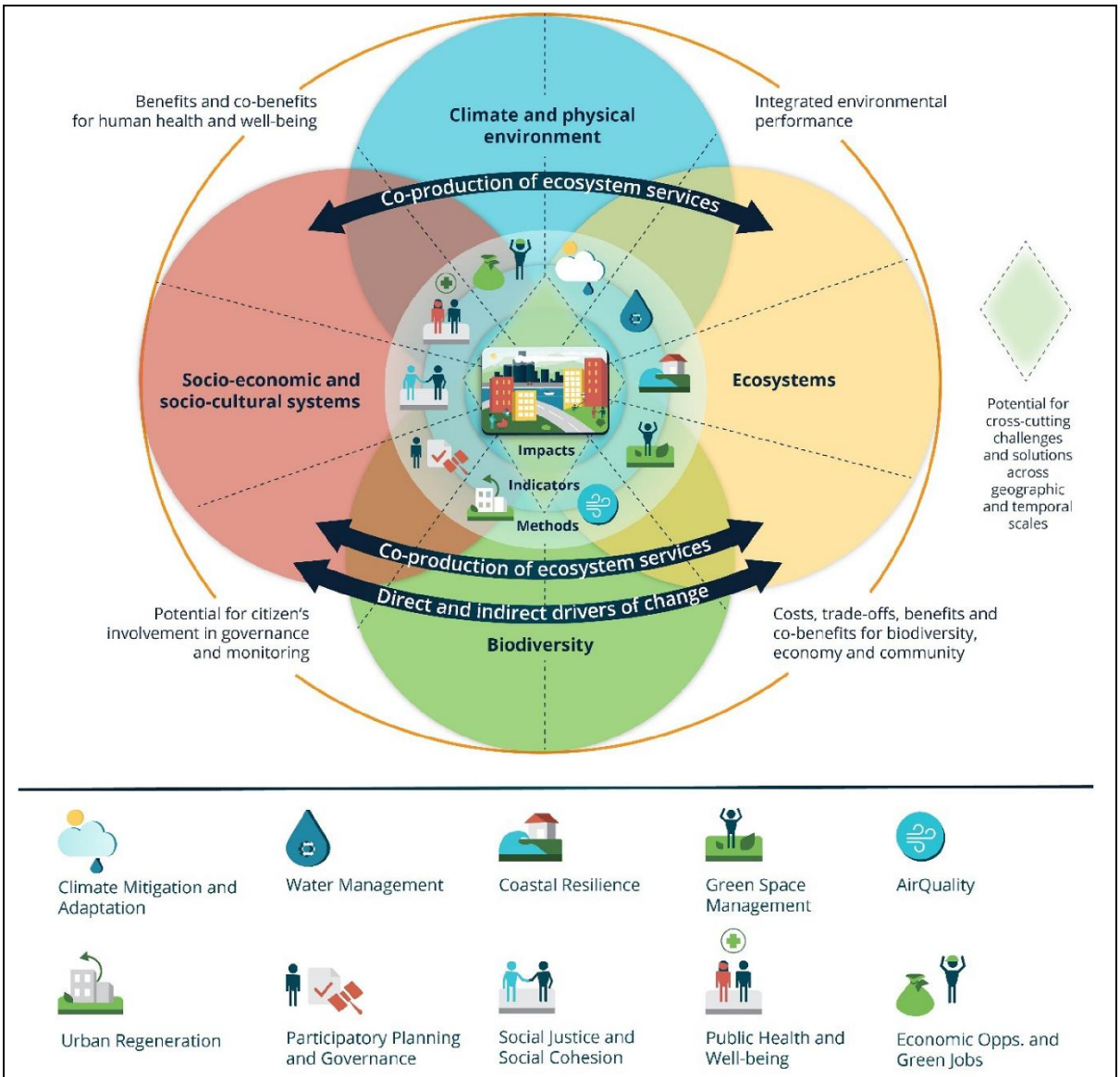

Figure 3 The NBS assessment framework

The framework considering different elements of the system, the 10 challenge areas and indicators and methods for assessing NBS impacts within and across challenge areas. Source: Raymond et al. (2017)

Within REGREEN, we have developed a conceptual framework which integrates these concepts, and facilitates a full understanding of how the natural capital in cities interacts with the human capital, and more broadly in the interactions with citizens who use and benefit from the services that NBS provide (Fig. 4).

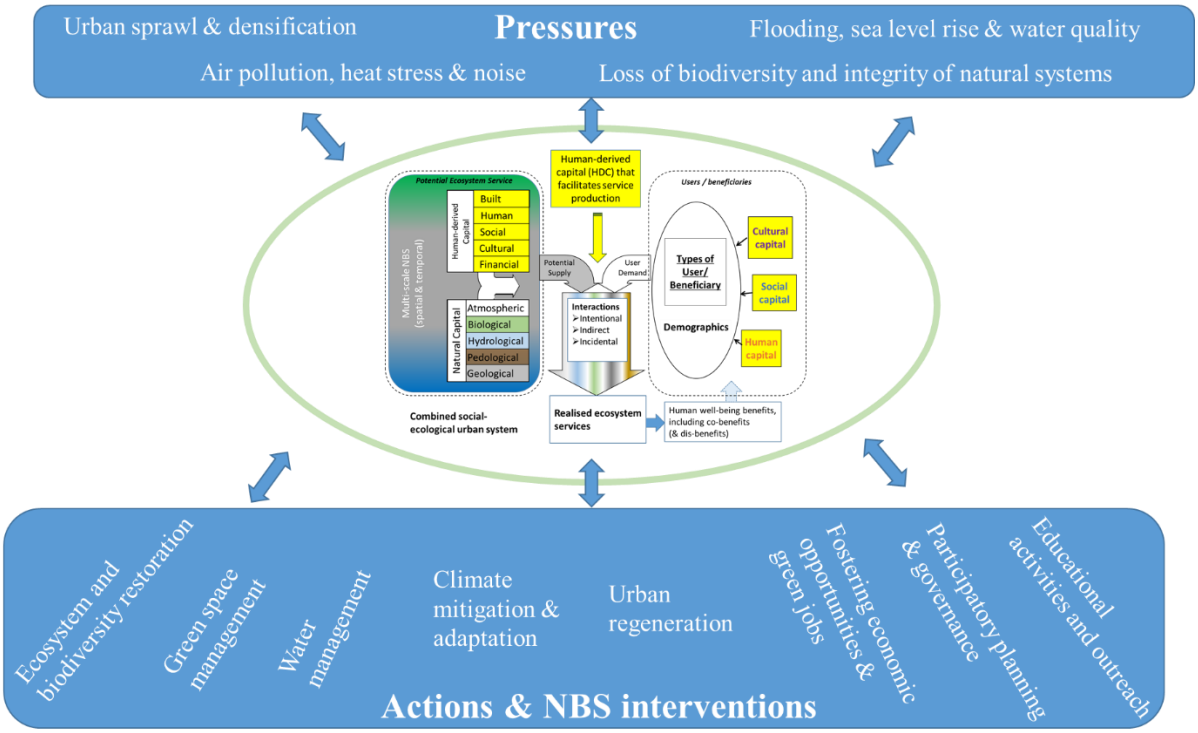

Figure 4 Conceptual framework showing how NBS actions can deliver solutions in response to pressures. Building on frameworks in Jones et al. (2016; 2021).

In 2021, the European Commission published a comprehensive handbook "Evaluating the impact of nature-based solutions - A handbook for practitioners" based on findings of several EU-funded projects with an NBS focus (see box below).

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.

Source: https://op.europa.eu/en/publication-detail/-/publication/d7d496b5-ad4e-11eb-9767-01aa75ed71a1

An informative example for how such integrated impact assessments for NBS can be visualised is found in the dashboard approach presented in the EU project Connecting Nature, which is based on "The Connecting Nature Impact Assessment Framework: developing robust monitoring and

evaluation plans for nature-based solutions"[4]. The guidebook outlines the Connecting Nature "process of developing robust monitoring and evaluation plans for nature-based solutions". The guidebook states that "Robust evaluation supports planners and decision-makers in building solid evidence-based understanding as to the impact of nature-based solutions and enhancing cost-effective and socially beneficial policy, building a foundation for scaled up delivery".

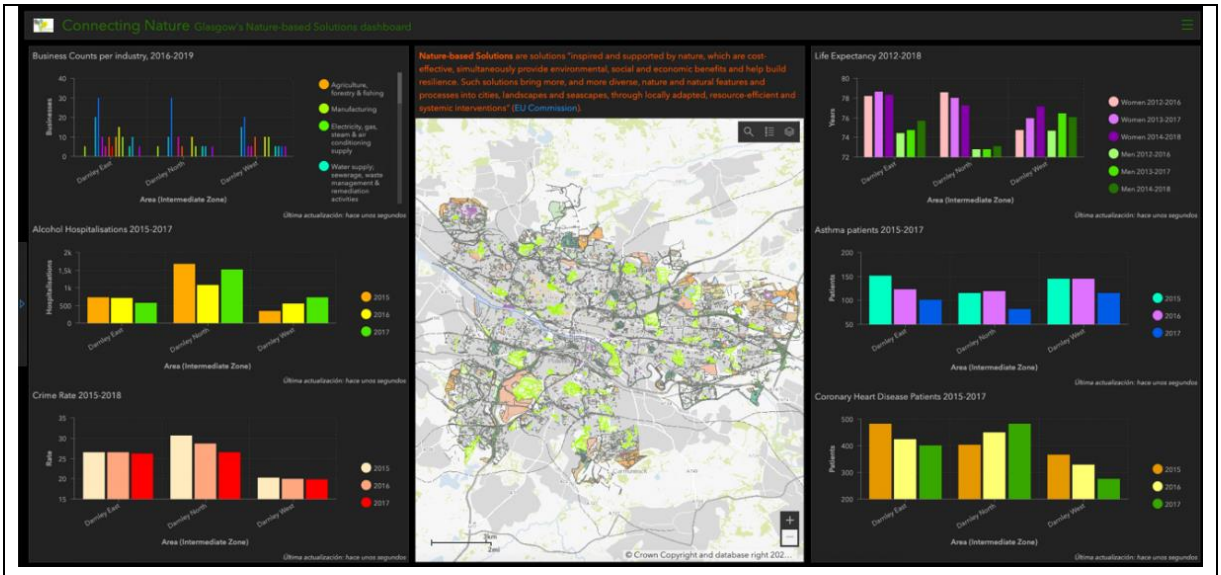

Figure 5. The Glasgow Connecting Nature Dashboard demonstrates an approach how to visually unify and integrate different results.

When assessing the impact current and future benefits should be identified and taken in account with trade-offs with the aim of ensuring that an ecosystem is not changed in a favour of particular ecosystem service or resource. NBS design should provide a process for fair and transparent negotiation of trade-offs and compensation for loss of local opportunities.

3.4.2 Key building blocks and recommendations for an integrated assessment of NBS

While conceptual approaches and frameworks may differ in scope and focus, the overarching principles are the same. For our evaluation of NBS to be comprehensive, and account for all relevant co-benefits, dis-benefits and impacts, the following key elements appear to be essential:

- **Spatial scales:** accounting for both the proximal and distal effects of NBS interventions – here it is vital to clearly define the system boundary for the assessment, respectively the cut-off levels of influence beyond which the effect of an NBS implementation can be considered negligible
- **Topics and domains:** while a comprehensive assessment of everything would be ideal, this will typically be beyond the scope, as well as not cost-effective to undertake. An inter-and transdisciplinary dialogue at an early stage, agreeing on the key topics and domains for the assessment prior to evaluating NBS would be beneficial to provide the system boundaries for such an assessment. Beyond the conceptual aspects, determining an appropriate framework for the assessment and the relevant parameters for a quantitative evaluation will be indispensable to guide the process.

[4] https://connectingnature.eu/sites/default/files/images/inline/Impact%20Assessment.pdf

- **Visualisation:** For co-production and transdisciplinary dialogue with a range of stakeholders in particular, identifying best practice approaches for the visualisation of outputs from the assessment at an early stage will enhance the accessibility and transparency of the process. As the interconnections between NBS and their effects at different spatial scales and across domains are inherently complex, appropriate visualisation tools can make a marked difference for the communication of NBS selection and implementation.

In general, participatory approaches for modelling and mapping the impacts of NBS across a range of scales, topics and domains could build on existing tools, e.g. the Participatory System Mapper (PRISM[5]) developed by the Centre for the Evaluation of Complexity Across the Nexus (CECAN[6]). PRISM provides an environment that makes it easy to draw networks (or 'maps') of systems, working together collaboratively and visually exploring complex relationships between and within systems. Similar approaches for participatory mapping and assessment of complex systems are applied by the Urban Health and Wellbeing programme (UHWB[7]), an interdisciplinary body of the International Science Council, hosted by the Institute of Urban Environment (IUE) of the Chinese Academy of Sciences (CAS). In a virtual session at VIRTUAL SCIDATACON 2021 on "Collaborative Systems Modelling (CSM): Understanding the Health Co-Benefits of Urban Green Spaces", one of the foci was on how CSM can help better understand complex relations and can provide decision support for urban planners, decision-makers and citizens on how to plan, manage and make use of urban green spaces. Several contributions, including from Future Earth, highlighted the importance of taking a systems approach e.g. as applied by Vester (1988) in defining 'eight basic biocybernetic rules', which was further expanded by Harrer (2010). Dyball and Newell (2015) and Newell and Proust (2018) addressed complexity issues with a sustainability focus as well, and promote the concept of complex systems approaches to tackle interconnected challenges in urban sustainable development. The degree to which these scientific concepts and approaches are sufficiently mature and applicable to an operational, integrated evaluation of NBS interventions could be a focus of our methodological development in REGREEN.

3.4.3 Trade-offs between short and long term benefits

One must recognize and address the trade-offs between the production of a few immediate economic benefits for development and future options for the production of the full range of ecosystem services. Focusing only on simple bankable projects will not exploit the multitude of societal benefits NBS can have in the long term. NBS should avoid changing or simplifying an ecosystem, in favour of a particular service or resource. Instead, a thorough understanding of trade-offs between current and future benefits is important when deciding among different NBS activities. Understanding and providing a process for fair and transparent negotiation of trade-offs, and a recognition of the relative performance of NBS types to address a range of challenges are essential for ensuring successful NBS (Maginnis et al., 2004).

[5] https://prsm.uk/
[6] https://www.cecan.ac.uk/
[7] http://www.urbanhealth.cn/en/

4 REPLICABILITY AND SCALABILITY OF NBS

Scalability refers to the possibility of increasing the size of a project without compromising its efficiency and effectiveness under similar contextual conditions. Replicability refers to the possibility of applying the same solution/technology to achieve the same objective in a different city, region, or county, this in a different context.

Replicability may be in terms of:

i) both scale (i.e. the extent to which a solution can adapt to the different configurations of the environment) or
ii) a specific case (i.e. whether the solution can be replicated in a specific, different context).

Scalability and replicability depends also on the type of NBS and the socioeconomic and geographic preconditions of a city, region or country.

Factors	Scalability	Replicability
Technological	Standardisation Maturity	Modularity Adaptability
Ecological	Environmental impact in similar systems	Environmental impact in different systems
Educational	Knowledge on benefits	Knowledge on benefits in different settings Technical skills
Citizens involvement	Participatory approach	Participatory approach, Consideration of socio- cultural aspects
Political-institutional	Regulatory environment Institutional support	Regulatory environment Institutional support
Economic/Business	Economies of scale Profitability	Market design

Table 1 Scalability and Replicability of NBS solutions. Adapted for EU Smart City Replication guide[8]

Technological factors

NBS has different degrees of technology needs. Many of them are low-tech options. In the case of new and emerging technologies, higher maturity is required for scalability and replicability. This includes not only technologies themselves but also their implementation and maintenance. Standardisation and modularity of technologies eases scalability and replicability.

Ecological factors

The services and potential solutions provided by an ecosystem are specific to the context. The same type of NBS does not necessarily deliver the same kinds and magnitude of effects in different setting (Fletcher et al. 2021). The ecological but also economic assessment of a NBS should tbe aken to a broader system perspective.

[8] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/16946;keyword=GrowSmarter;isExactMatch=false

Educational factors

Brink et al., (2018) note that co-creation of knowledge between participants in municipal-led projects allows for "(re)integration of knowledge from the trans-disciplinary learning space into both societal and scientific practices". The REGREEN ULL revealed the urgent need for education especially of the economic benefits (valuation) of NBS. New kind of experts are needed in the field to create baselines of current state of climate pressures and understanding of NBS options to mitigate those challenges.

Political-institutional factors

Nature-based solutions require a collaborative governance approach. They are often initiated by local governments and require multiple actors to be linked. Governance arrangements should therefore engage local actors of all relevant countries to facilitate a transboundary approach to governance. Often, transboundary and largescale projects are governed by government officials, big donors, and other powerful players (IUCN, 2021). They lack local inclusion which makes it difficult to establish a sense of local ownership and secure genuine local participation. NBS needs adaptive management based on continuous monitoring and evaluation to be able to take account of uncertainty, ecosystem complexity, and changes over time. Adaptiveness also needs to be anchored in the institutions and organisations that govern the NBS (IUCN, 2021).

REGREEN experiences

In Velika Gorica, politicians are somewhat unaware of NBS. That means that education (of politicians) is necessary. Of course, if the public indicate a "want" of NBS the politicians will follow. Funding mechanisms are lacking. In the Paris Region the continuance of application of NBS is very low. It depends on political urgency and available budgets. In order to have NBS as part of long-term policy strategy, a visioning exercise with politicians is required. Planning/rules should be changed so that NBS is part of the developing / expanding city. In Arhus there is a high awareness of possible benefits of NBS and willingness by the municipality to implement them.

Citizen's involvement

Beneficiaries of NBS include communities, vulnerable and marginalised groups. They may benefit from the NBS or suffer negative consequences from the NBS. Their insights and activities can help make the NBS a success or lead to its failure. It is therefore important that citizens voices are heard and reflected in all stages of NBS planning, design and implementation (see IUCN 2021).

Economic factors and business models

Currently, there is a range of Nature-based solutions (NBS) emerging mostly with strong public funding elements. A market for NBS has however not yet emerged. While mostly NBS are implemented as pilots the full range of economic and societal benefits for NBS are not systematically understood and mapped and are not sufficiently used to back the business and investment case for NBS. The numerous benefits may include mitigation and adaptation to climate change (including the reduction of urban heat island effect and flood mitigation), reduction of pollution, improved biodiversity and ecosystem services, increased well-being for citizens, including physical and mental health or recreation, social cohesion, and community building. It is important to looking into the cost-effectiveness of different systems in which NBS fulfil specific roles rather than specific projects. The system characteristics of many NBS also entail that the solutions are not mutually exclusive. The choice is not between one or the other NBS. Instead, a combination of NBS in a common project might be the relevant scale to apply the cost-effectiveness method. A problem in replicable business

models is that replicability means the standardization of approaches. NBS should be location specific to reap the full range of benefits. One size often does not fit all cases of NBS implementation. Replicability can lead to an NBS solution that has the "lowest common denominator". This means that the replicable solution may be a poor solution and lead low satisfaction with the results of NBS.

Table 2 shows the different challenges and approaches across the REGREEN ULLs that may determine scalability and replicability.

Velika Gorica – is a small city and is looking for small-scale NBS that could be implemented at many places or replicated in other cities in Croatia. Buildings as the demo building are widespread in Croatia.
Aarhus– many NBS are small scale (i.e. local parks) but the municipality is trying to integrate this is regional planning so that the individual small NBS act as a large NBS (providing interconnectivity between them).
Paris region– small-scale NBS. It is difficult to develop NBS at a large scale (with the exception of riverbanks and wetlands). New big parks are almost impossible due to competition with urbanisation.

Table 2. ULL challenges of scalability and replicability of NBS

5 GUIDANCE ON NBS INTERVENTIONS

This guidance documents has shown the complexity in choosing appropriate NBS interventions. This chapter first provides a matrix that may help decision makers to better understand the ability of different NBS to address a range of urban challenges and summarizes key issues to be considered when choosing NBS or NBS combinations

Matrix of NBS Interventions

In order to provide guidance to city decision-makers, there is a strong need to better understand the ability of different NBS to address a range of urban challenges. This allows them to determine, for a given NBS type, how well it mitigates particular urban challenges, and whether it is the best option for a specific pressure such as air pollution removal, flood risk (water flow management), or physical and mental wellbeing of citizens, and which other co-benefits it provides. In REGREEN, we have created an expert-derived matrix (Fig. 6) which collates the ability of each NBS type to address the key challenges being explored in our ULLs. The matrix reports the 'per unit area' efficiency of an NBS type for each challenge. Impact scores were derived through discussion across experts in REGREEN.

			Matrix against service delivery (typical efficiency per unit area)									
			Negligible - zero or almost none; Low; Medium or extremely variable, High, Very high									
Brief description	**Object type**	**Object category**	**Air pollution removal**	**Noise mitigation**	**Heat mitigation**	**Water quality mitigation**	**Water flow management**	**Carbon sequestration**	**Biodiversity**	**Physical activity**	**Social interactions**	**Restoring capacities - stress reduction and cognitive restoration**
Mainly private space linked to dwellings	**Gardens**	**Balcony**	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Medium	Negligible	Low	High
		Private garden	Low	Negligible	Medium	Medium	Medium	Low	High	Very high	Medium	Very high
		Shared common garden area	Low	Low	Medium	High	High	Low	Low	Medium	High	Medium
Mainly public space, but some access restrictions may apply	**Parks**	**Pocket park**	Low	Low	Low	High	High	Low	Medium	Low	Very high	High
		Park	High	High	High	High	High	High	High	Very high	Very high	Very high
		Botanical garden	High	Very high	Very high	High	High	High	Very high	Medium	High	Very high
		Heritage garden	Medium	High	High	High	High	Medium	High	Medium	High	Very high
		Nursery garden	Medium	Low	Low	High	High	Medium	Low	Low	Medium	Medium
Civic areas designed primarily for specific amenity uses	**Amenity areas**	**Sports field**	Low	Negligible	Low	Low	Low	Low	Negligible	Very high	High	Low
		School yard	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Very high	Very high	High
		Playground	Negligible	Negligible	Negligible	Low	Low	Negligible	Negligible	Very high	Very high	High
		Shared open space (not green)	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Medium	Very high	Low
Mainly civic areas designed primarily for specific uses (not primarily leisure)	**Other public space**	**Cemeteries**	Medium	Medium	Medium	Low	Medium	Medium	Medium	Low	Low	High
		Allotment/shared urban growing	Medium	Negligible	Low	Negligible	High	Negligible	Medium	High	High	Very high
		City farm	Medium	Negligible	Low	Negligible	High	Negligible	Medium	Medium	Medium	High
		Adopted public space	Medium	Negligible	Low	Low	Low	Negligible	Medium	Negligible	Low	Medium
Linked to transport and access	**Linear features/routes**	**Street tree**	High	Low	Medium	Negligible	Low	Medium	High	Negligible	Low	High
		Cycle track	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Very high	Medium	High
		Footpaths, including along water	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Very high	Very high	Very high
		Road verge	Low	Negligible	Low	Medium	Medium	Low	Low	Negligible	Negligible	Low
		Riparian woodland	Very high	Very high	Very high	Very high	Very high	Very high	Very high	High	Medium	Very high
		Hedges	Medium	Low	Medium	High	High	Medium	Medium	Negligible	Negligible	Medium
Constructed green and blue space, added to infastructure	**Constructed GBS on top of infrastructure**	**Green roof**	Low	Negligible	Low	Low	Very high	Low	Low	Negligible	Negligible	Low
		Green wall	Medium	Medium	Low	Negligible	Low	Low	Low	Negligible	Negligible	Medium
		Roof garden	Medium	Low	Medium	Low	Low	Medium	Medium	Low	High	Very high
		Pergola	Medium	Negligible	High	Negligible	Low	Medium	Low	Negligible	Low	High
Infrastructure designed to incorporate some GBS components	**Hybrid GBS (for water)**	**Permeable paving**	Negligible	Negligible	Negligible	High	High	Negligible	Negligible	Low	Negligible	Negligible
		Permeable walkway	Negligible	Negligible	Negligible	High	High	Negligible	Negligible	Medium	Low	Negligible
		Permeable roadway	Negligible	Negligible	Negligible	High	High	Negligible	Negligible	Low	Negligible	Negligible
		Permeable parking	Negligible	Negligible	Negligible	High	High	Low	Negligible	Negligible	Negligible	Negligible
		Attenuation pond	Low	Low	Low	Very high	Very high	Medium	High	Negligible	Low	Medium
		Flood control channel	Low	Negligible	Low	Medium	Very high	Low	Medium	Negligible	Low	Negligible
		Rain garden	Medium	Negligible	Low	Very high	High	Medium	Medium	Negligible	Negligible	High
		Bioswale	Medium	Negligible	Low	Very high	Very high	Medium	Medium	Negligible	Negligible	Low
Bluespace features	**Wetlands**	**Wetland**	Medium	Low	Medium	Very high	Very high	Medium	Medium	Low	Medium	Very high
		River/stream	Low	High	High	Medium	High	Low	High	Medium	High	Very high
		Canal	Low	Low	Medium	Low	Medium	Low	Low	Medium	Medium	Very high
		Pond	Low	Low	Low	Medium	High	Medium	High	Negligible	High	High
		Lake	Low	Medium	High	Medium	High	Medium	Very high	High	High	Very high
		Reservoir	Low	Medium	High	Medium	Very high	Medium	High	High	High	Very high
		Estuary/tidal river	Low	Medium	High	Medium	N/A	Low	Very high	Medium	High	Very high
		Sea	Low	Medium	High	Medium	N/A	Very high	Very high	Very high	Very high	Very high
Other un-sealed features without specified use, often on private land	**Other non-sealed urban areas**	**Woodland (other)**	Very high	Very high	Very high	Very high	Very high	Very high	Very high	High	High	Very high
		Grass (other)	Low	Negligible	Low	Medium	High	Low	Medium	Very high	Very high	Medium
		Shrubland (other)	Medium	Negligible	Low	High	Very high	Medium	High	Medium	High	High
		Sparsely vegetated land	Negligible	Negligible	Negligible	Low	Low	Negligible	Low	Medium	High	Medium

Figure 6. Matrix describing 'per unit area' performance of NBS types to address a range of urban challenges.

Figure 7 below summarizes key considerations that need to be taken when choosing NBS or NBS combinations. While they may not be all relevant for private actors, they need to be considered by public bodies designing policies and strategies. The also help guiding private actors towards choices of high societal value while still enabling a business case.

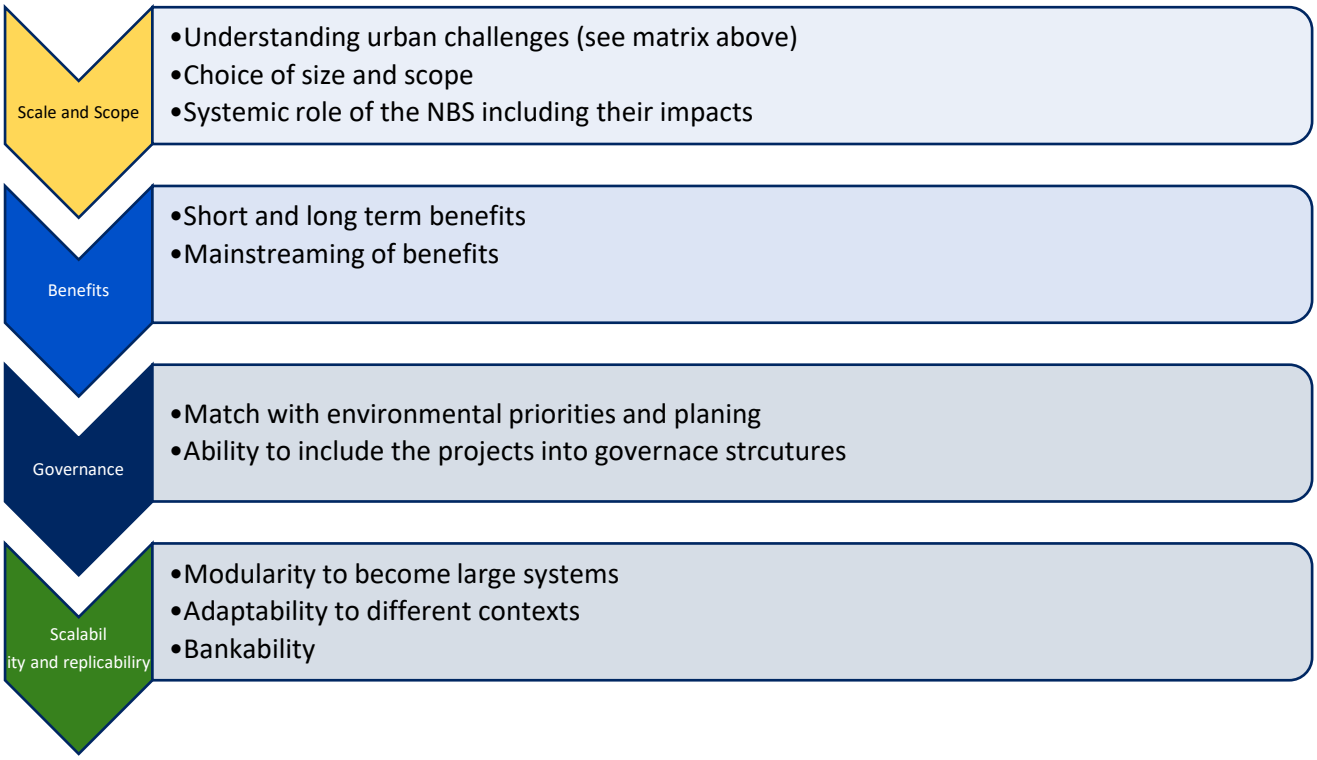

Figure 7 Key considerations to be taken when choosing NBS or NBS combinations

6 CONCLUSIONS

This report showed that the choice of NBS project is a complex process and it needs continuous development of guidance practices. Based on knowledge of environmental and social pressures, public or private bodies choose NBS on a range of factors that may be different for companies and policymakers. There is no clear-cut answer on the scale and scope of NBS as the choice is highly location and system-dependent. Even when large-scale NBS cannot be implemented due to geographical restrictions, small-scale NBS may have a large impact on the surrounding socioeconomic systems.

As the report shows for assessing drivers, pressures and impacts existing concepts could be used that may differ in scope and focus, while the overarching principles are the same. For evaluation of NBS to be comprehensive, and account for all relevant co-benefits, dis-benefits and impacts, spatial scales as well an inter-and transdisciplinary dialogue at an early stage, agreeing on the key topics and domains for the assessment prior to evaluating NBS would be beneficial. This should include appropriate visualisation tools as the interconnections between NBS and their effects at different spatial scales and across domains are inherently complex.

While for private investors a scalable business model will be of high importance, public bodies should consider the broader environmental and social impacts of NBSs as well as their integration in the environmental policies at multiple scales. This includes integration at the level of comprehensive planning (visionary focus, longer time horizon, large scale), detailed planning, and implementation projects. Private actors may have a limited view on societal benefits but are highly important for NBS investments, thus public bodies should guide and assist private investors in making their decisions while choosing appropriate NBS.

Scalability and replicability of NBS depend, as the report showed on a range of factors, including ecological, economic, or political-institutional contexts. A key feature of high-quality NBS is in having a connection with other measures that increase the performance of public good services. A certain level of standardization should be introduced in the implementation of the NBS to ensure replication, but not to compromise the multiple benefits of NBS on the local level.

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