Legal and institutional arrangements to sustain NBS for social inclusion

Deliverable 4. Legal and institutional arrangements to sustain NBS for social inclusion to support Themes 2.1, 2.2 and 2.4 (led by OsloMet; supported by all partners, except WUR and TYPSA for theme 2.1). The main task is to identify up-to-date indicators for the evaluation of the societal benefits of NBS particularly in socio-economic challenging neighborhoods. Indicators will mainly be concerned with the planning stage and may include community acceptance and increased amenity as a surrogate measure of increased community well-being.

1. Introduction

This document presents a report on the work carried out under WP4 to identify basic indicators of up-to-date indicators for the evaluation of the societal benefits of NBS particularly in socio-economic challenging neighborhoods. The report is divided into three parts. The first part presents the results of an in-depth literature study covering 102 tools related to Nature Based Solutions. The aim of the review was to collect and evaluate as many tools as possible to identify the basic up-to-date indicators for the evaluation of the societal benefits of NBS particularly in socio-economic challenging neighborhoods indicators. All the tools were classified and the results of the work were collected in tabular form.

The second part of the report is selected information obtained from one of the EKLIPSE project outomes. This information includes a list of basic up-to-date indicators for the evaluation of the societal benefits of NBS particularly in socio-economic challenging neighborhoods, the identification of which was the purpose of WP4. Please note that only the information most relevant to RainSolutions has been selected.

The third part is a collection of references developed on the basis of a literature study and a project outcome described in the second chapter.

2. Methodology

This document presents the review of the most updated tools related to the NBS area. The 102 tools including frameworks, reviews, case studies, knowledge platforms, databases, interactive maps and software were gathered and presented. Due to very dynamic development of the NBS field, only the most updated tools were presented. The review contains tools published in years 2015 to 2021, among which the majority in 2021 is still supported by authors or actively operating community.

Tools were searched using Elsevier, Scopus, ScienceDirect, ResearchGate and Google Scholar. The search was performed with the following keywords: Nature Based Solutions, NBS, Nature Inspired Solutions, Green infrastructure, Climate change, Climate change mitigation, Resilient cities, Sustainable development and Sustainable cities. The search for new tools was extended with backward and forward references.

The review was also based on the following database-type tools: Horizon 2020 Environment and resources data hub, Climate ADAPT, Water Action Hub, Global Environment Facility, EU Smart Cities Information System and UN Environment Programme World Conservation Monitoring Centre. These tools provide access to databases containing EU and worldwide projects and actions. Their deliverables were inspected, and the most relevant were presented in this article.

The review tools were divided into two subgroups: textbooks and web-based tools. All textbook abstracts were read in detail, then the whole text was screened. Each textbook was categorized into one or more of three categories: framework, review, case study. Web based tools were manually investigated and categorized into one or more of six categories: software, interactive map, database, knowledge platform, framework and case study. In many cases strict categorization would end in assigning particular tool in most, or even all categories which not necessary represent the nature of the tool – e.g. book containing framework and NBS types review could present one case study, which is less than several percent of total content. In that case categorization was performed subjectively based on paper expert knowledge in order to assign tool to most fitted category.

3. NBS tools types

The aim of this work is to collect the most up-to-date tools for the NBS research area. The review contains 102 different both text and web-based tools, summarized in Table 1 and 2. Each tool presents a different approach to NBS, usually depending on the author's background and scope of interest. Therefore a methodology for tools categorization has to be developed. Figure 1 shows the methodology for tools categorization used in this article. All reviewed tools fulfill at least one category, while most of them cover more.

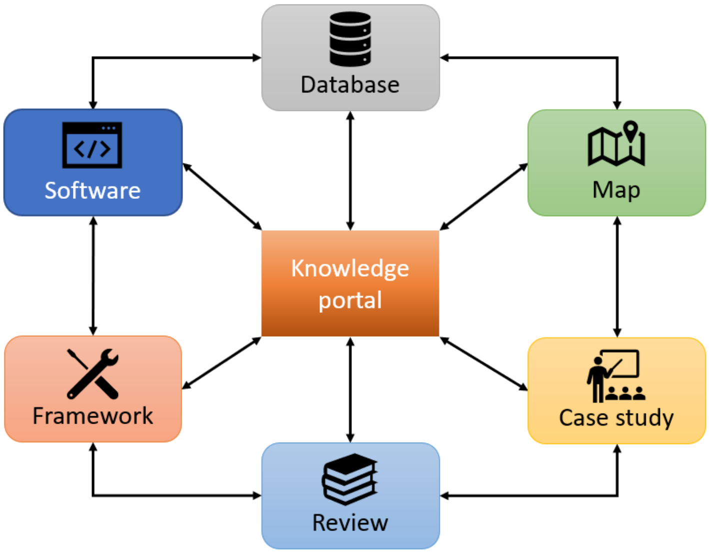

Fig 1. NBS tools can be divided into following categories: Software, Database, Interactive Map, Case Study, Review and Framework

For the clarity of this document, all NBS tools were also divided into two groups: textbooks and web-based tools. The textbooks cover all printed documents such as projects and institutions reports, agendas or published books. This review contains only high volume and high content publications. Single research journal articles, despite of their value were omitted in presented review. However the references to the most valuable papers can be found in 'Review' type tools. Figures 2 and 3 show the metadata of the review. For textbooks, the tools are divided fairly evenly between all categories. For web-based tools, underrepresentation of Software category is noticeable. The biggest representation of 'Knowledge platform' can be explained by the fact that this type of tools usually mix with other category tools.

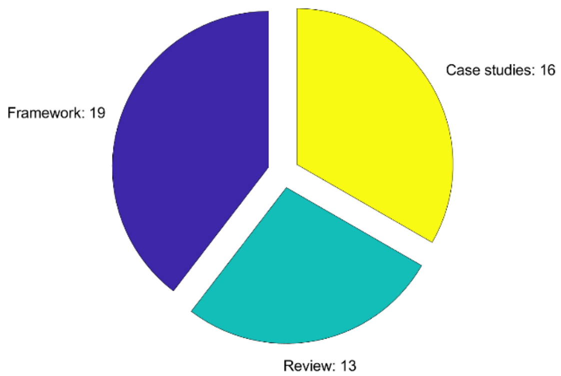

Fig 2. NBS textbooks tools

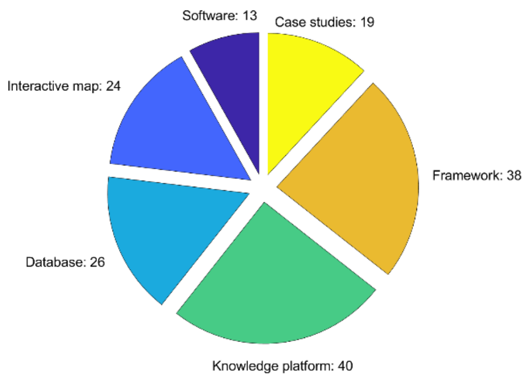

Fig 3. NBS web-based tools

Textbook type tools are divided into three categories: Framework, Review and Case studies (Fig. 4). It has to be noticed that most of the tools present holistic approach to the NBS matter. Each tool usually has content from all categories. For example most of the tools contain some information on the NBS framework, and usually gives at least a few references. Therefore for the purpose of this review, all categories were assigned to the tools proportionally to the amount of content presented by each of them. For example if some tool contains most of the content on Case study, and only a small portion of information on Framework and short literature review, it would be assigned only to one category (Case study). If content is spread more evenly, it would be assigned to more than just one category.

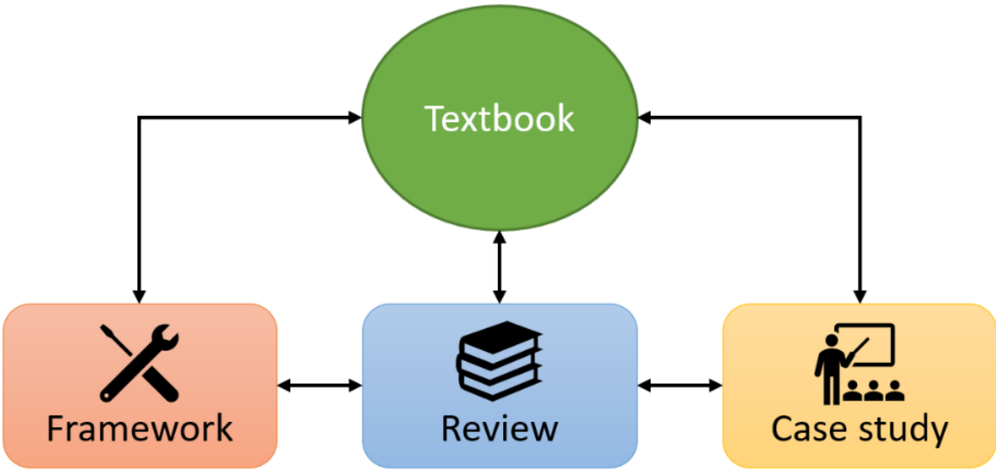

Fig 4. NBS textbooks tools - categories

Framework (F) – This type of tools contain detailed guidelines and trainings allowing for implementation and management of projects utilizing NBS. Usually, these documents familiarize the reader with the concept of NBS in detail. Different types of solutions, their advantages, disadvantages and intended uses are shown. These documents may contain guidelines on project management, different strategies involving stakeholders and funding possibilities. Sometimes these solutions offer ready to use tools in a form of brochures, questionnaires, presentations or games. Some of the documents cover topics related to project assessment and evaluation. Tables with parameters, references to case studies or calculation sheets can be provided. Framework category tools can be prepared in a different level of detail, as well as the theme scope.

Fig 5. NBS textbook type tool - Framework

Each framework-type tool presents different approach to NBS. The "Increasing infrastructure resilience with Nature-based Solutions (NbS) (Silva et al. 2020), offers technical guidance for project developers. The documents proposes the 12 steps covering all project phases from problem definition to NBS operation, monitoring and evaluation. Also the techniques for stakeholder engagement and adaptive approach to planning and management are shown and explained. The "Scalling Green Stormwater Infrastructure Through Multiple Benefits in Austin, Texas" (Diringer 2020), as the title suggests is focused only on particular implementation of

NBS. There are also more documents like ThinkNature (Somarakis 2019) offering general view on NBS topic. That kind of books provide good introduction to NBS, with information complexity adjusted to a novice reader.

Review (R) – contain extended review of the current state of the art on NBS. Usually these are references to literature (articles, books), frameworks, knowledge portals, case studies etc. These documents usually contain short descriptions of the collected tools. Also reviews provide some categorization and often an assessment of the degree of suitability for a specific application. These documents are useful at any stage of the NBS project as a tool that allows users to quickly build a knowledge base. It has to mentioned, that the state of the art, especially for emerging topics like NBS are dynamic. Thus review type tools tend to go out of date relatively quickly. Thus for each new NBS project, new review should be ensured.

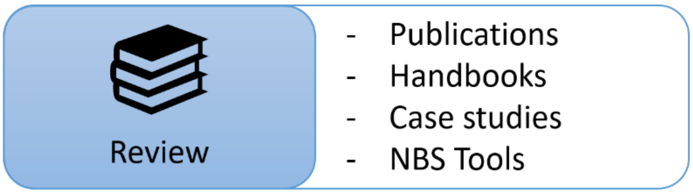

Fig 6. NBS textbook type tool - Review

A good example of review tool is the 'Nature Networks Evidence Handbook" (Humphrey 2020) presents the detailed review of useful map-based models and tools. Tools like 'Ordnance Survey base maps', 'Landscape Character Assessments', "Environment Agency flood risk map" and 17 more were presented, described and evaluated. Tool offers also a wide list of references, including most up to date positions from 2019. Some tools as "Metropolitan Agriculture and Nature-Based Solutions" (Cavallo 2018) presents 6 articles, gathered in form of a book. Each chapter covers different area of research related to NBS, from case study of Bologna (chapter 2), to Manifesto for the new agro-ecological city (chapter 6).

Case Studies (C) – This type of tools contain detailed descriptions of the completed NBS project. The reader is usually provided with name, goal, location, starting and ending date, budget, financing unit, programme and other metadata. Description of the project goals and how they were fulfilled (or not) is given usually with detailed description of each conducted phase. Complete case studies tools provide also parameterization of implemented NBS as well as its assessment according to one of the frameworks. These documents can be an inspiration for new NBS projects, as well as a reference base for their evaluation.

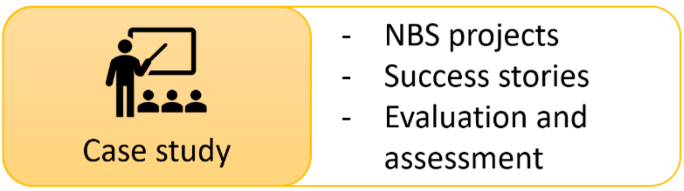

Fig 7. NBS textbook type tool – Case study

Most of textbook-type tools contains at least a few examples of case studies (Zareian 2021). However some publications like "A Technology Portfolio of Nature Based Solutions" (O'Hogain 2018) are specifically focused on case studies detailed review. This particular book presents detailed description of 13 case studies located in Holland, Spain, Slovenia and Ireland. For each study a concept, design criteria, key drivers, operation characteristic, performance and resource recovery products are shown. The book is full of pictures, which helps the reader to get familiar with all case studies and provides inspiration for further ideas.

Table 1. NBS textbooks tools - review

F	-	Framework
R	-	Review
C	-	Case Studies

Year	**Name**	**F**	**R**	**C**	
2021	Nature-based Solutions to Climate Change Adaptation in Urban Areas	X			(Kabisch 2017, Talebmorad 2021)
2020	Increasing Infrastructure Resilience with Nature-Based Solutions (NBS)	X			(Silva et al. 2020)
2020	Living lab handbook for urban living labs developing nature-based solutions	X			(Habibipour et al. 2020)
2020	Guidance for using the IUCN Global Standard for Nature-based Solutions	X			(IUCN 2020)
2020	Nature-based solutions in cities	X			(Dolman 2020)
2020	Open Standards for the Practice of Conservation Version 4.0	X			(CMP 2020)
2020	Incorporating Multiple Benefits into Water Projects: A Guide for Water Managers	X			(Diringer et al. 2020, Ostad-Ali-Askari et al. 2017)
2020	Scaling Green Stormwater Infrastructure Through Multiple Benefits in Austin, Texas	X			(Diringer 2020)
2020	Nature Networks Evidence Handbook	X	X		(Humphrey 2020)
2020	Nature-based Solutions for Resilient Ecosystems and Societies.		X	X	(Ghyani 2020)
2019	Thinknature Nature-Based Solutions Handbook	X			(Somarakis 2019)
2019	The Bingo E-book	X		X	(The Bingo 2019)
2019	Nature Based Solutions–Technical Handbook	X			(Eisenberg 2019)
2019	Toolkit for Mainstreaming Nature-Based Solutions into Nationally Determined Contributions		X		(Seddon 2019)
2019	Nature-based Solutions		X	X	(Kalsnes 2019)
2019	Nature-based Solutions in Nationally Determined Contributions		X		(Seddon 2019)
2019	Augmenting Landscape Democracy through Nature Based Solutions and Immersive Practice		X		(Common Ground 2019)

2019	Towards Nature-based Solutions in the Mediterranean			X	(Canals Ventín 2019)
2019	Equitable Development and Urban Park Space			X	(Bogle 2019)
2019	World Urbanization Prospects		X		(United Nations 2019)
2019	The EU – Brazil Sector Dialogue on nature-based solutions		X	X	(Herzog 2019)
2018	Nature-Based solutions for water	X			(WWAP 2018)
2018	Urban nature atlas: a database of nature-based solutions across 100 european cities		X	X	(Almassy 2018)
2018	"Nature-Based Solutions for agricultural water management and food security"		X	X	(Sonneveld 2018)
2018	Metropolitan Agriculture and Nature-Based Solutions		X	X	(Cavallo 2018)
2018	Evaluating Nature-Based Solutions	X		X	(Huthoff 2018)
2018	A Technology Portfolio of Nature Based Solutions	X	X	X	(O'Hogain 2018)
2017	An impact evaluation framework to support planning and evaluation of nature-based solutions projects	X	X		(Raymond 2017)
2017	Innovative governance for urban green infrastructure: A guide for practitioners	X	X	X	(Ambrose-Oji 2017)
2017	Diffusion of Innovations and Decentralized Green Stormwater Infrastructure: a Case Study of the Headwaters of Waller Creek Watershed, Austin, Texas			X	(Johnston 2017)
2017	Implementing naturebased flood protection	X		X	(World Bank 2017)
2016	Nature-based solutions for building resilience in towns and cities	X		X	(Asian Development Bank 2016)
2016	Nature-based solutions to climate change mitigation and adaptation in urban areas	X		X	(Kabisch 2016)
2015	Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities	X			(Cecchi 2015)
2015	Transforming our world: the 2030 Agenda for Sustainable Development	X			(Cf 2015)

Web-based tools are a separate category presented in the following review paper. Tools usually developed as the deliverables of NBS, or more broadly, environmental projects. Some of web-based tools are powered to local or worldwide organizations as their contribution to environment protection and sustainable development. Web-based tools were divided into six different categories, based on provided services. Similarly to textbooks, each web-based tool can cover more than one single category.

Software (S) - this category includes all software tools that can be used in the context of NBS project. This category starts from simple calculators, going through dedicated tools for modeling specific NBS types, to advanced programs based on machine learning techniques.

Fig 8. NBS web-based type tool – Software

Among all of the considered tools, software has the lowest representation. The projects worth noting are: The Climate Interactive and OpenForis. The Climate Interactive offers three simulators: EN-ROADS, C-ROADS and the ALPS. The first one, EN-ROADS models policies for energy, transportation, land use and new technologies directed to mitigate climate changes. The C-ROADS simulates greenhouse gas reductions in order to meet the Paris Agreement targets. The simulations encompass China, US, EU, India and other areas. Lastly the ALPS simulator is used to compare different agriculture policy scenarios, such as: changing land use, livestock and crop practices.

On the other end, the OpenForis is a tool responsible for data collection, analysis and reporting. The data collection happens through a mobile application. After collection the data is sourced into a global database. This way the tool has access to new data as long as the users maintain the app usage, so the analysis is up-to-date.

Interactive map (M) – this type of tools containing interactive maps, allowing the user to get access to wide range types of information within user friendly interface. Interactive maps are usually linked to databases. They can also contain links to ongoing or finished NBS projects in a given area (case studies). More advanced maps are integrated with software tools, allowing for a clear visualization of the data.

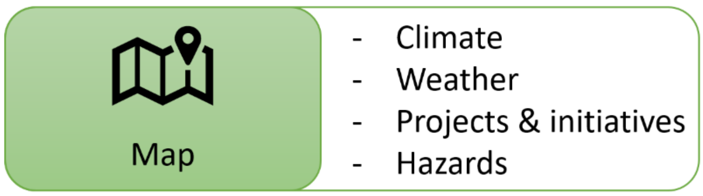

Fig 9. NBS web-based type tool – Interactive map

There are many NBS tools using interactive map to show the data in user friendly manner. The exemplary tool is 'Our World in Data' tool. Currently it provides over 3000 charts across almost 300 topics from the areas of demographic change, food and agriculture, energy and environment, innovation and technological changes, poverty and economic development, living conditions, community and wellbeing, human rights and democracy, violence and war, education and knowledge. The Climate Watch Tool provides interactive map for National Determined Contributions to Sustainable Development Goals linkages. For each country the tool presents the full list of actions and their detailed description.

Database (D) – tools containing all types of databases which can be utilized for NBS projects. The most popular databases are those containing climate and environmental data. However economic and sociological data are also available. Historical data usually covers the beginning of the 20th century. However, the forecast horizons are 2030 or even 2100.

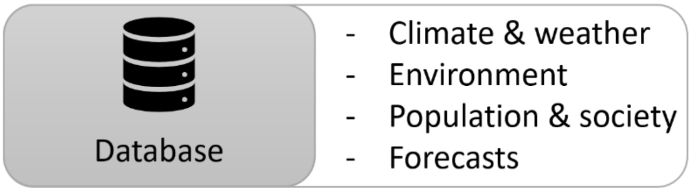

Fig 10. NBS web-based type tool – Database

Climate Action Tracker tracks the effects of current policies on emissions, impact of pledges, targets and NDCs and fair share and comparability of effort. The data is presented in a user friendly interface along with an interactive map. Another good example is the Resource Watch (WRI), which provides hundreds of datasets on the state of the resources and citizens. Data is presented on an interactive map with user friendly interface. The tool covers the following topics: food and agriculture, energy, climate, forests, water, society, ocean and cities.

Knowledge platform (P) – web portals containing all types of information related to NBS. They can contain all NBS tools, news, forums and announcements. The main feature of these type of tools is that their operation is based on interpersonal interactions. It is a meeting place for people dealing with NBS around the world. These tools are the most important part of the NBS community. Tools from this category marked with the date 2020 are the places that are still 'alive'. It means that there is still traffic and some level of moderation. On the other hand, those marked with earlier dates are the tools that (for various reasons) have lost the support of their creators / moderators. These tools can still constitute a collection of valuable information.

Fig 11. NBS web-based type tool – Knowledge platform

There are many useful knowledge platforms. Almost all web-based tools presented in this review were developed by, or in close collaboration with organizations providing their own knowledge platforms. Platforms like Organization for Economic Co-operation and Development, United Nations Climate Change, The International Union for Conservation of Nature (IUCN) and many others give the highest quality content and gathers specialists worldwide.

Framework (F) – Tools containing detailed guidelines for NBS project management. Guidelines are published on websites or are given in a form of textbooks. Almost all web-based tools contains some guidelines or frameworks. They are used as exemplary description of NBS concept. Frameworks and guidelines are not unified yet end each community tries to develop their own standards.

Fig 12. NBS web-based type tool – Framework

Case studies (C) – tools containing short or detailed descriptions on finished and ongoing NBS projects. Case studies usually contain metadata like project names, dates, authors and financing units as well as references (usually hyperlinks) to projects - direct links to publications and project reports and other deliverables. Some tools provide also assessment of particular case study and its usability for the future projects. Case studies type tools are usually linked with Interactive apps and Databases.

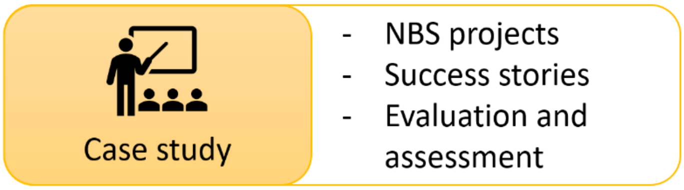

Fig 13. NBS web-based type tool – Case studies

There are many case-studies type tools, usually provided as knowledge platforms. The Adaptation Knowledge Portal provides access to 422 different case studies. The case studies consists of the metadata as geographic region, adaptation sector theme, climate hazard. Each study contains short description and reference. The similar amount of case studies (420 cases) is provided by Green Growth Knowledge Platform.

Table 2. NBS knowledge portal tools – review

F	-	Software
M	-	Interactive Map
D	-	Database
P	-	Knowledge platform
F	-	Framework
F	-	Case Study

Year	**Name**	**S**	**M**	**D**	**P**	**F**	**C**
2020	Climate Interactive	X	X		X	X	
2020	Future City Flow	X				X	
2020	Crowther Lab	X	X	X		X	
2020	BINGO	X				X	
2020	CLARA	X				X	
2020	Clarity	X		X		X	
2020	Oasis Loss modeling framework	X			X		
2020	DHI Worldwide	X				X	
2020	Weather Alert Emilia-Romagna	X	X	X			
2020	ClimeFish	X		X			
2020	Global Forest Watch		X	X	X		
2020	Open Foris	X	X		X		
2020	Horizon 2020 Environment and resources data hub		X	X			
2020	World Resources Institute		X	X	X	X	
2020	Our World in Data		X	X			
2020	Climate ADAPT		X	X	X	X	X
2020	DRMKC - Risk Data Hub		X	X		X	
2020	Water Action Hub		X		X		X
2020	World Database of Key Biodiversity Areas		X	X		X	

2020	Nature4Climate		X		X		
2020	ClimateWatch		X	X			
2020	Global Environment Facility		X	X	X		X
2020	Resource Watch (WRI)		X	X			
2020	Protecting Water Atlas (TNC)		X	X	X		
2020	Nature-Based Solutions Policy Platform		X		X		
2020	Climate Action Tracker			X			
2020	The world Bank			X	X		
2020	Organization for Economic Co-operation and Development			X	X	X	
2020	Green Growth Knowledge Platform			X	X	X	X
2020	Adaptation Knowledge Portal (UNFCCC)			X	X	X	X
2020	The International Union for Conservation of Nature (IUCN)			X	X	X	X
2020	NDC Support Programme				X	X	X
2020	United Nations Climate Change				X	X	X
2020	Connecting nature				X	X	X
2020	Open Standards for the Practice of Conservation				X	X	X
2020	EU Smart Cities Information System				X	X	X
2020	NDC Partnership				X	X	X
2020	Natural Capital Project				X	X	X
2020	Caribbean Climate Change Tools				X		X
2020	The Nature of Cities				X		X
2020	UN Environment Programme World Conservation Monitoring Centre				X		X
2020	EKLIPSE				X	X	
2020	Sustainable Development Goals				X	X	
2020	CEO Water Mandate				X	X	
2020	Global Platform for Sustainable Cities				X	X	
2020	Green Lending Forum				X	X	
2020	ALTER-Net				X		
2020	Restore Our Future, Boon Challenge				X		X
2020	BRIGAID				X		
2019	Protected Planet		X	X		X	
2019	Oppla		X		X		X
2019	Global Surface Water Explorer		X	X			
2019	NDC-SDG Connections Database			X			
2019	Smart Mature Resilience				X	X	X
2019	ThinkNature				X	X	
2019	CONSTRAIN					X	
2018	CCAFS Mitigation Options Tool	X		X			
2018	ECOLEX The gateway to environmental law		X				
2018	APFM Associated Programme on Flood Management				X	X	
2017	RISC-KIT Toolkit	X	X	X		X	
2017	CAIT Climate Data Explorer		X	X	X		
2017	Natural Hazards - Nature Based Solutions		X		X		
2017	Ecosystem Services Assessment Support Tool					X	
2017	RAMSES					X	
2017	ECONADAPT Toolbox					X	

2017	BiodivCanada					X	
2017	Nature 4 Water					X	

NBS classification

Most of NBS are very complex systems. They can provide multiple services in the different levels. Thus the indicators for each NBS has to be identified regarding to how do we classify particular NBS. There is no one uniform classification approach (EKLIPSE, 2016). A multilevel classification is presented below:

Approach 1 (A1) – Approach based on NBS typology. In this approach, all NBS are classified in three general categories with subcategories.

Table 3. NBS classification – Approach A1 (EKLIPSE, 2016)

Category	Subcategory
TYPE 1 - Better use of protected/natural ecosystems (minimal intervention)	Protection and conservation strategies in terrestrial (e.g. Natura2000), marine (e.g. MPA), and coastal areas (e.g. mangroves) ecosystems
TYPE 2 - NBS for sustainability and multifunctionality of managed ecosystems. (managed systems)	Agricultural landscape management Coastal landscape management Extensive urban green space management Monitoring
TYPE 3 - Design and management of new ecosystems (new systems)	Intensive urban green space management Urban planning strategies Urban water management Ecological restoration of degraded terrestrial ecosystems Restoration and creation of semi-natural water bodies and hydrographic networks Ecological restoration of degraded coastal and marine ecosystems

Approach 2 (A2) – Approach based on the area for which NBS is used. The list is open and new positions can be added if needed.

Table 4. NBS classification – Approach A2 (EKLIPSE, 2016)

NBS Approach (A2)	Climate adaptation approaches
	Community based adaptation
	Ecosystem based adaptation
	Ecosystem based management
	Ecosystem based mitigation Ecosystem based disaster risk reduction Ecological engineering Ecological restoration Infrastructure related approaches Natural resources management

	Sustainable agriculture/agro-forestry/aquaculture

Approach 3 (A3) – Approach based on challenge that NBS is expected to solve. The list contain the recent challenges but can be updated in the future if needed.

Table 5. NBS classification – Approach A3 (EKLIPSE, 2016)

NBS Challenge to solve (A3)	Climate mitigation and adaptation Water management Coastal resilience Green space management Air quality Urban regeneration Participatory planning and governance Social justice and social cohesion Public health and well-being Potential of economic opportunities and green jobs

Approach 4 (A4) – Approach based on ecosystems services that NBS is expected to deliver. In this approach, all NBS are classified in three general categories: Provisioning services, Regulation & Maintenance, and Cultural.

Table 6. NBS classification – Approach A4 (EKLIPSE, 2016)

Ecosystems services (A4)	Provisioning services	Fisheries and aquaculture Water for drinking Raw (biotic) materials Water for non-drinking purposes Raw materials for energy
	Regulation & Maintenance	Carbon sequestration Local climate regulation Water purification Air quality regulation Erosion prevention Flood protection Maintaining populations and habitats Soil formation and composition Pest and disease control
	Cultural	Recreation Intellectual and aesthetic appreciation Spiritual and symbolic appreciation

Benefits classification and examples

As it was mentioned above, NBS are usually complex and multilevel systems which provide services depending on perspective. Single NBS, depending on the perspective operates in many dimensions such as spatial, temporal, ecological, social, jurisdictional, cultural or economical. Also the different scales has to be considered. Particular NBS has substantially different impact on the single human than on whole community or even the whole region. Although if designed and managed properly, NBS can provide services and benefits for all stakeholders. The list of selected Benefits is listed below.

Ecosystem services – general

- Provisioning services
    - Nutrition and food security
    - Drinking water resources
- Regulations and Maintenance
    - Carbon sequestration
    - Biodiversity including genetic resources
    - Pollinators for food security and biodiversity
    - Flood risk control, storm-water management
    - Erosion control
- Cultural and social
    - Aesthetic improvement
    - Cultural heritage
    - Active life style
    - Restoration from stress or illness
    - Knowledge creation, education and awareness raising
    - Social cohesion, social capital
- Economic
    - Touristic development
    - Increased regional value
    - Other economic benefits

Fine scale NBS - correspond to everyday lives of people. This scale NBS has usually limited impact on overall climate change. Although fine scale is a place, where regular citizen can be fully engaged in design as well as building process. Thus fine scale NBS pays a significant role in increasing awareness of people and its role cannot be omitted.

Examples:

- Yards, gardens, pocket and neighborhood parks
- Vegetated roofs and walls, trees
- Water elements, edible planting

Social services:

- Equal access to nature
- Soft mobility
- Place for sports, playing, gardening, picnicking, convivial spending of time
- Places for gathering and socializing

Social benefits:

- Neighborhood satisfaction

- Encourage social bonds with neighborhood, feeling of place identity
- Enhancement of well-being of urban residents

Local scale – corresponds to functioning of communities. This scale NBS provides significant services for both environment and society.

Examples:

- Trees, parks, forests and other green spaces

Environmental benefits:

- Moderate local climate
- Alleviate heat island effect
- Improving air quality
- Protecting wildlife
- Lowering flood risk and conserving water
- Local vegetation

Water management services:

- Reduce peak runoff and flooding risk
- Urban storm-water management systems
- Reduction of surface runoff and pollutants therein

Social services:

- Accessibility to greenways between destinations
- Restorative environment
- Quiet spaces, multisensory landscapes

Social benefits

- Social cohesion
- Improving society health both physical and mental (e.g. stress recovery)
- Improving quality of life in urban areas
- Sense of community, feeling of trust, friendliness and shared values and norms

Regional scale – corresponds to functioning of whole society, economy and environment. Usually introduction of this scale NBS has to be coordinated by local governors, countries or even global organizations like UE.

Examples:

- Large natural areas, large conservation areas, large connected green infrastructure
- Law regulations

Environmental benefits:

- Prevention of original spices

- Climate change mitigation

Water management services:

- Support all local scale NBS water management services and make them coherent

Social services:

- Support all local scale NBS social services and make them coherent

Social benefits

- Overall improving of human well-being

Particular NBS services could be beneficial for some stakeholders and at the same time has no practical meaning for other stakeholders. In the worst scenario, some NBS can be counter-beneficial for some groups of stakeholders (e.g. strict building construction regulations vs real estate developers), which also has to be considered. The proper identifying of benefits and stakeholders is one of the main task in NBS planning.

The table below shows the examples of benefits and possible risks for selected NBS actions. The list is not close and can be appended by much more examples.

Table 7. Benefits and possible risks for selected NBS actions (EKLIPSE, 2016)

Benefits	**Local risks**	**Wide-scale risks**
Reduction of air pollution	Release of VOC, increased pollution by slowing air flow	Pollution emissions during production and transport
Support biodiversity, offer space for declining species	Damaging biodiversity via transport of exotic species	Homogenized landscapes with one-size-fits-all solutions
Mitigation of urban heat island	Heat retention via prevention of air flow	Increased global warming due to carbon release during production and transport
Preventing and recovering from pluvial flooding	Flood risk not reduced enough due to poor solutions	Exacerbating could burst and sea level rise due to carbon release
Improved landscape and greenspace connectivity	Malfunctioning connectivity for the related organisms	Wide-scale dispersal of unwanted organisms
Noise abatement	Noise from management machinery or unexpected forms of use	Noise from production and transport
Social cohesion and social inclusion	Exclusion due to failure of recognizing different user groups' needs	Segregation due to unequal access to NBS
Offer public pace and accessibility	Spaces remaining unused	Wasted natural resources

Savings in energy use and costs vi cooling Increased value of the space or area	Cooling impact not achieved due to unsuitable plants Inequality among different societal groups, space needed for NBS	Fossil fuels used for material production Gentrification of urban areas

Performance indicators for NBS

Nature Based Solutions are complex systems which provides multiple services in different levels. What is more, the same type of NBS can provide different services depending on the particular application. Reliable evaluation of NBS depends on the choice of proper performance indicators. This should be done in the planning stage, before the particular NBS is even created.

Project development:

- Planning stage
    - Define project goals
    - Specify the strategy and design approach
- Execution stage
    - Develop detailed design
    - Build
    - Implement
- Delivery stage
    - Operate
    - Maintain
    - Monitor
    - Follow-up

Performance indicators for NBS

For each NBS, a set of indicators should be defined at planning stage of the project. The indicators has to corresponds to project goals and be used for measuring the effectiveness of chosen strategy. The time for evaluation of NBS is during delivery stage.

The following content is provided based on report: "An impact evaluation framework to support planning and evaluation of nature-based solutions projects (2017)". The report was provided by EKLIPSE, founded by European Union's Horizon 2020 (agreement number 690474).

The Approach 3 (NBS challenge) was chosen to present the framework for choosing proper indicators for NBS actions. For other approaches, the framework has to be adjusted. Figure 14 shows the graphic illustration for Approach 3. All challenges requires different actions and thus different sets of indicators for its evaluation.

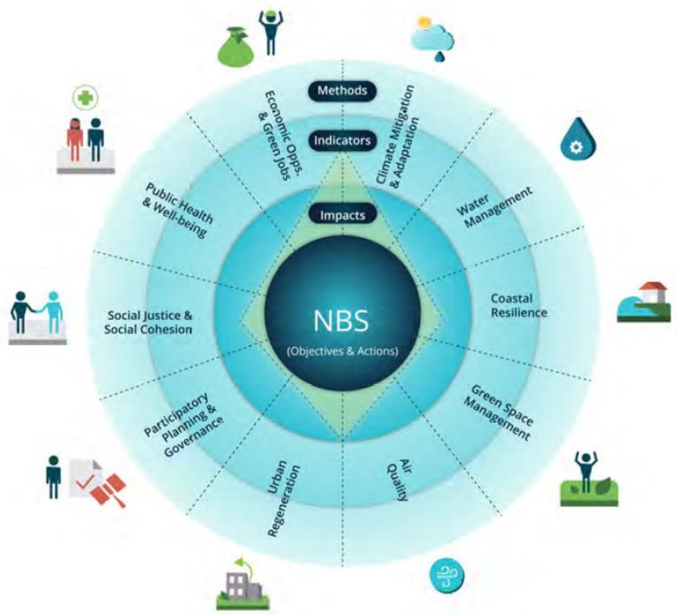

Fig 14. Approach 3 - climate resilience challenges (EKLIPSE, 2016)

Challenge 1: Contribution of NBS to Climate Resilience

Table 8. Challenge 1 - Potential actions for global climate mitigation and expected impacts (Climate Resilience) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Increasing the area of (or avoiding the loss of) green space, particularly wetlands and tree cover, for both direct and indirect carbon storage	• Carbon sequestration in vegetation and soil (Davies et al., 2011; Pataki et al., 2006) • Reducing the temperature at meso or microscales, thus decreasing the energy demand for cooling, especially in warmer climates and reducing associated carbon emissions (Akbari, 2002) • Increased flood regulation (meso or microscale impact) (Pregnolato et al., 2016)
• Minimalizing the net sequestration of carbon through species selection and management practices i.e. improving mitigation as well as choosing species that are adopted to future conditions	• Climate change mitigation and carbon storage by vegetation, including carbon stored in soil (Davies et al., 2011; Pataki et al., 2006) • Improved air quality (mesoscale impact) (Baró et al.,2014)

Table 9. Challenge 1 - Potential climate adaptation actions at the meso and microscale and expected impacts (EKLIPSE, 2016)

Potential actions	Expected impacts

• Increasing the area of (or avoiding the loss of) vegetation an particularly tree cover • Increasing green walls and roofs to cool down the city through outdoor energy management using shading and the latent heat of evapotranspiration of plants and soils.	• Maximize cooling effect by evapotranspiration and shading, thus reducing local temperatures and ameliorating heat island effect and heat stress (Alexandri and Jones, 2008; Fioretti et al., 2010; Kazmierczak, 2012) • Securing long-term carbon storage in vegetation and soil and avoid carbon emissions from land-use changes • Increased energy saving at building and street level through the insulating effect of plants (Alexandri and Jones, 2008; Zinzi and Agnoli, 2011) • Reducing wind speed and thus wind chill in cold climates

Table 10. Challenge 1 - Examples of indicators for assessing the impact of climate mitigation actions at the macroscale (Climate Resilience) (EKLIPSE, 2016)

Indicators	**Metric**
• Carbon storage and sequestration in vegetation and soils (Davies et al., 2011; Demuzere et al., 2014)	• Tons of carbon removed or stored per unit area per unit time (Zheng et al., 2013), total amount of carbon (tones) stored in vegetation (Davies et al.,2011) • Comparison with calculations of carbon consumption of equivalent non-NBS actions (e.g. through Life Cycle Assessment) • Allometric forest models of carbon sequestration developing using proxy data obtained from Lidar data (Giannico et al., 2016) • Growth rates derived from Forest Inventory Analysis (Zheng et al., 2013)
• Monetary values: value of carbon sequestration by trees (Baró et al., 2014)	• Measurements of gross and net carbon sequestration of urban trees based on calculation of the biomass of each measured tree (i-Tree Eco model), translated into avoided social costs of CO2 emissions (USD t^-1 carbon)

Table 11. Challenge 1 - Examples of indicators for assessing the impact of climate adaptation actions at the meso and microscale (Climate Resilience) (EKLIPSE, 2016)

Indicators	**Metric**
• Temperature reduction	• Decrease in mean or peak daytime local temperatures (Celsius degrees) • Measures of human comfort e.g. ENVIMET PET – Personal Equivalent

	Temperature, or PMV – Predicted Mean Vote • Heatwave risk (number of combined tropical nights (>20C) and hot days (>35C))
• Energy and carbon savings from reduced building energy consumption	• kWh/y and t C/y saves

Challenge 2: Water Management

Table 12. Challenge 2 - Examples of indicators (Water Management) (EKLIPSE, 2016)

Indicators	**Scale**				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
Physical indicators					
Run-off coefficient in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et al., 2014; Scharf et al., 2012)	X	X	X	X	X
Flood peak reduction (Iacob et al., 2014), increase time to peak (%) (Iacob et al.,2014)	X	X	X	X	
Reduction of drought risk (probability)	X	X			
Increasing ground water availability (depth to groundwater) (Feyen and Gorelick, 2004)	X	X			
Absorption capacity of green surfaces, bioretention structures and single trees (Armson et al., 2013; Davis et al., 2009)				X	X
Nutrient abatement, abatement of pollutants (% nutrient load, heavy metals)	X				
Ground water quality (nutrient load, heavy metals)	X				
Increased evapotranspiration measured/modelled (Litvak and Pataki,2016)	X	X	X	X	X
Temperature reduction in urban areas (C, % of energy reduction for cooling) (Demuzere et al., 2014)	X	X	X	X	
Economic indicators					
Economic benefit of reduction of stormwater to be treated in public sewerage system € (Deng et al.,	X	X	X		

2013; Soares et al., 2011; Xiao and McPherson, 2002)					
Reduction of inundation risk for critical urban infrastructures (probability) (Pregnolato et al., 2016)			X	X	
Stage-damage curves relating depth and velocity of water to material damages € (de Moel et al., 2015)		X	X		

Table 13. Challenge 2 - Examples of methods for assessing the indicators (Water Management) (EKLIPSE, 2016)

Monetary assessments	• Estimation of avoided damages and costs from flooding e.g. stage-damage curves relating depth and velocity of water to material damages ($) (de Moel et al., 2015) • Avoided costs from increased water quantities to be treated in sewerage systems ($) (Deng et al., 2013; Soares et al., 2011; Xiao and Mc Pherson, 2002) • Linear cost benefit assessments (CBA), introducing flexibility for adaptive solutions into the assessment of infrastructure measures (Deng et al., 2013) • Extended cost benefit assessments (social cost benefit analysis, SCBA) including also social cost and benefits (taxes, subsidies, etc.) (City of Copenhagen, 2014; Leonardsen, 2013)
Non-monetary assessments	• Reduction of inundation risk for critical urban infrastructures (probability) based on hydraulic modelling and GIS assessment (Pregnolato et al., 2016).
Environmental assessments	• Assessment of run-off coefficients in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et al., 2014; Scharf et al., 2012) • Modelling of flood peak reduction (Iacob et al., 2014) • Experiments and measurements assessing the absorption capacity of structures (e.g. green roofs, bioretention structures) and single trees (Armson et al., 2013; Davis et al., 2009) • Measurement of water and ground water quantity and quality (pollutants, nutrients) e.g. increasing ground water availability (depth to groundwater) (Feyen and Gorelick, 2004) • Modelling of options for stormwater management in the urban environment, including the quantification of SUDS benefits with the BeST model (Morales-Torres et al., 2016)
Integrated approaches (including co-benefits)	• Modelling of services provided by vegetation (trees) with the i-Tree Eco model – a suite of models and parameters based on experiences in different climatic zones for the assessment of ecosystem services produced by urban trees including stormwater management as well as carbon sequestration and other co-benefits (Soares et al., 2011) • Assessment of wider social costs and benefits of water management strategies using the ecosystem services assessment framework. Cultural services, recreation, aesthetic values, and tourism values are

	mostly assessed using interviews and participatory approaches, including participatory mapping (Brown and Fagerholm, 2014; Haase, 2015; Iacob et al., 2014; Kati and Jari, 2016; Keeley et al., 2013; Raymond et al., 2009) • CBA approaches: further to conventional and social integrated approaches, introduce flexibility for adaptive solutions into the assessment of infrastructure measures (Deng et al., 2013)

Challenge 3: Costal Resilience

Table 14. Challenge 3 - Potential actions and expected impacts (Costal Resilience) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Use NBS against coastal storms and sea level rises (Yepsen et a., 2016) and protect the population from these risk in combination with engineered structures (Stark et al., 2016)	• Increased population and infrastructures protected by a cost-effective creation of NBS and increased resilience of cities (Cohen-Shacham et al., 2016)
• Promote various NBS in costal areas that can maintain or restore valuable coastal ecosystems and coastal biodiversity (Barbier, 2013)	• Better protection and restoration of coastal ecosystems including valuable species and habitats (Gedan et al., 2011)
• Integrate development and conservation objectives using a better quantification of ecosystems services (Piwowarczyk et al., 2013)	• Sustainable development of coastal regions and reduced conflicts over resources or land-use (Narayan et al., 2016)

Table 15. Challenge 3 - Examples of indicators (Costal Resilience) (EKLIPSE, 2016)

Indicators	Scale				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
Physical indicators (Fagherazzi, 2014; Gedan et al., 2011; Grabowski et al., 2012; Stark et al., 2016)					
Shoreline characteristics and erosion protection	X	X			
Soil, temperature, drainage			X		
Flooding characteristics	X	X			
Economic indicators (Gedan et al., 2011; Narayan et al., 2016; Shuster and Doerr, 2015)					
Avoided damage costs			X	X	X
Changes in property value				X	X
Social and education indicators (Piwowarczyk et al., 2013; Schuster & Doerr, 2015)					
Recreation and public access		X	X		
Number of students benefiting from education and research about costal resilience/amenity	X				
Biological indicators					

(Bell, 1997; Yepsen et al., 2016)					
Estimates of species, individuals and habitats distribution	X	X			
Invasive and planted species	X	X	X		
Algal bloom	X				
Chemical indicators (Grabowksi et al., 2012; Yepsen et al., 2016)					
Concentration of nutrients			X	X	
Salinity, pH			X	X	

Table 16. Challenge 3 - Examples of methods for assessing the indicators (Costal Resilience) (EKLIPSE, 2016)

Indicators types	Examples
Physical	Land-use and land cover changes, monitoring of physical parameters, number and extent of flooded areas, spatial analysis, GIS-based spatial analysis and modelling (Cohen-Shacham et al., 2016; Langemeyer et al., 2016; Liu et al., 2014)
Economic	Cost-benefit analysis, price analysis, willingness to pay (Narayan et al., 2016)
Social and educational	Surveys, estimates of the potential of NBS tourism, number of visitors, number and extent or research and education programs (Petrosillo et al., 2006; Voyer et al., 2013)
Biological	Estimated habitat suitability index and modelling, species census, spatial distribution of vegetation, normalized vegetation index, monitoring using citizen applications (Baggett et al., 2014; Barbier et al., 2013; Neckles & Dionne, 2000)
Chemical	Lab and field analysis of water quality, permanent monitoring systems (Ghervase et al., 2012; Orhel & Register, 2006)

Challenge 4: Green Space Management (including enhancing/conserving urban biodiversity)

Table 17. Challenge 4 - Potential actions and expected impacts (Green Space Management) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Inventories, hierarchizing and representation of green and blue spaces (e.g. Mapping and Spatial Planning) (Buijs et al., 2016; Davies et al., 2015; Hansen et al., 2015; Martos et al., 2016)	• Clear accounts of existing, restored, modified and new NBS (Buijs et al., 2016; Buizer et al., 2015; Elands et al., 2015)
• Set clear and measurable quality and quantity requirements for existing and new NBS (Mazza et al., 2011; Pinho et al., 2016)	• Increase of quality and quantity of green and blue existing, restored and new NBS (Gómez-Baggethun and Barton, 2013)
• Make use of innovative, interdisciplinary planning methods for green space co-design and co-implementation, including development of innovative social models	• Increased stakeholder awareness and knowledge about NBS and ecosystem services, as well as citizen participation in the management of NBS (Filibeck et

for long-term positive management (Derkzen et al., 2015; Fernandez et al., 2015)	al., 2016; Hansen et al., 2015; Mell et al., 2013)
• Create, enlarge, fit out, connect and improve green and blue infrastructure by implementing NBS projects (Kazmierczak and Carter, 2014; Landscape Institute, 2009; Madureira et al., 2011)	• Improve the connectivity and functionality of green and blue infrastructures (Brown et al., 2015; Niemelä, 2014)
• Conserve, improve and maintain existing NBS areas in respect to biodiversity (Elands et al., 2015; Elmqvist et al., 2015)	• Increase achievement of biodiversity targets (Elands et al., 2015; Elmqvist et al., 2015)

Table 18. Challenge 4 - Examples of indicators (EKLIPSE, 2016)

Indicators	**Scale**				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
Distribution of public green space – total surface of per capita (Badiu et al., 2016; Gómez-Baggethun and Barton, 2013; La Rosa et al., 2016)	X	X	X		
Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value (Kabisch and Haase, 2014)	X	X	X	X	
Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014)	X	X	X	X	
Changes in the pattern of structural and functional connectivity (Iojă et al., 2014)	X	X			
Species richness and composition in respect to indigenous vegetation and local/national biodiversity targets (Cohen et al., 2012; Krasny et al., 2013)	X	X	X	X	X

Examples of methods for assessing the indicators

- Categorizing and rating of different NBS types and their impact potential (Akbari et al., 2016; Bowler et al., 2010b; Cvejić et al., 2015; Derkzen et al., 2015; Lehmann et al., 2014; Manso and Castro-Gomes, 2015; Perez et al., 2011; Shishegar, 2015).

- Comparing the overall linkage between NBS sites and the status of NBS implementation (Botzat et al., 2016).
- Questionnaires applied to the population for the recreational and cultural benefits of green spaces (Kabisch and Haase, 2014).
- Mapping of user values attached to green/blue areas (Raymond et al., 2016b; Vierikko and Niemelä, 2016; Wang et al., 2015a).
- Digital mapping (e.g., remote sensing, GIS) of the potential for NBS and status of implementation (Badiu et al., 2016; Gómez-Baggethun and Barton, 2013; La Rosa et al., 2016).
- Ecological and connectivity modelling for biodiversity benefits (Pino and Marull, 2012; Pirnat and Hladnik, 2016).
- Identification of NBS indicators using field surveys, (random) located plots, which are regularly resurveyed.

Challenge 5: Air Quality

Table 19. Challenge 5 - Potential actions and expected impacts (EKLIPSE, 2016)

Potential actions	Expected impacts
• Planning trees: o In private domestic gardens (Davies et al., 2011) o Along the streets (Baró et al., 2014; McDonald et al., 2007; Mullaney et al., 2015) o In urban parks (Yin et al., 2011)	• Reduction of air pollutants through increased deposition (Baró et al., 2014; Bealey et al., 2007; Grote et al. 2017; Tallis et al., 2011) • A number of co-benefits including stormwater run-off mitigation, microclimate regulation through shading, habitat and food provision for biodiversity, noise shielding and recreational and cultural services (Mullaney et al., 2015)
• Building green roofs and green walls (Li and Babcock, 2014) and green walls (Joshi and Ghosh, 2014)	• Capture of air pollutants through deposition (Speak et al., 2012) • A number of co-benefits both for the outdoor (e.g. stormwater retention) and for the indoor environment (i.e. reduced energy needs and a more pleasant environment due to the higher thermal and noise insulation) (Wang et al., 2016)
• Maintaining existing green infrastructure (Davies et al., 2011)	• A wide range of co-benefits including shading, water retention, dry precipitation, infiltration

Table 20. Challenge 5 - Examples of indicators (Air Quality) (EKLIPSE, 2016)

Indicators	Scale				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
Non-spatial indicators of gross quantities: annual amount of	X	X	X	X	

pollutants captured by vegetation (Bottalico et al., 2016)					
Non-spatial indicators of net quantities: net air quality improvement (pollutants produced – pollutants captured + GHG emissions from maintenance activities) (Baró et al., 2014)		X	X	X	
Non-spatial indicators of shares: share of emissions (air pollutants) captured/sequestered by vegetation (Baró et al., 2014)		X	X	X	
Spatial indicators: pollutant fluxes per m2 per year (Manes et al., 2016; Tallis et al., 2011)		X	X	X	
Monetary values: value of air pollution reduction, total monetary value of urban forests including air quality, run-off mitigation, energy savings and increase in property values (Soares et al., 2011)		X	X		
Other indicators: health impact indicators such as premature deaths and hospital admissions averted per year (Tiwary et al., 2009)	X	X	X		

Examples of methods for assessing the indicators

- The i-Tree Eco (updated version of the former UFORE model) suite is available to quantify air pollution reduction and global climate regulation in biophysical and monetary terms using field data collected through a defined sampling protocol (Nowak et al., 2008).
- The "Tiwary method" can be applied to calculate pollution reduction by vegetation, as an alternative to the UFORE model (Tiwary et al., 2009).
- Spatially-explicit models consider the differences in both urban forest structure and pollution concentrations in the different areas (Escobedo and Nowak, 2009). Manes et al. (2016) proposed a method based on the pollution flux approach to map air purification using spatially-explicit data on ecosystem types and characteristics (particularly leaf area index, LAI), and pollution distribution. i-Tree Eco can also be run in a spatially-explicit domain, in order to obtain spatial measures of air purification (Bottalico et al., 2016).
- Models to calculate deposition and capture of pollutants usually adopt hourly meteorological and pollution concentration data. Tallis et al. (2011) proposed and tested a useful approach that uses seasonal data instead.
- Other (complex) numerical methods describe the interactions between vegetation and pollutants at the micro scale (Joshi and Ghosh, 2014) or simulate the emission and deposition processes based on trajectory and dispersion models, e.g. the atmospheric

transport FRAME (Fine Resolution Atmospheric Multi-species Exchange) model (Bealey et al., 2007).

- The economic value of air purification can be measured using avoided costs for health care or replacement costs for artificial treatment. Co-benefits can also be estimated: indoor energy savings can 25 be quantified in terms of avoided energy expenditures; the value of aesthetic quality is commonly estimated through "hedonic pricing" (increased property values) or "willingness to pay" methods (Wang et al., 2015a); and the value for carbon sequestration can be based on international carbon market prices (Zheng et al., 2013).

Challenge 6: Urban Regeneration

Table 21. Challenge 6 - Potential actions and expected impacts (Urban Regeneration) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Enforce micro-scale and cross-scale interactions, consider urban hinterland and 'distant landscapes' (Andersson et al. 2014) • Increase ecological connectivity across NBS sites • Enhance biodiversity and community engagement (e.g. creating community gardens of pocket parks) • Design rain gardens or façade greening systems	• Greater ecological connectivity across urban regeneration sites, and across scales • Increased extent of greenery on urban facades
• Support energy efficiency in building design and layout, building form, infiltration and ventilation, insulation, heating and lighting (Hemphill et al., 2004) • Encourage re-use of building materials in new construction and promote efficient use of resources, materials and construction techniques that maximize the effective life-cycle of the building (Hemphill et al., 2004)	• More energy efficient building design and long-term use • Reduction in the amount of building material going to land-fill duced use of energy in the production of building materials and the construction of new buildings
Convert brownfield to green areas in urban regeneration project (Mathey et al., 2015) • Design for: o Richness in urban environments, such as the promotion of street life, natural surveillance, visual richness, public art, and street furniture (Biddulph, 2011) o Diversity in use, such as mix of people, mix of uses, appropriate densities and visual diversity (Biddulph, 2011) o Ease of movement including through movement, priority given to public	• Local citizens have a say in the design and management of homes and office buildings, contributing to social justice outcomes • Increased amount of green open space for residents • Increased cultural richness and diversity in urban areas, as well as improved ease of movement

transport, priority given to innovative parking, meeting needs of people with sensory impairments (Biddulph, 2011)	
• Provide the urban brand with a narrative and a value aimed at changing the perception of potential users or visitors, whether they are citizens, international tourists or investors	• Changing images of the urban environment, attracting new residents, visitors, tourists and investors

Table 22. Challenge 6 - Examples of indicators (Urban Regeneration) (EKLIPSE, 2016)

Indicators	**Scale**				
			Meso		Micro
	Regional	Metropolitan	Urban	Street	Building
Urban green indicators					
• Urban green: index of biodiversity, provision and demand of ecosystem services	X	X	X	X	X
• Ecological connectivity (Pino and Marull, 2012)	X	X	X		
• Accessibility (Schipperijn et al., 2010) : distribution, configuration, and diversity of green space and land use changes (multi-scale; (Goddard et al., 2010))	X	X	X		
• Ratio of contaminated land: percentage of contaminated area reclaimed				X	X
• Reclamation of contaminated land: percentage of contaminated area reclaimed			X	X	X
Building efficiency and environmental design indicators					
• Reclamation of building materials: percentage reclaimed from existing buildings					
• Energy efficiency: building materials/construction methods based on points awarded according to energy efficiency checklist					X
• Incorporation of environmental design: percentage of total building stock					X
• Land devoted to roads: percentage of site area occupied by roads	X	X	X	X	

Socio-cultural indicators					
• Conservation of build heritage resources: percentage of built from retained for culture					X
• Land dedicated to pedestrians: percentage of road network	X	X	X	X	
• Public transport links: walking distance to nearest facilities			X	X	
• Access to open space: average journey time for residents/employees by foot or average distance to sports center, recreation area, or green space		X	X	X	
• Access to cultural facilities: average journey time for residents on foot or average distance to cultural center		X	X	X	
• Access to housing: affordability and choice	X	X	X		
• Levels of devices contributing to the safety of users in the neighborhood: lighting of common areas, access control, presence of technical or specialized staff, etc.					X

Examples of methods for assessing the indicators

- Document and analyse the best replicable practice of NBS in multidisciplinary terms.
- Biodiversity mapping (in a temporal context; Ramalho and Hobbs, 2012), LIDAR, spatial analysis and ES mapping (considering ES bundles and functions, synergies and trade-offs, (de Groot et al., 2010; Fisher et al., 2009; Haase et al., 2012; Pauleit and Duhme, 2000), integrated design (Farr, 2011; McHarg, 1969). 29
- Measurement on maps and city plans (Laprise et al., 2015).
- Qualitative analysis of interventions on buildings and surroundings (Laprise et al., 2015).
- Quantitative analysis of building typologies, measures and devices supporting flexibility (Laprise et al., 2015).
- Energy balance checklists. Values depend on whether it is a new construction or a renovation, according to the building type (Laprise et al., 2015).
- Structured interviews with architect/developer (Hemphill et al., 2004).
- Interviews and surveys with local communities (see participatory planning and governance).

Challenge 7: Participatory Planning and Governance

Table 23. Challenge 6 - Potential actions and expected impacts (Participatory Planning and Governance) (EKLIPSE, 2016)

Potential actions	Expected impacts

• Design knowledge co=production process to bring openness, transparency in governance process, and legitimacy of knowledge from citizens/civil society, practitioners and policy stakeholders (Crowe et al., 2016; Frantzeskaki and Kabisch, 2016; Specht et al., 2016) • Create different institutional spaces for cross-sectoral dialogue and interactions of different stakeholders for strengthening/fostering adaptive co-management and knowledge sharing about urban ecosystems (Crowe et al., 2016; Dennis and James, 2016; Fors et al., 2015; Frantzeskaki and Tilie, 2014; Ugolini et al., 2015) • Enable cross-sectoral partnerships for NBS design, implementation and maintenance (Crowe et al., 2016; Krasny et al., 2014; Specht et al., 2016; Ugolini et al., 2015)	• Legitimate different forms and systems of knowledge in participatory planning process, empowering citizens/civil society, practitioners and policy stakeholders involvement in NBS projects • Social learning about the location and importance of different types of socio-cultural values for NBS, enabling NBS to be designed in line with community aspirations and expectations • Policy learning leading to more efficient design, delivery and monitoring of NBS • Inter-departmental collaboration leading to NBS designs for multi-functionality • Improved co-ordination of NBS strategies within and across levels of governance
• Support process that enrich or regenerate ecological memory for restoring urban ecosystems with NBS (Colding and Barthel, 2013)	• Improved understanding of different perceptions of urban nature. Integration of these understandings into urban design is likely to lead to higher levels of ownership of NBS by local communities
• Promote and work towards creative designs of NBS in cities that adaptive over time (Collier et al., 2013; Vandergert et al., 2015)	• NBS that are flexible to changing environmental, social or economic conditions
• Support community-based projects on greening and restoring urban green spaces that also ensure accessibility to these spaces and stewardship (Dennis and James, 2016; Krasny et al., 2014)	• Increased accessibility to green open space, supporting social justice outcomes

Table 24. Challenge 6 - Examples of indicators (Participatory Planning and Governance) (EKLIPSE, 2016)

Indicators	**Scale**				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
• Openness of participatory process (Frantzeskaki and Kabisch, 2016; Luyet et al., 2012; Uittenbroek et al., 2013)	X	X	X	X	
• Legitimacy of knowledge in participatory process (Frantzeskaki and Kabisch, 2016; Luyet et al., 2012)	X	X	X		

• Social learning concerning urban ecosystems and their functions/services (Colding and Barthel, 2013)	X	X	X	X	
• Policy learning concerning adapting policies and strategic plans by integrating ecosystem services and possibly their valuation (Crowe et al., 2016; Uittenbroek et al., 2013; Vandergert et al., 2015)	X	X	X	X	X
• Perceptions of citizen on urban nature (Buchel and Frantzeskaki, 2015; Colding and Barthel, 2013; Gerstenberg and Hofmann, 2016; Scholte et al., 2015; Vierikko and Niemelä, 2016)	X	X	X		
• Social values for urban ecosystems and biodiversity (Brown and Fagerholm, 2014; Kenter et al., 2015; Polat and Akay, 2015; Raymond et al., 2014, 2009; Scholte et al., 2015)	X	X	X		

Examples of methods for assessing the indicators

- Action research, case study, surveys (Specht et al., 2016)
- Q method (Buchel and Frantzeskaki, 2015)
- Narrative analysis, statistical analyses (Buchel and Frantzeskaki, 2016; Gerstenberg and Hofmann, 2016; Hansen et al., 2016)
- Fuzzy cognitive mapping (Gray et al., 2015)
- Actor–network analyses, interpretative methods (Frantzeskaki and Tillie, 2014; Hansen et al., 2016)
- Environmental valuation methods (monetary and non-monetary) (Kenter, 2016; Raymond et al., 2014; Scholte et al., 2015)
- Ecological psychology methods (Heft, 2012)
- Environmental psychological methods (Gifford, 2014)
- Expert-based approaches (Scholte et al., 2015)
- Knowledge synthesis (Pullin et al., 2016)

Challenge 8: Social Justice and Social Cohesion

Table 25. Challenge 6 - Potential actions and expected impacts (Social Justice and Social Cohesion) (EKLIPSE, 2016)

Potential actions	Expected impacts

• Distribute various types of NBS across urban areas to ensure a range of ecosystem services and experiential qualities of place are available to people from different socio-economic backgrounds (Raymond et al., 2016b)	A greater diversity and number of people having the opportunity to experience and enjoy the natural environment through investments in NBS in multiple areas (Natural England, 2014)
• Support experiential learning and capacity building programs on NBS in ways that meet the varying requirements, rights and duties of local residents (Krasny et al., 2013)	• An increase in communities sense of ownership of local natural places (Natural England, 2014) • More people having opportunities for learning about nature and gaining new sills; building trust, tolerance and respect between groups
• Actively engage excluded social groups in the design, delivery and monitoring of NBS, as well as in the rules to support the governance of NBS	• NBS designed, delivered and monitored in ways that reflected the needs and interests of typically excluded social groups
• Build the capacity of typically excluded groups to participate in NBS decision-making processes. Capacity building can include efforts directed to improving basic literacy and numeracy, physical security, employment, information and recognition as a citizen (Rutt and Gulsrud, 2016)	• Typically excluded groups having the capacity to actively engage in NBS decision-making process, thereby supporting social cohesion among diverse-economic groups

The table below shows the possible indicators for different measurement scales. It has to be mentioned that the list shows only selected indicators and should be treated as a sort of guideless. For each NBS action, the indicator list has to be prepared individually.

Table 26. Challenge 6 - Examples of indicators (Social Justice and Social Cohesion) (EKLIPSE, 2016)

Indicators	**Measurement scale**				
	Mesoscale			Microscale	
	Regional	Metropolitan	Urban	Street	Building
Social Justice (Comim et al., 2008; Nussbaum, 2011; Sen, 2005)					
• The availability and distribution of different types of parks and/or ecosystems services with respect to specific individual or household socioeconomic profiles and landscape design (Cohen et al., 2012; Ernstson, 2013; Ibes, 2015; Kabisch and Haase, 2014; Raymond et al., 2016b; Shanahan et al., 2014)		X	X	X	

• Access to financial resources, including indicators of income per capita in a given neighborhood, or urban area (Klasen, 2008)			X	X	
• Bodily integrity: being able to move freely from place to place, to be secure against violent assault, including indicators of crime by time of day (Felson and Poulsen, 2003)				X	X
• Senses, imagination and thought: being able to use the senses, to imagine, think, and reason about the environment, informed by indicators of levels of literacy, mathematics and science knowledge (Chen and Luoh, 2010; Elliott et al., 2001)				X	X
• Emotions: being able to have attachments to things and people outside ourselves; to love those who love and care for us, including indicator of place attachment, empathy and love (Lawrence et al., 2004; Manzo and Devine-Wright, 2014; Perkins et al., 2010; Raymond et al., 2010)			X	X	X
• Being able to participate effectively in political choices that govern one's life, including indicators on level and quality of public participation in environmental management (Reed, 2008; Reed et al., 2009)	X	X	X	X	X
Social cohesion					
• Structural aspects: indicators of family and friendship ties; participation in organized associations; integration into the wider community (Cozens and Love, 2015; Stafford et al., 2003)	X	X	X	X	X
• Cognitive aspects: indicators of trust, attachment to neighborhood, practical help, tolerance and respect (Mihaylov and Perkins, 2014; Uzzell et al., 2002)				X	

Examples of methods for assessing the indicators

- Public participatory GIS to assess experiential qualities (Brown et al., 2014; Laatikainen et al., 2015; Raymond et al., 2016b; Wang et al., 2015a).
- Ethnographic accounts of justice (Checker, 2011).
- Spatial analysis of the relationships between ecosystem services, park type and socio-economic profiles (Cohen et al., 2012; Hughey et al., 2016; Kabisch and Haase, 2014).

- Actor–Network Analysis (Ernstson, 2013; Ernstson et al., 2009).
- Historical analysis of the process of creating just or unjust environmental conditions (Schönach, 2014).
- Psychometric methods to assess place attachment, love or empathy (Lawrence et al., 2004; Perkins et al., 2010; Raymond et al., 2010), or the underlying structure of social cohesion (Comstock et al., 2010; de Vries et al., 2013; Stafford et al., 2003).
- Self-reporting instruments to assess indicators of literacy, numeracy and perceived levels of crime and safety.
- Grounded Theory (Strauss and Corbin, 1990) or Thematic Analysis (Braun and Clarke, 2006) techniques to explore the categories and sub-categories of meaning underpinning constructs like senses, imagination and thought related to NBS.

Challenge 9: Public Health and Well-being

Table 27. Challenge 6 - Potential actions and expected impacts (Public Health and Well-being) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Distribute various types of urban green spaces as NBS across urban areas	• Provision of health benefits and ecosystems services, which are available to people from different age groups and socio-economic backgrounds
• Provide adequate urban planning and design mechanisms to ensure sufficient green space provision for positive health effects	• A greater diversity and number of people having the opportunity to benefit from the positive health effects from urban green spaces
• Design of urban green spaces, such as parks and playgrounds, should take in account the need of children and the elderly while taking measurements to minimize the risk of injures	• Improving of opportunities for exploration by children and improvement of immune systems already in children
• Provide proper urban green space design, maintenance and recommendations to minimize trade-offs (allergenic pollen, transmission of vector-borne diseases)	• Decrease of detrimental effects of urban green spaces

Table 28. Challenge 9 - Examples of indicators (Public Health and Well-being) (EKLIPSE, 2016)

Indicators	Measurement scale				
	Mesoscale			Microscale	
	Regional	Metropolitan	Urban	Street	Building
Psychological indicators (Relaxation and restoration, sense of place, exploratory behavior, socializing)					
• Reduction in chronic stress and stress-related diseases measured through repeated salivary cortisol sampling (Roe et al., 2013; Ward Thompson et al., 2012) and hair cortisol (Honold et			X	X	X

al., 2016); use cortisol slope and average cortisol levels as an indicator of chronic stress					
• Cognitive and social development in children: indicators related to improvement in behavioral development and symptoms of attention deficit/hyperactivity disorder (ADHA) elated to green space use; questionnaire indicators on socio-demographic and household characteristics, the time spent playing in green and blue spaces, ADHD symptom criteria, such as emotional symptoms, inattention, conduct problems, hyperactivity/inattention, and peer relationship problems; and a strength subscale for prosocial behavior (Amoly et al., 2014)			X	X	X
• Mental health changes measured through Mental Well-being scales asking participants how they have felt over the previous four weeks in relation to a number of items (e.g. feeling relaxed, feeling useful), with responses rated on a 5-point scale from 'none of the time' to 'all of the time' (Roe et al., 2013)			X	X	X
Health indicators related to physical activity (Sports and leisure activities including e.g. walking, cycling)					
• Number and share of people being physically active (min. 30min 3 times per week)			X		
• Reduced percentage of obese people and children; reduced overall mortality and increased lifespan			X		
• Reduced number of cardiovascular morbidity and mortality events			X		
Health indicators related to ecosystem service provision (Buffering of noise and air pollution, reduced heat, exposure to microflora)					
• Reduced autoimmune diseases and allergies (Tamosiunas et al., 2014)			X		
• Reduced cardiovascular morbidity and mortality			X		
• GIS related indicators: NDVI, proximity measures (green space of min. 2ha within 300m) (Maas et al., 2006; Vries et al., 2003), percentage	X	X	X	X	X

of green space (Kabisch and Haase, 2014; van den Berg et al., 2010)					

Examples of methods for assessing the indicators

- Self-assessment of perceived general health through on-site questionnaires or postal surveys using Likert scales (for assessment of stress-levels, relaxation, etc.), e.g. asking participants to rate how closely their mood matched certain statements of mood (Honold et al., 2012).
- Questionnaire surveys with parents and teachers, e.g. on strengths and difficulties (SDQ), and ADHD/DSM-IV (Amoly et al., 2014).
- Mobile electroencephalogram (EEG) system outdoors and EEG-based emotion recognition software for functional brain imaging to record any stress reduction as people walk into urban green spaces (Aspinall et al., 2015).
- Wearable sensors to demonstrate the effects of walking in a green space on brain activity (Aspinall et al., 2015).
- Spatial analysis of the relationships between accessibility, ecosystem services, park type and socioeconomic profiles (Cohen et al., 2012; Hughey et al., 2016; Kabisch and Haase, 2014, Annerstedt van den Bosch 2016).
- Assessing effects of nature experiences through assignment of participants to particular exercises (e.g. walk in nature for a certain time) followed by psychological assessments and assessments of affective and cognitive functioning (Bratman et al., 2015a, 2015b).

Challenge 10: Potential for Economic Opportunities and Green Jobs

Table 29. Challenge 9 - Potential actions and expected impacts (Potential for Economic Opportunities and Green Jobs) (EKLIPSE, 2016)

Potential actions	Expected impacts
• Encourage methods to transfer the benefits of common good provided by NBS to the initiators of NBS, e.g. through tax reductions or subsidies (Meulen et al., 2013)	• Increased willingness to invest as more of the co-benefits accrue to the initiator • Increased competitive advantage for cities applying NBS measures • Net additional jobs in the green sector fueled by new green investments
• Support vocational training programs to enhance skills in the design and delivery of NBS measurements (Falxa-Raymond et al., 2013)	• Increased knowledge on NBS and the appropriate implementation of the NBS measures • Individual earning uplift arising from skills enhancement in the design and implementation of NBS
• Increase knowledge and awareness on NBS in the urban environment for stakeholders and policy makers	• Increase in implementation of NBS and associated employment as initiators become more familiar with NBS solutions • Policy makers will develop an active approach towards NBS application within the public domain and infrastructure • Policy makers will develop an active approach towards NBS application and

	possible provision of (co)financing arrangements for private properties • Increased knowledge base, as more implementation of NBS will increase their application under diverse circumstances
• Develop online NBS impact calculation tools	• Increased awareness of NBS solutions and their effectiveness and (co)benefits • Increased knowledge base on values of NBS impacts
• Restore or plant green spaces of other NBS	• Creation of green jobs relating to construction and maintenance of NBS (Saraev, 2012) • Benefits for work productivity including reduced absenteeism (Saraev, 2012) • Increased commercial (Gensler, 2011) and domestic property prices (Eftec, 2013; Forestry Commission, 2005; Lutttick, 2000) • Attraction of business (Eftec, 2013) • Increased social interaction

Table 30. Challenge 9 - Examples of indicators (Potential for Economic Opportunities and Green Jobs) (EKLIPSE, 2016)

Indicators	**Scale**				
	Meso			Micro	
	Regional	Metropolitan	Urban	Street	Building
• Number of subsidies or tax reduction applied for (private) NBS measures (Meulen et al., 2013)	X	X	X	X	X
• Number of jobs created (Forestry Commission, 2005); gross value added (Forestry Commission, 2005)	X	X	X		
• Change in mean or median land and property prices (Forestry Commission, 2005)	X	X	X	X	X
• New business attracted and additional business rates (Eftec, 2013)	X	X	X		
• Resource efficiency in the urban system (CO_2 emissions per capita, CO_2 emissions for transportation per capita, etc.) (OECD, 2013)	X	X	X		

• Public-sector cost per net additional job (Tyler et al., 2013)	X	X	X		
• Net additional positive outcomes into employment (Tyler et al., 2013)	X	X	X		
• Net addition jobs (Tyler et al., 2013) in the green sector enabled by NBS projects	X	X	X		
• Gross value added per employees based on full-time equivalent jobs (Tyler et al., 2013) in the green sector	X	X	X		
• Production benefit: earning uplift arising from skills enhancement in the design and implementation of NBS (Tyler et al., 2013)	X	X	X		
• Consumption benefits: property betterment and visual amenity enhancement resulting from NBS (Tyler et al., 2013)	X	X	X		

Examples of methods for assessing the indicators

- Cost Effectiveness Assessments (CEA), assessing the performance (non-monetary, single outcome) of the measures against their costs
- Multi-criteria Analysis (MCA), assessing the performance (non-monetary, multiple outcomes) of the measures through public or expert opinion
- Social Costs and Benefits Approach (SCBA), analysing the monetised costs and benefits from the effects of the measures discounted over time
- GIS/Satellite/aerial imagery inventories (e.g. for green roofs, parks, public gardens) to assess impacts of measures (e.g. on health, real estate values).
- Land use changes from planning documents and maps (urban regeneration plans, including more green spaces) to assess ambitions and plans.

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