URBAN GreenUP

D1.2: Societal Challenge Catalogue

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Abbreviations and Acronyms

AQPs	Air Quality pollutants
CC	Climate Change
GDP	Gross Domestic Products
GHGs	Greenhouse Gases
GI	Green Infrastructure
KPI	Key Performance Indicator
N/A	Not applicable
NBS	Nature-Based Solutions
PM	Particulate matter
RUP	Renaturing Urban Plan
SuDS	Sustainable Urban Drainage Systems
UHI	Urban Heat Island

0 Abstract

The aim of this report is to provide a useful catalogue for the standardisation of a method to identify and classify the main societal city challenges. Such a catalogue will allow practitioners to be able to examine these challenges in a simple way with accurate information about how these challenges might affect cities and how and why cities might come to understand urban vulnerability as soon as possible.

Although initially the title of this deliverable was "Climate Change Challenge Catalogue", during the development of the joint work needed to prepare this deliverable its approach was redefined to cover a wider definition of "challenge". This was because nature-based solutions (NBS) are solutions to a number of societal challenges and not only climate change issues. For that reason, the title was modified to the current one. Urban GreenUP approach contains 10 challenges (based on classification created by the EKLIPSE initiative):

1. Climate mitigation and adaptation;
2. Water management;
3. Coastal resilience;
4. Urban green space management (including enhancing/conserving urban biodiversity);
5. Air/ambient quality;
6. Urban regeneration;
7. Participatory planning and governance;
8. Social justice and social cohesion;
9. Public health and well - being and
10. Potential for new economic opportunities and green jobs.

For this reason, a brief subset of challenges in form of cards has been developed to form this catalogue, including their definition as well as key indicators and methods for assessing the possible impacts to be achieved using NBS in cities.

This document allows the reader to identify what, where and why the challenge is crucial as well as how and in what way the different nature-based solutions studied within URBAN GreenUP framework may contribute to dealing with them, considering different criteria.

WHAT: Definition of the challenge and relevant information.

WHY: Explanation about why each challenge is key for the cities and the reasons for choosing it to deal with NBS are described in this section.

HOW: Prioritisation (up to 5) of the potential NBS to deal with it and expected impacts.

HOW MUCH: Which KPIs can be used to measure the impact of the NBS in the challenge.

Another criteria that could have been added is **WHO** will be the final users of the methodology. The answer would be common for every challenge and in order to lighten this document is included below. As it was mentioned before, this catalogue allows practitioners to be able to asses the social challenges of cities. The main users of this catalogue and who would make use of the methodology of the Project could be the municipalities (technical and policy-makers),

companies related to NBS as suppliers and landscapers designers, among others. In addition, any citizen is invited to review the catalogue in order to learn a way to structure the main challenges that cities should face and how they can cope them with nature.

The catalogue is a part of the URBAN GreenUP methodology for the Renaturing Urban Planning concept (RUP) which incorporates urban planning aspects directly related with NBS as a part of the Sustainable Urban Planning (SUP). This methodology will support the direct implementation of one or a set of NBS in a specific area of the city to address specific challenges in a more effective way. It provides specific concepts definition and includes main NBS identified to deal with these challenges as well as different key performance indicators defined to measure their impacts.

This catalogue establishes the main city challenges that can be tackled and solved with NBS and provide bases for the city diagnosis together with the assessment of city boundaries and barriers (deliverable 1.5). In addition, this catalogue could also be complemented with the NBS catalogue (deliverable 1.1).

It is for these reasons that an easy-to-use catalogue has been designed by projecting a multi-card structure. The catalogue collects several environmental challenge characteristics and in practice, it is a **climate change & societal threats repository** that includes **existing information** about **current challenges**, **NBS recommended to deal with them** as well as **technical** and **parametrisation** aspects, in a standardised manner ready to be used in a systemic procedure of planning or decision making processes.

1 Introduction

1.1 What is a Societal Challenge Catalogue?

One of the meanings considered by the Cambridge dictionary for the noun "catalogue" is *"to make a written record of things in the form of a list in a particular order"*. Wikipedia[1] defines Climate Change as *"a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years)* and the United Nations Framework Convention on Climate Change (UNFCCC)[2] outlines it as *a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.* Combining all of them, the objective of this deliverable, as part as URBAN GreenUP project development is obtained, *"to detail the parameterisation of the each challenge previously identified by the bibliography as well as any other challenge that could be identified during the research process".*

Responding to climate change is a profound challenge. A variety of actors are involved in urban climate governance, with municipal governments, international organisations and funding bodies pointing to cities as key areas for response. Several cities in Europe have taken steps to develop innovative approaches for addressing environmental challenges and the impacts of the economic crisis through the use of nature-based solutions. These solutions to societal challenges are inspired and supported by nature (living solutions). They are adaptable, multi-purpose and resource efficient and provide simultaneously environmental, social and economic benefits, such as city resilience improvement to climate change and natural disasters, contributing to both climate change adaptation and mitigation[3]. For this reason, it can be concluded that, to address urban challenges, nature-based solutions are making the transition towards a social and economic model that is in balance with, and inspired by, nature.

Apart from climate change, there are other societal challenges, mainly at city scale, that can be addressed with NBS. During the initial defining process of the approach and scope and content for this deliverable, it was decided to follow the societal challenge classification develop by the EKLIPSE Expert Working Group[4] collected in their report as a reference. This approach contains 10 challenges:

1. Climate mitigation and adaptation;
2. Water management;
3. Coastal resilience;

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[1] https://en.wikipedia.org/wiki/Climate_change (last visit May 2018)

[2] http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=689 (last visit June 2018)

[3] Christos Fragakis, "Sustainable cities through nature-based solutions". Info day Smart Cities and Communities, Brussels, 6 November 2015.

[4] "An impact evaluation framework to support planning and evaluation of nature-based solutions projects" EKLIPSE Report.

4. Urban green space management (including enhancing/conserving urban biodiversity);
5. Air/ambient quality;
6. Urban regeneration;
7. Participatory planning and governance;
8. Social justice and social cohesion;
9. Public health and well - being and
10. Potential for new economic opportunities and green jobs.

Currently a global/common methodology to integrate the possibilities of naturalising cities via nature-based solutions does not exist. Despite significant challenges facing the development and implementation of urban policies, there is already evidence of an increasing number of projects and initiatives taking place in cities that are apparently concerned with climate change. URBAN GreenUP project is an important example.

Nature-based solutions have emerged as a concept to operationalise an ecosystem services approach within spatial planning policies and practices to fully integrate the ecological dimension alongside traditional planning concerns.

Until now, renaturing interventions have been applied to specific climate issues in cities, forgetting the integration essential character of these actuations. RUPs development and deployment constitute a complementary and cost-effective way to mitigate and fight against climate change in urban environments and is aligned with EU 2020 Biodiversity and Green Infrastructure Strategy. The development of very ambitious urban planning to Climate Change mitigation highly based on NBS will dynamize the European market of this sector. Designers, providers and installers will increase their business due to this new demand creating new economic opportunities.

It is for these reasons that an easy-to-use catalogue has been designed by projecting a multi-card structure. The catalogue collects several environmental challenge characteristics and in practice, it is a **climate change & societal threats repository** that includes **existing information** about **current challenges**, **NBS recommended to deal with them** as well as **technical** and **parametrisation** aspects, in a standardised manner ready to be used in a systemic procedure of planning or decision making processes.

1.2 What are the Objectives of a Societal Challenge Catalogue?

Main problems related with climate change could be mitigated with NBS and based on this, the key objective of URBAN GreenUP are defined as the demonstration of an innovative methodology to renaturing cities through piloting different actions and considering advanced technologies, towards the adaptation of the cities to fight against the climate change.

To this purpose, new tools, as this catalogue, will support the methodological process and help in the generation of RUP's scenarios and allow for its evaluation.

The methodology will be tested both by project partners and for external stakeholders that could be included in a methodological real processes, in order to be able to fix the different parts that make up the process, articulate them and scale them up, generating a useful, replicable and exploitable methodology both within Europe and beyond.

This is why the core objective of this catalogue is **the standardisation of a method to identify and evaluate the city in respect of several societal city challenges in a simple way,** which will allow for a clear, simple and user-friendly diagnosis. It provides a first critical introduction to the selected challenges, climate change among others, giving an overview of their emergence as urban policy issues.

It is focused on a brief subset of challenges directly related to NBS including their definition, key indicators and methods for assessing the impacts and evaluating the NBS effectiveness, all of them focused on this specific set of challenges.

This catalogue examines the challenges of creating accurate and useful information about how environmental challenges might affect cities, and how and why cities might come to understand urban vulnerability in relation to different key societal challenges, climate change among others, as part of the URBAN GreenUP project development.

Finally, it is important to highlight that a **combined reading of this report together with the "NBS catalogue" will provide a comprehensive analysis of the main current urban environmental challenges and how to deal with them**, both of them illustrated with very useful information in form of information cards.

1.3 How the is the Catalogue Structure?

As mentioned below, challenges are presented in cards and each card is structured following the sections:

WHAT: This section defines the challenge, includes the description, its origin and its main background. All the relevant information to introduce the challenge is included here.

WHY: The explanation about why each challenge is key for the cities and the reasons for choosing it to deal with NBS are described in this section.

HOW: The prioritisation of the potential NBS actions (up to 5 types to avoid overloading the cards) to deal with the challenge and the expected impacts for these actions are here shown.

HOW MUCH: The target of this section is to explain which KPIs can be used to measure the impact in the challenge based on each particular NBS selected before (in HOW section). The number shown below KPIs names correspond to the code assigned in the global list of KPIs developed within the framework of the project. No additional information or calculations are here presented because this information can be extracted from other deliverables.

LINKS AND REFERENCES: Citations are an essential part of the information contained within the card and those used for the challenges description are here presented.

1.4 Definition of Concepts to be used in the Catalogue

Climate adaptation: The capacity to react and respond to an external stimulus or stress such as climate change,

Climate mitigation: The potential of improving the current status of a parameter or driver through active or passive behaviour, in this case through reducing greenhouse gas emissions or sequestering carbon.

Greenhouse gases (GHGs): In this report, the terms greenhouse gases (GHGs) and climate pollutants are used. GHGs are typically defined by the gases included in the Kyoto Protocol i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF6), hydrofluorocarbons(HFCs) and perfluorocarbons(PFCs). Nitrogen trifluoride (NF_3) was added in 2012 (Doha amendment). The term climate pollutants includes aerosols.

Air Quality Pollutants (AQPs): They typically are considered to be carbon monoxide (CO); nitrogen oxides (NOx); sulphur dioxide (SO_2), particulate matter (PM). Also includes non-methane volatile organic compounds (NMVOCs) as an O_3 precursor and ammonia (NH_3) as a PM precursor.

1.4.1 Challenges Definitions

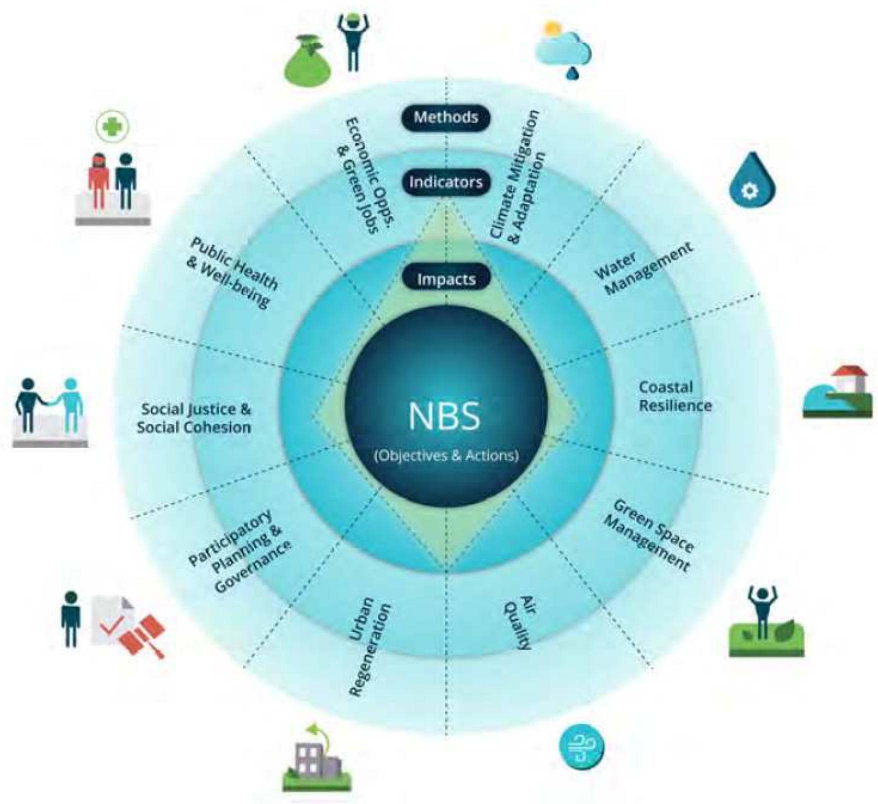

Figure 1: EKLIPSE challenges

Climate mitigation and adaptation: This concept includes the capacity to react and respond to an external stimulus or stress such as Climate Change, and the potential of improving the status of a parameter or driver through active or passive behaviour, in this case through reducing greenhouse gas emissions or sequestering carbon.

Water management: How the NBS can contribute to solve the three principal problems: flood risk, water scarcity and water quality.

Coastal resilience: This concept refers to the ability of coastal ecosystems to reorganise keeping its functions, structure, identity and regenerative capacity when they are threatened. NBS can increase coastal resilience by protecting communities against extreme events.

Urban green space management: Green spaces are important reservoirs of urban biodiversity, providing resources, ecosystem services and habitats for species of interest, improving functional and structural connectivity at the urban level.

Air quality: NBS based on the creation, enhancement, or restoration of ecosystems in human-dominated environments play a relevant role in removing air pollutants and carbon dioxide, reducing the air temperature (which slows down the creation of secondary pollutants) and increasing oxygen concentration, contributing to a beneficial atmospheric composition for human life.

Urban regeneration: This concepts aims at improvements in the economic, physical, social and environmental conditions of an urban area that has been subject to negative change and is considered non-resilient. NBS projects need to harmonize urban regeneration, aesthetic appeal, urban development, urban structure, design, social justice, urban ecology and its relations to energy and water uses.

Participatory planning and governance: NBS design and implementation require a holistic and transdisciplinary planning approach that conciliates different types of knowledge. Furthermore, NBS must focus on the interests and perceptions of citizens, examining the changes in policy narratives when incorporating the ecosystem services framework in planning.

Social justice and social cohesion: This concepts aims at comprising the environmental justice and social cohesion supported by NBS in urban areas, through a multi-dimensional approach.

Public Health and Well-being: NBS can contribute to a wide range of positive psychological and physiological benefits, improving overall human health.

Potential of economic opportunities and green jobs: Increasing green areas and NBS results in considerable economic benefits (increased real estate values, positive health effects, improved water management…). In addition, NBS generate co-benefits that can create opportunities for "Green businesses" and "Green-Collar Jobs".

1.4.2 KPIs General Framework

The Key Performance Indicators (KPIs) are based on the Eklipse mechanism framework[5], where a robust set of KPIs were selected and established by challenges that relate to NBS.

The KPIs can be utilised by:

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

The intention of the KPIs is to list a robust set of indicators that will evaluate the progress and the application of the NBS at each of the demo cities. It is desirable that each city can quantify continuously according with each goal for KPIs and Challenge. In order to guarantee a comparable approach among the demo cities, there were selected a set of KPI named CORE KPI, see the Table 1 and Figure 2.

CH	KPI DEFINITION
1	Tonnes of carbon removed or stored per unit area per unit time
	Total amount of carbon stored in vegetation
	Decrease in mean or peak daytime local temperatures
	Heatwave risks
	Use of *Star tools* to calculate projected maximum surface temperature reduction
2	Run-off coefficient in relation to precipitation quantities
	Absorption capacity of green surfaces, bioretention structures and single trees
	Temperature reduction in urban areas
	Areas (Ha) and population (inhab) exposed to flooding
	Drinking water provision
	Water for irrigations purposes
	Volume of water removed from water treatment system
	Volume of water slowed down entering sewer system
3	Not selected
4	Accessibility (measured as distance or time) of urban green spaces for population
	Weighted recreation opportunities provided by Urban Green Infrastructure
	Production of food
	Increased connectivity to existing GI
	Pollinator species increase
5	Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities concentration recorded ug/m3
	Trends in emissions NOX, SOX
	Monetary values: value of air pollution reduction; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values. use of GI Val to calculate the value of air quality improvements
	Number of deaths from air, water and soil pollution and contamination

[5] "An impact evaluation framework to support planning and evaluation of nature-based solutions projects" EKLIPSE Report.

CH	KPI DEFINITION
	Air quality parameters NOx, VOC, PM etc.
6	Accessibility: distribution, configuration, and diversity of green space and land use changes (multi-scale ;). - Green spaces quantity
	Savings in energy use due to improved GI
7	Perceptions of citizens on urban nature - Green spaces quality
8	Green intelligence awareness.
9	Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit
	Increase in walking and cycling in and around areas of interventions
10	Number of jobs created; gross value added

Table 1: Core KPIs table

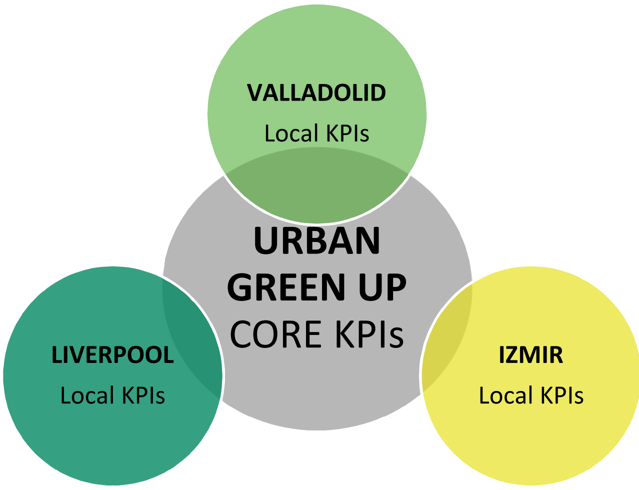

Figure 2: KPIs infographic

Valladolid local KPIs:

- kWh/y and t C/y saved.
- Flood peak reduction. Increase in time to peak (%).
- Reduction of drought risk (probability).
- Intercepted rainfall (m^3 $year^{-1}$).
- Share of green areas in zones in danger of floods (%).
- Population exposed to flood risk (% per unit area).
- Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals). (Chemical Oxygen Demand (COD) (mg/L); Biochemical Oxygen Demand (BOD) (mg/L); Total Solids (SST) (mg/L)).
- Distribution of public green space – total surface or per capita.
- Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.
- Sustainability of green areas.
- Quality of life for elderly people.
- Perceptions of connectivity and mobility.
- Mean levels of exposure to ambient air pollution (population weighted) (proposed indicator for SDG target 3.9).
- Assessment of typology, functionality and benefits provided pre and post interventions.
- Openness of participatory processes.

- Legitimacy of knowledge in participatory processes.
- Crime reduction through police reports and local authority data.
- Number of subsidies or tax reductions applied for (private) NBS measures[6].
- New businesses attracted and additional business rates[7].
- Consumption benefits: property betterment and visual amenity enhancement resulting from NBS[8].

Liverpool Local KPIs:

- Measurements of gross and net carbon sequestration of urban trees based on calculation of the biomass of each measured tree (i-Tree Eco model), translated into avoided social costs of CO_2 emissions (USD t-1 carbon). LIV WORDING: Economic value of carbon sequestration by vegetation as a result of NBS over 25 years.
- Use of Star tools to calculate projected maximum surface temperature reduction.
- Run-off coefficient in relation to precipitation quantities (mm/%).
- Nutrient abatement, abatement of pollutants (%, nutrient load, heavy metals). (Chemical Oxygen Demand (COD) (mg/L); Biochemical Oxygen Demand (BOD) (mg/L); Total Solids (SST) (mg/L)).
- Recreational (number of visitors, number of recreational activities) or cultural (number of cultural events, people involved, children in educational activities) value.
- Increase in density and seasonal spread of floral resources for pollinators.
- Increase in plant species richness and functional diversity as a result of NBS.
- Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9).
- Assessment of typology, functionality and benefits provided pre and post interventions
- Savings in energy use due to improved GI.
- Perceptions of citizens on urban nature- green spaces quality[9,10,11,12,13].
- Crime reduction through police reports and local authority data.
- Perceptions of health and quality of life.

[6] Meulen, S. et al. Vergoedingen voor ecosysteemdiensten, 2013.

[7] Economics for the Environment Consultancy (Eftec). Green Infrastructure's contribution to economic growth: a review. A Final Report for DEFRA and Natural England, London, 2013.

[8] Tyler, P. et al. Valuing the benefits of urban regeneration. Urban Stud. 50, 169–190, 2013.

[9] Buchel, S. et Frantzeskaki, N. Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands. Ecosyst. Serv. 12, 169–177, 2015.

[10] Colding, J., Barthel, S. The potential of "Urban Green Commons" in the resilience building of cities. Ecol. Econ. 86, 156–166, 2013.

[11] Gerstenberg, T., Hofmann, M. Perception and preference of trees: A psychological contribution to tree species selection in urban areas. Urban For. Urban Green. 15, 103–111, 2016.

[12] Scholte, S.S.K. et al. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecol. Econ. 114, 67–78, 2015.

[13] Vierikko, K., Niemelä, J. Bottom-up thinking—Identifying socio-cultural values of ecosystem services in local blue–green infrastructure planning in Helsinki, Finland. Land Use Policy 50, 537–547, 2016.

- Change in mean or median land and property prices (Forestry Commission, 2005). LIV WORDING: Changes in mean house prices/rental markets.
- New businesses attracted and additional business rates (Eftec, 2013). LIV WORDING: Increased returns of business rates with NBS.

Izmir Local KPIs[14]:

- Measures of human comfort e.g. ENVIMET PET — Personal Equivalent Temperature, or PMV — Predicted Mean Vote.
- KWh/y and t C/y saved.
- Energy, water and carbon reduction via urban farming (Climate-smart Greenhouse).
- Increase in shadow surface (m^2)
- Distribution of public green space – total surface or per capita[15,16,17].
- Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted) concentration recorded µg/m^3.
- Pollutants removed by vegetation (in leaves, stems and roots) (kg ha^{-1} $year^{-1}$).
- Perceptions of citizens on urban nature - Green spaces quality.
- Urban green spaces per capita
- Urban Farming Educative/ participate activities, Learning for producers.

The KPIs are described in different working packagers among the project. In WP5, deliverable *5.1. Techincal KPIs definition* set the KPIs and a first stage approach. In deliverable *5.3 City diagnosis and monitoring procedure*, aim to establish the processes to follow in the project. Then in each city WP (2, 3, 4) there are specific deliverables that tackle each city monitoring procedures, fully describing each KPI, method, related NBS, calculation, measurement, sources, etc.

1.4.3 Link with NBS Catalogue

NBS catalogue is a part of the URBAN GreenUP methodology for RUP concept which incorporates the urban planning aspects directly related with the nature-based solutions as a part of the Sustainable Urban Planning, to support the direct implementation of one or a set of NBS in a specific area of the city to address also specific challenges in a more effective way.

[14] The number of KPIs selected depends on the NBS typology and expected impact in each city. Izmir KPIs list cover most of core KPIs even when the total number is smaller than in the other two cities.

[15] Badiu, D.L., et al. Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study Ecol. Indic. 70, 53–66, 2016.

[16] Gómez-Baggethun, E., Barton, D.N. Classifying and valuing ecosystem services for urban planning. Ecol. Econ. 86, 235–245, 2013.

[17] La Rosa, D., Spyra, M., Inostroza, L. Indicators of cultural ecosystem services for urban planning: A review. Ecol. Indic. 61, 74–89, 2016.

In practice, it is a kind of an NBS implementation assistant-repository, and includes existing information about NBS, technical, economic and social aspects, in a standard way to be used in a systemic procedure of planning or decision-making.

The key role of the catalogue is to act as a central reference in the development of Renaturing Urban Plans (RUPs) by presenting a set of NBS options, each of which will have been built in at least one of the participating cities in the URBAN GreenUP project.

Not every NBS in the catalogue will suit every part of every city. The RUP development process serves to enable selection of appropriate NBS from the catalogue for each city, recognising that a wide array of factors will be relevant in determining the suitability of an individual NBS. These factors include:

1. The built forms of the city;
2. The budget the city holds for NBS deployment, and its ability to leverage funding;
3. The challenges that the city wishes to address using NBS;
4. The social, cultural, legal and political context of the city; and/or
5. The ability of relevant institutions to design, construct and maintain NBS.

Factor number 3 is the key to understanding the interactions between this deliverable and the deliverable 1.1. HOW section in each Challenge card includes the NBS from the Catalogue with a major impact on it.

NBS catalogue includes both technical and non-technical NBS. This classification separates NBS that require a physical implementation (such as a green roof or a green cycling route) from NBS without physical implementations (non-technical). Both address different social, environmental, social and/or economic challenges, but non-technical have more influence social and/or economic challenges. Most of NBS collected in the NBS catalogue are technical solutions covering different potential impacts in all the societal challenges. However, non-technical solution are also important to face up societal challenges related with health, well-being or social justice and social cohesion. Non-technical solutions include a deeply educational and awareness component in order to improve the knowledge regarding NBS.

On the NBS catalogue, each NBS has a technical card with the explanation about how each one address different challenges and it is linked to the main challenge (that is, that one reached most effectively). In this way, the person who consults the document will be able to select easily which NBS is the most appropriate according to the challenges that the city wishes to address. And linked to this, the objective in D1.2 has been established from another point of view but fully complementary to D1.1. As stated above, the objective, in this catalogue, is to present **a compilation of cards about the main societal city challenges at present** and it contains quick and simple information for the reader so that, in a glance, people can discover the most important options to deal with the challenges of their cities.

Deliverables 1.1 and 1.2 are complementary and indispensable to develop the innovative methodology to renaturing cities to be created within URBAN GreenUP project.

1.4.4 Challenges Scales Definition

One of the major issues in implementing NBS for urban climate resilience and in understanding their potential impact and effectiveness is related to the scale of intervention. Action on climate mitigation can span the micro level of a single building, the meso level of the whole city or country and the macro level of the entire planet, though it has essentially a macro (global) scale effect through affecting global concentrations of greenhouse gases. Climate adaptation is more often planned and implemented at the meso (national) to micro (local) level, and the impacts are also at these levels.[18]. For this catalogue, the scales defined for the challenges as well as for the NBS implementation are included under micro level definition and each concept indicates the area where the positive effects of the NBS in relation to the challenge could be noticed and it is equal to the scale defined in deliverable D1.1 to ensure coherence.

The definitions are:

R=Regional: It is an urban unit superior to the concept of metropolitan area, with a centre in a large city, which subordinates to it the productive, tertiary, etc. activities of the entire region.

M=Metropolitan: It is an urban region that encompasses a central city (the metropolis) that gives its name to the area and a series of cities that can function as dormitory, industrial, commercial and service cities.

U=Urban: City, town, village without its metropolitan area.

S=Street: Thoroughfare of a population that is generally limited on both sides by blocks or rows of buildings.

B=Building: Type of construction made from solid materials and used to put people and objects up.

It concept is further developed in section “Where” in each card.

[18] “An impact evaluation framework to support planning and evaluation of nature-based solutions projects” EKLIPSE Report.

2 Climate Change Challenges in Cities

2.1 Climate Mitigation & Adaptation

Climate Mitigation & Adaptation

1 WHAT	
	There is no doubt that **climate change** and **global warming** are the most prominent environmental challenges and threats that the world has been experiencing over the last couple of decades. The third assessment report of the Intergovernmental Panel on Climate Change [1] states that most of the global warming within the last 50 years is due to anthropogenic factors. Increased concentrations of greenhouse gases, especially carbon dioxide, is a result of global warming. The change of atmospheric composition will continue during the 21st century, accelerating the global climate change, which is already under way. The effects of climate change are raising the frequency and intensity of water shortages, floods and storms worldwide [2]. In other words, the atmosphere and ocean have warmed due to human influence on the climate systems, changes in the global water cycle have occurred as well as reductions in snow and ice, in global mean sea-level and in some climate extremes [3]. In Europe, some of the observed changes have established records in recent years. Europe has experienced the warmest decade since global temperature records became available. Human influence (emissions of GHGs primarily) together with changes in land use have been the main causes of the observed warming since the mid-20th century [3]. For instance, annual mean temperature and the frequency and duration of heat waves have increased across Europe since the mid-20th century. Precipitation has generally increased in Northern and Northwestern Europe whereas it has generally decreased in Southern Europe. Snow cover has been decreasing and most permafrost soils have been warmed. The frequency and intensity of extreme temperature and precipitation events are expected to increase [3,4]. **Climate resilience** is based on two interacting concepts: "**adaptation**", the capacity to react and respond to an external stimulus or stress such as climate change, and "**mitigation**", the potential of improving the current status of a parameter or driver through an active or passive behaviour, specifically through reducing GHG emissions or sequestering carbon [5,6]. Actions on climate mitigation can span the micro level of a single building, the meso level of the whole city or country and the macro level of the entire planet [7].

Climate Mitigation & Adaptation

WHAT	If climate change mitigation and adaptation fail, this will cause more extreme weather events, natural catastrophes, food crises, water crises, biodiversity loss and an ecosystem collapse. They will also result in a chain reaction for other sectors as well [2].
WHY	Cities are home to more than half of the world population and much of the world industry. By 2050, more than 70 % of the population (6.4 billion people) is projected to live in urban areas [8]. Therefore, climate change is the most threatening environmental challenge for urban landscapes because cities are also particularly vulnerable to climate change – both because extreme weather events can be especially disruptive to complex urban systems and because the most part of the world urban population live in low-lying coastal areas. Vulnerability to storm surges and sea levels are set to increase over the coming decades rapidly [8]. Urban areas are key players with respect to climate change. They are not only contributing to climate change but also affected by its impacts. This is why cities need to be adapted to the expected changes on time to protect inhabitants, assets and critical infrastructure [9]. Cities have a unique ability to address global climate change challenges. Choices made in cities today about long-lived urban infrastructure will determine the extent and the impact of climate change, its ability to achieve emission reductions and its capacity to adapt to changing circumstances [8]. For instance, in European cities, due to climate change, hundreds of millions of people will experience rising sea levels, inland floods, more frequent and intense storms and more frequent periods of extreme heat and cold in the coming years [10]. According to the report of UN-Habitat 2009 [11], different challenges are being faced by many cities these days, including the lack of green development ratio to the built environment. Accordingly, a comprehensive set of green policies and strategies has been indicated to be used for filling the gap between urban and green development toward a higher resilience and adaptability to climate change [12]. Cities in Turkey, for instance, are not different than other European cities in terms of factors that threaten the quality of life. They have been experiencing many problems such as high air pollution, urban heat islands, hotter summers, extreme drought seasons, frequent flooding, decreasing surface waters and ground water tables. Furthermore, the lack of climate sensitive strategies and approaches in relevant city policies and action plans can be added

Climate Mitigation & Adaptation

WHY	to these problems. 55 % of the observed European cities indicate that they have already implemented an adaptation action plan, with large cities acting as frontrunners in this area (75 %). Additionally, 82.5 % of cities are already implementing adaptation actions and more adaptation actions to deal with 1) more intense rainfalls (50 %), 2) an increased urban heat island effect (27.5 %), 3) hotter summers (25 %) and 4) hotter days (25 %) [9]. Given this background on the cities vulnerability to climate change and the crucial significance of mitigation and adaptation measures, what are needed are reasonable and sustainable strategies, plans and implementations. In this case, nature-based solutions (NBS) could be the right answer to increase the resilience of the cities and mitigate the negative effects of climate change. NBS, in this context, are sustainable interventions in order to increase the resilience as well as providing a wide variety of ecosystem services for city dwellers in urban landscapes. This is why urban green areas can play an important role in mitigating the effects of climate change [13]. In the case of the NBS proposed in this project, it is intended that green measures or interventions where green areas predominate can decrease urban heat island effect, increase the permeability of urban surfaces, the amount of air pollutants captured and carbon sequestered by trees and manage run-off in a sustainable way.
WHERE	R / M / U / S / B In general, actions on climate mitigation can span the micro level of a single building, the meso level of the whole city or country and the macro level of the whole planet [7]. Although a higher resilience and adaptability to climate change starts with large-scale strategies and implementations, the integration of different actions at different scales tends to decrease day to day. For instance, establishing large green reserves and ecological or green networks that continue in urban landscapes in form of interconnected system are sustainable solutions to sequester more carbon and reduce urban heat island effect as well as controlling run-off and regulating waterways regionally. However, it is important to note that cities (urban scale) are key elements in climate mitigation and adaptation because they are more vulnerable to climate change for the reasons explained in previous sections. Particular adaptation actions to achieve it are tree planting and/or the creation of green space, followed by resilience and resistance measures for buildings and crisis

Climate Mitigation & Adaptation

	management including warning and evacuation systems [9].
SUB-CHALLENGES identification & description	**Mitigation** An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases, sometimes referred to as limiting climate change [14].
	Adaptation Adjustment in natural or human systems to a new or a changing environment. Adaptation to climate change refers to adjustments in natural or human systems in response to actual or expected climatic stimulus or their impacts, which moderate harm or exploit benefits. Several types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation and autonomous and planned adaptation. The terms provision or adjustments can be used in other contexts [14].

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Urban Carbon Sink	Action that includes increasing urban green areas by planting new trees to maximize **carbon sequestration**. Additional benefits are air purification because of the capture of particulate matter, creation of more **shadow surfaces** and **reduction of Urban Heat Island** (UHI) **effect** because of this NBS implementation.
2. Urban Trees: Shade trees, cooling trees, planting and renewal urban trees, arboreal areas around urban areas and trees renaturing parking.	This NBS is based on planting of trees individually or by groups in urban areas as part of cities green infrastructure that underpins city growth, providing **shady places** to **reduce UHI effect** and improve user's well-being, enhancing local aesthetics, reducing surface run-off and ensuring **evapotranspirative cooling effect**.
3. Vertical green structures: Green façades, green noise barriers or vertical mobile garden.	Vertical green structures cover building walls or create vertical structures with vegetation in different ways. Green wall is a wall completely or partially covered with greenery. For instance, a green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Vertical green structures **cool the air through water an**

Climate Mitigation & Adaptation

	evaporation reducing UHI effect and save energy in buildings. Green façades also offer economic, environmental, aesthetic and physiological benefits to the urban environment. They are also natural air-filters, creating a cleaner environment and provide high leaf surfaces. Green Noise barriers are designed to reduce the noise, these barries a specific geometry favouring sound reflection and a specific substrate favouring sound absorption.
4. Green Covering Structures: Green covering shelters, green roofs and green shady Structures.	Green covering structures are structures that cover buildings, bus stations or car parks and they have a vegetative layer grown on it. They are characterized as water-resistant and have some additional layers to allow healthy vegetation growth. These infrastructures **reduce UHI effect** and the **use of energy in air conditioning and heating in buildings** besides urban run-off water by retention layers. The creation of small ecosystems is encouraged increasing green areas in cities, that is, the main expected impact of this action.
5. Cool pavement	This NBS includes reflective/permeable pavements that help to achieve **lower surface temperatures and reduce the amount of heat absorbed into the pavement**, both of them important for **local cooling strategies in cities** and for **reducing UHI effect**. Usage of high-reflective or permeable paving materials and/or thinner pavements allows reducing absorption and retention of heat comparing with conventional ones. Vegetated and permeable pavements allow water penetrates through the voids and pores, feeding groundwater.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Tonnes of carbon removed or stored per unit area per unit time (ton CO_2/ha) (ton CO_2/year). ***KPI 1***	This KPI calculation is based on CO_2 removals per specimen planted and this data will be applied to the whole project subsequently, depending on the number of specimens expected at the end. Plant structure in each technology is analysed regarding the type of plant species and their total number. The choice of plants shall be set out specifically, taking into account their own air amelioration capability.

Climate Mitigation & Adaptation

Total amount of carbon (tonnes) stored in vegetation (ton C/ha) (ton C/year). ***KPI 2***	The amount of carbon stored in vegetation is calculated by using biomass calculations. The amount of C stored in vegetation at sub-demo areas will be calculated both pre- and post-intervention.
Decrease in mean or peak daytime local temperatures (°C). ***KPI 7***	To evaluate this KPI is necessary to measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Then, these data are comparing to measurements taken at equivalent locations on equivalent stretches of street without those NBS, at a similar time of day on the same dates or continuously. The calculation of daily, weekly, monthly and annual mean levels (night and day) of temperature and relative humidity at each stretch is essential to allow the comparison of mean values for NBS interventions and control sample locations, to be done at each study site.
Heatwave risks (number of combined tropical nights (>20 °C) and hot days (>35 °C) (nº days). ***KPI 9***	In order to achieve this KPI, it is necessary to measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. To calculate the number of tropical nights per month (summertime) and per year following the city location settings is needed to allow the comparison with values taken at equivalent locations on equivalent stretches of street without those NBS, at a similar time of day on the same dates or continuously. The calculation of the number of tropical nights and heatwaves monthly (summertime) and yearly, assessing hourly mean values of temperature at each stretch is included. Finally, a comparison of mean values for NBS intervention and control sample locations will be done at each study site.
Energy and carbon savings from reduced building energy consumption (kWh/y and tonnes carbon/y saved). ***KPI 10***	To measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention is the first step to asses this KPI. Buildings classification at NBS locations and one building modelling for each class are necessary followed by models simulations, cooling energy consumption measurement and a pre- and post-intervention cooling energy consumptions comparison. Then, the calculation will be extended to all the buildings in NBS locations.

Climate Mitigation & Adaptation

	If modelling is not possible, it is necessary to obtain a specific city mean heat gain value correlation, based on the decrease in air temperature and cooling energy consumption due to the interventions. Finally, corresponding carbon savings from reduces energy consumption is evaluated.

LINKS and REFERENCES

Keywords used	Climate change, climate mitigation, climate adaptation, urban heat island, heatwave risks
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Table 2: Climate Mitigation & Adaptation challenge card

2.2 Water Management

Water Management

2 WHAT	
	Water is the primary medium through which climate change influences Earth's ecosystem and thus the livelihood and well-being of societies. Global warming is likely to intensify, accelerate or enhance the global hydrological cycle [1]. Changes in precipitation, which higher average temperatures and temperature extremes are projected to cause, will affect water resources availability through changes in form, frequency, intensity and distribution of precipitation, soil moisture, glacier- and ice/snowmelt, river and groundwater flows, and lead to further deterioration of water quality. In some regions, droughts are exacerbating water scarcity and thereby negatively impacting people's health and productivity. Ensuring that everyone has access to sustainable water and sanitation services is a critical climate change (CC) mitigation strategy for the years ahead [2]. **Challenges** Higher temperatures and extreme, less predictable, weather conditions are projected to affect availability and distribution of rainfall, snowmelt, river flows and groundwater, and further deteriorate water quality. Low-income communities, who are already the most vulnerable to any threats to water supply are likely to be worst affected. More floods and severe droughts are predicted. Changes in water availability will also impact health and food security and have already proven to trigger refugee dynamics and political instability. **Facts and figures (UN-Water)** • Globally, water scarcity already affects four out of every 10 people. A lack of water and poor water quality increases the risk of diarrhea, which kills approximately 2.2 million people every year, as well as trachoma, an eye infection that can lead to blindness, and many other illnesses [3]. • Increasing temperatures on the planet and more variable rainfalls are expected to reduce crop yields in many tropical developing regions, where food security is already a problem [3]. • By 2025, 1.8 billion people are expected to be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under water stress conditions [4]. • With the existing climate change scenario, by 2030, water scarcity in some arid and semi-arid places will displace between 24 million and 700 million people [5].

Water Management

<table>
<tr><td>WHAT</td><td>

- By the 2080s, land unsuitable for agriculture in sub-Saharan Africa die to severe climate, soil or terrain constraints may increase by 30 to 60 million hectares.
- Scientists, farmers and the business community consider variability, casted as 'extreme weather events', as one of the most likely production risks over the next ten years [6].

</td></tr>
<tr><td>WHY</td><td>

Climate change is adding a new challenge to urban water management. With climate change and climate variability impacts, cities will increasingly experience difficulties in efficiently managing more scarce and less reliable water resources, as well as in coping with floods and droughts. With more frequent and intense extreme climate events caused by climate change, cities need to become more resilient to natural disasters such as floods and droughts.

Water is a vital resource that is too often taken for granted. Individuals, infrastructure and industry all have a range of fundamental water-related requirements that encompass supply, wastewater treatment and drainage services. Meeting these direct needs – while ensuring resilience against extreme climate-related and other events – is a major challenge facing the cities of the future. When planning for future cities, an authentically holistic approach is essential if the dependency on water and the need to protect the wider environment and vital natural assets are all to be accommodated effectively [7].

Water shortages, flooding and watercourse pollution are all signs of stress where developed areas have a troubled interaction with the natural water cycle and where, conversely, water has become a risk or a nuisance rather than an asset or an opportunity.

Under the current urban model, neither the supply of the required resources to the inhabitants of the city nor their conservation can be assured for such a high population concentration. The number of large cities prone to insufficient water supplies could increase over the next 25 years — even without accounting for climate change [8].

New water sources, such as reclaimed water or rainfall reuse, are then of extreme importance to guarantee the proper water demand of cities. The reuse of water for different purposes depending on its purity and type is essential to maximising this valuable and limited resource.

Traditional urban water management relies on central organised infrastructure, the most important being the drainage network and the water distribution network.

To meet new challenges, such as CC and changes in the population and land use (growth as well as shrinkage in the cities), it is

</td></tr>
</table>

Water Management

WHY	commonly agreed that water infrastructure needs to be more flexible, adaptable and sustainable [9,10]. These efforts towards increased sustainability are denoted Sustainable Urban Drainage Systems, SUDS; water sensitive urban design, WSUD; low impact development, LID; and best management practice, BMP [11]. The common feature of all solutions is the push from a central solution to a decentralized solution in urban water management. When rain falls on a natural landscape, it soaks into the ground (infiltration), evaporates, is taken up by plants (evapotranspiration) and some of it eventually finds its way into streams and rivers. These stages of the water cycle can be impeded when land is altered by development. In urban areas, there tends to be less permeable ground available for infiltration and less vegetation for evapotranspiration. When rain falls on impermeable surfaces, much more of it turns into surface water runoff, which can cause flooding, pollution and erosion problems. Climate change projections show it is likely that heavy rainfall and flooding will become more frequent. Continuing to provide new sewer capacity to cope with these growing risks is unaffordable. The traditional method of draining surface water runoff from built-up areas, through underground pipe and tank storage systems, was intended to protect public health and prevent local flooding by taking the water away from source as quickly as possible. Most of the sewer systems in Europe are combined systems where the water runoff mixes with sewage. In such systems, this can place a significant and unpredictable burden on wastewater treatment works, triggering some of the untreated sewage to spill into receiving watercourses via combined sewer overflows (CSOs). Flooding (contaminated with sewage) can also occur from surcharged manholes. In more recent developments, separate sewerage networks have generally been provided for the foul and the surface water systems. The foul water is piped to the wastewater treatment works, while the surface water is piped to the nearest watercourse. These separate surface water sewers reduce the risk of CSO spills, but still transfer the pollutants present in urban runoff (including potential misconnections) from the urban surface directly to receiving waters. Although attenuation tanks and flow controls may sometimes be used to control increased peak flow rates, changes in discharge frequencies and volumes are generally not addressed, and these can lead to physical impacts such as erosion and disturbance to habitats and ecosystems.
WHERE	R / M / U / S / B

Water Management

<table>
<tr><td>SUB-CHALLENGES identification & description</td><td>Flooding: With a changing climate, the frequency of flood peaks is predicted to increase. Estimations point towards an average doubling of severe flood peaks with a return period of 100 year within Europe by 2045 [12]. In addition, this is matched by a rise in sea level that, together with a predicted increase in windstorm frequency, will lead to an increase in coastal flooding [13]. As most of the urban areas within Europe are situated either on floodplains or along the coast, these two types of flooding will have a major impact across European cities. Climate driven increasing sea levels in certain areas of Europe will also translate into more frequent basement flooding [14].

Water scarcity: by 2030 there will be a global gap between water supply and demand of 40 %. Water has a very local dimension, and scarcity and droughts have far reaching consequences. Various regions in Europe (North, South, East and West) are threatened by a lack of water or under stress of salinization.

Water quality: there is a long list of molecules that threaten the health of our drinking water, livestock, process water, fish, shellfish and swimming water: pharmaceuticals, personal care products, organic compounds, endocrine disruptors, pesticides, and other priority substances. The traditional waste water treatment plants are not designed to eliminate these substances.

Circular Economy: the drive for a circular economy puts water at the centre. As the most common used solvent on the planet most of our resources end up in water. Communal waste water treatment plants are a good source for energy, nutrients, cellulose, bioplastics and proteins. Industrial waste water can contain metals, minerals, proteins and fatty acids. Closer to the source leads to higher quality of recovered material.</td></tr>
<tr><td colspan="2">HOW</td></tr>
<tr><td><u>Prioritised</u> potential actions to deal with this challenge</td><td>Expected impacts for these actions</td></tr>
<tr><td>1. SuDs:
• SuDs
• Grassed swales and water retention ponds
• Rain garden</td><td>SuDS are drainage systems that are considered environmentally beneficial, causing minimal or no long-term detrimental damage. Designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies.</td></tr>
</table>

Water Management

2. Flood actions: • Urban catchment forestry • Hard drainage-flood prevention Unearth water courses • Channel renaturing • Floodable parks • Green roofs	NBS design to **"slow the flow" of water** through the catchment, thus **reducing flood risk** and the **amount of polluted water entering the sewerage system**. A floodable park consists on a vegetated detention basin designed for short-term temporal water storage by using an existing natural depression in the ground or by creating a new one. Green roofs are a green infrastructure (GI) option that can be applied to virtually any rooftop given weight load capacity. It is calculated that green roofs can suppose an 85 to 90 per cent **reduction in peak runoff coefficient** compared to an impermeable surface [15].
3. Water treatment: • Green filter area • Natural wastewater treatment • Electrowetland • Green roof	NBS aiming at **removing the pollutants in water** (mainly wastewater): organic matter, nutrients and other contaminants such as heavy metals and emerging contaminants. Depending on the final effluent's quality the reclaimed water can be reused for urban purposes (irrigation of green areas) increasing the availability of water resources in the city. Additionally, there is an increasing number of studies exploring the way of integrating **wastewater treatment** (mainly grey water) in green roofs. This technology appears a promising method for dual purpose water recycling and urban cooling [16].
4. Green pavements: • Hard drainage pavements • Green pavements / green parking pavements • Cycle-pedestrian green pavement	Pavements with a **high drainage capacity** that allow storm water to permeate through the surface and are retained before being released into managed water systems. These pavements **reduce the impact of rainwater** on urban infrastructures and wastewater municipal treatment plants.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Run-off coefficient in relation to precipitation quantities. ***KPI 16***	This KPI estimates the volume of runoff reduction by urban green spaces in each of the different sites where NBS´s will be allocated. It is based on the Soil Conservation Service Curve Number (SCS-CN) method [17].

Water Management

Absorption capacity of green surfaces, bio-retention structures and single trees ***KPI 20***	The use of urban greenspace is increasingly being identified as a tool to reduce runoff and so mitigate the negative effects of urbanization upon the hydrology of urban areas. This KPI measures the bioretention capacity of green spaces related to the soil infiltration and retention capability and the interception of the rainfall and evapotranspiration by the vegetation. Also based on the SCS-C method.
Temperature reduction in urban areas. ***KPI 22***	Green and blue urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapotranspiration, which leads to two benefits: improved thermal comfort and reduced energy use.
Areas and population exposed to flooding. ***KPI 29***	This KPI evaluates the increasing on green areas and its relation with the flooding risks.
Drinking water provision ***KPI 33***	KPI related to the consumed volume of drinking water in households, building and companies in the city. Measurements through individual water meters.
Water for irrigation purposes. ***KPI 34***	Some NBS are able to treat wastewater at the time other ecosystem services are provided. As a function of the effluent quality, several uses for the regenerated wastewater can be considered, one of which is for irrigation purposes.
Volume of water removed from water treatment system. ***KPI 38***	Green infrastructure can prevent rainfall from entering the water treatment system by allowing it to soak into the soil or to evaporate back into the air.
Volume of water slowed down entering sewer system. ***KPI 39***	This KPI is principally based on investigating rate change in runoff production at field or plot scale.

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Keywords used	Water, floods, water scarcity, water quality, sustainable water management.

Water Management

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Table 3: Water Management challenge card

2.3 Coastal Resilience

Coastal Resilience

3 **WHAT**	Tens of millions of people worldwide will be affected by coastal flooding in the next few decades due to sea-level rise and associated increases in wave action and surges. In addition, coastal habitats are facing increasing risks worldwide as a result of human activity. These habitats provide a number of ecosystem services or benefits, including coastal protection, fish production, recreation and other economic and cultural values. In many occasions, the degradation of coastal habitats can result in a decrease in coastal protection and in increasing the risk of coastal flooding [1]. Coastal resilience means building the ability of a community to "bounce back" after hazardous events such as hurricanes, coastal storms and flooding – rather than simply reacting to impacts. Resilience is important everywhere because all communities face hazard threats such as droughts and flooding. Coastal areas have additional hazard risk from storms such as hurricanes and increased population pressures, making resilience particularly important in those locations. The ability of a community to recover successfully is linked to the strengths and capacities of individuals, families, businesses, schools, hospitals and other parts of the community. There are also more people moving into high-risk areas such as the coast. With these population increases, homes, businesses and infrastructure are also at great risk of damage. Resilience is our ability to prevent a short-term hazard event from turning into a long-term community-wide disaster. While most communities prepare themselves to respond to emergencies effectively, many of them are not adequately prepared to recover in the aftermath [1,8,9].
WHY	Resilience is important everywhere because all communities face hazard threats such as droughts and flooding. Coastal areas have additional hazard risk from storms such as hurricanes and increased population pressures, making resilience particularly important in those locations. Coastal flooding due to extreme weather events and sea level rise is of growing global concern [3] and increasing coastal resilience to these threats is a priority for many countries and a global need [2]. Flooding, erosion, inundation and extreme weather events affect hundreds of millions of vulnerable people, important infrastructure, tourism and trade, causing significant human suffering and important losses to national economies.

Coastal Resilience

WHY	In 2011, insured losses from natural disasters reached an all time high and impacts could be worse with climate change and population growth. The proportion of the world's GDP annually exposed to tropical cyclones has increased from 3.6 percent in the 1970s to 4.3 percent in the first decade of the 2000s [4]. Insurers have paid more than $300 billion for coastal damages from storms in the past 10 years, which often goes toward rebuilding similar coastal infrastructure that is still vulnerable to coastal storms and flooding. In the context of long-term coastal risk management planning, there are wide ranges of potential approaches that can be adopted to achieve resilience. These can be divided into three categories: • Natural and nature-based options: working with existing or new/designed features such as wetlands, beaches, dunes, barrier islands, sea grass beds and/or reefs. • Non-structural – land planning policies: building codes and emergency responses such as early warning and evacuation plans. These options can involve removing risks by avoiding or moving inappropriate development in vulnerable areas or flood proofing buildings to reduce their vulnerability to flood damage. • Structural options: hard engineered options such as seawalls breakwaters, surge barriers, groynes, levees and sills. There is a growing body of evidence, from both scientific research and experiences during recent storms, that natural habitats and landforms can fulfil a vital function in coastal risk reduction. Intertidal and sub-tidal habitats (such as coral reefs, saltmarsh, mangroves and beaches) dissipate wave energy naturally, reducing erosive forces while backshore and upland features (such as sand dunes, ridges and forests) provide effective barriers to storm surge propagation and its consequent flooding. These features also provide a multitude of other benefits including aesthetics, habitat and species conservation and development buffers. A significant benefit of natural defences is their in-built ability to 'adapt' to natural change over time. Natural features respond to both occasional (e.g. storms) and chronic (e.g. sea level rise) events dynamically by rebuilding or migrating landwards. Their form is maintained and the provision of sources of sediment is not disrupted. In some occasions, additional maintenance activities such as sediment nourishment may be required. This natural response to adaptation makes these features highly sustainable as a long-term coastal risk management option.

Coastal Resilience

WHY	Even in locations where built assets are at very high levels of risk, a structural protection such as levees or walls it is deemed necessary. Natural defences in front of these structures can greatly reduce their day-to-day exposure, increasing their life and reducing maintenance commitments [5, 6]. There is an increasing need to inform about decisions with scientific evidence and the use of nature-based solutions by: ▪ Developing hybrid approaches that link natural and built defence structures to reduce the risks of sea level rise and storm surge. ▪ Managing freshwater resources in innovative ways to benefit nature, economy and society. ▪ Connecting freshwater resources to coastal habitats and communities. ▪ Accounting for multiple ocean benefits provided by various ecosystems through comprehensive marine planning. ▪ Illustrating mitigation pathways that reduce CO_2 levels through improved management of forest, wetland and grassland ecosystems. ▪ Reducing water treatment costs for downstream cities while improving biodiversity and human health in upstream watersheds. ▪ Using water markets to incentivize conservation and reallocate saved water back to freshwater and estuary ecosystems.
WHERE	M/U
SUB-CHALLENGES identification & description	Coastal Resilience promotes advance planning to **mitigate disaster vulnerability**, and encourages the use of nature-based approaches where appropriate. While no amount of either natural or built infrastructure will provide protection from the biggest coastal hazards, there is substantial evidence that coastal natural habitats can effectively protect coastlines and reduce human vulnerability to more typical annual and decadal coastal hazard events.
	Coastal Resilience affects not only the biggest coastal hazards when disaster events occur but also could have a great influence in social and economic aspects such as the ones related with the bathing water quality or the loss of important ecosystems due to water

Coastal Resilience

	management issues, continuous erosion or the construction pressure in the shoreline.

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Planting and renewal of urban trees	Wooded areas support coastal resilience against natural disasters such as mangroves or cassowaries forests.
2. Planting and renewal of shade and cooling trees	Wooded areas support coastal resilience against natural disasters.
3. Arboreal areas around urban areas	Arboreal interventions at coastal wetlands will regulate the surface runoff and decrease flooding risk.
4. Trees renaturing parking	The trees installation in park zones will allow improve the filtration of runoff water and decrease flooding risk.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Shoreline characteristics and erosion protection ***KPI40***	Physical indicators: land-use and land cover changes, monitoring of physical parameters, number and extent of flooded areas, spatial analysis, GIS-based spatial analysis and modelling. [7]
Soil, temperature, drainage ***KPI41***	
Flooding characteristics ***KPI42***	
Avoided Damage Cost ***KPI43***	Economic indicators: cost-benefit analysis, price analysis, willingness to pay. [7]
Changes in property value ***KPI44***	

Coastal Resilience

Recreation and public access ***KPI45***	Social and educational indicators: surveys, estimates of the potential of NBS tourism, number of visitors, number and extent of research and education programs. [7]
Number of students benefiting from education and research about coastal resilience/amenity ***KPI46***	
Estimates of species, individuals and habitats distribution ***KPI47***	Biological indicators: estimated habitat suitability index and modelling, species census, spatial distribution of vegetation, normalized vegetation index, monitoring using citizen applications. [7]
Invasive and planted species ***KPI48***	
Algal bloom ***KPI49***	
Concentration of nutrients ***KPI50***	Chemical indicators: lab and field analysis of water quality, permanent monitoring system. [7]
Salinity, pH ***KPI51***	

LINKS and REFERENCES

Keywords used	Coastal risk reduction, resilience, flooding, erosion, extreme weather events, sea level rise, high-risk areas
Links and references	[1] The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature- Based Defences, Narayan S. et al, 2016. [2] A global strategy for protecting vulnerable coastal populations, Science, 345 (2014), pp. 1250-1251, E.B. Barbier, 2014. [3] IPCC Working Group II Climate Change 2014: Impacts, Adaptation, and Vulnerability Intergovernmental Panel on Climate Change (2014). [4] United Nations, European Commission, Food and Agriculture Organization, International Monetary Fund, Organization for Economic Cooperation and Development, and World Bank Group.

Coastal Resilience

	2012. System for Environmental-Economic Accounting: Central Framework. [5] Coastal Risk Reduction - Integrating Natural Defenses into a Sustainable Coastal Risk Management Framework, CH2M, 2016. [6] http://www.conservationgateway.org/ConservationPractices/Marine/crr/ library/Documents/TNC_CH2M_Natural%20Defenses%20report.pdf. [7] An impact evaluation framework to support planning and evaluation of nature-based solutions projects - An EKLIPSE Expert Working Group report (2017). [8] https://oceanservice.noaa.gov/facts/resilience.html. [9] http://unstats.un.org/unsd/envaccounting/White_cover.pdf.

Table 4: Coastal Resilience challenge card

2.4 Urban Green Space Management

Urban Green Space Management

4 **WHAT**	Urban Green space management here refers to the existence, planning, and on-the-ground management of green and blue infrastructure in urban areas. Green and blue infrastructure includes both natural and semi-natural elements in urban areas, and provides a range of ecological and socio-economic benefits [3]. The challenge can be used to refer to issues and interventions at a wide range of scales, from the building and street level all the way to the regional level. For the purposes of this catalogue, the term "green infrastructure" or GI will be used, but this does include blue infrastructure as well.
WHY	GI essentially provides the life support system for urban areas [1]. When implemented strategically and at a large enough scale, GI is multi-functional, meaning it provides a wide range of ecosystem services alongside a range of cultural and social values. The quantity and quality of GI is thought to be particularly important for [7,8,3,4]: - Promoting ecosystem health, function, and conservation of biodiversity - Provision of ecosystem services - Enhancing human health, social cohesion well-being GI can also provide a wide range of other benefits that link directly to all the other challenge areas. This includes the development of a green economy, sustainable land and water management (e.g. Sustainable Urban Drainage systems are often GI), mitigation of climate change impacts (e.g. reduction in urban heat island effect), and reduction of air pollution. Societal benefits extend to mental health and well-being, with studies showing measurable health benefits (e.g. reduction in salivary cortisol and blood pressure) after just 5 minutes of exposure to urban nature, particularly when active [5]. They also show lower rates of blood pressure and depression are evident among urban residents who spend 30 minutes or more per week in green space [6]. These health and well-being benefits are important not just at the individual level, but if implemented widely could save expenditure on health care. By increasing the extent and improving the quality of GI in areas of cities where health outcomes are poor, it could also play an important role in addressing multiple deprivations. Biodiversity decline is also one of the major environmental challenges globally. When planned and implemented strategically across an urban area, GI can make an important contribution to addressing this challenge by providing structural and functional connectivity and habitat.

Urban Green Space Management

WHY	Renaturing cities, including expansion of GI, also increases the species richness of a range of flora and fauna, including pollinators, which provide vital ecosystem services locally but are on the decline [2]. However, urban GI is often low in diversity and located opportunistically rather than planned and implemented as an NBS. Intentional intervention to increase functional and structural connectivity, as well as species richness of these areas, can contribute to addressing this challenge, with urban planning and the development of green space management plans being a key point of intervention, particularly in rapidly expanding urban areas.
WHERE	M/U
SUB-CHALLENGES identification & description	N/A

HOW	
Prioritised potential actions to deal with this challenge	**Expected impacts for these actions**
1. Planting and renewal of urban trees	Strategic species choice in planting and renewing urban trees can **support biodiversity** by providing islands of respite from grey infrastructure and **critical habitat** for struggling or targeted dependent organisms, such as a specific bird species. Strategic choice in species and planting in corridors can enhance **wildlife habitat** and functional and structural **connectivity**.
2. Arboreal areas around urban areas	Arboreal areas on the urban periphery can represent important **wildlife corridors** in a fragmented landscape.
3. SuDs	SuDs encompass a wide variety of solutions, including rain gardens and swales. When they **contain native plants**, SuDs can **provide habitat for beneficial pollinators, plants and birds**. If planted strategically in green corridors, they can also improve **connectivity** and as rain gardens can increase both quality and quantity of green areas and create new ecosystems.
4. Pollinator verges and spaces	New or existing linear features (verges) or patches (spaces) of green space, sown with a wildflower-rich grassland seed mix, to provide nectar and pollen to attract foraging insect pollinator species (**provide food and habitat**). Linking areas of flower-rich green space to **create sustainable networks** of pollinator habitat within the urban area. This can also include low cost activities such as reduced mowing frequency.

Urban Green Space Management

5. Green resting areas and parks	Green resting areas, parks, and parklets are **green spaces** that play a central role in policies related to health, nature conservation and spatial planning. These areas are **multifunctional**, and can provide many environmental (i.e. pollution control, local reduction in urban heat islands, increased biodiversity), economic (i.e. increased property values, reduced expenditure on health care) and psychological (i.e. wellbeing) benefits. They also play important social roles in **passive recreation** (resting, relaxation, observing nature, social contact) and can form part **active recreation and transport corridors**.

HOW MUCH	
KPIs used to assess NBS impacts in this challenge	**General KPI description**
Increased connectivity to existing GI ***KPI 76***	The extent and spatial arrangement of accessible green space within each sub-demo area may have an important influence on public health and wellbeing; as well as having the potential to increase biodiversity. Vegetated areas provide cooling on hot days through evapo-transpiration; and trees reduce radiant heat by shading, making public space and travelling routes more comfortable for people on days when temperatures in urban areas are high. This KPI will focus on public accessible green space and omits private gardens.
Pollinator species increase ***KPI 77***	Increase in density and seasonal spread of floral resources for pollinators, measured through ecological surveys of selected taxa at NBS pre-intervention and post-intervention. Pollinator species richness/abundance/seasonal spread at NBS pre and post intervention will then be compared.
Increase in plant species richness and functional diversity as a result of NBS ***KPI added***	Increase in plant species richness and functional diversity measured through ecological surveys of selected taxa at NBS pre-intervention and post-intervention. Plant species richness and functional diversity at NBS pre and post intervention will then be compared.
Increase in Insectivore (e.g. bat) abundance and use of corridors for movement as a result of NBS. ***KPI added***	Increase in insectivore (e.g. bat) abundance and use of corridors for movement will be measured through ecological surveys of insectivores in areas with NBS pre- and post-intervention. Changes in abundance and movement will then be compared.

Urban Green Space Management

Accessibility of urban green spaces for population ***KPI 53***	Calculation of the shortest distance (linear) between the population in the NBS (line type), and the NBS location centroid. Results obtained in distance (m) and time (min). Tool: Geographic Information Systems. GIS analysis of distance of NBS site from home, schools, and businesses. Land use cover will also be analysed in GIS to show what each area is comprised of, what different NBS are located within each site, and what socio-economic amenities can be identified. (Links to recreation opportunities).
Recreational or cultural value ***KPI 54***	Baseline and post-intervention measurements of engagement with NBS through walking and cycling, Types of activity undertaken in/with NBS (other than walking and cycling), frequency of interaction with NBS. Reported as frequency count data (interactions/week) (number of visitors, number of recreational activities).

LINKS and REFERENCES

Keywords used	Green space, blue space, open space, biodiversity, urban biodiversity, green infrastructure, blue infrastructure, pollinators
Links and references	[1] Benedict, M.A. and McMahon, E.T., 2006. Green infrastructure. *Island, Washington, DC.* [2] Connop S., Vandergert P., Eisenberg B., Collier M. J., Nash C., Clough J. & Newport D. 2016. Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. *Environmental Science & Policy,* 62**,** 99-111. [3] Raymond C.M., Frantzeskaki N., Kabisch N., Berry P., Breil M., Nita M.R., Geneletti D. & Calfapietra C., (2017), A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas, Environmental Science and Policy, 77, 15-24. [4] Sinnett, D., Smith, N., & Burgess, S. (2015). *Handbook on Green Infrastructure: Planning, design and implementation*. (D. Sinnett, N. Smith, & S. Burgess, Eds.). Cheltenham: Edward Elgar Publishing Ltd. [5] Shanahan D. F., Fuller R. A., Bush R., Lin B. B. & Gaston K. J. 2015. The Health Benefits of Urban Nature: How Much Do We Need? *BioScience,* 65**,** 476-485. [6] Shanahan D. F., Bush R., Gaston K. J., Lin B. B., Dean J., Barber E. & Fuller R. A. 2016. Health Benefits from Nature Experiences Depend on Dose. *Scientific Reports,* 6**,** 28551.

Urban Green Space Management

Links and references	[7] Tzoulas K., Korpela K., Venn S., Yli-Pelkonen V., Kazmierczak A., Niemela J. & James P., 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and urban planning*, *81*(3), pp.167-178. [8] Vujcic M., Tomicevic-dubljevic J., Grbic M., Lecic-Tosevski D., Vukovic O., & Toskovic O., 2017. Nature-based solution for improving mental health and well-being in urban areas. Environ Res. 158: 385-392

Table 5: Urban Green Space Management challenge card

2.5 Air Quality

Air Quality

5 **WHAT**	A number of factors threaten the quality of life in European cities and in most of the world. The drivers include increasing pollution levels, urban heat islands, flooding and extreme events related to Climate Change, as well as decreased biodiversity [1]. These can have detrimental effects for human health and well-being. **Air quality** is a major concern worldwide, particularly in urban areas, due to its direct consequences on **human health, plants, animals, infrastructure and historical buildings** (among others). In the political agenda, air quality issues can be coupled with climate change mitigation policies as described in Challenge 2.1, since many actions aimed at air quality improvement involve a concurrent reduction of GHG emissions. This is the case, for example, of reductions of fossil fuel combustion since its derived emissions contain CO_2 and other greenhouse gases (GHGs) and pollutants directly affecting human health. Nevertheless, measures to improve urban air quality and mitigate climate change tend to be considered separately even though many pollutants affect both environmental impacts. The emission of the traditional air quality pollutants (AQPs) either direct or indirectly as a result of atmospheric chemistry, affect the concentrations of several climate pollutants. At the same time, the increase of air temperature due to global warming affects the concentrations of the AQPs. Some AQP, such as ozone (O_3), are also GHGs. These interactions between them are complex and can both enhance and mitigate global warming. Accordingly, a large number of abatement measures are beneficial for mitigating both impacts; however there are some measures that may be beneficial for mitigating climate change but increase emissions of the key urban air pollutants, and vice versa. **Policies to reduce climate change and improve urban air quality** have generally been considered in isolation, with more importance being paid to the mitigation of climate change than to urban air quality over recent years. In the long term, large reductions in both the AQPs and GHGs are needed to minimise climate change and improve public health. Therefore, priority should be given to measures where there are clear co-benefits such as energy conservation measures. However, large emission reductions from this type of measures can be difficult to achieve and there will continue to be a need to use legislation to force the adoption of low AQP emitting technologies despite some CO_2 penalties. Fuel switching to renewable fuels offers a huge potential for co-benefits, with only biomass and biofuels being problematic in terms of indirect GHG emissions from land use changes and higher emissions of particulate matter (PM) from solid biomass and gaseous pollutants from some liquid biofuel blends [2].

Air Quality

WHAT	Air pollution is a local, pan-European and hemispheric issue. Air pollutants released in one country may be transported in the atmosphere, contributing to or resulting in poor air quality elsewhere. **Particulate matter**, **nitrogen dioxide** and **ground-level ozone**, are now generally recognised as the three pollutants that most significantly affect **human health**. Long-term and peak exposures to these pollutants range in severity of impact, from impairing the respiratory system to premature death. Around 90 % of city dwellers in Europe are exposed to pollutants at higher concentrations than the air quality levels deemed harmful to health. For example, fine particulate matter ($PM_{2,5}$) in air has been estimated to reduce life expectancy in the EU by more than eight months. European Union legislation sets air quality standards [3] (Directive 2008/50/EU) for both the short-term (hourly/daily) and long-term (annual). Air pollution also **damages our environment**. Problematics such as acidification was substantially reduced between 1990 and 2010 in Europe's sensitive ecosystem areas that were subjected to acid deposition of excess sulphur and nitrogen compounds. Less progress was made in environmental problematics such as eutrophication, which is caused by the input of excessive nutrients into ecosystems. The area of sensitive ecosystems affected by excessive atmospheric nitrogen diminished only slightly between 1990 and 2010. High ozone concentrations also cause crop damage is caused. Most agricultural crops are exposed to ozone levels that exceed the EU long-term objective intended to protect vegetation. This notably includes a significant proportion of agricultural areas, particularly in southern, central and eastern Europe. There are various **sources of air pollution**, both anthropogenic and of natural origin: ▪ burning of fossil fuels in electricity generation, transport, industry and households; ▪ industrial processes and solvent use, for example in chemical and mineral industries; ▪ agriculture; ▪ waste treatment; ▪ volcanic eruptions, windblown dust, sea-salt spray and emissions of volatile organic compounds from plants are examples of natural emission sources. Another type of air pollution is **noise** [5]. However, in this catalogue noise pollution analysis has been included in challenge 9 related to public health and well-being.

Air Quality

WHY	NBs based on the creation, enhancement, or restoration of ecosystems in human-dominated environments also exploit the synergy between ecosystem processes that regulate pollutants and CO_2 in the atmosphere. Vegetation affects air quality mainly through the removal of air pollutants (PM10, NO_2, O_3) through dry deposition, although certain species can also emit biogenic volatile organic compounds (BVOC), which are ozone precursors. However, vegetation can also reduce air temperature, which reduces the emission of BVOCs and slows down the creation of secondary pollutants such as O_3 [4,5]. Therefore, vegetation could be selected to reduce to a minimum this kind of emissions [6]. Despite their limited contribution compared to the overall production of pollutants and GHG emissions at the city level, measures to tackle air quality by enhancing green infrastructure can be considered a good investment due to the number of co-benefits that they produce and their contribution to amenity value over time [7] but with a limited impact at district or city scale. Green infrastructures are beneficial but most of them do not represent a solution to remove completely air pollution from cities. It should be kept in mind that trying to reduce the concentration of a pollutant once it is already diluted is much more inefficient than when acting directly on the source. However, NBS could be used to treat local problems by placing vegetation systems [8] near to high traffic roads as capture or barrier to "protect" dense hedges, hospitals, schools, etc. Finally, the effectiveness of green infrastructure-based strategies to meet environmental policy targets can vary greatly across pollutants. Accordingly, while NBS can significantly remove PM from air and therefore, should be considered during urban policy-making, other pollutants should be addressed by different methods/technologies to reach detectable effects. Some of the traits that are beneficial for air pollution mitigation may act in opposite directions for specific services: for instance, uptake capacity increases air quality but decreases plant health, while other traits such as a large leaf area help cool the environment and at the same time reduce air pollutants. It should also be mentioned that ecosystem services are sometimes indirectly related, for example by modifying the microclimate and thus energy consumption, which then reduces anthropogenic emissions. The complexity of the matter has prevented holistic investigations for specific cities or regions, although model approaches that integrate at least some aspects are already available [9]. Some NBS have the capacity to attenuate the noise levels or to isolate zones of others with higher levels. URBAN GreenUP will carry out a

Air Quality

	demonstration of a NBS specifically design to reduce noise levels and to isolate some pedestrian or cycle areas of traffic noise.
WHERE	B / S / U
SUB-CHALLENGES identification & description	Air pollutants may be categorised as primary (directly emitted to the atmosphere) or secondary (formed in the atmosphere form precursor pollutants). **Primary pollutants. Particulate Matter (PM, $PM_{2,5}$ and PM_{10}).** **Particulate matter**, also known as particle pollution, is a complex mixture of solid particles and liquid droplets that are incorporated into the air matrix that can be inhaled. PM is commonly measured according to particle sizing and divided in two main groups: $PM_{2.5}$ and PM_{10} (particles smaller than 2.5 and 10 µm, respectively) Once inhaled, these particles can affect the heart and lungs [11]. **PM_{10}** is limited by EU Ambient Air Quality Directives to a yearly average 40 µg/m^3 and a daily value of 50 µg/m^3 [12]. However, concentrations were above the EU limit value in large parts of Europe in 2015. There were 19 % of stations with concentrations above the daily limit value for PM_{10} in 20 Member States and five other reporting countries [12]. From those stations, 95 % were either urban (78 %) or suburban (17 %). Regarding the **$PM_{2.5}$**, EU legislation limit of yearly average is of 25 µg/m^3. Again, concentrations were higher than the limit value in 3 Member States (Poland, Italy and Czech Republic) and 3 other reporting countries (Albania, the Former Yugoslav Republic of Macedonia and Kosovo). These values above the limit value were registered in around 6 % of all the reporting stations and also occurred primarily (93 % of cases) in urban or suburban areas [12].
	Primary pollutants. Nitrogen oxides (NO_X, NO and NO_2). Nitrogen oxides are a group of gases made up of nitrogen and oxygen that cause acid rain and other environmental problems, such as smog and eutrophication of coastal waters. Burning fossil fuels, such as coal and gasoline, releases NO_X into the atmosphere [11]. Twenty-two of the EU-28 recorded concentrations above the annual limit value (10.5 % of all the stations measuring NO_2 [12]). EU Ambient Air Quality Directives limit NO_2 concentrations to a yearly average of 40 µg/m^3.
SUB-CHALLENGES identification & description	**Secondary pollutants. Ozone (O_3).** Known as tropospheric or ground-level ozone, this gas is harmful to human health and the environment. Since it forms from emissions of volatile organic compounds (VOCs) and nitrogen oxides (NO_X), these pollutants are regulated under air quality standards [11].

Air Quality

	Long-term objective for ozone concentrations is established at 120 µg/m^3 by the EU Ambient Air Quality Directives and the target value for the daily 8-hour mean is of 120 µg/m^3. 18 Member States and 7 other reporting countries registered concentrations above the O_3 target value more than 25 times. In total, 41 % of all stations reporting O_3 with the minimum data coverage of 75 % showed concentrations above the target value for the protection of human health in 2015 (considerably more stations than over the previous 5 years). In addition, only 13 % of all stations fulfilled the long-term objective and 88 % of the stations with values above the long-term objective were background stations [12].

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Urban Garden BioFilter	This NBS uses a special substrate (mixture of urban by – products) as filter media to **capture pollutants** (mainly **NO_x** and **PM**) form the air of underground car parks without waste generation.
2. Urban Trees including: planting and renewal of urban trees; shade trees; cooling trees; trees renaturing parking and arboreal areas around urban areas	This NBS includes individual large street trees as well as the larger areas of woodland in the urban fringes. Trees perform multiple functions in urban areas and are a vital element of our green infrastructure. Strategic positioning of **large shade and cooling trees** within urban areas can provide shade to buildings, reducing heat loading on building, provide islands of respite from high temperatures and **capture some air pollutants (mainly PM)** by dry deposition in our urban areas.
3. Green façade	It is a wall completely or partially covered with greenery. A green façade with climbing plants uses a trellis system to hold the vines of plants that are rooted in the ground or containers. Green façades offer economic, environmental, aesthetic and physiological benefits to the urban environment. They are **natural air-filters** mainly for **PM**, creating a cleaner environment and provide high leaf surfaces.
4. Green shady structures	Pieces of stretched textile structure on which an inert substrate is installed, covered with seeds, which germinate and grow on the textile structure. This NBS can be fixed to the facades of the buildings on the street or by posts fixed to the sidewalk and it creates high leaf surfaces in pedestrian areas.

Air Quality

5. Green fences	This NBS is designed to **reduce the traffic noise** that arrives the pedestrian area and the homes on the street. Green noise barriers have a specific geometry that favours sound reflection and on the other hand, they have vertical garden modules with a specific substrate that favours sound absorption. Additionally, this solution creates high leaf surfaces near of emission sources increasing **air pollutants (mainly PM) capture** of vegetation.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Annual mean levels of fine particulate matter (e.g. $PM_{2.5}$ and PM_{10}) in cities (population weighted) concentration recorded µg/m^3. ***KPI 83***	Measure air concentrations of $PM_{2.5}$ and PM_{10} at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of road without street trees/green wall at a similar time of day on the same dates.
Trends in emissions NO_X, SO_X. ***KPI 84***	Measure air concentrations of NOX, SOX, VOC at identified sampling points close to planned nature-based interventions and highway improvement schemes both pre- and post-intervention. Compare this data for differences and also compare this data to historical city wide data and trends.
Mean levels of exposure to ambient air pollution (population weighted) (proposed indicator for SDG target 3.9). ***KPI 86***	Measures the level of population exposed to low air quality levels in the city. It will be calculated from ground measurements by the official Air Quality monitoring networks in cities. Additionally, information on the type of the zone (road traffic, city background, industrial, etc.) has been assigned to the different areas/streets of the city to weight population.
Monetary values: value of air pollution reduction [14]; total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values [15]. Use of GI val to calculate the value of air quality improvements.	Measures the monetary benefit associated to air pollution reduction. It quantifies the avoided damages and costs resulting from the air pollution reduced due to the implementation of the NBS. The market costs of air pollution include reduced labour productivity, additional health expenditure, and crop and forest yield losses. These costs will be partially avoided due to air pollution improvement.

Air Quality

KPI 88	
Air quality parameters: NO_x, VOC, PM, etc. ***KPI 92***	Measure air concentrations of NO_2, $PM_{2.5}$ and PM_{10} at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of road without street trees/green wall at a similar time of day on the same dates.

LINKS and REFERENCES

Keywords used	Air quality, air pollutants, nitrogen oxides (NO_X), particulate matter, $PM_{2,5}$, PM_{10}, Ozone (O_3), human health, Biogenic Volatile Organic Compounds (BVOC).
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Air Quality

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Table 6: Air Quality challenge card

2.6 Urban Regeneration

Urban Regeneration

6 **WHAT**	Nowadays urbanisation is rising so fast that is becoming in a global phenomenon and gaining importance at planetary level. Seventy percent of earth surface will be shaped by human influence by the year 2050. In so-called Age of Anthropocene or Post-Natural Age, nature-culture dichotomy has been altered by human culture which means that urban nature has been emerged. For this reason, coupled with climate change effects and uneven urbanization practices, cities and city-regions in the world should find new forms of relationships with nature. The rapid developing and change of industrial activities, the uncontrolled urban sprawl as well as the large, concentrated and often culturally diverse populations have created a multitude of social and health problems [1]. Regarding urban regeneration, cities and urban communities have to cope with derelict industrial sites, dis-functioning urban areas, social exclusion, inequalities and degraded urban environments. These challenges have serious impacts on human health, quality of life, well-being and security of citizens, particularly among the less privileged social classes. Growing urban populations and economic activities also require a new urban development at a rapid pace, which often causes severe environmental problems. This situation disturbs the regenerative capacity of natural ecosystems. Cities consume over two-thirds of the world energy and account for more than 70 % of the global CO_2 emissions generated by human activity. In cities, buildings are responsible for consuming a significant amount of energy (approx. 40 % of the UK and US emissions) [2]. Therefore, it is important to promote energy conservation retrofits to reduce the energy consumption and the cost of heating, cooling and lighting buildings. Urban regeneration involved a policy of slum clearance and replacements during the postwar period. By the late 1960s, most Western European countries substituted this approach by promoting renovation. Early regeneration programmes involved the demolition of inner city slums and the reallocation of residents to new development areas towards suburban locations. By the mid-1970s, it was recognized that social problems were not able to be solved by providing new housing simply. Residents were often disconnected from their social networks as well as from essential community services. This property-led approach had limited social and environmental benefits and emphasized the problem of displacing local residents via gentrification [3]. Since the post-industrial era (1990s), urban development rates for developed countries are constant with some decreasing periods

Urban Regeneration

WHAT	because cities have experienced deindustrialisation and out-migration [4]. As it has been explained before, there was an excessive urban growth for the developing world because of an industrialization process at a rapid pace during almost the entire 20th century. This uneven growth blocked the access to water and energy infrastructure. Rural to urban migration was obvious with squatter settlements which regeneration was mostly the property-led redevelopment projects without environmental concerns [4]. Urban regeneration comes from a variety of names, including “urban renewal”, “urban refurbishment”, “redevelopment” and “urban retrofit” and it can take many forms. Environmentally sustainable urban regeneration simply means the “recycling” of land and buildings, saving on demolition waste and new construction materials, as well as reducing demand for peripheral urban growth and facilitating densification and compactness of existing urban areas [5].
WHY	For property-led urban regeneration schemes, economic development often takes precedence over environmental concerns so that environmental sustainability is often ignored. Therefore, a policy shift towards renovation rather than demolition is necessary and it could be interpreted as an option towards a more environmentally sustainable regeneration. Nowadays, people relate urban environments to places for interaction, where innovation, knowledge and creativity are the main drivers [6]. This understanding of urban reality also needs a new approach to the existent urban factories, in order to prepare them for a low-carbon, dynamic and sustainable development [7]. Low-carbon sustainable development has become a goal in some urban regeneration programmes recently translated into the minimisation of required inputs of energy, water, food, materials, etc. as well as process outputs such as waste, heat, air and water pollution, carbon emissions, etc. [5]. A healthy environment and the urban regeneration process have to complement each other in innovative forms like the use of NBS [8]. Investment in sustainable transport such as cycling can support people to lead a more active lifestyle in their day-to-day with plenty of benefits for physical and mental health. Investments in quality and connectivity of public areas for playing, sporting and food growing can also enhance them. The availability of fresh fruit and vegetables throughout the city (i.e. allotments, community gardens or private gardens), for instance, can support a healthy diet and local food culture [5].
WHERE	M / U / S / B

Urban Regeneration

SUB-CHALLENGES identification & description	**Managing urban growth:** integrated urban built areas with planning strategies such as green growth (i.e. Blue and Green Corridors within the City).
	Redevelopment areas: Conversion of brownfield and degraded areas (i.e. abandoned industrial sites with toxic soils) to green areas [4].
	Urban Retrofitting: Improve Robustness, Sustainability and Energy Performance of Grey Structures (buildings, roads, water channels and other infrastructures), progress towards green buildings by NBSs and green rating systems (i.e. LEED, BREEAM)

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Urban Trees including: Planting and renewal of urban trees, shade trees, cooling trees; trees renaturing parking and arboreal areas around urban areas, urban catchment forestry	Planting and renewal of trees can **facilitate urban and peri-urban regeneration by adding amenity value to an area**. An interconnected network of green spaces **minimizes** the negative effects arising from **urban expansion** and **habitat fragmentation**.
2. Sustainable urban Drainage Systems (SuDs) including: grassed swales and water retention ponds, rain gardens, hard drainage-flood prevention, floodable park, hard drainage pavements, green pavements)	SuDs provide opportunities to create aesthetically pleasing **green and blue corridors**. They can also improve people well-being if they live or work near them or visit or pass through the area. **Amenity benefits** can be obtained in **new constructions and retrofitted** or redeveloped areas, often relate to the pleasure derived from its usefulness. In dense urban environments, SuDs integrated with drainage pavements provide **protection from massive flooding** that cause serious economic costs to those areas that have not enough stormwater infrastructure. These unearth water courses are critical infrastructures that may provide healthy living areas for urban regeneration projects by changing water course management and additional channel modifications.
3. Retrofitting solutions, green over grey including: green filters, natural wastewater treatment, biofilters, community composting; green façades, green roofs, green covering	**Retrofitting solutions increase economic value** (i.e. tax benefits) and the lifespan of grey structures like buildings [1]. Having plants (in the form of green façades, for instance) in and around a building add colour, texture and interest together with biodiversity

Urban Regeneration

shelters, green shady structures, green noise barriers, electro wetlands and green resting areas with parklets and urban orchards.	benefits to urban landscapes. This leads to increase in the use and the investment into an area and can clean pollutants to achieve more living environments, reduce waste and public health benefits.
4. Cycle and pedestrian green routes	Cycle and walking greenway provide an **alternative for mobility** and **recreational**, public health and well-being opportunities. **Reducing the use of vehicles** means fewer emissions of greenhouse gases mitigating climate change, as well as reduced air pollution. Creating a well-connected net of cycle paths and providing green shady routes encourages its use also for mobility purposes.
HOW MUCH	
KPIs used to assess NBS impacts in this challenge	**General KPI description**
Accessibility: distribution, distance, spatial configuration to NBS and green spaces. Diversity of NBS (land use and functionality). ***KPI 95***	This KPI is focused on evaluating the benefits obtained from the implementation of different types of NBS in cities, for example: new green cycle lanes and re-naturing existing bike lanes, green resting areas, cycle-pedestrian green paths, vertical green interventions and horizontal green interventions, urban farming promotion (through urban orchards), community composting and small-scale urban livestock. Educational activities, like educational paths, and urban farming educational initiatives are also evaluated with this KPI.
Assessment of typology, functionality and benefits provided pre and post interventions. ***KPI 109***	This is a global indicator which aims to analyse urban regeneration (metropolitan or urban scale) taking into account typology, functionality and benefits. Its results will show the potential of a NBS to protect, improve and regenerate urban spaces.
Savings in energy use due to improved GI. ***KPI 110***	Energy sector is the largest single source of global GHG emissions and responsible for over a quarter of all EU GHG emissions. Green infrastructures can play a key role in reducing the negative impacts of this sector by reducing consumption, providing bioenergy and facilitating carbon uptake and storage. This KPI aims at quantifying both the energy savings and the bioenergy generated by all the NBS implemented.

Urban Regeneration

LINKS and REFERENCES	
Keywords used	Urban regeneration, brownfield, retrofitting
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Table 7: Urban Regeneration challenge card

2.7 Participatory Planning and Governance

Participatory Planning and Governance

7 **WHAT**	Governance refers to a system of social coordination for resolving common problems and achieving common goals [1]. In simple terms, governance is about what you are doing, why you are doing it, who is involved, and how you go about it [2]. The term governance is used because the process of decision-making and actions required are necessarily *beyond* government. The inclusion and active participation of a wide range of stakeholders is essential to resolving the systemic nature of sustainability challenge because, as with other 'wicked' policy problems, governance systems struggle to cope with the ill-defined problem boundaries and the diverse ways in which facts, values, and interests come together to frame policy-making as s [1,3,4,6]. In collaborative governance, the formal institutions of government provide not only the hard infrastructure of the planning system, but also a soft form of infrastructure called "relation-building" [3; p. 200]. This soft infrastructure is the locally specific space where social, political, and intellectual capital is formed. Collaborative planning is central to the particular form of governance that is most fit for implementing NBS, called collaborative governance. Collaboration is borne out of practical need, as ecological features and processes cross jurisdictional boundaries, scales, tenures, economic sectors, and political portfolios. Authority, capacity, and responsibility for NBS implementation thus do not lie with a single, central entity. and consequently, achieving objectives requires involving multiple stakeholders [5,6,7]. Participatory planning and governance increasingly encompasses broader changes in the way society approaches environmental challenges. Top-down and command-and-control approaches to regulation are increasingly replaced with partnerships and preferential use of non-regulatory approaches, such as market-based instruments, voluntarism, and education often executed via collaborative partnerships [8]. Combined with government austerity, moves towards devolved responsibility and alternative funding models [9], these changes require, at the very least, increased coordination between actors to implement NBS, and widespread collaboration and participation of diverse stakeholders in order to mainstream the use of NBS. This challenge includes both planning and governance because the two work hand in hand. Planning is an important part of governance in that it injects a strategic, long-term vision into governance and provides a space for actors to collectively think and act on issues [3]. Strategic planning in particular is important if NBS are to be effective. It is absolutely essential that NBS are implemented at a landscape scale in order to effectively address societal and environmental challenges such as climate change [10], and

Participatory Planning and Governance

	landscape-scale efforts, by their very nature, require collaborative and participatory decision-making processes and coordinated action. In the collaborative planning model, planning occurs through a series of face-to-face dialogues between experts and stakeholders, i.e. actors with an interest in the outcomes at hand [11].
WHY	Participatory Planning and Governance is an importance aspect of urban management, as it provides a structure for the inclusion and discussion of information and expertise from a range of stakeholders, who may otherwise be excluded from decision-making. Participatory processes are, at their core, about ensuring democratic principles of good governance are integrated into planning [4,12,13]. Collaborative planning is also thought to increase institutional capacity by bolstering formal institutions, filling institutional gaps, producing action agendas, and generating innovative ways of solving problems [3,11]. Critically, collaborative and participatory processes build social, political, and intellectual capital within governance systems, which in turn provides new resources for further capacity building [3]. This not only creates new knowledge, but it fosters the changes required to approach urban challenges in new and creative ways, which is essential for mainstreaming the use of NBS in urban planning. Many communities of interest exists in urban areas including local resident groups, community groups associated with specific sites or issues, as well as local businesses, who have a stake in the ways in which the landscape is developed and managed [14]. Within current landscape management practices, there is variation in how such groups are allowed to engage in landscape discussions with local governments. Consequently, the extensive knowledge these stakeholders is often absent from urban greening discussions to the detriment of achieving policy objectives and improving local landscape conditions [15]. Participatory planning is also important for building co-productive capacity, which has proven particularly important for adaptation and mitigation of transformative environmental changes, such as climate change. Co-productive capacity is: “the combination of scientific resources and governance capability that shapes the extent to which a society, at various levels, can operationalize relationships between scientific and public, private and civil society institutions and actors to effect scientifically informed social change” [16]. It rejects clear separations between science, politics, policy, and practice [17,18] and is at the heart of mainstreaming NBS because renaturing cities inevitably involve a constant negotiation between scientific knowledge and socio-economic and political imperatives.

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WHY	Through a process of participatory planning and governance, there is greater scope to foster co-production and capacity building, whilst ensuring the wide range of knowledge and preferences are captured and integrated into decision-making. There is an extensive range of participatory and consultative methods that can be used to engage the public, businesses and other stakeholders in environmental discussions. Where such practices exist there is a marked improvement in the level of technical and experiential details embedded within decision-making, and a greater level of acceptance from local communities where engagement activities have been undertaken [19,20]. This latter point relates to the responses of stakeholders who feel they have been listened to and who can identify how their comments, concerns and ambitions have been included in policy decisions. There is also evidence that where participatory planning and governance practices exist there is a level of trust between local government and local residents and businesses, as they can identify greater transparency between the decision-making process and local opinions [19,20,21]. Participatory and collaborative processes can also be an effective mechanism to ensure that a programme of investment is deemed acceptable to local communities. In urban areas where they landscape has changed rapidly in the twenty-first century there is a wealth and academic and practitioner research highlighting the discontent of local communities who feel they have been excluded from the scoping, design and management of their local environments [20]. Consequently, where people are encouraged to participate in consultation and engagement activities there is, in many locations, a positive response to the types of NBS proposed in development. Such processes represent a new way of approaching urban planning and environmental management, as historically people have had little input into the design of public spaces, green spaces or parks, and thus do not feel the same level of attachment to them. This can also lead to people viewing investment as being not for them, but for other people, because it does not necessarily respond to the socio-economic our ecological needs of a given areas [14, 21]. Participatory planning is thus important for fostering inclusion, place attachment, and ownership of NBS interventions, and public support for investment in renaturing cities. Within the URBAN GreenUP project, participatory planning and governance is being used to facilitate a dialogue between partners in each of the front runner cities. Each has proposed a suite of NBS investments, which are being discussed with local communities to assess their appropriateness for the social and ecological environment. The proposed benefit of this process is to ensure that local communities are (a) supportive, (b) engaged and (c) find use/value in the proposed NBS investments.

Participatory Planning and Governance

	Due to its location of the investments, which are predominately in urban cores, riverfront areas, and in residential locations, businesses and local residents need to be supportive to ensure that these spaces are used and cared for. In addition, across front-runner and follower cities there is a wealth of knowledge regarding landscape functionality and value, which can be integrated into the URBAN GreenUP project.
WHERE	R / M / U
SUB-CHALLENGES identification & description	**Green integrated management,** where citizens form an active part of the urban planning process, in close connection to the stakeholders, craft people, small/medium enterprises and municipalities and government.
	Environmental awareness, adaptation to the local, European regulations on reduction of greenhouse gas emissions and sustainable city growth and maintenance.
	City identity, where citizens recognized the city problems as their own problems, city achievements as an effect of their participation.

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Vertical and horizontal green infrastructure: green façade with climbing plants; hydroponic green façade; vertical mobile garden; floating gardens; green covering shelters; green roofs, green noise barriers; green fences; green shady structures; urban garden bio-filter.	A green structure build on wood, metallic modular structures, independent or adapted to the existing structures and completely or partially covered with greenery, should allow the smooth greenery integration into the city urban structure. In consequence, the urban environment is positively impacted (air quality, climate regulation, pollination, educational values, aesthetic values, recreation and ecotourism, inspiration) and **the citizens and local stakeholders are considered into the city planning and governance process** through offering of economic, environmental, aesthetic and physiological benefits.
2. Tree related actions: shade / cooling trees, urban trees, arboreal areas, trees renaturing parking.	All actions related to the three integration into the urban organism, into its structure and geometry, should allow the urban re-generation influencing also social aspects of the city. In consequence, the urban environment is positively affected (air quality /climate

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	regulation, pollination, educational values, aesthetic values, recreation and ecotourism, sense of place, cultural heritage values), and the **citizens might be considered into the greenery zones urban planning process actively**.
3. Promotion of NBS at citizen scale: engagement portal for citizen; promotion of ecological reasoning and intelligent; single desk for RUP deployment; city mentoring strategy (staff exchange activities).	All actions related to the **promotional, dissemination and evaluation actions of the NBS renaturing urban process**. In effect the city sustainable growth is influences by a self-propelled mechanism, where one citizens influence and conscience another.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Perceptions of citizens on urban nature - green spaces quality ***KPI 117 ***	Periodic surveys can be performed via the smartphone application. The % of satisfaction can be determined with the number of participants above a threshold. Qualitative and quantitative measures of awareness of NBS (and its social, economic and ecological values). Moreover, satisfaction survey of NBS investment and changes in environmental quality. Reported perception of NBS and value to social, economic and ecological landscape.
Openness of participatory processes ***KPI 111***	Indicators of public participation (nº processes / year) or (population reached). Public information processes. Non-technical actions.
Legitimacy of knowledge in participatory processes. ***KPI 112***	Indicators of public characteristics (type of population). Regulation and legal information process. Non-technical actions.

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Table 8: Participatory Planning and Governance challenge card

2.8 Social Justice and Social Cohesion

Social Justice and Social Cohesion

8 WHAT	**The Challenge** It is important that NBS projects are selected and designed in ways that support both social justice and social cohesion [1,2]. The same is true for the citizen engagement processes surrounding NBS delivery [3,4]. Urban NBS has an important role to play in supporting **social cohesion** in cities, in a range of ways, including: - Providing services that support social cohesion such as opportunities for sport, play or production of food or fuel [5]. - Creating high-amenity public spaces such as parks and streetscapes that are attractive places for passive recreation [2]. This is associated with the encounter or observation of people of different culture, income, age, gender, ability, sexuality etc. [6]. - Creating spaces or features that contribute to the shared identity of a city, such as iconic parks and squares, or a particular street tree or flower that become associated with a city [5,6]. **Social justice** is an important consideration in NBS provision in many cities for a few reasons. Successfully delivering NBS is usually positive, but not necessarily just or inclusive 1. It is important to work with awareness of the following realities that apply to most cities: - NBS and their associated services in cities are not equally distributed spatially, and some areas will have greater need. - NBS in cities are not equally accessible or welcoming to all people. - The maintenance of existing NBS is not equally distributed. - Processes for selection and design of NBS do not always include everyone equally, nor are all views for participants in these processes treated equally. - Enforcement efforts in urban green spaces may not always be equally applied. - NBS design and functioning may not reflect the values and cultures of all people. - New NBS projects do not always equally benefit all people. The factors that often determine who the ‘haves’ and ‘have-nots’ are the same familiar social divisions that most modern cities are grappling with 7–9. Issues include the following:

Social Justice and Social Cohesion

WHAT	- Wealth and social class. - Gender and sexual orientation. - Ethnicity, culture and migrant status. - Disability. - Age. It is important that design, delivery and consultation around NBS plans and projects is done in a way that includes these groups [1].
WHY	To many, cohesion and justice may be inherently desirable outcomes. Without careful consideration in design, engagement and operation of urban NBS, projects may in fact undermine social justice and cohesion. This is not only problematic for those that holder these values as inherent, but also from a range of instrumental perspectives: • Equality forms a major theme of the Charter of Fundamental Rights of the European Union (Articles 20-26); by extension, projects should be socially just. • Social cohesion is desirable in terms of public health outcomes and in enabling physical activity [10,11] and may play a role in limiting crime [12]. • Socially just projects that build cohesion have stronger socio-political support when trade-offs must be made in terms of budgets or allocations of space. The unsuccessful London Garden Bridge project is an example of a major NBS intervention that was widely critiqued because it was perceived to be a socially unjust investment, given that the project was in an already very privileged area and would be private, but partially funded with public money.
WHERE	R / M / U / S / B – issues of justice and inclusion can occur even within a building, all the way to between municipalities or regions.
SUB-CHALLENGES identification & description	4 key areas of focus are essential in ensuring projects address issues of social justice and cohesion constructively. These are Distribution, Procedure, Recognition and Capability [13]. Each can be clearly defined, but is challenging to deliver in each area fully.
	Distribution It is important that NBS programs deliver NBS projects equitably, both in terms of spatial distribution as well as facilitating access for the full range of socioeconomic groups. Equal maintenance effort

Social Justice and Social Cohesion

SUB-CHALLENGES identification & description	also forms part of this sub-challenge. It is critical that projects avoid entrenching existing patterns of privilege [1].
	Procedure The procedure of NBS planning and development must be closely scrutinised to ensure it is socially just and promotes cohesion. Genuine inclusion of diverse views in the selection, development and operation of urban NBS is critical, and it is key that this engagement is carried out in a way that promotes cohesion rather than conflict or competition. In many cases this will require a step away from traditional 'top down' processes of engagement [1,13].
	Recognition Explicit efforts to involve marginal groups in NBS delivery is important, recognising that different groups such as migrants or the elderly will have different notions of what quality is in a design; work conducted from a framework of recognition has a better chance of addressing these diverse needs [14,16].
	Capability Different groups will have different capabilities to participate in NBS projects, based on fundamental factors such as literacy, safety and employment [13]. This not only creates an impetus to make extra efforts with some groups, but also note that NBS projects can be supportive to marginal groups by enhancing their capacity to engage in the projects and strategies that are developed in their local areas.

HOW

Note: while some specific NBS may be more supportive of inclusion and cohesion than others, it is vital to acknowledge that this Challenge primarily relates to changing how we work on our NBS projects. Any of the NBS listed below or in the catalogue can be delivered in a more or less inclusive way and accordingly the table below is to be seen as indicative only.

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Urban Orchard, Community Composting and Small-scale livestock. Climate Smart Greenhouses	**Collaborating with neighbours** to produce compost, food and livestock presents opportunities to build cohesion in neighbourhoods and potentially **encounter people of different backgrounds**. Greenhouses and associated markets **create new attractions in the community** and for diverse groups to gather.

Social Justice and Social Cohesion

2. Floodable Parks	Floodable parks, when designed well, can be **experienced and enjoyed by greater diversity and number of people** from different socio-economic backgrounds.
3. Urban Trees and Urban Catchment Forestry	The planting, monitoring and management of urban trees and peri-urban trees can improve safety and community strength, particularly when done as part of a **community program**. Forestry activities that **involve the community in both planting and management can support social cohesion**.
4. Channel Re-naturalisation	Re-naturalised channels can function as parklands and support **a range of activities** that can bring the **community together** and include **marginal groups**, if designed with this in mind.
5. Raingardens	Rain gardens can be viewed as an innovative drainage facility, **encouraging people** to create their own rain gardens and share results, **increasing social cohesion**.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
1. Social Cohesion	Structural aspects: indicators of family and friendship ties; participation in organised associations; integration into the wider community.
2. Social Cohesion	Cognitive aspects: indicators of trust, attachment to neighbourhood, practical help, tolerance and respect.
3. Social Cohesion	Access to financial resources, including indicators of income per capita in a given neighbourhood, or urban area.
4. Social Justice	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.

Social Justice and Social Cohesion

5. Social Justice	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.
6. Social Justice	Emotions: being able to have attachments to things and people outside ourselves; to love those who love and care for us, including indicators of place attachment, empathy and love.
7. Social Justice	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.
8. Social Justice	Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities.
9. Social Justice	Crime reduction through police reports and local authority data.
10. Social Cohesion	Green intelligence awareness.

LINKS and REFERENCES

Keywords used	Equity, Social Justice, Environmental Justice, Social Inclusion, Disadvantage, Gentrification, Place making.
Links and references	[1] Haase, D., Kabisch, S., Haase, A., et al. Greening cities – To be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat Int. 2017;64:41-48. doi:10.1016/j.habitatint.2017.04.005. [2] Wolch, J.R, Byrne J, Newell JP. Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." Landsc Urban Plan. 2014;125:234-244. doi:10.1016/j.landurbplan.2014.01.017. [3] Buijs AE, Mattijssen TJ, Van der Jagt AP, et al. Active citizenship for urban green infrastructure: fostering the diversity and dynamics of citizen contributions through mosaic governance. Curr Opin Environ Sustain. 2016;22(February):1-6. doi:10.1016/j.cosust.2017.01.002. [4] Mattijssen TJM, van der Jagt APN, Buijs AE, Elands BHM, Erlwein S, Lafortezza R. The long-term prospects of citizens managing urban green

Social Justice and Social Cohesion

Links and references	space: From place making to place-keeping? Urban For Urban Green. 2017;26:78-84. doi:10.1016/J.UFUG.2017.05.015. [5] Van der Jagt APN, Szaraz LR, Delshammar T, et al. Cultivating nature-based solutions: The governance of communal urban gardens in the European Union. Environ Res. 2017; 159 (October 2016):264-275. doi:10.1016/j.envres.2017.08.013. [6] Peters K, Elands B, Buijs A. Social interactions in urban parks: Stimulating social cohesion? Urban For Urban Green. 2010;9(2):93-100. doi:10.1016/j.ufug.2009.11.003. [7] Wilkerson ML, Mitchell MGE, Shanahan D, et al. The role of socio-economic factors in planning and managing urban ecosystem services. Ecosyst Serv. 2018;31:102-110. doi:10.1016/j.ecoser.2018.02.017. [8] Boulton C, Dedekorkut-howes A, Byrne J. Factors shaping urban greenspace provision: A systematic review of the literature. Landsc Urban Plan. 2018;178(May):82-101. doi:10.1016/j.landurbplan.2018.05.029. [9] Rigolon A. A complex landscape of inequity in access to urban parks: A literature review. Landsc Urban Plan. 2016;153:160-169. doi:10.1016/j.landurbplan.2016.05.017. [10] Yip C, Sarma S, Wilk P. The association between social cohesion and physical activity in canada: A multilevel analysis. SSM -Popul Heal. 2016; 2(September): 718-723. doi:10.1016/j.ssmph.2016.09.010. [11] Robinette JW, Charles ST, Gruenewald TL. Neighborhood cohesion, neighborhood disorder, and cardiometabolic risk. Soc Sci Med. 2018;198(December 2017):70-76. [12] Matsukawa A, Tatsuki S. Crime prevention through community empowerment: An empirical study of social capital in Kyoto, Japan. Int J Law, Crime Justice. 2018;:1-13. doi:10.1016/j.ijlcj.2018.03.007. [13] Rutt RL, Gulsrud NM. Green justice in the city: A new agenda for urban green space research in Europe. Urban For Urban Green. 2016;19:123-127. doi:10.1016/j.ufug.2016.07.004. [14] Zhai Y, Baran PK. Urban park pathway design characteristics and senior walking behavior. Urban For Urban Green. 2017;21:60-73. doi:10.1016/j.ufug.2016.10.012. [15] Wu KC, Song LY. A case for inclusive design: Analyzing the needs of those who frequent Taiwan's urban parks. Appl Ergon. 2017;58:254-264. doi:10.1016/j.apergo.2016.06.015. [16] Jay M, Schraml U. Diversity in mind: Towards a differentiated understanding of migrants' recreational practices in urban forests. Urban For Urban Green. 2014;13(1):38-47. doi:10.1016/j.ufug.2013.10.001.

Table 9: Social Justice and Social Cohesion challenge card

2.9 Public Health and Well-being

Public Health and Well-being

9 WHAT	Climate change affects the social and environmental determinants of health – clean air, safe drinking water, sufficient food and secure shelter [1]. More than half of the world's population lives in urban areas (towns and cities), and this number is projected to increase to two in three people by 2050 [2]. Climate change and other environmental issues affect all populations; however it is most threatening in urban areas where the majority of the population live. This means that the consequences of climate change, poor air quality and other current concerns are often very obvious and disruptive to urban living, and can affect services such as sanitation leading to public health issues. The effects of climate change, such as heatwaves, will mean that urban areas in particular become increasingly uncomfortable, with vulnerable members of society feeling the impacts most [3]. In the heat wave of summer 2003 in Europe for example, more than 70 000 excess deaths were recorded [4]. High temperatures also raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease [5]. Air quality is also a major concern worldwide, particularly in urban areas, due to its direct consequences on human health, plants, animals, infrastructure and historical buildings (among others). Climate change means that floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century [6]. Floods contaminate freshwater supplies, and cause pollution detrimental to human health and wellbeing.
WHY	Nature-based solutions can contribute to a wide range of positive psychological and physiological benefits mitigating the effects of climate change or the poor air quality, for instance, and improving overall human health and well-being.
WHERE	R / M / U / S / B
SUB-CHALLENGES identification & description	Reduce the risk of factors affecting human health, especially to vulnerable communities
	Foster an increment in physical activity
	Improve mental health and wellbeing

Public Health and Well-being

HOW	
Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees renaturing parking and Arboreal areas around urban areas	Increased tree planting provides shade and evaporative cooling that help to keep neighbourhoods cooler [7] ensuring that towns and cities continue to be healthy, comfortable, and attractive places to live. Strategic positioning of shade trees within urban areas can provide shade to buildings, reducing heat loading on building and provide islands of respite from high temperatures in our urban areas. They provide spaces within the urban fabric for respite from direct sunlight and high temperatures at times of heatwave in particular.
2. Urban Catchment Forestry	Planting trees in urban areas also helps to regulate storm water. This is vital in a changing climate with projections for more intense rainfall events. The drainage patterns of towns and cities have been modified greatly with underground sewers taking on the role of streams and rivers. This NBS is specifically designed for urban areas to "slow the flow" of water through the catchment, and is particularly effective in dealing with intense periods of heavy rain. The impact of such interventions is reduced flood risk of polluted water, which would have a negative impact on public health.
3. Green Façade	Vegetated green and living walls are natural air-filters, creating a cleaner environment and provide high leaf surfaces. Reduced temperature created by the green facades lead to greater human comfort and improved mental wellbeing.
4. Cycle and pedestrian green routes	Cycle and walking greenway provide recreational, public health and well-being opportunities. Reducing the use of vehicles means fewer emissions of greenhouse gases mitigating climate change, as well as reduced air pollution. Providing green shady routes encourages walking and cycling, as well as their connection to nature.
5. Green filters areas/green noise barriers	Green fences provide new vertical green surface on one side to reduce the negative effect of the traffic noise, and improving air quality from adjacent roads. These provide both physical and mental well-being benefits.

Public Health and Well-being

HOW MUCH	
KPIs used to assess NBS impacts in this challenge	**General KPI description**
Heatwave risks (number of combined tropical nights (>20 °C) and hot days (>35 °C) (nº days). ***KPI 9***	Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Calculate the number of tropical nights per month (summertime) and per year following the city location settings. Compare these data to values taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously. Calculation of the number of tropical nights and heatwaves monthly (summertime) and yearly assessing hourly mean values of temperature at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site.
Decrease in mean or peak daytime local temperatures (°C). ***KPI 7***	Measure air temperature and relative humidity at sampling points at a range of radii from NBS locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of street without those NBS at a similar time of day on the same dates or continuously. Calculation of daily, weekly, monthly and annual mean levels (night and day) of temperature and relative humidity at each stretch. Comparison of mean values for NBS intervention and control sample locations will be done at each study site.
Noise reduction rates applied to UGI within a defined road buffer DB(A) M-2 vegetation unit. ***KPI 128***	Measure noise levels at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention (with or without) to serve as input to model simulations and to create a noise map. The measurements before and after the intervention have to be made on similar dates, same day of the week and hour. Simulations with and without NBS will be assessed to define the impact of the NBS.
Increase in walking and cycling in and around areas of interventions. ***KPI 139***	Measure amount of cycling and walking around the intervention areas through surveys, self-reported questionnaires and static counters.

Public Health and Well-being

LINKS and REFERENCES	
Keywords used	Climate adaptation, public health, urban heat island, heatwave risks, mental wellbeing.
Links and references	[1] World Health Organisation – Climate Change & Health Joseph Rowntree Foundation (2011). [2]http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html [3] Climate change, justice and vulnerability. http://bit.ly/16STKgy [4]. Robine, J.M., Cheung, S.L., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.P., et al. C R Biol. 2008;331(2):171-8. [5]http://www.who.int/news-room/fact-sheets/detail/climate-change-and-health [6] IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of CC. Contribution of Working Group III to the 5th Assessment Report of the IPCC [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. [7] http://ec.europa.eu/environment/basics/health-wellbeing/noise/index_en.htm. [8] Gill et al (2007). Adapting cities for climate change: the role of the green infrastructure. Built Environment, 33 (1), 115-133. This study was part of the Adaptation Strategies for Climate Change in Urban Environments (ASCCUE) project. [9] Peng, L.L.H., Jim, C.Y. Seasonal and diurnal thermal performance of a subtropical extensive green roof: The impacts of background weather parameters. Sustainability 2015; 7: 11098-11113.

Table 10: Public Health and Well-being challenge card

2.10 Potential of Economic Opportunities and Green Jobs

Potential of Economic Opportunities and Green Jobs

10 WHAT	
	Climate change presents one of the greatest challenges to society today. About half of the human population globally lives in urban areas and by 2020, according to United Nations and European reports, 75 % of Europe's population will be living in cities. Our cities possess several problems, such as pollution, climate and water disturbs and depletion of natural resources. Furthermore, as Climate Change arises, more frequent and extreme weather events take place, such as summer storms, flash flooding and heatwaves [4]. This new paradigms create several social and ecological disturbances, as well as economic imbalances. In this context, the concept of sustainable development emerged, bringing together environment, economy and society in a holistic and integrated way. The classic definition of sustainable development, "meeting the needs of the present without compromising the ability of future generations to meet their needs" was produced by the Brundtland report [1] and is being continuously improved and some boundaries have been surpassed. Nowadays, it is perceived that humanity's well-being depends on the environment, and the boundaries between these two dimensions are not neat and sharp, they are diffuse and contain several flows [10]. This trans-disciplinary view considers that sustainable development, as well as economic growth must be designed in an integrative and inclusive way, recognizing the importance of ecosystem integrity and social equity. Climate change has several negative economic impacts, that arise from the following aspects: - New climate patterns, such as increased heat stress, leading to several health risks; - More frequent and intensive floods; - Increase of soil erosion; - Increase of desertification and land abandonment; - Damage to property and infrastructures; - Reduced water quality and decreased availability of water resources; - Changes in species distribution and biodiversity and new risks of extinction; - Changes in agricultural patterns, new diseases and pests; - Increase of forest fires.

Potential of Economic Opportunities and Green Jobs

WHAT	The observed changes in climate are already producing wide-ranging impacts on the economy, according to the report "Climate Change, impacts and vulnerability in Europe 2016". Climate projections indicate that climate-related extremes will increase in the future, and the economic costs of climate change can be very high. Climate-related extreme events in European Economic Area (EEA) countries account for more than EUR 400 billion of economic losses since 1980 [8]. Therefore, new development must be resilient, adapting to the impacts of climate change and reducing anthropogenic forces of the climate system. The concept of NBS is particularly embedded in the wider discussions on climate change adaptation, ecosystem services and green infrastructure [4; 12]. In order to balance the negative economic impacts arising from climate change, it is imperative to adopt measures that contribute to climate change adaptation and mitigation. Sustainable development and integration of green infrastructure offers an attractive economic Return On Investment (ROI) and a range of other benefits to society [2; 12; 16]. The need to mainstream NBS into urban planning is widely supported by both academic and governmental bodies. Expanding sectors related to innovation and NBS is an essential part of European politics [5; 6; 7]. The market of green jobs has been constantly monitoring trends that show a market increasing in quantity and quality. In this context, various initiatives have been developed to deepen multi-stakeholder partnerships, private sector leadership and citizen engagement, which have supported the expansion of economic opportunities and green jobs [3; 4; 15]. The market of green jobs is increasing in a consistent way, which leads to the provision of long-term, secure and sustainable new jobs and opportunities [4].
WHY	Climate change has significant impacts on ecosystem functioning, well-being of people and economy. In addition to Climate Change, urbanisation increases the interlinked pressures in the city, which pose additional significant challenges to sustainable development and the provision of ecosystem services in urban areas. However, NBS have the potential to balance and minimize these pressures, taking into account the services provided by nature [12]. The investment in NBS in urban areas represents an investment in ecosystems and society, with a high financial return. The economic values attached to NBS can be classified as use values and non-use

Potential of Economic Opportunities and Green Jobs

WHY	values. Use values are divided into direct use value, indirect use value and option use value. The direct use value includes consumptive values (market-priced products that derive from green infrastructure, such as timber and urban agriculture) and non-consumptive values (social benefits derived from a pleasant landscape, as well as recreational activities) [2; 12; 14]. The indirect use value include protection functions, such as mitigation of urban climate, reduction of heat island effect, regulation of urban hydrology, reduction of pollution and increase of resiliency to extreme climate conditions related to climate change. These values represent a high economic return, reducing costs related to buildings' heating and cooling, associated with artificial reduction of pollution, related to artificial urban drainage systems, linked to health disorders that arise from climate extreme events, among other savings. The option use value includes the willingness to ensure the personal use of green infrastructure [2; 14]. The non-use values include request values (e.g. willingness to ensure use of green infrastructure by future generations, and nature, cultural and historic preservation values), as well as existence values (e.g. preserving urban biodiversity). Existence values include the Willingness to Accept Compensation (WTA) for the availability or loss of ecosystem services. In addition, the implementation of NBS in urban areas increases tourism and real estate values, which benefits both society and the urban development [2; 14]. In conclusion, the integration of NBS in urban areas generates several economic co-benefits and contributes to climate change mitigation and adaptation. To date, an increasing number of NBS projects have been implemented. Consistent scientific evidence regarding the impacts of NBS in the process of climate change mitigation and adaptation has been presented widely through interdisciplinary approaches. These studies also include how NBS might be assessed economically and how economic valuation and related concepts may provide justification to the introduction of NBS in cities [12]. NBS represent a significant ROI and even at a conservative estimate, the NBS industry produces promising figures. For example, the German, Swiss and Austrian green roof market is very mature and across these countries, a minimum of 10.3 Mm^2 of green roofs are installed each year [4; 9]. Outside these three main European markets, several other cities, such as London, Rotterdam and Paris, are showing a significant increase in the installation of NBS such as green roofs. In addition, independent market research estimates

Potential of Economic Opportunities and Green Jobs

WHY	that in 2017 there has been installed around 1 million m^2 of green walls, which represents an investment of 680 M€ [4]. NBS represent an attractive investment and in this context, the building-related benefits of green infrastructure investments are crucial. Private investment is usually based on financial benefits, for example savings in heating and cooling, increased energy efficiency, heightened property values and extended lifespan of building materials [4; 15; 16]. The private sector represents a valuable partner for implementing NBS, having the potential to offer innovative solutions to urban challenges. This sector is able to provide insights and perspectives, which are complementary to those from governments and civil society. Their specific knowledge of markets, management experience and detailed advanced research can be valuable assets in the context of implementing NBS [11]. Multi-stakeholder partnerships, civil society organisations, scientists and other urban stakeholders are crucial to highlighting the value of NBS for sustainable urban development and economic prosperity [15]. Producing strong evidence on NBS for climate change adaptation and mitigation and raising awareness of their multiple benefits is decisive for the development of new economic opportunities. NBS have the potential to facilitate cooperation between sectors and contribute to a more holistic approach to the development of green jobs. The engagement of citizens is also a crucial aspect in this process, as it allows the implementation of more effective environmental regimes that address societal challenges and needs [15; 16]. NBS represents an opportunity not only to protect the environment, but also to improve business prospects and the position of the EU in international markets. According to the Amoeba model, the implementation of NBS possesses several crucial stakeholders [13], as forthwith indicated: - Change agents: Non-governmental organizations, universities, pioneering investors, designers and architects; - Transformers: European Union, selected municipal departments, mainstream media, significant developers and investors; - Controllers: Ministries, top city authorities responsible for construction regulation and governmental institutions; - Mainstreamers: Private investors, architects and designers, construction companies and developers, residents, city officers (urban planning, local development, municipal investments, etc.);

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WHY	- Laggards: Construction companies and developers. In conclusion, NBS implementation creates several economic opportunities and builds a solid range of green jobs. Collaboration between different NBS stakeholders can improve their technical capacity, competitiveness and business opportunities [13]. The multifunctionality of NBS promises high economic return on investments, and in order to encourage diffusion of NBS, policy instruments must be developed. These instruments can include information systems, fostering cooperation, planning procedures and setting incentives [3].
WHERE	R / M / U
SUB-CHALLENGES identification & description	Providing **information** to disseminate NBS industry: Green infrastructure planning that implements NBS requires information about the benefits, costs and ecosystem services provided. The ecosystem services provided by NBS must be assessed to assist municipal and private decision-making. NBS industry must include proper evaluation and a sound information basis.
	Fostering **multi-stakeholder cooperation**: Promoting intra-municipal cross department NBS strategies, inter-municipal exchange platforms, public-private partnerships and citizens' engagement. This cooperation will minimize trade-offs to other sectors and will boost synergies.
	Developing **legislation and policies** that promote NBS implementation: The establishment of legislation, regulations and policies may create opportunities for some NBS businesses.
	Implementing appropriate **planning procedures**: Urban development plans are essential tools for urban decision-making and thus the integration of NBS into the respective procedures. Urban development plans must maximize ecosystem services and the resilience of urban environment, promoting human health and a more effective mitigation and adaptation to climate change.
	Setting several **financial incentives** for the implementation of NBS: These financial incentives can include municipal fees and charges, municipal tax revenues, fiscal transfers.

Potential of Economic Opportunities and Green Jobs

HOW

Prioritised potential actions to deal with this challenge	Expected impacts for these actions
1. Most of NBS	The design, construction and implementation of NBS in the frame of metropolitan greening masterplan lead to the creation of green jobs, both direct and indirect.
2. Green façade	Green façades create direct jobs for maintenance and installation and other opportunities and indirect economic activity through the whole value chain.
3. Green Roof	Green roofs create direct jobs for maintenance and installation and other opportunities and indirect economic activity through the whole value chain.
4. Green Resting Areas	Green resting areas create maintenance jobs. Green resting areas improve the overall ecologic and aesthetic quality of urban environment, attracting visitors and tourists.
5. Urban Orchard	Vegetable gardens, urban orchards other related activities have been always considered as a source of basic food and economic aid, particularly on deprived areas and periods of economic recession. Urban orchard, as means of good supplier, can provide new business models, new economic opportunities and green jobs.

HOW MUCH

KPIs used to assess NBS impacts in this challenge	General KPI description
Number of subsidies or tax reductions applied for (private) NBS measures. ***KPI 140***	This index means to quantify the number of private subsides and number of tax reductions that arise from the implementation of NBS.
Number of jobs created; gross value added. ***KPI 141***	The KPI presented aims at quantifying both the number of jobs created by the implementation of NBS and also the contribution of NBS to economy. Gross value added provides a quantification of the amount of goods and

Potential of Economic Opportunities and Green Jobs

	services produced by NBS less the cost of all inputs and raw materials that are directly attributable to the production of NBS.
Change in mean or median land and property prices. ***KPI 142***	This index means to quantify the increase of value of real state that arises from the implementation of NBS.
New business attracted and additional business rates. ***KPI 143***	The KPI presented aims at evaluating the development of new and business that emerge as a result of NBS implementation. The KPI also intends to quantify additional business rates.
Consumption benefits: property betterment and visual amenity enhancement from NBS. ***KPI 150***	This index means to quantify consumption benefits that arise from non-consumptive values (e.g. recreation and aesthetic experiences).

LINKS and REFERENCES

Keywords used	Climate change adaptation, sustainable development, economic growth, Return on Investment, use values, non-use values, financial incentives, ecosystem services valuation.
Links and References	[1] Brundtland, G.H., Khalid, M., Agnelli, S., Al-Athel, S.A., Casanova, P.G., Chidzero, B.T.G., Padika, L.M., Hauff, V., Lang, I., Shijun, M., Botero, M.M., Singh, N., Nogueira-Neto, P., Okita, S., Ramphal, S.S., Ruckelshaus, W.D., Sahnoun, M., Salim, E., Shaib, B., Sokolov, V., Stanovik, J., Strong, M. & MacNeill, J. (1987). *Report of the World Commission on Environment and Development: Our Common Future*. Genebra, Switzerland. [2] de Roo (2011). *The Green City Guidelines: Techniques for a healthy liveable city*. Editor: Mark Long. The Green City Publications. 99 pp. [3] Droste, N., Schroter-Schlaack, C., *Hansjurgens*, B. & Zimmermann, H. (2017). Implementing Nature-Based Solutions in Urban Areas: Financing and Governance Aspects. *In*: Kabisch, N., Korn, H., Stadler, J. & Bonn, A. (editors). pp: 307-321. [4] Enzi, V., Cameron, B., Dezsényi, P., *Gedge*, D., Mann, G. & Pitha, U. (2017). Nature-Based Solutions and Buildings – The Power of Surgaces to Help Cities Adapt to Climate Change and to Deliver Biodiversity. *In*: Kabisch, N., Korn, H., Stadler, J. & Bonn, A. (editors). pp: 159-183. [5] European Commission (2016). *Supporting the Implementation of Green Infrastructure – Final Report*. 203 pp.

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Table 11: Potential of Economic Opportunities and Green Jobs challenge card

3 Conclusions

This catalogue is written to enable the reader to get a clearer view of the ways in which the climate change together with others key societal challenges are affecting citizen's life.

The catalogue is the culmination of the work developed regarding main current societal challenges by URBAN GreenUP project partners and it includes the knowledge and experience of a wide range of experts to select the best options to deal with them through the inclusion of nature-based solution in RUPs development.

By this way, the characterisation of different key challenges is done. All of them have been briefly evaluated within this catalogue with the aim of defining their impact to improve the behaviour of the cities regarding them.

The catalogue:

- Provides a credible and transparent approach to qualify and report the current main societal challenges in cities;
- Enhances the credibility of NBS projects to deal with these challenges accounting by means of concepts, procedures and impacts summarised in form of cards; and
- Provides the standardisation for the societal challenges identification as a part of the URBAN GreenUP modular methodology, for renaturing urban planning concept (RUP).

Although the challenges are extensive, there is a considerable flexibility in the ways of meeting them. This catalogue pretend to make easier the employment of better interdisciplinary work that maximizes the integration of new concepts and ideas into renaturing urban plans. Cards presented should not be viewed as a series of potential add-ons, but as a summary of fundamental changes to be taken into account in design strategies that will not just improve building performance, for instance, but also add new and interesting aspects to the ever-evolving potential expression in buildings, parks and / or streets (among others) aesthetics, and in the potential comforts these zones can provide.

Ten challenges have been studied therefore ten cards with easy-to-use information have been developed to create this catalogue. During its elaboration, key features of each challenge identified have been taken into account to describe them in relation to different aspects, all of them included within URBAN GreenUP project development.

First of all, **climate mitigation and adaptation** challenge is presented and with its study the background on vulnerability of the cities to climate change and the crucial significance of mitigation and adaptation measures are detailed, among other key characteristics. Then, **water management** and **coastal resilience** are analysed. Climate change projections show it is likely that heavy rainfall and flooding will become more frequent and coastal areas have additional hazard risk from storms, such as hurricanes and increased population pressures, therefore the analysis of these challenges are particularly important nowadays.

Urban green space management is the fourth challenge addressed and one of the conclusions obtained with its analysis is that the intentional intervention to increase functional and structural connectivity, as well as species richness of these areas, can contribute to addressing this challenge effectively. How to do this is explained briefly in its card.

Regarding **air quality**, which is a major concern worldwide, particularly in urban areas, due to its direct consequences on human health, measures to tackle air quality by enhancing green infrastructure can be considered a good investment due to the number of co-benefits that they produce and their contribution to amenity value over time. For this reason, it is considered a crucial societal challenge and more details to know it in deep are described in its card.

Growing urban populations and economic activities also require new urban development in rapid pace that often caused severe environmental problems, this is why **urban regeneration** is considered as a significant challenge and its analysis s here included.

Participatory planning and governance, the sixth challenge addressed, includes both planning and governance because the two work hand in hand and strategic planning in particular is important if NBS are to be effective so it is absolutely essential these solutions are implemented at a landscape scale in order to effectively address societal and environmental challenges. More details regard this issue are included in its card.

NBS projects are selected and designed in ways that support both **social justice** and **social cohesion** therefore both aspects represent another key societal challenge to play in supporting social cohesion in cities. It is important that design, delivery and consultation around NBS projects is done in a way that includes these groups, more information regarding these aspects are included in its card.

NBS can contribute to a wide range of positive psychological benefits mitigating the effects of climate change and improving overall human health. That is why **public health and well-being** is a present-day challenge in directly relation to nature-based solutions therefore it is presented in this catalogue.

At last but not least, the challenge referred to the **potential of economic opportunities and green jobs** is included too. It can be described as an underpinning strategy, such as the mainstreaming of environmental policies or a supportive economic structure therefore a progress toward goals defined by green jobs can be measured by a wide range of indicators or concepts, some of them presented here briefly.

In short, thanks to those who helped prepare this catalogue, the impact of these challenges across economic, environmental, social and aesthetical issues meant that it was important for them to be identified. Together they formed a **climate change & societal threats repository**, to provide a comprehensive analysis of the main current urban environmental challenges and how to deal with them.

"Green is a process, not a status. We need to think of 'green' as a verb, not as an adjective".

- Daniel Goleman -