URBAN GreenUP

D1.1: NBS Catalogue

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[1] PU = Public

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0 Executive summary

The target of this document is the definition of a catalogue of Nature Base Solutions (NBS) that include all the possible characteristics (technical, economic, environmental, and social) of each one of them; in order to be able to select the best options to introduce them in the development of a RUP, allowing the definition of different scenarios, which have been evaluated to define its viability and impact to improve the behaviour of the city regarding the climate change challenges.

During the process, features of each NBS identified have been taken into account, in order to be able to describe the impact of the technology since economic, environmental, social and aesthetical issues, for which it has been necessary to identify the KPIs that have been taking into account in each implementation for measuring the behaviour of NBS, as well as the qualitative features. On the other hand, the process of implementation and the stakeholders that take part on it has also been taken into account.

This catalogue allows to identify solutions taking different criteria's depending on characteristics of the city/area, problems, challenges, budget, social issues, climate, previous experiences, etc.

1 Introduction

Nature-Based Solutions (NBS) have emerged as an approach to promoting sustainability in urban areas, due to the growing number of people living in our cities (approximately 70% of the current European Union population). The impacts this has on building density and the use of environmental resources has affected the functionality of many socio-economic and ecological systems and the delivery of ecosystem services. This includes the pollution and overuse of water and terrestrial resources, exacerbation of natural hazards, decline in quality of life, and degradation of air quality, leading to a myriad of impacts on the quality of urban environments and their human populations, with significant implications for the sustainability and economic viability of European cities.

To counteract these impacts, the European Commission (2015) is supporting research and practical delivery of NBS in urban areas through the Horizon 2020 programme. The programme adds to the evidence base that investment in "nature", in its many forms, can act as a viable solution to constantly changing urban circumstances. Based on the promotion of ecosystem services[2] and the connective[3], accessible[4] and multi-functional[5] principles of green infrastructure (GI)[6], NBS are being promoted as a smarter way to integrate ecological thinking into engineered (i.e. built environment) systems (Liquete et al., 2016). NBS is not an entirely new concept, as a wealth of evidence exists discussing the value of investment in urban nature (cf. the urban ecology literature, Niemelä, 1999; Wu, 2014).

However, the promotion of "nature" as the central principle of investment does differ from previous forms of green space and landscape development (Nesshöver et al., 2016). By working with nature as a core delivery goal, rather than against it or as an afterthought, investments in NBS can offer cost-effective, innovative and responsive forms of urban management which can support greener and more sustainable growth in Europe's cities (Eggermont et al., 2015; Fan et

[2] Ecosystem services are composed on regulating, supporting, provisioning and cultural services, all of which help regulate the functionality of environmental resources (Ahern, Cilliers, & Niemelä, 2014; Hansen & Pauleit, 2014).
[3] Connectivity refers to the physical or spatial layout of green infrastructure resources and is connections to other comparable or supporting resources. Connectivity can be achieved through the provision of linking landscape features such a river corridors or footpaths, and uses the conceptual understanding of networks and systems to support green infrastructure functionality (Austin, 2014).
[4] Accessibility refers to ways in which human and non-human populations can access green infrastructure resources. This includes a reflection on the location of a green infrastructure site in relation to local people, the barriers to engagement or use, i.e. fences, locked gates or transport infrastructure, and the distance a resource is from its user population (Mell, 2016).
[5] Within the green infrastructure literature 'multi-functionality' is discussed as the co-location of social, economic and ecological benefits in a single location or across a green infrastructure network. Multi-functionality does not imply that social, economic and ecological benefits are required to be located in all spaces but argues that homogenous spaces are more likely to promote mono-functional uses/benefits compared to those green infrastructure that are composed of a diverse set of landscape resources (Benedict & McMahon, 2006; Mell, 2016).
[6] Green infrastructure was defined by Benedict & McMahon (2002:6) in a North American context as: "Green infrastructure is our nation's natural life support system — an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America's communities and people."

al., 2017). Unfortunately, the understanding and capacity within government and the environmental and business sectors to implement NBS varies spatially and across governance levels (local, regional, state, and national) and between institutions and organisations (Kabisch et al., 2016). Consequently, although advocates are arguing for investment in NBS, there remains a limited understanding of the added value that NBS can provide in urban development. This compounds the technical, legal and political challenges faced by practitioners, scientists and decision-makers working in cognate sustainability disciplines, who struggle to integrate the growing body of evidence supporting investment in green infrastructure, ecosystem services and NBS into environmental management and urban planning practices (Lewinsohn et al., 2015; Nesshöver et al., 2016).

To address this disparity, the main goals of the European Commission (2015) are to ensure that NBS and the Re-Naturing of Cities deliver the following through its Horizon 2020 funded projects and its wider programme of research and implementation:

1. Enhance the framework conditions for nature-based solutions at EU policy level
2. Develop a European Research and Innovation Community for nature-based solutions
3. Provide the evidence and knowledge base for nature-based solutions
4. Advance the development, uptake and upscale of innovative nature-based solutions
5. Mainstream NBS within the international Research & Innovation agenda.

This paper discusses the proposed meanings, uses and limitations of a NBS approach to managing urban areas. Drawing on a range of academic and practitioner material, it illustrates where complementarity between locations, policies and approaches exist, as well as identifying where gaps in our knowledge of NBS remain. This frames the discussion of NBS through its definitions and its use in practice, and is followed by an analysis of how NBS are being articulated within the accompanying academic/practitioner literature. In each of the following sections, the added value that NBS can provide to urban planners and managers is highlighted, in conjunction with the existing issues which limit the integration of NBS into development programmes.

1.1 What is a Nature Based Solution?

Several definitions have been proposed for NBS in the academic and practitioner literature, many of which reflect the proposals made by the European Commission when they stated that NBS are:

> *'solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience'*

Within this definition, the European Commission approach NBS as a method of providing added socio-economic value to existing approaches, using ecological systems and functions to address societal and ecological challenges in urban environments. The European Commission's use of 'resilience' terminology couches their thinking in an understanding that the governance of urban areas is directly linked to the decisions being made regarding economic stability and social, which are all tied to the inclusiveness, functionality and quality of life of urban landscapes (Kabisch et al., 2016). Thus, NBS are offered as a mechanism to promote resilience within socio-political discussions of landscape and urban development.

The ability of an urban environment to be, primarily, economically and, latterly, socially and ecologically vibrant has been proposed as being of paramount importance to the on-going promotion of NBS as an alternative of established built environment forms of development (Fan et al., 2017; Maes & Jacobs, 2017). NBS as a concept has the potential to help re-orient urban planning processes in a productive way, offering something above and beyond the concepts of sustainability and resilience. Rather than conserving the existing resource base, they shift the focus to improving and proactively adapting and mitigating social and environmental challenges in urban areas through ecological investment. To that end, Fan et al. (2017) state that research focussing on NBS is shifting the emphasis of development towards a recalibration of the pillars of sustainability towards a nature-centric hierarchy. Thus, Fan et al., Fink (2016) and Kabisch et al. (2016) argue that NBS are being promoted as a mechanism to rethink the primacy placed upon economic viability issues; placing environment at the heart of development in a way that is also economically tenable.

These discussions counter the established narrative of urban development by offering NBS as a comparable and, critically, more effective method of achieving ecological resilience to the impacts of socio-economic and physical change in urban areas. The benefits of ecologically-centred investment include the delivery of comparable benefits to engineered solutions but they are less expensive and more reactive to changes in the fabric of an urban environment (van Wesenbeeck et al., 2014); thus they offer a more dynamic tool for alleviating the pressures of urban landscapes (Eggermont et al., 2015). It is further suggested that NBS provide a mechanism to optimise the benefits of ecological systems within the built environment, promoting a more nuanced appreciation of "nature" within urban policy and planning practice to ensure different stakeholders can more effectively engage with NBS and traditional engineered solutions.

Eggermont et al.'s (2015) proposal argues that NBS is a hybrid concept combining several different ecological approaches to management simultaneously, such as ecosystem services and GI, enabling its advocates to align discussions nature-focussed interventions with more established forms of urban development (see also Pontee et al., 2016). NBS thus potentially offer a wider portfolio of investment and management options for city planners and governments that have been promoted as being adaptable to urban change when compared to current built environment techniques (Nesshöver et al., 2016). This suggests that NBS may also offer a more viable means to address the divergent needs of diverse stakeholders while promoting multi-functionality and accessibility (Eggermont et al., 2015). Thus, NBS are proposed as shifting the emphasis of urban development away from simply meeting the needs of a location in terms of transport, housing and commerce by "learning" from previous green space/landscape management to integrate new, i.e. urban pollinators or moveable gardens and existing approaches to "urban nature", i.e. sustainable urban drainage or investment in urban greening, within a flexible approach to environmental management focussing on specific solutions to identified problems (Kabisch et al., 2016).

In addition, Kabisch et al. (2016) argue that the ability of NBS to address multiple socio-economic and ecological issues enables users to think more innovatively about how to release pressures on land, management and policy. This can be seen in Balian, Eggermont, & Le Roux's (2014) definition of NBS:

> *'…the use of nature in tackling challenges such as climate change, food security, water resources, or disaster risk management, encompassing a wider definition of how to conserve and use biodiversity in a sustainable manner.' (p.5)*

Nesshöver et al. (2016) present a more detailed exploration of these issues, reviewing both the International Union for the Conservation of Nature (IUCN) and European Commission approaches to NBS. In their discussion, they highlight the role of NBS in promoting health and well-being, solutions for water management and climate change, and societal challenges such as food security that NBS can help mitigate. The scope of their analysis may prove too broad for some commentators but they argue that by using NBS within urban design and implementation strategies that the utility of natural systems that reflect on the diversity of nature rather than the more static approaches to investment currently witnessed in urban development. This extends the previous debate by suggesting, via the IUCN definition, that NBS offer multiple and simultaneous benefits which can address societal, economic and ecological issues within a nature-centric form of management (Baig et al., 2015; Cohen-Shacham et al., 2016; European Commission, 2015). The diversity and flexibility of NBS, and their capacity to address multiple challenges in a way that is tailored to local areas, also means that they address the main shortcomings of existing environmental management approaches (Boyd and Folke, 2011; Chaffin et al. 2014; Clement et al. 2016a). All of this suggests that NBS have the potential, which is currently being evidence via the Horizon 2020 and EKLIPSE programmes, to offer a more comprehensive and effective means of responding to environmental change and building social and ecological resilience.

Building on the European Commission's succinct definition of NBS discussed earlier, the Commission proposed a more extensive definition of NBS that aims to provide a more robust basis for its use:

> *'Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve*

desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth. This implies that maintaining and enhancing natural capital is of crucial importance, as it forms the basis for solutions. These nature-based solutions ideally are resilient to change, as well as energy and resource efficient, but in order to achieve these criteria, they must be adapted to local conditions.

The "nature-based solution" concept builds on and supports other closely related concepts, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation/mitigation, and green and blue infrastructure. They all recognise the importance of nature and require a systemic approach to environmental change based on an understanding of the structure and functioning of ecosystems, including human actions and their consequences. Nature-based solutions, however, have a distinctive set of premises: (i) some societal challenges stem from human activities that have failed to recognize ecological limitations; (ii) sustainable alternatives to those activities can be found by looking to nature for design and process knowledge. They therefore involve the innovative application of knowledge about nature, inspired and supported by nature, and they maintain and enhance natural capital. They are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives.'
European Commission (2015:24)

This more extensive presentation of the European Commission's proposals for NBS provides greater detail and focus for member states, allowing them to work more effectively with the concept when compared to other, and more succinct definitions (cf. Balian, Eggermont, & Le Roux, 2014).

Central to this expanded definition is the maintenance and/or enhancing of natural capital, as this provides the most basic elements from which NBS can be derived to deliver socio-economic and ecological solutions. In addition, NBS acknowledge that human interactions with the landscape can be both positive and negative (Cohen-Shacham et al., 2016; Raymond et al., 2017). This contrasts to the wider literature debating engineered solutions which promote positive assessments of human-orientated landscape management stating that non-ecological solutions have also been successfully addressed climatic, water and ecological problems (Firehock, 2015). NBS, however, argue against this narrative stating that investment in "nature" should be promoted in the place of engineered approaches to address both the design and practical solutions derived from traditional development practices. Thus, NBS provide a platform for practitioners and stakeholders to rethink both their development and management practices by placing innovative environmental and nature based options at the heart of development, management and design in urban areas.

The question may arise, is the Nature-Base Solution exactly the same as Nature-Base Technology? The difference may be determined by scale. All the NBS or NBT should support/be a part/or related to urban/local systemic approach, like ecosystem service, ecosystem-based adaptation/mitigation, and green and blue infrastructure.

1.2 What is an NBS catalogue?

Nature- Based Solutions Catalogue (NBSC) is a part of the URBAN Green UP modular methodology, for Renaturing Urban Planning concept (RUP) 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 NBSs in a specific area of the city to address also specific challenges in a more effective way.

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.

1.3 What are the objectives of an NBS catalogue?

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 this 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:

- The built forms of the city
- The budget the city holds for NBS deployment, and its ability to leverage funding
- The challenges that the city wishes to address using NBS
- The social, cultural, legal and political context of the city
- The ability of relevant institutions to design, construct and maintain NBS

These factors mean that of the NBS outlined in this document, different cities may opt to deploy entirely different selections in very different spatial patterns and with different governance and financial arrangements. This NBS catalogue identifies the key traits of each NBS, serving as the foundation of the RUP process, including costs (capital and maintenance), key ecosystem services provided, scale and a brief description of the NBS itself.

A number of other methodological outputs in the Urban GreenUP project will support cities in their selection from the NBS options outlined in this catalogue as they work toward development of individual long-term RUPs.

1.4 Definition of concepts

1.4.1 Challenges

The standardization of the method is one of the most relevant milestones of URBAN GreenUP objectives. For that reason, a parameterisation is needed. Challenges previously identified by the bibliography as well as any other challenges that could be identified during the research processes. The parameterisation will allow identifying the factors that influence each challenge to analyse and assess them, in quantitative and/or qualitative technique according to each case and evaluate the city in respect of each city challenge and their own diagnostic.

EKLIPSE help us as a basis and it is integrated in the Project Methodology as a decision-making.

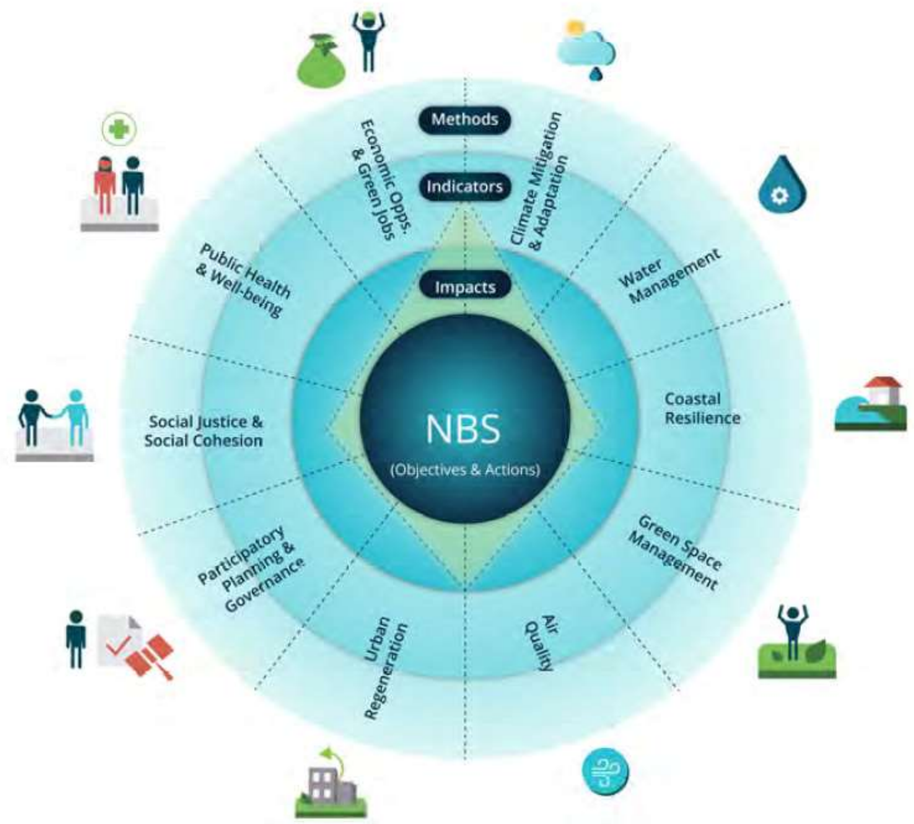


Figure 1 EKLIPSE challenges

Climate change 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 current 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 reorganize keeping its functions, structure, identity and regenerative capacity when they are threatened. NBS can increase coastal resilience by protecting communities against extreme events.

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 Ecosystem services provided

First of all, we have to know that an ecosystem *is a dynamic complex of plant, animal, and microorganism communities and the non-living environment, interacting as a functional unit. Humans are an integral part of ecosystems*.[7]

The ecosystem services are "*the benefits people obtain from ecosystems*"[3], in other words "*the direct and indirect contributions of ecosystems to human wellbeing*" [8].

There are several classifications of ecosystem services. The most used classifications can be found in the *Ecosystems and human well-being a framework for assessment*[3], in *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*[4] and in the *Common International Classification of Ecosystem Services* (CICES 2013).

In this catalogue we are going to use the classification of the Millennium Ecosystem Assessment.

The MA categorized ecosystem services into four categories:

- Provisioning Services: These are the products obtained from ecosystems.
- Regulating: Indirect benefits from nature generated through regulation of ecosystem processes.
- Cultural: Non-material benefits from nature.
- Supporting: Fundamental ecological processes that support the delivery of other ecosystem services.

Provisioning Services	Regulating	Cultural	Supporting
• Food and fiber • Fuel • Genetic resources • Biochemicals, natural medicines, and pharmaceuticals • Ornamental resources • Fresh water	• Air quality maintenance • Climate regulation • Water regulation • Erosion control • Water purification and waste treatment • Regulation of human diseases • Biological control • Pollination • Storm protection	• Cultural diversity • Spiritual and religious values • Knowledge systems • Educational values • Inspiration • Aesthetic values • Social relations • Sense of place • Cultural heritage values • Recreation and ecotourism	• Soil formation • Nutrient cycling • Primary production

Table 1 Ecosystem services (Millennium Ecosystem Assessment, 2003, p. 56)

[7] Millennium Ecosystem Assessment (MA). (2003). *Ecosystems and human well-being a framework for assessment*. Washington, USA: Island Press.

Available at: http://pdf.wri.org/ecosystems_human_wellbeing.pdf

[8] The Economics of Ecosystems and Biodiversity, (TEEB). (2010). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. London, UK: Earthscan.

Urban GreenUP project in order to evaluate impacts and trade-offs of NBSs implemented in front-runner cities are using the Ecosystem Services Assessment (ESA) approach. ESA approach is based on urban ecosystem services. This methodology try to quantify the benefits that people obtain from ecosystems. Each NBS provides a service to the ecosystem in which it is implemented. One of the objectives of this catalog is to identify what service each NBS provides, in order to evaluate the benefits of each NBS.

2 NBS Index

2.1 How to use this index

In the section 2 you could find a list where all the Urban GreenUp Nature Based Solutions (NBS) are described. There are 46 NBS divided into 14 groups according to their category. The groups are:

Green Route (1 NBS)	**Arboreal interventions** (5 NBS)	**Carbon capture** (1 NBS)	**SUDs** (3 NBS)	**Flood actions** (4 NBS)	**Water treatment** (2 NBS)	**Green pavements** (4 NBS)
Smart soils (3 NBS)	**Pollinator** (5 NBS)	**Vertical GI** (5 NBS)	**Horizontal GI** (5 NBS)	**Pollutants filter** (2 NBS)	**Resting areas** (2 NBS)	**Urban farming** (4 NBS)

Table 2 NBS of Urban GreenUP

All NBS are in a table like this:

Urban GreenUP Category	NBS	Description	Main Challenge	Ecosystem services provided	Estimated budget and maintenance	Scale of intervention
Horizontal GI	**Green roof**	The external upper covering of a building which the main objective is […]		1) Air quality maintenance 2) Climate regulation […]	60 €/m² *Source: Prices taken from Spanish market* . Maintenance: Pruning and care of the vegetation […]	**B**

Table 3 Example of NBS index

Category: Name of the category in the Urban GreenUp project.

NBS: Name of the NBS

Description: Brief description of each NBS. In this column, you could read about how this NBS is.

Main challenge: The symbol of the main challenge. You can consult all of them in the section *1.4.1 Challenges*. In this column of the table you can see only the main challenge. Each NBS faces different challenges, but here we include only the challenge that is reached most effectively. In this way, you can select the NBS according to their efficiency in each challenge.

Ecosystem services provides: You can consult the entire list in the section 1.4.2 Ecosystem services provides.

Estimated budget: In this column you can consult this information:

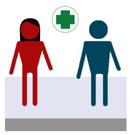
On the one hand, the approximate construction budget. This approach includes the cost of materials and labor. All these prices are in Euros (€) per Unit. The unit could be m (meters), m^2, m^3, tonnes… depending on the units of measurement of the NBS. Next to this value, you can find the source from which it has been extracted.

On the other hand, a brief description of maintenance. You could read about what maintenance operations must be carried out according to certain conditions.

Scale of intervention: This concept indicates the area where the NBS could be implemented. The values 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.

2.2 NBS index

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
Green route	Cycle and pedestrian green route	Bicycle and pedestrian green route is the part of green corridor works like linear greenway in the city. It characterized by pathways that provide recreational, public health and well-being opportunities, as well as transportation linkages. It serves to connect cyclists and pedestrians to nature.		1) Regulation of human diseases 2) Social relations 3) Recreation and ecoturism	€40 /m^2 *Prices taken from Turkish market.* Maintenance: Clear drainage channels and culverts, sweep debris and surface (especially in the fall), mow verges, cut trees and other vegetation, repair / replace damaged / lost signs, maintain lighting, furniture, structures if necessary.	**U**
Arboreal Interventions	Shade trees	A selection of trees series positioned in strategic locations to maximise summer time shading. 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.		1) Climate regulation 2) Aesthetic values 3) Recreation and ecoturism	€4 – 12000 /tree *Source: Prices taken from English market. The price depends on size, species and method of growth.* Maintenance: Three yearly cycle of inspection & maintenance; watering, pruning or pollarding if necessary	**S**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Cooling trees	Trees series planted to take advantage of evapotranspirative cooling. Species selected are those, which transpire at high rates to maximise their cooling effect. Provision of a constant water supply to such trees is essential to ensure this function is effective. As with shade trees, this NBS requires careful selection of the tree species to enable cooling. Different trees respond in different ways to increased temperature, matching trees that will continue to achieve the cooling effect through their transpiration, with the projected heatwave conditions is possibly the key consideration of this NBS.		1) Climate regulation 2) Aesthetic values 3) Recreation and ecotourism	€2-12000 /tree *Source: Prices taken from English market. The price depends on size, species and method of growth.* Maintenance: Appropriate cycle of inspection (3-5 years) & maintenance; watering, pruning or pollarding if necessary.	**S**
	Planting and renewal urban trees	Installation of large number of trees or renovation urban trees population. This NBS provides shady places and improve user's well-being as well as connection to nature. Endemic character of the arboreal species implanted it be taken into account since this is a guaranty of tree adaptation to soil and climate conditions.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Pollination 5) Storm protection 6) Inspiration 7) Aesthetic values 8) Social relations 9) Sense of place 10) Cultural heritage values 11) Recreation and ecotourism	€2-12.000 /tree *Source: Prices taken from English market. The price depends on size, species and method of growth.* Maintenance: Appropriate cycle of inspection (3-5 years) & maintenance; watering, pruning or pollarding if necessary	**U** **S**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Arboreal areas around urban areas	This NBS is based on creating new woodland areas that links the dense urban centres with the rural hinterland. This woodland areas help achieve future sustainable growth of the cities and also provide for a neighbourhood-pack effect. Endemic character of the arboreal species implanted it be taken into account since this is a guaranty of tree adaptation to soil and climate conditions.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Pollination 5) Storm protection 6) Inspiration 7) Aesthetic values 8) Social relations 9) Sense of place 10) Cultural heritage values 11) Recreation and ecotourism	€12.000 -200.000 /tree *Source: Prices taken from English market. The price depends on size, species and method of growth.* Maintenance: Appropriate cycle of inspection (3-5 years) & maintenance; watering pruning or pollarding if required	**U** **M**
	Trees re-naturing parking	Vacant or derelict areas in our towns and cities are often converted to temporary areas for car parking. These sites are often unsightly, with little concern for the image of the site, its impacts on neighbouring areas, nor for the issues m such as increased surface water runoff that might be exacerbated by the car park. This NBS is based on the use of trees, planted into the ground or in well-designed containers to improve local aesthetic and reduce surface water run off of this vacant or derelict areas.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Pollination 5) Storm protection 6) Aesthetic values	€2.000- 200.000 /tree *Source: Prices taken from English market. The price depends on size, species and method of growth.* Maintenance: Appropriate cycle of inspection (3-5 years) & maintenance; watering, pruning or pollarding if required	**S**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
Carbon capture	Urban carbon sink	Increasing urban green areas by planting Trees to maximize carbon sequestration around a new green corridor. Increased urban green areas provide many valuable ecosystem services such as regulating storm water infiltration, improving air quality, reducing urban heat island effects, provisioning food and habitats for many species, providing recreation and nature education for the city dwellers.		1) Climate regulation 2) Air quality maintenance 3) Aesthetic values 4) Recreation and ecotourism 5) Water regulation	€ 125 - 650 /tree *Source: Prices taken from Turkish market. Depending on the type of tree (Tilia cordata, Platanus orientalis or Pistacia terebinthus), size and age price is changing within this range.* Maintenance: Regular watering (esp. in dry season), and pruning and grafting (if necessary) in every 4-5 years.	U
SUDs	SUDs	SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies.[9]		1) Disturbance regulation 2) Water regulation 3) Erosion control and sediment retention 4) Waste treatment 5) Cultural	*Budget depending on the final solution implemented (to be checked). Source:*www.susdrain.org Usually SUDs components are on or near the surface and most can be managed using landscape maintenance techniques. Remedial maintenance: inlet/outlet repair, erosion repairs, reinstatement of edgings, reinstatement following pollution, removal of silt build up.	U S M

[9] http://www.susdrain.org/delivering-suds/using-suds/background/sustainable-drainage.html

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Grassed swales and water retention ponds	A swale is a rain garden placed in the side of a road, with a soakaway underneath. Typically, the swale also serves as a traffic harassment. A soakaway (dry well, infiltration well) is a pit in the ground, stabilised with a porous material wrapped in geotextile and covered with topsoil and vegetation.[10] Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. [11]		1) Disturbance regulation 2) Water regulation 3) Erosion control and sediment retention 4) Waste treatment 5) Cultural	Capital costs: €10-€60 /m^3 storage volume Maintenance costs: €1-€5 per m^2 pond surface area[11] Maintenance: Regular maintenance activities include litter and debris removal; vegetation maintenance; inlet/outlet inspection and maintenance; and sediment removal from forebay. Less frequent maintenance may include sediment removal from permanent pond; repairs; ongoing inspections and monitoring.	U S M

[10] Hoffmann, B., Laustsen, A., Jensen, I. H., Jeppesen, J., Briggs, L., Bonnerup, A., Milert, T. (2015). Sustainable Urban Drainage Systems: Using rainwater as a resource to create resilient and liveable cities. State of Green.

[11] http://nwrm.eu/measure/retention-ponds

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Rain gardens	A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation. The plants in Rain gardens must cope with dry and with wet conditions.[12]		1) Disturbance regulation 2) Water regulation 3) Water supply 4) Erosion control and sediment retention 5) Waste treatment 6) Cultural	€40 /m^2 *Source: Prices taken from Portuguese market, Lid-stormwater.net, and Rain Garden Alliance. The price depends on soil composition, existence of irrigation system, and species.* Maintenance: Appropriate cycle of inspection (1-2 years) & maintenance; maintenance operations include watering, pruning, pollarding, substitution of mulching and periodic review of the irrigation system (if present).	U S
Flood actions	Urban catchment forestry	The drainage patterns of towns and cities have been modified greatly. Catchment areas for water are now based on road and building layout, with underground sewer system taking on the role of the streams and rivers as the collecting and discharge points for water in the city. This NBS is based on renaturing these urban catchments by planting urban trees, with specific design to "slow the flow" of water through the catchment. The impact of well-planned urban catchment forestry interventions is reduced flood risk and a reduced amount of polluted water entering the sewerage system.		1) Climate regulation 2) Water regulation 3) Storm protection 4) Aesthetic values 5) Sense of place 6) Recreation and ecotourism	€100.000- 200.000 *Source: Prices taken from English market. The price depends on size of tree/s and tree pit design.* Maintenance: Appropriate cycle of inspection (3-5 years) & maintenance; watering, pruning or pollarding if required.	U S M

[12] Hoffmann, B., Laustsen, A., Jensen, I. H., Jeppesen, J., Briggs, L., Bonnerup, A., Milert, T. (2015). Sustainable Urban Drainage Systems: Using rainwater as a resource to create resilient and liveable cities. State of Green.

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
Hard drainage-flood prevention	Unearth water courses	Focussed on de-culverting watercourses in urban areas to provide opportunities to daylight. This involves excavating water courses and the removal of built infrastructure to 'daylight' the water channel. The process can support more effective flood risk management as it provides opportunities to re-naturalise water courses/corridors using NBS. Daylighting can also promote ecological and habitat diversity. There are also possibilities to utilities to improve their waste water/sewage management and treatment.		1) Storm protection 2) Water regulation 3) Genetic resources 4) Erosion control	This intervention depends on many factors. An intervention like that can include all this work items: soil movements, public sewerage system, public illumination, pavements, road signs, street furniture, gardening, irrigation systems, drainage system and water network. Example: Interior green ring, 585 meters, in Vitoria – Gasteiz, Spain : €3.792.185´74[13-14]	**R** **U** **M** *It depends on how much of a watercourse is artificial in the first place.*
	Channel re-naturing	Removal of the existing concrete river banks of channel and replace it with a modular green system called *Terramesh walls* that stabilise earth embankment and create green slopes by requiring vegetation.		1) Water regulation 2) Erosion control 3) Aesthetic Values 4) Recreation and ecotourism	€100 / m^3 - 2520 m^3 *Source: Prices taken from Turkish market.* Maintenance: Annual maintenance cost includes pruning and moving the existing vegetation and watering daily in summer time.	**U**

[13] Source: http://www.vitoria-gasteiz.org/docs/wb021/contenidosEstaticos/adjuntos/es/44/31/44431.pdf

[14] Project: http://www.vitoria-gasteiz.org/wb021/http/contenidosEstaticos/adjuntos/es/44/11/44411.pdf

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Floodable park	A floodable park basically 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. Floodable parks are free from water in dry weather flow conditions whereas in wet weather flow conditions excess surface run-off or excess water flow from rivers, streams, open channels, which may lead to flooding episodes, can be temporary stored. After the flood episode is over, stored water may be slowly drained out to a nearby watercourse, using an outlet control structure to control the flow rate.		1) Flood protection 2) Water regulation 3) Air quality maintenance 4) Aesthetic and recreation values	€15-25 /m^2 *Source: Prices taken from Spanish market. The price depends on the depth of the detention basin, the existing geology at the site and size of the floodable park to be designed.* Annual maintenance costs must include the necessary pruning and mowing of the vegetation existing in the park as well as the periodical cleaning tasks of the park and inlet and outlet control structures of water flow of the detention basin.	**R** **M** **U**
Water treatment	**Green filter area**	Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater. The residual water partially evaporates and the rest is taken up by the roots of trees and filtered through the soil. Before application to the soil, it is desirable to introduce a primary treatment system, to remove coarse solids, sand, grease and solids. But these systems provide more than just simple purification, because while treating the water, we are also producing biomass with high economic value.		1) Water regulation 2) Water supply 3) Erosion control and sediment retention 4) Waste treatment	€ 100 / PE (population equivalent) *Source: IMDEA Water* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**U**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Natural wastewater treatment	Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica. The flow-sheet can be completed by sand filtration and chlorination (disinfection) for the later water reuse.		1) Water regulation 2) Water supply 3) Erosion control and sediment retention 4) Waste treatment 5) Recreation 6) Cultural	€ 275 – 450 / PE (depending on the population size) * PE: population equivalent *Source: Ortega, E., Ferrer, Y., Salas, J.J., Aragón, C., Real, A. 2010. Manual para la implantación de sistemas de depuración en pequeñas poblaciones. Ministerio de Medio Ambiente y Medio Rural y Marino. ISBN: 978-84-491-1071-9.* Maintenance: Includes cleaning tasks, waste management, plants pruning, civil works maintenance, and water quality control. Depending on the population served, it is estimated to cost between €20-50 /p.e.-year[15].	**U**
Green pavements	**Hard drainage pavements**	Hard drainage pavements are a combination of built and impervious surfaces and permeable material. They allow storm water to permeate through the surface and are retained before being released into managed water systems. They differ from sustainable urban drainage (SUDs) or porous pavements, as they are not designed with a permeable membrane but a combination of hard (engineered) and an ecological (NBS) surface.		1) Water regulation 2) Water purification and waste treatment 3) Erosion control	€15 - 20 /m² *Source: Prices taken from Spanish market. The price depends on the size. The budget includes material and construction.* Maintenance: Clean the surface regularly	**S** **U**

[15] Ortega, E., Ferrer, Y., Salas, J.J., Aragón, C. Real, A (2010) Manual para la implantación de sistemas de depuración en pequeñas poblaciones. Ministerio de Medio Ambiente, Medio Rural y Marino. Gobierno de España

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Green pavements green parking pavements	NBS destined to replace grey urban pavement with 50% vegetal soil and high drainage capacity. This kind of pavements has gaps, which will be filled with smart soil and with specific creeping grass species with a short growing and minimum maintenance and are appropriate for bikes, pedestrian and motor vehicles.		1) Water regulation 2) Water purification and waste treatment	€30-90 /m^2 *Source: Prices taken from price generator taking into account the Spanish market* Maintenance: Decennial maintenance cost starts in: € 4.23 in the first 10 years Care of the vegetation, in case it is native vegetation selected, the water maintenance should not be needed.	U
	Cycle-pedestrian green pavement	This NBS includes green pavements in a special structure with filter properties and are appropriated for pedestrians and cyclists. This NBS allows manage the water runoff and it could be used for cyclist and pedestrian in the cycle-pedestrian areas. This kind of pavements will serve to reduce cycle speed in specific urban sections with many pedestrians. Thereby, it will avoid the small flood accumulation surfaces and this water will can be used to irrigate other NBS (resting areas an pollinator´s modules) in order to integrate several green infrastructures and several users of them. These sections of pavements will indicate slow velocity zones where the pedestrian presence is possible (street crosses, pedestrian stops, etc.).		1) Water regulation 2) Water purification and waste treatment 3) Recreation and ecotourism	€60-100 /m^2 *Source: Prices taken from price generator taking into account the Spanish market* Maintenance: Decennial maintenance cost starts in: € 4.23 in the first 10 years Care of the vegetation, in case it is native vegetation selected, the water maintenance should not be needed.	U

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Cool pavement	Cool pavements (roads, platforms, pavement around buildings, parking areas, etc.), are important for the local cooling strategies in a city using high-reflective or permeable paving materials and/or thinner pavements to reduce absorption and retention of heat comparing with concrete and asphalt.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Water purification and waste treatment	Permeable cement concrete: €45 /m^2 Concrete lattice: €10 /m^2 *Source: Prices taken from Turkish market.* Maintenance: Applying light-colored coating to increase reflectance. Pruning vegetation which grows in permeable pavings.	**U** **S**
Smart soils	Enhanced nutrient managing and releasing soli	Biochar is mainly used here, which is a highly porous charcoal material, produced by pyrolysis of biomass. Ongoing research suggests biochar added to soils may provide long-term stable storage of carbon in addition to improving soil fertility; its porous structure enabling increased absorption of pollutants from urban surface-water run-off and the slow release of plant nutrients. Improving soil functioning; providing soil nutrients for increased vegetation growth in NBS (increased net primary productivity), which in turn will provide enhanced carbon sequestration in vegetation and soils.		1) Carbon sequestration 2) Nutrient retention and release 3) Water purification	€1-17 /kg Maintenance: €3-50 /m^2 annually *Source: Prices taken from English market.*[16]	**S**

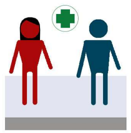
[16] www.britishbiocharfoundation.org

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Smart soil production in climate-smart urban farming precinct	In climate-smart urban farming precinct there is smart soil production area targeting dense urban areas, poor with soil and leftover spaces near urban areas. This type of soils have a combined or individual applications of different types of biochar. With this NBS there are water and carbon savings per unit area and eliminated discontinuity risk of agricultural production due to climate change.		1) Carbon sequestration 2) Water regulation 3) Climate regulation 4) Erosion control	€12-15/m^2 Maintenance: No maintenance cost *Source: Prices taken from Turkish market*	**S** **U**
	Smart soil as substrate	Different types of smart soils can be elaborated from agrofood sludge and biomass (biochar). The properties of NO_x fixation and self-fertilizer are achieved through the addition of encapsulated bacteria which accelerate the nitrogen cycle of the soil, increasing the absorption of atmospheric pollutants and the concentration of nitrates available for plants in the soil. These innovative soils could be used in several NBS. The technosoils contain a large amount of organic matter which improves the availability of nutrients and better holding water capacity which reduces the amount of irrigation needed.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Erosion control 5) Water purification and waste treatment	€50-80 /m^3 Smart soil without bacterias *Source: Estimated budget based on the cost of possible raw materials in the Spanish market. There is no smart soil with encapsulated bacteria on the market, it only exists at experimental level, so it can´t be given an approximate price.* Maintenance: doesn´t need maintenance, only replacement if necessary or once its useful life is finished (it depends on the edaphoclimatic conditions).	**U**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
Pollinator	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. Linking areas of flower-rich green space, both new and existing, to create sustainable networks of pollinator habitat within the urban area. This can also include low cost activities such as reduced mowing frequency.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values 6) Social relations 7) Recreation and ecotourism	€3-10 /m^2 *Source: Prices taken from Spanish market. The price includes the preparation of soil and the distribution of seeds.* Maintenance: weeding, planting (if annuals), watering, and possibly mowing and pruning.	**S** **U**
	Pollinators walls/vertical	Vegetated 'green' or 'living' walls, supporting flowering plants, which can provide nectar and pollen to attract foraging insect pollinator species. Either incorporated into new building design, or retrofitted, green walls are continuous or modular structures containing organic or inorganic growth media in which plants are rooted. For the system to be sustained, water and nutrients are required (which can be supplied using an automated irrigation system).		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€250 /m^2 – €800 /m^2 *Source: Prices taken from Spanish market. The price depends on the size of the garden.* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**B**
	Pollinator roofs	A green roof designed to attract biodiversity (especially pollinators) as a mean to compensate ecological habitat fragmentation. To optimise its functions, it must include various microclimates, native shrubs, pollen and nectar-rich plants, tall grasses, meadows, rocks, branches, birdhouses, bee nest boxes and water sources.		1) Climate regulation 2) Disturbance regulation 3) Pollination 4) Biological control 5) Refugia 6) Genetic resources.	€60 - 90 /m^2 *Source: Prices taken from Spanish market. The price depends on the size of the roof.* Maintenance: Pruning and care of the vegetation depending on the type of species. In the case of having irrigation, periodic review of the installation.	**B**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Natural pollinator´s modules	Natural Pollinator' modules are spaces with water, flowers and insects included in urban green areas. Flowers attract pollinating insects and provide a sustainable system of food sources for them and a safe habitat to feed, rest and thrive too. Pollinating insects are indicators of air quality improve cultures and some of them are predatory insects with positive effects in natural and biological pest control. This NBS must have special attention to install anti-allergy species of plants and will support biodiversity by creating wildlife friendly spots and areas which contribute to preserve and enhance the urban biodiversity at local level. Natural pollinator's modules have an estimated surface between 10 – 40 m^2		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Educational values 5) Aesthetic values 6) Recreation and ecotourism	€3400 /module *Source: Spanish market. That includes: Fertile land, Irrigation, Plants, Soil container (optional), Maintenance, …* Maintenance: Pruning and care of the vegetation. In the case of having irrigation, periodic review of the installation.	**U**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Compacted pollinator´s modules	Compacted pollinator’ modules are boxed spaces with water, flowers and insects, which could be installed into the city, sharing the space with building and other urban infrastructures. Flowers attract pollinating insects and provide a sustainable system of food sources for them and a safe habitat to feed, rest and thrive too. This NBS must have special attention to install anti-allergy species of plants and will support biodiversity by creating wildlife friendly spots and areas which contribute to preserve and enhance the urban biodiversity at local level. The modular presentation makes its transport easier; therefore it could be located according to urban needs, serving also as tool for traffic regulation or urban decorative element. Compacted pollinator’s modules have an estimated surface of 5- 10 m^2.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Educational values 5) Aesthetic values 6) Recreation and ecotourism	€2380 /module *Source: Spanish market. That includes: Fertile land, Irrigation, Plants, Soil container (optional), Maintenance, …* Maintenance: Pruning and care of the vegetation. In the case of having irrigation, periodic review of the installation.	**U**
Vertical GI	Green fences	Green fences will be made out of wood covered with climbers and shrubs as green elements that allow development of new vertical green surfaces and hence rising pollinator species by creating habitats. While they are acting green safety elements, they will be functioning as habitats. Their heights and configuration should be designed in such a way that they will not constitute a visual barrier for the people.		1) Air quality maintenance 2) Pollination 3) Aesthetic values 4) Recreation and ecotourism	€25-30/m^2 *Source: Prices taken from Turkish market* Maintenance: Pruning and retouch work on vegetation, painting and varnishing the woodwork.	**S** **B**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Green noise barriers	This NBS is a specific type of vertical garden that reduces the negative effect of the traffic noise due to the curve shape and a special finishes. It has a curve self-supporting structure. On the side of the traffic, the finish is metallic to permit the reflection of the noise and on the other side it has a vegetal finish. The size of these NBS depends on the height of the buildings that need to be protected.		1) Air quality maintenance 2) Climate regulation 3) Regulation of human diseases 4) Pollination 5) Aesthetic values	€600 /m² – €900 /m² *Source: Prices taken from Spanish market. The price depends on the size of the garden.* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**S**
	Green façade with climbing plants	A green façade is a wall completely or partially covered with greenery. It 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.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€150 - 200 /m² *Source: Prices taken from Spanish market. The price depends on the size of the garden.* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**B**
	Hydroponic green façade	It is a constructive system that allows planting on a vertical façade. This NBS is built with a substructure and a waterproof panel. The substructure is affixed to the façade. The plants grow in a fibrous material that is affixed to the panel. This fibrous material always is wet because the irrigation system soaks it. The water of the irrigation system nourishes de plants.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€250 – 800 /m² *Source: Prices taken from Spanish market. The price depends on the size of the garden.* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**B**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Vertical mobile garden	It is a constructive system that allows planting on a vertical surface. This NBS has its own structure so it is not affixed to any building. The system has a waterproof panel and a fibrous material where the plants grow. This fibrous material always is wet because the irrigation system soaks it. The water of the irrigation system nourishes de plants.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€550 /m^2 *Source: Prices taken from Spanish market. The price depends on the size of the garden. This prize is for 4 m^2 of surface.* Maintenance: Pruning and care of the vegetation and periodic review of the irrigation system.	**S**
Horizontal GI	**Floating gardens**	Development of areas of green space located on pontoons, floating platforms or barges hosted within marine/water based locations. Floating gardens are self-contained ecological units. Floating gardens provide habitats for varied marine/terrestrial species, opportunities for urban agriculture and climate change mitigation. They can also act as connective features linking habitats across urban boundaries (dependent on size/location and species mix). The strength and extent of the floating garden depend on the construction of the raft and the weight of the material placed/grown on it.		1) Air quality maintenance 2) Water purification and waste treatment 3) Pollination 4) Inspiration 5) Aesthetic values 6) Recreation and ecotourism	€150 – 200 /m^2 *Source: Prices taken from Spanish market. The price is based on floating gardens made with bio-rolls.* Floating gardens should be relatively self-sustainable, but may require weeding, restoration after storm events, and water pollution may need to be addressed if nutrient runoff causes excessive eutrophication.	**S**
	Green covering shelters	This NBS is a specific type of green roof. This GI integrates specific vegetation in curve or flat surfaces with a minimum maintenance. This type of green roof is very light and we can use it in structures that do not support much weight. It could be installed in small or big coverage infrastructures, like bus shelter or existing covering shelters.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€60 – 100 /m^2 *Source: Prices taken from Spanish market. The price depends on the size of the NBS.* Maintenance: In the case of having irrigation, periodic review of the system.	**B**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Electro wetland	Natural wastewater treatment system with two electrodes placed within the treatment bed that generates electricity from the oxidation of the organic matter by means of exoelectrogenic bacteria (Bioelectrochemical System, BES). Low input sensors can be powered with the electricity produced by the wetland. The integration of BES in the system also allows increasing the efficiency of the water treatment.		1) Water purification and waste treatment 2) Climate regulation 3) Knowledge systems 4) Educational values 5) Aesthetic values 6) Bioelectricity generation	€150 /m^2 *Source: Corbella, C. 2017. CONSTRUCTED WETLAND - MICROBIAL FUEL CELLS: electricity generation, treatment efficiency improvement, COD bioindication and clogging assessment. PhD Thesis. Universitat Politècnica de Catalunya, Spain* Maintenance: Includes cleaning tasks, waste management, plants pruning, civil works maintenance, and water quality/electricity control. Depending on the population served, it is estimated to cost between €20-50 /p.e.-year[17].	**U**
	Green roof	The external upper covering of a building which the main objective is to favour the growth of vegetation keeping the habitability conditions in the rooms below. The inclination of the roof must be between 0 and 45º. The green roofs have a waterproofing resistant to the penetration of roots and several additional layers that allow the correct development of the vegetation.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values 6) Social relations 7) Recreation and ecotourism	€60 - 80 /m^2 *Source: Prices taken from Spanish market* Maintenance: Pruning and care of the vegetation depending on the type of species. In the case of having irrigation, periodic review of the installation.	**B**

[17] Ortega, E., Ferrer, Y., Salas, J.J., Aragón, C. Real, A (2010) Manual para la implantación de sistemas de depuración en pequeñas poblaciones. Ministerio de Medio Ambiente, Medio Rural y Marino. Gobierno de España

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Green shady structures	Green shady structures can cover car park areas or streets by using textile structures with vegetation specially adapted to climate conditions. This textile structure could be attached to façades or it could have a metallic structure attached to the street. The plants grow in a fibrous material that is affixed to the textile structures. This fibrous material always is wet because the irrigation system soaks it.		1) Air quality maintenance 2) Climate regulation 3) Pollination 4) Inspiration 5) Aesthetic values	€900 – 1000 /m^2 *Source: Prices taken from Spanish market.* Maintenance: Periodic review of the irrigation system and replant plant species if some die.	S
Pollutants filter	Green filter area	Areas of green space/NBS located in interface locations such as roadsides, between industrial/commercial premises and public spaces, and screening of noise generation activities. Takes the form of a 'green barrier' using street trees, hedges and areas of green space (with a vertical elevation) to filter sound. Green filter areas in the form of street trees, hedges and green walls also filter pollution from vehicles, intercept pollutants from business/industrial orientated activity, and can be beneficial in storm water/rainfall interception, retention and controlled release.		1) Air quality maintenance 2) Climate regulation 3) Regulation of human diseases 4) Pollination 5) Aesthetic values	€2-4 /m^2 filter strip area Although locating NBS could be costly due to problems with underground service complications Source: Environment Agency, based on UK market Maintenance may include mowing and repair of eroded or damaged areas.	S
	Urban garden bio-filter	This NBS uses a special substrate (mixture of urban by – products) as filter media to capture pollutants (NOx, PM, CO, benzene, toluene, etc.) from the air of underground parking without waste generation. This NBS uses a rhizodegradation process in which contaminants are degraded in the rhizosphere (area of soil surrounding the roots of the plants) by means of microbial activity which is enhanced by the presence of plant roots.		1) Air quality maintenance 2) Climate regulation 3) Regulation of human diseases 4) Aesthetic values	Aprox. €3000-3500 /m^2 (there should be considered a minimum initial cost for equipment's needed by case) *Source: Prices taken from the innovative prototype example ("Grabgas project"), it is only prototype and not commercial price.*	S U

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
Resting areas	Parklets	Parklet or pocket park is provides opportunities for people to create small but important public spaces right in their own neighbourhoods. Parklets encourages walking and cycling.		1) Outdoor recreation 2) Pollination 3) Aesthetic values	€160 /m^2 *Prices taken from US market. The whole parklet cost can range from around 5000 to 15000 USD depending on design and materials.* Maintenance: Sweeping and rinse out the parklet area and close surrounding is required at least a month. Parklets may have used several years and likely require some renovations from time to time according to daily use, and the outdoor conditions.	S
	Green resting areas	Green resting areas are green spaces projected for social passive recreation (resting, relaxation, observing nature, social contact). It can be considered as sitting areas on public parks and streets. The development of green resting areas plays a central role in policies related to health, nature conservation and spatial planning. These areas offer many environmental (i.e. pollution control, biodiversity) economic (i.e. property value) and psychological (i.e. wellbeing) benefits.		1) Air quality maintenance 2) Climate regulation 3) Water regulation 4) Erosion control 5) Pollination 6) Aesthetic values 7) Recreation and ecotourism	€40 /m^2 - €60 /m^2 *Source: Prices taken from Portuguese market. The price depends on species, soil composition, existence of irrigation system, and existence of inert elements.* Maintenance: Appropriate cycle of inspection (1-2 years) & maintenance; maintenance operations include watering, pruning, pollarding, substitution of mulching and periodic review of the irrigation system (if present).	U S
Urban farming	Climate-smart greenhouses	Smart Greenhouse is a self-regulating, micro-climate controlled environment for optimal plant growth.Building planned greenhouses have some specific parts inside; those parts are showed different aspects of climate changes and continuously agricultural production under changing climate condition.		1. Carbon sequestration 2. Climate regulation 3. Water purification 4. Inspiration 5. Educational values 6. Social relations	€ 110-120/ m^2 *Source: Prices are taken from Turkish market by İzmir Metropolitan Municipality* Maintenance: Air Treatment & Management Equipment	S

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Urban orchards	Urban orchards are areas of land dedicated to the organic cultivation of vegetables or fruits and flowers. The activity needs regular irrigation and regular intervention in order to maintain the agronomic conditions to cultivate. These organic surfaces are located in the urban areas. In general, non-profit associations, neighbourhood associations or the city council are the usual management entities. Unemployed, retired people, families with limited resources or people interested in it usually are in charge of exploiting them. Urban orchards are considered social spaces where people and families achieve/obtain profits from nature and healthy vegetables from orchards.		1) Food and fiber 2) Water regulation 3) Social relations 4) Sense of place 5) Recreation and ecotourism 6) Primary production	Initial operating cost: €30.470 *Source: Spanish market* *Estimated costs:* - *Fertile land: €0.15/ l (10 m3 = €1,500)* - *Tools: for 1-3 people € 150, from 8 to 10 people € 400* - *Common zones: pollinators modules, waste bins, pergola with tables and benches. €3.000* - *Personal salary technical assistance/maintenance: public staff* - *Plants: It will be on the beneficiary* *Irrigation:* - *Pipped water for every single orchard: €500* - *Water tank for winter or emergencies: €70 /tank of 1000 l* - *Drip irrigation system: € 100 /25 m^2* The initial installation of the orchard implies a medium cost, mainly dedicated to the facility building. However, the later maintenance will be low.	**U**
	Community composting	Community composting activity is a method for treating solid waste in which organic material is broken down by microorganisms in the presence of oxygen to a point where it can be safely stored, handled and applied to the environment as a fertilizer and soil amendment. Organic material is delivered from the community and commercial activities: urban allotments, small-scale urban livestock, nearby restaurants, markets, fruit stores, etc. The objective is to close the loop on organics recovery. Likewise, this NBS has educational and engagement purposes.		1) Knowledge systems 2) Educational values 3) Social relations 4) Soil formation 5) Nutrient cycling	€0 - 50 /m^2 *Source: Prices taken from Spanish market. €0 if it is done on the ground, or the cost of doing it yourself and maintaining it would be mostly invested in labor. If you buy can be at least €50 at the beginning and with good maintenance, no other cost would be necessary.* Maintenance: Clean the space regularly	**U**

Category	NBS	Description	Main Challenge	Ecosystem services provides	Estimated budget and maintenance	Scale of intervention
	Small-scale urban livestock	*It is a form of small livestock keeping that is concentrated in and around cities. Small farm animals like poultry, pigs, and rabbits; provide meat, milk and eggs for families use. Animals can create problems such as smell, risk of disease, pollution of waterways, or quarrels between neighbours when they invade and damage gardens. However, they can also be a source of income; they provide food or services, help to reduce the volume of organic waste and can be part of social networks that are only clear to those who are involved in them.* (Source: FAO) [18] This NBS is perfect to implement with urban orchards and community composters.		1) Food and fiber 2) Educational values 3) Social relations 4) Primary production	Initial operating cost: €500 *Source: Spanish market* Estimated costs: *The costs related to buy animals could imply €50/year.* It will be not necessary a veterinary cost since the amount of animal will be low. *The cost related to build the hen house is around €400 (it will be made with wood and other natural materials)* Feed: around €1/kg of feed and/or house organic waste for poultry and pigs.	**U**

Table 4 NBS index

[18] http://www.fao.org/docrep/004/Y0500E/y0500e02.htm#TopOfPage

3 NBS Cards

3.1 How to use the NBS Cards

In the section 3 you could find the cards of each of the NBS. In each card you could consult:

Title:

Name of the NBS	Main challenge	Urban GreenUp category.

Description:

TECHNICAL DESCRIPTION	GRAPHIC DETAIL
Information about the materials, the construction…	Graphic information: photo, diagram… some drawing that provides clear information about the solution.

Challenge table: Here you could consult all the challenges that the NBS gets.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Type of challenge	General description about how the NBS gets the challenge	Values from studies or experiences that show how the NBS gets the challenge.	This concept indicates the area where the positive effects of the NBS have been noticed. The values are: R=Regional / M=Metropolitan / U=Urban S=Street / B=Building.	Simple chart to measure incidence

IMPLANTATION: Soft/Medium/Hard	AMORTISATION: Short term/Medium term/long term/no amortization
Degree of intervention in the environment. It takes into account the modifications that the environment suffers, when we incorporate the NBS, and the possible disadvantages of removing it in the future. • Soft: The NBS don't create important modifications in the environment. • Medium: The NBS creates some modifications in the environment. • Hard: The NBS creates a lot of modifications in the environment.	Period of recovery of the initial economic investment of the NBS. • Short term: 0 – 10 years • Medium term: 10 – 20 years • Long term: 20 – 50 years • No amortization

3.2 NBS Cards

Cycle and pedestrian green route	Green Route

TECHNICAL DESCRIPTION

Cycle and pedestrian green route is the part of green networks in the city. It characterized by pathways that provide recreational, public health and well-being opportunities, as well as transportation linkages (Figure 1). It serves to connect cyclists and pedestrians to nature. In this sense, this new generation multi-objective greenways go beyond recreation and beautification to address such areas as habitat needs of wildlife, promoting urban flood damage reduction, enhancing water quality, providing a resource for outdoor education, and other green infrastructure objectives (Searns, 1995).

Cycle and pedestrian green route combine natural planting or water systems together with paths for people on foot or by bike deliver a range of benefits:

- Improve bicycle and pedestrian transportation
- Improve public health through active living
- Enhance biodiversity (clear skies, clean rivers, and protected biological reserves)
- Enhance cultural awareness and community identity

Benefit is realized depends largely on the nature and types of the cycle and pedestrian green route system being implemented:

- Newly planned: This type of cycle and pedestrian green route integrates other nature-base solutions (i.e. shading trees, green pavement) with active travel modes together from the start (Figure 2).
- Retrofitted: This requires existing or abandoned roads/routes implemented together with other nature-based solutions.

GRAPHIC DETAIL

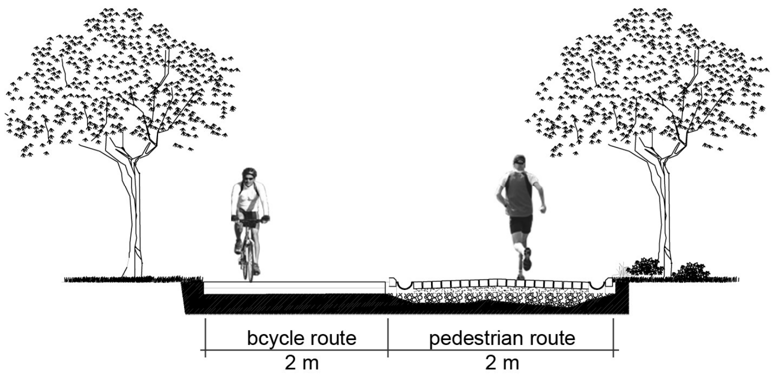
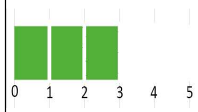
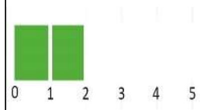
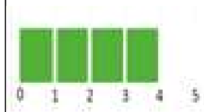
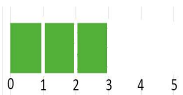
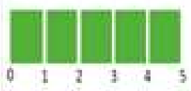


Figure 2 Dimensions of cycle and pedestrian green route

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Cycle and pedestrian green route can reduce the heat island effect, if they located in dense urban areas and supported by cooling trees.	Urban trees alongside with cycle and pedestrian green route have the capacity to moderate temperatures by providing shade and cooling an area, thus helping reduce the risk of heat-related illnesses for city dwellers (Wolch et al., 2014)	U	
Water Management	Water can cause tremendous damage to paths and pools of water spoils a cycle journey and walking experience. Creation of cambers or falls across paths can reduce flooding when it rains. It is also vital to use permeable material to drain away the rainwater. This can also allow water penetrates down and feeds the groundwater (Sustrans Design Manual, 2014).	Copenhagen Green Routes experience illustrates benefits of these routes for stormwater management (CSGN, 2018). Networks of cycling and pedestrian green routes safeguard water quality, provide habitat for plants and reduce downstream flooding (Walmsley, 2006).	S	
Air Quality	Cyclists and pedestrians are exposed to higher air pollution levels than motor vehicle occupants. Cycle and pedestrian green route contain buffer green that can enhance air quality by absorbing certain airborne pollutants from the atmosphere.	Studies on air quality reported that vegetation barriers and trees along roads/routes reduce roadside pollutant concentrations (Abhijitha et al., 2017). Green cycle and pedestrian routes alleviate automobile congestion and traffic-related air and noise pollution (Cavill and Davis, 2007).	U/S	
Social Justice and Social Cohesion	Giving more priority to creating green walking and cycling routes provide liveable environment for people to socialise and play in.	Copenhagen has implemented 58 km of integrated 'Green Walking and Cycle Routes' across a city with a ratio of typically 20% pedestrians to 80% cyclists. These routes are attractive to diverse range of people. Copenhagen experience indicates that 20% of users were found to be new cyclists to the area (CSGN, 2018).	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Public Health and Well-being	Walking and cycling have been recognized as an important potential means to promote public health. Therefore, cycle and pedestrian green route	Academic studies combining walking and cycling indicate that these activities reduce the risk of cardiovascular events, type-2 diabetes, hypertension and adiposity, and improves fitness (Oja et al., 2011). Active transportation such as walking and bicycling supports physical activity into daily routes and reduces obesity (Wolch et al., 2014).	U/S	

IMPLANTATION: SOFT/Medium/Hard	**AMORTISATION: short term/MEDIUM TERM/long term/no amortisation**
Cycle and pedestrian routes are the parts of urban green areas in the form of green network. Therefore, they can be easily installed and if necessary replaced with sole cycling route or green way.	A high standard of design and construction will mean less maintenance in the future. Cycle and pedestrian routes get the recovery of the investment in about 10 years.

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Urban Trees including: Planting and renewal of urban trees; Shade Trees; Cooling trees; Trees re-naturing parking and Arboreal areas around urban areas | **Arboreal Interventions**

TECHNICAL DESCRIPTION

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. The following are five types of NBS that arboreal interventions can provide:

Urban trees are a vital element of our green infrastructure. There is a vast worldwide literature on the development, delivery and management of the urban forest. Strategic positioning of large shade and cooling 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. Vacant or derelict areas in our towns and cities are often converted to temporary areas for car parking.

Around the densely developed centres of our urban areas are often larger areas of woodland, providing a wider range of NBS. Creating new woodland areas, linking the dense urban centres with the rural hinterland can provide a rich resource for NBS to help achieve future sustainable growth.

Each intervention will be designed to meet the objectives of the landowner, be appropriate to its context (right tree in the right place) and achieve multiple benefits.

GRAPHIC DETAIL

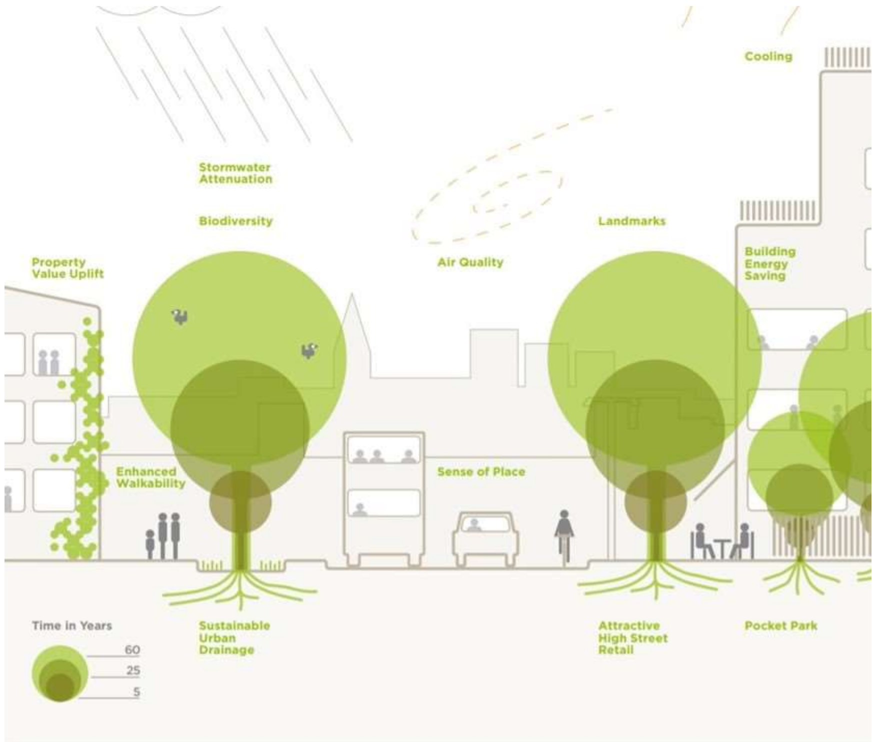
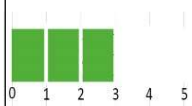
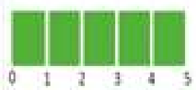
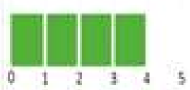
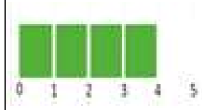
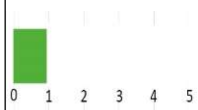
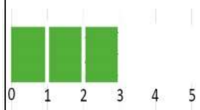
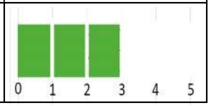
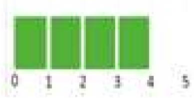
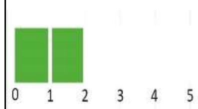


Figure 3 Trees in the Townscape

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Tree and woodland planting is a highly cost-effective and achievable way to reduced carbon dioxide and helps us adapt to likely changes in climate. Species selected include those are resistant to disease and which transpire at high rates to maximise their cooling effect. Provision of a constant water supply to such trees is essential to ensure this function is effective. Wooded areas also support coastal resilience against natural disasters	A review by Gago et al (2013) found that strategic tree planting reduces the intensity of the urban heat island effect. Analysis by Scharenbroch (2012) found that current urban tree populations have the capacity to sequester moderate amounts of carbon. Research by Foster et al, 2011 around coastal resilience is particularly significant because a growing majority of the world's largest cities exist within coastal zones (Neumann et al, 2015), and projected impacts of climate change include rising sea levels and intensifying weather variability and volatility (Lennon et al, 2014; Tibbetts, 2015).	U/S	
Water Management	Urban trees have a high propensity to intercept and abate runoff following extreme weather events, when compared not only against impervious surfaces, but also against other forms of naturally permeable land cover types, including lawns. Arboreal areas can alleviate the impacts of flooding in urban areas.	A study by Armson et al (2013) found that urban surface water runoff was reduced by as much as 62% where trees and tree pits were present, in comparison with areas of continuous asphalt. They also found that one young tree, planted in a small pit over an impermeable asphalt surface, can reduce urban surface water runoff by around 60%, even during winter dormancy.	U/S	
Green Space Management	Strategic species choice in planting urban and peri-urban trees can support biodiversity by providing important wildlife corridors in a fragmented landscape.	Alvey (2013) highlights the importance of urban trees along streets and within parks to address issues associated with biodiversity loss, including biotic homogenisation. Wildlife corridors are important in helping to overcome habitat fragmentation, enabling species to reach sparse resources, and ensuring that populations of species do	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		not become isolated or weakened by inbreeding (O'Brien, 2006).		
Air Quality	The planting urban and peri-urban trees, with careful consideration of location and species, can mitigate urban air pollution.	Abhijith et al (2017) found that trees improve urban air quality by increased pollutant deposition and dispersion, if species choice and management practices are appropriate for the immediate physical environment. Jones et al (2017) point out that trees intercept and capture airborne pollutants at intensities that depend upon the location and extent of vegetation. Arboreal areas outside of urban areas, for example, mitigate higher levels of ammonia.	U/S	
Urban Regeneration	The planting and renewal of trees can facilitate urban and peri-urban regeneration by adding amenity value to an area, with an increase in property value seen where tree cover is increased.	In North West England, a view of a natural landscape added up to 18% to property value, and residents in peri-urban settings are willing to pay £7,680 per household for views of broadleaved woods (Cousins and Land Use Consultants, 2009).	M/U	
Participatory Planning and Governance	The multi-functionality of urban and peri-urban trees, and the diverse range of potential beneficiaries, necessitate extensive stakeholder engagement in planning for implementation, and allows for interdisciplinary input.	In a social research report, states that there are multifarious social and political processes and structures that influence decision-making around street tree planting alone; these extend beyond legislation, ownership, policy, standards, organisational structure, cultural norms, and social networks.	U/S	
Social Justice and Social Cohesion	The planting of urban trees and peri-urban trees can improve safety and community strength.	It was reported by Dandy (2010) that urban trees can have a 'safety value,' with inverse correlations found between increased greenspace (including tree cover)	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		and reductions in crime rates and road traffic accidents. Dandy (2010) notes that one potential explanation for this is the increased social cohesion associated with increased use of urban forests.		
Public Health and Well-being	The planting of urban trees can support physical and mental health and wellbeing. Increased tree planting and the strategic positioning of trees within urban areas provide shade and evaporative cooling that help keep neighbourhood's cooler. Tree lined streets encourages walking and cycling which increase levels of physical activity.	Controlling for confounding factors, an increase in urban tree cover is associated with improved mental health (Willis & Petrokofsky, 2017). Children living on treeline streets have been shown to have lower rates of asthma. (O'Brien, et al 2010).	U/S	
Potential of economic opportunities and green jobs	Managing and improving arboreal areas around urban areas can support local employment.	Landscaping improvements in Portland Basin, Tameside and Winsford, Cheshire yielded respectively over 16% and 13% net growth in employment (BE Group, 2014).	R/M/U	

IMPLANTATION: SOFT/Medium/Hard The NBS don't create important modifications in the environment.	**AMORTISATION: SHORT TERM/Medium term/long term/no amortisation** The arboreal interventions get the recovery of the investment in about 5 years.

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- Figure 2: http://www.tdag.org.uk/

Urban Carbon Sink	Carbon capture

TECHNICAL DESCRIPTION

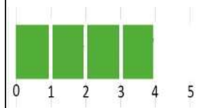
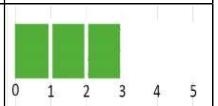
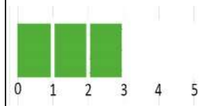
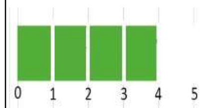
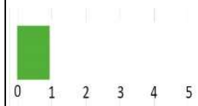
Urban Carbon Sink is the action covers planting trees to maximize carbon sequestration around a new green corridor mainly. Increase in shadow surface is another purpose of the action and trees such as *Tilia cordata*, *Platanus orientalis* and *Pistacia terebinthus* will be planted to increase the shadow surface area and to help to reduce the effects of heat island.

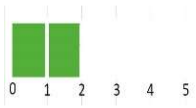
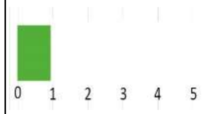
Air purification by means of removal of Nitrogen Dioxide (NO_2), Ozone (O_3), Sulphur Dioxide (SO_2), and PM10 particulate matter is one of the other effects of urban carbon sink.

With all these urban green areas provide many valuable ecosystem services such as regulating storm water infiltration, improving air quality, reducing urban heat island effects, provisioning food and habitats for many species, providing recreation and nature education for the city dwellers.

GRAPHIC DETAIL

Figure 4 Example of Urban carbon Sink

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	The plants are sequestering carbon and reduce the effects of climate change	The results revealed that tree and shrub canopy cover 48.3 % of the campus. While about 321.57 tons of Carbon Dioxide was sequestered annually, 8107.86 tons of Carbon Dioxide was stored by plants. (Hepcan & Hepcan, 2016)	U	
Water Management	The retention layer of trees reduces urban run-off water	Urban green areas provide many valuable ecosystem services such as regulating storm water infiltration (Hepcan & Hepcan, 2016)	U	
Green Space Management	Planting new trees increase the green areas and create new micro ecosystems	Planting new trees, "provisioning food and habitats for many species, providing recreation and nature education for the city dwellers" (Hepcan & Hepcan, 2016)	U	
Air Quality	The plants are able to absorb polluting substances and improve air quality	The results revealed that tree and shrub canopy cover 48.3 % of the campus. While about 321.57 tons of Carbon Dioxide was sequestered annually, 8107.86 tons of Carbon Dioxide was stored by plants. In addition, it was calculated that these plants removed about 28.70 kg of Carbon Monoxide (CO), 143.85 kg of Nitrogen Dioxide (NO_2), 1.58 tons of Ozone (O_3), 90.6 kg of Sulfur Dioxide (SO_2), 69.61 kg PM2.5 and 479.90 kg PM10 particulate matter per year (Hepcan & Hepcan, 2016)	U	
Urban Regeneration	Planting new trees increase the economic value of the area and decrease the costs caused by air pollution	Assessing Air Quality Improvement as a Regulating Ecosystem Service in the Ege University Housing Campus	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Public Health and Well-being	Trees improve air quality as well as quality of living for the citizens.	The results revealed that tree and shrub canopy cover 48.3 % of the campus. While about 321.57 tons of Carbon Dioxide was sequestered annually, 8107.86 tons of Carbon Dioxide was stored by plants. In addition, it was calculated that these plants removed about 28.70 kg of Carbon Monoxide (CO), 143.85 kg of Nitrogen Dioxide (NO_2), 1.58 tons of Ozone (O_3), 90.6 kg of Sulphur Dioxide (SO_2), 69.61 kg PM2.5 and 479.90 kg PM10 particulate matter per year (Hepcan & Hepcan, 2016)	U	
Potential of economic opportunities and green jobs	Planting new trees create maintenance jobs	Maintenance-related costs begin at the time of planting (also called installation costs) and continue throughout a tree's useful life through the time of removal (Vogt et al. 2015, The Costs of Maintaining and Not Maintaining the Urban Forest)	U	

IMPLANTATION: SOFT/Medium/Hard	**AMORTISATION: Short term/Medium term/LONG TERM/no amortisation**
This NBS does not need important changes on build environment. It can be easily implemented on demo sites with different physical conditions and can be easily removed when necessary.	Actions going to be implemented in terms of Urban Carbon Sink will have a recovery of investment period up to 30 years.

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SUDs

SUDs

TECHNICAL DESCRIPTION

SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies.

SuDS take inspiration from natural features and processes like uptake of water by plants, soil infiltration, pools, ponds, marshes, wetlands, springs, streams and rivers.

SuDS work by holding rainwater back, treating pollution and releasing it slowly, without overwhelming the watercourse or sewer system into which it flows, thereby reducing flooding.

SuDS are more sustainable than traditional drainage methods because they:

- Manage runoff volumes and flow rates from hard surfaces, reducing the impact of urbanisation on flooding
- Provide opportunities for using runoff where it falls
- Protect or enhance water quality (reducing pollution from runoff)
- Protect natural flow regimes in watercourses
- Are sympathetic to the environment and the needs of the local community
- Provide an attractive habitat for wildlife in urban watercourses
- Provide opportunities for evapotranspiration from vegetation and surface water
- Encourage natural groundwater/aquifer recharge (where appropriate)

GRAPHIC DETAIL

Figure 6 SUDs Features

- Create better places to live, work and play.

SuDS can take many forms, both above and below ground. Some types of SuDS include planting, others include proprietary/manufactured products. In general terms, SuDS that are designed to manage and use rainwater close to where it falls, on the surface and incorporating vegetation, tend to provide the greatest benefits. Most SuDS schemes use a combination of SuDS components to achieve the overall design objectives for the site.

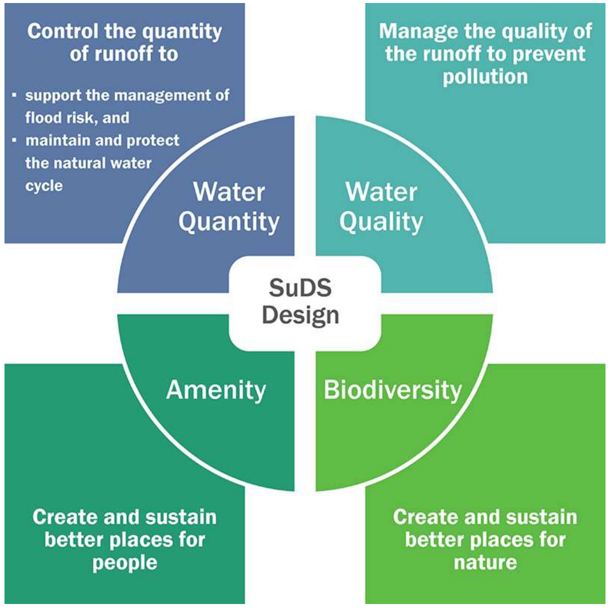
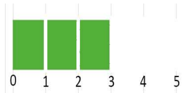
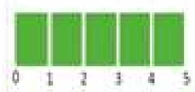
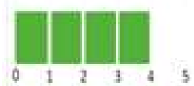
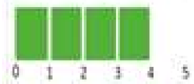


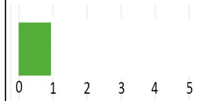
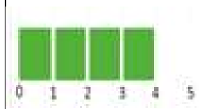
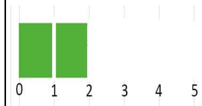
Figure 5 SUDs Design

Figure 7 Linear wetland, Scotland

Figure 8 Detention basin – near play area

Figure 9 Permeable paving

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	SUDS can replace some of the evaporative cooling lost through urbanisation, and can therefore provide climate change adaptation and mitigation against Urban Heat Island (UHI) effects. Vegetated SUDS devices provide the means to regulate climate, intercept stormwater and sequester or capture carbon leading to economic impacts of increased house prices and lowered energy costs (Tratalos et al. 2007).	SUDS can reduce local average air temperatures by up to 1°C (*URSULA project).* Wanphen and Nagano (2009) suggest that green roofs can reduce building surface temperatures as well as those in the surrounding atmosphere and hence reduce the need for air conditioning.	U/S	
Water Management	The SuDS approach involves slowing down and reducing the quantity of surface water runoff from a developed area to manage downstream flood risk, and reducing the risk of that runoff causing pollution. This is achieved by harvesting, infiltrating, slowing, storing, conveying and treating runoff on site and, where possible, on the surface rather than underground.	Green roof can absorb up to 100% of incident rainfall, dependent on conditions, and regionally with only 10% of roofs greened, a 2.7% reduction in storm water runoff can result, with a 54% average reduction in runoff per individual building (Mentens et al. 2006). TSS, NH4+-N and COD could be effectively removed by grassed swale, and the removal rate of these pollutants are significantly correlated with hydraulic detention time, void fraction of surface clay and adsorption capability of plant roots.,	U/S	
Green Space Management	The occurrence of SUDS solutions such as green roofs, rain gardens and swales can contribute to increase biodiversity locally. The SUDS solutions and the water cycle is becoming the focal point when creating green corridors and resilient cities by integrating nature into urban life.	It is possible to choose a strategy for the chosen plants in SUDS elements to support certain insects (i.e. bees, butterflies) and thereby birdlife, amphibians and/or native plants.	U/S	
Air Quality	Some SUDs components (eg trees, green roofs, green walls, swales, basins) can have a positive	The effect on air quality depends on the type of SUD implemented.	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	effect on local air quality, particularly in areas where air pollution is an existing problem (ie air quality management areas). They can absorb or remove certain pollutants, including nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulates (PM10) and ozone (O_3), providing a number of benefits to people that live, visit or pass through the area.			
Urban Regeneration	SuDS provide opportunities to create visually attractive green (vegetated and landscaped) and blue (water) corridors in developments connecting people to water. This in turn can improve the well-being of people that live or work in, or visit or pass through, the area, as the benefit pathway diagram below shows. Amenity benefits can be delivered in new build, retrofit or redevelopment situations and often relate to the pleasure derived from or the usefulness of components provided.	According to several studies, houses with a view of green are 1-15% more valuable. Offices with green spaces nearby can be 10% more valuable (*de Roo, 2011*).	M/U	
Public Health and Well-being	There is growing evidence to suggest that just being in the presence of green space improves people's quality of life and health. Those SUDs based on the creation of green areas, therefore, have a positive effect on public health and well-being.	Various authors (e.g. de Vries et al. 2003; Groenewegen et al. 2006; Maas et al. 2006) have also shown that proximity to green space in an otherwise dense urban area has a positive impact on perceptions of health and well-being.	U/S	
Potential of economic opportunities and green jobs	The design, construction and implementation of SUDs in the frame of metropolitan greening masterplan lead to the creation of green jobs (this	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	effect might not be noticeable in case of punctual actions).			

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
SuDs can be easily built in areas like driveways, walkways, parking lots, compacted lawn areas, roofs, and residential gardens.	Depending on the SUD implemented the amortisation period will vary.

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- Figure 5 : http://www.peterborough-suds.org/wp-content/uploads/2015/09/Peterborough-SuDS-Guide-1.1.pdf
- Figure 4, 6, 7 and 8: Source: The SUDs Manual_ CIRIA

Grassed swales and water retention ponds

SUDs

TECHNICAL DESCRIPTION

Swales are shallow, flat bottomed, vegetated open channels designed to convey, treat and often attenuate surface water runoff. When incorporated into site design, they can enhance the natural landscape and provide aesthetic and biodiversity benefits. They are often used to drain roads, paths or car parks, where it is convenient to collect distributed inflows of runoff, or as a means of conveying runoff on the surface while enhancing access corridors or other open space. Swales can have a variety of profiles, can be uniform or non-uniform, and can incorporate a range of different planting strategies, depending upon the site characteristics and system objectives.

Grassed swales have the capability to reduce runoff volume and improve water quality. Volume reduction occurs primarily through infiltration into the soil, either as the water flows over the slide slope perpendicular to the roadway into the swale or down the length of the swale parallel to the roadway. Pollutant removal can occur by sedimentation of solid particles onto the soil surface, filtration of solid particles by vegetation, or infiltration of dissolved pollutants (with stormwater) into the soil (Abida and Sabourin 2006). When solid particles settle to the soil surface or are captured by filtration on vegetation, the TSS concentration of the runoff is reduced and overall water quality is improved as long as the solids do not become resuspended.

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments.

Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled

GRAPHIC DETAIL

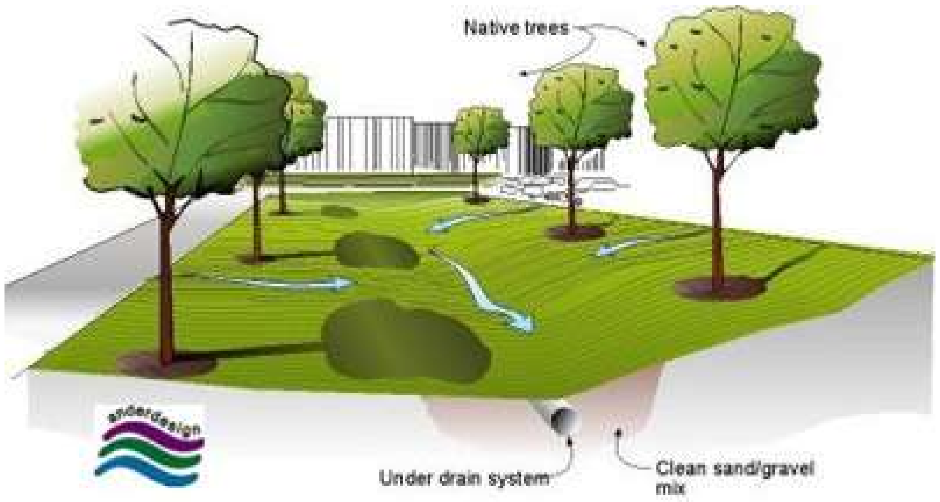


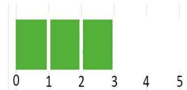
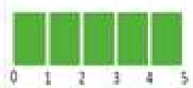
Figure 10 Under drain system

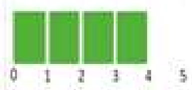
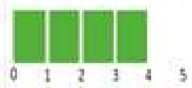
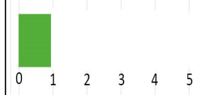
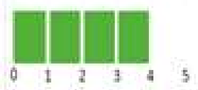
rate. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.

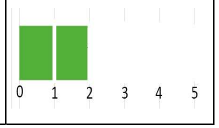
Ponds should contain the following zones:

- a sediment forebay or other form of upstream pre-treatment system (i.e. as part of an upstream management train of sustainable drainage components)
- a permanent pool which will remain wet throughout the year and is the main treatment zone
- a temporary storage volume for flood attenuation, created through landscaped banks to the permanent pool
- a shallow zone or aquatic bench which is a shallow area along the edge of the permanent pool to support wetland planting, providing ecology, amenity and safety benefits.

Figure 11 Stormwater retention pond

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Please, check the section for SUDs.	Please, check the section for SUDs.	U/S	
Water Management	Grassed swales have the capability to reduce runoff volume and improve water quality. Pollutants such as total suspended soils (TSS), total nitrogen (TN) and total phosphorus (TP) can be removed in swales through infiltration, chemisorption, sedimentation and filtration by soil particles and grassed blades (Stagge *et al*, 2012).	TSS removal by grassed swale is a physical process and sedimentation plays a primary role (Fletcher *eet al,* 2002). Particularly, Deletic and Fletcher (2006) analyzed the exponential decay of TSS concentration in grassed swale and found that TSS removal rate increased with the increasing of hydraulic residence time. Previous studies showed a great fluctuation of heavy metals removal by grassed swales. Lead is one of	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		the most concerning heavy metals in stormwater runoff and shows the greatest removal by grassed swales, with event mean concentration (EMC) reductions of 18 – 94 % (Rushton 2001). Zinc, similarly, is one of the most prevalent heavy metals in stormwater runoff, with EMC reductions of 75 – 91% (Barret et al., 1998). However, nutrients, such as nitrogen compounds (NH_4^+ -N, NO_3^- -N) and phosphorus are different from the other pollutants. Grassed swales have shown wide variability in removing nutrients, especially for nitrogen (Jia et al 2013). A typical study of grassed swale in Florida have shown that ammonia-nitrogen (NH_4^+ -N) could be effectively removed by grassed swale, conversely, nitrate-nitrogen (NO_3^- -N) is largely suspended in water with rather low removal rate.		
Green Space Management	Please, check the section for SUDs.	Please, check the section for SUDs.	U/S	
Air Quality	Please, check the section for SUDs.	Please, check the section for SUDs.	U/S	
Urban Regeneration	Please, check the section for SUDs.	Please, check the section for SUDs.	M/U	
Public Health and Well-being	Please, check the section for SUDs.	Please, check the section for SUDs.	Check the section for SUDs.	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Potential of economic opportunities and green jobs	Please, check the section for SUDs.	Please, check the section for SUDs.	Check the section for SUDs.	

IMPLANTATION: soft/MEDIUM/Hard	AMORTISATION: SHORT TERM/Medium term/long term/no amortisation
Vegetated swales can be easily implemented as they are linear structures. However, if combined with water retention ponds, surface requirements are larger.	Vegetated swales get the recovery of the investment in about 5 years.

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  Figure 10 and 11: Source: Natural water retention measures

Rain gardens

Flood actions

TECHNICAL DESCRIPTION

A rain garden is a bioretention shallow basin designed to collect, store, filter and treat water runoff. To optimise its functions, it must include a porous soil mixture, native vegetation and some hyperaccumulator plants, capable of phytoremediation.

The rain gardens are built with:

- A perforated pipe connecting to basin or stream outlet. **(1)**
- Gravel pipe bed. **(2)**
- Native soil. **(3)**
- Soil mixture of 50% sand, 20-30% compost and 20-30% topsoil. Sand creates a draining soil. **(4)**
- Overflow control structure. **(5)**
- Vegetation. Native plants with deep root systems that absorb runoff and pollutants. **(6)**
- Curb and gutter. **(7)**
- Curb cut to allow water to enter the rain garden. **(8)**

GRAPHIC DETAIL

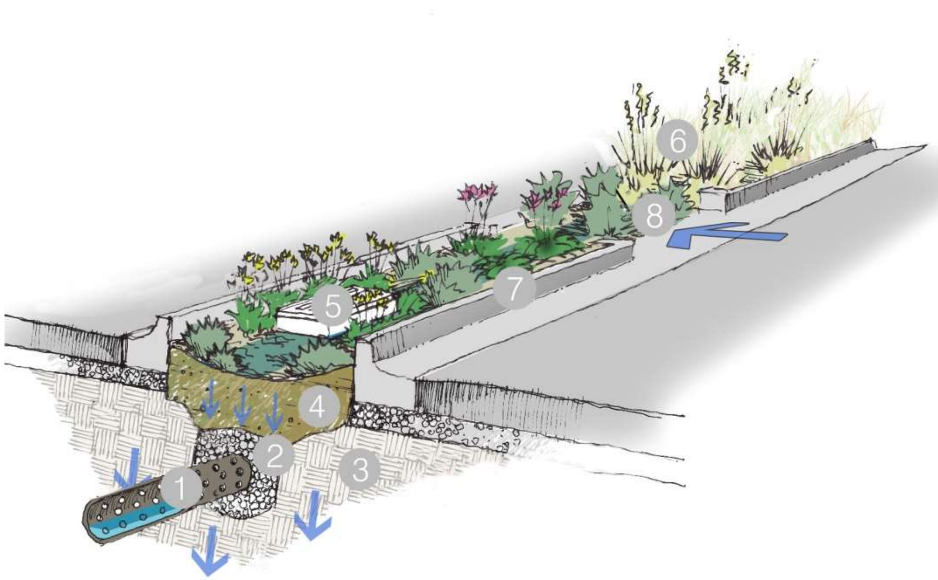
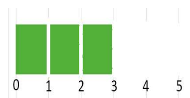
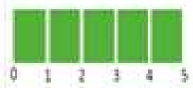
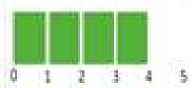
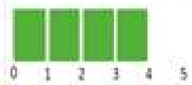
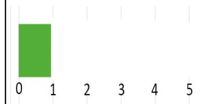
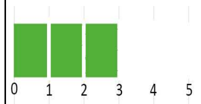
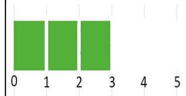
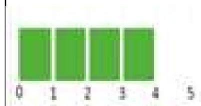
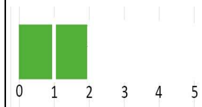


Figure 12 Perspective drawing of rain gardens

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Rain gardens reduce the heat island effect, especially when they contain trees.	For every 10% of green surface area that is increased, the temperature drops by 10º C *(De Roo, 2011)*.	U/S	
Water Management	Rain gardens allow stormwater to infiltrate, recharge aquifers, and reduce park flows. In addition, they provide water pollutant treatment.	Rain gardens enable a high infiltration of water. The vast majority (98,8 %) of inflow leaves the rain garden as subsurface flow. A rain garden with 1 m of native loamy sand soil mixture, vegetation and a bark mulch layer has an infiltration capacity of 11 cm/hour *(Dietz & Clausen, 2005).*	U/S	
Green Space Management	Rain gardens increase the green areas and create new little ecosystems. When rain gardens contain native plants, they provide habitat for beneficial pollinators, plants and birds.	The Case Study *Eastgate Yard Rain Garden* has shown that rain gardens provide habitat for wildlife and give people a place to enjoy nature.	U/S	
Air Quality	Rain garden contain plants capable of reducing some pollutants such as nutrients and metals.	A raingarden built in Connecticut was able to absorb 35,4% of NO_3, 84,6% of NH_3, 31,2% of Total Kjeldahl Nitrogen (TKN) and 32% of Total Nitrogen (TN) *(Dietz and Clausen, 2005; Dietz, 2007)*	U/S	
Urban Regeneration	Rain gardens represent an important technique of sustainable drainage, harmonizing the serious impacts of urbanization and soil sealing.	Every year, heavy rains lead to massive flooding across Seatle. An average rain garden (3 x 3,5 m) naturally filters 30,000 gallons of water per year (*12000 Rain Gardens in Puget Sound*).	M/U	
Participatory Planning and Governance	Rain gardens can be implemented including participatory planning. As a Best Management Practice (BMP), decentralization of stormwater management involves private property and possible liabilities.	A comprehensive monitoring program near Cincinnati showed that rain gardens provided sufficient enough incentive to encourage residents to participate in decentralization of municipal stormwater management (*U.S. Environmental Protection Agency*).	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Social Justice and Social Cohesion	Rain gardens can be viewed as an innovative drainage facility, encouraging people to create their own rain gardens and share results, increasing social cohesion.	Maplewood, Minnesota has implemented a policy of encouraging residents to install rain gardens. A focus group was held with residents and published so that other communities could use it as a resource (*Department of Landscape Architecture of University of Minnesota*).	U	
Public Health and Well-being	The plants present in rain gardens are able to absorb pollutants (phytoremediation) and increase water quality. Views of green increase people health and well-being.	A rain garden built in Maryland was able to absorb 15% of nitrate, 43% of copper, 70% of lead and 64% of zinc *(Dietz and Clausen, 2005; Dietz, 2007)*. Research has shown that views of green cause positive changes in systolic blood pressure *(Pretty et al., 2005)*, restore cognitive abilities *(Kaplan and Kaplan, 1989)* and decrease mental fatigue *(van den Berg et al., 2007)*.	U/S	
Potential of economic opportunities and green jobs	Projecting rain gardens reduces costs related to the implementation of conventional urban drainage systems. The construction of rain gardens creates several jobs.	-	U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: SHORT TERM/Medium term/long term/no amortisation
This NBS can be easily built in areas like driveways, walkways, parking lots, compacted lawn areas, roofs, and residential gardens. Often the required location and storage capacity of the garden must be determined first.	Rain gardens get the recovery of the investment in about 5 years.

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- Figure 12: Adapted from *Nvision Design Studio*.

Urban catchment forestry

Flood actions

TECHNICAL DESCRIPTION

Surface water flooding and poor water quality are already challenges in urban areas, with significant economic costs and impacts on health and wellbeing, and they are set to intensify with climate change and increasing urbanisation. Whilst traditional engineering approaches are part of the solution, evidence suggests that urban trees can also play a role. This can be done by preserving woodlands, forests and natural vegetation in watersheds; enhance urban and suburban tree canopy; protect trees at development sites; and increase the use of trees in storm water drainage systems.

It also include the use of tree pits which are adapted hold the water whilst ensuring good aeration, irrigation and space for the root system in order that urban trees thrive and provide long-term canopy cover.

GRAPHIC DETAIL

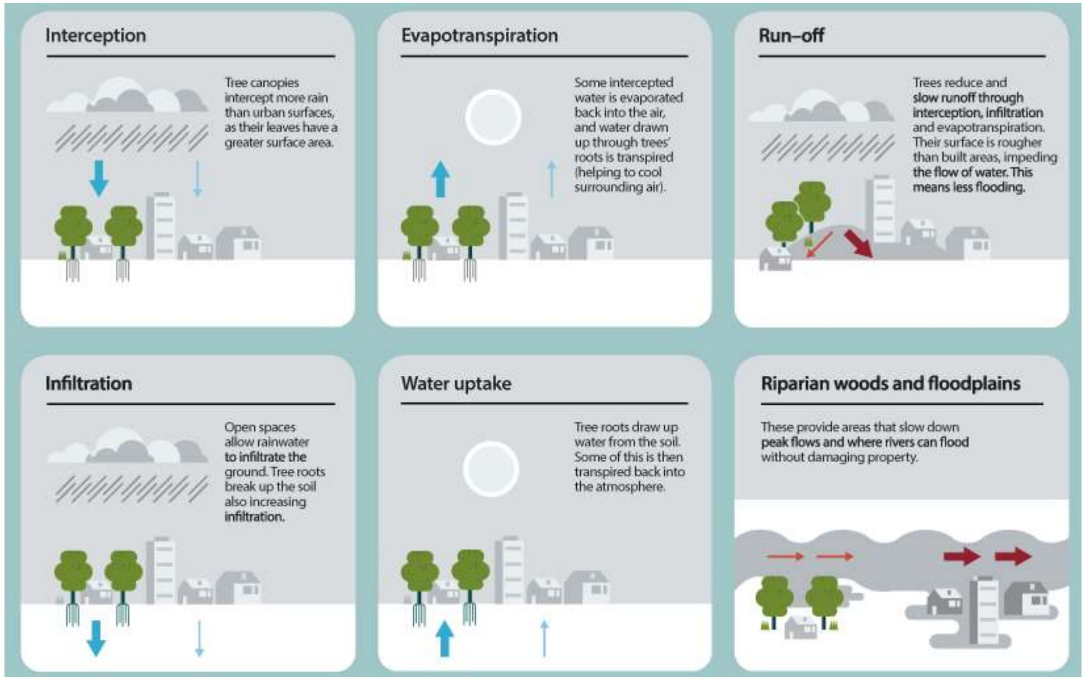
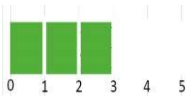
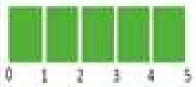
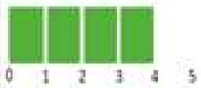
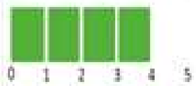
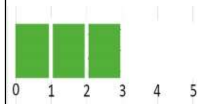
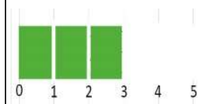
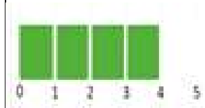
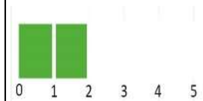


Figure 13 How trees can help reduce flooding

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	With climate change we are likely to experience more rain in winter, less rain in summer and more heavy rainfall events.	Individual trees in full leaf intercept up to 79% of a 20mm, 24 hr rainfall event (Xiao & McPherson, 2003)	U/S	
Water Management	Urban trees have a high propensity to intercept and abate runoff following extreme weather events, when compared not only against impervious surfaces, but also against other forms of naturally permeable land cover types, including lawns.	Increasing tree cover by 10% in town centres reduces runoff from an 18mm rainfall event by 8% (Gill, 2006)	U/S	
Green Space Management	Strategic species choice in planting urban trees to manage water can also support biodiversity by providing important wildlife corridors in a fragmented landscape.	Alvey (2013) highlights the importance of urban trees along streets and within parks to address issues associated with biodiversity loss, including biotic homogenisation.	U/S	
Air Quality	The planting urban and peri-urban trees primarily for water management provide additional benefits including mitigating urban air pollution.	Abhijith et al (2017) found that trees improve urban air quality by increased pollutant deposition and dispersion, if species choice and management practices are appropriate for the immediate physical environment. Jones et al (2017) point out that trees intercept and capture airborne pollutants at intensities that depend upon the location and extent of vegetation. Arboreal areas outside of urban areas, for example, mitigate higher levels of ammonia.	U/S	
Urban Regeneration	The planting of trees can facilitate urban and peri-urban regeneration by adding amenity value to an	In North West England, a view of a natural landscape added up to 18% to property value, and residents in peri-urban settings are willing to pay £7,680 per	M/U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	area, with an increase in property value seen where tree cover is increased	household for views of broadleaved woods (Cousins and Land Use Consultants, 2009).		
Participatory Planning and Governance	The multi-functionality of urban and peri-urban trees, and the diverse range of potential beneficiaries, necessitate extensive stakeholder engagement in planning for implementation, and allows for interdisciplinary input.	In a social research report, states that there are multifarious social and political processes and structures that influence decision-making around street tree planting alone; these extend beyond legislation, ownership, policy, standards, organisational structure, cultural norms, and social networks.	U/S	
Social Justice and Social Cohesion	The planting of urban trees and peri-urban trees can improve safety and community strength.	It was reported by Dandy (2010) that urban trees can have a 'safety value,' with inverse correlations found between increased greenspace (including tree cover) and reductions in crime rates and road traffic accidents. Dandy (2010) notes that one potential explanation for this is the increased social cohesion associated with increased use of urban forests.	U	
Public Health and Well-being	The planting of urban trees can support physical and mental health and wellbeing. Flooding in urban areas has a negative impact on mental wellbeing.	Controlling for confounding factors, an increase in urban tree cover is associated with improved mental health (Willis & Petrokofsky, 2017).	U/S	
Potential of economic opportunities and green jobs	Managing and improving arboreal areas around urban areas can support local employment.	Landscaping improvements in Portland Basin, Tameside and Winsford, Cheshire yielded respectively over 16% and 13% net growth in employment (BE Group, 2014).	R/M/U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: SHORT TERM/Medium term/long term/no amortisation
The NBS don't create important modifications in the environment.	The arboreal interventions get the recovery of the investment in about 5 years.

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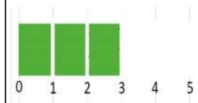
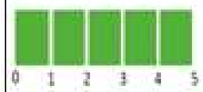
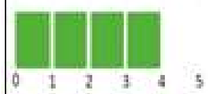
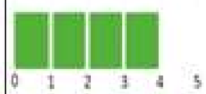
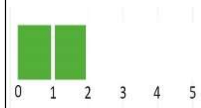
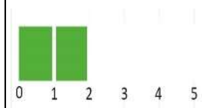
Hard drainage-flood prevention – Unearth water courses		Flood actions

TECHNICAL DESCRIPTION	GRAPHIC DETAIL
This NBS focuses on the delivery additional ecological components within a hard/built engineered approach to water management. They aid the reduction in pluvial flood risk in urban areas and improve the quality of water within sewerage systems. The main approaches and benefits of hard drainage flood prevention are: Hard drainage flood prevention includes river engineering and dam construction to control the amount of discharged. Dams can be built to hold water back and release it in a controlled way. Water is held in a reservoir behind the dam, and can provide an additional use, such as hydroelectric power or recreation. The river channel may be widened or deepened allowing it to carry more water. A river channel may be straightened so that water can travel faster along the course. The channel course of the river can also be altered, diverting floodwaters away from settlements. Considerations in designing hard drainage flood prevention: The dam specifications need to consider sediment trapping behind the dam wall, which can lead to erosion downstream. In addition, altering the river channel may lead to a greater risk of flooding downstream, as the water is carried there faster.	 Figure 14 Example of hard drainage solution

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Hard drainage flood prevention provides an engineered solution to manage the stresses associated with extreme weather events within an urban water system.	The modifications made to the River Don in Sheffield (UK) following the 2007 floods and the provision of EU funding have seen the flow and quality of water running through the river channel improve. This has aided the city of Sheffield in their management of possible flood events (South Yorkshire Forest Partnership & Sheffield City Council, 2012).	U	
Water Management	Flood prevention, more effective control of water resources and flow, as well as providing scope for improve water quality.	-	U	
Green Space Management	Hard drainage flood prevention can create new green/blue spaces around dammed areas, which provide ecological and socio-economic benefits for the environment and society.	The opening of the Walthamstow Wetlands in London (UK) in 2017/18 to the public indicates that engineered landscapes can be managed for ecological, as well as economic and social benefits. To date the site has attracted large number of visitors and has used the sites information boards/website to educate people about the value of effective water and ecological management.	U	
Urban Regeneration	Building in hard drainage flood prevention in the form of new water resource can support the provision of new/accessible NBS within development projects. They can also be used to promote economic uplift due to the improved ecological and aesthetic value that they add to a site.	Waterfront developments in Ahmedabad (India), Shanghai (China), London (UK) and Vancouver (Canada) have all made use of use of changing water course management and the additional channel modifications to promote urban regeneration (Mell, 2016; Mell, 2017).	U	
Public Health and Well-being	An increased capacity of water management system can improve water quality and by	Evidence from Natural England and the Forestry Commission in England and the European Union (through the Phenotype: Health from outside in	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	association human health. There is also a lower incidence of water borne diseases where effective management of the NBS is in place. In addition where new green/blue resources are developed they can be viewed as providing opportunities for people to interact more directly with the landscape improving health and well-being.	programme) indicate that health and well-being are improved through access to attractive and functional blue/green environments.		
Potential of economic opportunities and green jobs	During the construction of new resources/engineered solutions new employment opportunities can be developed. There is also scope to reduce the costs of flooding to individuals and businesses through more effective management of urban water resources.	The Metropolitan Water Reclamation District of Chicago with the Army Corps of Engineers and the Illinois Department of Natural resources re-engineered the flow of the Chicago to lower the impacts of flooding in metropolitan region of Chicago. This involved a combined us of hard drainage flood prevention and the creation of NBS wetlands (Mell, 2016)	U	

IMPLANTATION: Soft/Medium/<u>**HARD**</u> This NBS create important modifications in the environment.	**AMORTISATION:** Short term/Medium term/long term/<u>**NO AMORTISATION**</u> This type of interventions has a very high cost, and is very difficult to get the recovery of the investment.

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- Potential of economic opportunities and green jobs: https://www.mwrd.org/irj/portal/anonymous?NavigationTarget=navurl://ac86fd166ae2f8997581bde33ae1034a ; http://elpc.org/tag/metropolitan-water-reclamation-district/

Channel re-naturalization

Flood Actions

TECHNICAL DESCRIPTION

Terramesh is a soil reinforcement system which consists of panels of double twist hexagonal woven heavy zinc and PVC coated wire mesh used for stabilizing steep slopes and vertical walls (Jayswal et al., 2014).

A wedge of topsoil is placed behind the front face to facilitate a vegetative green finish.

The modular terramesh walls will be implemented in river banks following the removal of concrete walls.

Terramesh systems mainly consist of:

- Hexagonal wire mesh (1)
- Coconut fiber blanket or hexagonal wire mesh (2)
- Welded mesh panel (3)
- Interlayering material (4)
- Triangle bracket (5)
- Pre-formed steel strut (6)

GRAPHIC DETAIL

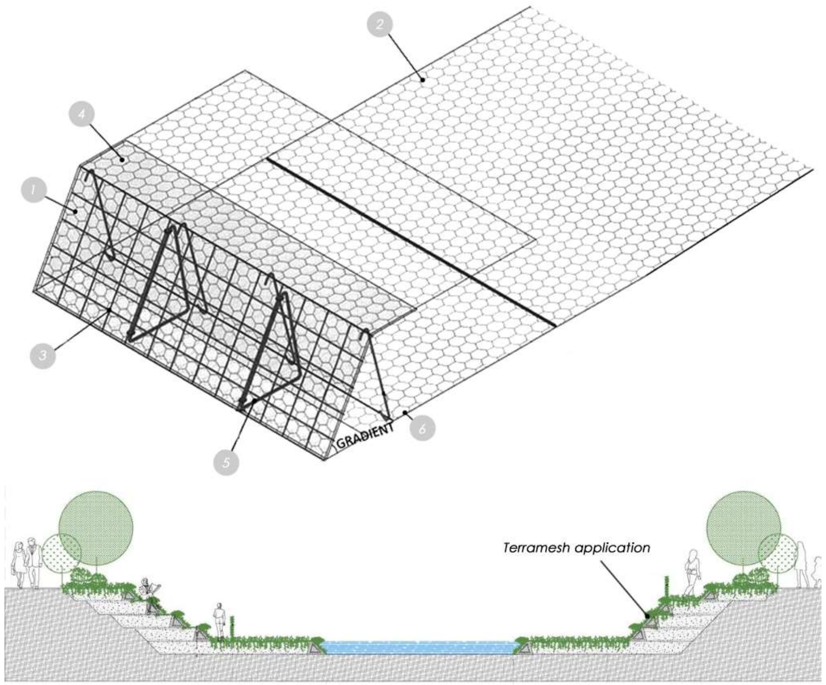
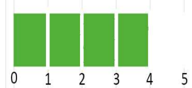
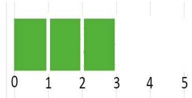
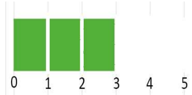
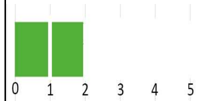


Figure 15 Techinal details of a terramesh system and a sample section of its use

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	Modular terramesh walls provide effective flood protection by stabilising earth embankment		U	
Green Space Management	Terramesh walls increase green areas around urban rivers and result in formation of new little ecosystems by creating green slopes	Ryan et al. (2009) highlights the economical and physical advantages of facings using welded wire or gabions and also emphasises that they provide possible treatment of the face for vegetative effects.	S	
Public Health and Well-being	Terramesh implementation enhances aesthetic values around rivers by replacing concrete river banks with soft green vegetation texture.	Some of the advantages of modular terramesh wall systems are described as they provide good drainage that provides increased stability, and possible treatment of the face for architectural effects (Ryan et al., 2009).	S	
Potential of economic opportunities and green jobs	As modular terramesh system is a living green system, it creates maintenance jobs.	Freeman and Fischenich (2000) stated that gabions need to be checked for broken wires and repaired if necessary to protect stone contained in the gabions from being removed by the force of water passing the cage. Any large woody vegetation that has started to grow in the gabions should be removed and any damage to the gabions repaired. This may include replacing lost stone and repairing any damaged wire.	U	

IMPLANTATION: Soft/MEDIUM/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
This NBS needs specific calculations according to the situation and characterization of every river channel. It does create important modifications in the environment	The terramesh system get the recovery of the investment between the 10 and the 20 years.

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Floodable park

Flood Actions

TECHNICAL DESCRIPTION

Floodable parks can be designed to control flow rates and decrease flow peaks by storing excess floodwater and releasing it slowly once the risk of flooding has passed. This type of Natural Based Solutions (NBS) can play a particularly important role in mitigating potential impacts caused by surface run-off water from rain, flash-floods or from small and medium sized watercourses. Other potential benefits that floodable parks can provide are among others, reducing the water flow entering the public sewerage system together with delivering amenity and biodiversity benefits.

When planning and designing a floodable park, special consideration must be taken to the following issues:

Selection and siting of floodable parks

Groundwater levels should be taken in to account to ensure that the basin will not fill with groundwater, reducing the storage capacity for surface runoff. For these reasons geotechnical investigations at site are required as well as to confirm the land stability and underlying soil/geology conditions prior to construction.

Detention basin design (1)

The storage capacity of the detention basin of the floodable park should be designed to be appropriate for the contributing catchment area as well as rainfall characteristics. The size of a detention basin is dependent on several factors such

GRAPHIC DETAIL

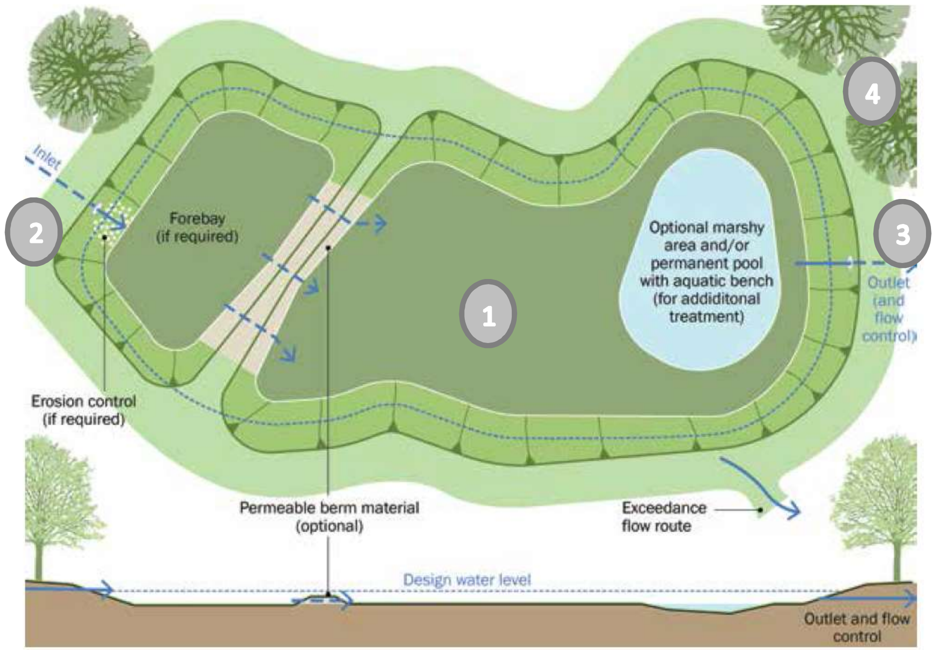


Figure 16 Plan and profile view of a design schema of a floodable park (CIRIA 2007)

as topography, the effective contributing area, and the relationship between the amounts of incoming and discharged water. They can be designed to be any size, depending on the storage requirements. *CIRIA (2007)* makes recommendations as to the design, including:

- A maximum depth of not more than 3m.
- The basin floor should be made as level and flat as possible to maximise storage potential and minimise the risk of erosion. This will also reduce flow velocities within the basin and maximise pollution removal potential for detention basins *(CIRIA, 2007)*.
- Recommended length:width ratio of between 2:1 and 5:1.
- Side slopes should not normally be greater than 1 in 4 for reasons of safety, ease of maintenance and amenity.
- Special account should be taken of natural features that could be used to form the basin and/or provide additional storage areas in order to minimise the earth-moving tasks and the need for artificial landscaping.

Inlet waterflow control structure design (2)

A spillway or a similar structure must be designed and built in order to keep under control overflow from rivers, streams or other watercourses. The inlet waterflow control structure must start diverting flow from river or streams to the detention basin when the capacity of a watercourse is exceeded and excess water spills out from the channel onto adjacent urban low-lying areas.

Outlet waterflow control structure design (3)

The design of floodable parks must allow to give back the stored water to the watercourse relatively fast after a flooding episode. The detention basin should be empty completely in a period of 24-48 hours after the flood event has occurred. In addition, installing no-return flap valves to avoid downstream water to return to the detention basin must be considered.

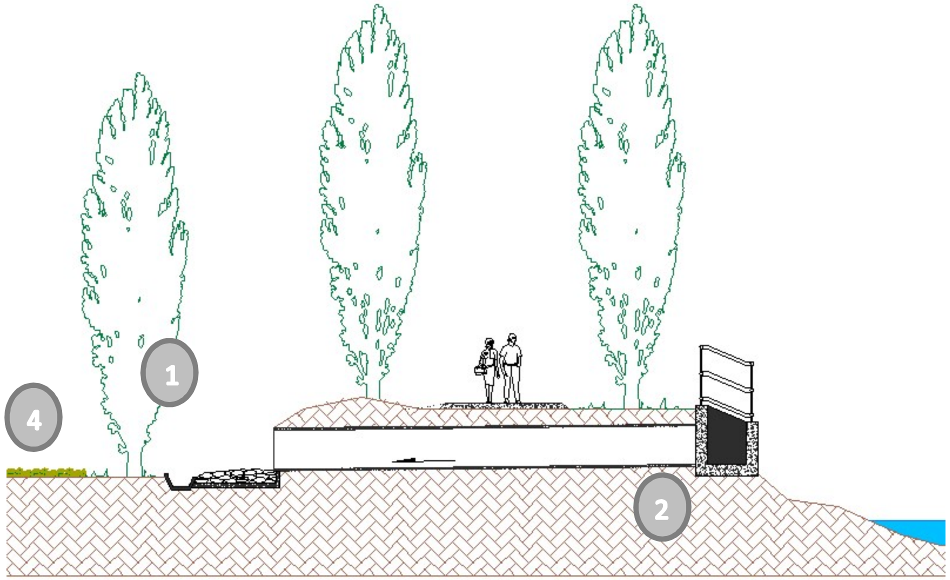
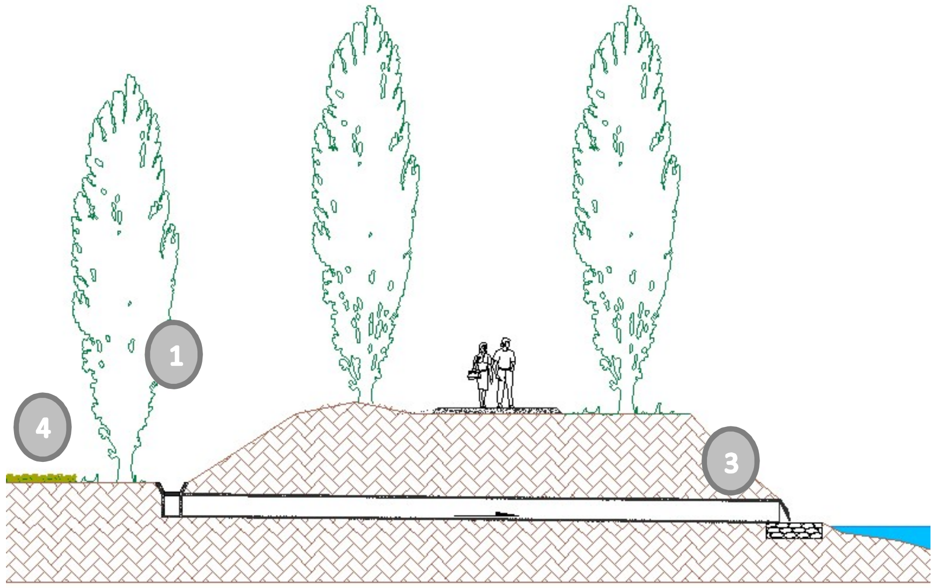
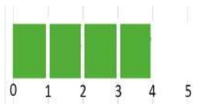
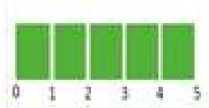
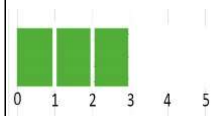
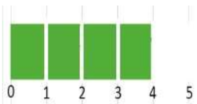
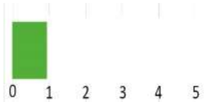
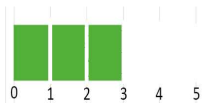
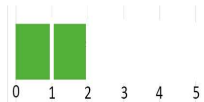
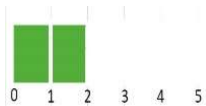


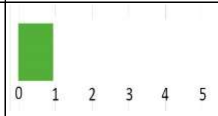
Figure 17 Profile view of an inlet waterflow control structure

Amenity and planting design (4)	
NBS such as floodable parks are relatively high land-take measures. However, they are well suited to dual purpose use (e.g. open spaces such as public parks), which can be achieved by taking into account at an early planning and design stage these recommendations among others *(CIRIA, 2007)*: ▪ Landscape design and planting should take account local environment and vegetation. Wherever possible, retain existing habitats and vegetation and incorporate these into the landscape design. ▪ Maximise the use of plants that are native and of local provenance, appropriate to the region and suited to local soils and hydrology. ▪ Never introduce invasive species. ▪ Choose species which, when planted together, maximise all-year-round leaf coverage, flowering and fruiting periods to provide food and shelter for invertebrates and birds. Finally, additional floodable park design features should include an emergency spillway for safe overflow when storage capacity is exceeded, maintenance access, pedestrian paths throughout the park and an appropriate landscaping integration.	 Figure 18 Profile view of an outlet waterflow control structure

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Trees and plants of floodable parks are sequestering carbon and contributing to reduce the effects of climate change.	Researchers have been conducted in order to assess and quantify the carbon storage and sequestration by urban trees (*Davies et al., 2011*). Carbon sequestration	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	Floodable park through increasing the urban vegetated urban area also may help to reduce the heat island effect, especially when trees are planted.	by trees can also be estimated in monetary values (*Baró et al., 2014*). Local temperatures and ameliorating heat island effects and heat stress can be reduced by trees evapotranspiration and shading (*Alexandri and Jones, 2008*).		
Water Management	Floodable parks can play a particularly important role in mitigating potential impacts caused by surface water flooding, sewer flooding, or as in this case, from small and medium sized watercourses. They can be designed to control flow rates by storing floodwater and releasing it slowly once the risk of flooding has passed. Also, they are useful in reducing floodwater entering into the public sewerage system, and consequently, being treated at the water treatment plant. If floodable parks are vegetated, The layer of trees and plants increases the absorption capacity of run-off water.	Floodable parks can avoid material damages and reduce cost due to flood events. Studies related to estimation of avoided damages and cost from floodings have been conducted by *de Moel et al. (2015)*. Also avoided costs from increased water quantities to be treated in sewerage systems have been estimated by *Deng et al. (2013).* Green surfaces, bioretention structures and single trees provide many valuable ecosystem services such as water run-off reduction (*Armson et al., 2013*).	U	
Green Space Management	Floodable parks contribute to increase green and blue areas surface throughout the cities. Moreover, this type of NBS can be useful to improve the connectivity and functionality of green and blue infrastructures.	*Brown et al. (2015)* exposed that implementing NBS projects can create, enlarge, fit out, connect and improve green and blue infrastructures.	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Air Quality	Vegetation existing in floodable parks contributes to absorb polluting substances and improve air quality.	Research results revealed that parks with various types of vegetation played an important role in ameliorating air quality in urban areas through the reduction of suspended particles (TSP), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) (*Yin et al., 2011*).	U	
Urban Regeneration	By creating new urban green spaces, floodable parks may contribute some aesthetic benefit to the urban landscape and if they are designed properly, they may help to increase the economic value of the area.	According to several studies, houses with a view of green are 1-15% more valuable. Offices with green spaces nearby can be 10% more valuable (*de Roo, 2011*).	U	
Participatory Planning and Governance	Floodable parks may be designed by means of participatory planning and community involvement.	Positive findings as to engaging residents to propose ideas and perceptions concerning urban ecosystems and their functions through participatory processes have been obtained by *Frantzeskaki and Kabisch (2016)*.	U	
Social Justice and Social Cohesion	Floodable parks can be experienced and enjoyed by greater diversity and number of people from different socio-economic backgrounds.	Improved cohesion between different socio-economic backgrounds may be achieved through investments in NBS across urban areas (*Natural England, 2014*).	U	
Public Health and Well-being	Public green spaces contribute to reduce noise levels, heat islands and air pollution, improving, consequently, quality of living for the citizens.	Several studies show that increasing the green areas in the urban environment has considerable positive health effects such as reduction in chronic stress and stress-related diseases (*Roe at al., 2013*); cognitive and social development in children (*Amoly et al., 2014*); increase of number of people being physically active, which is directly related to have less likelihood to suffer a cardiovascular disease (*Tamosiunas et al., 2014*); and	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		to reduce potentially autoimmune diseases and allergies (*Kuo, 2015*).		
Potential of economic opportunities and green jobs	Implementing a floodable park involves creating maintenance jobs since necessary pruning and mowing of the vegetation existing in the park are required. Furthermore, periodical cleaning tasks of the park and inlet and outlet water flow control structures as well as sediment removal after a flood event are also needed.	A review of the economic benefits of investing in green spaces carried out by *Saraev (2012)* states that developing NBS create green jobs as consequence of their construction and periodical maintenance.	U	

IMPLANTATION: Soft/MEDIUM/Hard	AMORTISATION: Short term/MEDIUM TERM/Long term /no amortisation
The degree of intervention in the environment will mainly depend on the volume of earth from the ground to be excavated and then transported to create the depression used as detention basin.	Actions to be implemented related to the floodable park will have a period of investment recovery up to 15 years.

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Green filter area

Water treatment

TECHNICAL DESCRIPTION

Green filter is a land application system for treating water (wastewater). It consists of a plot area, sized according to the influent to be treated, which has forests installed and is irrigated with wastewater.

The residual water partially evaporates and the rest is taken up by the roots of trees and filtered through the soil.

Before application to the soil, it is desirable to introduce a primary treatment system, to remove coarse solids, sand, grease and solids. But these systems provide more than just simple purification, because while treating the water, we are also producing biomass with high economic value.

Land Application Systems are considered a reliable, robust and low maintenance technology. This, together with the moderate cost of implementation, makes Land Application Systems a very competitive technology for treating wastewater from small towns or isolated areas.

Moreover, the production of biomass, either high quality (cycles greater than 10 years) or intensively (cutting cycles 2 to 3 years), generates a by-product of commercial value that reduces the final running and maintenance costs. Additionally, the added value generated by the capture of CO_2 in the biomass growth processes may constitute an input to be considered in the case of larger installations.

Recharging with the treated surplus is another big advantage, which can enable reuse in periods of great demand.

Finally, the environmental impact caused by this type of treatment is minimal, and in some cases positive, as it generates a forest ecosystem of great natural and scenic value.

GRAPHIC DETAIL

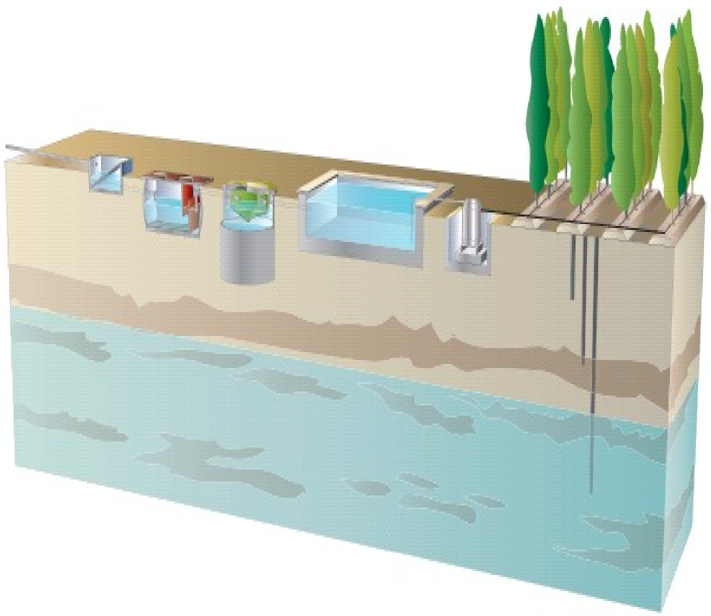
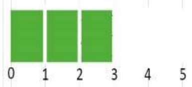
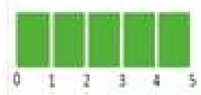
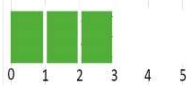
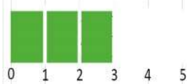
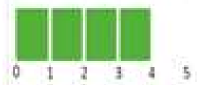
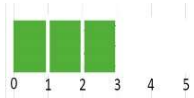


Figure 19 Example of green filter area

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Trees and plants of floodable parks are sequestering carbon and contributing to reduce the effects of climate change. Floodable park through increasing the urban vegetated urban area also may help to reduce the heat island effect, especially when trees are planted.	Researchers have been conducted in order to assess and quantify the carbon storage and sequestration by urban trees (*Davies et al., 2011*). Carbon sequestration by trees can also be estimated in monetary values (*Baró et al., 2014*).	U	
Water Management	The green filter is designed to treat wastewater before its discharge into the environment (soil). It the latest stage of a treatment train, therefore the water quality is expected to meet the regulations related to wastewater treatment/ reuse.	The expected removal rates of the green filter are similar to the ones reported for other natural technologies such as constructed wetlands (90-95% for suspended solids; 85-90% for BOD_5; 80-90% for COD; 20-30 N_{total}; 20-30 P_{total} (Ortega, Ferrer, Salas, Aragón, & Real, 2010)).	U	
Green Space Management	The Green Filter means the creation of a green area but some limitations to access to citizens must be established in order to avoid the contact with the pathogens in the wastewaters.	Related to the other challenges	U	
Air Quality	Tress existing in green filters contributes to absorb polluting substances and improve air quality.	Research results revealed that parks with various types of vegetation played an important role in ameliorating air quality in urban areas through the reduction of suspended particles (TSP), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) (*Yin et al., 2011*).	U	
Urban Regeneration	By creating new urban green spaces, Green Filters may contribute some aesthetic benefit to the urban landscape and if they are designed properly,	According to several studies, houses with a view of green are 1-15% more valuable. Offices with green	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	they may help to increase the economic value of the area.	spaces nearby can be 10% more valuable (*de Roo, 2011*).		
Potential of economic opportunities and green jobs	The Green Filter, such as any other wastewater treatment plant, demands operation & maintenance tasks which require skilled personnel (supervisor and operators). Depending on the size and complexity of the installation the periodicity of those tasks will vary.	Around 160 h/year of operator are required for O&M for a natural wastewater treatment plant (Ortega, Ferrer, Salas, Aragón, & Real, 2010). Therefore, the installation of this NBS will partially contribute to the generation of green jobs.	U	

IMPLANTATION: Soft/Medium/HARD

NWTP is based on natural wastewater technologies which are characterised by large surface-requirements (3-5 m^2/PE).

AMORTISATION: short term/MEDIUM TERM/long term/no amortisation

The Green Filter get the recovery of the investment between the 10 and the 20 years.

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- Figure 19: Source, IMDEA Water *(http://www.water.imdea.org/sites/default/files/pdf/publicity/fichas/ENG/Offer_LAND%20APPLICATION%20SYSTEMS.pdf)*

Natural wastewater treatment

Water treatment

TECHNICAL DESCRIPTION

Wastewater treatment plant based on the combination of natural treatment systems, such as constructed wetlands and ponds, following the concept of waterharmonica.

Constructed wetlands are water purification systems that reproduce the processes of contaminant elimination which occur in natural wetlands. Therefore, constructed wetland technology operates as a complex ecosystem made of the following elements (Vymazal, 2008; Kadlec et al., 2009):

- The water to be treated, which flows through the filtrating substrate and/or vegetation.
- The substrate, which is the support of the plants and has to retain the microbial population (in the form of a biofilm), and is essential in most processes aimed at removing the wastewater contaminants.
- The emerging aquatic plants (macrophytes), which supply surface area for the formation of bacterial films; they facilitate the filtration and adsorption of the wastewater constituents, they help to oxygenate the substrate and remove the nutrients as well as controlling the growth of algae by limiting the penetration of sunlight. Furthermore, the vegetation helps to integrate these treatment devices in the landscape.

Traditionally, there are two types of constructed wetland depending on the type of water flow: surface flow or subsurface flow. In Surface Flow Wetlands, SFW, or Free Water Surface Wetlands, FWS, the wastewater flows over the substrate whilst in Subsurface Flow Wetlands, SSFW, or Vegetated Submerged Beds, VSB, the water flows underground through the interstitial spaces of the filtrating bed.

GRAPHIC DETAIL

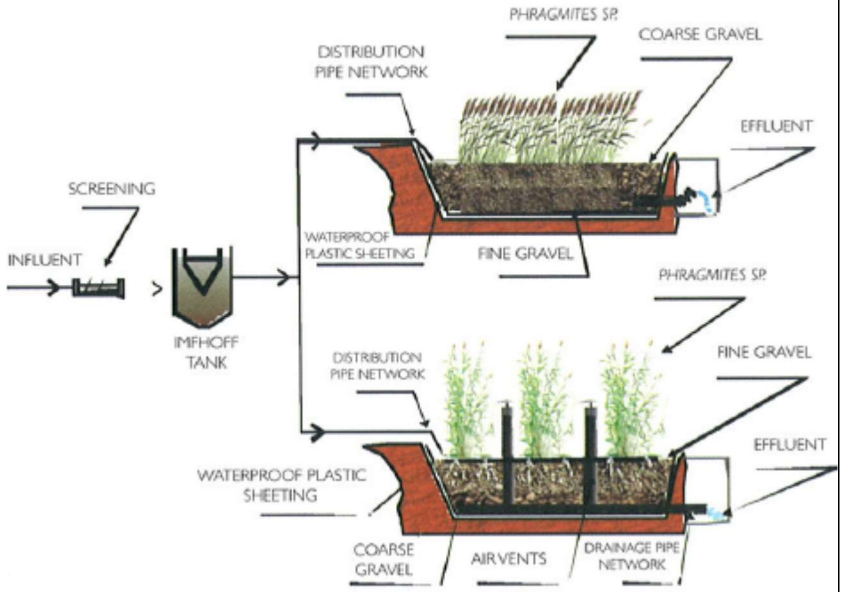
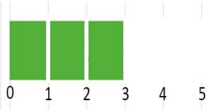
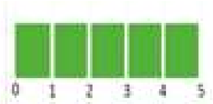
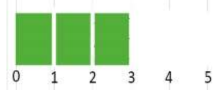
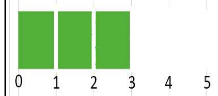
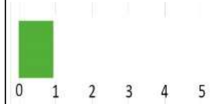
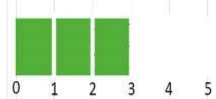


Figure 20 Horizontal and vertical subsuperficial flow constructed wetland

This NBS is based on the concept of the *Waterharmonica*, which has been developed by the water boards Hoogheemraadschap Hollands Noorderkwartier (Ruud Kampf) and Wetterskip Fryslân (Theo Claassen). The Waterharmonica aims for integrated water management, bringing the engineering world of the "Water Chain" and the ecological world of the "Water System" together. Waterharmonica systems have been constructed in various places in The Netherlands firstly on a small scale but now also on a large scale. At sites where the Waterharmonica is combined with an ecological connecting corridor it can function as a stepping stone or habitat. The Waterharmonica is very well suited to play a role in urban water management see for plans in several cities like Apeldoorn Arnhem and Amstelveen (Veluwe 2005, Arcadis 2004 and Leloup Voort et al 2012).

A consequence of the Waterharmonica approach is the creation and restoration of wetlands and the conversion of costs of water purification into economic and natural revenues for citizens but also for water authority. This applies to an even greater extent to the developing world (Mels Martijn et al 2005). The sensible use of water and nutrients help fight poverty and simultaneously conserves and enhances important ecosystems. It is not only the solution to a waste water problem; it is especially an area and ecosystem-oriented approach.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	The presence of vegetated areas in combination of water ponds may reduce locally the heat island effects. Organic matter oxidation releases some GHG such as CO_2 and CH_4. On the contrary, the presence of vegetation may reduce the GHG emissions.	Values of heat island effect reduction are expected to be within the range of bibliography reported for similar GI (reductions between 1.3 and 2.8 ºC have been reported (Demuzere et al., 2014)). GHG emission from constructed wetlands has been measured in full-scale constructed wetlands in the last decade. The CO_2 -eq ranges from 660 to 800 mg CO_2-eq/m^2/h depending on the type of CW (Mander *et al.*, 2014).	U/S	
Water Management	The NTWP is addressed to remove the pollutants (organic matter and nutrients) that are found in the wastewater. Besides, the treated water may be reuse for different purposes (i.e, irrigation of green areas), after a complementary treatment, thus, increasing the availability of water resources.	The expected removal rates of the NTWP are close the ones reported for conventional constructed wetlands (90-95% for suspended solids; 85-90% for BOD_5; 80-90% for COD; 20-30 N_{total}; 20-30 P_{total} (Ortega, Ferrer, Salas, Aragón, & Real, 2010)). The introduction of a disinfection unit as the latest stage, may allow also the	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		reduction of pathogens, required for the safe water reuse.		
Green Space Management	The NTWP means the creation of a green area but some limitations to access to citizens must be established in order to avoid the contact with the pathogens in the wastewaters.	Related to the other challenges	U	
Air Quality	An improper management of the facility may lead to anaerobic or septic conditions with the consequent generation of bad odours (H_2S).	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U	
Urban Regeneration	By creating new urban green spaces, NTWP may contribute some aesthetic benefit to the urban landscape and if they are designed properly, they may help to increase the economic value of the area. Limitations to this potential may appear in case of bad odours.	According to several studies, houses with a view of green are 1-15% more valuable. Offices with green spaces nearby can be 10% more valuable (*de Roo, 2011*).	U	
Potential of economic opportunities and green jobs	The NTWP, such as any other wastewater treatment plant, demands operation & maintenance tasks which requires skilled personnel (supervisor and operators). Depending on the size and complexity of the installation the periodicity of those tasks will vary.	Around 160 h/year of operator are required for O&M of a NTWP (Ortega, Ferrer, Salas, Aragón, & Real, 2010). Therefore, the installation of this NBS will partially contribute to the generation of green jobs.	U	

IMPLANTATION: Soft/Medium/HARD	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
NWTP is based on natural wastewater technologies which are characterised by large surface-requirements (3-5 m^2/PE).	The NWTP get the recovery of the investment between the 10 and the 20 years.

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Hard drainage pavements

Green pavements

TECHNICAL DESCRIPTION

Hard drainage pavements, also known as porous pavements, are nature-based infrastructure which provides opportunities for increased percolation of rain and surface water through a paved surface. They are constructed of smaller areas of impermeable surface compared to more traditional paving, which is interspersed with greased or areas of sand to allow water to dissipate through the surface more quickly. Hard drainage pavements can also trap suspended solids and thus filter out pollutants associated with stormwater. The central goal of hard drainage pavements is to control stormwater, reduce runoff and surface water stagnation and improve water quality in substrate layers via additional filtration. They are suitable for pedestrian and cycling activity, as well as car parks and other areas of standing water.

Hard drainage pavements can be constructed from a variety of materials whose main property is the additional filtration of rainfall/stormwater from a surface area to a substrate. The most common forms of hard drainage pavement are:

1. Porous concrete
2. Porous asphalt
3. Permeable interlocking concrete pavers
4. Polymer-based grass pavers, grids and geocells

Their construction includes the creation of a series of layers that provide opportunities for rainfall/water to permeate through the surface to the substrate. This includes the porous top layer (porous concrete/asphalt or interlocking pavers) which are placed over a rock/stone reservoir or filter layer, which provides space for water to leach through the different layers. Depending on the location of intervention there may also be a fabric membrane installed as the bottom layer. The thickness of the reservoir/filter membrane varies depending on the climatic conditions, with areas of heavily rainfall requiring a deeper layer to mitigate the additional flow and time needed to dissipate.

GRAPHIC DETAIL

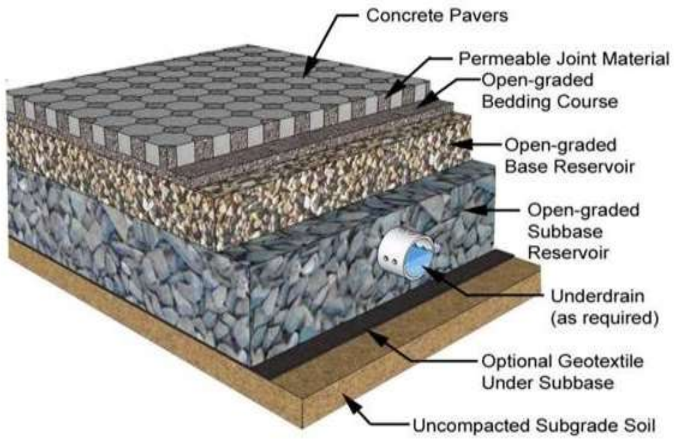
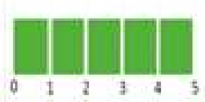
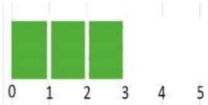
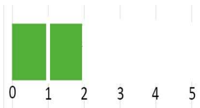
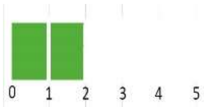
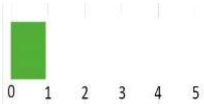


Figure 21 Example of a hard drainage pavement

In addition, depending on the type of hard drainage system utilised the physical composition of the porous layer will vary. Porous concrete/asphalt and permeable interlocking concrete pavers will have a uniform look (depending on their design). However, polymer based grass pavers, grids and geocells have a more varied form (due to the design of different manufacturers), and this can include the use of hexagonal cells which are subsequently filled with natural material, i.e. soils.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	Hard drainage pavements increase the level of infiltration and retention of rainfall thus helping to alleviate spikes in peak flow. They can also help remove suspended particulate matter from water systems thus lowering the impacts on water quality. Permeable pavements re-produce the flow reduction and water quality improvement properties of natural surfaces and vegetation, reduce the amount of overland flow reaching receiving waters, thereby reducing peak flows in rivers and streams (Pratt et al. 1989, Legret et al., 1996).	Up to 95% of surface water can be absorbed through the additional of hard drainage pavement. In addition, depending upon site conditions it may be possible to allow the captured water to slowly infiltrate into the ground or discharge into the next stage of the management train. The typical flow rate of water leaving a permeable pavement is 2 to 7 l/s/ha (litres/second/hectare) (Breet Paving – Technical Data Sheet: Permeable Questions FAQs) Research by the Construction Industry Research and Information Association (CIRIA) has shown that a permeable pavement can remove 60 – 95% of suspended solids and 70–90% of hydrocarbons. The result of this is that the water infiltrating into the ground, or draining into the next stage of the management train, is significantly higher quality than if using an impermeable surface coupled to attenuation tank (Breet Paving – Technical Data Sheet: Permeable Questions FAQs).	U	
Green Space Management	Vegetated permanent pavements increase the green areas and allow water penetrates down through the voids, feeds the groundwater.	Related to the other challenges.	S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Urban Regeneration	Hard drainage pavements can be used to improve the permeability of urban areas and housing development thus alleviating the instance of surface water flooding. They can be developed as part of an integrated SUDS system to (a) decrease the likelihood of flooding and associated insurance/rehabilitation costs and (b) increased the economic value of a property due to the amenity and aesthetic quality they add to the location.	Hard drainage pavements have been used across the USA to alleviate surface water flooding in business parking lots leading to a decreased incidence of surface water flooding (Mell, 2016). They have also been shown to illustrate how NBS can be integrated into urban development policy to minimise the ongoing impacts of climate change (Whitford, Ennos & Handley, 2001 "City form and natural process" L&UP). Research in Australia has also shown a positive response from local communities to the implementation of hard drainage pavements when they witness their effectiveness (Ball & Mearing, 2003, Using permeable eco-paving to achieve improved water quality for urban pavements, Pave Africa)	S	
Public Health and Well-being	Hard drainage pavements can lower the level of pollutants in the water system thus decreasing the opportunities for water based disease to occur.	They can be viewed as improving the quality of life of a local communities through increased aesthetic quality and a decreased instance of flooding in homes (and the associated respiratory illnesses) (Dunn, 2010, Siting Green Infrastructure: Legal and Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities).	U	
Potential of economic opportunities and green jobs	Reduced surface water flooding decreases the incidence of disturbance to economic activity due to road closure and inactivity.	The integration of hard drainage pavements can provide additional economic opportunities for construction and maintenance of these resources. They can also minimise disruption to communities and businesses due a decreased instance of flooding (Newell et al., 2013, Green Alley Programmes, Cities;	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		Jaffe, 2010, Reflections of GI economics, Environmental Practice).		

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: Short term/Medium term/Long term /NO AMORTISATION
The implementation of this NBS is based on replacing the existing pavement in the city so the NBS don't create important modifications in the environment.	The implementation of this NBS mainly helps reduce runoff and flood events. Amortization could be achieved if several episodes of flood occurred.

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Green pavements green parking pavements

Green pavements

TECHNICAL DESCRIPTION

Green pavers bring a lot of benefits, starts to be quite popular solution offered at the construction market, so thanks to that relatively budget-friendly and niece solution for any urban structure. It fit in perfectly with any street scene and they provide extra benefits when it comes to spatial effects, drainage and even traffic signalling. Green pavers have extra-large recesses all round to establish a green street scene without the need to install separate spacers. The greenery ensures that some of the water evaporates while some of it is absorbed.

Some of the benefits:

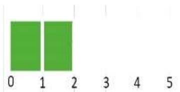
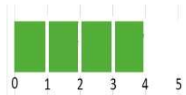
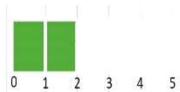
- Growable surface (pcs/m^2)
- Water infiltration
- Modular dimensions and freedom to lay patterns (walking routes)
- Variation of pcs/m^2
- Preservation of laying pattern
- Suitable for light vehicular traffic
- Low maintenance
- Relatively low costs

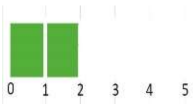
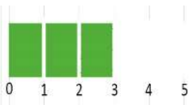
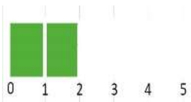
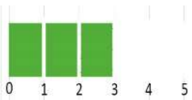
To achieve a greener effect, simply removing the occasional paver from the pavements is not sufficient. In practice it will detract from the overall coherence of the pavement and the pavement will end up skew. There are existing commercial solutions with a hollow plastic brick which ensures a good connection I the laying pattern and in which grass has sufficient room to grow. The dedicated reinforced ribs ensure strengths and stability, enabling the pavers or slabs around the plastic brick neatly in place. Sizes and tolerances of the available

GRAPHIC DETAIL

Figure 22 Example on green pavements components and its implementation.

on the market solutions are exactly tailored to our paver sizes (21 x 10.5 x 8cm). The circumference of the plastic element is slightly smaller and they sit somewhat lower as well, so that they sink further down within the pavement.	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green pavements decrease heat absorbed and can lower surface temperatures. This decrease in surface temperatures can temporarily offset warming caused by greenhouse gases.	According to EPA (2012), every 10% increase in solar reflectance could decrease surface temperatures by 4°C. If pavement reflectance throughout a city were increased from 10 to 35%, the air temperature could potentially be reduced by 0.6°C.	U	
Water Management	The greenery ensures that some of the water evaporates while some of it is absorbed (the degree of permeability is the decisive factor; stone chippings can be used as a jointing material). Permeable pavements re-produce the flow reduction and water quality improvement properties of natural surfaces and vegetation, reduce the amount of overland flow reaching receiving waters, thereby reducing peak flows in rivers and streams (Pratt et al. 1989, Legret et al., 1996).	Comparing the performance of permeable pavements to conventional ones, Pratt et al. (1989) found that the discharge rates from permeable pavements were significantly lower (30% of peak rainfall rate) and the time of concentration was greater (5 to 10 minutes, compared to 2 to 3 minutes for traditional pavements).	U	
Green Space Management	Green pavers fit in perfectly with any street scene and they provide extra benefits when it comes to spatial effects, drainage and even traffic signalling.	There are solutions available at the market showing examples with the green pavers establishing a green street scene, depending on its functionality, without the need to install separate spacers. (ex. Kellen Green Paving, UK)	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Air Quality	By adding the greenery into the urban space, the air quality increase. The microclimate improvement by temperature, humidity, by air pollutants absorption increase.	Rosenfeld et al. (1998) simulated the air quality effects of deploying cool community strategies (higher albedo roofs and pavements, increasing tree cover) in Los Angeles, which resulted in a 12% reduction in smog exceedance.	U	
Urban Regeneration	By adding the greenery into the urban space, the climate mitigation, water management, air quality increase, as an effect the urban regeneration is positively affected, more comfortable and enjoyable urban spaces.	Thermal comfort of pedestrians was simulated for a neighborhood in Eastern Los Angeles County for various strategies including solar reflective cool roofs, vegetative green roofs, solar reflective cool pavements and increased street-level trees. Results showed that greenery integrated caused significant reductions in surface air temperatures and small changes in mean radiant temperature during the day (Taleghani et al., 2016).	U	
Public Health and Well-being	Related to the Air Quality, thanks to the reduction of the pollutants, the public health and well-being can be positively affected.	Dowling (2014) reported that in Melbourne-Australia appr. 200 heat-related deaths recorded in 2013, in comparison to the state road toll of 242 deaths. By 2030, the number of deaths as a result of heat is expected to double.	U	
Potential of economic opportunities and green jobs	Every 1°C temperature reduction that can be achieved through the better design of cities can equate to 5% energy saving through reduced cooling. Green pavers material production creates a new economic sector and job opportunities.	AECOM (2015) published a report on the impacts of heat, heat waves and the intensification of the urban heat island effect on health, transport infrastructure, energy demand and infrastructure, trees and animals and crime. The report concluded that "The total economic cost to community due to hot weather is estimated to be $1.8 billion in present value terms. Approximately one-third of these impacts are due to heatwaves. Of the total heat impact, the urban heat	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		island effect contributes appr. $300 million in present value".		

IMPLANTATION: SOFT/ Medium /Hard	AMORTISATION: SHORT TERM/medium term/long term/no amortisation
The NBS don't create important modifications in the environment.	The period of recovery of the initial economic investment of the NBS is between 1 and 5 years.

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Cycle-pedestrian green pavement

Green pavements

TECHNICAL DESCRIPTION

This NBS includes green pavements in a special structure with filter properties and is appropriated for pedestrians and cyclists. This NBS allows manage the water runoff and it could be used for cyclist and pedestrian in the cycle-pedestrian areas. This kind of pavements will serve to reduce cycle speed in specific urban sections with many pedestrians. Thereby, it will avoid the small flood accumulation surfaces and this water will can be used to irrigate other NBS (resting areas an pollinator´s modules) in order to integrate several green infrastructures and several users of them.

Some of the Benefits:

- Water infiltration
- Modular dimensions and freedom to lay patterns (walking routes)
- Suitable for cyclists and pedestrians
- Multiple applications (sidewalks, street furniture zones, and entire roadways)
- Low maintenance
- Relatively low costs

Previous pavements must be designed to account for the native subsoil infiltration rate. The depth of the pervious layer, void space, and the infiltration rate of the underlying soils result in the desired storage volume and intended drain time of the facility.
Selection of pavements, such as permeable pavers, permeable concrete, permeable asphalt or other materials, should be based on engineering constraints and the surrounding street context.
Utilize an underdrain system to treat overflow, or if partial infiltration is preferred, to convey remaining runoff to the municipal sewer system.

GRAPHIC DETAIL

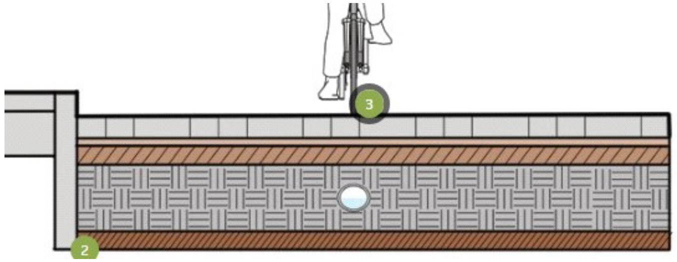
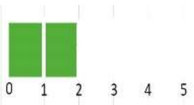
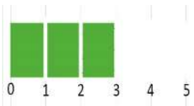
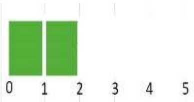
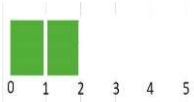
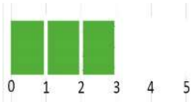
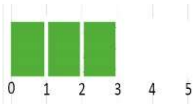
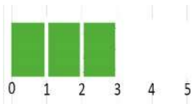


Figure 23 Example on cycle green pavements section and implementation.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green pavements decrease heat absorbed and can lower surface temperatures. This decrease in surface temperatures can temporarily offset warming caused by greenhouse gases.	According to EPA (2012), every 10% increase in solar reflectance could decrease surface temperatures by 4°C. If pavement reflectance throughout a city were increased from 10 to 35%, the air temperature could potentially be reduced by 0.6°C.	U	
Water Management	The greenery ensures that some of the water evaporates while some of it is absorbed (the degree of permeability is the decisive factor; stone chippings can be used as a jointing material). Permeable pavements re-produce the flow reduction and water quality improvement properties of natural surfaces and vegetation, reduce the amount of overland flow reaching receiving waters, thereby reducing peak flows in rivers and streams (Pratt et al. 1989, Legret et al., 1996).	Comparing the performance of permeable pavements to conventional ones, Pratt et al. (1989) found that the discharge rates from permeable pavements were significantly lower (30% of peak rainfall rate) and the time of concentration was greater (5 to 10 minutes, compared to 2 to 3 minutes for traditional pavements).	U	
Green Space Management	Green pavers fit in perfectly with any street scene and they provide extra benefits when it comes to spatial effects, drainage and even traffic signalling.	There are solutions available at the market showing examples with the green pavers establishing a green street scene, depending on its functionality, without the need to install separate spacers. (ex. Kellen Green Paving, UK)	U	
Air Quality	By adding the greenery into the urban space, the air quality increase. The microclimate improvement by temperature, humidity, by air pollutants absorption increase.	Rosenfeld et al. (1998) simulated the air quality effects of deploying cool community strategies (higher albedo roofs and pavements, increasing tree cover) in Los Angeles, which resulted in a 12% reduction in smog exceedance.	U	

Urban Regeneration	By adding the greenery into the urban space, the climate mitigation, water management, air quality increase, as an effect the urban regeneration is positively affected, more comfortable and enjoyable urban spaces.	Thermal comfort of pedestrians was simulated for a neighborhood in Eastern Los Angeles County for various strategies including solar reflective cool roofs, vegetative green roofs, solar reflective cool pavements and increased street-level trees. Results showed that greenery integrated caused significant reductions in surface air temperatures and small changes in mean radiant temperature during the day (Taleghani et al., 2016).	U	
Public Health and Well-being	Related to the Air Quality, thanks to the reduction of the pollutants, the public health and well-being can be positively affected.	Dowling (2014) reported that in Melbourne-Australia appr. 200 heat-related deaths recorded in 2013, in comparison to the state road toll of 242 deaths. By 2030, the number of deaths as a result of heat is expected to double.	U	
Potential of economic opportunities and green jobs	Every 1°C temperature reduction that can be achieved through the better design of cities can equate to 5% energy saving through reduced cooling. Green pavers material production creates a new economic sector and job opportunities.	AECOM (2015) published a report on the impacts of heat, heat waves and the intensification of the urban heat island effect on health, transport infrastructure, energy demand and infrastructure, trees and animals and crime. The report concluded that "The total economic cost to community due to hot weather is estimated to be $1.8 billion in present value terms. Approximately one-third of these impacts are due to heatwaves. Of the total heat impact, the urban heat island effect contributes appr. $300 million in present value". Another study claims that a 1°C temperature increase boosts cooling loads by 1.5 million kWh/year, generating 1000 tonnes in carbon dioxide emissions (AILA, 2016).	U	

IMPLANTATION: SOFT/ Medium /Hard	AMORTISATION: SHORT TERM/medium term/long term/no amortisation
The NBS don't create important modifications in the environment.	The period of recovery of the initial economic investment of the NBS is between 1 and 5 years.

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Cool Pavement

Green Pavements

TECHNICAL DESCRIPTION

In many cities, pavements (roads, platforms, pavement around buildings, parking areas, etc.) represent the largest percentage of a community's land cover (30-40%), compared with roof and vegetated surfaces (Akbari et al., 1999; Akbari and Rose, 2008).

Cool pavements are reflective/permeable pavements that help lower surface temperatures and reduce the amount of heat absorbed into the pavement.
Solar reflective "cool" pavements stay cooler in the sun than conventional pavements. Pavement reflectance can be enhanced by using reflective aggregate, reflective or clear binder or reflective surface coating.

Permeable pavements—which allow air, water, and water vapour into the voids of a pavement, keeping the material cool when moist.

Cool pavements may include:

1. *Conventional asphalt pavements*, which consist of an asphalt binder mixed with aggregate, can be modified with high solar reflectance (SR) materials or treated after installation to raise reflectance.

2. *Conventional concrete pavements* (due to the grey colour they reflect sun light).
3. *Other reflective pavements*, made from a variety of materials, are mostly used for low-traffic areas, such as side-walks, trails, and parking lots. Examples include: Resin

GRAPHIC DETAIL

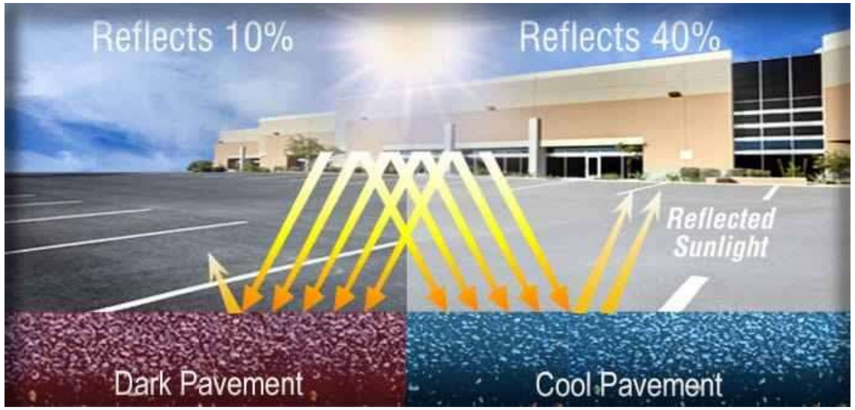


Figure 24 Surface reflectance.

based pavements, which use clear tree resins in place of petroleum-based elements to bind an aggregate coloured asphalt and coloured concrete, with added pigments or seals to increase reflectance.

4. *Non-vegetated permeable pavements* contain voids and are designed to allow water to drain through the surface into the sub-layers and ground below. These materials can have the same structural integrity as conventional pavements. Examples include porous asphalt or open graded friction course asphalt pavements (they improve road friction in wet weather), and rubberized asphalt (also reduce noise), pervious concrete, brick or concrete pavement blocks,

5. *Vegetated permeable pavements* use plastic, metal or concrete lattices to support and allow grass or other vegetation grow in the lattices. They are suitable in areas with low traffic flow (Subramanian, 2014).

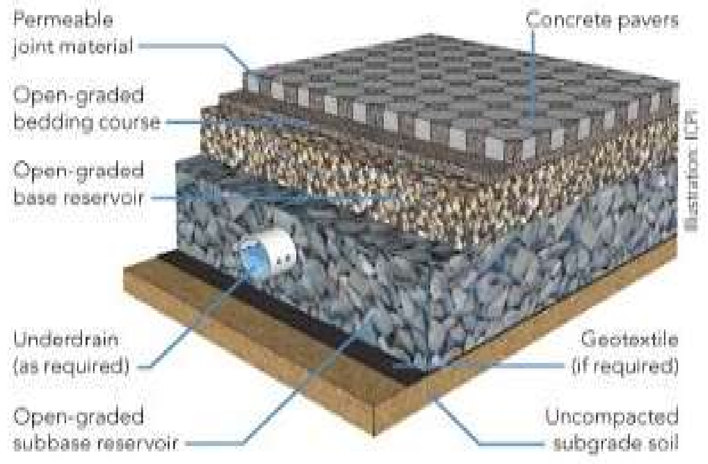
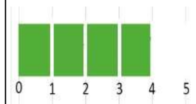
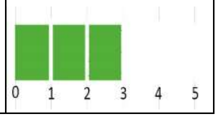
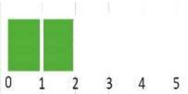
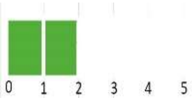
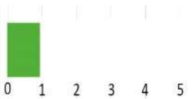
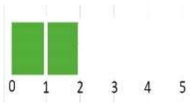
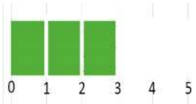


Figure 25 Permeable pavement.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Cool pavements decrease heat absorbed at the Earth's surface and thus can lower surface temperatures. This decrease in surface temperatures can temporarily offset warming caused by greenhouse gases.	According to EPA (2012), every 10% increase in solar reflectance could decrease surface temperatures by 4°C. If pavement reflectance throughout a city were increased from 10 to 35%, the air temperature could potentially be reduced by 0.6°C.	U	
Water Management	Cool pavements lower surface temperatures, thereby cooling storm water and lessening the damage to local watersheds (Pratt et al., 1995).	Laboratory tests with permeable pavements have shown reductions in runoff temperatures of 2-4°C in	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	Permeable pavements re-produce the flow reduction and water quality improvement properties of natural surfaces and vegetation, reduce the amount of overland flow reaching receiving waters, thereby reducing peak flows in rivers and streams (Pratt et al. 1989, Legret et al., 1996). Vegetated and permeable pavements allow water penetrates down through the voids and pores, feeds the groundwater.	comparison to conventional asphalt pavement (James, 2002). Comparing the performance of permeable pavements to conventional ones, Pratt et al. (1989) found that the discharge rates from permeable pavements were significantly lower (30% of peak rainfall rate) and the time of concentration was greater (5 to 10 minutes, compared to 2 to 3 minutes for traditional pavements).		
Green Space Management	Vegetated permanent pavements increase the green areas and allow water penetrates down through the voids, feeds the groundwater.	Related to the other challenges	U	
Air Quality	By decreasing urban air temperatures, cool pavements can slow atmospheric chemical reactions that create smog.	Rosenfeld et al. (1998) simulated the air quality effects of deploying cool community strategies (higher albedo roofs and pavements, increasing tree cover) in Los Angeles, which resulted in a 12% reduction in smog exceedance. About 1/5th of this effect was attributable to pavements that are more reflective.	U	
Urban Regeneration	Cool pavements offer healthier, more comfortable and enjoyable urban spaces.	Thermal comfort of pedestrians was simulated for a neighbourhood in Eastern Los Angeles County for various strategies including solar reflective cool roofs, vegetative green roofs, solar reflective cool pavements and increased street-level trees. Results showed that cool pavements increased reflected sunlight from the ground to pedestrians at a set of unshaded locations decreasing their thermal comfort. On the other hand, cool pavements at average 5 m from roadways and	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		underneath pre-existing tree cover, caused significant reductions in surface air temperatures and small changes in mean radiant temperature during the day (Taleghani et al., 2016).		
Public Health and Well-being	Cool pavements cool the city air, reducing heat-related illnesses, slowing the formation of smog, and making it more comfortable to be outside. Pedestrians also benefit from cooler air and cooler pavements.	Dowling (2014) reported that in Melbourne-Australia appr. 200 heat-related deaths recorded in 2013, in comparison to the state road toll of 242 deaths. By 2030, the number of deaths as a result of heat is expected to double.	U	
Potential of economic opportunities and green jobs	Every 1°C temperature reduction that can be achieved through the better design of cities can equate to 5% energy saving through reduced cooling. Cool pavement material production creates a new economic sector and job opportunities.	AECOM (2015) published a report on the impacts of heat, heat waves and the intensification of the urban heat island effect on health, transport infrastructure, energy demand and infrastructure, trees and animals and crime. The report concluded that "The total economic cost to community due to hot weather is estimated to be $1.8 billion in present value terms. Approximately one-third of these impacts are due to heatwaves. Of the total heat impact, the urban heat island effect contributes appr. $300 million in present value". Another study claims that a 1°C temperature increase boosts cooling loads by 1.5 million kWh/year, generating 1000 tonnes in carbon dioxide emissions (AILA, 2016).	U	

IMPLANTATION: Soft/ MEDIUM /Hard	AMORTISATION: SHORT TERM/Medium term/long term/no amortisation
This NBS can be used at roads, platforms, pavement around buildings, parking areas etc. It can be easily replaced with any other pavement material when necessary.	The period of recovery of the initial economic investment of the NBS is between 0 and 5 years.

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- Figure 11: Source: http://www.stixnstones.com/benefits-of-permeable-green-enviornmental-pavers.

Enhanced nutrient managing and releasing soil

Smart soil

TECHNICAL DESCRIPTION

These soils are mainly biochar, which is defined as a solid material obtained from thermochemical conversion in an oxygen limited environment.

Quality, and especially toxicants, are problematic in biochar, so a number of certification schemes have been developed. For example, the European Biochar certification and the International Biochar Initiative (IBI) have created certification program to ensure biochar meets certain minimum standards. The quality of biochar is measured in these schemes by considering organic carbon levels, ash content, and biomass.

Such schemes also consider the whole product lifecycle, such as carbon stability, metal contamination levels, economic viability, and sustainable provision of feedstock.

GRAPHIC DETAIL

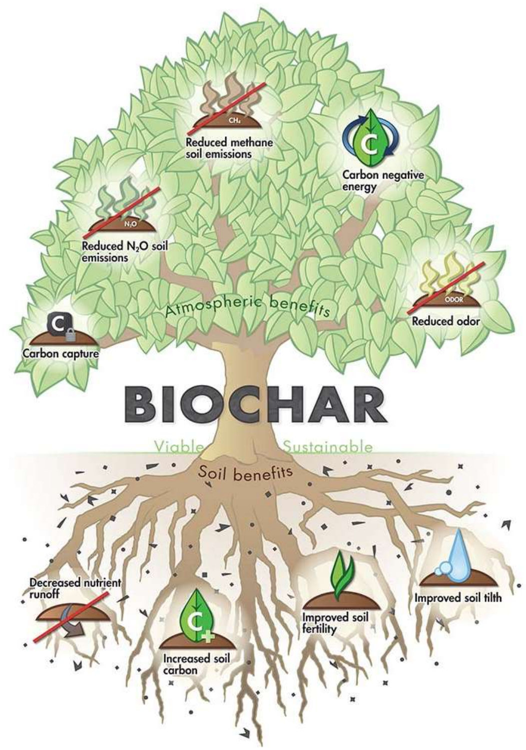
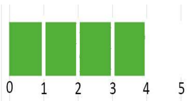
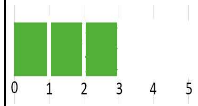


Figure 26 What is biochar?

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Smart soil reduces soil greenhouse gas emissions and heat island effect. It improved soil physicochemical and biological properties. Low use efficiency of fertilizer (leaching and gaseous emission of nutrient)	It is estimated that 1.05t CO_2, 0.4t NO_2 and 0.075t fertilizer will be avoided per year. In summer time, plant cover will also help to reduced heat island effect up to 1.5^0C.	S/U	
Water Management	Increasing soil water holding capacity and high cation exchange capacity (CEC)	The CEC of biochar produced from cordgrass appeared to increase from 8.1 to 44.5 cmolc kg^{-1} and then decreased to 32.4 cmolc kg^{-1} when the pyrolysis temperature increased from 200 to 550 ◦C (Harvey et al., 2011). For instance, with the decrease of the volatile matter content within corncob biochar, the specific surface area of the corncob biochar increased from 61.8 to 192.9 $m^2\ g^{-1}$ (Liu X et al., 2014).	S/U	

IMPLANTATION: Soft/ <u>MEDIUM</u> /Hard	**AMORTISATION:** Short term/<u>MEDIUM TERM</u>/long term/no amortisation
This NBS creates some modifications in the environment so there are some disadvantages of removing it in the future	The period of recovery of the initial economic investment of the NBS is between 10 and 20 years.

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- Technical description: http://www.european-biochar.org/en
- Technical description: http://www.biochar-international.org/
- Graphic detail: http://www.biochar-international.org/sites/default/files/CHARTREE3.jpg

Smart soil production in climate-smart urban farming precinct

Smart Soil

TECHNICAL DESCRIPTION

Smart Soil holds the key not only to improving agricultural productivity, but also making significant contributions to climate mitigation. In climate-smart urban farming precinct there will be smart soil production area targeting dense urban areas, poor with soil and leftover spaces near built residential district.

In this study, the construction of a strategic pathway to utilize pyrolysis technology and biochar use in agriculture will be actualized with potential and feasible utilization techniques.

Smart soil produced in climate-smart urban farming precinct will also be used in Zoo green car park area enriching the capacity of green shady structures.

Biochar sequestration:

So given a certain amount of carbon that cycles annually through plants, half of it can be taken out of its natural cycle and sequestered in a much slower biochar cycle (see graphic). By withdrawing organic carbon from the cycle of photosynthesis and decomposition biochar.
The biomass is converted into biochar and because of its stability sequesters all but 5 percent of the carbon (in this illustration) in the soil and hence has the ability to provide a carbon negative source of energy.

GRAPHIC DETAIL

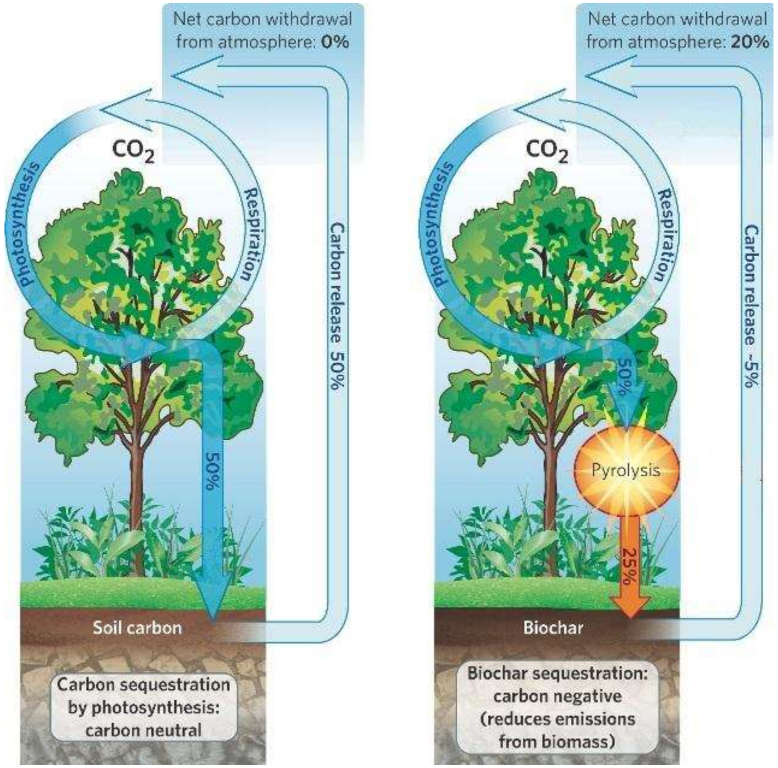
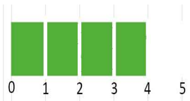
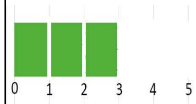


Figure 27 Differences between carbon cycles of standard soil and biochar implementation

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Smart soil reduces soil greenhouse gas emissions and heat island effect. It improved soil physicochemical and biological properties. Low use efficiency of fertilizer (leaching and gaseous emission of nutrient)	It is estimated that 1.05t CO_2, 0.4t NO_2 and 0.075t fertilizer will be avoided per year. In summer time, plant cover will also help to reduced heat island effect up to 1.5^{0}C.	S/U	
Water Management	Increasing soil water holding capacity and high cation exchange capacity (CEC)	The CEC of biochar produced from cordgrass appeared to increase from 8.1 to 44.5 cmolc kg^{-1} and then decreased to 32.4 cmolc kg^{-1} when the pyrolysis temperature increased from 200 to 550 ◦C (Harvey et al., 2011). For instance, with the decrease of the volatile matter content within corncob biochar, the specific surface area of the corncob biochar increased from 61.8 to 192.9 m^2 g^{-1} (Liu X et al., 2014).	S/U	

IMPLANTATION: Soft/ <u>MEDIUM</u> /Hard	**AMORTISATION:** <u>SHORT TERM</u>/medium term/long term/no amortisation
This NBS creates some modifications in the environment so there are some disadvantages of removing it in the future	The period of recovery of the initial economic investment of the NBS is between 1 and 5 years.

REFERENCES:

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- Graphic detail: https://utahbiomassresources.org/

Smart soil as substrate		Smart soils

TECHNICAL DESCRIPTION

Smart soils elaboration has a twofold purpose, on the one hand the used waste is valued, minimizing the potential environmental impacts derived from poor management of them and, on the other hand, degraded soils are recovered without excessive costs.

Components of the mixtures have different and individual characteristics, according to the final destination of the smart soil elaborated: depending on their fertilizing, structuring and water properties.

Smart soils derived from non-hazardous waste must comply the main functions of the soils, be susceptible to evolve by soil formation processes and realize an efficient stabilization of the carbon in the soil and in the biomass.

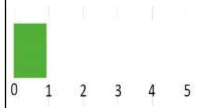
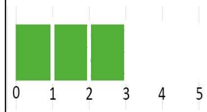
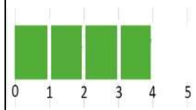
Smart soils are used in recovery processes of degraded and / or contaminated soils and water, areas with rocky outcrops, covering of tailings, areas affected by urban works and urban / peri-urban infrastructures (such as roundabouts, roadsides and non-recreational garden areas), industrialized areas, mines and quarries or silvicultural soils degraded by erosion, fire or loss of productive capacity, intensive forestry soils and non-food biomass crops.

Smart soils may be are made from residues coming from agrifood sludge and biomass residues coming from different types of pruning (urban and non-urban) and other waste.

Specific bacteria can be added to the technosols so that they are released gradually. These bacteria are achieved by the Technosols be able to actively capture NOx, performing the N cycle correctly, and improve availability to plants, developing their self-fertilizing capacity.

GRAPHIC DETAIL

Figure 28 Smart soil made from sludge and agro-food waste

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Carbon sequestration.	It has been shown that the application of compost to soil increases the uptake of organic carbon in soils. The magnitude varies according to the quantity applied, the quality of the compost and the pedoclimatic conditions. (Farinaa; R. 2018).	S/U	
Water Management	Improve water holding capacity and nutrient availability. Water contamination will be decreased by reducing the amount of fertilizers added to the soil.	Adding organic waste and biochar is a practice largely documented in the literature as a way to improve water holding capacity (Deeb, M. 2016) (Abideen Zainul, 2017).	S/U	
Air Quality	Smart soils remove air pollutants (NOx) and carbon dioxide, reducing air temperature (which slows down the creation of secondary pollutants) and increasing oxygen concentration, contributing to a beneficial atmospheric composition for human life.	The reuse and recovery, promoting the capture or at least minimizing greenhouse gas emissions of waste, can be done in the technosols while improving the quality of the environment and increasing biological activity, productivity and biodiversity (Macías, F. 2011). Microencapsulation of bacteria is widely used to obtain different agricultural inputs (Díaz-Franco, A. 2008). There are no bibliographical references about bacteria encapsulated in soils, only the own experience in the SUSTRATEC project from CARTIF.	U	

IMPLANTATION: <u>SOFT</u>/ Medium /Hard	AMORTISATION: <u>SHORT TERM</u>/medium term/long term/no amortisation
The NBS don't create important modifications in the environment.	The period of recovery of the initial economic investment of the NBS is between 1 and 5 years.

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- Figure 28: Source: SUSTRATEC Project. CARTIF.

Pollinator verges and spaces

Pollinator

TECHNICAL DESCRIPTION

New or existing linear features (verges) or patches (spaces) of green space that are designed and/or maintained to attract pollinators. This can include one or all of the following activities:

- Reducing mowing, rotational or mosaic cutting, partial cutting, and changing the timing of cutting
- Removing grass cuttings from verges to enhance plant biodiversity
- Reducing herbicide and pesticide and replacing with manual and integrated pest management approaches to address weed and pest issues
- Replacing grasses and sowing verges with a wildflower-rich seed mix to provide nectar and pollen to attract foraging insect pollinator species
- Carefully selecting tree species and preferentially planting locally native species
- Linking areas of flower-rich green space, both new and existing, to create sustainable networks of pollinator habitat
- Planting specific species such as Yellow Rattle (*Rhinanthus minor*)

GRAPHIC DETAIL

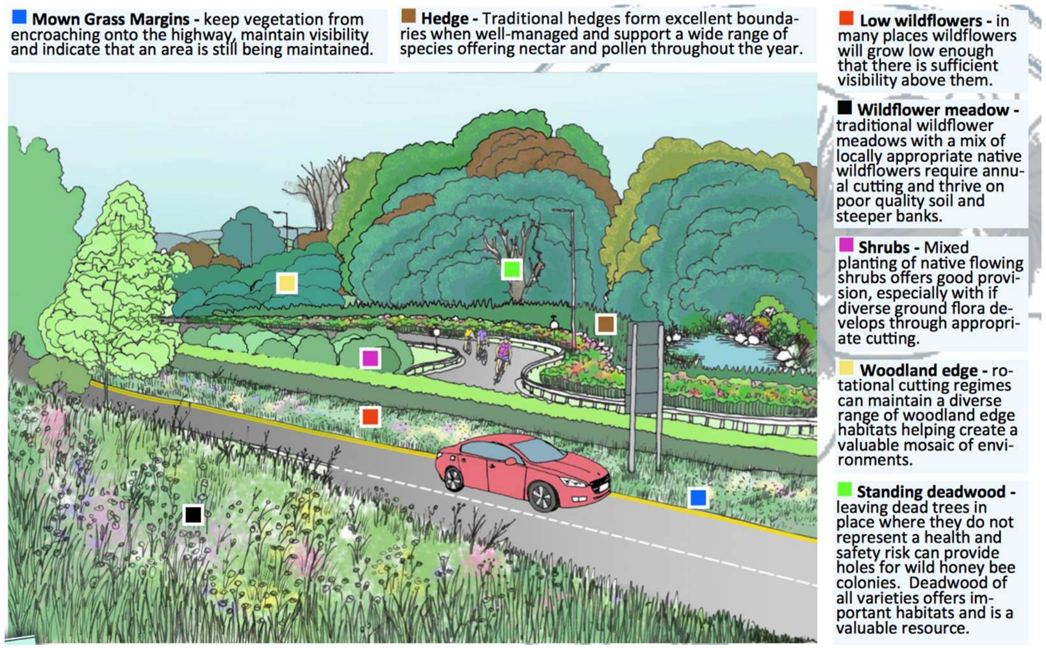
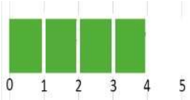
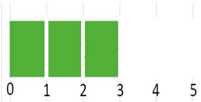
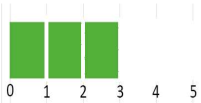


Figure 29 Example of green verges and green spaces

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Green Space Management	Pollinator verges provide much-needed food and habitat for pollinator species, enhancing biodiversity of both plant and animal species.	Experience in the UK and elsewhere suggests reduced mowing and intentional planting of native wildflower species enhances habitat for pollinators. For instance, controlled studies in urban areas have found sown plots can have 25 times more flowers, 50 times more bumblebees, and 13 times more hoverflies compared to paired control plots (Blackmore and Goulson 2014).	U/R	
Climate change mitigation & adaptation	Like all vegetation, pollinator verges can have a small effect on mitigating local heat island effects by reducing ambient temperature in urban areas.	Pollinator verges can make a small contribution to mitigating heat island effects unless they include significant tree plantings (O'Sullivan et al. 2017).	U/S	
Air Quality	Roadside vegetation is particularly beneficial for enhancing air quality due to its proximity to traffic.	Trees and species with rough, hairy or waxy leaves are particularly effective at trapping pollutants, including ozone, nitrogen dioxide, sulphur dioxide and small particulates (O'Sullivan et al. 2017).	U/S	

IMPLANTATION: SOFT/Medium /Hard	AMORTISATION: Short term/MEDIUM TERM/long term/no amortisation
The NBS don't create important modifications in the environment.	Pollinator verges can actually save money through reduced maintenance costs, including less labour and lower spending on chemicals. Increased pollination can also increase agricultural yield, leading to higher profits in for urban agriculture and in peri-urban areas.

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Pollinators walls/vertical

Pollinator

TECHNICAL DESCRIPTION

Vegetated ‘green’ or ‘living’ walls, supporting flowering plants, which can provide nectar and pollen to attract foraging insect pollinator species. Useful in urban areas when verges and open spaces are limited.

- These can be incorporated into new building design or retrofitted.
- Continuous or modular structures containing organic or inorganic growth media in which plants are rooted.
- Plants need to be carefully selected to support local pollinator species, and are often selected based on locally rare flower species that were once more abundant to replace dwindling habitat for pollinators.
- Pollinator walls often also contain insect ‘hotels’.
- For the system to be sustained, water and nutrients are required (which can be supplied using an automated irrigation system).

GRAPHIC DETAIL

Types of plants that attract pollinators

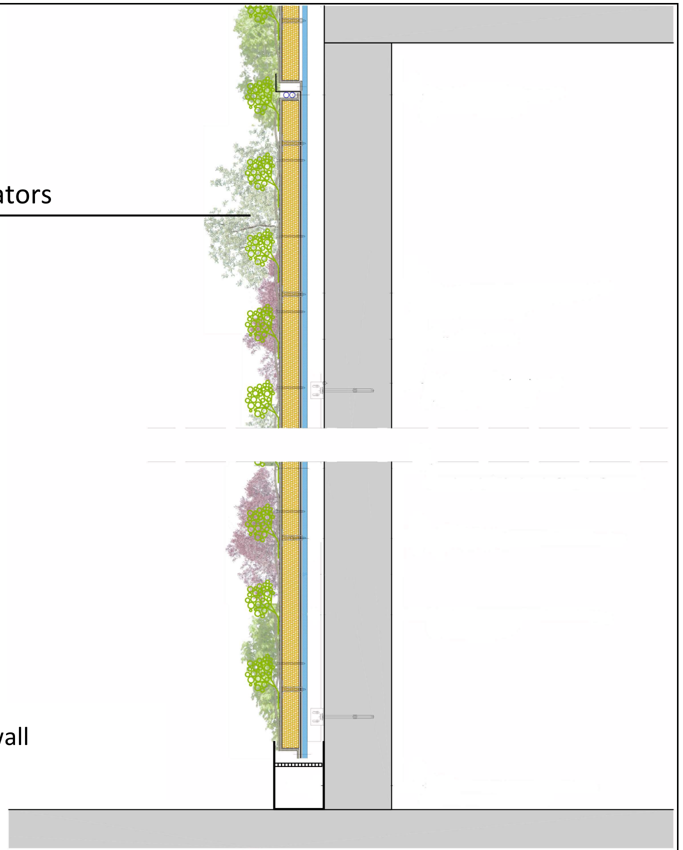
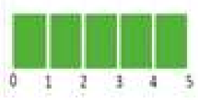
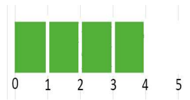
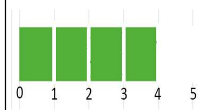
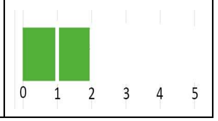
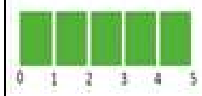


Figure 30 Example of pollinator wall

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Green Space Management	Pollinator walls provide much-needed food and habitat for pollinator species, enhancing biodiversity of both plant and animal species.	There is anecdotal evidence that living walls can increase the presence of pollinators, but more robust quantification is needed (Francis and Lorimer 2011; Whittinghill and Rowe 2012). In general, vertical walls are currently thought to be limited in terms of biodiversity provision, but more research is needed to understand their ecological contributions (Enzi et al. 2017).	S	
Climate change mitigation & adaptation	Green façades reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. Green façades protect buildings from the precipitation and the sun, improving indoor climate.	Hydroponic green façade can reduce the interior temperature of a building to 5ºC in summer, as well as keep it in winter. (H. Akira, 2010). Green façades help reduce energy costs in buildings by 0,71-19 €/m^2 (de Roo, 2011).	B	
Air Quality	Green noise barriers are natural air-filters, creating a cleaner environment. The vegetation metabolizes harmful toxins while releasing oxygen.	Captures airborne pollutants and atmospheric deposition on leaf surfaces (Sheweka and Mohamed 2012).	U/S	
Urban Regeneration	Green façades increase the economic value and the lifespan of buildings. Green façades add colour, texture and interest to the urban landscape.	Studies have shown that having plants around a building can increase real estate values by up to 20% (*Green Over Grey*). The installation of green façades can earn buildings LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5-57 /m^2 (*Ambius*).	U	
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	-	S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Public Health and Well-being	Views of green have several positive effects on human health and this NBS is able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves.	Research has shown that views of green cause positive changes in systolic blood pressure (Pretty *et al.*, 2005). Conclusion of the study Evaluation of green walls as a passive acoustic insulation system for buildings: The calculated weighted sound reduction index was R_w = 15 dB, and the correction terms were Ctr = −1 dB for traffic noise and C = −1 dB for pink noise. (Azcora et al., 2014)	U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
Green façades usually do not require any extra structural requirements. They are most commonly attached to concrete walls, but can attach to almost anything, or even be free-standing. We can remove this NBS easily if we want.	Green façades get the recovery of the investment between the 10 and the 20 years. This amortization is related to energy saving, it is not related to the increase in pollinators.

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Pollinator green roof		Pollinator

TECHNICAL DESCRIPTION

A green roof designed to attract biodiversity (especially pollinators) as a mean to compensate ecological habitat fragmentation. To optimise its functions, it must include various microclimates, native shrubs, pollen and nectar-rich plants, tall grasses, meadows, rocks, branches, birdhouses, bee nest boxes and water sources. The inclination of the roof must be between 0 and 45º.

A pollinator green roof is built with:

- A waterproof layer. The material must to be resistant to roots: PVC, EPDM… **(1)**
- A separating layer. This layer must to protect the waterproof layer. It is usually use geotextile sheets. **(2)**
- A draining layer. This layer creates an air chamber that allows excess water to be evacuated. **(3)**
- Water retention layer. Layer with a singular geometry that allows the water retention. **(3)**
- Filtering layer. This layer prevents the loss of fine from de substrate.**(4)**
- Absorbent layer. It has made by materials which retain water and they liberate it slowly. **(4)**
- Substrate. Support layer of the vegetation where the work of the roots takes place. **(5)**
- Vegetation - Native shrubs, pollen and nectar-rich plants, tall grasses, meadows. **(6)**

GRAPHIC DETAIL

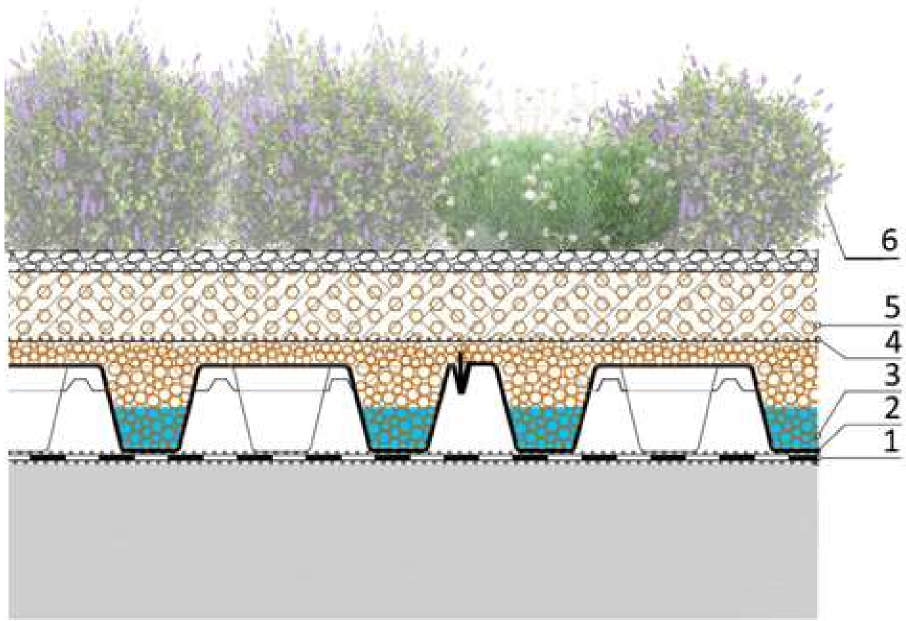
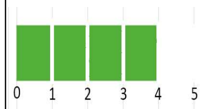
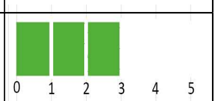
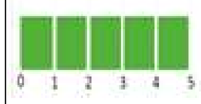
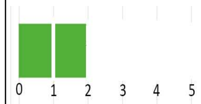
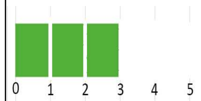
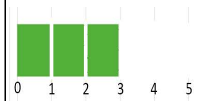
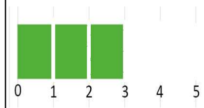
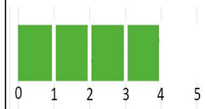
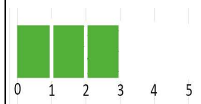


Figure 31 Section of pollinator green roof

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Pollinator green roofs reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating.	If the 6% of the roof surface of Toronto was green roof, the summer temperature would decrease 1 or 2 degrees. (*Canadian Environmental Assessment Agency*). Addition of 30% in green roof area would reduce the electricity consumption by 2.56 W/m^2/day (Razzaghmanesh *et al*., 2015).	U/B	
Water Management	The retention layer and substrate of pollinator green roofs reduce urban run-off water.	A green roof with 20 cm of substrate and expanded clay, is able to retain 90l/m^2 of water (Dürr 1995)	U	
Green Space Management	Pollinator green roofs provide foraging opportunities for urban wildlife, representing notable compensatory habitats.	According to a study published by *Buglife* (which monitored pollinator roofs for 3 years), flower-filled and mixed planting rooftops help to attract pollinators, and they can even provide habitat for rare species.	U	
Air Quality	The plants present in pollinator green roofs are able to absorb polluting substances.	A green roof with 60 m^2 is able to absorb 15 kg of heavy metals (Darlington, 2001).	U	
Urban Regeneration	Green roofs increase the economic value of the building. Green roofs increase the lifespan of the roof. Pollinator green roofs add colour, texture and interest to the urban landscape.	Lifespan of a roof is up to 20 years longer when it contains a green roof (de Roo, 2011).	U	
Participatory Planning and Governance	Pollinator green roofs represent an opportunity for participatory planning and community involvement.	Rotterdam gives subsides of 30 €/m^2 to homeowners to build a green roof. The city of Toronto is developing a *Pollinator Protection Strategy* intended to raise awareness, develop new education and training, evaluate and invest in green spaces (especially	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		pollinator roofs), as well as re-examine city maintenance practices.		
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	-	S	
Public Health and Well-being	Pollinator green roofs offer opportunities for communities to observe and experience flora and fauna. Creating a biodiverse living roof leads to great benefits for people to contact with wildlife.	There is a genetic predisposition for people to prefer biodiverse environments, resulting in various health benefits (Kaplan & Kaplan, 1989).	U	
Potential of economic opportunities and green jobs	Pollinator green roofs create maintenance jobs.	-	-	

IMPLANTATION: Soft/MEDIUM/Hard This NBS can be built on any roof that resists more than 75Kg/m^2. The inclination of the roof must be between 0 and 45º. Depending on these conditions the type of the green roof will be different. We can remove this NBS easily if we want to change the roof.	**AMORTISATION: short term/MEDIUM TERM/long term/no amortisation** Pollinator green roofs get the recovery of the investment between the 10 and the 20 years.

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Natural pollinator´s modules

Pollinator

TECHNICAL DESCRIPTION

NATURAL POLLINATORS MODULES (NPollM) These spaces will be designed to attract pollinators and biodiversity in general by weather conditions (colder areas in hot periods and refugee for wintertime) and feeding (water and food providing areas for pollinators). **Food and refugee providers**.

It is important to incorporate in this NBS housing for pollinators, both insects and other species as birds, bats and small reptiles… It will have the housing function but also it will be an awareness element for citizens.

This NBS is complemented with Compacted Pollinator's modules; CPolM (see factsheet), which help to connect green spaces in urban areas; CPolM should be designed and installed to create connexions among green areas or to create connexions networks among green and blue areas in urban environments.

Connectivity. The distance between modules will be affected by the characteristics of the urban space, the presence of other green elements (like street trees or bush lines), space availability, etc.

Additionally, this NBS could include some **site furnishing** as street seats, drinking water fountain or some elements to create shadow areas as trees or shadow pergolas with plants.

Key Elements

- **Plants (trees, bushes and flowers)**. This NBS will put special attention to install anti-allergy species (*Lavandula latifolia*, *Rosmarinus officinalis*, *Salvia*

GRAPHIC DETAIL

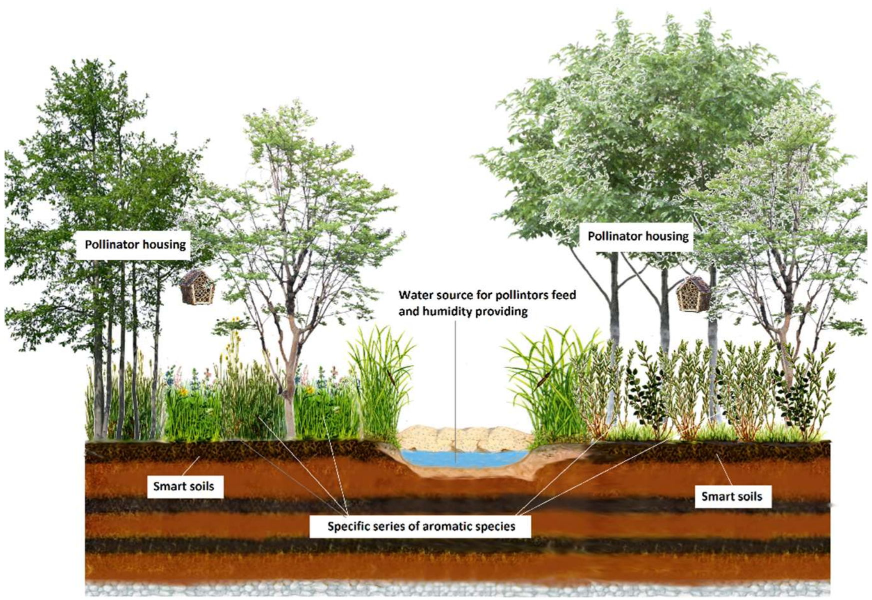


Figure 32 Simulation of a Natural Pollinator's module

lavandulifolia, *Corylus avellana*, *Malus* spp. *Acer campestre*, *Viburnum tinus*, *Cistus spp*. etc..).

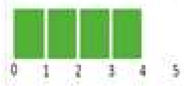
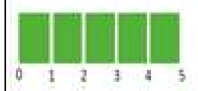
- **Water source**. It could include a rain garden (see factsheet) that contributes to the management of water; because is a bioretention shallow basin designed to collect, store, filter and treat water runoff. An irrigation system could be installed to supply needs if necessary.
- **Housing for biodiversity** (pollinators, birds, other insects,…). These pollinator-nesting blocks (also called pollinator houses, bee houses or bee hotels) will support biodiversity by creating wildlife friendly spots or areas and contribute to preserve and enhance the local biodiversity in urban areas.
- **Protection elements**. Anti-vandalism elements like thorn bush fences could be included in the NBS.
- Street seats, water sources for humans, shadow structures or elements (shadow tree), etc. **Site furnishing**.
- **Additional functionality**. Rainwater collection can be integrated throughout a SUD and addressed to an indoor storage area that will provide additional moisture to the plant substrate.

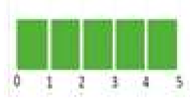
Key design criteria

- Total surface of Natural pollinators modules between 10-20m^2 (standard but it depends on the available space). The shape of the module can be adapted to the available land.
- Creation of a modules network (habitats for biodiversity) connecting green areas in the city.
- Two different classes of modules. One of them with high diversity of flowering plants and the other one for monitoring purposes.

Figure 33 Rain garden graphic © TNC

• Monitoring units - One or two plants species per module. It is necessary to create "big" areas containing the same structure of plants (amount and species) (at least 5-10 m^2). • Natural/organic building materials. • Urban Landscape architecture criteria in the city must be taken into consideration.	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	This indicator is directly related to the infiltration/drainage capacity of soils and storage elements included in the module. It could be assessed at high or at local level for the quantification of run-off coefficient at city or local flood risks reductions. The methodology for calculating it is not established but there are references that are being discussed at NBS European projects level in Task force groups promoted by EASME and EU Commission. URBAN GreenUP will adopt the methodology selected and will determine the baseline.	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U/S	
Green Space Management	This NBS will increase awareness of the benefits of re-naturing cities, making the cities healthier and greener A new space management is demanded; green spaces will also become entertainment and educational spaces and grey areas will be reduce in order to improve air quality and act as a noise barrier.	A detailed spatio-temporal understanding of the ecological interactions linking flowering plants and insect pollinators across cities. Increased appreciation for and connection with urban nature in city residents. A detailed understating of the distribution and host-associations of non-native (e.g. European honeybee) and invasive (e.g. African carderbee) insect pollinators. NESP-CAUL Hub project Luis Mata and Sarah Bekessy RMIT UNIVERSITY	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	This NBS allows managing the traffic too.	(Luis Mata, from RMIT UNIVERSITY, provide us this information for the URBAN GreenUP project)		
Air Quality	The impact of this solution on air pollutants concentration it will be very low. This usually is the main indicator regarding air quality. However, this NBS as many others, is a humidity source and emits pleasant aromas. On the other hand, these solutions will include Smart soils which are able to capture NOx and SOx, however the amount used in each module will be low. This indicator will be assessed and calculated through data from RCCAVA.	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U/S	

IMPLANTATION: SOFT/Medium/Hard

The NBS don't create important modifications in the environment.

AMORTISATION: SHORT TERM/Medium term/long term/no amortisation

The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

REFERENCES:

- Deliverable 2.2 Baseline document to Valladolid
- URBAN GreenUP
- NESP-CAUL Hub project Luis Mata and Sarah Bekessy RMIT UNIVERSITY
- AGUADO MARTÍN, Luís Óscar. Guía de campo de los polinizadores de España. Ediciones Mundi-Prensa. Syngenta.
- Figure 7: https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newjersey/nj-rain-garden-graphic-large.jpg

Compacted pollinator´s modules

Pollinator

TECHNICAL DESCRIPTION

This NBS is specially recommended to “urban grey areas”. These modules are suitable for areas without availability of natural soil in order to create new habitats for a diverse pollinators wildlife in cities. **Habitats for urban spaces**.

These modules will be designed to attract pollinators and biodiversity in general by weather conditions (colder areas in hot periods and refugee for wintertime) and feeding (water and food providing areas for pollinators). **Food and refugee providers**.

It is important to incorporate in this NBS housing for pollinators, both insects and other species as bats and small reptiles. It will have the housing function but also it will be an awareness element for citizens.

Another important function of this NBS is connecting isolated green areas in cities; CPollM should be designed and installed to create connexions among green areas or if it is possible to create a connexions network among green and blue areas in urban environments. **Connectivity**. Distance between modules will be affected by the characteristics of the urban space, the presence of other green elements (like street trees or bush lines), space availability, etc.

Additionally CPollM could include some **site furnishing** as street seats, a drinking water fountain, street lighting or some elements to create shadow areas as trees or shadow pergolas with plants. In addition, CPollM could incorporate some natural protective elements against **vandalism** as a fence of white hawthorn, for example.

Finally, CPollM should be designed in a simple way with elements which make easier the replication by citizens in balconies or bar terraces.

GRAPHIC DETAIL

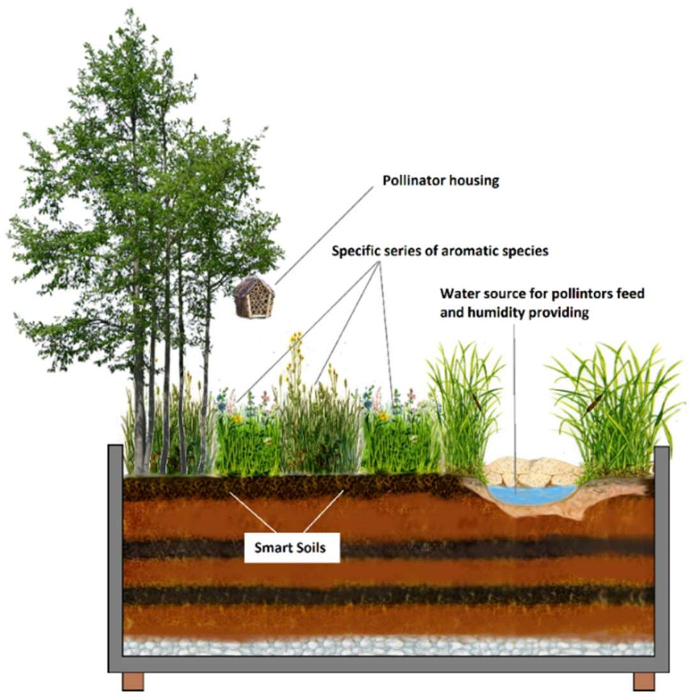


Figure 34 Compacted Pollinator’s modules

Key Elements

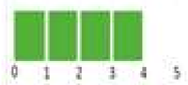
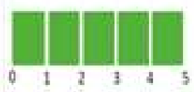
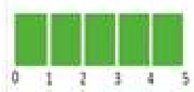
- **Plants (trees, bushes and flowers)**. This NBS will put special attention to install anti-allergy species (*Lavandula latifolia*, *Rosmarinus officinalis*, *Salvia lavandulifolia*, *Corylus avellana*, *Malus* spp. *Acer campestre*, *Viburnum tinus*, *Cistus* spp. etc.).
- **Water source**. This is a key element at least for Compacted Pollinator's modules. It will be necessary to include some water element.
- **Housing for biodiversity** (pollinators, birds, other insects,…). These pollinator-nesting blocks (also called pollinator houses, bee houses or bee hotels) will support biodiversity by creating wildlife friendly spots or areas and contribute to preserve and enhance the local biodiversity in urban areas
- Protection elements. Anti-vandalism elements like thorn bush fences could be included in the NBS.
- Street seats, water sources for humans, shadow structures or elements (shadow tree), etc. **Site furnishing**.
- **Additional functionality**. Rainwater collection can be integrated from the gutter and addressed to an indoor storage area that will provide additional moisture to the plant substrate. To avoid flooding problems in the gutter can be integrated an external side emergency exit that directs the excess water to the current management system.

Key design criteria

- Total surface of Compacted Modules between 4-5m^2 (it will necessary to standardize the modules size).
- Creation of a modules network (habitats for biodiversity) connecting green areas of the city.
- Monitoring units - One or two plants species per module.
- Natural/organic building materials.
- Urban Landscape architecture criteria in the city must be taken into consideration.

Figure 35 Balcony garden web Drinking througts.

Figure 36 Pollinators hotels.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	This indicator is directly related to the infiltration/drainage capacity of soils and storage elements included in the module. It could be assessed at high or at local level for the quantification of run-off coefficient at city or local flood risks reductions. The methodology for calculating it is not established but there are references that are being discussed at NBS European projects level in Task force groups promoted by EASME and EU Commission. URBAN GreenUP will adopt the methodology selected and will determine the baseline.	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U/S	
Green Space Management	This NBS will increase awareness of the benefits of re-naturing cities, making the cities healthier and greener A new space management is demanded; green spaces will also become entertainment and educational spaces and grey areas will be reduce in order to improve air quality and act as a noise barrier. This NBS allows managing the traffic too.	A detailed spatio-temporal understanding of the ecological interactions linking flowering plants and insect pollinators across cities. Increased appreciation for and connection with urban nature in city residents. A detailed understating of the distribution and host-associations of non-native (e.g. European honeybee) and invasive (e.g. African carderbee) insect pollinators. NESP-CAUL Hub project Luis Mata and Sarah Bekessy RMIT UNIVERSITY (Luis Mata, from RMIT UNIVERSITY, provide us this information for the URBAN GreenUP project)	U/S	
Air Quality	The impact of this solution on air pollutants concentration it will be very low. This usually is the main indicator regarding air quality. However, this NBS as many others, is a humidity source and emits pleasant aromas.	At this phase of the Project, no references have been found. URBAN GreenUP will take into account/consideration.	U/S	

	On the other hand, this solutions will include Smart soils which are able to capture NOx and SOx, however the amount used in each module will be low. This indicator will be assessed and calculated through data from RCCAVA.			

IMPLANTATION: Soft/Medium/<u>HARD</u> The NBS creates a lot of modifications in the environment.	**AMORTISATION:** <u>SHORT TERM</u>/Medium term/long term/no amortisation The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

REFERENCES:

- Deliverable 2.2 Baseline document to Valladolid
- URBAN GreenUP
- NESP-CAUL Hub project Luis Mata and Sarah Bekessy RMIT UNIVERSITY
- AGUADO MARTÍN, Luís Óscar. Guía de campo de los polinizadores de España. Ediciones Mundi-Prensa. Syngenta.
- Figure 36, source: Societé Nationale d’horticulture de France (SNHF).

Green fences

Vertical GI

TECHNICAL DESCRIPTION

The main objectives are to provide a green separation between river and pedestrians and create little habitats for wildlife. It is built as a part of river and riverbank re-naturing.

- It is basically built out of impregnated wood and covered with flowering plants in particular.
- It is not a continuous fence along the river. It is interrupted in some spots.
- Its height varies but it is not higher than the eye level of a sitting person around the sitting areas.
- 3 x 10 cm pickets; 5 x 10 cm backers
- Heights 120-150 cm

GRAPHIC DETAIL

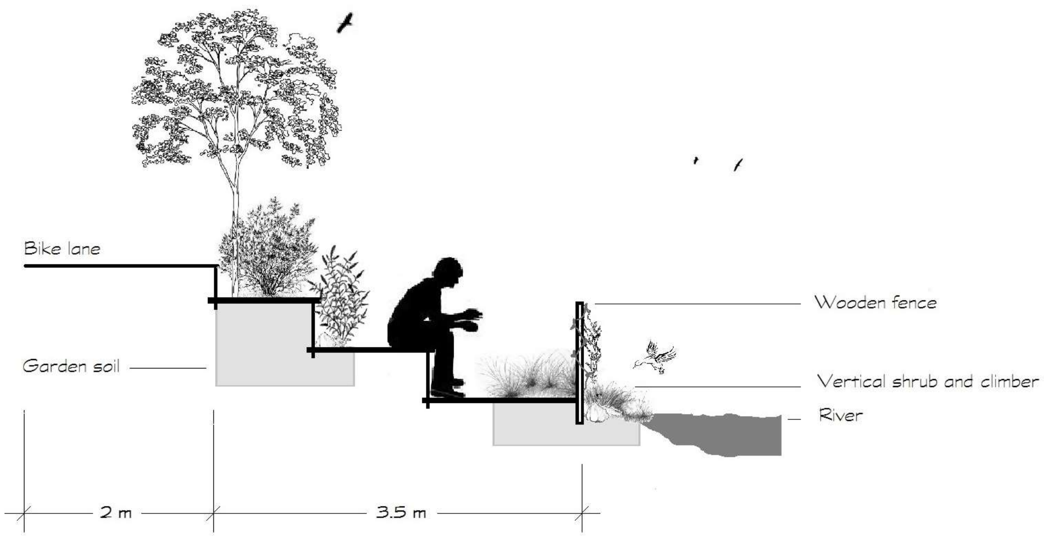
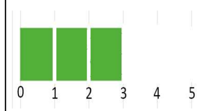
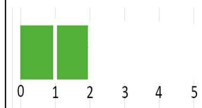
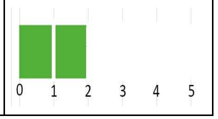


Figure 37 Section of a green fence

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Green Space Management	Green fences increase the vertical green areas and create new little habitats	Live fences may act as tools for biodiversity conservation by providing habitat for native species (Pulido-Santacruz and Miguel Renjifo, 2011.	U/S	
Air Quality	Green fences may help improving air quality	Green fences/walls and roofs are effective to reduce pollution in streets/open roads (Abhijith et al., 2017; Gromke et al., 2016).	U/S	
Public Health and Well-being	Green fences may help improving air quality	Green fences/walls and roofs are effective to reduce pollution in streets/open roads (Abhijith et al., 2017; Gromke et al., 2016).	U/S	

IMPLANTATION: <u>SOFT</u>/ Medium /Hard	**AMORTISATION: <u>SHORT TERM</u>/Medium term/long term/no amortization**
This NBS can be built anywhere without particular requirements and it does not create important modifications.	The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

REFERENCES:

- Abhijitha, K.V., Kumara, P., Gallagher, J., McNabolac , A., Baldaufe, R., Pillag , F., Broderickc, B., Di Sabatinoh, S., Pulvirenti, B. (2017). Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments: A review, Athmospheric Environment, 162, 71-86.
- Gromke, C., Jamarkattel, N., Ruck, B., 2016. Influence of roadside hedgerows on air quality in urban street canyons. Atmospheric Environment 139 (2016) 75-86.
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Green noise barriers

Vertical GI

TECHNICAL DESCRIPTION

This NBS is designed to reduce the traffic noise that arrives at the homes on the street. On the one hand, the green noise barriers have a specific geometry that favors sound reflection and on the other hand, they have a vertical garden modules with a specific substrate that favors sound absorption.

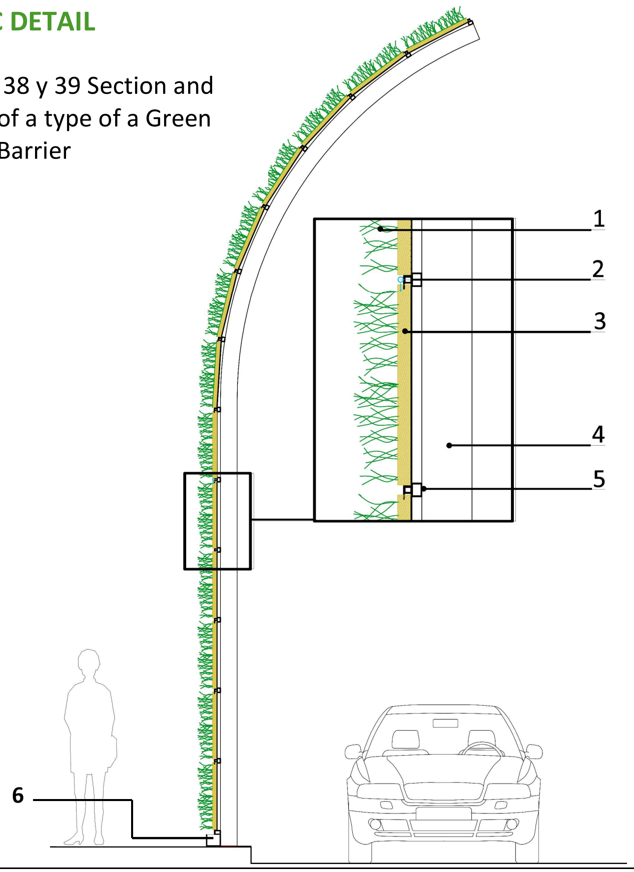
The green noise barriers are built with:

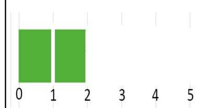
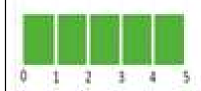
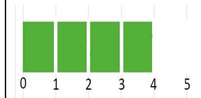
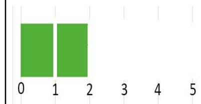
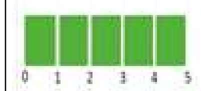
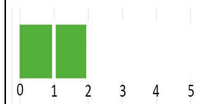
- Structure. Metallic structure with a specific geometry that allows the reflection of the noise. This structure is affixed to the pavement. **(4)**
- Metallic piece affixed to the structure that fastens the vertical garden modules. **(5)**
- Vertical garden modules. Pieces formed by a metal sheet on which a rock wool substrate is adhered. **(3)**
- Irrigation system. Drip irrigation pipes that soak the substrate. **(2)**
- Vegetation. The vegetation are plants with little nutrient and water needs. They are species resistant to local climate suitable for growing in an inert substrate such as rock wool. **(1)**
- Water collection system. All the water from the irrigation system is collected on the bottom of the garden. **(6)**

The dimensions of this NBS depend on the geometry of the structure (straight, curved or both) the height of residential buildings and the width of the street.

GRAPHIC DETAIL

Figure 38 y 39 Section and detail of a type of a Green Noise Barrier



Challenge	Description	Experience / Study	Challenge Scale	Valuation
Green Space Management	The green sound barriers manage to introduce large vegetable surfaces without occupying large urban spaces.	About 3 to 10 m^2 of plant vertical surface can be installed on 0.5 m^2. With this numbers we can calculate that this NBS gets about 6 to 20 m^2 of green surface for each square meter of urban land.	S	
Air Quality	Green noise barriers are natural air-filters, creating a cleaner environment. The vegetation metabolizes harmful toxins while releasing oxygen.	1 m^2 of vegetation cover generates the oxygen required by a person throughout the year. (Darlington, 2001) 1 m^2 of plant cover traps 130 grams of dust per year. (Darlington, 2001)	S	
Urban Regeneration	Installing vegetable surfaces in the city brings new aesthetic values and revalues the neighborhoods where these NBS are located.	Studies have shown that having plants around a building can increase real estate values by up to 20% (*Green Over Grey*).	S	
Participatory Planning and Governance	The decision of the location of this NBS could be a good opportunity for citizens to decide where they need to solution the noise problems of the city.	-	U	
Public Health and Well-being	Vegetable surfaces are able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves.	Conclusion of the study Evaluation of green walls as a passive acoustic insulation system for buildings: The calculated weighted sound reduction index was R_w = 15 dB, and the correction terms were Ctr = −1 dB for traffic noise and C = −1 dB for pink noise. (Azcora et al., 2014)	S	
Potential of economic opportunities and green jobs	This type of NBS needs periodic maintenance. That need creates new jobs.	This NBS needs one maintenance day per month. Depending on the size, it may take more than a day.	U	

IMPLANTATION: Soft/ MEDIUM /Hard	AMORTISATION: Short term/MEDIUM TERM/long term/no amortisation
This NBS creates some modifications in the environment so there are some disadvantages of removing it in the future.	The period of recovery of the initial economic investment of the NBS is between 10 and 20 years.

REFERENCES:

- Z.Azkorra, G.Pérez, J.Coma, L.F.Cabeza, S.Bures, J.E.Álvaro, A.Erkoreka, M.Urrestarazu. Evaluation of green walls as a passive acoustic insulation system for buildings. Applied Acoustics 89 (2015) 46–56.
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- Darlington, A., Dat J. F., Dixon, M. A. 2001. The biofiltration of indoor air: Air flux and temperature influences the removal of toluene, ethylbenzene, and xylene. Environ. Sci. Technol. 35: 240-246.

Green Façade with climbing plants

Vertical GI

TECHNICAL DESCRIPTION

A green façade 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.

Unlike green panels that can be integrated into the building only if engineered to hold the weight (80-100 kg/m^3), this type of green façades can be planted in the ground/container and using a trellis system they can be attached to any building or structure.

This green façade is built with:

- A soil container. **(1)**
- Soil mixture of 30% sand, 30% compost and 40% topsoil. **(2)**
- A trellis system. **(3)**
- Climbing plants (for example *Hedera helix*, *Parthenocissus tricuspidata*, *Wisteria* sp. and *Vitis* sp.) **(4)**
- Air gap between the building and the trellis system (optional). **(5)**

GRAPHIC DETAIL

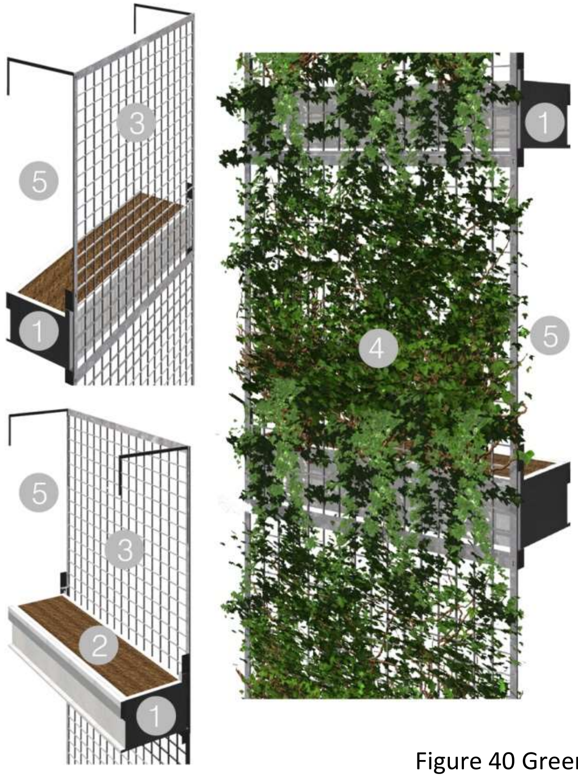
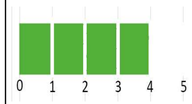
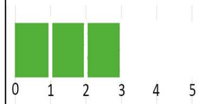
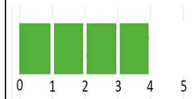
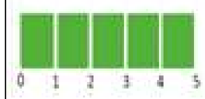
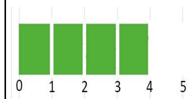
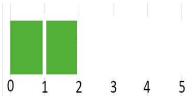
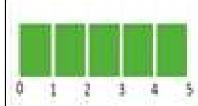
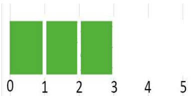


Figure 40 Green façade with climbing plants

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green façades reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. Green façades protect buildings from the precipitation and the sun, improving indoor climate.	Green façades help reduce energy costs in buildings by 0,71-19 €/m^2 (de Roo, 2011). Green façades can reduce wall surfaces temperatures by as much as 10º C (*Ambius*).	U/B	
Water Management	Green façades naturally absorb and filter stormwater, and have high rates of evapotranspiration, which contributes to a normal water cycle. Green façade's roots and microorganisms remove water pollutants.	A simulated study showed greenwalls retained comparably favourable amounts of stormwater (when compared to bare walls), contributing to stormwater mitigation (Kew *et al*., 2014).	U	
Green Space Management	Green façades represent valuable compensatory habitats for insects and birds.	According to a study in the UK, birds exploited green walls and façades for nesting, food and shelter, but were never found on bare control walls. 137 species of insects were also found in green walls and façades (*Chiquet et al*., 2012).	U	
Air Quality	Green façades are natural air-filters, creating a cleaner environment. Green façades metabolize harmful toxins while releasing oxygen.	The carbon sequestered from a 20 m^2 green façade is about the same as a medium sized tree (*Green Over Grey*). A wall with *Hedera helix* can catch 6 g of PM10 per m^2.	U	
Urban Regeneration	Green façades increase the economic value and the lifespan of buildings. Green façades add colour, texture and interest to the urban landscape.	Studies have shown that having plants around a building can increase real estate values by up to 20% (*Green Over Grey*). The installation of green façades can earn buildings LEED points, and if the building reaches LEED certification, can receive tax credits between 6,5-57 €/m^2 (*Ambius*).	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		Green façades protect buildings from precipitation, wind, UV radiation and corrosive acid rain, increasing the integrity and longevity of buildings (*Green Over Grey*).		
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	-	S	
Public Health and Well-being	Green façades offer opportunities for communities to observe and experience flora and fauna. Views of green have several positive effects on human health.	Research has shown that views of green cause positive changes in systolic blood pressure (Pretty *et al.*, 2005), restore cognitive abilities (Kaplan and Kaplan, 1989) and decrease mental fatigue (van den Berg *et al.*, 2007). Views of green increase work productivity (de Roo, 2011) and decrease surgery time of recovery (Ulrich, 1984).	U	
Potential of economic opportunities and green jobs	Green façades create maintenance jobs.	This NBS needs one maintenance day per month. Depending on the size, it may take more than a day.	U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: SHORT TERM/medium term/long term/no amortisation
Green façades with climbing plants usually do not require any extra structural requirements. They are most commonly attached to concrete walls, but can attach to almost anything, or even be free-standing. To provide support for plants, twining or clinging self-climbers can be used. We can remove this NBS easily if we want.	Green façades get the recovery of the investment between the 5 and the 10 years. Green façades with climbing plants are both low-cost and low-maintenance in comparison to other greening options.

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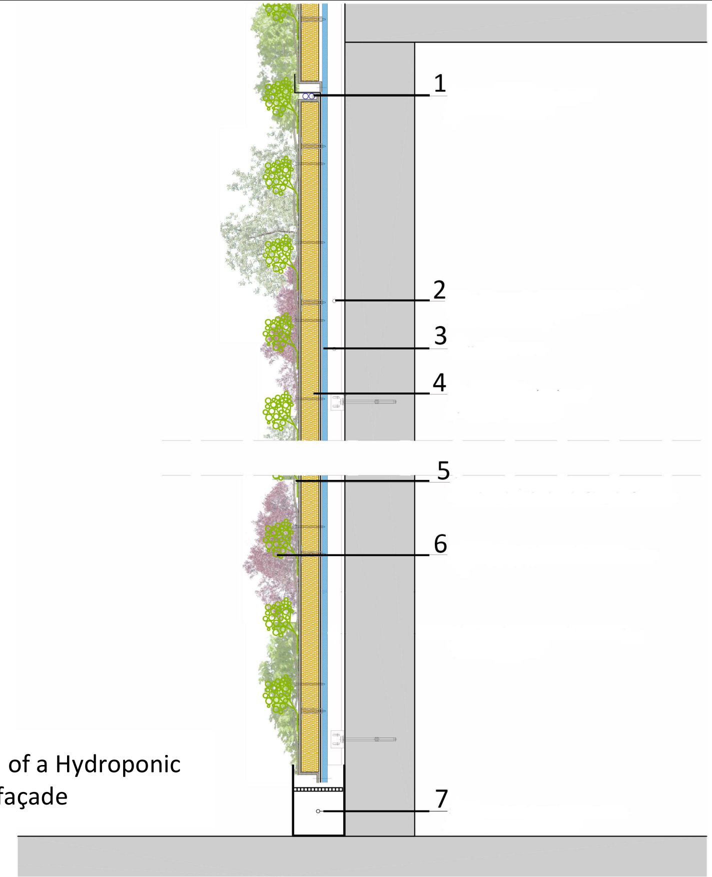
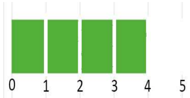
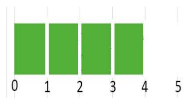
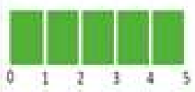
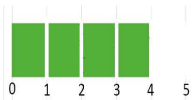
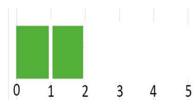
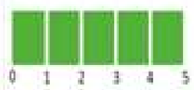
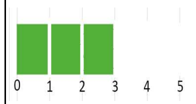
Hydroponic green façade

Vertical GI

TECHNICAL DESCRIPTION	GRAPHIC DETAIL
A hydroponic Green façade is a constructive system that allows to plant vegetable species in the entire vertical surface of a façade. The structure that supports this system is affixed to the façade. On this structure are placed different layers and a hydroponic substrate in which the plants grow. The green noise barriers are built with: • Irrigation system. Drip irrigation pipes that soak the substrate. **(1)** • Metallic structure. This structure is affixed to the façade. The structure is formed by metallic frames separated 45 – 60 cm **(2)** • Waterproof layer. Foamed PVC panel **(3)** • Hydroponic substrate. Special rock wool panels for vegetation growth. **(4)** • Hydroponic substrate. Geotextile where the vegetation grows. **(5)** • Vegetation. The vegetation are plants with little nutrient and water needs. They are species resistant to local climate suitable for growing in an inert substrate such as rock wool. **(6)** • Water collection system. All the water from the irrigation system is collected on the bottom of the garden. **(7)** In a hydroponic facade we can use the two hydroponic substrates (**4** & **5**) or only one of them.	 Figure 41 Section of a Hydroponic green façade

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green façades reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. Green façades protect buildings from the precipitation and the sun, improving indoor climate.	Hydroponic green façade can reduce the interior temperature of a building to 5ºC in summer, as well as keep it in winter. (H. Akira, 2010). Green façades help reduce energy costs in buildings by €0,71-19/m^2 (de Roo, 2011).	U/B	
Green Space Management	The green sound barriers manage to introduce large vegetable surfaces without occupying urban spaces. This NBS creates new ecosystems for birds and insects.	After the construction of the green facade of the Congress Palace of Vitoria increased the number of butterflies and birds in the area.	U	
Air Quality	Green noise barriers are natural air-filters, creating a cleaner environment. The vegetation metabolizes harmful toxins while releasing oxygen.	1 m^2 of vegetation cover generates the oxygen required by a person throughout the year. (Darlington, 2001) 1 m^2 of plant cover traps 130 grams of dust per year. (Darlington, 2001)	U	
Urban Regeneration	Green façades increase the economic value and the lifespan of buildings. Green façades add colour, texture and interest to the urban landscape.	Studies have shown that having plants around a building can increase real estate values by up to 20% (*Green Over Grey*). The installation of green façades can earn buildings LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5-57 /m^2 (*Ambius*).	U	
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	-	S	
Public Health and Well-being	Views of green have several positive effects on human health and this NBS is able to reduce noise	Research has shown that views of green cause positive changes in systolic blood pressure (Pretty *et al.*, 2005). Conclusion of the study Evaluation of green walls as a passive acoustic insulation system for buildings: The	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	thanks to the absorption of the substrate and the reflection of its leaves.	calculated weighted sound reduction index was R_w = 15 dB, and the correction terms were Ctr = −1 dB for traffic noise and C = −1 dB for pink noise. (Azcora et al., 2014)		
Potential of economic opportunities and green jobs	Green façades create maintenance jobs.	This NBS needs one maintenance day per month. Depending on the size, it may take more than a day.	U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
Green façades usually do not require any extra structural requirements. They are most commonly attached to concrete walls, but can attach to almost anything, or even be free-standing. We can remove this NBS easily if we want.	Green façades get the recovery of the investment between the 10 and the 20 years. Hydroponic green façades are more expensive than the green façade with climbing plants.

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- Ambius: https://www.ambius.com/green-walls/benefits/
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Vertical mobile garden

Vertical GI

TECHNICAL DESCRIPTION

A vertical mobile garden is a constructive system that allows to plant in vertical self-supporting structures. This NBS can be located anywhere in the city, as long as in that place there are a water tap and a connection with the sewage system. On this structure are placed different layers and a hydroponic substrate in which the plants grow.

The vertical mobile garden is built with:

- Metallic structure. This structure is self-supporting **(1)**
- Waterproof layer. Foamed PVC panel **(2)**
- Hydroponic substrate. Special rock wool panels for vegetation growth. **(4)**
- Vegetation. The vegetation are plants with little nutrient and water needs. They are species resistant to local climate suitable for growing in an inert substrate such as rock wool. **(3)**
- Water collection system. All the water from the irrigation system is collected on the bottom of the garden in a tank. **(5)**
- Irrigation system. It is formed by four horizontal drip irrigation pipes that soak the substrate, two vertical pipes and a pump into the tank. **(1)**

There must be a water inlet and an outlet in the tank.

GRAPHIC DETAIL

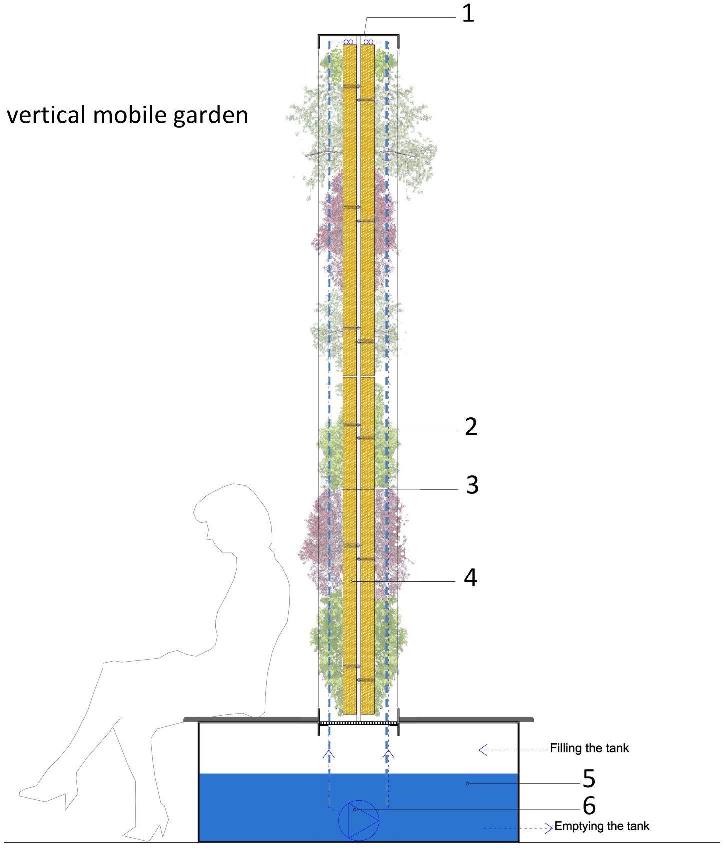
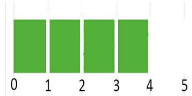
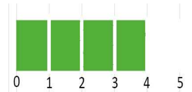
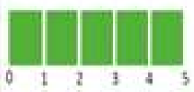
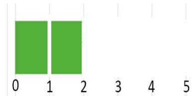
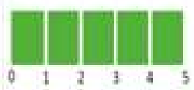
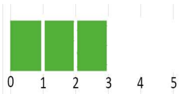


Figure 42 Section of a vertical mobile garden

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green façades reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating. Green façades protect buildings from the precipitation and the sun, improving indoor climate.	Hydroponic green façade can reduce the interior temperature of a building to 5ºC in summer, as well as keep it in winter. (H. Akira, 2010). Green façades help reduce energy costs in buildings by €0,71-19 /m^2 (de Roo, 2011).	U/B	
Green Space Management	The green sound barriers manage to introduce large vegetable surfaces without occupying urban spaces. This NBS creates new ecosystems for birds and insects.	After the construction of the green facade of the Congress Palace of Vitoria increased the number of butterflies and birds in the area.	U	
Air Quality	Green noise barriers are natural air-filters, creating a cleaner environment. The vegetation metabolizes harmful toxins while releasing oxygen.	1 m^2 of vegetation cover generates the oxygen required by a person throughout the year. (Darlington, 2001) 1 m^2 of plant cover traps 130 grams of dust per year. (Darlington, 2001)	U	
Urban Regeneration	Green façades increase the economic value and the lifespan of buildings. Green façades add colour, texture and interest to the urban landscape.	Studies have shown that having plants around a building can increase real estate values by up to 20% (*Green Over Grey*). The installation of green façades can earn buildings LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5-57 /m^2 (*Ambius*).	U	
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	-	S	
Public Health and Well-being	Views of green have several positive effects on human health and this NBS is able to reduce noise	Research has shown that views of green cause positive changes in systolic blood pressure (Pretty *et al.*, 2005). Conclusion of the study Evaluation of green walls as a passive acoustic insulation system for buildings: The	U	

	thanks to the absorption of the substrate and the reflection of its leaves.	calculated weighted sound reduction index was R_w = 15 dB, and the correction terms were Ctr = −1 dB for traffic noise and C = −1 dB for pink noise. (Azcora et al., 2014)		
Potential of economic opportunities and green jobs	Green façades create maintenance jobs.	This NBS needs one maintenance day per month. Depending on the size, it may take more than a day.	U	

IMPLANTATION: SOFT/Medium/Hard This type of vertical garden does not need any intervention, because this NBS is mobile. We can remove this NBS easily if we want.	**AMORTISATION: short term/MEDIUM TERM/long term/no amortisation** Green façades get the recovery of the investment between the 10 and the 20 years. This type of vertical garden is more expensive than the green façade with climbing plant and the hydroponic green façade.

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- de Roo, M. (2011). The green city guidelines – Techniques for a healthy liveable city. Available at www.thegreencity.com
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- Green Over Grey: http://www.greenovergrey.com/green-wall-benefits/property-value.php
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- Darlington, A., Dat J. F., Dixon, M. A. 2001. The biofiltration of indoor air: Air flux and temperature influences the removal of toluene, ethylbenzene, and xylene. Environ. Sci. Technol. 35: 240-246.

Floating gardens

Horizontal GI

TECHNICAL DESCRIPTION

Floating gardens can take many forms including pontoons, floating platforms and barges. They can vary in size from small individual platforms to longer pontoon systems as seen on the River Seine (Paris) and the Chicago river (Chicago). In urban areas they can be placed on non-tidal water bodies such as dock systems, lakes, canals and ponds as tidal areas may damage the gardens structure.

Some are constructed from a plant material floating sub-layer such as water hyacinths and then have planted flora, fauna or food products growing on top. Others use materials with a natural buoyancy, i.e. plastics or woods, as the sub-layer. Floating gardens provide habitats for varied marine/terrestrial species, opportunities for urban agriculture and climate change mitigation. They can also act as connective features linking habitats across urban boundaries (dependent on size/location and species mix).

The strength and extent of the floating garden depend on the construction of the raft and the weight of the material placed/grown on it.

GRAPHIC DETAIL

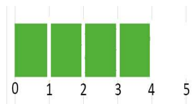
Figure 43 Bristol Harbourside Floating Gardens

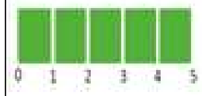
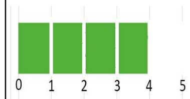
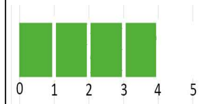
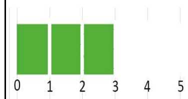
To ensure that the floating garden is structurally sound (and flexible to development contexts) the following issues surrounding their engineering should be taken into consideration:

- Marine-grade engineering to withstand all weather conditions
- Locking stainless steel quick connect system, making it easy to add additional gardens
- Fully cross-braced structure for added strength
- UV resistant thermo-fused tough floats
- Concrete anchors secured using weighted guide rail

Floating gardens provide benefits for water quality and air pollution/climate change mitigation. They also act as a key additional habitat for a diverse range of water based, insect and bird species within urban areas.

Figure 44 Example of floating gardens made with bio-rolls

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	Through the construction and management of an additional set of ecological resources located within a water body/course floating gardens can help filter pollutants from these systems. They also provide habitats for water based biodiversity and can act as a food source for aquatic and bird species.	The Gowanus Canal Conservancy have used floating gardens with plants labelled as 'producers' and 'cleaners' to help purify and improve the water quality of the Gowanus Canal. Similar practices have been identified in the Philippines where floating gardens are being used remove/moderate the level of heavy metals and excessive nutrients in the water system of Paranaque City. The Drijvend Groen' (Floating Greenery) project in Rotterdam in using comparable investments to manage the quality in the city's waterways.	U	

Green Space Management	Floating gardens provide an additional set of green spaces that can utilise otherwise redundant spaces. They can provide recreational, socio-cultural, and ecological benefits in terms of environmental education, the provision of spaces for interaction, and additional water/terrestrial habitats in high-density urban areas.	-	U/S	
Air Quality	Due to the increased proportion of NBS/GI being developing in urban areas floating gardens have the potential to increase the level of pollution being taken out of the atmosphere. This depends on the specific flora/fauna mix of each floating garden.	1 m^2 of vegetation cover generates the oxygen required by a person throughout the year. (Darlington, 2001) 1 m^2 of plant cover traps 130 grams of dust per year. (Darlington, 2001)	U	
Urban Regeneration	Investment in high quality floating gardens can be associated with property uplift in urban areas (i.e. Liverpool, Paris and London). They can also promote increased tourism and spend when they are located in sites with high footfall and an attractive amenity offer.	The provision of pontoons/platforms on the Chicago River (Chicago), River Seine (Paris), and in the Little Venice area of London have shown that investment in NBS can lead to economic uplift in property, increased use and spend in an area, and further inward investment into an area.	U	
Potential of economic opportunities and green jobs	Investment in high quality floating gardens can be associated with property uplift in urban areas (i.e. Liverpool, Paris and London). They can also promote increased tourism and spend when they are located in sites with high footfall and an attractive amenity offer. During the construction phase there is also the potential to create jobs for both qualified and unqualified personnel.	The provision of pontoons/platforms on the Chicago River (Chicago), River Seine (Paris), the Little Venice area of London and in Bristol Harbourside have shown that investment in NBS can lead to economic uplift in property, increased use and spend in an area, and further inward investment into an area. There are also examples where floating gardens have been used to grow food (either publically or privately) such as on the Bronx River	U	

IMPLANTATION: SOFT/Medium/Hard This type of NBS doesn't create important modifications in the environment.	AMORTISATION: short term/medium term/long term/NO AMORTISATION

REFERENCES:

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- Water management: http://erdb.denr.gov.ph/index.php/newsbriefs/409-uthrc-establishes-floating-gardens-in-selected-urban-areas
- Water management: https://www.portofrotterdam.com/en/news-and-press-releases/floating-islands-greenify-and-improve-rotterdam's-water
- Water management: http://urban-green.nl/projecten/drijvend-groen/
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- Urban regeneration: https://www.kickstarter.com/projects/1996859969/floating-gardens-in-the-chicago-river
- Urban regeneration: http://www.chicagomag.com/Chicago-Magazine/May-2017/Urban-Rivers-Floating-Gardens/
- Urban regeneration: https://frustratedgardener.com/2017/06/05/the-floating-pocket-park-merchant-square-london/
- Urban regeneration: https://www.hortweek.com/floating-pocket-park-opens-connecting-public-space-londons-canal-network/parks-and-gardens/article/1435189
- Potential of economic opportunities and green jobs: http://www.urbangardensweb.com/2013/08/12/floating-gardens-giant-chalkboards-and-climbing-walls-on-banks-of-seine-in-paris/
- Potential of economic opportunities and green jobs: https://www.susdrain.org/files/resources/Presentations/Tamasine1.pdf
- Potential of economic opportunities and green jobs: https://www.theverge.com/2017/7/12/15949842/swale-floating-food-forest-barge-foraging-new-york-bronx

Green covering shelters		Horizontal GI

TECHNICAL DESCRIPTION

A Green covering shelter is a very light type of green roof. This type of green roof has a very light and thin substrate to avoid that the roof has a lot of weight. The vegetation should to be small.

A green covering shelter is built with:

- Gravel on the perimeter, to facilitate the drainage of water. **(1)**
- A waterproof layer. The material must to be resistant to roots: PVC, EPDM… **(2)**
- A separating layer. This layer must to protect the waterproof layer. It is usually use geotextile sheets. **(3)**
- Hydroponic substrate. Special rock wool panels for vegetation growth **(4).** This type of substrate is lighter than the granular substrates.
- Vegetation. The best vegetation for this NBS are different species of sedum. This type needs little water and it has a low maintenance. **(5)**
- Irrigation system. Drip irrigation pipes that soak the substrate. **(6)**

It is important to know the strength of the structure before installing this NBS, because is necessary to know if the structure is able to support this type of roof.

GRAPHIC DETAIL

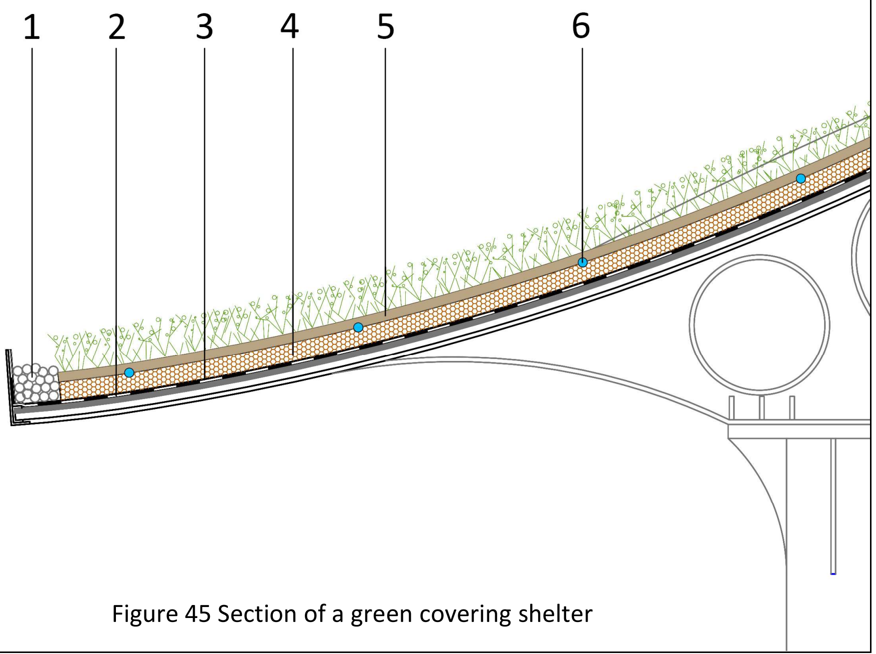
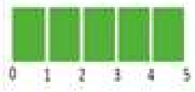
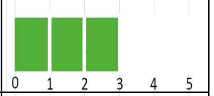
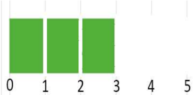
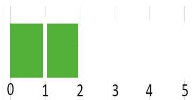
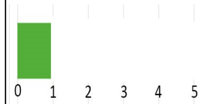
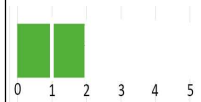
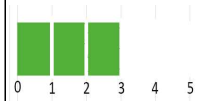


Figure 45 Section of a green covering shelter

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green roofs reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating.	"The Tokyo-based Organization for Landscape and Urban Greenery Technology Development estimates that if half of the roofs in the city were planted with gardens, daytime high temperatures in summer would fall by 0.84ºC." (Trautlein, 2003) In summer days with a 16 cm thick substrate the temperature can be reduced up to 15ºC. In winter days with the same substrate the temperature under the substrate can be maintained up to 13 ºC above the outside temperature.(G. Minke 2005)	U/B	
Water Management	The retention layer reduces urban run-off water	A green roof with 20 cm of substrate and expanded clay, is able to retain 90l/m^2 of water (Dürr 1995).	U	
Green Space Management	Green roofs increase the green areas and create new little ecosystems	Green roofs serve several functions related to urban biodiversity (Mann, 2002b). They act as stepping stones between nature reserves, such as parks on the edges of cities, and uncolonized habitats in the middle of the city. They provide a return area for plants and animals that previously inhabited an area that has undergone disturbance and development. They also can serve as permanent substitute habitats for plant and invertebrate communities.	U	
Air Quality	The plants are be able to absorb polluting substances	A German study demonstrated that green roof vegetation can significantly reduce diesel engine air pollution (Liesecke and Borgwardt, 1997) Yok Tan and Sia (2005) found a 37% and 21% reduction of sulfur dioxide and nitrous acid respectively directly above a newly installed green roof. Others have estimated that	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		green roofs can remove dust particulates per year per square meter of grass roof (Peck and Kuhn, 2001)		
Urban Regeneration	The green roofs increase the economic value of the building.	The installation of green roofs can earn building LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5 – 57/m[2]	U	
Public Health and Well-being	This NBS is able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves.	Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves because of the nature of the substrate and vegetation. At the airport in Frankfurt, Germany, a 10 cm deep green roof reduced noise levels by 5 dB (Dunnett and Kigsbury, 2004) Other research shows that 12 cm of green roof substrate alone can diminish noise by 40dB (Peck and Kuhn, 2001)	U	
Potential of economic opportunities and green jobs	The green roofs crate maintenance jobs	This NBS needs a person in charge of taking care of the vegetation and reviewing the irrigation installation.	U	

IMPLANTATION: SOFT/Medium/Hard	**AMORTIZATION: SHORT TERM/medium term/long term/no amortization**
The NBS don't create important modifications in the previous structure.We can remove this NBS easily if we want.	The green roofs get the recovery of the investment between the 0 and the 10 years.

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- Ambius: https://www.ambius.com/green-walls/benefits/

Electrowetland

Horizontal GI

TECHNICAL DESCRIPTION

An Electrowetland is a natural wastewater treatment system that generates electricity from the oxidation of the organic matter. It is based on a conventional Horizontal Subsurface Flow Constructed Wetland (HSSF CW) in which electrodes are introduced. Therefore, it consists on a planted and permanently flooded gravel basin in which wastewater flows horizontally from one side to the other of the system crossing the electrode layer. Electrodes implementation and the electrical connection stablished through them stimulate the development of an exoelectrogenic biofilm able to transfer the electrons resulting from the degradation of the organic matter to an external circuit thus generating electricity. Wastewater treatment efficiency is also improved resulting in lower wetland surface requirements when compared to conventional wetlands. To date, very few Electrowetland pilot-scale experiences have been reported and therefore, the design specifications stablished in this document constitute a proposal based on the conclusions obtained in the lab-scale experiments already published.

Conventional HSSF CWs – design parameters (Ortega, Ferrer, Salas, Aragón, & Real, 2010)

- Range of application: <2000 he
- Surface requirement (aprox.): 5m^2/p.e.
- Total bed depth: 0.4-0.6 m
- Organic loading: 8.7 g BOD/m^2·d

GRAPHIC DETAIL

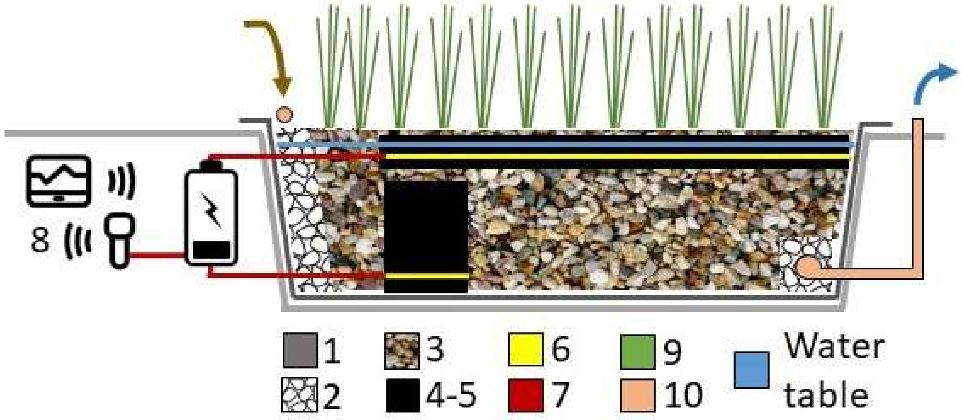
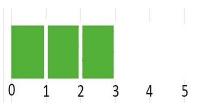
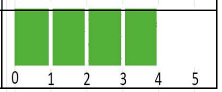
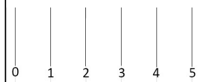
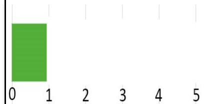


Figure 46 Section of Electrowetland

Electrowetlands are built with the following materials:

(1) Liner: implemented at the bottom of the treatment bed in order to prevent untreated wastewater percolation into subsurface water bodies. The material selected must be impermeable and resistant to root penetration.
(2) Coarse gravel: placed at the inlet/outlet regions in order to distribute wastewater through wetland section and to guarantee a good wetland's drainage, respectively.(Kadlec, & Wallace, 2009)
(3) Non-conductive filter bed: made with gravel of a grain-size distribution of about 8-16 mm. (Kadlec et al., 2000)
(4) Anodic electrode: vertical layer made with a conductive and biocompatible filtering material in which the electrons resulting from the oxidation will be generated and transferred to the external circuit. (Corbella, 2017)
(5) Cathodic electrode: horizontal layer made of a conductive granular material that is placed at the wetland's surface and where electrons coming from the external circuit will be used to reduce atmospheric oxygen. This layer must be, at least, 10 cm height in order to ensure its constant contact with the water table regardless water level variations within the system. (Corbella, 2017)
(6) Electron collector layers: made of a mesh conductive material and placed in the middle of the conductive anodic and cathodic filter beds. They serve to collect and release the electrons.
(7) External circuit: electrical circuit that connects the anodic and the cathodic granular electrodes collecting the electricity generated.
(8) Energy harvesting and sensoring system: Electronic devices to harvest the energy produced and to use it to power low-consuming sensors of temperature and relative humidity.
(9) Vegetation: aquatic vegetation is planted all through the wetlands' surface. Soft tissue emergent, including *Phragmites*, *Typha*, and *Schoenoplectus (Scirpus)* are the most common species used. (Kadlec, & Wallace, 2009)
(10) Inflow and outflow piping

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Electrowetland constitutes a green based infrastructure in a completely urbanized area and therefore it participates in the reduction of the heat island effect.	Values of heat island effect reduction are expected to be within the range of bibliography reported for similar GI (reductions between 1.3 and 2.8 ºC have been reported (Demuzere et al., 2014)).	U	
Water Management	As a wastewater treatment, an Electrowetland is able to remove organic matter, nitrogen and	Removal rates of at least those reported for conventional Horizontal Subsurface Flow Constructed	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	phosphorus from wastewater by means of physical, chemical and biological processes.	Wetlands (HSSF CWs) (90-95% for suspended solids; 85-90% for BOD_5; 80-90% for COD; 20-30 N_{total}; 20-30 P_{total} (Ortega, Ferrer, Salas, Aragón, & Real, 2010)) are expected for the Electrowetland.		
Green Space Management	Electrowetland increases the green areas that can act as drivers for sustainable development. However due to the presence of wastewater in the systems, it is not accessible to citizens.	Beyond wastewater treatment, constructed wetlands constitute urban biodiversity hotspots in which aquatic fauna and flora can grow thus preserving and enhancing biodiversity. (Martis, Mulas, Malavasi, & Marignani, 2016)	U	
Air Quality	Plants present in the Electrowetland are CO_2 consumers. However, certain amounts of greenhouse gases are emitted while wastewater is treated as a consequence of oxidation of the organic matter (CO_2, CH_4) or the nitrification/denitrification process (N_2O).	The relative contribution to CH_4 and N_2O emissions from a treatment system will depend on the environmental conditions. The fluxes of N_2O–N, CH_4–C, and CO_2–C from Constructed Wetlands in Europe ranged from 22.1 to 1000, 232 to 38000, and 2840 to 93000 mg m^{-2} d^{-1}, respectively (Søvik et al.,2006). However, as function of its lifespan, CWs constitute a carbon source or a carbon sink. (Brix, Sorrell & Lorenzen, 2001)	U	
Urban Regeneration	Due to its capacity to generate electricity from the oxidation of the organic matter, Electrowetlands can result in energy savings. However, only low input devices, such as sensors, could be powered.	Maximum power of 44 mW/m^2 of wetland surface has been reported from lab-scale Electrowetlands. (Doherty, et al., 2015)	U	
Potential of economic opportunities and green jobs	Although HSSF CWs are linked to low operation and maintenance costs some process monitoring and cleaning tasks are required. Construction phase also results in job creation both for qualified and unqualified personnel.	13 different maintenance activities have to be conducted including cleaning tasks, wastewater analysis, operation control and plants trim. Accordingly, a worker time of about 160 h/year is required. (Ortega, Ferrer, Salas, Aragón, & Real, 2010)	U	

IMPLANTATION: Soft/MEDIUM/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
This NBS can be built on any place that generates wastewater with a significant content of organic matter. Load requirements of the supporting surface must be taken into consideration in order not to generate any structural affection in urban areas. Depending on the wastewater being treated each Electrowetland will have different characteristics (grain size, total surface, bed depth, etc.). Depending on its configuration (surface unit vs excavated basin) its affection when removed will vary.	The Electrowetland get the recovery of the investment between the 10 and the 20 years.

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Green Roof

Horizontal GI

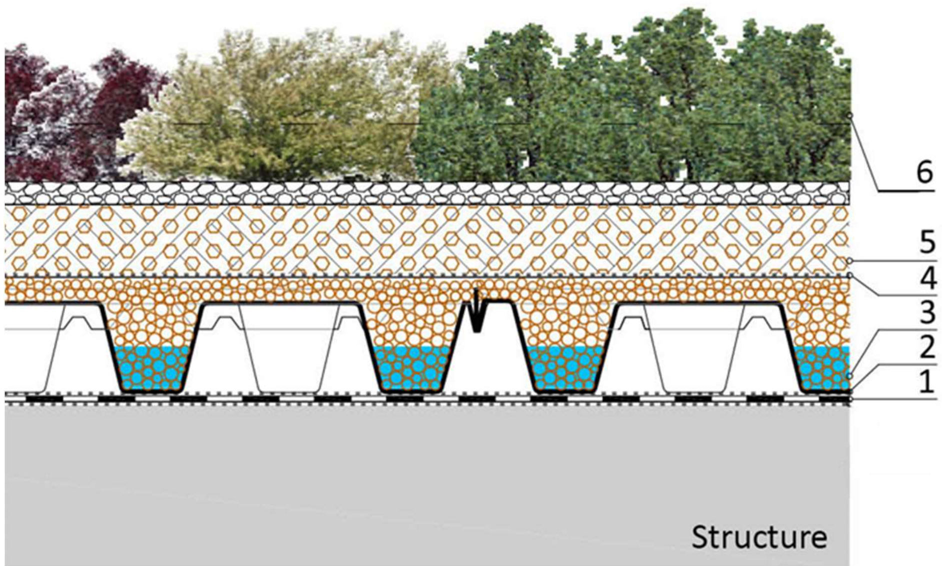
TECHNICAL DESCRIPTION

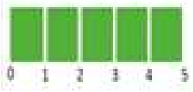
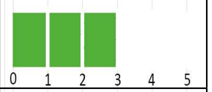
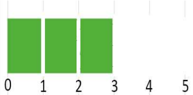
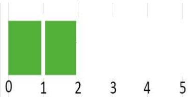
The external upper covering of a building which the main objective is to favour the growth of vegetation keeping the habitability conditions in the rooms below. The inclination of the roof must be between 0 and 45º.

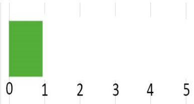
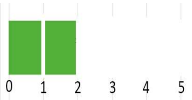
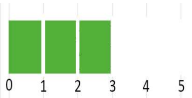
The green roof are built with:

- A waterproof layer. The material must to be resistant to roots: PVC, EPDM… **(1)**
- A separating layer. This layer must to protect the waterproof layer. It is usually use geotextile sheets. **(2)**
- A draining layer. This layer creates an air chamber that allows excess water to be evacuated. **(3)**
- Water retention layer. Layer with a singular geometry that allows the water retention. **(3)**
- Filtering layer. This layer prevents the loss of fine from de substrate.**(4)**
- Absorbent layer. It has made by materials which retain water and they liberate it slowly. **(4)**
- Substrate. Support layer of the vegetation where the work of the roots takes place. **(5)**
- Vegetation. The select species depends on the climate, the depth and the composition of the substrate, if we put an irrigation system…

GRAPHIC DETAIL



Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green roofs reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating.	"The Tokyo-based Organization for Landscape and Urban Greenery Technology Development estimates that if half of the roofs in the city were planted with gardens, daytime high temperatures in summer would fall by 0.84ºC." (Trautlein, 2003) In summer days with a 16 cm thick substrate the temperature can be reduced up to 15ºC. In winter days with the same substrate the temperature under the substrate can be maintained up to 13 ºC above the outside temperature.(G. Minke 2005)	U/B	
Water Management	The retention layer reduces urban run-off water	A green roof with 20 cm of substrate and expanded clay, is able to retain 90l/m^2 of water (Dürr 1995).	U	
Green Space Management	Green roofs increase the green areas and create new little ecosystems	Green roofs serve several functions related to urban biodiversity (Mann, 2002b). They act as stepping stones between nature reserves, such as parks on the edges of cities, and uncolonized habitats in the middle of the city. They provide a return area for plants and animals that previously inhabited an area that has undergone disturbance and development. They also can serve as permanent substitute habitats for plant and invertebrate communities.	U	
Air Quality	The plants are be able to absorb polluting substances	A German study demonstrated that green roof vegetation can significantly reduce diesel engine air pollution (Liesecke and Borgwardt, 1997) Yok Tan and Sia (2005) found a 37% and 21% reduction of sulfur dioxide and nitrous acid respectively directly above a newly installed green roof. Others have estimated that	U	

		green roofs can remove dust particulates per year per square meter of grass roof (Peck and Kuhn, 2001)		
Urban Regeneration	The green roofs increase the economic value of the building.	The installation of green roofs can earn building LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5 – 57/m^2	U	
Public Health and Well-being	This NBS is able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves.	Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves because of the nature of the substrate and vegetation. At the airport in Frankfurt, Germany, a 10 cm deep green roof reduced noise levels by 5 dB (Dunnett and Kigsbury, 2004) Other research shows that 12 cm of green roof substrate alone can diminish noise by 40dB (Peck and Kuhn, 2001)	U	
Potential of economic opportunities and green jobs	The green roofs crate maintenance jobs	This NBS needs a person in charge of taking care of the vegetation and reviewing the irrigation installation.	U	

IMPLANTATION: SOFT/Medium/Hard This NBS can be built on any roof that resists more than 75Kg/m^2. The inclination of the roof must be between 0 and 45º. Depending on these conditions the type of the green roof will be different. We can remove this NBS easily if we want to change the roof.	**AMORTIZATION: SHORT TERM/medium term/long term/no amortisation** The green roofs get the recovery of the investment between the 0 and the 10 years.

REFERENCES

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- Ambius: https://www.ambius.com/green-walls/benefits/

Green shady structures

Horizontal GI

TECHNICAL DESCRIPTION

Pieces of stretched textile structure on which an inert substrate is installed. This inert substrate is 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.

The green shady structures are built with:

- A waterproof layer formed by a PVC sheet. This layer is tensioned by a steel cable. The steel cable could be fixed to a façade or to a post. (In the figure 28 the cable is fixed to the façades) **(1)**
- Hydroponic substrate. Geotextile where the vegetation grows. This geotextile is glued to PVC. **(2)**
- Irrigation system located on the top of the PVC sheet. Irrigation system located on the top of the PVC sheet. It is formed by drip irrigation pipes that soak the substrate.**(3)**
- Vegetation planted in seeds. The vegetation are plants with little nutrient and water needs. They are species resistant to local climate suitable for growing in an inert substrate such as geotextile. **(4)**
- Water collection system. All the water from the irrigation system is collected on the bottom of the garden. **(5)**

Public lighting **(6)**

GRAPHIC DETAIL

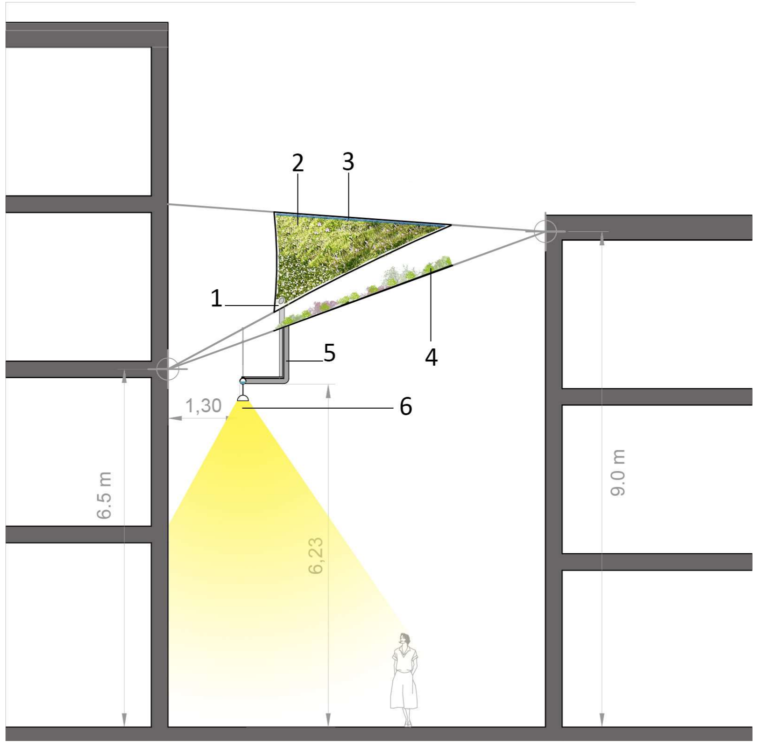
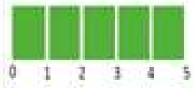
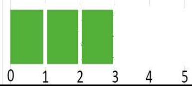
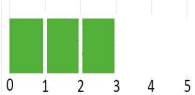
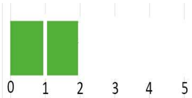
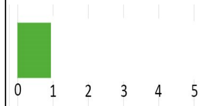
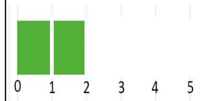
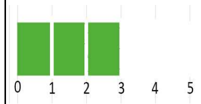


Figure 47 Image of green shady structures in a Valladolid's street

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green roofs reduce the heat island effect. They increase the thermal insulation in the building and therefore reduce the use of energy in air conditioning and heating.	"The Tokyo-based Organization for Landscape and Urban Greenery Technology Development estimates that if half of the roofs in the city were planted with gardens, daytime high temperatures in summer would fall by 0.84ºC." (Trautlein, 2003) In summer days with a 16 cm thick substrate the temperature can be reduced up to 15ºC. In winter days with the same substrate the temperature under the substrate can be maintained up to 13 ºC above the outside temperature.(G. Minke 2005)	U/B	
Water Management	The retention layer reduces urban run-off water	A green roof with 20 cm of substrate and expanded clay, is able to retain 90l/m^2 of water (Dürr 1995).	U	
Green Space Management	Green roofs increase the green areas and create new little ecosystems	Green roofs serve several functions related to urban biodiversity (Mann, 2002b). They act as stepping stones between nature reserves, such as parks on the edges of cities, and uncolonized habitats in the middle of the city. They provide a return area for plants and animals that previously inhabited an area that has undergone disturbance and development. They also can serve as permanent substitute habitats for plant and invertebrate communities.	U	
Air Quality	The plants are be able to absorb polluting substances	A German study demonstrated that green roof vegetation can significantly reduce diesel engine air pollution (Liesecke and Borgwardt, 1997) Yok Tan and Sia (2005) found a 37% and 21% reduction of sulfur dioxide and nitrous acid respectively directly above a newly installed green roof. Others have estimated that	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		green roofs can remove dust particulates per year per square meter of grass roof (Peck and Kuhn, 2001)		
Urban Regeneration	The green roofs increase the economic value of the building.	The installation of green roofs can earn building LEED points, and if the building reaches LEED certification, can receive tax credits between €6,5 – 57/m^2	U	
Public Health and Well-being	This NBS is able to reduce noise thanks to the absorption of the substrate and the reflection of its leaves.	Hard surfaces in urban areas are more likely to reflect sound, whereas green roofs absorb sound waves because of the nature of the substrate and vegetation. At the airport in Frankfurt, Germany, a 10 cm deep green roof reduced noise levels by 5 dB (Dunnett and Kigsbury, 2004) Other research shows that 12 cm of green roof substrate alone can diminish noise by 40dB (Peck and Kuhn, 2001)	U	
Potential of economic opportunities and green jobs	The green roofs crate maintenance jobs	This NBS needs a person in charge of taking care of the vegetation and reviewing the irrigation installation.	U	

IMPLANTATION: soft/**MEDIUM**/Hard This NBS creates some modifications in the environment so there are some disadvantages of removing it in the future. This NBS creates modifications in the buildings of the street or on the pavement.	**AMORTIZATION:** short term/**MEDIUM TERM**/long term/no amortization The green shady structures get the recovery of the investment between the 10 and the 20 years.

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Green filter area

Pollutants filter

TECHNICAL DESCRIPTION

Green filter areas are vertical green infrastructure interventions, constructed to provide a visual barrier and/or and pollution filter between roads or industrial operations and public space or walkways. Green filter areas may take the form of street trees, green walls (screens), shrubs or hedges. Trees, shrubs or climbers may be planted directly into the ground or into containers. Green filter planting may be combined with solid barrier construction to reduce noise impact.

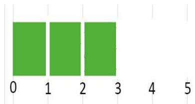
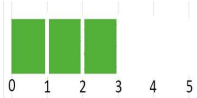
Choice of plant species and urban layout is important in designing vertical vegetation interventions for air pollution mitigation. Higher rates of particulate capture are associated with the complex shoot structure and finer leaves of conifer species (Beckett *et al*. 2000; Freer-Smith *et al*. 2005). Whilst trees and shrubs can remove gaseous pollutants from the atmosphere and provide large surface areas for deposition of particulate pollutants, careful design of the vertical green filter area, accounting for local conditions, is required to avoid exacerbation of local pollutant concentrations through reducing airflow and slowing dispersal. Increased height (over 5m) and width (10m) will in general increase the effectiveness of green filter areas in reducing concentrations of airborne pollutants (Baldauf, 2016). Both density (to allow maximum deposition) and porosity (to allow penetration rather than deflection of airflow) of low vegetation barriers close to pollution source are important for effective capture of particulate pollutants (Janhäll, 2015). Gaps in green vegetation barriers can result in increased downwind ambient pollution concentrations (Baldauf, 2016).

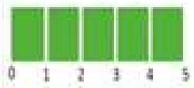
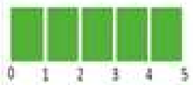
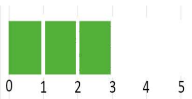
Design and maintenance considerations include: avoiding obstruction of driver and pedestrian lines of site and access; irrigation during drought; pruning annual growth; and removal and replacement of dead vegetation; Choice of woody vegetation should take into

GRAPHIC DETAIL

Figure 48 Example of green filter area

consideration: stress tolerance; selection of non-deciduous species to provide a year-round barrier; and avoidance of poisonous, invasive or allergenic species, or species associated with pollutant emissions (including VOCs) (Baldauf, 2016).	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green filter areas contribute to the effect of urban vegetation in reducing the urban heat island effect and to the sequestration of carbon by vegetation.	The trees and shrub species which constitute green filter areas contribute to the general effect of urban vegetation in reducing the urban heat island effect through evaporative cooling, and to the sequestration of carbon by vegetation.	S	
Water Management	Where green filter vegetation is rooted in permeable substrate at ground level, surface water run-off may be absorbed; reducing demand on urban drainage systems during periods of high precipitation.	Roadside green filter areas can be constructed to control surface water run-off from impermeable pavement or road surfaces, mitigating local surface water flooding and pollution (Baldauf, 2016). Tree and shrub canopies intercept rainfall, reducing the speed at which rainfall enters the drainage system (Dover, 2015).	S	
Green Space Management	Green filter interventions can be retro-fitted into areas of dense urban infrastructure, increasing available habitat for birds and insects, and providing linear features connecting existing areas of urban greenspace.	Studies of urban biodiversity show that highly-mobile taxa, including pollinators, will use patches of urban green space separated by dense infrastructure, and that flowering plants in urban areas can attract a diverse range of pollinator species (Hennig and Ghazoul 2012, Baldock et al. 2015). Design considerations for green filter interventions include avoiding providing connectivity for invasive species through the urban environment (Baldauf, 2016).	S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Air Quality	The woody shrubs and/or trees which constitute green filter areas have the capacity to reduce concentrations of airborne gaseous and particulate pollution, improving environmental conditions impacting public health.	Through increasing the surface area available for particulate deposition and by increasing the length of the pathway for dispersal of pollutants, vertical green filter areas may reduce concentrations of airborne pollutants in adjacent pedestrian areas (Ferranti *et al.* 2017). Particulates deposited on leaf surfaces include trace heavy metals originating from road transport vehicles, including lead, cadmium, copper, zinc, iron and manganese (Aničić *et al.* 2011; Ugolini *et al*. 2013; Liang *et al*. 2017).	S	
Urban Regeneration	Green filter areas can provide a visual and physical barrier between roads or industrial compounds, increasing the aesthetic value of urban areas.	-	S	
Public Health and Well-being	See Air Quality (above)	-	S	
Potential of economic opportunities and green jobs	Green job opportunities associated with design, construction and the ongoing maintenance of green filter areas	-	U	

IMPLANTATION: <u>SOFT</u>/Medium/Hard We can remove this NBS easily if we want to change something on the street.	**AMORTIZATION: <u>SHORT TERM</u>/medium term/long term/no amortization** The green roofs get the recovery of the investment between the 0 and the 10 years.

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Urban garden bio-filter

Pollutants filter

TECHNICAL DESCRIPTION

This NBS uses a special substrate (mixture of urban by –products) as filter media to capture pollutants (NOx, PM, CO, benzene, toluene, etc.) form the air of underground parking without waste generation. This NBS uses a rhizodegradation process in which contaminants are degraded in the rhizosphere (area of soil surrounding the roots of the plants) by means of microbial activity which is enhanced by the presence of plant roots. That takes place in soil to the process.

Some of the Benefits:

- Reduction of gaseous contaminants and CO_2 concentration at the outflow position
- Balance of the flow, temperature, humidity and contaminants concentration
- Depending on implementation design it adds aesthetics values to the urban street.

In the biofilter the contaminated air is introduced in the plenum chamber by a side inlet pipe. The air is injected through the pipe and there are no additional physical distributors within the plenum chamber volume to control the air flow once it enters the chamber. The principal advantage of this design concept is its relative simplicity and ease of construction.

GRAPHIC DETAIL

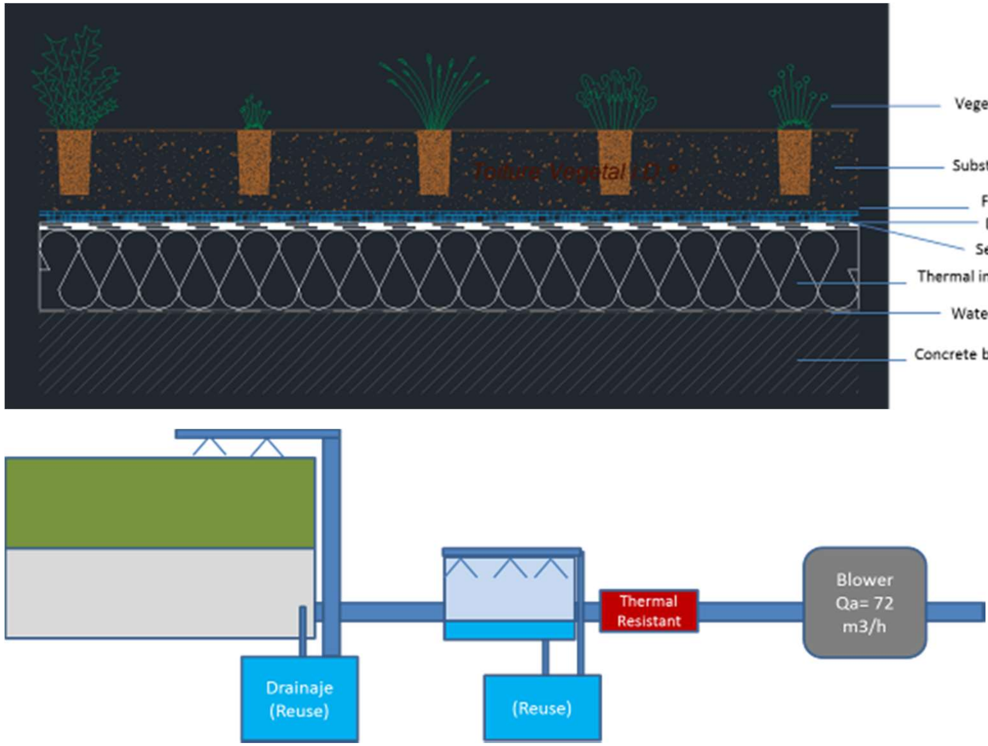
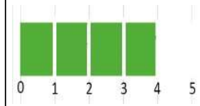
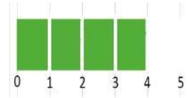
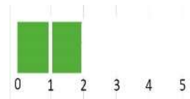
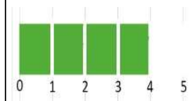
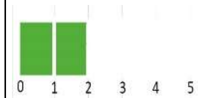


Figure 49 First Prototype scheme by EU “Grabgas” Project.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Increased temperatures during summer in cities amplify energy demand for air conditioning. Urban heat island (UHI) raises electricity demand during summer. Thanks to the vegetated green surface of this NBS heat absorbed by the urban surface is decreased and can lower surface temperatures. This decrease in surface temperatures can mitigate urban heat island effect.	According to EPA (2012), every 10% increase in solar reflectance could decrease surface temperatures by 4°C. If pavement reflectance throughout a city were increased from 10 to 35%, the air temperature could potentially be reduced by 0.6°C.	U	
Air Quality	Increased greenhouse gases cause global warming and climate change while the pollutants negatively impact human health as well as the decline of air quality. This NBS improves the air quality as it is designed to decrease the CO_2 gas emissions and to capture pollutants (NOx, PM, CO, benzene, toluene, etc) from the air of underground parking.	Rosenfeld et al. (1998) simulated the air quality effects of deploying cool community strategies (higher albedo roofs and pavements, increasing tree cover) in Los Angeles, which resulted in a 12% reduction in smog exceedance.	U	
Urban Regeneration	By greening the local landscape and reducing urban heat island effect this NBS affects positively urban regeneration leading to more comfortable and enjoyable urban spaces with aesthetical values.	Thermal comfort of pedestrians was simulated for a neighbourhood in Eastern Los Angeles County for various strategies including solar reflective cool roofs, vegetative green roofs, solar reflective cool pavements and increased street-level trees. Results showed that greenery integrated caused significant reductions in surface air temperatures and small changes in mean radiant temperature during the day (Taleghani et al., 2016).	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Public Health and Well-being	Due to the improvement of air quality, thanks to the reduction of the gaseous pollutants, public health and well-being can be positively affected by this NBS.	Dowling (2014) reported that in Melbourne-Australia appr. 200 heat-related deaths recorded in 2013, in comparison to the state road toll of 242 deaths. By 2030, the number of deaths as a result of heat is expected to double.	U	
Potential of economic opportunities and green jobs	The solution has high cost at it initial innovation phase, however the balance between the profits and implementation costs (having in mind it future commercialization costs) it is interesting. Smart filter material production creates a new economic sector and job opportunities. Every 1°C temperature reduction that can be achieved through the better design of cities can equate to 5% energy saving through reduced cooling.	AECOM (2015) published a report on the impacts of heat, heat waves and the intensification of the urban heat island effect on health, transport infrastructure, energy demand and infrastructure, trees and animals and crime. The report concluded that "The total economic cost to community due to hot weather is estimated to be $1.8 billion in present value terms. Approximately one-third of these impacts are due to heatwaves. Of the total heat impact, the urban heat island effect contributes appr. $300 million in present value". Another study claims that a 1°C temperature increase boosts cooling loads by 1.5 million kWh/year, generating 1000 tonnes in carbon dioxide emissions (AILA, 2016).	U	

IMPLANTATION: SOFT/Medium/HARD This NBS creates a lot of modifications in the environment.	**AMORTIZATION:** Short term/ Medium term/LONG TERM/no amortization The urban garden bio-filter get the recovery of the investment between the 20 and the 50 years

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Parklets

Pollutants filter

TECHNICAL DESCRIPTION

Parklet or pocket park provides opportunities for people to create small but important public spaces right in their own neighbourhoods (Figure 1). Parklet repurposes part of the street next to the sidewalk into a public space for people. It provides amenities like seating, planting, bicycle parking, and art. Parklets encourages non-motorized transportation.

Technical specifications of parklets are well documented as design guides (i.e. San Francisco Parklet Manual, 2015). These documents typically include;

- Site selection and outreach
- Proposal review and selection
- Design development and permitting procedures
- Fabrication and installation (Figure 2)
- Post-construction

GRAPHIC DETAIL

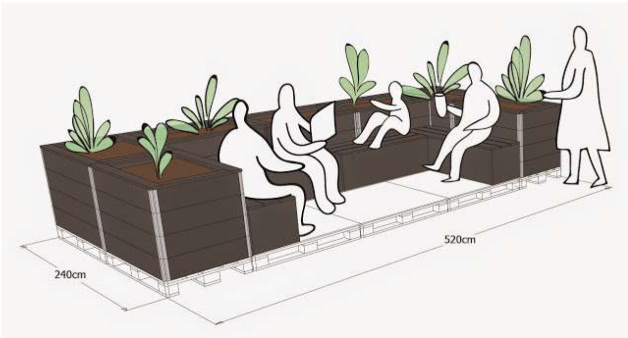


Figure 50 Size of the parklet

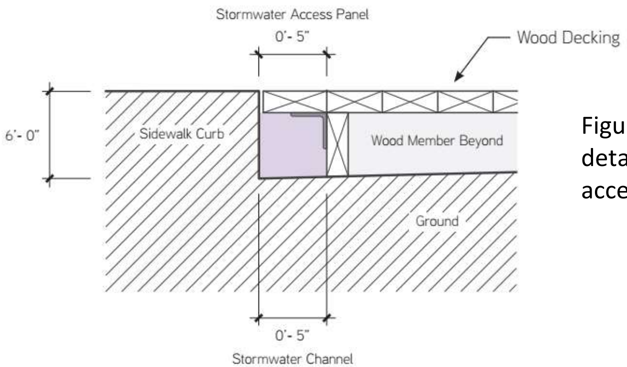
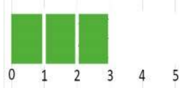
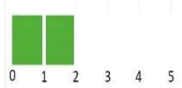
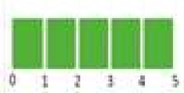
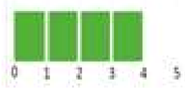
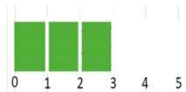
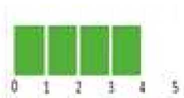


Figure 51 Example from technical details of a parklet (stormwater access channel)

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Water Management	Parklets are not necessarily used in water management schemes. However, they can be amalgamated with other nature-based solutions such as bioswales that allows permeable surfaces against stormwater runoff.	There are very few experimental project proposals on how to use parklets to abate stormwater management (i.e. WDCD Climate Action Challenge).	U/S	
Green Space Management	Parklets are a form of green space in a micro scale. They provide seating, greenery and space to passers-by. Depends on their design some parklets may cover air purifying plants and pollinator houses that serve as green buffers for hosting biodiversity.	Based on some studies by experts, it will suppose that parklets may cover approximately 35 sqm more of green areas, 30 sqm of shadow areas and 20.8 ton CO_2 avoided per annum (Strohbach et. al, 2012). Littke's study (2016) on parklets of San Francisco reveals that only 5 to 10 percent of parklet surface is devoted to green area.	U/S	
Urban Regeneration	Parklets may increase property values and drive up revenues for nearby businesses. A parklet opposite a shop or cafe has proved a useful way of getting passers-by to slow down and stop in, making them a potential tool in regeneration, especially for local shopping streets. Parklets can be a part of solution for a city's need for more public space in its commercial corridors. They transform underutilized street space into vibrant public space. It can also be produced by retrofitted materials.	There are no scholarly proven examples of increase in property values near parklet locations. However, many impact study reports suggest that local business near parklets benefited from this street regeneration process. From the business perspective, there was not any negative impacts businesses attributed to parklets (San Francisco Parklet Impact Study, 2011)	S	
Participatory Planning and Governance	Parklets empower community groups and businesses to enhance the pedestrian friendliness of their street and encourage people's engagement with the urban environment through the creation of micro	According to Littke (2016) parklets are connected to values of community engagement, bottom-up urban solutions and reclaiming. Despite the active citizenship and tactical urbanism features most of the parklets in San Francisco have sponsored by	S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
	public places. Parklets are the parts of tactical urbanism that are a new bottom-up approach to urban planning and design. They allow citizens to take back their cities from cars.	nearby cafes and restaurants. This make fear of commercialization of public land and parklets cannot be controlled by the business that installed them.		
Social Justice and Social Cohesion	Parklets are safe, people-friendly environments that offer inviting café-style chairs and tables, benches, and trees and plants. These people places are designed to give residents extra space to walk, bike, dance, skate, sit, hang out with friends and meet their neighbours. Parklets extends community ties and creates public interaction opportunities among city residents.	It was reported by San Francisco Parklet Impact Study (2011) that the number of people stopping to engage in stationary activities (i.e. standing, sitting) significantly increased on weekdays.	U/S	
Public Health and Well-being	Parklets create micro public spaces network and support hectic city life that enhance health, prosperity, and happiness of urban residents.	Walking and cycling is key to public health and well-being. San Francisco Parklet Impact Study (2011) notes that there was an incremental increase in the number of bikes parked in observed parklet locations. The same study also confirmed that pedestrian traffic was only marginally increased after the parklet was installed.	U/S	
Potential of economic opportunities and green jobs	Parklets have been considered as parts of street improvement and regeneration projects. The local business and especially downtown property owners on shopping streets benefited from this process.	A sporadic evidence on parklets for the city of Sydney suggests increased business activity, 15 per cent increase in sales during the four months the parklet was installed. San Francisco Parklet Impact Study (2011) also found that parklets and the increase in activity they attract make nearby businesses more visible. The number of businesses applying for parklet permits in those areas	S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		indicates that they see an economic benefit to investing in these new public spaces.		

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: SHORT TERM/medium term/long term/no amortisation
Parklets can be easily built in areas along side with urban roads, often the shopping streets. Its location is generally offered by community organizations and neighbouring business comply with a permit of local government.	Parklets are tactical solutions and generally starts as special events or temporary use. They should meet maintenance and upkeep rules and comply with permit regulations and public access requirements. Therefore, a parklet can be removed any time if not fulfilled any of those procedures. Due to its public function parklet investments are sponsored and maintained by community organizations, neighbouring business and municipal organizations.

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Green resting areas

Horizontal GI

TECHNICAL DESCRIPTION

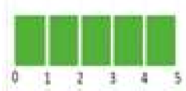
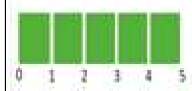
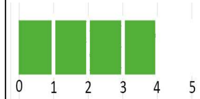
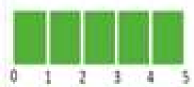
Green resting areas are green spaces projected for social passive recreation (resting, relaxation, observing nature, social contact). The development of green resting areas plays a central role in policies related to health, nature conservation and spatial planning.

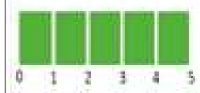
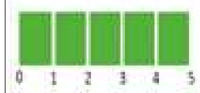
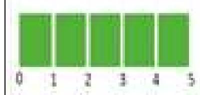
Green resting areas are built with:

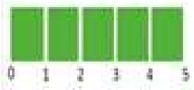
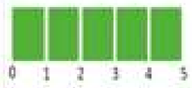
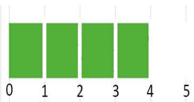
- Native soil. **(1)**
- Compacted soil mixture of 20-30% sand, 20-30% compost and 30-40% topsoil. **(2)**
- Draining gravel layer. This layer all allows excess water to be infiltrated. **(3)**
- Vegetation - Tree. The selection of species depends on the climate, the depth and the composition of the substrate, if we put an irrigation system… **(4)**
- Vegetation – Shrubs**.** The selection of species depends on the climate, the depth and the composition of the substrate, if we put an irrigation system… **(5)**
- Lighting equipment to ensure comfort and safety of the green resting area. **(6)**
- Bench attached to a concrete foundation. **(7)**
- Pavement area built above a *tout-venant* 20 cm layer. **(8)**

GRAPHIC DETAIL

Figure 52 Example of a Green resting area

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	Green resting areas reduce the heat island effect.	An increase of tree cover by 10% results in a temperature decrease of 1,4 ºC (Tyrvainen *et al.*, 2005). The thermoregulation capacity of an average tree in a "hotspot" in the city has a benefit of 30 €/year (de Roo, 2011).	M/U	
Water Management	Green resting areas decrease impervious surfaces, and provide water retention possibilities on site, increasing recharge of aquifers and reducing peak runoff problems.	Studies show that in green spaces only 10% of rainwater will experience superficial runoff (50% will be infiltrated in soil and 25% will return to atmosphere through evapotranspiration), which contributes for the regulation of hydrological flows (Bernatzky, 1983).	U	
Coastal Resilience	Green resting areas implemented near the coast increase the ability of the landscape to return to its original form after hazardous events such as hurricanes, coastal storms and flooding.	The capacitance, damping and integrity of ecosystem response to coastal environmental fluctuations depend on the total area of green infrastructure solutions (*The Nature Conservancy*). Boston has developed a plan to prevent flooding in its most vulnerable waterfront neighbourhoods by projecting elevated green areas (Gibson, 2017).	M/U	
Green Space Management	Green resting areas contribute to soil formation, nutrient cycling, trophic-dynamic regulation of faunistic populations, and offers habitat for resident and transient species.	Studies have showed biodiversity is the precondition for ecosystem services in urban areas (de Groot *et al.*, 2002). Studies have concluded some conditions to increase biodiversity in green resting areas are: dimension of the green space, plant diversity, presence of herbaceous borders and water sources, presence of pollen and nectar-rich species, fruit trees and rocks/gravel for insect resting (Tyrvainen *et al.*, 2005; Hoffman, 2011; de Roo, 2011).	U	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		There has been a growing spread of "*outdoor living laboratories*" in green resting areas (*American Society of Landscape Architects*).		
Air Quality	Plants in green resting areas are able to remove air pollutants, urban *smog* (atmosphere suspended particles) and intercept ultraviolet radiation. Through photosynthesis, plants are able to sequester carbon dioxide and release oxygen, maintaining a beneficial atmospheric composition for human life.	Trees present in big scale urban green spaces can filter up to 85% of atmospheric pollution, while some aligned trees can filter up to 70% (Bernatzky, 1983). An average tree in the city is able to capture about 100 g particulate matter (PM10), which equals the particulate matter emission from a private car that travels 1500 km (Tonneikck, 2008). A single mature tree can absorb carbon dioxide at a rate of 22 kg/year and release enough oxygen back into the atmosphere to support 2 human beings (McAliney, 1993).	U	
Urban Regeneration	Green resting areas increase the economic value of the buildings. An interconnected network of green spaces adds form to urban patterns, creating points of interest and harmonizing negative effects arising from urban expansion and habitat fragmentation. The increase of green resting areas creates aesthetically pleasant places in urban context.	Houses with a view of green are 1-15% more valuable. Offices with green spaces nearby can be 10% more valuable (de Roo, 2011). In New York, cost-benefit analysis has shown that every dollar invested in green space delivers 5 back for the city (Long, 2012).	M/U	
Participatory Planning and Governance	Green resting areas represent an opportunity for participatory planning and community involvement.	Participatory planning and community involvement have been increasingly adopted in the project of green resting areas. One example is the project of green resting areas in High Point (Seattle), which involved	U/S	

Challenge	Description	Experience / Study	Challenge Scale	Valuation
		the community in all design aspects of the project, implementing features that represent the community's wishes, needs and desires (*American Society of Landscape Architects*).		
Social Justice and Social Cohesion	Greener environments encourage people to spend more time in outdoor spaces, increasing the rates of social interaction and cohesion.	Studies have shown green resting areas increase social cohesion, building a solid community sense (de Roo, 2011). Studies in the Netherlands have concluded that the quantity and quality of greenery in a neighbourhood is associated with its social cohesion (de Vries *et al.*, 2013). Recent studies concluded the presence of green resting areas in neighbourhoods reduces adolescent's aggressive behaviour (*Journal of the American Academy of Adolescent Psychiatry*).	U/S	
Public Health and Well-being	Green resting areas offer diverse conditions for amenity purposes (recreation, relaxing, observing nature), having several positive impacts in human health and well-being.	Studies have demonstrated that users of green resting areas live longer (Takano *et al.*, 2012), have reduced cardiovascular diseases (Michel & Popham, 2008), enhanced physical activity, reduced obesity, reduced risk of allergies and asthma and improved functioning of the immune system (Godbey, 2009). These users also have improved mental health and cognitive function (Pretty *et al.*, 2005).	U/S	
Potential of economic opportunities and green jobs	Green resting areas create maintenance jobs. Green resting areas improve the overall ecologic and aesthetic quality of urban environment, attracting visitors and tourists.	In Philadelphia, urban green spaces are calculated to yield annually direct savings of $1.1 billion annually, and contributions of $40 million in revenue attracting tourism (Long, 2012).	U	

IMPLANTATION: SOFT/Medium/Hard	AMORTISATION: short term/MEDIUM TERM/long term/no amortisation
Green resting areas can be easily implemented in various environments, like parks, community gardens, neighbourhoods, streets. Green resting areas must offer places for relaxation and passive recreation (benches and other urban equipment) and can also offer opportunities for active recreation (for example outdoor fitness equipment and playground equipment).	Green resting areas get the recovery of the investment between the 5 and the 10 years.

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Climate-smart greenhouses

Urban farming

TECHNICAL DESCRIPTION

Climate-smart greenhouse can be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change. Climate smart soil and agriculture will be practice in a greenhouse and on field together.

Critical agricultural production will be produced under changed climate condition in future. Considering these condition, most of the critical agricultural products will be produce in greenhouses instead of using fields. Therefore, the greenhouses must have some spatial construction that use less energy that produced by dam or other sources. Because water in reservoirs will be used for drinking and if possible for irrigation. We need to hold water in greenhouses as liquid or gas formed. For this proposes spatial roof design will be planned for reuse water from gas to liquid forms.

Green houses will be including several sections inside. One part of them will be used for illuminating desertification and soil degradation. Another part will use for plants productions.

The area in the greenhouse needs to be used effectively for agricultural production. We will design spatial platforms for horizontal plantation. One of them is a stabile horizontal platform that has seven or eight seeding shelves. The other horizontal platform will be design as several shelves that can be vertically revolving to gain sunlight equally. Agricultural production will be done as hydroponic method (Figure 55).

GRAPHIC DETAIL

Figure 53 Example for a smart greenhouse

Figure 54 Cross-section view for the climate smart greenhouse

Water demand of greenhouses will be obtained from portable distiller to desalinize saline water to fresh water.

Sunlight will use main energy sources for heating and also for lightening. Energy will be produce from both photovoltaic battery and parabolic concave collectors.

Two greenhouses each with 1,000 m2 area will be built to illustrate the effects of climate change on urban and rural green vegetation. The greenhouses also will be use to demonstrate producing agricultural crop continuously under changed climate condition.

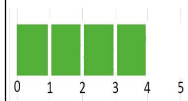
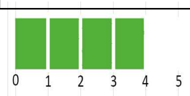
Urban farming/community practices/new social forms of organization will be demonstrated in the climate-smart urban farming precinct in the special project area.

This NBS employs Greenhouses facilities to illustrate the effects of climate change on urban green vegetation used in urban green areas and farming (for both urban and periurban areas). This practice will help to select adequate vegetal species for Urban farming and to establish community practices and new social forms of organization.

High velocity evaporation accelerates movement of salty ground water to soil surface. Field crops production and horticulture will be limited due to salinization and alkalization of soils. Producing some agricultural crops will be demonstrated on salty soils using spatial field design. Dibbling process will be done on high ridge (around 70 cm from soil surface level). The ridges will be placed on a pebbly layer with a thickness of 20 cm for disturbing capillarity and prevent from salty ground water (Fig.56).

Figure 55 Vertical platforms for agricultural production

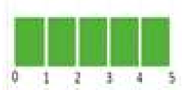
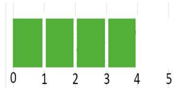
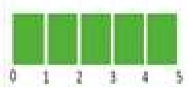
Figure 56 Layers to prevent soil from salty ground water

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Climate change mitigation & adaptation	It will benefit from nearby peri-urban agricultural areas that give farmers to better production planning and implementation abilities. The high used of coal in Izmir has a significant negative effect on local air quality.	Even a 1% decrease in coal household coal use has the potential to decrease by almost 500t/year CO_2 emission and it will improve urban air quality.	S	
Water Management	Reducing irrigation water requirement.	In 2,000 m^2 greenhouse area water savings from water-resistant plants will be 5 - 7.5t/year.	S	

IMPLANTATION: soft/<u>MEDIUM</u>/Hard This NBS creates some modifications in the environment so there are some disadvantages of removing it in the future.	**AMORTISATION:** short term/<u>MEDIUM TERM</u>/long term/no amortisation The period of recovery of the initial economic investment of the NBS is between 10 and 20 years.

Urban orchard		Urban farming.

TECHNICAL DESCRIPTION	GRAPHIC DETAIL
Small plots will be used as cultivation area, making the management easier and using drip irrigation systems. The orientation will be North-South, in a flat cultivated surface or with a gentle slope in order to help the water evacuation. This water could be reused for irrigation proposes. The plots can be delimited with bricks, wood or not and other kind of small and natural fences; and filled with compost, peat, topsoil. The exploitation of these agricultural surfaces can be carried out by families with shortage of resources, neighbourhood associations, unemployed or retired people, which will have technical support from the very beginning from agronomical specialist (it takes part of the educational activities of the urban orchard). It is considered a social/community space where people and families can obtain profit from nature (healthy vegetables cultivated by themselves with traditional techniques, enjoy the calm and beauty of green and natural areas improving their wellbeing, etc.) Different plants grow in these plots: Vegetables for food, companion planting as natural pest controller and attract pollinators, fruit trees, etc. This kind of urban agricultural activities can include sustainable energy systems as the combination with solar panels to the pump for irrigation system.	  Figure 57 Example of Urban Orchards

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Green space management	Urban orchards increase green areas and contribute to create new urban ecosystems. Different plants grow in these plots: fruit trees, Vegetables for food, companion planting as natural pest controller and attract pollinators.	Cities are in continuing expansion. Due to that cities have many empty plots which disfigure neighbourhoods creating slams and giving unsanitary problems. In addition, a large number of urban gardens imply a high maintenance costs and a high water consumption. Therefore, the best option is to alternate social gardens with public spaces.	U/S	
Urban regeneration	Reduce pollution, take up carbon dioxide and produce oxygen. Also, this action contributes to regenerate the aged biodiversity in urban spaces.	Convert brownfield and degraded areas to green areas in urban regeneration projects (Mathey et al., 2015). Vegetable gardens have many benefits in the city and in the citizenship. It makes the cities more resilient, favouring local consumption and the citizens become less stressed and healthier. (Detroitagriculture.net)	U	
Potential of economic opportunities and green jobs	Vegetable gardens have been always considered as a source of basic food and economic aid, particularly on wars and periods of economic recession. (Manual práctico del huerto ecológico, Mariano Bueno). Urban orchard, as means of good supplier, can provide new business models, new economic opportunities and green jobs	Increase property value, household production of fruit and vegetables reduces their food bills, and when growers earn a living from sales. FAO	U	

IMPLANTATION: Soft/MEDIUM/Hard	AMORTISATION: SHORT TERM/Medium term/long term/no amortisation
The NBS creates some modifications in the environment.	The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

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- Detroitagriculture.net

Community composting

Urban farming.

TECHNICAL DESCRIPTION	GRAPHIC DETAIL

TECHNICAL DESCRIPTION

In order to develop an optimal composting process, it is very important that the raw materials are suitable for composting and there should have a correct proportion in the mixture of different structures and type of fibres, size of particles, adequate percentage of water, natural ferments, etc. In addition, the volume and aeration are decisive parameters for the correct formation of the compost.

The minimum volume should be a $1m^2$. The dimensions of the composter should be of minimum 50 cm and maximum 150 cm for side, and a maximum height of 160 cm. The pH must be maintained between 6 and 7; and the temperature also should be maintained between 35 and 65 ºC. The composting time depends on many factors and it can take from 1 to 6 months.

The composter can be made of different materials: recycled pallets, wooden box, waste bins, plastic containers ...

To elaborate compost is necessary:

- Vegetable materials, Waste from cleaning grain, Crop residues...
- Water (humidity)
- Air: a good oxygenation is needed

Regarding the composting methods, four ways of composting have been identified

GRAPHIC DETAIL

Figure 58 Example of community composting

Figure 59 Composting set in Valladolid.

=> **Vermicomposting**: Red worms in bins feed on food scraps, yard trimmings, and other organic matter to create compost.

=> **Onsite composting**: small amounts of wasted food can compost onsite.

=> **Pile composting**: In aerated static pile composting, organic waste mixed in a large pile. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added so that air can pass from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Air blowers might be activated by a timer or temperature sensors.

=> **House and community composting (HCC):** In-vessel composting can process large amounts of waste without taking up as much space as the windrow method and it can accommodate virtually any type of organic waste. This allows good control of the environmental conditions such as temperature, moisture, and airflow.

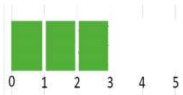
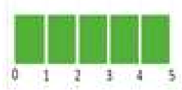
https://www.epa.gov/sustainable-management-food/types-composting-and-understanding-process#vermi

- This NBS is perfect to be implemented in urban orchards and livestock, since there are direct synergies: Urban orchards provide organic waste to feed composters
- Chickens clean the compost of weeds, rodents and insects
- The compost helps to warm the domestic animals and feed the wildlife of birds.

Figure 61 Different bins for composting.

Figure 60 Vermicomposting.

Figure 62 Composting process is helped by chickens.

Challenge	Description	Experience / Study	Challenge Scale	Valuation
Urban regeneration	Reducing waste , sustainable waste treatment	The organic fraction is the largest single type of municipal waste generated per inhabitant, at 35-45% depending on the area.	M/U/S/B	
Potential of economic opportunities and green jobs	Reducing house waste and getting an economic organic fertilizer for orchards and gardens. These activities can provide new economic opportunities and green jobs.	116,443 tonnes of organic bio-wastes were collected in 2015, in the Metropolitan area of Barcelona, which equates to 72.5 kg per inhabitant and per year, or about 200g per day, 19,000 tons of compost were generated in 2015. In Galicia, the waste management system has created 150 new jobs directly related to waste collection and treatment.	M/U/S/B	

IMPLANTATION: Soft/**MEDIUM**/Hard This NBS creates some modifications in the environment and it NBS is directly related to educational and awareness activities.	**AMORTISATION:** **SHORT TERM**/Medium term/long term/no amortisation The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

REFERENCES:

- https://zerowasteeurope.eu/downloads/separate-collection-the-path-to-composting/
- https://www.epa.gov/sustainable-management-food/types-composting-and-understanding-process#vermi
- Graphic detail: https://www.familyhandyman.com/garden/composting-tips/view-all/
- Image 36: Vermont compost company – Pat Foreman

Small-scale urban livestock

Urban farming.

TECHNICAL DESCRIPTION

This action has mainly a didactic and recreational purposes. This NBs aims to promote the urban farming activities among special groups of population (children, disability people, elderly population, drugs rehabilitation, etc.).

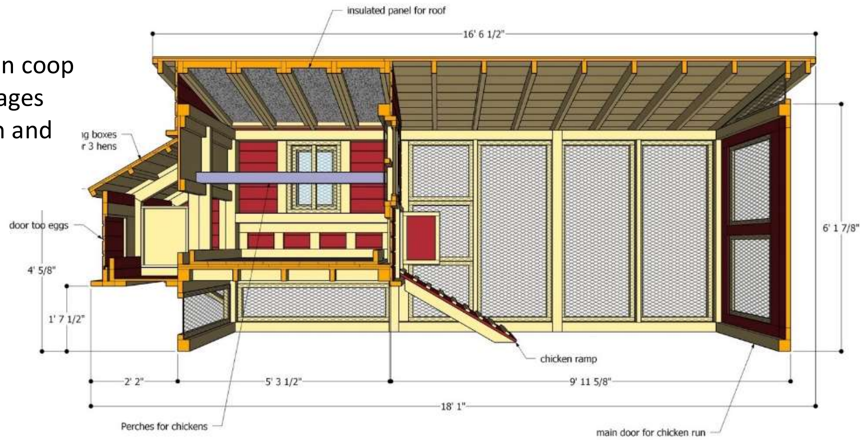
In the case of poultry houses, the breeding and feeding can be done simultaneously to composting. It provides animals with heat and food and hens eliminates weeds, rodents and insects from composting, improving their quality.

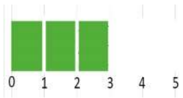
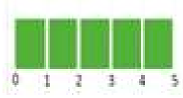
The livestock must be built according to the ordinance for animal welfare.

The livestock housing should be built of wood to ensure the insulation, ventilation, lighting, positioning, nesting, perches, waste collection and protection from the elements and other predators.

GRAPHIC DETAIL

Figure 63 Example of chicken coop plans construction, rabbit cages and aquaponics system (fish and vegetables production)



Challenge	Description	Experience / Study	Challenge Scale	Valuation
Urban regeneration	Many cities and municipalities are changing their ordinances to allow people to keep poultry. (University of Arkansas)	The breeding of animals for self-consumption fosters in the target population good agricultural practices, productive diversification, food security and sovereignty, the application of clean technologies for the protection of the environment for the benefit of human health. (Source: CORDES's annual memory)	M/U/S/B	
Potential of economic opportunities and green jobs	This NBS help to get basic food and economic aid.	Almost 18 billion birds are raised each year in the world and produce more than 22 million tons of manure. Poultry manure is rich in nitrogen and phosphorous .(Agribusiness handbook, Poultry, meat & eggs, FAO, 2010)	U	

IMPLANTATION: <u>SOFT</u>/Medium/Hard	**AMORTISATION: <u>SHORT TERM</u>/Medium term/long term/no amortization**
The NBS doesn't create important modifications in the environment. This NBS is directly related to educational and awareness activities.	The period of recovery of the initial economic investment of the NBS is between 0 and 10 years.

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  http://www.homegardendesignplan.com/

4 Review of Concepts, Evidence, and Use associated with Nature Based Solutions

This section reviews the academic literature to understand the state of the current evidence for the use of nature based solutions, how they fit with other types of urban interventions, and how they fit within existing political landscapes and policy debates.

4.1 Nature vs. technological investment vs. grey/built infrastructure

One of the key debates regarding the use of NBS is its focus. Should NBS mimic or represent only natural systems and practices or is there scope to integrate a more technological approach to their use in practice? Moreover, questions arise focussing on where NBS should be situated in the range of environment and landscape practices currently being used to shape urban development (e.g. GI, ecosystem services, biomimicry, hard and soft engineering practices), and how this influences the choices being made by built environment specialists (Pontee et al., 2016). This is a crucial debate for NBS, as Nesshöver et al. (2016) promote NBS as a direct challenge to existing grey infrastructure practices and argue that NBS are needed to promote a transition to a more socio-economic and ecological approach to urban management; Liquete et al. (2016) consider NBS as a companion and not a replacement for engineered solutions.

A key aspect of the debates supporting NBS has been the subtle shift in emphasis that places 'nature' at the centre of development debates. This has extended the discussions of human-environmental interactions inherent in green infrastructure planning, a major departure from the broader policy/practice evaluations proposed in the more generic 'green space' literature (Albert & Von Haaren, 2014; Hansen & Pauleit, 2014). The NBS literature concentrates on the inclusion of 'nature' in its widest sense in all development, and promotes the ecological value of NBS as of equal importance to socio-cultural and economic benefits (Kabisch et al., 2016). This has shifted the framing of landscape planning as although green infrastructure was the most recent (and widely accepted) articulation of green/landscape debates it emphasised the broader links between people, place, policy and the landscape, and not a primary nature-centric form of investment (Mell, 2016; Eggermont et al., 2015; Hansen & Pauleit, 2014). Green infrastructure planning therefore promotes a human-environmental paradigm for urban development that locates nature within the broader discussion of development (Austin, 2014). NBS differs from this approach as it attempts to moves development forward positioning 'nature' as the central aspect of urban growth. This does not necessarily undermine the need to consider the social and economic benefits of non-NBS but actively promotes nature as a key development principle. Moreover, within the literature NBS they debate the ecological focus that development should take extending the rationale for the use of the key principles proposed in green infrastructure planning, namely connectivity, accessibility and multi-functionality (Kabisch et al., 2016; Sinnett, Smith, & Burgess, 2015).

Although the principles of green space planning, greenways, ecosystem services and green infrastructure remain central to the promotion of NBS, they do not form the central tenants of its use (Cohen-Shacham et al., 2016). This can be considered as a significant departure from the literature but provides opportunities for a broader acceptance of ecologically focussed planning in Europe, as concepts such as green infrastructure are not universally used. For example, Germany has retained its use of “green space planning” terminology in many regions despite the ubiquity of green infrastructure in planning discussions (Kabisch & Haase, 2014; Mell et al., 2017); whilst in Italy urban woodlands/forestry is a more prominent form of landscape investment (Gasparella et al., 2017; Sanesi et al., 2017). However, in locations where green space planning dominate, such as in Germany, the proposal for nature to be the central characteristic of development may be accepted, as it maps more effectively onto existing green space practices. Therefore, despite the perceived need to reconsider or at least align the terminology used to support NBS there is scope to align the key principles of existing green space planning practices with the definitions of NBS proposed in the literature. The EKLIPSE framework (Raymond et al., 2017) and the wider pan-European Horizon 2020 portfolio may therefore act as a litmus test to assess whether NBS can be considered as being universally accepted.

A key aspect of this process is the presentation of NBS as a complementary rather than transformative approach to urban development. Partially, this reflects the scope of investment opportunities associated with NBS but also supports Fan and colleague’s (2017) proposal that NBS are a more responsive form of development that can address the climatic, physical and socio-economic problems associated with urban development. Thus, NBS are viewed as being more adaptive to change than traditional investment practices, a view also shared by Eggermont et al. (2015). Fink (2016) also argues that NBS support a developing equilibrium between people, technology, the environment and policy to achieve a more sustainable balance of meeting social needs, supporting ecological systems and economic growth within urban areas. NBS therefore extend existing ecological thinking to promote stronger links between people and the physical landscape using ‘nature’ as the conduit for this process. However, Fink (2016) proposes that in addition to natural resource management that “green technology” in the form of green walls, roofs and ecologically sensitive buildings, can play a key role in this process as it utilises different aspects of NBS to deliver benefits.

NBS also sit within wider discussions about the interactions between socio-economic and ecological systems, and approaches for managing such interactions in a more comprehensive way. Eggermont et al. (2015) contribute to this conversation, discussing how biodiversity and human interactions with nature need to be placed at the centre of the current and future urban development debates. They identify NBS as a continuum of approaches to investment, reflected by the URBAN GreenUP NBS catalogue, that complement engineered solutions but importantly promote the use of ecological systems thinking as the basic principle of development. Although this leads to a more pluralistic approach to development it should also ensure that environmental considerations become located in all future urban development conservations. NBS therefore is not separate from water and engineered solutions, but a way of complementing these practices from a more ecological perspective (Nesshöver et al., 2016). Moreover, van Wesenbeeck et al. (2014) state that NBS is one of the family of options among a broader range of solutions to urban development, not the only one. However, they also discuss how NBS aid urban adaptation by providing choice for planners, developers and architects within nature/technology/built infrastructure debates and can be used to reverse some of the cost, maintenance and delivery issues associated with engineered solutions such as channelization or hardscaping of urban areas. Consequently, some have suggested that NBS should not be used to "solve" problems, but to promote greater interactivity between people/nature to support the development of resilient and sustainable systems (Scott et al., 2016). This, as argued by Connop et al. (2016), is context driven; and although we can identify practices that can be utilised in alternative urban and climatic locations, NBS should reflect the physical and socio-economic needs of a location.

4.2 Politics of investment in NBS: finance, societal use and inclusion of urban nature in policy

To mainstream the use of NBS in practice requires a transition from academic debate to the promotion and acceptance by urban and environmental planners to generate broader support from decision-makers and political leaders. This includes proposals for the inclusion of robust arguments regarding the economic viability of NBS, their value to society and the business community, and the role they can play in addressing the key urban issues of the 21st century, e.g. climate change, biodiversity loss, water management, and human health and well-being. This requires a leveraging of multiple perspectives linked to the political agenda of a specific location, which Nesshöver et al. (2016) argue should reflect the complexities and interactions of social, economic and ecological variables. This ensures the options for NBS investment are context-specific, and takes advantage of their flexibility as a tool for managing cities in an era of rapid social and environmental change.

Such times call for significant restructuring of how cities are managed, with Maes & Jacobs (2017) proposing a set of objectives that urban areas should deliver in terms of the evolving understanding socio-economic and ecological value associated with NBS and propose the integration of a comprehensive ecological systems thinking approach to future city management. Within their discussion NBS are proposed as providing leverage for planners and environmental advocates to advance truly 'ecological' forms of investment. The uptake of such practices is though predicated on a wider awareness of the fact that NBS can more effectively deliver economic returns, societal benefits, and ecological solutions in a cost-effective way (Kabisch et al., 2016). For this to occur there is a need to balance the agendas of diverse development, environmental and user groups, which requires greater engagement from decision-makers in the process from the inception to implementation. While transforming the way cities are managed may be the ultimate goal, we should see successful change as an incremental increase in the use of NBS to promote an evidence base for the transition from 'grey' or engineered solutions to ecologically focussed options (Maes & Jacobs, 2017). Progress in this areas can, however, be undermined where political agendas are focused on more traditional solutions, where a lack of reliable (and useable) data exists or where awareness of alternative investment approaches stifle innovative approaches to solving social and ecological challenges (Eggermont et al., 2015).

In addition to greater engagement of stakeholders to facilitate the use of NBS in urban development, there has also been a significant discussion reflecting the need to communicate the benefits of NBS effectively to all stakeholders to generate social acceptance for their use. A substantial proportion of this literature focuses on communicating benefits to gain a social licence for using NBS, rather than empowerment of communities to drive the NBS agenda. Within this context Liquete et al. (2016) note that advocates need to be careful in how the benefits of investment in NBS are communicated, as the links between socio-economic and ecological value need to be emphasised, especially if there is uncertainty in how NBS can address existing sustainability issues. In addition, Bennett, Cassin, & Carroll (2016) discuss how the successful communication of the benefits associated with NBS can help bridge disciplinary and socio-political gaps in the knowledge of lay people to ensure NBS gain leverage within policy/practice and public debates. They go on to argue that this does not require a wholesale shift in thinking from only utilising engineered solutions to solely those that are rooted in nature, but alternatively facilitates a debate between built environment and nature specialists about how best to integrate NBS into development and management options. Partly, this reflects the discussion presented by Raymond et al. (2017), who examine the ways in which NBS have been developed as a response to changing societal understanding and uses of the landscape. This, they conclude, established a critical need to rethink how 'nature' is valued in urban areas by experts, politicians and the public. They, like Bennett, Cassin, & Carroll (2016) and Kabisch et al. (2016) view NBS as a bridge between the positives of engineered forms of urban landscapes, i.e. its structural integrity, and the nature- sensitive forms of environmental management that landscape specialists see in NBS.

However, NBS potentially have negative political ramifications. If they are not developed and managed effectively their ecological systems could fail and the costs of replacement could be seen as being a prohibitive misuse of public/private funds (Raymond et al., 2017). It can be argued, however, that even where NBS may not be 100% successfully implemented, they promote greater equity and access to nature in urban areas by replacing the barriers created by physical engineered solutions (Scott et al., 2016). Moreover, as GI and public green spaces can be seen to facilitate multiple uses, access points and activities simultaneously they can be a more cost-effective way to moderate the exclusionary character of existing infrastructure (Mell, 2016). Furthermore, Vujcic et al. (2017) argue that NBS provide a cost-effective option to address issues associated with vulnerable populations, such as climate change or flooding without being too expensive. Thus, NBS can be thought of as providing a basis for a cost effective co-development of green and grey infrastructure that includes the technical aspects of existing development practices but which are aligned with more ecologically focussed management techniques.

4.3 Cost-benefits of NBS compared to grey/built infrastructure

In addition to generating a political acceptance of NBS as an effective way of delivering socio-economic and ecological benefits across urban areas, there is also a further need to clarify the added economic value that investments in environmental resources can make. In Fan et al.'s

(2017) discussion of NBS, they propose that the responsive nature of ecological systems provides an essential form of landscape protection that is responsive to changes witnessed within the environmental and built structures of urban areas. This is essential in areas where climate change mitigation/adaptation needs are becoming increasingly embedded within planning policy and practice. For Mediterranean countries these discussions are increasingly acute as drought, heat waves and flash flooding are being witnessed more frequently (Iglesias et al., 2007). Vujcic et al. (2017) discussed this, outlining how NBS could act to relive stress and mental fatigue, thus increasing the productiveness of people through interactions with NBS resources. It is also interesting to note that Bennett, Cassin, & Carroll (2016) considered NBS to be a trade-off between the production of sustainable urban spaces, the provision of socio-economic amenities and on-going ecological protection. NBS should therefore be thought of as playing a several alternatives yet complementary roles in urban management.

NBS can therefore be used as leverage to improve the use of nature in cities by highlighting the cost reductions in to primary health care, improvements in personal and communal well-being and energy savings associated with building management systems utilising NBS to mitigate climate change. The lower cost of implementation and maintenance of NBS can arguably make them a preferential delivery option compared to traditional forms of grey infrastructure investment (van Wesenbeeck et al. 2014). This analysis is supported by Keesstra et al. (2018), who outline how NBS are cheaper to develop, manage and repair compared to traditional forms of built infrastructure (or more technological interventions), as nature is viewed as being increasingly adaptive to fluxes in urban and ecological systems (Liquete et al., 2016). Thus, the explicit focus on natural systems provides an economic competiveness to NBS that is not witnessed in other forms of investment. This supports the view presented by Pontee et al. (2016) who argued that NBS are low cost and a 'no regret' form of investment, as they can work with or instead of engineered solutions, and therefore provide options and variability for planners/decision-makers to work with. Moreover, although NBS can be ecologically or technologically-based, they should be both cost-effective and innovative (Nesshöver et al., 2016). Liquete et al. (2016) argued within a similar assessment of NBS that they nurture and enhance existing opportunities for investment in natural capital, promote jobs and the low carbon economy, and offer a more sustainable approach to landscape management. This has helped establish the parameters of NBS within the increasingly monetized urban development environment, placing nature on a comparable level as other infrastructure, as it becomes seen as being 'cost-competitive'. Such a long-term competitiveness is, as Maes & Jacobs (2017) discuss, essential in promoting economic development security and provides key components in the transition to a joint socio-economic and ecological approach to benefits and valuation that can lead to incremental change in policy and practice.

4.4 Management and maintenance issues

Due to the variability of NBS and its implementation, there is a corresponding diversity in how the resources should and can be managed. NBS has been proposed as an adaptive form of management to regulate uncertainty and reverse the negative impacts of previous development (van Wesenbeeck et al. 2014). NBS could enhance the transformative capacity of urban areas to mitigate climatic or social variation, but in most places they will likely be embedded within a portfolio of engineered and alternative ecological management systems, practices and resources to provide nature-centric solutions at different scales (Nesshöver et al. 2016). Both groups of authors noted above agree that NBS can help planners and environmental advocates to respond to uncertainty in urban systems through more adaptive and innovative management of the natural environment. This is best achieved, Nesshöver et al. (2016) suggest, by using NBS as part of a nested or integrated approach to management that makes best use of a range of environmentally focussed development options. This can be achieved if NBS are considered alongside other landscape solutions, such as GI planning (Liquete et al., 2016), as these concepts provide a much larger and established evidence base that can be used to situate NBS within a continually evolving planning system. Therefore, by using NBS in tandem with, for example, ecosystem services approaches landscape managers can consider both as tools for more effective management that can be used in conjunction with the proposed outcomes of an investment simultaneously, enabling maintenance and enhancement of both the quality and quantity of urban nature (Bennett et al., 2016).

There is also a discussion within the NBS literature that argues for a more integrated approach to the inclusion of the social elements of urban landscape discussing how an understanding of society and societal needs is an essential aspect of investment in NBS. This includes the embedding of local knowledge (consonance), environmental education, and increased participation in the governance of urban landscapes, as engagement with these aspects of development provide the context for development, help to ensure the retention of vital 'synusia' species and potentially promote a more long-term engagement with environmental issues (Connop et al., 2016). However, scholars caution against overly optimistic projections of the future use of NBS or other forms of landscape planning (Mell, 2016), as a shift away from grey or engineered approaches to NBS engineering may be a long-term process (Raymond et al., 2017). Thus, if NBS can be positioned as a viable investment option within normative urban development debates, then a much greater awareness of context-specific issues concerning appropriate ecologically and socio-economic issues can be embedded within the investment and management of urban areas. The use of NBS is not though proposed as a panacea for the lack of integration of environmental knowledge in existing urban development practices. Alternatively, their use would enable environmental advocates to engage in a dialogue with decision-makers and, potentially, with a set of investment options that are rigorously evidenced, economically viable and socio-culturally appropriate.

4.5 Functionality: social and ecological

Whilst creating effective approaches to management and generating political support for NBS may be a long-term process, there are the beginnings of debate being formed in the research literature supporting both the functionality and benefits of NBS. NBS are being presented as delivering what Liquete et al. (2016:392) call 'smarter systems', promoting multiple benefits, i.e. what green infrastructure advocates call multi-functionality, 'inspired by, supported by or copied from nature that help societies address a variety of environmental, social and economic challenges in sustainable'. All of which aids the development of well managed and diverse ecosystems that support greater resilience in urban areas. Vujcic et al. (2017) go further and argue that NBS hold a restorative value in urban management discussions as tools to promote ecological and socio-economic benefits through a re-established connection of people with nature. The long-term socio-ecological benefits of this association include improved mental and physical health and well-being, greater social inclusion and economic prosperity. It also promotes a better knowledge of NBS and its role in managing urban systems as 'nature' is located within a 'soft operating space' in terms of urban development and management (Maes & Jacobs, 2017). Therefore, through the rehabilitation of landscape resources based on the increased use and understanding of NBS knowledge of landscape systems and structures can be embedded more effectively within policy and practice (Keesstra et al., 2018).

Multi-functionality is central to advocating for the use of NBS, as it offers a diverse and innovative family of approaches to deliver multiple benefits for society and the environment (Eggermont et al. 2015). Moreover, even where NBS is used to retrofit urban infrastructure they can still be considered to support the performance of multiple functions and deliver a range of benefits, to help rebalance previous regimes and problems caused by built infrastructure (Fink, 2016). Where such investment has taken place, i.e. Italy, Serbia and across Mediterranean climates, we are seeing an increase in societal value placed on nature, indicating that there is a growing visibility and value being attributed to NBS (Keesstra et al., 2018; Liquete et al., 2016; Vujcic et al., 2017). This is visible in the evaluations associated with investment in green infrastructure across Europe related to the Valuing Attractive Landscapes in the Urban Economy (VALUE), Green SURGE, and TURAS greening projects (South Yorkshire Forest Partnership & Sheffield City Council, 2012; Hansen et al., 2017; Connop et al., 2013). These projects employed NBS within constrained urban environments across the Europe Union illustrating the multi-functional benefits that landscape improvements could deliver. This includes the economic value of green space identified in Belgium, Germany and the UK through VALUE (Mell et al., 2016; Wilker & Rusche, 2013)and the increased awareness and use of urban greening in Sweden, Italy, and Portugal (Hansen et al., 2015; Spanò et al., 2015; Spanò et al., 2017). Thorslund et al. (2017) go further suggesting that with the emerging evidence base the value of NBS is becoming increasingly visible, which potentially provides scope for a the baseline position of resource value and policy-making to shift include or focus on NBS. Such impacts have been evidenced for green infrastructure through the Green SURGE project and are emerging via the Town & Country Planning Association lead 'Planning for Environment and Resource efficiency in European Cities and Towns' (PERFECT) project where the uptake of urban nature is being debated within policy and decision-making arenas (https://www.tcpa.org.uk/perfect-project) through a better understanding of the added-value that nature can bring to urban investment and management. This reflects greater flexibility that NBS have in urban development, as the use of the concept is not fixed to historical form of investment (Nesshöver et al., 2016). These assertions are, at this point, based on scant empirical evidence, but looking to the literature on policy learning and institutional change is likely to bring more concrete insights into exactly how NBS might be able to fundamentally change approaches to urban management.

4.6 Types of NBS

As discussed in greater depth in the WP1 Catalogue, NBS can take many forms, each of which provides a range of social, economic and ecological benefits. Within the broader literature focussed on green infrastructure, ecosystem services and green management there is a prominence of categorising what spaces or resources are being debated (cf. Natural England & Landuse Consultants, 2009). Whilst this provides a set of parameters that managers and investors can use to frame their discussions of NBS some commentators have stressed it may not be a necessity for effective management (Mell, 2016; Sinnett et al., 2015). Moreover, any review of the types of spaces/resources under consideration in NBS debates varies depending on geographical location, ecological perspective or socio-political approaches to landscape and urban management (Kabisch et al., 2016). However, to ensure that URBAN GreenUP provides a robust baseline of NBS it must include a reflection on the types of spaces that are being considered within the project. WP1 provides a more in-depth discussion of alternative NBS investments; a review of the literature several key types of NBS can be identified, namely:

1. Water; wetlands; flood prevention; floodplains (Liquete et al., 2016; Maes et al., 2012; Bennett et al., 2016; Keesstra et al., 2018; Thorslund et al., 2017); storm water management (Connop et al., 2016); rain gardens (Connop et al., 2016); SUDS (Connop et al., 2016)
2. Terrestrial resources including forests; sustainable agriculture (Bennett et al., 2016); soil management (Keesstra et al., 2018); rewilding of urban areas (Keesstra et al., 2018); meanwhile and untidy spaces (Connop et al., 2016); trees and hedges as health benefits (Shanahan et al., 2015);
3. Biodiversity and ecologically diverse habitats (Liquete et al., 2016); bio-retention schemes (Panno et al., 2017);
4. Societal-based values; horticulture therapy; forest schools (Vucjic et al., 2017); community gardens (Panno et al., 2017); urban regeneration projects (Panno et al., 2017); decreased UHI (Shanahan et al., 2015);
5. Carbon storage (Maes et al., 2012; Keesstra et al., 2018); biomass storage and sequestration (Shanahan et al., 2015).

This is not an exhaustive list but highlights the variability of NBS that can be used to address urban issues through different terrestrial and water-based mediums. It also illustrates that NBS can be delivered at a number of scales. The WP1 Catalogue provides a more detailed and rigorous analysis of the types of resources or investments that can be considered NBS.

4.7 Complementing NBS with other green space and ecosystem-based practices

As discussed previously, NBS is essentially an umbrella term referring to established practices to provide ecosystem services, the building of natural capital and innovative practices that provide co-benefits beyond those provided by standard practices in urban planning, such as GI and ecosystem-based management (Raymond et al. 2017). It is this alignment with familiar landscape management practices that has helped NBS gain traction in practice. Furthermore, the literature notes that NBS is capable of delivering each of the four categories of ecosystem services: supporting, provisioning, regulating or cultural services, which enables them to link the ecological and social benefits associated with development. Mindful planning and implementation will ensure that NBS contributes to service provision in each of these categories, making them a useful means of providing environmental benefits. At the same time, NBS need to be understood as a tool that reaches beyond ecosystem service approaches because they have the potential to provide co-benefits (e.g. socio-cultural, economic, governance) (Raymond et al. 2017).

Much of the literature on NBS discusses what they can offer above and beyond more familiar ecosystem service approaches. For example, Pontee et al. (2016) identify a range of fully natural and hybrid approaches to NBS in coastal areas, demonstrating that they are often cheaper than standard engineering approaches in providing ecosystem services. This view is supported by Raymond et al. (2017), who propose that NBS provide scope for planners and other nature advocates to move beyond simple discussions of ecosystem services to integrate a more holistic, cost-effective and adaptive form of management in urban areas. Even where they have slightly higher construction costs, such solutions can deliver a much wider range of ecosystem service benefits, although findings of this nature should be generalised with caution, as the wide variability of NBS interventions and diversity of implementation contexts mean costs versus benefits will differ significantly across different areas (Pontee et al. 2016). Other authors, such as Scott et al. (2016), suggest that NBS are a way of operationalising an ecosystem services approach within spatial planning, arguing that the added value of NBS is that they can integrate ecological concerns alongside traditional planning concerns, and in so doing more effectively mitigate human impacts, break down sectoral and spatial barriers in planning, and provide a more comprehensive way to deliver benefits in urban areas. Most authors highlight the ecological dimension of NBS as a pathway to achieving co-benefits for society, and stress that socio-economic and governance dimensions require more focused attention in planning and delivery if NBS are to deliver benefits in these areas.

Meanwhile, other authors argue for highlighting the socio-economic benefits first and foremost, such as Lafortezza & Chen (2016), who frame NBS as a human-centred approach. They argue that NBS can be focussed on ecosystem services but centred on key services provided to people, particularly human health and well-being, to enable advocates to successfully shape public policy. Such an approach could offer longer-term benefits for urban planning. A number of authors including (Maes & Jacobs, 2017) argue this as a way of promoting NBS to facilitate a transition from the use of natural resources without reflection on their socio-economic values to a more explicit reflection on the environmental values that can be embedded within development. Extending this argument NBS can be postulated as a bridge between the increasing understanding of the provisioning, supporting, regulating or cultural services provided by nature and existing built environment practices. Thus, NBS offer planners a portfolio of investment options that can help renature, support and diversify the resource base of an urban area without harming its productivity or value of a landscape using NBS (Bennett et al., 2016).

The fact that NBS should be inspired by, and supported by nature means that they can be a more effective and efficient means of addressing urban challenges. Ideally NBS will be biologically productive and self-organising, thus they can be a more cost effective way of enhancing ecosystem services than GI or hard engineering approaches (Panno et al., 2017). This efficiency is explicitly built into the definition of NBS for Maes and Jacob (2017), who define NBS as way of operationalising ecosystem service approaches specifically with decreased input of non-renewable resources and increased investment in renewable natural processes. By investing in renewable natural processes, NBS can not only be more economically sustainable over the longer term, but can also be a more efficient way of providing benefits. The proposed ecological and socio-economic benefits are, thus, more readily quantifiable than for other approaches to managing urban challenges (Thorslund et al. 2017). A clear demonstration of the wide range of benefits provided by NBS is provided by Connop et al. (2016), who outlines a biodiversity-led approach to urban greening that attends to governance and policy aspects, delivering extensive co-benefits beyond increasing species richness in green space. Their approach attends to both social and environmental needs, and in so doing provides a demonstration of how NBS can offer added value above and beyond traditional GI projects. This includes building urban resilience and adaptive capacity in formal and informal sectors, enhancing policy and scientific learning, overcoming negative public perceptions, and quantifying both costs and benefits. They suggest adopting a social-ecological systems-based approach is integral to the success of NBS if it is to embed a more robust form of ecological knowledge and social needs within policy than is typical for other green space planning approaches.

4.8 Scale of NBS investment

Scale is a significant aspect of the value of NBS. Although a substantial proportion of the research focussed on NBS concentrates on smaller interventions, they have untapped potential as a landscape-scale management tool, as they draw on ecological systems thinking. The potential for scaled investment is discussed by Fan et al. (2017) who argue that multi-scale NBS offer additional options for nature to be used within and across urban areas and boundaries. Within this discuss there are clear links between the framing of NBS and the principles outlined by Hellmund & Smith (2006) and Firehock (2015) and reflects one of the most prominent arguments found in the greenways and green infrastructure literature, which argues for a multi-scale approach to investment and management (cf. Austin, 2014; Benedict & McMahon, 2006). In both literatures, ecological and socio-economic benefits are attached to the linking of resources across landscape and political boundaries, as they then provide accessible and connective resources that promote interaction and use, for example in Atlanta or Stockholm (Andersson et al., 2014; Mell, 2016). In addition, the promotion of a systems approach to landscape management requires planners to understand the ways in which biodiversity, water systems and urban movement shape the use of the landscape (Ahern, 1995; Niemelä, 2014). The diversity of NBS available to planners and NBS advocates provides greater scope for the assessment of a wide range of investment alternatives that can address significant urban challenges and wide-ranging benefits in urban areas, enhancing accessibility and equitably distributing solutions across an urban area. Eggermont et al. (2015) support this view proposing that although NBS provide planners with a suite of investment options that can be used to adapt urban areas to the 'wicked' challenges associated with climate change, whilst they can also be extremely effective at dealing with local environmental issues. Raymond et al. (2017) emphasise the need to implement NBS at multiple scales to upscale the evidence collected from the relatively small-scale (i.e. localised) interventions that have been advocated for to date in NBS conversations. The development of a multi-scalar approach and successful upscaling, they note, will require the creation of a corresponding scientific evidence base that illustrates the links between NBS interventions and the potential socio-economic and ecological benefits they can deliver.

However, there is a need to reflect upon the implicit challenges of implementing NBS as the scale of intervention increases. The creation of multi-actor partnerships is therefore essential as they support, in many locations, a more collaborative process of governance linked to stakeholder engagement that enable them to address challenging implementation issues (Meerow & Newell, 2017; Ryan et al., 2002). While scale should always be aligned with the nature of the urban challenge, large-scale interventions are particularly important as they support broader spatial needs of different ecosystems. For example, Thorslund et al. (2017) argue that the large-scale nature of many environmental challenges, e.g. climate change, land use change, affect landscape scale water management, and lead to calls for large-scale interventions if we are to restore hydrological function and water balance. This view is also proposed in the research of Hellmund & Smith (2006) who examine the role greenways can play in establishing an equilibrium between the protection of environmental systems, the economic cost of management, and the needs of human populations to access natural areas outside of city boundaries. While scientific understanding needs to occur at multiple scales, these authors argue that for important ecological features, large-scale understanding and interventions are essential.

Scale mismatches are, however, common in environmental management, and NBS are no different. Thus, if NBS are to effectively address urban challenges, they need to be implemented at the right scale. Similarly, within the broader discussions proposed by Kabisch et al. (2016) and Eggermont et al. (2015) there is a discussion focussing on the relevance of the 'right' scale for investment in NBS. They examine how working at the appropriate scale is essential if a NBS resource it is to remain functional, and propose that NBS interventions should include knowledge of wider systems thinking, as well as a local understanding of nature to ensure complementarity between approaches. This is reflective of the IUCN literature which discusses how biodiversity and climate change are predominately concerned with a better understanding of the interaction of ecological and built environment systems (Cohen-Shacham et al., 2016). Strategies to address scale mismatches will require an interdisciplinary, systems thinking approach that considers the specific features of the urban challenges to be addressed and feasible options for their resolution. A diagnostic approach to designing NBS interventions, where scale is explicitly considered (c.f. Rijke et al., 2012), can help support a suitably scaled approach to investment in urban nature.

The concept of a 'cascade' is a useful way of understanding the relationship between scale of intervention and outcomes in NBS investment. This is captured in the ecosystem services cascade framework developed by Maes et al. (2012), wherein they demonstrate the link between ecosystem services and human health and well-being through a cascading set of spatially explicit processes. Such an approach points to the value of viewing NBS investment as a cascade, with investment in ecosystem services at larger scales having effects not only at that scale, but all the way down to very local scales, e.g. investment in water quality at a basin-wide scale results in a reduction of local treatment costs and improved health at local scales. Their approach provides a more consistent methodological framework for deciding the spatial distribution of costs and benefits and evaluating the effectiveness of NBS, thus providing a useable tool and knowledge base for making decisions about the 'right' scale of intervention.

Other authors have discussed this cascade, but Keesstra et al. (2018) discuss it in the sense that an individual NBS is unlikely to solve significant challenges like land degradation, but that a cascade of different NBSs at different scales has the potential to address such challenges, build resilience of entire ecosystems, and help countries meet sustainable development goals. While most scale discussions focus on the spatial dimension of ecological systems and human impacts, Xing, Jones, & Donnison (2017) discuss scale in a different way, proposing ways that NBS can be retro-fitted into indoor and outdoor urban design, integrating them from the building scale to the meso-city scale. While they highlight the value of small-scale investments, they argue that such interventions are often ineffective for dealing with the main challenges such as water management, climate change, biodiversity loss, and food production unless combined with other NBS. Green roofs, for example, can effectively deal with rainfall events if implemented across a catchment, but they are unlikely to make a significant impact on water management issues unless combined with other NBS (Xing et al., 2017). Such literature highlights that, while NBS are flexible and scalable, scale matters if they are to provide a measurable impact on the key challenges faced in by urban areas (Benton-Short & Short, 2008; Goode, 2014; Lachmund, 2013).

4.9 Policy environment for NBS

Finally, there is a need to consider the pace at which the policy environment for NBS is changing. With the support of the European Commission and the Horizon 2020 programme NBS are gaining both visibility and traction within policy across the EU. Some authors, such as Fink (2016), have argued that NBS enhance ecosystem services, but also support growing environmental awareness support greener cities and a more environmentally conscious public. This, they suggest, helps to cultivate a greater sense of stewardship and potentially lead to behavioural change. In this sense, Fink views policy as a 'context destabiliser' which provides a window of opportunity to disrupt conventional, 'business as usual' practices, meaning that NBS can lead to bigger policy changes once a crucial threshold (which varies depending on the intervention) is met. The potentially disruptive nature of NBS, and the requirement that interventions be implemented through multi-stakeholder partnerships has led to additional discussions of responsibility for stakeholders to establish who has rights to the landscape, and who should be managing it (Connop et al., 2016; Faehnle et al., 2014). The impetus for implementing NBS in a democratic, collaborative way is bolstered by the arguments of Scott et al. (2016), who argue that NBS should be considered as a public good and one that should be included in urban policy. These authors illustrate how the governance changes required to support NBS can help cities overcome existing silo thinking that act as barriers to effectively addressing urban challenges. The outcome of which is a reduction in vulnerability, e.g. to extreme climate events, increasing urban resilience, and the promotion of socio-ecological multi-functionality and interactivity between people and landscape resources (Beatley, 2000; Ugolini et al., 2015). All of which are key policy mandates in many European cities (European Commission, 2015).

To help facilitate the establishment of NBS within policy there is a need for it to be linked with existing data sets, analysis and practices to ensure that NBS (and other green space management practices) are seen to both complement and extend existing practices (Fan et al., 2017; Meerow & Newell, 2017). However, although we may be witnessing a growing catalogue of NBS projects producing evidence of its socio-economic and ecological benefits there remains a slower pace of change in policy emphasis utilising NBS within national and sub-national policy across the EU (Nesshöver et al., 2016). NBS can, and are though being promoted as a catalyst for investment in some countries such as the UK, Germany and Spain, where investment in urban nature is being linked directly with economic development agendas (Raymond et al., 2017; Vujcic et al., 2017). This process is dependent on an understanding of the benefits of NBS and their inclusion within policy, which continues to vary between locations due to sovereign approaches to land use planning across the European Union (Shwatrz et al., 2014). Thus, an understanding of the existing resources base, geographical differences in the planning policy/practice frameworks (and families), and the scale of interventions being proposed are all important characteristics to consider when attempting to embedded NBS into policy. Raymond et al. (2017) explore this process indicating the need for an effective and appropriate governance framework to be in place to support NBS if they are to be delivered and managed effectively. They argue that in such situations that the benefits that NBS can deliver through innovative design and investment are understood and can be related to existing planning systems.

4.10 Policy learning

If NBSs are to be embedded into policy, planning and management practice, they will need to be accepted not only as new tools, but as a useful perspective and viable pathway for resolving urban challenges. Here there is a great deal of insight to be gained from the policy and institutional literature, particularly that on institutional change and policy learning. To date, much of the policy focussed on NBS has developed through instrumental policy leaning based on experimentation, analysis and reporting (Challies et al., 2017). In many locations, the uptake of NBS thinking has followed the advocacy generated from green space planning, i.e. in Germany, and more recently from green infrastructure planning in many other parts of Europe (Cohen-Shacham et al., 2016; Vujcic et al., 2017). This has followed the normative approach to policy formation based on testing, evidence generation, and consultation with key stakeholders.

While this has linked the NBS evidence base to decision making in partnerships between policy-makers, environmental experts and academics (Kabisch et al., 2016), this type of learning seldom leads to the systemic learning required to mainstream the use of NBS. In the literature, this type of instrumental learning (i.e. learning new facts and perspectives) is most common in policy implementation and planning practice, but it seldom leads to the substantive changes required to deal with challenging social, economic, and environmental issues (cf. Argyris 1993; Pahl-Wostl et al., 2010; Suškevičs et al., 2017). The instrumental learning that has characterised NBS practice to date is known as 'single-loop' learning, but for complex and intractable urban environmental, social, and economic challenges, there is a need to question underlying assumptions of existing policies, programmes, organisations, and practices. This often requires re-evaluation of the philosophy and rationale (e.g. theories of cause and effect) that underpin existing practices. This is known as 'double-loop' learning, which involves reframing the problem, re-thinking goals and interests, and even applying different values (Innes and Booher, 2016). 'Triple-loop' learning goes one step further, and occurs when current assumptions no longer appear to hold. This type of learning is transformative, and it is generally the type required for the significant challenges that face urban areas, like climate change (Gupta 2016). Policy learning of this type is social, as it requires learning not just at an individual level but also across different groups and organisations involved in managing urban areas.

Mainstreaming the use of NBS requires attention to the conditions that support learning and policy change, but thus far the NBS literature has not sufficiently engaged with these bodies of literature. There are many strategies that could inform approaches in both leader and follower cities in URBAN GreenUP and the Horizon 2020 programme more broadly. Several of those conditions are part of the projects already. This includes feedback (e.g. monitoring post intervention) and systems understanding (e.g. baseline monitoring), which are known to be critical facilitators of learning are already occurring. However, self-reflection on (and revision of) management approaches, policies, plans and – perhaps most importantly - underpinning philosophies post-intervention is a critical element for learning neglected in typical project management processes (Clement et al. 2016a). One of the distinct differences between NBS and other approaches to greening cities is that it is problem-oriented, and this orientation is known to more effectively foster learning than more general goal-orientated approaches (Ansell, 2011). Still, the scale of the problems NBS address, both in terms of spatial scale and temporal scales, presents a significant challenge for mainstreaming their use. For example, there is a mismatch between the timescales involved in understanding ecological systems and learning how to solve environmental challenges, yet social and political timescales are more relevant for establishing expectations for what can be achieved. This is one reason that evidence for the efficacy of NBS will never, by itself, lead to their widespread use.

Also relevant is the strong bias towards habit and maintaining the status quo in institutions, which needs to be overcome to integrate new approaches into management and planning, including the innovative use of NBS. Pilot studies demonstrating innovations, as in projects like URBAN GreenUP, can illustrate the added value (economically, socially and ecologically) of investing in NBS. Izmir, Liverpool and Valladolid can be thought of as urban laboratories where NBS experiments are being undertaken, monitored and evaluated to inform further forms of policy (and development). This sort of intentional experimental testing in diverse environments is known to support learning (Clement et al. 2016b), but achieving longer-term change based on this learning in both leading and follower cities requires focused strategies. As noted throughout this paper, NBSs have the advantage of complementing existing approaches, which can make incremental change in the use of NBS within the cities more likely, but achieving larger scale changes across urban areas will require reorienting city governance in a new direction (Clement et al. 2015).

There are a number of practical strategies that are known to facilitate this, including working with “institutional entrepreneurs”. This term refers to individuals, organisations, and their networks that recognise when dominant approaches are not working, and are skilled in the art of achieving change within the constraints of existing institutions (Mintrom and Norman, 2009; Clement et al., 2016a). This form of entrepreneurship is different to that required in business, with a such entrepreneurs needing to be skilled in particular strategies relating to advocacy, discourse, vesting, constructing identities, changing normative associations, constructing shadow networks outside of formal institutions, timing, mimicry, theorising, and educating (Lawrence et al. 2009). This literature is extensive, but looking at it more deeply could help city managers better understand some of the essential (but often neglected) strategies for mainstreaming NBS. Strategies range from the overtly political (advocacy) to subtly introducing change by aligning it with existing practice (mimicry). Identifying skilled institutional entrepreneurs can be challenging because, in most cases, they are not “leaders” in the traditional sense, yet they provide an important form of leadership that can change habits and standard practices within organisations. These types of changes are known to support larger-scale transformations in policy and practice (Ansell 2011; Clement et al., 2015), thus the work of such entrepreneurs behind the scenes is often more important than that of visible political and organisational leaders for achieving the sort of stable, widespread change that can normalise the use of NBS.

4.11 Summary

NBS is an increasingly popular approach for addressing environmental, social, and economic challenges in urban areas, and one where Europe has been leading the way in terms of defining and implementing such interventions (Eggermont et al., 2015). As a result, the EU’s definition of NBS has been widely adopted, and provides a shared understanding and robust basis for what NBS are. Beyond this, there is still debate in the literature about where NBS sit alongside other approaches to urban and environmental planning and management (Kabisch et al., 2016). There is general agreement within the academic, policy-making and practitioner literature that NBS provide ecosystem services, but whether they are an extension of ecosystem service approaches or merely a means to operationalise the concept is still a point of discussion (Cohen-Shacham et al., 2016). Most authors promote NBS as an innovative suite of approaches that are complementary to more conventional ‘hard’ engineered approaches, as well as more traditional greening approaches like GI and ecosystem-based management. A key point of difference is that NBS should be focused on solving urban problems and not just ‘greening’ cities delivering ecosystem services and a range of co-benefits for society, the economy, and governance systems (Panno et al., 2017). There is a great deal of potential for NBS to solve local challenges (e.g. localised flooding) as well as contribute to addressing bigger global challenges (e.g. climate change), but NBS interventions need to be at the appropriate scale and tailored to local contexts.

In most situations, a cascade of NBS approaches, from very small interventions like a green roof to major projects like re-naturing a river, are required to effectively address urban challenges (Thorslund et al., 2017).

The use of NBS may be politically challenging to achieve up front, but the literature on policy learning, participatory governance, and adaptive governance all offer insights into how to mainstream NBS and change the 'business as usual' approach to landscape and urban planning. While the cost of NBS can seem daunting in a time of government austerity, the fact that NBS almost require, by definition, multi-stakeholder partnerships, make them more resilient to government financial circumstances than wholly public-funded interventions (Raymond et al., 2017). Moreover, NBS is usually more cost-effective than hard engineering approaches in the long run, mainly due to lower maintenance costs when NBS are designed to be self-sustaining. The balance between costs and benefits favours NBS because they provide a wider range of benefits for ecological, economic and social systems. The diversity and flexibility of NBS is also a positive, making them a more effective choice for building adaptive capacity and resilience, reducing vulnerability, and providing tailored solutions that incorporate both scientific evidence and community needs.

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