LIFE my building is green

LIFE17 ENV/ES/000088

Application of Nature-Based Solutions for local adaptation of educational and social buildings to Climate Change

Action: A.2. Elaboration of projects for the application of nature-based solutions prototypes in pilot buildings

Deliverables: A.2.1) Elaboration of NBS databases and work matrix

A.2.2) Elaboration of 7 NBS projects

Date: 08/07/2022

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Deliverable: Elaboration of NBS databases and work matrix

Date: **08/07/2022**

Data Project

Project location:	Spain
Project start date:	01/09/2018
Project end date:	31/08/2022
Total budget:	2.854.102 €
EU contribution:	1.697.369 €
(%) of eligible costs:	59,99 %

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1. SUMMARY (ENGLISH)

This document is part of Action A2. "*Drafting of projects for the application of prototypes of natural-based solutions in pilot buildings*" that embodies it in the form of deliverable. For the development of the project, it is essential to carry out a set of preparatory tasks in terms of the collection of existing information and subsequent design and development of innovative natural-based solutions that respond positively to the expected results with the project.

Action A2 are divided into three sub-actions: A2.1 "*Collecting information on natural-based solutions in European and NBS project databases*", A2.2 "*Developing a decision instrument for the selection NBS*" and A2.3 "*Preparation and drafting of projects*".

This document describes the fulfilment of these three sub-actions included in the following chapters. Information on sub-action A2.1 can be found in Chapter 5 on NBS and its attached database. The information regarding sub-action A2.2 is contemplated in chapter 7 on selection criteria. Chapter 8 presents the NBS identified for each pilot building as well as presents the projects and technical information.

Chapter 6 is dedicated to the design and development of prototypes and innovative solutions of natural basis, especially those considered useful for the LIFE project, both at the design level, as well as by innovative application and development, thus complying with the requirements of the project.

2. RESUMEN (ESPAÑOL)

Este documento es parte de la acción A2. "*Redacción de Proyectos para la aplicación de prototipos de soluciones de base natural en edificios piloto*" que lo encarna en forma de entrega. Para el desarrollo del proyecto es esencial llevar a cabo un conjunto de tareas preparatorias en términos de recopilación de información existente y posterior diseño y desarrollo de soluciones innovadoras de base natural que respondan positivamente a los resultados esperados con el proyecto.

La Acción A2 se divide en tres subacciones: A2.1"*Recopilación de información sobre soluciones basadas en el medio natural en proyectos y bases de datos europeas*", A2.2 "*Elaboración de un instrumento de decisión para la selección de NBS*" y A2.3 "*Preparación y redacción de proyectos*".

Este documento describe el cumplimiento de estas tres subacciones incluidas en los capítulos siguientes. La información sobre la subacción A2.1 se puede encontrar en el capítulo 5 sobre NBS y su base de datos adjunta. La información relativa a la subacción A2.2 se contempla en el capítulo 7 sobre los criterios de selección. En el capítulo 8 se presenta el NBS identificado para cada edificio piloto, así como los proyectos y la información técnica.

El capítulo 6 se dedica al diseño y desarrollo de prototipos y soluciones innovadoras de base natural, especialmente las consideradas útiles para el proyecto LIFE, tanto a nivel de diseño, como por la aplicación y desarrollo innovadores, cumpliendo así con los requisitos del proyecto.

3. RESUMO (PORTUGUÊS)

O presente documento enquadra-se na Ação A2. "*Redação de Projetos para a aplicação de protótipos de soluções de base natural nos edifícios piloto*" que a corporiza sob a forma de entregável. Para o desenvolvimento do projeto é fundamental proceder a um conjunto de tarefas preparatórias ao nível da recolha da informação existente e posterior desenho e desenvolvimento de soluções de base natural inovadoras e que respondam positivamente aos resultados esperados com o projeto.

A Ação A2 desdobra-se em três subações: A2.1 "*Recolha de informação sobre soluções de base natural em projetos e bases de dados europeus*", A2.2 "*Elaboração de instrumento de decisão para seleção das NBS adequadas*" e A2.3 "*Elaboração e redação dos projetos*".

Este documento descreve o cumprimento destas três subações inseridas nos seguintes capítulos. A informação referente à subação A2.1 poderá ser encontrada no capítulo 5 sobre as NBS e respetiva base de dados em anexo. A informação referente à subação A2.2 está contemplada no capítulo 7 sobre critérios de seleção. O capítulo 8 apresenta as NBS identificadas para cada edifício piloto assim como apresenta os projetos e a informação técnica.

O capítulo 6 é dedicado ao desenho e desenvolvimento de protótipos e soluções inovadoras de base natural, especialmente as consideradas úteis para o projeto LIFE, quer ao nível do desenho, quer pela aplicação e desenvolvimento inovadores, cumprindo assim com os requisitos do projeto.

4. INTRODUCTION

Brief presentation of the project

The LIFE project "My Building Is Green" is a project developed by an Iberian consortium and funded by the LIFE Spain Program, with the aim of designing, developing and testing innovative nature-based solutions (NBS prototypes), to improve bioclimatic comfort of school buildings in order to improve the well-being of users.

The project gives greater prominence to the public building due to two key factors, firstly with the age of the various public buildings, mostly built before the 80s of the twentieth century and under constructive regulations not demanding in terms of indoor air quality and with few environmental, sustainability and energy efficiency concerns, and secondly due to the population that uses these same buildings, and which is subject to poor air quality indoors and climate discomfort in these buildings.

With these assumptions, the buildings with greater occupation of the most vulnerable age groups, such as children and the elderly, which often use educational, medical, and social assistance buildings, such schools, health centres and nursing homes. For My Building Is Green, and according to the responsibility and attributions of local partners, it was considered to act on school buildings as a way to seek to improve the bioclimatic comfort of children and other users (teachers and employees) with a view to increasing the resilience of these buildings and instilling concerns about the public building's adaptation to climate change.

In order to achieve this objective and with a view to the proposal and implementation of innovative solutions that allow schools to adapt to climate change, the project has 5 institutional partners, 2 of a technological nature, the *Consejo Superior de Investigaciones Científicas* CSIC and CARTIF, CSIC, which intervenes with the collaboration of two entities, Real Jardín Botánico, RJB and *Instituto de Ciencias de la Construcción Eduardo Torroja*, IETcc, and 3 local partners.

Technology partners have the task of designing and proposing NBS prototypes in collaboration with local partners (municipalities and regional authorities), with the responsibility and the task to collaborate in identifying the pilot schools involved in the project and ensuring implementation of prototypes in the selected buildings.

The local partners, Comunidade Intermunicipal do Alentejo Central, CIMAC, Diputación de Badajoz, DIPBA and Município do Porto, MP, using the criteria for selecting buildings and implementing action *A1. Collection of information and design of the technical criteria for selection and pilot buildings, have* selected the respective schools that will serve as pilot buildings to the mBiG. The following schools were identified whose characterization will be addressed later in this document. **CIMAC** selected a building in the Municipality of Évora, the Escola Básica do 1º Ciclo Horta das Figueiras (**EB1 Horta das Figueiras**), **DIPBA**, selected Colegio de Educación Infantil y Primaria Gabriela Mistral (**CEIP Gabriela Mistral**) in the Municipality of Solana de los Barros and the Municipality of **Porto** selected the Escola

Básica do 1º Ciclo do Falcão (**EB1 Falcão**), located in the eastern zone of the city, an area with more social and economic problems. The selection criteria and the weighting of the universe of schools considered by the three partners is included in the documents related to sub-actions *A1.1. Design and selection of technical criteria*, *A1.2. Inventory and selection of buildings* and *A.1.3. Administrative authorization* for intervention in the selected building (pilot).

Climate context

Climate change is consensually recognized as one of the great challenges facing humanity today. The high emission of greenhouse gases (much of it results from human activities such as cattle production and the combustion of fossil fuels) has contributed to a change in the overall composition of the atmosphere. This change affects the normal functioning of the terrestrial system (e.g. marine currents that are the engine of the entire earth's climate), which has profound implications for the climate, affecting different regions of the world in different ways.

Recent climate change has had widespread impacts on human and natural systems. In addition, implementing measures that increase resilience and enable sustainable development can accelerate climate change adaptation processes. At European level some of the main expected impacts have been identified, which are related to increased phenomena of intense precipitation, floods and / or prolonged droughts, increased frequency and duration of heat and / or cold waves and consequent island effect (heat and cold), coastal erosion and coastal overtopping.

The Fifth IPCC Report (Intergovernmental Panel on Climate Change) identifies that the vast majority of the risks and expected impacts will be concentrated in urban areas, which puts cities on the front line of those most affected by the expected vulnerabilities. Cities concentrate most of the built heritage and public services, which shows the need for local authorities to promote urban adaptation also from the point of view of the building, instilling appropriate building criteria and improving conditions of existing buildings.

To cope with these scenarios, European cities need to create conditions to improve bioclimatic comfort in public and private buildings. To help cities facing the multiple challenges expected in the coming decades, My Building Is Green focuses on improving building conditions by seeking to respond positively to climate change.

Expected results

In practical terms, mBiG will act directly on 3 school buildings (pilot schools) located within the geographical areas of local partners, with the implementation of nature-based solutions in specific parts of the building, such as rooftop, façade, and exterior space, with a view to improving indoor air quality, bioclimatic comfort and soil permeabilization, as tools for adapting buildings to climate change.

The development of the project will enable the achievement of a set of environmental, social, economic, governance and mobilization results in the face of improving the adaptation of cities to climate change. Some effects will be difficult to quantify and measure, but the following results are expected to be achieved with the project:

- Improve the well-being and thermal comfort of 1000 citizens;
- Reduce 27 ton CO_2 emissions per year;
- Reduce the emission of 144 kg of NOx per year;
- Collect 2700 m^3 of rainwater for reuse;
- Reduce 50% of water consumption for irrigation in each building;
- Increase by 5000 m^2 the sustainable green area in each building;
- Save near 1000€ per year in energy costs;
- Empower citizens to the use of NBS as a way to adapt to climate change;
- Aware the population to climate change through project dissemination actions;
- Mobilizing students and teachers on the issue of climate change;
- Produce good practice manuals for the application of NBS as a tool for adapting to climate change.

Document structure

This document aims to comprise action *A2. Drafting of projects for the application of nature-based prototypes in pilot buildings,* so it presents the compilation of some of the available nature-based solutions (sub-action A2.1.) and establishes guidelines for their selection and application as building adaptation tools (sub-action A2.2).

The document is structured according to the phases of the project and in order to be used as an instrument for the selection and application of some of the solutions described in buildings, so that, although it specifically addresses the pilot cases of the project, presents a description of a wide range of NBS as well as some technical criteria to assist in the selection of the solutions best suited to the typology of other buildings.

It is intended that this document becomes a practical guide for the selection and application of NBS for the adaptation of buildings to climate change, seeking to offer multiple solutions and opportunities appropriate to the various types of construction, to the different climates and the different vulnerabilities expected.

5. NATURE BASED SOLUTIONS

NBS presentation

In an increasingly urbanized world, nature – rich in intelligent and efficient solutions to the challenges of cities – has been forgotten in the design and management of urban spaces. Many of the green (vegetation) and blue (water) surfaces have been transformed over time into grey (impermeable) surfaces, with serious implications for the quality of life of the inhabitants and increasing environmental risks.

Currently, some of this natural engineering has been trying to rescue some of this natural engineering for cities in order to ensure sustainable, cost-effective, multifunctional, and flexible solutions to various environmental challenges. This movement recognizes that it is more advantageous – ecologically and economically – to work alongside nature and nature than against it.

The European Union developed the EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities, which aims to position the EU as leader in 'Innovating with nature' for more sustainable and resilient societies. The EU defines nature-based solutions "as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."

The main goals of the EU R&I policy agenda for Nature-Based Solutions and Re-Naturing Cities are to, enhance the framework conditions for nature-based solutions at EU policy level; develop a European Research and Innovation Community for nature-based solutions; provide the evidence and knowledge base for nature-based solutions; advance the development, uptake and upscale of innovative nature-based solutions and mainstream NBS within the international R&I agenda.

In order to achieve the EU goals on NBS and improve urban territories, many cities have been developing and supporting projects for the implementation of natural-based solutions with the intuition of promoting biodiversity, respecting the natural water cycle, increasing the capacity of carbon storage, enhance the soils, reduce energy consumption, making the city more pleasant and more comfortable for residents and visitors.

The project My Building is Green aims to strengthen and support cities, and EU within the shift of the old urban paradigm based on grey surfaces, and works to contribute with specific and innovative solutions with nature-based (more efficient, more sustainable, greener), to the adaptation of buildings improve the bioclimatic comfort and quality of life of users, but also act (each school), as an example, inspiration and a starting point for shift and adapt to climate change in cities.

NBS Inventory

According to the sub-action A2.1 Recompilation of information after review of European NBS databases, was made a brief survey of the NBS available in the various databases and catalogues of other European projects in order to compile the multiple nature-based solutions and best practices already developed and which are already being successfully implemented, in some of them.

For this compilation, were consulted the databases of projects and entities such as OPPLA[1], Nature4Cities[2], Clever Cities[3], Urban GreenUP[4], URBiNAT[5], Green Surge[6], UNaLab[7], ThinkNature[8], GrowGreen[9], EKLIPSE[10], LIFE REUSING POSIDONIA[11], BiodivERsA[12], NATURVATION[13], ProGIreg[14], Connecting Nature[15], Climate-ADAPT[16], Green Roofs[17], LandLab[18].

From the different databases consulted, those nature-based solutions that best fit the objectives of the My Building is Green project were identified and listed, which led to the production of an excel document (Annex 1) that summarizes a set of parameters that allows to draw comparisons between the various solutions.

[1] https://oppla.eu/
[2] https://www.nature4cities.eu/
[3] https://clevercities.eu/
[4] https://www.urbangreenup.eu/
[5] https://urbinat.eu/
[6] https://greensurge.eu/
[7] https://unalab.eu/
[8] https://www.think-nature.eu/
[9] http://growgreenproject.eu/
[10] https://www.eklipse-mechanism.eu/
[11] http://reusingposidonia.com/
[12] https://www.biodiversa.org/
[13] https://naturvation.eu/
[14] https://progireg.eu/
[15] https://connectingnature.eu/
[16] https://climate-adapt.eea.europa.eu/
[17] https://greenroofs.org/
[18] https://www.landlab.pt/

The following table presents and describes some of the parameters used in the NBS inventory:

Table 1. NBS inventory parameters description and filling options.

Parameter	Description	Fill options
NBS designation	NBS name	n.a.
Short description	Brief resume and description on the NBS. Some specific info on function, materials, and others.	n.a.
NBS category	Identify the main type of the NBS use, according to the options. Choose the best category that defines the NBS.	I. Better use of protected/natural ecosystems II. NBS for sustainability and multifunctionality of managed ecosystems III. Design and management of new ecosystems
Intervention Zone	Identify the main area of aplication	Roof Façade Interior Exterior (playground or outdoor) Multiple zones
Climate Change response	Identify the expected results of the NBS accoording to climate change	Carbon sequestration Local climate regulation Water purification Air quality regulation Erosion prevention Flood protection Maintaining populations and habitats Soil formation and composition Water management
Advantages and / or Benefits (social, economic and environmental)	Identify the advantages and / or benefits expected from the NBS application	Social: Aesthetic improvement; Wellbeing; Social cohesion and social inclusion; Offer public space and accessibility; Education and awareness raising.
		Economic: Savings resources; Increased value of the space or area; Touristic development; Increased regional value; Improve water management;

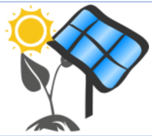
Parameter	Description	Fill options
		Sustainable urban drainage; Food production; Savings in raw material; Circular economy; Other benefits
		Environmental: Carbon sequestration; Reduction of air pollution; Mitigation of urban heat island; Preventing and recovering from pluvial flooding; Improved landscape and greenspace connectivity; Noise abatement; Support biodiversity, offer space for declining species; Pollinators for food security and biodiversity; Flood risk control, storm-water management; Drinking water and water resources; Soil formation and composition
Disadvantages and / or Limitations	Identify which disavantages or limitatios better suits the NBS	Low innovation Low cost-effectiveness (durability and/or sustainability) Low performance (social, economic, and/or environmental) Uncertainty of performance results Space requirements Accessibility requirements
Performance and efficiency (social, economic, and environmental)	Graduate the level of performance and / or efficiency of each NBS related with each area, social, economic and environmental.	Low Medium High
Application scale	Identify NBS's influencing area, according to the options.	Building / Infrastructure Playground or plot level Block level City level
Innovation	Graduate the level of innovation of the NBS.	Low Medium High
Best practices	Identify the project / entity were the NBS are being apllied	n.a.
Additional info / link	Describe additional information about the NBS and the link of the source.	n.a.

As referred, the Annex 1 presents the full table with the complete information on the NBS gathered to the project.

NBS mBiG data base

In this section, it is presented a general review and brief description of the main available NBS that were identified in the inventory matrix and could be installed in buildings such as schools or other public buildings like social centres. NBS have been categorized according the "intervention zone" in three types: roofs, façades, and exterior spaces. Each NBS include a brief description and the main challenges that can be faced up with them using the following icons:

Table 2. Challenges icons.

Challenge	Icon	Challenge	Icon
Carbon sequestration		Local climate regulation	
Air quality regulation		Maintaining populations and habitats. Biodiversity.	
Water treatment and management		Renewable energy production	
Carbon neutral cities		Soil formation and composition	
Flood protection		Erosion prevention	
Pest and control disease			

5.1 NBS for rooftops

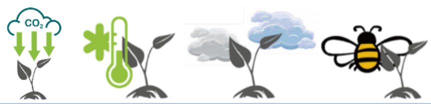
Table 3. General list of NBS suitable for rooftops.

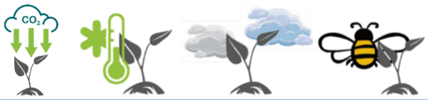
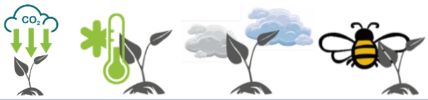
NBS	Brief description
Extensive Green Roofs **Climate and social challenges**	Green Roofs refer to space on the top of a building that is covered partially or entirely with vegetation that is planted in a growing substrate. Roof vegetation on thin substrate with little or no irrigation and management. Vegetation established either artificially by seeding or planting or naturally: mosses, succulents, few herbs, and grasses. 
Intensive Green Roofs **Climate and social challenges**	Green Roofs refer to space on the top of a building that is covered partially or entirely with vegetation that is planted in a growing substrate. Roof vegetation on thick substrate with irrigation and management. Vegetation established either artificially by seeding or planting or naturally: perennials, grasses, small tress, rooftop farming. 
Semi-intensive green roof **Climate and social challenges**	Green Roofs refer to space on the top of a building that is covered partially or entirely with vegetation that is planted in a growing substrate. Intermediate type, with mixed characteristics, between extensive and intensive green roofs. 
Urban Rooftop Farming **Climate and social challenges**	Urban rooftop farms are the spaces / areas located on the building's rooftops, used for growing vegetables, fruits and herbs. Rooftop farming is combining green roof, hydroponics, aeroponics or air-dynaponics systems or container gardens. 

NBS	Brief description
Wetland Roofs	A special type of extensive green roof that is even planted with wetland or marsh plants. It can help slow thing down and spread the impact of heavy rain out over a longer period along with rainwater collectors.
Climate and social challenges	
Green covering shelters / Sedum carpet	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 be small. This solution is planned for light shadow structures or bus stops. The “Sedum carpet” is a standard configuration for extensive eco-mulch / extensive landscaped mulch. It is a lightweight, attractive looking, natural looking garden cover that requires little maintenance.
Climate and social challenges	
Solar Bio Roof	Solar panels or solar energy production (whether for electric or thermal energy) can be integrated into green roofing systems. The height of the solar bases creates sufficient distance between the substrate layer and the solar panels, providing the plants with sufficient sunlight and allowing proper maintenance. In addition, temperature regulation provided by the green roof can increase energy production efficiency of solar panels in summertime.
Climate and social challenges	
Stormwater management roof	"Stormwater Management Roof" allows water retention on the roof and, consequently, the ability to soften rainwater runoff for public urban drainage systems. Water storage in a standard green roof system cannot be arbitrarily increased as more water can result in changes in the vegetation used. The system can hold up to approx. 80 l / m² of precipitation and then release to the urban drainage system over a predefined period (between 24 hours and a few days).
Climate and social challenges	

5.2 NBS for façades

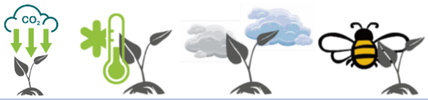
Table 4. General list of NBS suitable for façades.

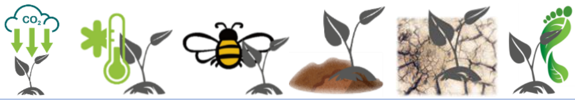
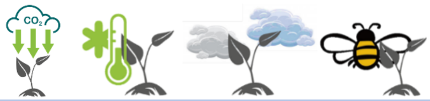
NBS	Brief description
Climate / Green Façades / Green Wall	Climate façades help reduce energy consumption for interior climate using plants grown in a supported vertical structure, cutting down heat loss in the winter and heat gain in the summer. Typologies: Hydroponic vertical garden; vertical garden substrate (with technical substrate); vertical garden substrate (with organic substrate); vertical garden with climbing vines.
Climate and social challenges	
Hydroponic green façade	This is a special type of green façade. A hydroponic Green façade is a constructive system that allows to plant and 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.
Climate and social challenges	
Living Wall	Living walls are self-sufficient vertical gardens that are attached to the exterior or interior of a building. Typologies: Hydroponic vertical garden; vertical garden substrate (with technical substrate); vertical garden substrate (with organic substrate); vertical garden with climbing vines.
Climate and social challenges	
Algae Production System	In the process of growing, algae consume CO_2, as well as producing an oil that can be turned into an environmentally friendly fuel. At the end of its lifecycle, the biomass of the algae can be processed into organic fertilizer.
Climate and social challenges	

NBS	Brief description
Vertical Farming	Vertical Farming, Z Farming or Horizontal Growing is the practice of using stereoscopic space to grow plants by utilizing the concept of cultivating plants or animal life within skyscrapers or on vertically inclined surfaces.
Climate and social challenges	
Live Panel	Live Panel is a modular system with removable cassettes (40 x 40 cm). These cassettes have cups for planting. Each line of cassettes is fixed to a 7 cm high plastic rail. The plastic chute works as a water reservoir. Through the capillary filter inside the cassettes, water flows from the reservoir to the plants. The Live Panel system is considerably more economical than other green wall systems and achieves a significant reduction in maintenance costs. It can be used both indoors and outdoors. Thanks to the modular design it can be designed according to the specific needs of each customer.
Climate and social challenges	
Green screen	Green Screen panels are pre-cultivated galvanized steel mesh fences, fully covered with vegetation, that allow immediate enclosure, providing protection and safety to the site. Green Screen panels can be applied in various situations such as parks, gardens, car parks, industrial areas, roofs, façades, balconies. Due to its green screen character, the panels are also used to mitigate the visual impact of infrastructures such as technical zones.
Climate and social challenges	
Wall planter	The Wall Planter system consists of overlapping pre-cultivated vegetation planters on a galvanized steel mesh, on new or existing building façades. The flower boxes are placed in a steel structure applied to the façade of the building. The system is equipped with a fully automatic irrigation incorporated in the aluminium flower boxes. It is also a drainage system and uses a specialized substrate to ensure plant health and well-being.
Climate and social challenges	

5.3 NBS for exterior areas (playgrounds or outdoor space of the buildings)

Table 5. General list of NBS suitable for playgrounds or outdoor space of the buildings.

NBS	Brief description
Green Wall **Climate and social challenges**	A green wall is comprised of plants grown in a supported vertical structure attached to an internal or external wall or freestanding. The structures vary modular systems to sheet or board-based structures with felt pockets to contain soil or other growing medium based on hydroponic principles and irrigation systems to provide water and nutrients required for the plants to stay alive. 
Nano Gardens **Climate and social challenges**	Nano gardens or square meter or balcony gardens are gardening techniques that allow people to grow plants using the constructed house and do not require separate green areas for gardening practices. 
Urban Park **Climate and social challenges**	Open space designed for recreational use. From a social point of view, parks can be divided into active recreation areas (such as lawns and playgrounds which often involve cooperation and team activities) and passive recreation areas (which consist of observation, walking, picnic… 
Wildlife Garden **Climate and social challenges**	A local green space, with a special management towards the promotion of urban biodiversity. 
Urban Forest **Climate and social challenges**	Urban woodland, designed and managed according to ecological, aesthetic, and economic principles. 

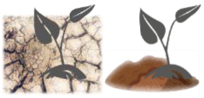
NBS	Brief description
Urban Vegetable Gardens **Climate and social challenges**	A plot of fertile soil in the urban area, intended for individuals or families who want to produce their own vegetables. 
Watercourse restoration **Climate and social challenges**	A forced underground watercourse, or part of it, is brought back to surface and its flowing canal recreated such as its banks. 
Tree lined streets **Climate and social challenges**	A street with one or two alignments of trees planted in pits or trenches. 
Permeabilization of impervious surfaces **Climate and social challenges**	Removal of impervious surfaces, replacement by permeable surfaces and/or plantation of vegetation. 
Urban Wetlands **Climate and social challenges**	Preservation and promotion of land that is saturated with water. This creates a distinctive and biologically diverse ecosystem. 
Renaturalization of brownfields, abandoned infrastructures and degraded ecosystems **Climate and social challenges**	Industrial areas abandoned city buildings or infrastructures can be renaturalized and upcycled to provide important ecological and social functions. Also neglected areas such as riverbanks, steep slopes and areas waiting for urban development can be subject to tree planting and green space development (even if temporary). 

NBS	Brief description
Green corridors **Climate and social challenges**	The corridor promotes a green link between the green spaces of the city. Ecological corridors can mitigate the loss and fragmentation of habitat. Corridors perform as “bridges” between habitats for species and they provide a flow of the natural or even anthropogenic caused disturbances. 
Treesolution Groasis **Climate and social challenges**	The Groasis system mimics mother nature in the way trees are planted. The seedling is placed carefully in the ground while protected by a box which supports its root using minimal water which is supplied through a simple drip mechanism. This means the root stays alive but is "starved" of water by, and thereby naturally induced to seek humidity in the deep. This stands in sharp contrast to standard irrigation practices whereby the root stays close to the surface in order to receive "human" support. In addition, Groasis applies complementary natural substances, e.g., improving the soil with Growmaxx compost and mycorrhizae to keep the plant healthy. The method has proven valid for varied plantations in 22 countries, regularly achieving more than 95 percent survival rates despite minimal water usage, low costs, and little need of maintenance. While this includes Urban Gardening, more research and development work will be undertaken through Urbinat to examine how the methodology can be further refined and tailored to supporting the establishment of valuable Public Green Space and Healthy Corridors in cities. Among the features to be refined, special boxes will be applied for planting larger trees, meaning that progress can be achieved at higher speed. In addition, research is to be undertaken on methods to co-deign and on avenues for spurring complementary innovation processes. 
Beehive provision and adoption **Climate and social challenges**	The provision of beehives, biodiversity gardens and habitat creation for the purpose of stimulating the proliferation of pollinating insects and birds. 

NBS	Brief description
Green visual barriers and noise mitigation **Climate and social challenges**	NBS designed to stablish a visual barrier in a concrete area and/or contribute to buffer the impact of noise outside an area. 
Green shady structures **Climate and social challenges**	This NBS is thought to bring shade to places where is not possible to plant trees or install another kind of NBSs that require more space. This NBS can be fixed to the façades of the buildings on the street or by posts fixed to the sidewalk. 
School orchard **Climate and social challenges**	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. 
Community composting **Climate and social challenges**	Composting area to be implemented in line with the orchard to provide a sustainable raw material to improve soil quality. 
Small-scale urban livestock **Climate and social challenges**	This NBS aims to promote the farming activities among children. It must be built according to the ordinance for animal welfare. 

NBS	Brief description
Arboreal interventions	This NBS includes individual large street trees, as well as the larger areas of woodland in schools with large playgrounds. Trees perform multiple functions in educational areas. 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.
Climate and social challenges	
Drainmax	The DRAINMAX is a 1.6 cubic meter lightweight plastic tunnel that creates a hollow space in the ground through which rainwater can be directly retained at the source and seep into the ground through the open bottom and side grooves. This product significantly reduces costs with more complex drainage and infiltration systems.
Climate and social challenges	
Purain	PURAIN filters rainwater, allowing it to be reused, for example in the irrigation of green spaces. Inspired by natural watercourses it has a hydraulic shoulder that automatically cleans the filter. Thanks to the special design, PURAIN filters can be used in private or industrial installations in roof areas ranging from 60m² to over 15,000m².
Climate and social challenges	
Live picture	Mobilane Live Picture is a live whiteboard with plants that can make your personal or professional environment greener and more enjoyable. This system is ecologically sustainable, harmonizes the internal atmosphere, creating a relaxing effect. The live picture "Live Picture" has an automatic capillary irrigation system. The frame itself is the plant water reservoir, with a hole in the upper part of the frame that allows the reservoir to be filled.
Climate and social challenges	

NBS	Brief description
Parklets	Parklet or pocket park provides opportunities for people to create small but important public spaces. 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 encourage non-motorized transportation.
Climate and social challenges	
Sustainable Urban Drainage Systems (SUDS)	Sustainable drainage systems that are often regarded as a sequence of management practices, control structures and strategies designed to drain surface water efficiently and sustainably, 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.
Climate and social challenges	
Rain Gardens	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.
Climate and social challenges	
Hard drainage pavements	Hard drainage 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.
Climate and social challenges	
Green pavements	Green surfaces installed into parking areas and pedestrian accesses. It contributes mainly to water infiltration and to mitigate heat-island effect.
Climate and social challenges	

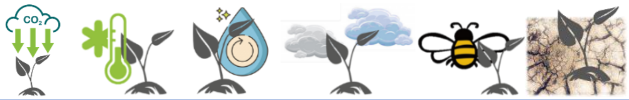
NBS	Brief description
Smart soil as a substrate **Climate and social challenges**	Smart soils elaboration has a twofold purpose, on the one hand the used waste is valued, minimizing the potential environmental impacts derived from poor management of them and, on the other hand, degraded soils are recovered without excessive costs. 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. 
Pollinators modules **Climate and social challenges**	Vegetated modules supporting flowering plants, which can provide nectar and pollen to attract foraging insect pollinator species. They can be installed as verges, walls (vertical), green roof, or in the garden either in natural soil or in a compacted structure. 
Cycle and pedestrian green route **Climate and social challenges**	Cycle and pedestrian green route are the part of green networks in the city. It promotes sustainable mobility. 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. 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. 

NBS	Brief description
Urban Carbon Sink	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 PM_{10} particulate matter is one of the other effects of urban carbon sink.
Climate and social challenges	
Green resting areas	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.
Climate and social challenges	
Trees Re-naturing parking	The urban heat island effect will be abated in parking areas by planting trees. This NBS will provide a new concept of parking which will integrate the urban activity of traffic with the nature activity urban green areas. Likewise, this action will contribute to the carbon sequestration activity and to retrofit parking areas. The trees installation in these zones will allow improve the filtration of runoff water.
Climate and social challenges	
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 considered since this is a guaranty of tree adaptation to soil and climate conditions.
Climate and social challenges	

NBS	Brief description
Cooling trees (species to maximize cooling effect) **Climate and social challenges**	Trees series planted to take advantage of evapo-transpirative cooling. Species selected will be those, which transpire at high rates to maximise their cooling effect. Provision of a constant water supply to such trees will be essential to ensure this function is effective. 
Shade trees (species to spread canopies) **Climate and social challenges**	Trees series positioned in strategic locations to maximise summertime shading. Species selected will be broad-leaved trees with spreading canopies to maximise shade in summer to reduce thermal gain of building, but open canopy in winter to allow for thermal gain in colder months. 
Green fences **Climate and social challenges**	The main objectives are to provide a green separation between river and pedestrians and create little habitats for wildlife. It is built as apart of river and riverbank re-naturing. 
Floating gardens **Climate and social challenges**	Floating gardens can take many forms including pontoons, floating platform sand 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. 
Green Filter area	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.

NBS	Brief description
Climate and social challenges	
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.) 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.
Climate and social challenges	
Floodable park	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.
Climate and social challenges	
Grassed swales and Water Retention Pounds	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.
Climate and social challenges	

NBS	Brief description
Green pavements – Green Parking Pavements	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.
Climate and social challenges	
Cool pavement	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 pavement, keeping the material cool when moist.
Climate and social challenges	
Channel re-naturalization	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 riverbanks following the removal of concrete walls.
Climate and social challenges	

NBS	Brief description
Urban Catchment forestry	Surface water flooding and poor water quality are already challenging 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.
Climate and social challenges	

6. NBS SELECTION

In this section it is included the selected prototype NBS that have been designed and proposed for the mBiG demos (prototype buildings). Here, is presented a brief summary of the NBS including the description and some illustrative pictures. Additionally, it has been included some innovative NBS from URBAN GreenUP solutions for playgrounds and outdoor spaces. This information has been included in the collaborative framework between both projects. Some prototypes are also based on existing solutions with innovative approaches.

6.1 mBiG NBS for rooftops

***mBiGBOX**. Prototype for roofs using containers with water reservoir.*

System that can be integrated into gravel roofs that are easy to install using a vegetable container with a reservoir to collect rainwater and condensates, an internal space of small dimensions to provide the initial substrate with fertilizers and planting and a multi-layer lower support to grow the roots once the plant has developed. The irrigation is carried out by means of hygroscopic wicks that connect the reservoir with two zones of the root area.

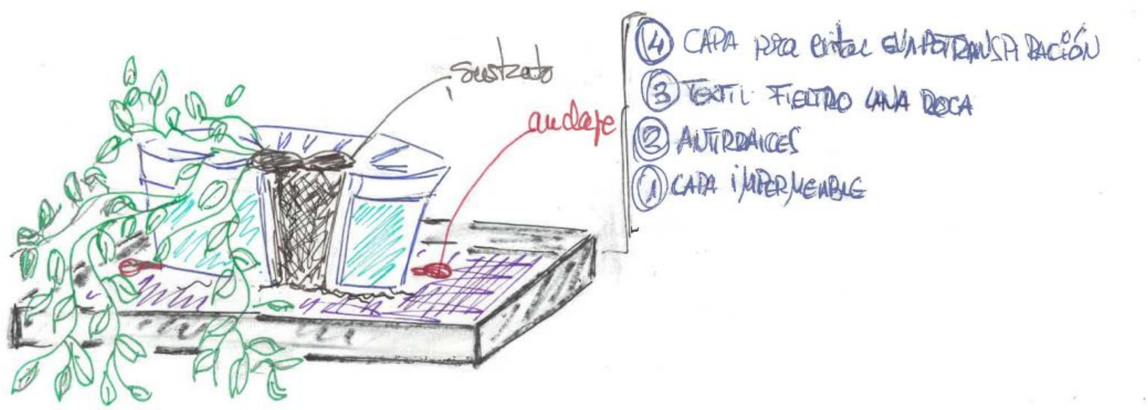


Figure 1. Basic scheme of mBiGBOX.

The System and even the reservoir itself will be covered by the roof gravel and can be completed with arlite or volcanic gravel. This coverage will reduce water loss due to evapotranspiration of the support layers and protect the reservoir from the sun. The main system components are:

- WATERBOXX® or similar water reservoir and plantation guide. It has a hygroscopic wick system to supply the water inside the reservoir to the specific root zone. The lid design allows the collection of water condensates that occur early in the morning.
- Specially designed substrate for the maintenance of the selected species.

- The characteristics of the selected species are under water requirement, creeping bearing and surface roots, native species and species indicated as beneficial for pollinators.
- Multilayer lower tray to contain the roots of the plant when it is grown. The layers have been designed to contain the root part of the plant and allow its expansion but without causing damage to the roof. From the bottom to the top it would be composed of:

Figure 2. Example of installation of mBiGBOX in a gravel roof. ©CARTIF.

  - Waterproofing layer. Although the roof is already waterproofed with this layer, we will achieve greater retention of the system water. EPDM membrane, PVC sheet or other equivalent material can be used.
  - Safeguard root barrier made of high strength polyethylene, flexible polyolefin, or non-woven geotextile.
  - **Option:** A double drainage layer and filter layer (to prevent fines from entering the channels of the filter layer) can be integrated to increase the storage capacity of rainwater.
  - Light substrate layer based on mineral wool, sheep wool, coconut fibre or felt.

The system is compatible with drip irrigation that can be integrated into the base structure. A more homogeneous vegetation maintenance would be achieved throughout the year. However, the initial design has been carried out so that it is not necessary to implement an irrigation system and the previous tests that are going to be carried out are aimed in this direction.

***mBiGBOX_Ex**. Prototype for roofs using containers with water reservoir and an extensive green roof.*

Integrable roof system that combines the mBiGBOX system and an extensive roof system. Alternative system to mBiGBOX for roofs with greater needs for green coverage and water retention.

The mBiGBOX system consists of a vegetable container with a reservoir to collect rainwater and condensates, an internal space of small dimensions to provide the initial substrate with fertilizers and planting and a multi-layer lower support to grow the roots once the plant has developed. The irrigation is carried out by means of hygroscopic wicks that connect the reservoir with two zones of the root area.

In the mBiGBOX_Ex system the substrate layer of the extensive green roof system is used as a layer to allow the root development of the plant integrated in the plant container.

The implantation density of the mBiGBOX system is one unit per square meter and the rest of the roof will be made based on an extensive green roof. The green roof on which its rests would be an extensive green roof of 8 cm of substrate to house sedum vegetation. The roof will have a draining nodular sheet with a capacity for water storage of 6 litres per square meter that will contribute to a more adequate management of rainwater that falls on the roof.

The uniformity of the extensive roof will be broken by integrating the mBiGBOX system with larger species that will allow services to the pollinators. In addition, aesthetically it will be different from conventional extensive systems that are more positive in a school environment. On the other hand, integrating the mBiGBOX into the extensive roof increases the amount of rainwater that can be stored per square meter by 15L.

Figure 3. Simulation of the mBiGBOX_Ex result for a school roof in Porto.

The components of the system are:

EXTENSIVE GREEN ROOF

- Anti-puncture geotextile layer
- Safeguard root barrier HDPE
- Anti-puncture geotextile layer
- Drainage layer HDPE with wate storage capacity
- Retaining layer / organic substrate for sedum roof
- Sedum plants

WATERBOXX® reservoir or similar

- WATERBOXX® or similar water reservoir and plantation guide. It has a hygroscopic wick system to supply the water inside the reservoir to the specific root zone. The lid design allows the collection of water condensates that occur early in the morning.
- Specially designed substrate for the maintenance of the selected species.
- The characteristics of the selected species are under water requirement, creeping bearing and surface roots, native species and species indicated as beneficial for pollinators.

The WATERBOXX® or similar vegetal container with water reservoir would be integrated over the rest of the extensive roof by placing it on the nodular sheet, the retaining blanket and the substrate and not installing the plant in that area.

The system is compatible with drip irrigation that can be integrated into the base structure. A more homogeneous vegetation maintenance would be achieved throughout the year. However, the initial design has been carried out so that it is not necessary to implement an irrigation system and the previous tests that are going to be carried out are aimed in this direction.

The plants to be installed in the mBiGBOX will be adapted to each location and a minimum of three different species will be used with staggered blooms and providing housing and food to various types of insects to promote biodiversity in the roof.

A highlight functionality of the roof that would have a water storage capacity of at least 21 l per square meter between what the mBiGBOX would capture and what the nodular sheet captures. To this value would be added what would accumulate in the substrate itself and the tissues presented by the system. The retention capacity can be increased if a nodular sheet with greater capacity is placed.

***mBiGTray**. Prototype for roofs by means of encapsulated trays with high water retention capacity.*

The system is of a multilayer tray to maintain cover vegetation that is encapsulated with a white waterproof sheet to collect rainwater and reduce water losses. The design of the system, including the selection of the appropriate plant species, has been done irrigation requirements but it is compatible with an irrigation system. In the upper part of the encapsulation there are some holes for planting plant species.

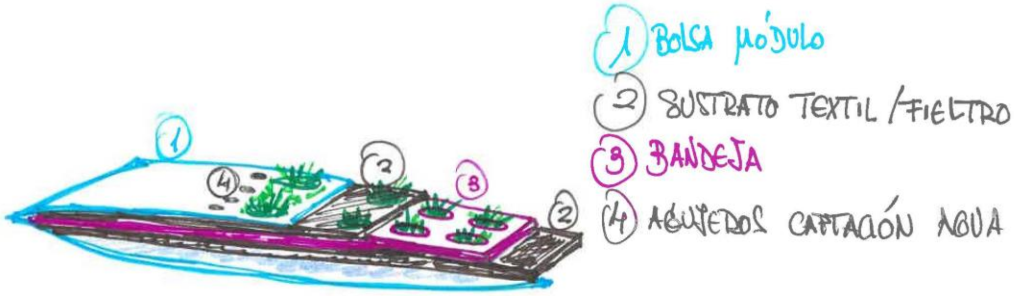


Figure 4. Basic scheme of the mBiGTray.

Schematically, the system would be a system of extensive vegetative cover pocketed to make it more resistant to times without rain.

This system allows the installation of the trays on the roof directly occupying 50% of the surface with the vegetal part initially and the rest with a white surface that avoids the excessive capture of thermal energy. The installation is carried out using a checked system in which the planting surfaces alternate with the water collection surfaces. In the zone of union of each module there are some holes that allow the entrance of water from the zone of collected of water towards the zone with the vegetal system.

mBiGTray have a drainage hole at the height of the surface of the tray to allow the greatest amount of water to be stored avoiding the pooling of the substrate in which the roots of the plants are found.

Figure 5. Side view of the mBiGTRay.

Both the weight of the tray itself and its flat design mean that, in principle, an auxiliary roof anchor system is not necessary. However, if the prevailing winds in the area were very strong, the system could be weighed down using draining aggregate as partial filling of the holes in the tray.

System components:

- The encapsulation material can be made of white EPDM or PVC. In principle, white PVC is selected as the first option by price mainly. The EPDM would cost approximately € 15 / m2 and PVC less than half. In addition, the weight per m2 is also higher. The durability of the two materials is similar for this application, both with a 10-year warranty.
- Tray is composed of a support with cavities to contain the planting substrate of the plants to be included. The modulated support is covered with a non-woven felt geotextile and introduced into the capsule. This tray allows structuring the planting of the vegetation, providing rigidity for handling the bagging and creating spaces for water storage inside.

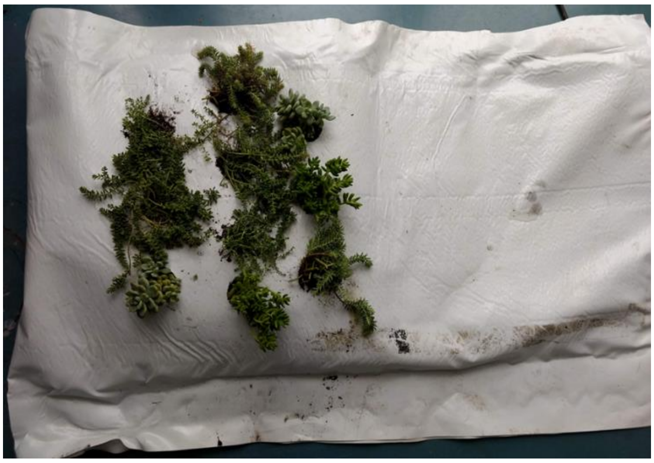


Figure 6. Initial stage of the first lab prototype of the mBiGTray.

- Between the tray and the geotextile is the material that acts as a substrate that can be both sheep's wool and sphagnum or other similar materials. This layer allows water capillarity transport from the water storage area to the upper zone.
- Above the geotextile is a layer of substrate encapsulated in a light geotextile. In this area it is where it contains the root part of the vegetation that is integrated into the system.

- The characteristics of the selected species are under water requirement, creeping and surface roots, native species and species indicated as beneficial for pollinators. A plantation of 16 plants per tray would be made. Initially there would be bands covered with vegetation and bands without vegetation but over the years one could have a complete green cover.

On the other hand, the system is compatible with drip irrigation that can be integrated into the base structure. A more homogeneous vegetation maintenance would be achieved throughout the year. However, the initial design has been carried out so that it is not necessary to implement an irrigation system and the previous tests that are going to be carried out are aimed in this direction.

Figure 7. 4 months of the first lab prototype of the mBiGTray.

mBiGCUVE. *Prototype for roofs by means of trays over plots based on extensive roof systems.*

This solution aims to shade roofs to reduce solar radiation and therefore the high temperatures reached in the summer months. Rooftops can have big thermal inertia and so it is important to reduce the direct sun irradiation in summer and wind and low temperatures effect in colder months. It will help to reduce energy losses in winter months and thus CO_2 emissions and energy consumption in heating, which are also project objectives. Considering the current state of the art, the main novelty expected in the field of green roofs is simply its greater implantation and diffusion in hot and dry climates. In this case, considering the objectives of the project, and the need for action in existing buildings, equally modular systems should be sought, easily mountable and demountable, adaptable to different buildings.

Design requirements for mBiGCUVE were easy to implement, modular, adaptable to any building, durable, accessible, and compatible with the building.

mBiGCUVE 1: (From Spanish initials of CUbierta VEgetal) systems supported on the roof, separated from it, that generate the effect of ventilated roof with an air chamber between the existing finishing gravel and the arranged system (in this way the current roof would be changed "Hot" to "cold cover"). Racks supported on raised “plots” must be arranged, on which to place removable “trays” that house a thin, extensive covering solution, with an improved substrate and with native species suitable for said thickness. We have worked with modular racks and trays that take advantage of the commercially available material, modulating the elements at 1,50 m, 3,00 m, 4,50 m, or 6,00 m, with widths of 1,00 m or depending of the measurements of the tray system.

Regarding vegetal species selection, it must be considered that, considering the maximum substrate thickness requirements, irrigation conditions and maintenance. The Royal Botanical Garden (CSIC) has selected the following species, including planting, acquisition, and maintenance requirements:

Perennials: *Dianthus carthusianorum; Festuca cinerea, Hybride Festuca cinereal; Gypsophila repens p.; Helianthemum nummularium; Koeleria glauca; Petrorhagia saxifraga; Saponaria ocymoides; Satureja montana ssp. illyrica; Saxifraga paniculata; Sempervivum hybride; Cerastium arvense; Hieracium pilosella; Potentilla neumanniana; Prunella grandiflora; Thymus doerfleri Thymus doerfleri Bressingham; Thymus serpyllum Serpol.*

Sedum: *Album, Acre, Reflexum, Sediforme, Rupestre, Ochroleucum, etc.*

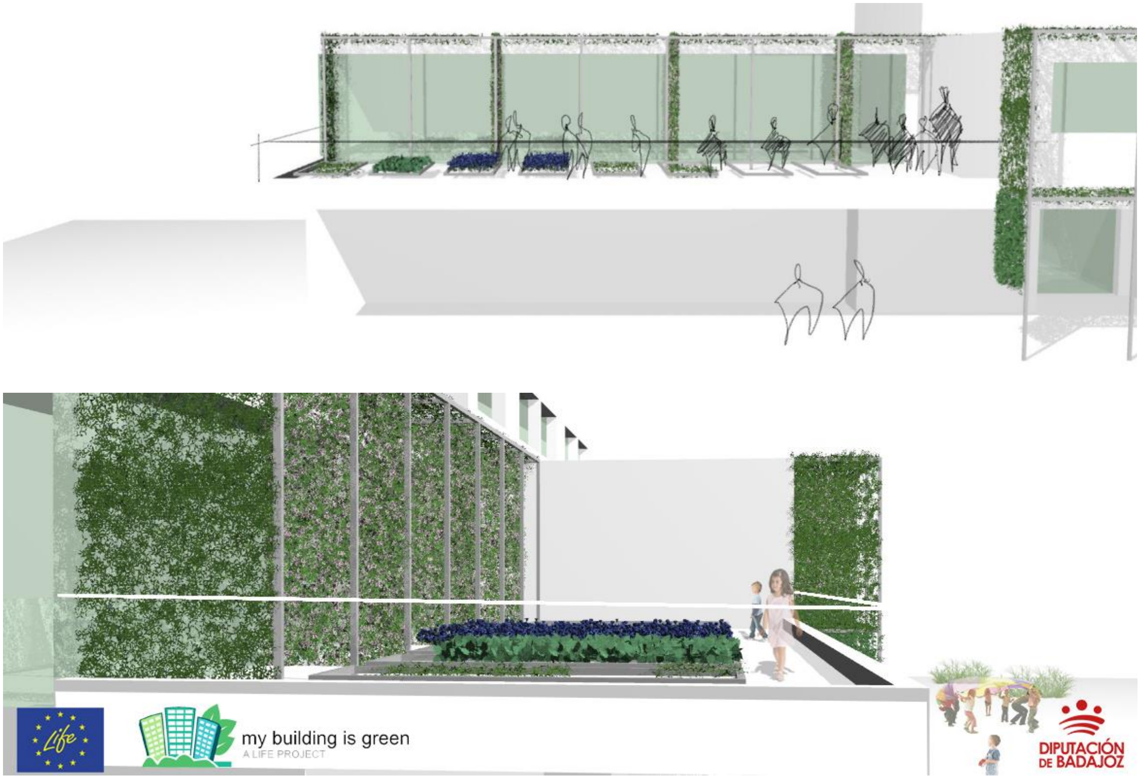


Figure 8. Visual recreation for the CEIP Gabriela Mistral with mBiGCuve.

mBiGCUVE_SUS. *Prototype for roofs by means of trays over plots based on extensive roof systems.*

mBiGCUVE_SUS. MBiGCUVE prototype but with a more sustainable substrate that uses recycled aggregate of ceramic origin for the formulation of the vegetable substrate. It also replaces the draining layer, usually made of plastic materials, with recycled aggregate with a larger grain size.

Water storage and nutrient supply is especially important for growing perennials and shrubs. In the case of the Project substrates, a finer granulometry (porcelain waste dust) and higher levels of organic matter will be combined depending on the native vegetation to be installed. In this way, the appropriate water levels required by the vegetation will be ensured, without reducing the volume of air in the substrate, avoiding compaction of the same.

***mBiGUL – Solution based on Green Urban Living System (GUL)**. Multifunctional systems for roofs based on expanded cork agglomerate for impermeabilization*

The Green Urban Living (GUL)[19] is a multifunctional system using expanded cork agglomerate for the construction of green roofs and living façades.

Although the use of urban green roofs is still infrequent, LIFE-mybuildingisgreen project aims to promote green roofs has a trend in urban architecture and planning, reconciling aspects related to adaptation of cities to the effects of climate change and to promote sustainable construction as well. This system was developed within a national project which aims to develop and validate new roof systems and green façades structured in expanded cork agglomerate (ICB), with a higher environmental and energy profile than conventional solutions and with a high capacity for energy customization and prefabrication. In these eco-designed systems, ICB will simultaneously provide:

- Thermal insulation of the building;
- Drainage functions;
- Retention functions;
- Carbon capture.

Cork is a raw material which is so perfect that no industrial or technological processes have yet been able to replicate. It has numerous advantages and benefits due to its key characteristics as, and it represents an innovative opportunity to incorporate cork-based materials in green roof systems. Some of the cork key characteristics are:

- Very light material - Over 50% of its volume is air, which makes it very light - it weighs just 0.16 grams per cubic centimetre and can float.
- Elastic and compressible - It is the only solid which, when compressed on one side, does not increase in volume on another; and as a result of its elasticity it is able to adapt, for example, to variations in temperature and pressure without suffering alterations.
- Impermeable to liquids and gases - Thanks to the suberin and ceroids contained in the cell walls, cork is practically impermeable to liquids and gases. Its resistance to moisture enables it to age without deteriorating.
- Thermal and acoustic insulator - Cork has low conductivity to heat, noise, and vibration. This is because the gaseous components contained in cork are enclosed in small impermeable compartments, isolated from each other by a moisture-resistant substance.

[19] http://www.itecons.uc.pt/projectos/greenurbanliving/index.php?module=sec&id=546&f=1

- Fire retardant - Cork is also a natural fire retardant: it burns without a flame and does not emit toxic gases during combustion.
- Highly abrasion resistant - Cork is extremely resistant to abrasion and has a high friction coefficient. Thanks to its honeycomb structure, its resistance to impact or friction is greater than that of other hard surfaces.
- Hypoallergenic - Because cork does not absorb dust, it helps protect against allergies and does not pose a risk to asthma sufferers.
- Natural touch - The natural texture of cork combines softness and flexibility to the touch with a naturally uneven surface. The variable degree of irregularity is given by the type of cork used and the finish chosen.

The cork also plays an important role in Portuguese Economy, representing 2% of Portuguese total exports, and due to its sustainable, environmental and economic benefits it seems to be an excellent material to incorporate in the project, as well as the use of the GUL, in order to test it to the adaptation to a climate change in a school building.

The GUL is four layer system, that uses ICB (Insulation Cork Board, an expanded cork agglomerate), followed by the filter layer (to prevent substrate particles from being removed and collapse water runoff), than is the substrate and above the planted layer whit the vegetation.

Figure 9. Prototype layer scheme based on the GUL system.

The substrate proposed to use, is a product developed by LandLab (the green roof company that will implement the NBS prototypes in Porto's school), the Intensive Technical Substrate, developed according to FLL regulations. The ITS consisting of special components with mineral base, which give it a medium-thick texture, high and balanced capillarity, and drainage. This substrate is characterized by having a high mineral component, free of parasites, weed species and pathogenic germs and great structural resistance. It is composed by:

- Fermented and certified pine bark humus, granulometry 0-15mm;
- Selected blond peat, granulometry 0-40 mm;
- Expanded clay - 2/4mm granulometry;
- Special volcanic rock, 3-9mm granulometry;
- pH corrected for 5.5-6.5.

The GUL system was the inspiration to the development of prototype, mBiGUL (mBiG Green Urban Living based), will be applied in Porto's school, EB1 Falcão, and its main benefits to LIFE-mybuildingisgreen project are related to the system being:

- Feature an eco-friendly design incorporating renewable and recyclable materials;
- Allow geometric customization;
- Be self-draining (no synthetic screens available);
- Autonomous water holding capacity;
- High thermal performance;
- High acoustic performance;
- Economically competitive, allowing to have tangible advantages in terms of its performance;
- Ease to applicate, making it a viable alternative to the solutions currently on the market.

Figure 10. Example of an installation using the GUL system. Source: Neoturf.

The mBiGUL prototype represents an integrated and ready-to-install solution, consisting of a multilayer system. The base is formed by a waterproofing layer followed by a layer of cork agglomerate (recycled and recyclable material), based on the GUL system developed by Amorim Isolamentos and which had the collaboration of Neoturf, Itecons (Institute of Research and Technological Development for Construction, Energy, Environment and Sustainability) and ANQIP (National Association for Quality in Building Facilities). Above the cork is placed an anti-root screen, followed by the substrate and the vegetation. The following figure presents a cross-section of the prototype.

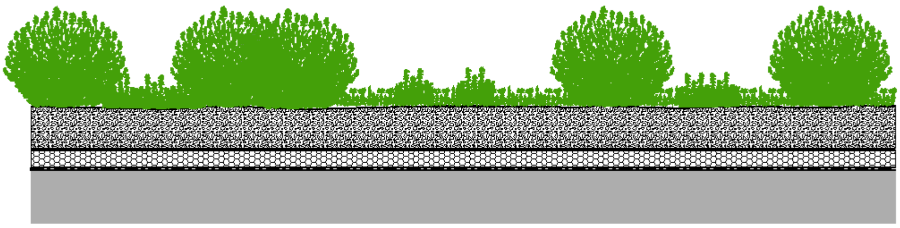


Figure 11. Transversal section of the composition of the mBiGUL prototype.

mBiGSECAR*. Sustainable solutions for the most of roof types and climate conditions.*

Sedum Carpet is a sustainable and 100% biodegradable vegetation cover solution, which was designed with the aim of reducing the installation time of a landscaped roof. It consists of a structure based on pre-planted coconut fibre with vegetation of the genus Sedum spp.

As plants of the genus Sedum (several varieties) have a set of ideal characteristics and adapted to the context of application in green roofs, as a high capacity of resistance to different weather conditions.

Figure 12. Sedum carpet model. Source: Landlab.

The Sedum is an Alpine plant. It is therefore a plant with an enormous capacity to withstand sudden temperature variations, such as a dry climate, poor soils with little organic matter, exposure to intense sun, places with snow, strong winds, among others. Sedum, depending on the variety, can adapt to extreme weather conditions, unlike most plant species. Like any CAM plant, it can reserve water in the leaves, which it uses only at night when temperatures are lower. In addition to daily thermal regulation (day and night), these plants also have the ability to contribute to thermal regulation by accumulating heat during the colder seasons (autumn and winter) and producing cooling (by evapotranspiration) in the warmer seasons (spring and summer).

This system allows to obtain an almost immediate vegetation cover, being an excellent solution for inclined structures, because it presents a great ease of application, low maintenance and a great resistance to weather conditions and low ecological requirements, (substrate and water).

After the application of the Sedum Carpet, the final aspect is of a uniform vegetation without any fault or empty space, because this type of vegetation presents a large root dispersion that allows a homogeneous coverage of the space. The use of different species and varieties of Sedum contributes to a greater diversity of the vegetation of the cover and giving a more natural and diverse appearance.

The multiplicity of Sedum species applicable in this system contributes to the wide range of uses and can be applied in most landscaped roofs and in various types of climate.

Figure 13. Sedum Carpet in a rooftop. Source: LandLab.

The advantages and benefits of this type of solution are varied as:

- Getting an almost instantaneous green cover;
- Free of weeds;
- Visually attractive;
- Simple and quick installation;
- 85% of vegetation guaranteed;
- Lightweight solution;
- Need for a reduced substrate layer (from 6cm);
- Resistant to various weather conditions;
- Biodegradable;
- Suitable for almost all types of roofing;
- Contributes to thermal insulation in summer and winter;
- Allows you to sound isolation;
- Less damage caused by birds because more than 85% of the cover is immediately covered with vegetation;
- Reduced maintenance system as it does not require cuts.

The Sedum Carpet also allows the reuse of rainwater, with a rainwater retention of approximately 50% (depending on regional differences) and provides substantial energy savings. Rainwater retention occurs through the storage of water by the plant for use in the driest periods, but also allows a greater regulation of precipitation flows, delaying the flow of rainwater and thus reducing flood flows and peaks in the management of urban stormwater system.

Maintenance of the Sedum Carpet

The Sedum Carpet, when properly installed, will require little maintenance. After installation, the system should be watered regularly for 2 to 3 weeks in order to ensure the correct initial development of the vegetation, and the consequent proliferation of the root system that makes up carpet. As the roots gradually take possession of the substrate it will only be convenient to fertilize the cover once or twice a year (April and/ or September).


Figure 14. Example of Sedum carpet on a roof. Source: Landlab.

Since Sedum is a preferably mountainous plant, in the case of use of the system in hot and dry climates, it may be necessary and appropriate to install an irrigation system for more frequent irrigation. The installation of a drip irrigation system, buried, will be a useful tool if you choose to use this system in the regions of Andalusia in Spain (Solana de los Barros) and Alentejo in Portugal (Évora).

The Sedum Carpet has the following features:

- Thickness 2 to 4 cm;
- Approximate dry weight 10g/m;
- Approximate saturated weight 15kg/m;
- Substrate Thickness Required >10 cm.

And main advantages:

- Ease of commissioning;
- Increased tolerance to dryness;
- Increased protection against weeds;
- Multiplicity of species that allow sensory and chromatic varieties and combinations: *Sedum album 'Coral carpet'; Sedum album 'Murale'; Sedum acre; Sedum sexangulare; Sedum 'Hispanicum minus'; Sedum spurium 'Fuldaglut'; Sedum floriferum; Kamschaticum sedum; Sedum hybridum 'Immergrunche'; Sedum Lydium* and *Sedum Reflexum.*

To the EB1 Falcão was developed a sedum carpet based prototype, which reflects the main benefits of the sedum carpet (a pre-planted layer), making its installation easier. The mBiGSECAR (SEdum CARpet), brings together the traditional component of a green roofing system with the ease of mounting and fixing a sedum mat, which makes this system ideal for installations on sloping roofs. This system was considered especially for EB1 Falcão due to its inclined covers, to enrich and diversify the set of solutions and constitute an experimental system for the teaching of the urban water cycle in real context. The combination of mBiGSECAR with mBiGPond allows to create a flow of rainwater between the catchment (cover - mBiGSECAR), routing to intermediate medium (deposit) and discharge in the receiver medium, pond (mBiGPond), where it will be reused for infiltration in the soil contributing to close the water cycle.

The mBiGSECAR is formed by a waterproofing layer, followed by a retaining blanket and a drainage element, to enhance the runoff of rainwater. On the drainage elements is placed the substrate, covered by a screen that will allow a greater fixation of the sedum mat to the substrate.

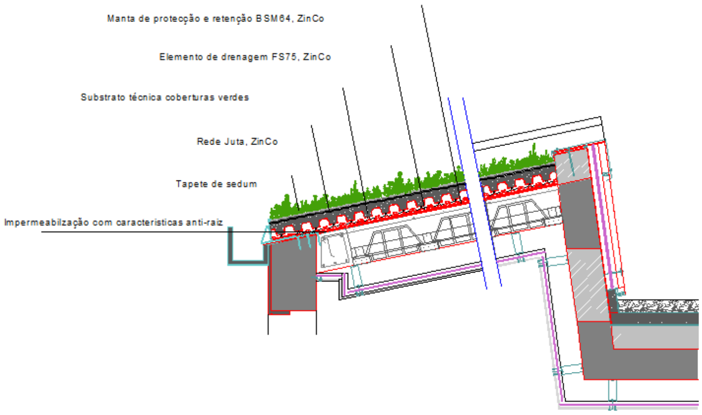


Figure 15. Transversal section of the composition of the mBIGSECAR prototype.

***mBiGBioSol**. The synergistic integration of renewable energy with biodiverse habitat creation.*

Bio Solar Roof is the combination of a green roof and a set of solar panels. In fact, the combination is not just a sum of benefits, but an almost perfect symbiosis between energy efficiency, biodiversity, and sustainable production. The installation of a green roof provides a number of environmental and economic benefits, notably in terms of regulating indoor temperature and promoting biodiversity, while allowing for greater durability of coverage (reducing exposure to elements) and reducing energy consumption in indoor air conditioning, resulting in effective savings.

On the other hand, solar panels contribute to the production of electricity from renewable and neutral sources, without carbon emissions to the atmosphere, while reducing the consumption and dependence of the building on the supply of electricity. However, the installation of solar panels on green roofs creates a symbiosis between both solutions. Solar panels provide strong shade and wind and rain protection to the vegetation of the cover, while the biological processes of evapotranspiration of plants contribute to the cooling of solar panels increasing their efficiency, and as such, obtaining a higher yield in energy production, which in the absence of green cover would be lower.

Since EB1 Falcão is one of the 25 schools in the city of Porto that will accommodate a set of solar panels according to a municipal program for the installation of energy production equipment for self-consumption called "Porto Solar", the prototype mBiGBioSol(**Bio Sol**ar Roof) was developed, as a proposal for the integration of the two projects in an innovative way and in a win-win prespective.

Thus, the mBiGBioSol presents itself as a modular system of fixation and support for photovoltaic solar panels, consisting of a modular draining base to which the panel support is fixed. The draining base had received ballast and substrate on which vegetation will be planted.

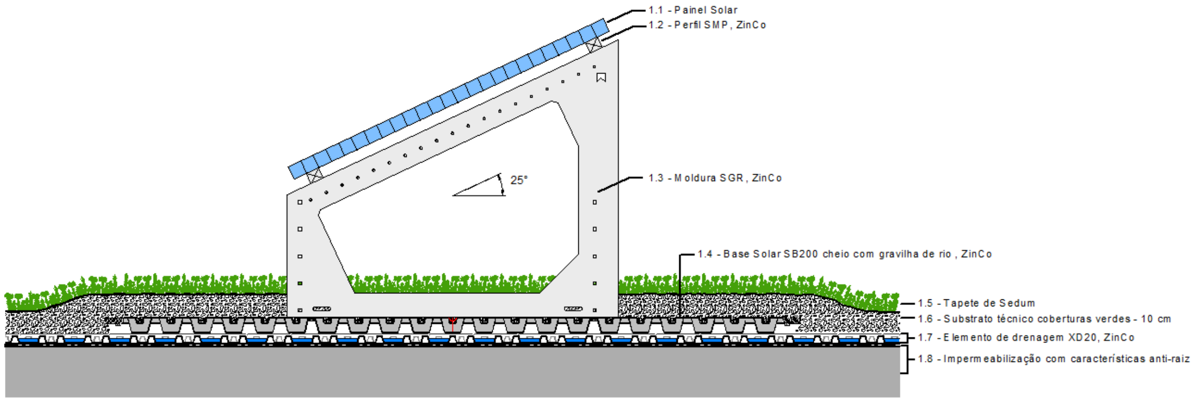


Figure 16. Transversal section of the composition of the mBIGBioSol prototype

6.2 mBiG NBS for façades

mBiGToldo*. Prototype for creating vertical green surfaces.*

The system has been designed to create vertical surfaces with vegetation of very low thickness and weight to create shading with a contribution of humidity to the environment. The system consists of an impermeable sheet on which a non-woven felt is adhered and on which a semi-woven substrate is projected. Due to the low thickness of the substrate, a hydroponic irrigation is integrated, which is distributed by gravity through the surface of the substrate. In the lower area, a channel for collecting excess water is integrated and returned to the irrigation station.

Figure 17. Basic scheme of mBiGToldo.

Irrigation is carried out through a hydroponic irrigation station with adequate programming to cover the needs of the vertical garden at all the seasons of the year and the environmental conditions. It is required to connect the irrigation station, to be installed under the level of the mBiGToldo, with all the gardens, both to provide the irrigation and to collect the rainwater dropped on the upper roofs.

The main mBiGToldo components are:

- Support frame. Structure with the appropriate dimensions made with the material with which the vertical wall structure that will support the prototypes of the façade is constructed.
- Waterproof support. It must be a sheet-shaped material resistant to punching and tearing to facilitate fixing. The currently recommended material is a PVC awning sheet, but more sustainable materials are being sought.
- Non-woven felt or rock wool-based root fixing sheet.
- Mix of substrate and compatible seeds that is applied by projection.
- The characteristics of the selected species will be easily propagated by seeds.
- Drip irrigation tube at the top and water collection gutter and embossed to excess water collection tube.

The system is only compatible with hydroponic drip irrigation that can be integrated into the support structure of the awning. The design includes a system for collecting excess irrigation water and returning it to the tank for the optimization of water consumption.

Among the species that can be used are *Festuca rubra*, *Agrostis estolonifera*, *Saginas ubulata* and *Cymbalaria muralis*, but others can be evaluated based on the location.

Figure 18. Lab prototype of mBiGToldo.

mBiGFAVE. *Prototype for creating vertical green surfaces.*

Shading of façades to reduce solar irradiation and therefore the high temperatures reached in summer months. Specifically, taking into account that the greatest temperature transmissions occur through the glazed holes (on the other hand necessary for the lighting of the spaces), it is about performing shading systems, mainly of gaps (although the shading of blind parts will also be beneficial), through nature-based solutions.

It has been opted for the realization of systems superimposed on the façade that generate shadows in the gaps, that is, that prevent direct radiation of the sun's rays over the gaps. This requires canopies, and elements flown on the façade that represent a parapet to the sun's rays. These elements will consist of solutions based on nature, plants, and plant species. The dimensions of plant protection should not prevent, as far as possible, the sun in winter. Considering this aspect, the implantation of deciduous species has been assessed.

Work has been done on the realization of a light and modular substructure that serves as a support for different plant solutions, separated from the façade and anchored to it at the level of floors and ceilings, to facilitate its adaptation to any building. It is designed for a maximum of 2 floors. Detachable, and serve as support for two possible solutions based on nature. It has been called FAVE (Spanish initials for VEgetal FAçade). It generates possible horizontal and vertical surfaces over the holes and in front of them, at a greater or lesser distance. On these surfaces, and by virtue of the orientation of the façade and the arrangement of the holes in each building, plant species will be available to serve as shading.

The system consists on a modular framework of shading of the façade by means of removable frames made with metal tubulars anchored to the façade at the level of floor slabs and supported on firm ground by mass concrete manholes.

Regarding vegetal species selection, it must be considered that during wintertime plant protections should allow sunlight to enter through the windows. Vegetal species must be deciduous and climbing. For instance, the Royal Botanical Garden (CSIC) has selected the following species, including planting, acquisition, and maintenance requirements, highlighting those deciduous ones.

Figure 19. Visual recreation for the CEIP Gabriela Mistral with mBiGFave.

mBiGFAC. *Prototype for creating vertical green surfaces.*

The façades have been the target of constant evolution, being a fundamental component of the building. The walls are also strongly exposed to natural elements, especially the sun, wind, and rain, so the installation of green walls allows to mitigate the impact of these elements on the structure, while promoting other advantages. The benefits are evident both for outdoor and indoor application and it is proven that an environment with vegetation has a positive effect on people's well-being.

Green façades have proven to contribute to the reduction of carbon dioxide and oxygen release, thereby reducing pollution, while contributing to the reduction of direct sun exposure and promoting the softening of indoor air.

For Falcão EB1, the **prototype mBiGFAC** (green **FAÇ**ade) was specially developed, a simple system of cables spaced between them, which support the development of a species of climbing vegetation. This simple solution not only promotes the diversity of solutions according to the needs and characteristics of the buildings, but also aims to be an experimental and demonstrative solution in the school, since most of the facades of The Falcon EB1 have tree alignments in the vicinity, thus contributing naturally to the effect of shade on the facades to the south, resulting from the strong sun exposure in the spring and summer months.

Thus, mBiGFAC consists of a cable system to support a climbing species. The plant species selected for placement on the green wall was the virgin vineyard, *Parthenocissus tricuspidata 'Veitchii'*, for being a kind of deciduous leaf, which allows in winter to let in sunlight, because it will be stripped of leaves, and in summer protect the building from the direct sun entrance, thus making the building thermally and energetically more efficient , relying on the beauty of the shades that this species takes, thus creating an environment that transforms with the seasons.

The virgin vineyard will be installed in a flower bed 30 cm thick, and that accompanies the entire length of the division. Between cables there will be a spacing of 30cm, with medium fixing support on the balcony and final in the space before the cover. Plants will be rooted in the soil and therefore do not require an expensive supply of water and nutrients. Minimal material use provides high energy benefits, with a long service life and low maintenance.

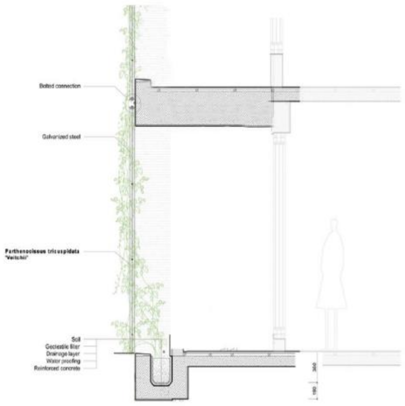


Figure 20. Transversal scheme of the composition of the mBIGFAC prototype. Example of green façade with cables.

6.3 mBiG NBS for exterior areas (playgrounds and outdoor spaces)

***mBiGRain**. Prototype for creating rain covers for playgrounds using a tree.*

Wooden module to create a space for protecting children when it is raining. This system integrates a deciduous tree to let the sunlight pass in wintertime and to shadow in summertime. The structure will have variable translucent areas in the cover according the location.

mBiGRain can be located with an existing old tree or with a new tree. mBiGRain can be created in isolated modules or can be connected to create different spaces.

mBiGRain is currently under development in collaboration with LIFE EcoTimberCell[20] for creating a sustainable solution promoting certified local wood. These works are being developed in the collaborative framework established between both projects.

Figure 21. Scheme of the mBiGRain.

Rainwater collected by the covering will be conducted to the centre area where a rain garden or a natural drainage system will be created in the tree pitch. Rain water will be infiltrated to rechard the soil. Different systems can be used to manage rainwater in the tree pitch. It will be defined properly for each location.

***UGUCompactPollinators**. Prototype for creating compacted pollinators modules.*

These small spaces are designed to attract pollinators and biodiversity in general as a refugee (colder areas in hot periods and refugee for wintertime) and feeding (water and food providing areas for pollinators). It also is important to incorporate in this NBS, housing for pollinators, both insects and other species as birds, bats… It will have the housing function but also it will be an awareness

[20] https://www.life-ecotimbercell.eu/

element for citizens. Each pollinator module can be installed on the floor and it is estimated a surface between 5-10 m^2.

Additionally, this NBS could include (depending on its location and characteristics) some site furnishing as street seats, drinking water fountain or some elements to create a point of interaction between nature and citizens in locations without nearby green areas.

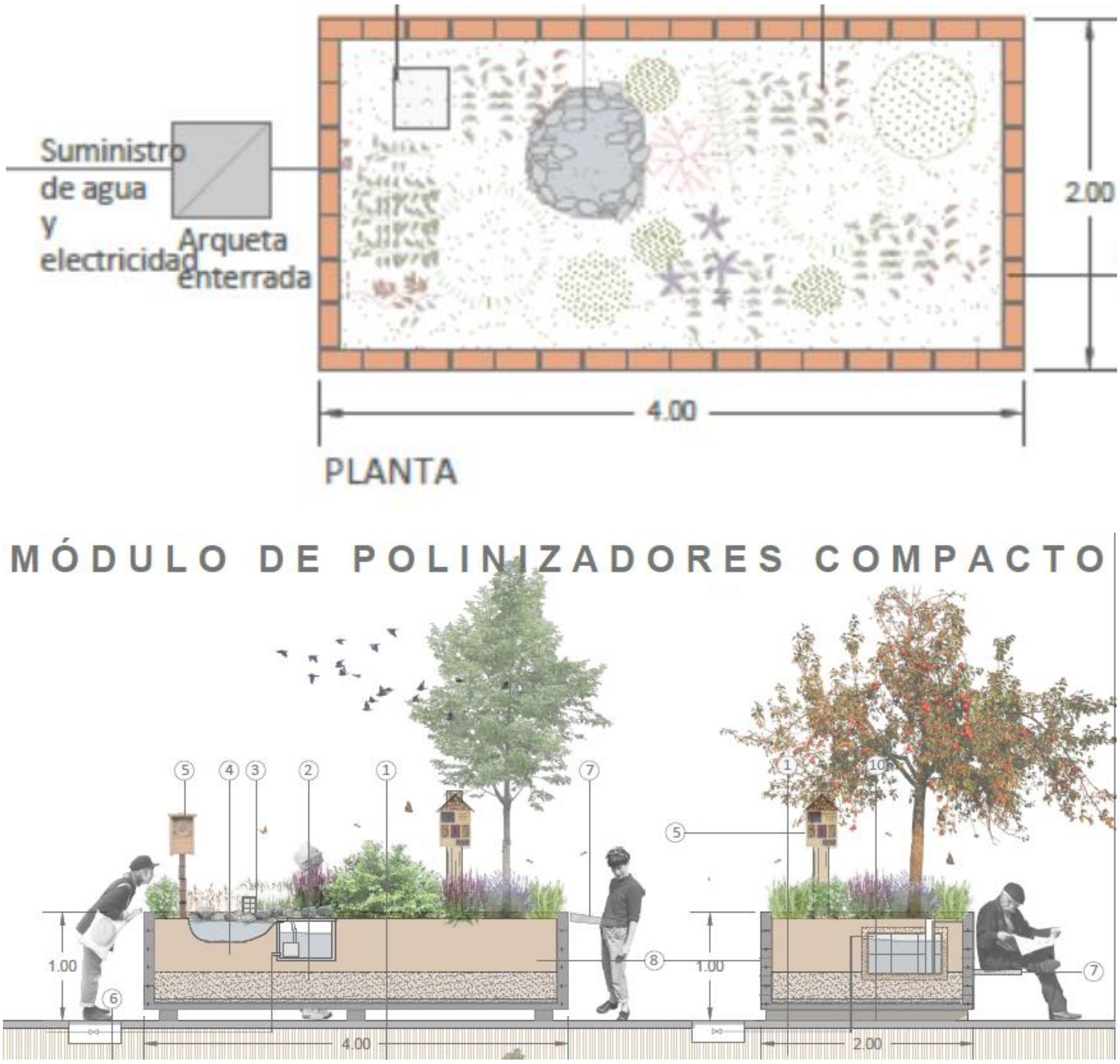


Figure 22. Schemes of UGUCompactPollinators.

The expected impact is help to create connexions or/and connexions networks among green and blue spaces or areas in urban environments, increase the level of biodiversity, improve air quality, run-off mitigation, energy savings, increase in property values, citizens well-being and social cohesion.

Connectivity. The distance between modules will be affected by the characteristics of the urban space, the presence of other green elements (like trees or bush lines), space availability, etc. These structures allocated in urban areas will help to connect different zones in the city with peri-urban area which is usually connected with countryside in some way.

This green space attracts pollinators and biodiversity through flowers and plants. To achieve that a favourable sequence of flowering permits the production of pollen, nectar and essential oils. For that reason, is compulsory to select an optimal combination of different native plants (to avoid the risk of introducing non-native invasive species and pathogens) (trees, shrubs, wildflowers) with different flowering to cover the period between March to November, overall in spring, when hunger gaps are most likely to occur.

Additionally, it is necessary to provide the modules with plenty of safe nesting habitats -- long grass, bare earth, crevices in dry stone-walls or wood - insect hotel, pollinator walls or bee towers for bumblebee, bees, pollinators, etc. All these elements will be done with free-pesticides and non-toxic materials.

Only then, it is achieved that pollinators arrive and establish in a continuous manner.

Key Elements description:

- **Constructive elements:** Natural/organic building materials (for instance wood).
- The **module** is big container plant or group of plots (creating several layers of different plants) that will be placed in the city. They must be mobile to be moved or displaced if needed. Therefore, it must be resistant and with comfortable dimensions to be used (consider the machinery of the municipality for its movement). Total surface of Compacted pollinator's modules between 5-10m^2 (standard but it depends on the available space). The shape of the module can be adapted to the available space.
- **Plants** (trees, bushes, and flowers). This NBS will put special attention to install native and anti-allergy species (*Lavandula latifolia, Rosmarinus officinalis, Salvia lavandulifolia, Corylus avellana, Malus* spp*., Acer campestre, Viburnum tinus, Cistus* spp. etc.) with different flowering periods.
- **Water** source.
- **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. Bees to keep their young need nectar and pollen, as well as areas of clear ground and full sun, old logs, or woods, and even areas with pieces of bark or stones.
- Street **seats**, water sources for humans, shadow structures or other elements (for instance shadow tree), etc. Site furnishing, to create a point of interaction between nature and citizens in the very centre of the city.
- **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.
- **Connectivity**: Creation of a modules network (habitats for biodiversity) connecting green areas in the city.

- **Flowers:** A selection of more convenient plants and combination of them will be done according different parameters like location, surrounding vegetation, pollen, and nectar accessibility for pollinators among other.
- Urban Landscape architecture criteria in the city must be taken into consideration.

***UGUNaturalPollinators**. Prototype for creating compacted pollinators modules.*

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

It is important to incorporate 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 people.

Figure 23. Scheme of UGUNaturalPollinators.

Each natural pollinator module can be installed on the ground and it is estimated a surface between 10-20 m^2.

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.
Locations will be selected depending on sunshine irradiation times and according with characteristics of surrounding area (vegetation, green areas, urban furniture, roads, etc.). Locations will be also selected in order to create connexions or/and connexions networks among green and blue spaces or areas in the urban environment. They will have additionally a source of irrigation or possibility of being irrigated in a simple way.

This green space attracts pollinators and biodiversity through flowers and plants. To achieve that a favourable sequence of flowering permits the production of pollen, nectar, and essential oils. For that reason, is compulsory to select an optimal combination of different native plants (to avoid the risk of introducing non-native invasive species and pathogens) (trees, shrubs, wildflowers) with different flowering to cover the period between March to November, overall in spring, when hunger gaps are most likely to occur.

It is also necessary to provide the modules with plenty of safe nesting habitats -- long grass, bare earth, crevices in dry stonewalls or wood - insect hotel, pollinator walls or bee towers for bumblebee, bees, pollinators, etc. All these elements will be done with free-pesticides and non-toxic materials.

Figure 24. Scheme of UGUNaturalPollinators.

Only then, it will be achieved that pollinators arrive and establish in a continuous manner.

Key Elements description:

- **Constructive elements:** Natural/organic building materials.
- The **soil/ground** will be SUDs made. In case of using substrate peat-free (Peat bogs are important habitat for many species, overall butterflies).
- **Plants** (trees, bushes, and flowers). This NBS will put special attention to install native and anti-allergy species (*Lavandula latifolia*, *Rosmarinus officinalis*, *Salvia lavandulifolia*, *Corylus avellana*, *Malus spp.*, *Acer campestre*, *Viburnum tinus*, *Cistus spp.* etc.) with different flowering periods.
- **Water** source.
- **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. Bees to keep their young need nectar and pollen, as well as areas of clear ground and full sun, old logs, or woods, and even areas with pieces of bark or stones.
- **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.
- **Flowers:** A selection of more convenient plants and combination of them will be done according different parameters like location, surrounding vegetation, pollen, and nectar accessibility for pollinators among other.
- Urban Landscape architecture criteria in the city must be taken into consideration.

UGUVegetablesGardens/UrbanOrchards. *Solution for creating vegetables gardens or urban orchards.*

This NBS is an area of land dedicated to the cultivation of vegetables, fruits, and flowers, for the purpose of food production. This kind of solutions takes place in public spaces, community gardens or private residential property. Unemployed, retired people, families with limited resource or people interested in it are usually in charge of exploiting them. This can be valid also for schools in collaboration with the teachers and students.

Variation in vegetable gardens:

- **Traditional**: The most common vegetables grown here and others less common like celery
- **Staple**: Only tomato and pumpkin.
- **Salad and herb**: Culinary herbs and traditional salad ingredients.
- **Complex**: the cultivation of all kind of vegetables takes place, including fewer common species grown here, like mizuna, miner's lettuce… Complex gardens produce the greatest volume of vegetables among those listed herein.
- **Tomato and parsley**: this garden have the most popular vegetables. For instance, tomato, lettuce, courgette…

Figure 27. Garden with aromatic plants (Salad and herb) © CARTIF.

Figure 26. Garden with only lettuces and cabbage and parsley type). © CARTIF

Figure 25. Integrated and soil garden. © CARTIF.

Variation in gardening practice:

- **Integrated**: avoidance of chemicals and GMOs
- **Chemical**: In these gardens the use of inorganic pesticides and herbicides is allowed.
- **Informed consumer**: private gardens cultivated by people interested in producing their own vegetables.
- **Soil**: improving the soil quality is its main aim.
- **Economic**: they are managed by garden practitioners that sell the vegetables that they produce. Most of them have greenhouses.

Different farming systems:

Furrow / in a row: The plants or seeds are directly placed on the flat ground or on the top of the furrows.

Figure 28. Examples of orchards in regular furrows. © CARTIF.

Terrace: method of growing crops on sides of hills or mountains by planting on horizontal terraces that have been dug out into the slope. Though labour-intensive, the method has been effectively employed to maximize arable land areas in different kinds of terrains and to reduce soil erosion and water losses.

Figure 29. Examples of orchards in terrace. © CARTIF.

Growing tables: the cultivation is on tables.

Figure 30. Example of growing tables. Photo: www.gardeners.com.

Keyhole or African orchard: it is a growing table with a composting basket in the centre.

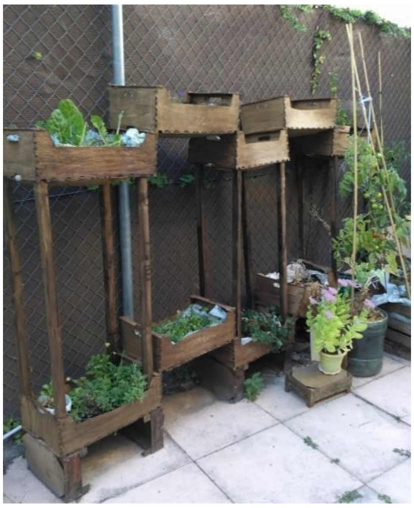
Figure 31. Keyhole at the Agricultural university INEA in Valladolid © CARTIF.

Parades en crestall: Divided cultivation; it must consist of at least 2 rectangles of land 1.5 m wide and 3 to 6 m long. These rectangles, called parades, are alternatively separated by two kinds of paths: straw and bricks paths, and only straw paths. You can only walk along the straw paths, thus facilitating teaching especially to the little ones. At each stop a high-density family of plants is cultivated to compete with the weeds. In addition, it is necessary to build as many stops as the number of rotations of cultivation that we want to make. Each parade has drip irrigation.

Figure 32. Examples of Parades crestall. © CARTIF.

Gardens on balcony and terrace: the cultivation of the vegetables is done in pots in private balconies and terraces

Balcony orchard © https://www.rojomenta.com/blog/consejos-huerta-urbana-balcones-terrazas/



Urban orchards in a terrace © CARTIF

Figure 333. Examples of orchard solutions for small spaces.

mBiGPond*. Proposal for exterior area to build a small water body to promote water infiltration into the soil*

An important part of the LIFE-mybuildingisgreen project focuses on the blue areas, from the perspective of water management, which may be due to the increase of the permeable area (favourable to the infiltration of water into the soil), the reuse of rainwater and the reduction of water for irrigation.

Following the solutions related to water, it would be important for the project to also contribute to the strengthening of this built urban relationship – permeabilized soil – water mass. In this context, urban ponds play an important role in the formation of small aquatic ecosystems of low demand and complexity.

The ponds are masses of standing water or very low current of a permanent or temporary nature, depending on the climate, the geology of the land and the availability of water. The ponds are characterized by their low depth, total penetration of light into the water, possibility of occurrence of plants throughout their area and absence of water stratification, and may originate from natural, geological or ecological processes, or, more commonly, as a result of human activities, intentional or not.

Ponds are true habitats, as many plants and animals have evolved for millions of years to adapt to the conditions of survival of the ponds and are currently dependent on this type of habitat for their survival.

Charco presents itself as a natural-based solution that acts in water management in several dimensions:

- Ensures the establishment of an aquatic ecosystem
- Ensures the availability of water (for fauna and flora)
- Promotes biodiversity
- Increases permeable area
- Boosts water infiltration into the soil
- Reduces the need for water for watering

In environmental terms it has multiple benefits and advantages in areas such as:

- **Biodiversity** – Many aquatic and animal plants (such as amphibians and macroinvertebrates) are totally dependent on these habitats to survive or reproduce. These bodies of water also provide food and refuge for numerous terrestrial species.
- **Freshwater reserve** – on a terrestrial scale, ponds around the world account for about 30% of the world's freshwater surface, making it an excellent tool in local water management.
- **Carbon sink** – Ponds collect and store large amounts of carbon dioxide (CO2) from the atmosphere, helping to regulate the climate.
- **Primary productivity** – Ponds have a high primary productivity (amount of organic matter produced by algae and plants from solar energy), constituting very important means of input and transfer of energy to higher trophic levels and surrounding ecosystems.
- **Environmental services** – Ponds perform important environmental functions, such as softening the effect of floods, maintaining soil moisture in dry periods, purifying water, and supplying underground aquifers. In addition, they play an important role in oxygen production, nutrient cycle, and soil formation.
- **Agriculture** – In traditional agricultural systems, ponds have important functions as drinking fountains for livestock and associated with irrigation systems.
- **Pest control** – Some species that occur in ponds, such as amphibians and dragonflies, help control agricultural pests or disease vector insects.
- **Landscape value** – The ponds and ponds have an important aesthetic and landscape value, creating water mirrors, which constitute spaces of contemplation and are indispensable elements in modern parks and gardens.
- **Educational value** – The ponds are important educational resources and in the context of ecotourism, because they allow the realization of numerous activities of a playful-scientific nature, such as the observation of birds, amphibians, and other animals.
- **Scientific value** – Ponds are places of study of excellence for numerous areas of science, such as biology, geology, and hydrology. In addition to the biodiversity of the ponds and their ecology, nutrient cycles, among others, the sediments of the ponds can also provide important information about the history of the environment.

Structure of a Pond

- **Flooding zone** – The water level of the ponds is subject to frequent variations and high intensity. In rainy winters, the water level can rise well above its normal margin, causing flooding of the surrounding area.
- **Margins** – The margin of a pond is defined by the boundary between the dry land and the flooded area of the pond. Although the margin moves according to variations in water level, it is in this interface zone where most emerging plants occur.
- **Shallow water zone** – Most species present in ponds live in areas where water is often less than 10 cm deep. These areas can be favoured by the existence of soft slope margins and irregularity of the topography of the bottom of the pond.
- **Deep water zone (flooded zone)** – This is the deepest and most flooded area for the longest time in the pond, being the area where the most underwater plants are found. It is generally thought that deep water areas are an essential component to the success of pond wildlife.
- **Pond benthos** – The bottom of the pond is especially important because it houses a wide variety of microorganisms, invertebrates, and plants, also serving as a place of posture for several species.

The ponds present themselves as an interesting solution when located in productive land, such as small family farms or urban gardens, favouring the infiltration of water in the soil and improving the availability of water in the soil, reducing the need for irrigation, contributing to the nutrient cycle, promoting biodiversity and fixing pollinators and also in pest control.

For greater efficiency and sustainability of the pond as NBS, it should be fed with the use of rainwater collected in the green roofs (increase the rainwater catchment area) and present the following constructive characteristics of a **mBiGPond**:

- Total area between 9 to 15m^2;
- Depth between 0.7 and 1.20m;
- Waterproofing screen in the bottom (to ensure a depth between 0.50 and 0.90 m);
- Construction of a deceleration basin of the speed of the water collected in the roofs;
- Construction of a water discharge zone in case of flooding (avoid flooding of surrounding land);
- Application of preventive water supply point in order to avoid total water loss in periods of prolonged drought.

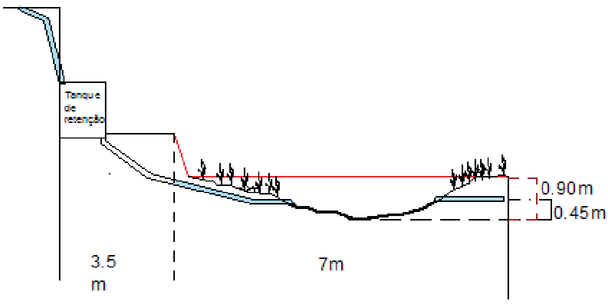


Figure 34. Transversal scheme of the mBiGPond prototype

7. SELECTION CRITERIA

A selection tool is developed to support in the initial analysis for identifying main mBiG NBS that can be applied in schools or social buildings. This tool is thought to be built in a co-development process which will involve different levels of stakeholders, experts and mBiG partners.

- **Stage 0 Identifying stakeholders.** The stakeholders' profiles are identified whom will be the potential users of the **mBiGTool**. This group is quite important in order to build an intuitive tool which fits with the needs of the end user. Experts, school principals, teachers, students, parents, citizens, workers, and managers of public buildings, can be part of this group. However, focused on the scope of the project, the most relevant stakeholder group is the school and/or residential building managers. They are the most likely user profile, since they are the ones who know first-hand the needs of their building and its users and the main issues in executing the interventions. In addition, they are users connected with the authority to request the interventions, so it is essential that they have this support tool for decision making.

Final Stage 0 Output: Stakeholders list.

- **Stage 1 Co-definition process.** Stakeholders play a crucial role in this process, by identifying criteria that will be included in the **mBiGTool**. The aim is to develop a simplified and intuitive list of challenges and barriers/enablers. In both cases, the process is quite similar: firstly, mBiG partners elaborate a technical list, then this list is asked to complete by the stakeholders, and they re-formulate the list in a more intuitive mode.
    - **Stage 1A Co-defining challenges.** MBiG expert partners developed agreed during a co-development process, based in their expertise.

Table 6. Challenge icons.

Challenge	Icon	Challenge	Icon
Carbon sequestration		Local climate regulation	
Air quality regulation		Maintaining populations and habitats. Biodiversity.	
Water treatment and management		Renewable energy production	
Carbon neutral cities		Soil formation and composition	
Flood protection		Erosion prevention	
Pest and control disease			

Then, the list is put in common with the stakeholders in order to:

- **Validate challenges**. Stakeholders are asked to evaluate their agreement with the challenges in terms of their relationship with the reality of their school or building. They can invalidate those that do not correspond to a plausible need in their environment or validating those that do.
- **Re-define challenges**. Although some challenges be validated, they might need a redefinition in order to achieve a better adaptation to the reality of the environment or a better understanding of the concept.
- **Create new challenges**. Stakeholders take a relevant role in the identification of new challenges that have not been presented by the MBiG experts but responds to a real need identified by the members of the community within the school or building.

Output: Challenges list.

- **Stage 1B Co-Identifying Barriers.** In parallel, stakeholders will also co-identify the different barriers and enablers that constrain the implementation of NBS within the building. Together with mBiG experts, they will build a comprehensive and categorized list of barriers which impact whether a positive or negative way in the implementation process of the NBS.

Output: Barriers and enablers list.

- **Stage 2 Co-creation process.**
    - **Stage 2A Co-creation NBS vs Challenges.** NBS experts will put in common the Challenges list with the mBiG NBS list. The objective is to evaluate the relationship between each challenge with each NBS. As a result, a relational matrix NBS vs Challenges will be produced that will serve as a calculation module for the **mBiGTool.**

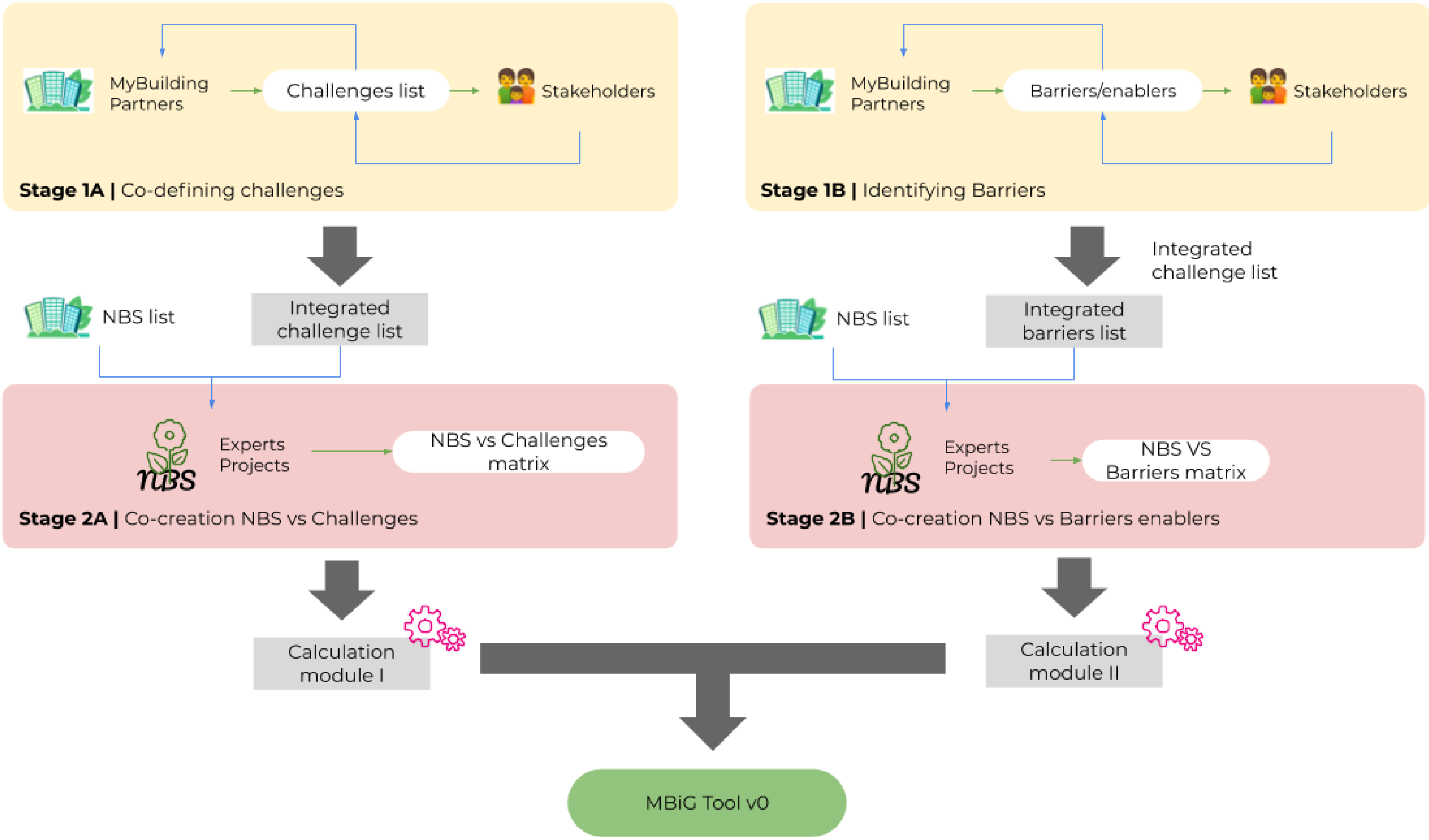
Output: Calculation Module I.

- - **Stage 2B Co-creation NBS vs Barriers enablers**. NBS experts will put in common the barriers and enablers list with the mBiG NBS list. The objective is to evaluate the relationship between each barrier (positive or negative) with each NBS. As a result, a relational matrix NBS vs Barriers will be produced that will serve as a calculation module for the **mBiGTool**.

Output: Calculation Module II.

*Final Stage 2 and 3 Output: **mBiGTool** _v0*

A workflow of the development of Stage 2 and 3 is shown in the next page.


MyBuilding Partners
Challenges list
Stakeholders
Stage 1A | Co-defining challenges
MyBuilding Partners
Barriers/enablers
Stakeholders
Stage 1B | Identifying Barriers
Integrated challenge list
NBS list
Integrated challenge list
NBS list
Integrated barriers list
Experts Projects
NBS vs Challenges matrix
Stage 2A | Co-creation NBS vs Challenges
Experts Projects
NBS VS Barriers matrix
Stage 2B | Co-creation NBS vs Barriers enablers
Calculation module I
Calculation module II
MBiG Tool v0

8. TECHNICAL INFORMATION ON SELECTED NBS

This chapter summarizes the technical information on the Nature Based Solutions (NBS) implemented in the three pilot buildings of the mBiG project. This information is related to action A2.3 “Elaboration and writing of technical projects”. The complete technical projects can be found in annex 3 “Constructions projects in pilot buildings”.

The selected Nature Based Solutions and their related information have been grouped into 7 projects or categories:

8.1 Plant species adapted to climate change. Analysis and selection criteria

This category does not include any NBS itself but it is very relevant to choose the best options in the other categories of NBS projects.

The selection of plant species has been made for exterior areas, façades and rooftops, including the following plant families: *Asteraceae*, *Crassulaceae*, *Fabaceae* and *Lamiaceae*.

Extended information about plant species adapted to climate change can be found in the deliverable C2.2 “Guide to the choice of plant species adapted to climate change”.

8.2 NBS applied in façades and indoor load-bearing walls

CEIP Gabriela Mistral: a light metallic structure has been built to protect the EAST façade from the sun. Over this structure, two NBS have been implemented:

- mBiGFAVE 1: this system foresees the insertion of plant pots in two directions: parallel and perpendicular to the façades to allow the growing up of climbing plants, generating shadow between holes and protecting the façade from the sun.

- mBiGFAVE 2 / mBiGToldo: continuous surfaces arranged in racks on which suitable species grow superficially. These systems have no organic substrate, but mineral or inert substrate, where hydroponic irrigation is needed (the water incorporates the nutrients).

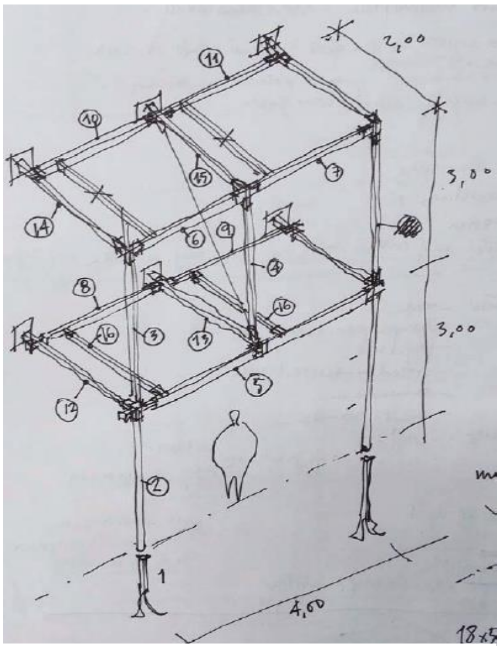


Figure 355. Scheme of FAVE systems © DIPBA

Indoor Green Wall: in a corridor of CEIP Gabriela Mistral where very high temperatures are usually achieved has been implemented a green wall with a broad variety of plant species to increase the student comfort in this room.

EB1 Falcão: implementing a steel cable wall covered by a deciduous vine (mBiGFAC) was suggested to reduce the temperature.

The selected species is *Parthenocissus tricuspidata* because it is fast-growing, losing its leaves in winter so that light can enter and heat the space being more energy-efficient.

This species changes its tonality throughout the year, adding beauty and dynamism, transforming the landscape of the place with the seasons.

The vine is placed every 60 centimeters, 3 meters along the façade, in a 50-centimeter wide bed, supported by squares connected to the upper area of the facade from which stainless steel cables with a thickness of 6 millimeters and length of 6 meters fall.

Due to the small size of the plot, the irrigation was implemented using a drip system.

EB1 Horta das Figueiras:

- mBiGToldo: the system consists of a waterproof sheet on which a non-woven felt adheres and on which a seeded substrate is projected. Due to the low thickness of the substrate, hydroponic irrigation is integrated and this is distributed by gravity through its surface. In the lower area, there is a channel for collecting excess irrigation that is returned to the irrigation station. The species of plants that will be used are *Festuca rubra, Agrostis estolonifera, Sagina subulata* and *Cymbalaria muralis*.

- mBiGFAC: this system is based on the implementation of tensioned steel cables set in a 2-meter high steel frame gantry, and attached to the building. Climbing plants will be laid along each of these cables and planted in beds at pavement level. This element, when the vegetation has grown, will act as a kind of green mantle leaning over the façade, producing shade, both on the façade and on the exterior floor of the building.

8.3 Sustainable and bioclimatic roofs

CEIP Gabriela Mistral: in this school, there will be three roofs with different implemented NBS:

- mBiGCUVE 1: systems applied over the existing roof to create an air chamber between the current gravel roof and the implemented system. In this way, the current "hot" roof has become a "cold" roof. Racks supported on raised "plots" have been arranged, on which to place removable "trays" that house a thin, extensive covering solution, with an improved substrate and with native species suitable for said thickness. Modular racks and trays that take advantage of the commercially available material have been used, modulating the elements at 150 cm, 300 cm, 450 cm or 600 cm, with widths of 100 cm or depending on the measurements of the tray system.

- mBiGCUVE 2: this system is a variety of the previous one. In this case, the racks include bigger containers in extreme and intermediate positions to allow the plantation of similar species to those used in the mBiGFAVE prototype (climbing plants). The use of deciduous plant species can be avoided to reduce the maintenance effort for this solution.

- mBiGCUVE_SUS: this system adds the use of a more sustainable substrate that includes recycled aggregates to perform the roof drain. In this case, the gravel and the geotextile used to protect the external thermal insulation are removed.

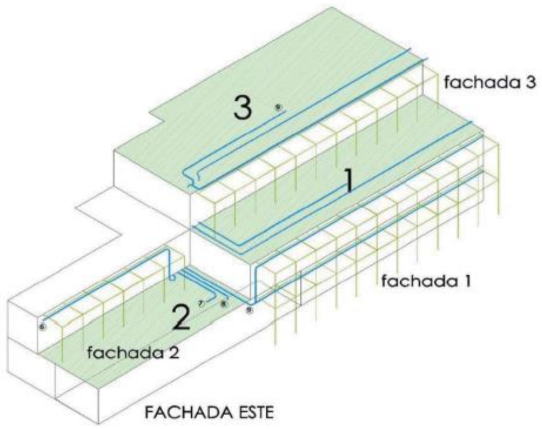


Figure 366. Roof location in CEIP Gabriela Mistral © DIPBA

EB1 Falcão:

- mBiGUL: the GUL roof will be installed with the innovative green roofing system with an expanded cork agglomerate (ICB). The cork agglomerate, 8 cm thick, will perform the functions of draining excess water, thermal insulation, waterproofing protection and acoustic insulation. This system captures carbon in its production cycle by using cork as a building biomaterial.
  The substrate profile will be 12cm and herbaceous species will be planted in alveolus, a planting strategy aimed at promoting biodiversity in the green cover. Perimeter strips of gravel 30 cm wide will be installed.

- mBiGBioSol: this is a system that combines the installation of solar panels with the existence of vegetation. The substrate profile will have a thickness of 10 cm, where a pre-cultivated *Sedum* carpet (mBiGSECAR) will be installed. Perimeter strips of gravel with variable widths between 22 and 30 cm will be executed.
  The inclusion of solar panels will be carried out through solar bases with ballast, without drilling the slab, guaranteeing its water tightness. The ballast will consist of 7 cm of river gravel.

- mBiGSECAR with mBiGPond: sloping green roofing will be carried out using the green roofing system up to 20º of inclination, which includes supports to be installed along the lowest point of the roof. The substrate profile will measure 10 cm and it will be filled with a pre-cultivated carpet of the *Sedum* genus.
  The excess of water from the roofing system will be sent to a water tank.

EB1 Horta das Figueiras:

- mBiGWTray: the system is composed of a multi-layered tray to maintain the vegetation of the roof encapsulated with a white waterproof sheet to collect rainwater and reduce water loss. The installation of auxiliary irrigation is not required. In this solution, the used plant species will be from the *Sedum* genus and they will comprise a density of 16 plants/m2.

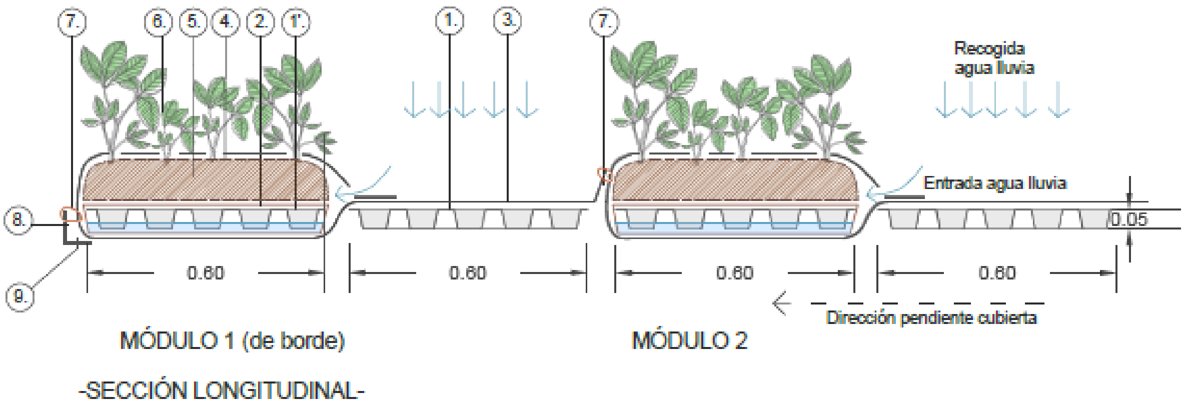


Figure 377. Scheme of mBiGTray module

8.4 Green sustainable outdoor areas

CEIP Gabriela Mistral & **EB1 Horta das Figueiras**: they foresee the plantation of trees in the game areas of these schools. The selected trees must be native species and own a high adaptation capacity to climate change. The selection has been made by experts from the Royal Botanical Garden.

EB1 Falcão: the waterproofing of a pond will be carried out through the placement of a geotextile screen to prevent the waterproofing screen from breaking. The water coming from two roofs of the Falcão School, one with vegetation and the other without it, will be sent from the retention water tanks to lower levels where the pond is located.

The vegetation proposed for this area owns phytoremediation characteristics, thus it will help to maintain the quality of the water that will infiltrate into the soil.

This space will create an important biodiverse area, where plants with riparian characteristics will appear and it will be colonized by small amphibians and insects.

Both spaces will be areas of excellent learning opportunities for the Falcão school students, as they will be able to observe the natural dynamics present in this project, the change and cycles of nature, the proliferation of new wildlife in the pond area and the reduction of temperature in the near environment and inside the student rooms.

8.5 Induced natural ventilation

CEIP Gabriela Mistral: five automatized windows with programmable opening and closing have been implemented to allow the circulation of fresh air in the school during night hours.

8.6 Structure for seasonal shadowing

CEIP Gabriela Mistral:

- PEVE (in Spanish PÉrgola VEgetal): it is a system similar to mBiGFAVE but thought to provide shadow in open outdoor spaces. It is a removable modular substructure made with hot-galvanized tubular steel. The approximate dimensions of each module are 2 m wide and 3 m high. The system uses climbing vines to create horizontal shadows and perpendicular vegetable screens. PEVEs have been placed in the parent's waiting area and in the children's playground.

- A game area has been paved, including an area with terraces covered with a wooden structure providing shadow to students. In this area, the SUVE has been implemented as will be explained in the next NBS category.

EB1 Horta das Figueiras: there has been a collaboration with the EcoTimberCell LIFE project to implement a wooden structure developed for this project or a similar one. This structure will provide a shadowed outdoor space for students.

8.7 Permeable surfaces

CEIP Gabriela Mistral: as has been mentioned in the previous NBS category, a permeable surface has been implemented in this school. It has been called SUVE (in Spanish SUelo VEgetal). This surface increases the infiltration process of rainwater in soil and allows the proliferation of natural vegetation in the area.

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10. APPENDIX

This document includes three annexes. Annex 1 is an excel document (Annex 1) that summarizes a set of parameters that allows to draw comparisons between the various solutions. Annex 2 is a document that presents a more complete description and some specific design details about prototype NBS solutions that have been used during implementation definition. This Annex 2 is the initial version of the deliverable "C2_2 Manuales Técnicos para la implementación de prototipos de NBS en las diferentes estructuras de los edificios piloto." Annex 3 is a zipped folder including the construction projects for the three pilot building of the project.