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

NBS prototypes

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

Deliverable: Elaboration of NBS databases and work matrix

Date: 31/12/2019

1. ANNEX 1. mBiG NBS prototypes

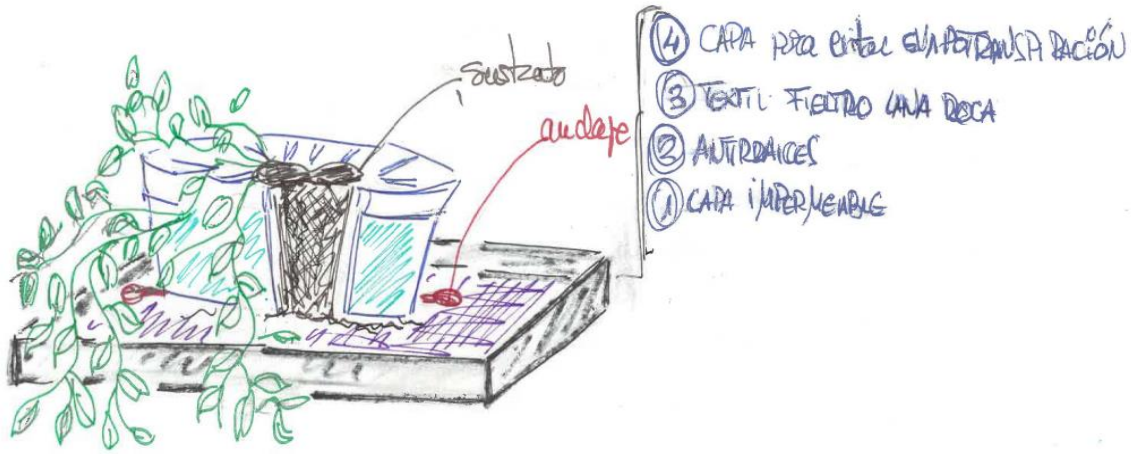
This annex presents detailed information about mBiG prototype NBS classified into three categories: rooftops, façades and outdoor space.

ROOFTOPS

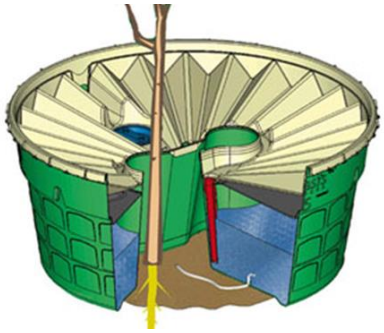
1. **mBiGBOX**. Prototype for roofs using containers with water reservoir.

General description

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.



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:
    - 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.

Dimensions

600x600x350mm and the high of the vegetal layer.

Weight

Around 60kg/m^2 (soil saturated with water).

Around 7kg/m^2 (dried soil).

Sustainability

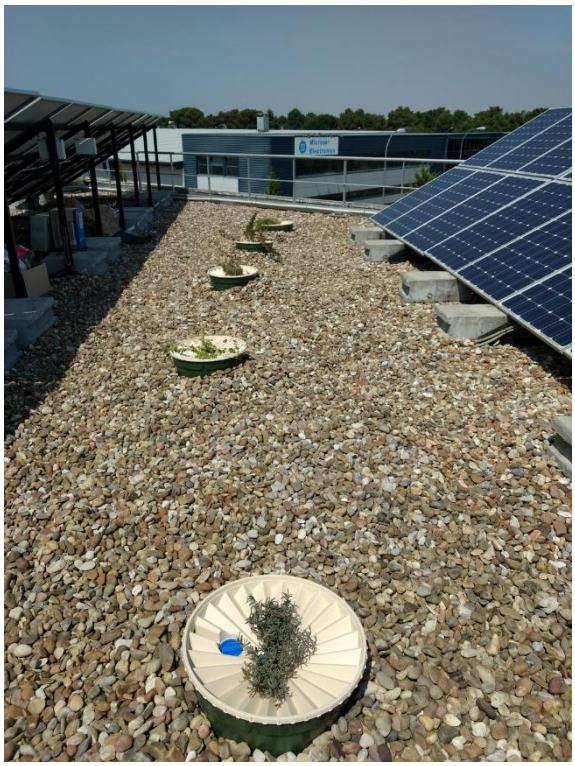
Work is being done to improve the sustainability of the solution in terms of the materials to be used.

- WATERBOXX® material is polypropylene that although it can be recycled (thermoplastic polymer) the current recovery and recycling rate is relatively low. As an alternative, work is being done to build this component from recovered tires.
- The material used as a light substrate is currently being evaluated. From the available materials, the most suitable would be sheep wool and its use will be prioritized according to availability and cost.

Related to maintenance operations, the sustainability of this solution is very high as it does not require irrigation, requires minimal interventions to manage the vegetation and help manage rainwater.

First attempts

System pictures during implantation.



SPECIFICATIONS (Roof 4x5m 20 m^2)

The roof would have 36 units of the system (density 1 module per 0.55m^2).

-	Waterproofing sheet PVC PNIS05ea (1,5mm) (8,83 €/m2) [1]	176,60€
-	Drainage layer Danodren R-20 o similar (7,29€/m^2)[2]	145,80€
-	Safeguard root barrier polyester CQEC02a[3] (2,51€/m2)	50,20€
-	Roots development layer Sheep wool 10cm[4] (11,7€/m^2)	234,00€
-	Vegetal substrate mBiG 100L (XX€/L)	
-	Plants	
-	Vegetal container with water reservoir[5] (20€/unit) 36 units	720,00€
-	Perimeter finishing 51cm CQEC50a[6] (20,16€/m lineal)	362,88€
-	Corner pieces CQEC61a 4 unidades[7] (15,46€/unidad)	61.84€
-	Labour (17horas) (37,56€/hora)	638,52€

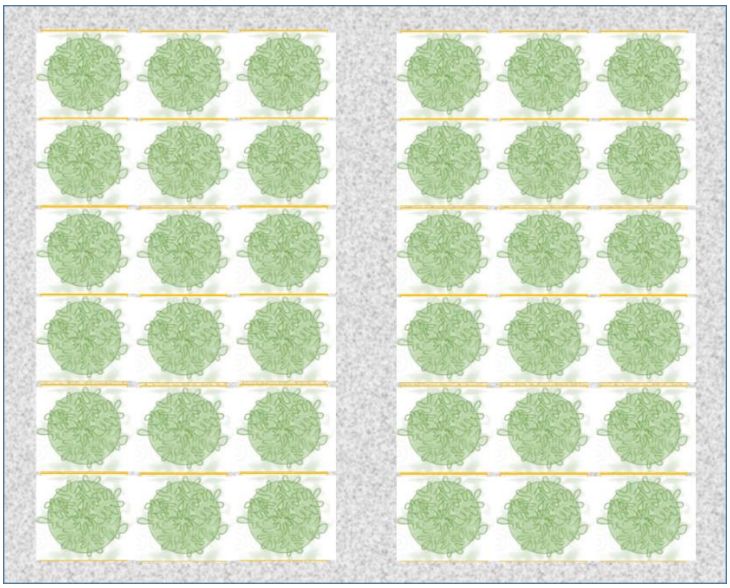
Commissioning

[1] Supplier budget basepaisajismo.com.
[2] http://www.danosa.fr/danosa/CMSServlet?node=desc_tarifa&lng=1&site=1
[3] https://basepaisajismo.com/Paisajismo_WEB/#uno.CQEC02a
[4] www.rmtinsulation.com
[5] https://accreviri.com/tienda/
[6] https://basepaisajismo.com/Paisajismo_WEB/#uno.CQEC50a
[7] https://basepaisajismo.com/Paisajismo_WEB/#uno.CQEC61a

The commissioning would take two phases. A first phase of implantation of the plant in the system that must be carried out at least 3 months before its installation to correct mistakes and ensure a good rooting. Each vegetable container with cistern covers an area of 0.4m2 (module 0.6x0.6m).

MOOC03a[8] h labour 1ª 20,09€/h

MOOC05a h Labour 17,47€/h



[8] https://basepaisajismo.com/Paisajismo_WEB/#cap.MOOC

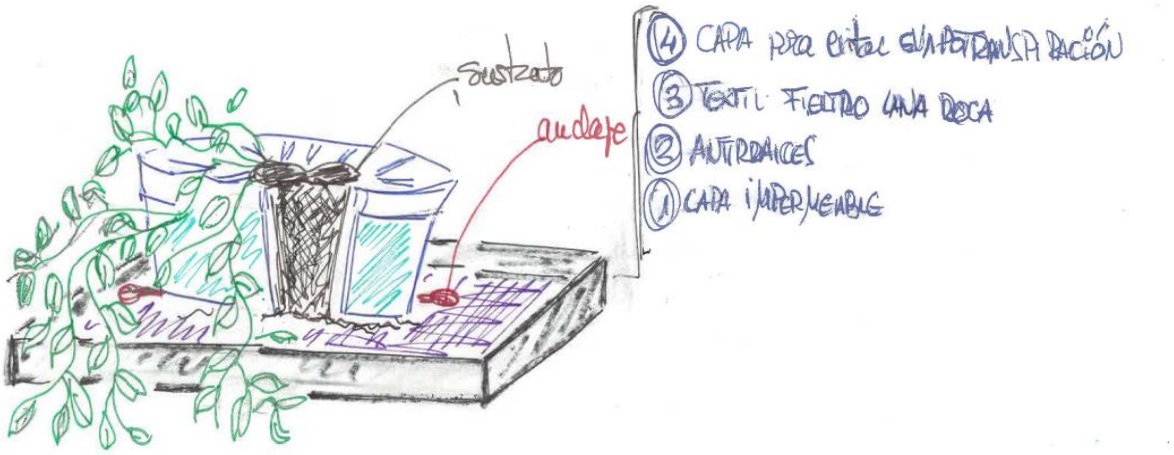
2. **mBiGBOX_Ex**. Prototype for roofs using containers with water reservoir and an extensive green roof.

General description

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.

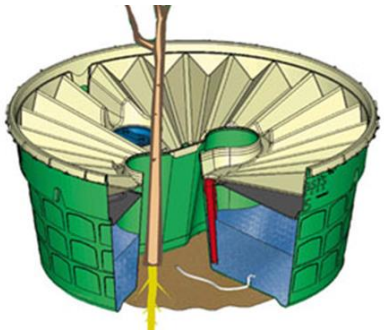


The implantation density of the mBiGBOX system is one unit per square meter and the rest of the roof will be made based on an extensive green roof. The green roof on which it rests would be an extensive green roof of 8 cm of substrate to house sedum vegetation. The roof will have a draining nodular sheet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

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 reser 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.

Dimensions

It covers the entire roof and the height depends on the size of the plants chosen for the container.

Weight

Around 60kg/m^2 (soil saturated with water).

Around 7kg/m^2 (dried soil).

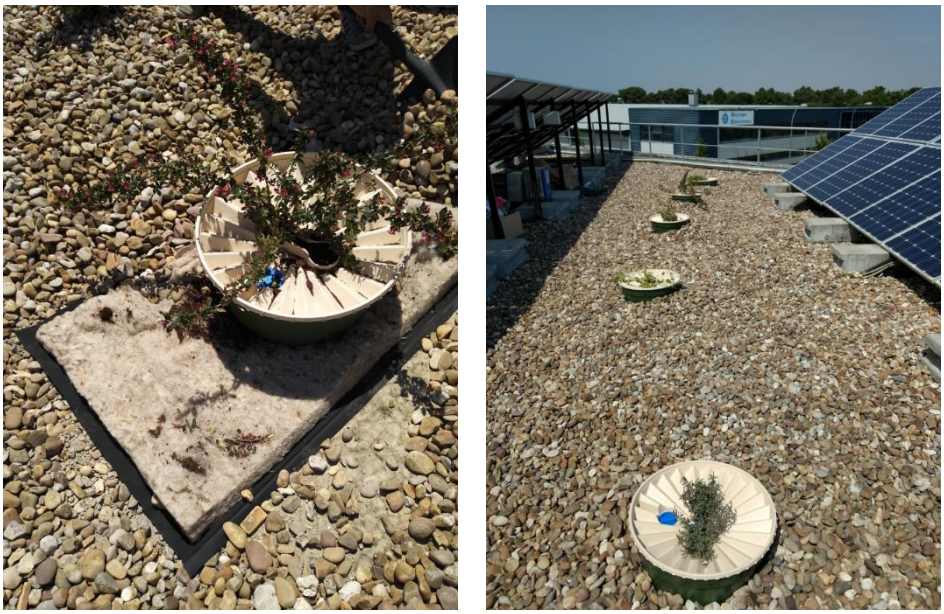
Sostenibilidad

Work is being done to improve the sustainability of the solution in terms of the materials to be used.

- WATERBOXX® material is polypropylene that although it can be recycled (thermoplastic polymer) the current recovery and recycling rate is relatively low. As an alternative, work is being done to build this component from recovered tires.
- The material used as a light substrate is currently being evaluated. From the available materials, the most suitable would be sheep wool and its use will be prioritized according to availability and cost.

Related to maintenance operations, the sustainability of this solution is very high as it does not require irrigation, requires minimal interventions to manage the vegetation and help manage rainwater.

First attempts



System pictures during implantation (only WATERBOXX® system).

The combined installation with an extensive green roof would prevent the installation of these lower layers shown in the figure. Only the wool layer would be necessary to improve the root development of the plant.

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

SPECIFICATIONS (Reference roof 20x15m 300 m^2)

The green roof would include 300 or 150 units of the system (density 1 / 0.5 module WATERBOX® or similar per m2).

- Anti-puncture geotextile layer 150gr/m^2 (whole surface).
- Safeguard root barrier HDPE de 800gr (whole surface).
- Anti-puncture geotextile layer 150gr/m^2 (whole surface).
- Drainage layer HDPE 2mm thickness and 6 l/m^2 water retention (whole surface).
- Retaining layer 500gr/m^2 (whole surface).
- Sedum plants 16plants/m2, B60.
- Roots development layer Sheep wool 50x50cm[9] (NITA-WOOL® batts or similar) one each container, 300 or 150 units.

[9] www.rmtinsulation.com / http://rmt-nita.es/esp/wool.php or similar

- Vegetal substrate mBiG for vegetal container with reservoir, 2 l/unidad (600 l o 300 l).
- Plants for vegetal container with reservoir, 300 ó 150 units.
- Vegetal container with reservoir [10] (20€/unidad) 300 units (1 u/m^2) o 150 units (0,5 u/m^2).
- Perimeter finishing 51cm CQEC50a[11] (70 metros).
- Corner pieces CQEC61a 4 unidades[12]
- Commissioning

The installation cost of this system would be around 100 €/m^2 for the option of 1 unit per square meter and around 90 €/m^2 for the option with 0,5 units per square meter (based on a price for the extensive cover base of around 70 €/m^2).

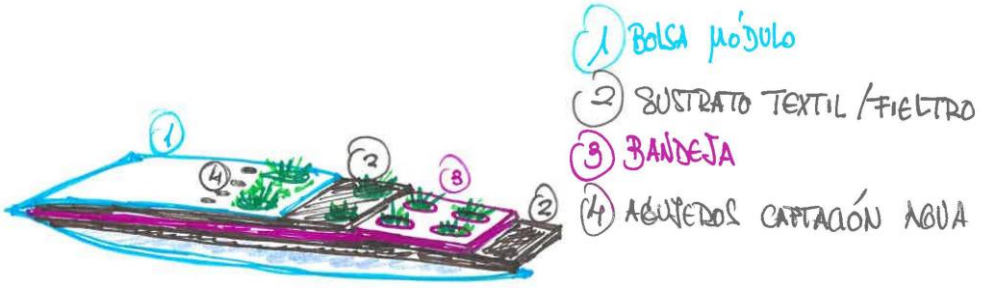
Following pictures are shown to visualize the installation density of the vegetable containers with 1 and 0,5 units per square meter of roof.

[10] https://accreviri.com/tienda/
[11] https://basepaisajismo.com/Paisajismo_WEB/#uno.CQEC50a
[12] https://basepaisajismo.com/Paisajismo_WEB/#uno.CQEC61a

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

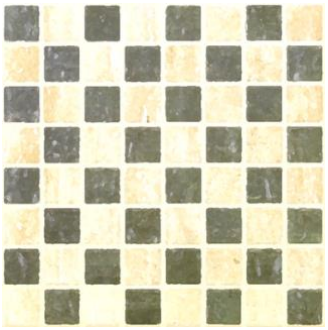
General description

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



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 checkered 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.

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 / m^2 and PVC less than half. In addition, the weight per m^2 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 nodulated 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.

- 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.

System costs

The system has been developed in trays of 1200x600mm dimensions. The estimated cost of the set for a roof of 100 m2 can be around € 125 per square meter.

Dimensions

Standard tray dimensions are 600x1200x100mm (plants height not included).

Weight

Around 120kg/m^2 (saturated with water)

Around 25kg/m^2 (dried)

Sustainability

Work is being done to improve the sustainability of the solution in terms of the materials to be used.

- The material of the outer bagging is polyvinyl chloride, PVC which although it can be recycled (thermoplastic polymer), the current recovery and recycling rate is relatively low[13]. Other alternatives are being sought using natural materials or, failing that, from recovered materials but it is not easy.
- Tray material is HDPE, polymer that is also recyclable[14] (thermoplastic) but other options are being evaluated although its replacement is not easy initially.
- The material used as a light substrate is currently being evaluated. Of the available materials, the most suitable would be sheep wool and its use will be prioritized according to availability and cost.
- Vegetal substrate will be bought locally.
- Plants will be bought locally.

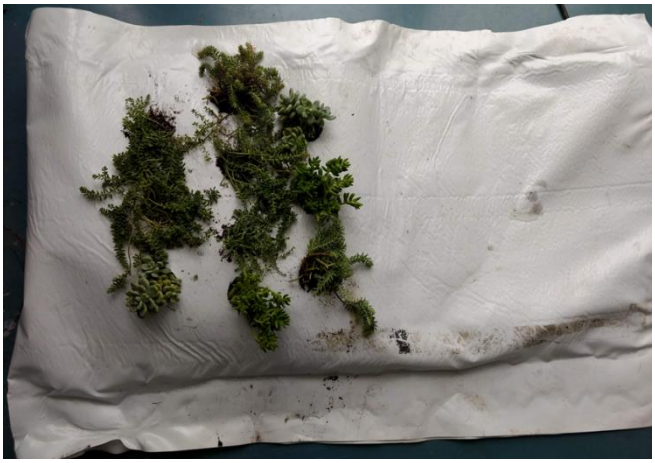
Related to maintenance operations, the sustainability of this solution is very high as it does not require irrigation, requires minimal interventions to manage the vegetation and help manage rainwater.

First attempts

Images of the first implanted system and one month later on the CARTIF roof. This prototype has not implemented the rainwater collection system that would consist of one holes in the centre of the tray that would allow rainwater to enter the interior of the tray.

[13] En el año 2016 se recicló en España el 4,6% del PP y en Europa el 4,2%. Fuente: https://www.plasticseurope.org/es/resources/publications/1240-plasticos-situacion-en-2018

[14] En el año 2016 se recicló en España el 5,5% del PP y en Europa el 5,0%. Misma fuente.



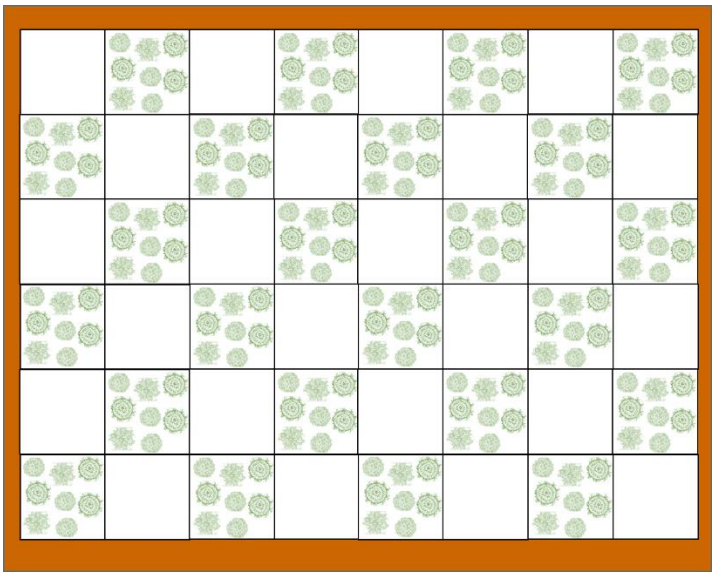
Specifications and estimated budget (Roof 100 m^2)

System density is 1 module each 2 m^2 . Whole roof with 50 units.

- Waterproof sheet PVC White
- Structuring layer: formed by a non-woven geotextile of high tenacity cut polypropylene fibres.
- Drainage and retainer layer. Nodular HDPE tray with expanded clay 50mm high.

- absorbent nonwoven textile
- Vegetal substrate mBiG
- Plants 16u/m^2, selected and locally adapted sedum
- Labour

- **Total (125€/m2) 12.500€**



4. **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. Taking into account 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, taking into account 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.

There are two alternatives for mBiGCUVE:

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.

mBiGCUVE 2: (From Spanish initials of CUbierta VEgetal) as a variant of the previous system, the racks would contain larger containers, at ends and / or intermediate points. In this case, the use of deciduous species will be assessed, taking into account that this kind of species have more maintenance requirements.

The specific design carried out for this project, the creation of a ventilated green roof, the modulation of the substructure, the possibility of mounting and dismounting, and adapting to any existing roof, converts the mBiGCUVE green shading system into a prototype, not previously marketed as such. On the other hand, the typology of buildings, public education and social services, has never been considered in the geographical context of the project or in these climatic regions of the EU for the implementation of green roofs or even any kind of NBS.

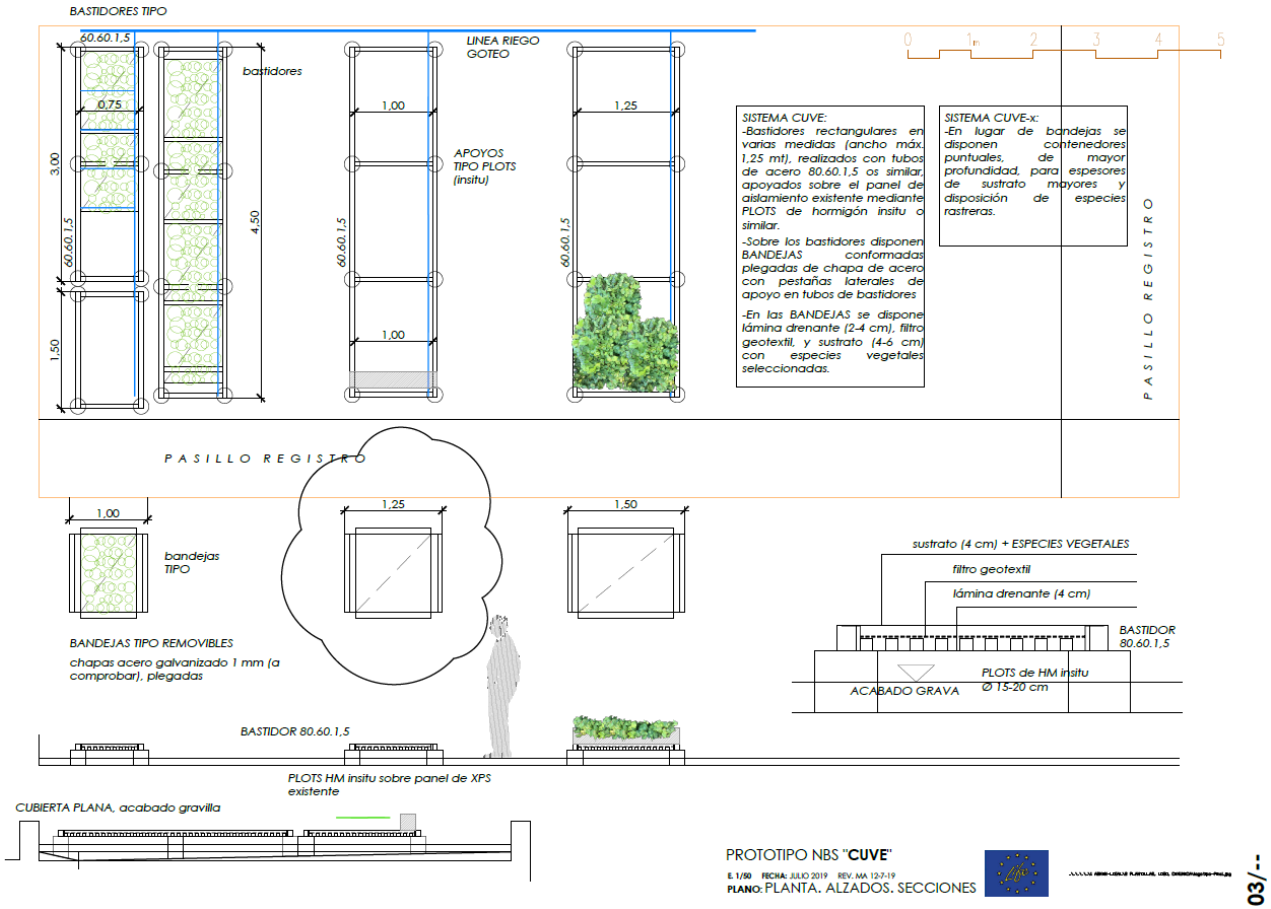
Regarding vegetal species selection, it must be consider that taking into account the maximum substrate thickness requirements, irrigation conditions and maintenance. The Royal Botanical Garden (CSIC) has selected the following species, including planting, acquisition and maintenance requirements:

Perennials: *Dianthus carthusianorum; Festuca Cinerea, Hybride Festuca cinerea híbrida; 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.*

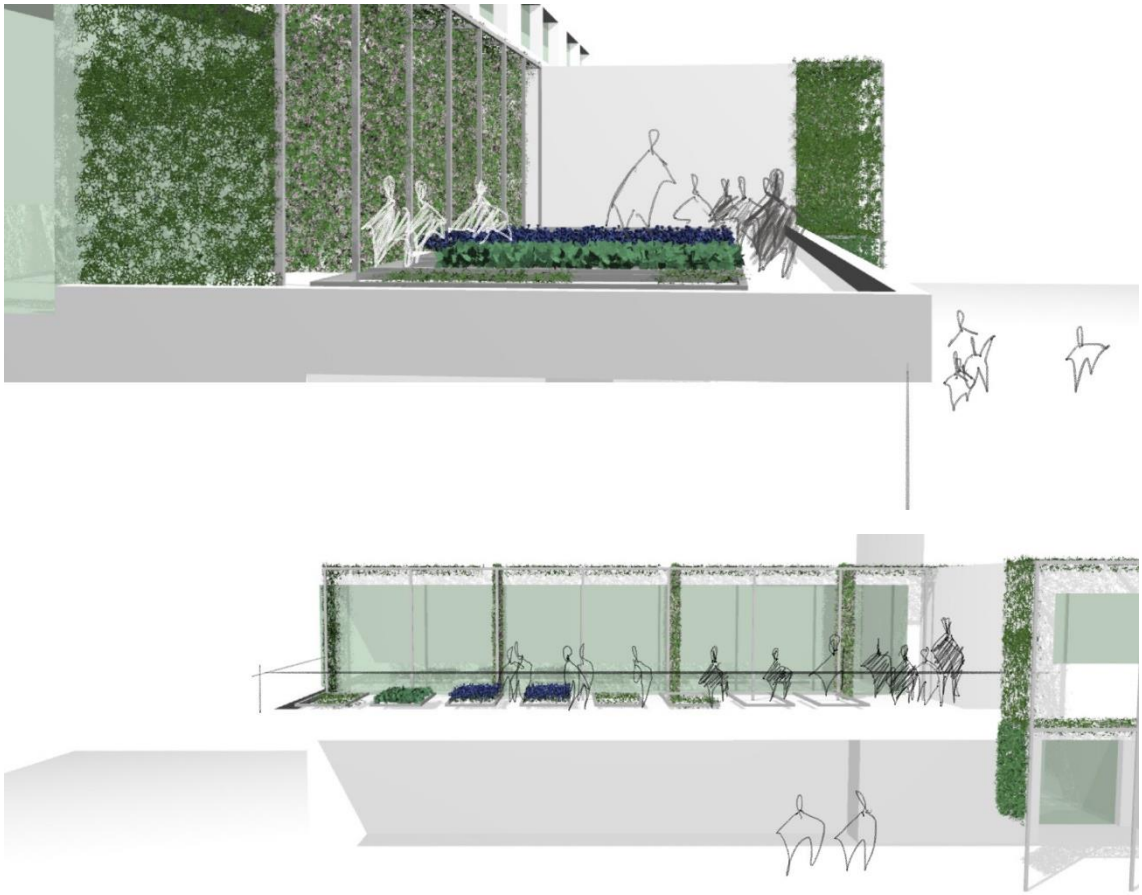
Dimensions

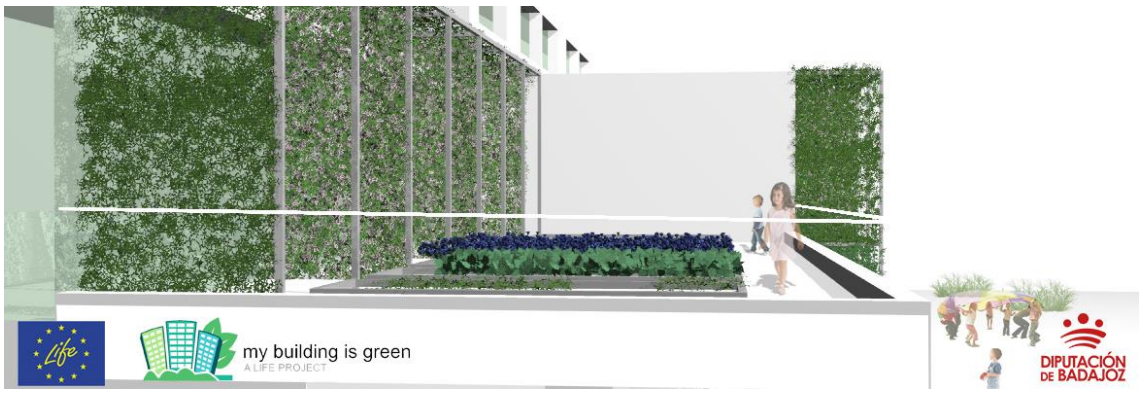
mBiGCUVE dimensions are shown in the following picture. Total dimensions can be modified to be adapted according to the installation requirements but module dimensions should be kept.


BASTIDORES TIPO
60.60.1,5
0,75
3,00
60.60.1,5
1,50
bastidores
4,50
LINEA RIEGO GOTEO
1,00
APOYOS TIPO PLOTS (insitu)
1,00
60.60.1,5
1,25
60.60.1,5
SISTEMA CUVE:
-Bastidores rectangulares en varias medidas (ancho máx. 1,25 mt), realizados con tubos de acero 80.60.1,5 os similar, apoyados sobre el panel de aislamiento existente mediante PLOTS de hormigón insitu o similar.
-Sobre los bastidores disponen BANDEJAS conformadas plegadas de chapa de acero con pestañas laterales de apoyo en tubos de bastidores
-En las BANDEJAS se dispone lámina drenante (2-4 cm), filtro geotextil, y sustrato (4-6 cm) con especies vegetales seleccionadas.
SISTEMA CUVE-x:
-En lugar de bandejas se disponen contenedores puntuales, de mayor profundidad, para espesores de sustrato mayores y disposición de especies rastreras.
0
1m
2
3
4
5
PASILLO REGISTRO
PASILLO REGISTRO
1,00
bandejas TIPO
1,25
1,50
BANDEJAS TIPO REMOVIBLES
chapas acero galvanizado 1 mm (a comprobar), plegadas
sustrato (4 cm) + ESPECIES VEGETALES
filtro geotextil
lámina drenante (4 cm)
BASTIDOR 80.60.1,5
PLOTS de HM insitu Ø 15-20 cm
ACABADO GRAVA
BASTIDOR 80.60.1,5
PLOTS HM insitu sobre panel de XPS existente
CUBIERTA PLANA, acabado gravilla
PROTOTIPO NBS "CUVE"
PLANO: PLANTA. ALZADOS. SECCIONES
03/--

Visual recreation of the solution

Following pictures show the visual recreation for the CEIP Gabriela Mistral School in Solana de los Barros in the province of Badajoz (Spain).





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

As the previous prototype system, 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. Taking into account 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, taking into account 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-SUS were easy to implement, modular, adaptable to any building, durable, accessible, compatible with the building, minor water requirements and more sustainable.

The improvements applied over the previous system mainly refer to the substrate. A new substrate has been formulated that contains a significant percentage of recycled aggregates from construction and demolition waste and a special formulation of the soil microbiota for use and to reduce the system's water needs.

Regarding configuration, as plane mBiGCUVE, mBiGCUVE-SUS can be mounted as:

mBiGCUVE-SUS 1 with the same characteristics than mBiGCUVE 1 (page 17 in this document).

MBiGCUVE-SUS 2 with the same characteristics than mBiGCUVE 2 (page 17 in this document).

The specific design carried out for this project, the creation of a ventilated green roof, the possibility of mounting and dismounting, and adapting to any existing roof, converts the mBiGCUVE green shading system into a prototype, not previously marketed as such. This system has several modications regarding previous system:

- This system has the particularity that it includes recycled aggregate to replace part of the components of the previous system. Firstly, the 4 cm thick draining sheet is replaced by a layer of recycled aggregate with a 5-10mm grain size.
- Anti-puncture geotextile layer 150gr/m2 (whole surface).
- 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.
- Additionally, substrate is co-inoculated with a fertilizing substrate with protists that are viable under the rooftop conditions. These protists should include heterotrophic strains

(for nutrient cycling) and autotrophic strains (for primary production). Here, we suggest increasing rapidly plant productivity by selecting heterotrophic and autotrophic protist strains from naturally arid environments.

Regarding vegetal species selection, it must be consider that taking into account 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 cinerea híbrida; 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.*

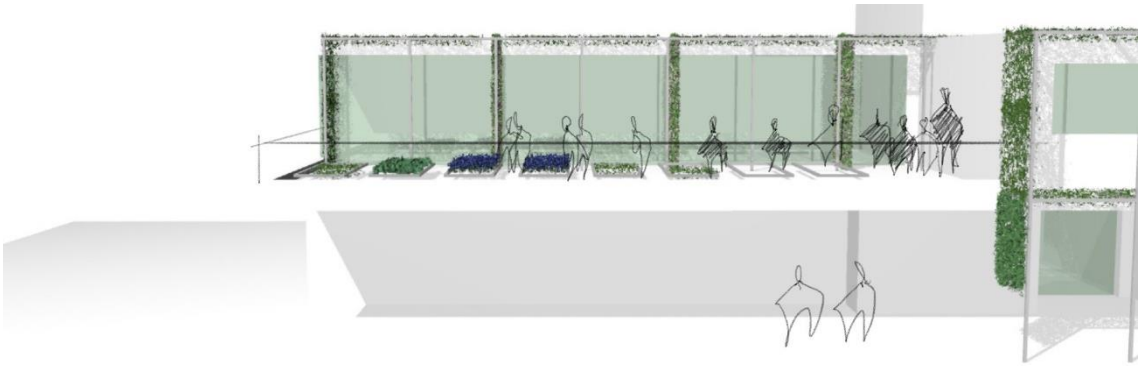
Sedum: *Album ,Acre , Reflexum, Sediforme, Rupestre, Ochroleucum, etc.*

Dimensions

mBiGCUVE dimensions are shown in the following picture. Total dimensions can be modified to be adapted according to the installation requirements but module dimensions should be kept.

Visual recreation of the solution

Following pictures show the visual recreation for the CEIP Gabriela Mistral School in Solana de los Barros in the province of Badajoz (Spain).



6. **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)[15] 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.

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

- 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.
- 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.

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.

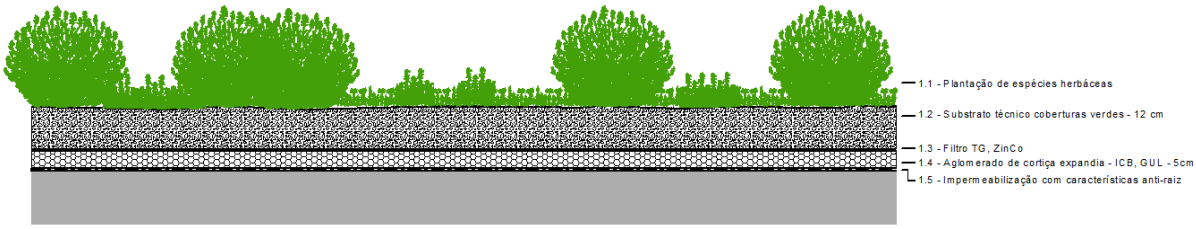
The GUL system was the inspiration to the development of prototype, mBiGUL (mBiG Green Urban Living based), will be applied in Porto's school, EB1 Falcão, and its main benefits to LIFE-mybuildingisgreen project are related to the system being:

- 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.

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.



Transversal section of the composition of the mBiGUL prototype.

7. . **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.

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.

Sedum Carpet in a rooftop. Source: LandLab.

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.

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).

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).

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

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.

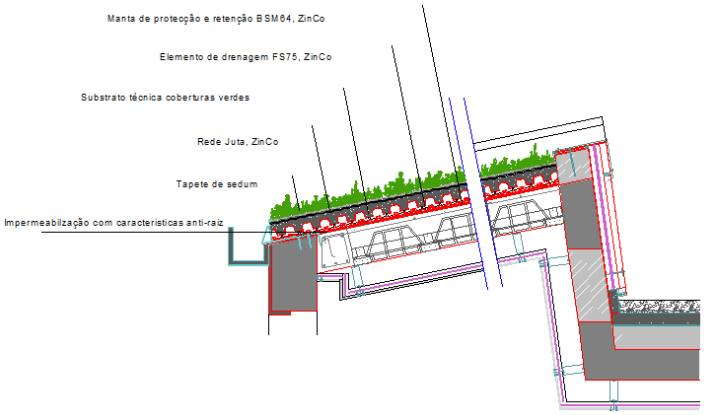
And main advantages:

- 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.



Transversal section of the composition of the mBIGSECAR prototype.

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

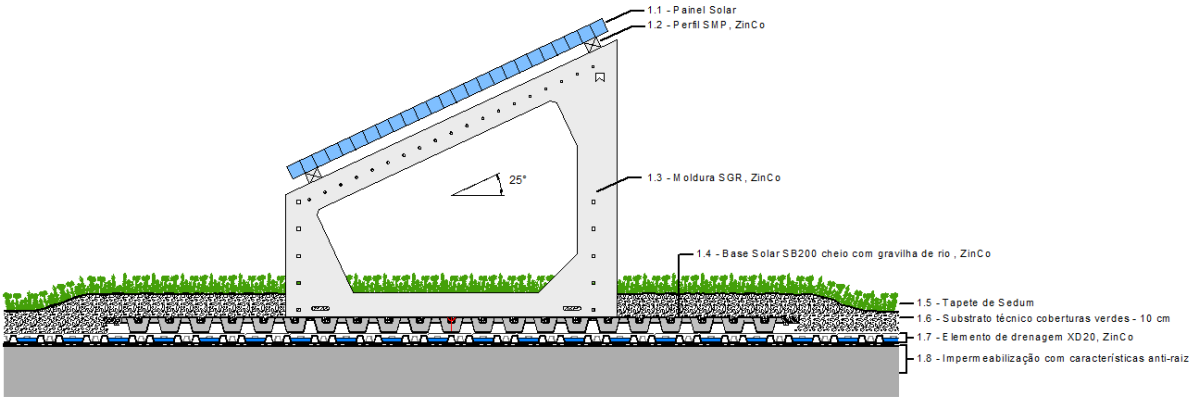
Bio Solar Roof is the combination of a green roof and a set of solar panels. In fact, the combination is not just a sum of benefits, but an almost perfect symbiosis between energy efficiency, biodiversity, and sustainable production. The installation of a green roof provides a

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 Solar 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.



Transversal section of the composition of the mBIGBioSol prototype

FAÇADES

1. **mBiGToldo**. Prototype for creating vertical green surfaces.

General description

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.

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 facade 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 and suggestions made by the Royal Botanic Garden.

Dimensions

2000x2000x20mm without vegetal species. This dimensions can be modified to be adapted according to the installation requirements.

Weight

The proposed module weight of 2000x2000x20mm with frame. The frame with a square section of 50x50,3mm would have an approximate weight of between 8-10kg (aluminium) and the awning (water saturated) would have a maximum weight of 40kg. The steel frame with the same dimensions would have a weight of approximately 30kg.

Sustainability

Work is being done to improve the sustainability of the solution in terms of the materials to be used.

- The material of the waterproof support is polyvinyl chloride, PVC which although it can be recycled (thermoplastic polymer), the current recovery and recycling rate is relatively low . Other alternatives are being sought using natural materials or, failing that, from recovered materials but it is not easy.
- The material used as a light substrate is currently being evaluated. Available materials could be non-woven textiles (PP), mineral wool and sheep wool. Of the available materials, the most suitable would be sheep wool and its use will be prioritized according to availability and cost.

Regarding to maintenance operations, the sustainability of this solution is moderate as it requires hydroponic irrigation for conservation under adequate conditions. However, the collection of leftover water and the integration of rainwater makes the system improve in this regard. The number of vegetation cutting and maintenance operations will depend on several factors that will have to be evaluated depending on the location of the system and the selected species. It will be evaluated during the Project.

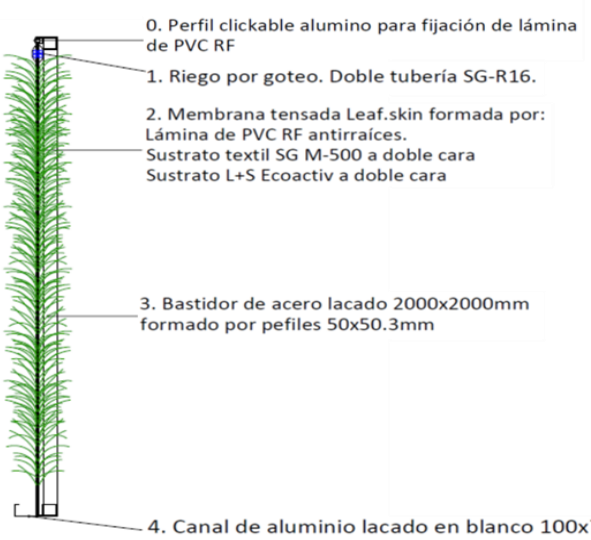
First attempts

SPECIFICATIONS (50 units 2x2m, 100 m^2)

The shading of the type facade would take 50 units of the system for a total of 100 m^2. Cost can be scaled by awning units.

- 2x2m lacquered aluminium frame with 40x40,4mm profiles
- Anchors in the corners of the frame for fixing to the FAVE system that allows modifying the installation angle with respect to the facade
- Waterproof sheet PVC FR 500gr/m2
- Double-layer polyester-acrylic nonwoven textile 3,8mm thickness, resistance 7,6kN/m, breaking strain 170kg
- Adhesion of the waterproofing sheet to the nonwoven textile by means of a specific adhesive for PVC with crosslinking additive
- mBiG Organic substrate adhered and seed species specially selected for the climate of the area
- Including installation of irrigation system by means of pipe of irrigation of drippers integrates two of 1,6l / h every 20cm.
- Connection to the irrigation system by means of 16mm polyethylene pipe with UV protection from the 25mm pipe to the dropper pipe
- Including lacquered aluminum channel for drainage collection.
- Commisioning

- **Total (250€/m2)** **25.000€**



Proposed anchoring systems

To fix the awning to the profiles, use a clip type profile of those available in the market.

2. **mBiGFAVE**. Prototype for creating vertical green surfaces.

General description

Shading of facades 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.

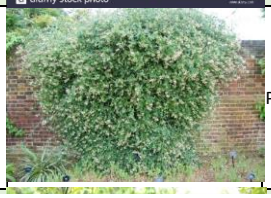
As main requirements, the prototype must aim the objectives of being easy to implement, modular, adaptable to any building, durable, accessible and compatible with the building.

It has been opted for the realization of systems superimposed on the facade 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 facade 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. Taking into account 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 FAcade). 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 facade by means of removable frames made with metal tubulars anchored to the facade at the level of floor slabs, and supported on firm ground by mass concrete manholes.

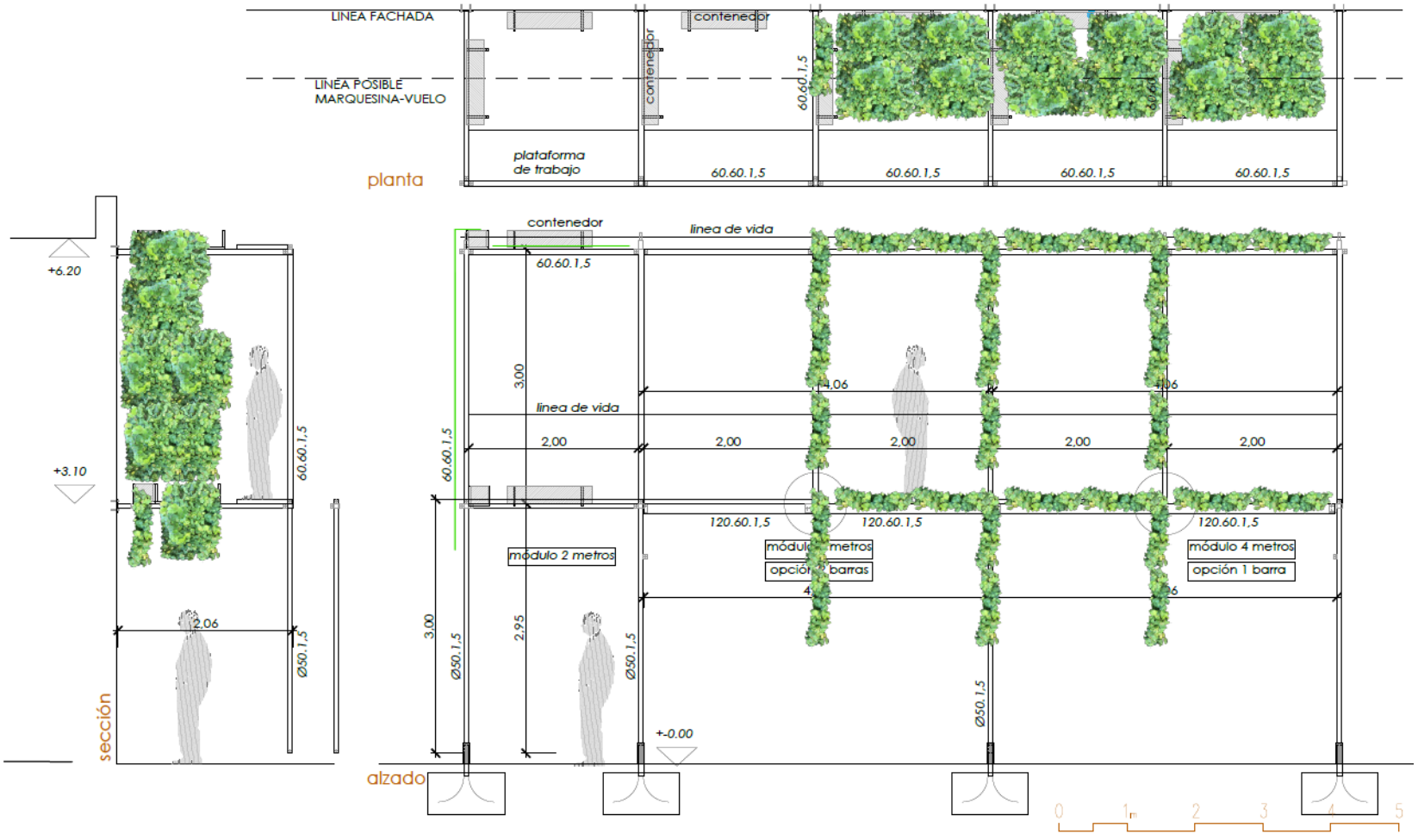
Regarding vegetal species selection, it must be consider that during winter time plant protections should allow sunlight to enter through the windows. Vegetal species must be deciduous and climbing. For instance, the Royal Botanical Garden (CSIC) has selected the following species, including planting,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

NOMBRE COMÚN	NOMBRE CIENTÍFICO	IMAGEN	CADUCA/ PERENNE	PROFUNDIDAD RECOMENDADA	SOL/ SOMBRA	CRECIMIENTO	RIEGO	OTROS
HIEDRA	HEDERA HÉLIX		PERENNE	80 CM	SOMBRÍA	20 mt		
JAZMIN SILVESTR	Jasminum fruticans		PERENNE / semicaducifolio	(50 cm)	SOL (4 H) / SOMBRA	1-2 mt		Abonado. Mediterráneo. Sotobosque encinares
JAZMIN COMÚN	Jasminum oficinale		PERENNE / semicaducifolio en algunos casos		SOL	6 mt. LENTO		Asia menor
JAZMIN ESTRELLADO	Trachelospermum jasminoides		PERENNE		SOL	10 mt		Importante guiarla
MADRESELVA ETRUSCA	Lonicera etrusca		CADUCA	70 cm	SOL/SOMBRA	4 mt		grandes macetas. Riego/abono
MADRESELVA Mediterránea	Lonicera implexa		PERENNE		SOL/SOMBRA			

PARRA	Vitis vinifera		CADUCA					
PARRA VIRGEN	Parthenocisus quinquefolia		CADUCA	50 cm	SOMBRA/SOL			nativa EEUU. espacio raíces
VIÑA DEL JAPÓN	Parthenocisus tricuspidata		CADUCA					nativa este Asia.espacio raíces
ajān /enredadera andaluza	CLEMATIS CIRRHOSA		PERENNE					
clemátide	CLEMATIS CAMPANIFLORA		PERENNE					sierra norte Andalucía. Sombra

Dimensions

FAVE dimensions are shown in the following picture. Total dimensions can be modified to be adapted according to the installation requirements but module dimensions should be kept.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planta
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+3.10
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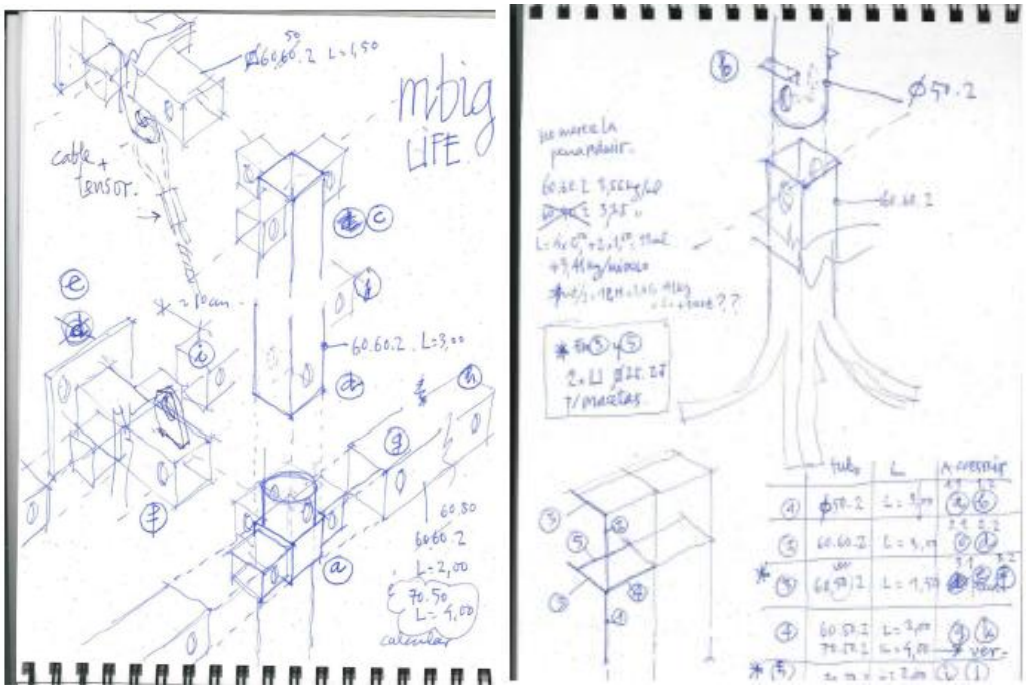


Weight

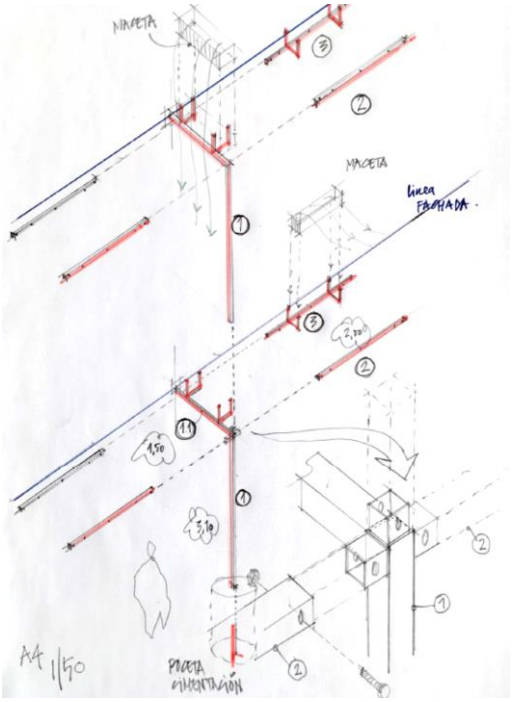
mBiGFAVE is a self-supporting solution.

Sustainability

Due to the mechanical and maintenances requirements, hot dipped galvanized steel has been the selected material.

Visual recreation of the solution

Following pictures show the visual reaction for the CEIP Gabriela Mistral School in Solana de los Barros in the province of Badajoz (Spain). In this case, mBiGFAVE has been designed for the East façade with vertical shadowing modules. mBiGFAVE designs for South façades would include horizontal shadowing modules.




MIGUEL ÁNGEL ANTÓN GAMERO
PROTOTIPO NBS "FAVE"
E. 1/50 FECHA: JULIO 2019 REV. MA 12-7-19
PLANO: PLANTA. ALZADOS. SECCIONES
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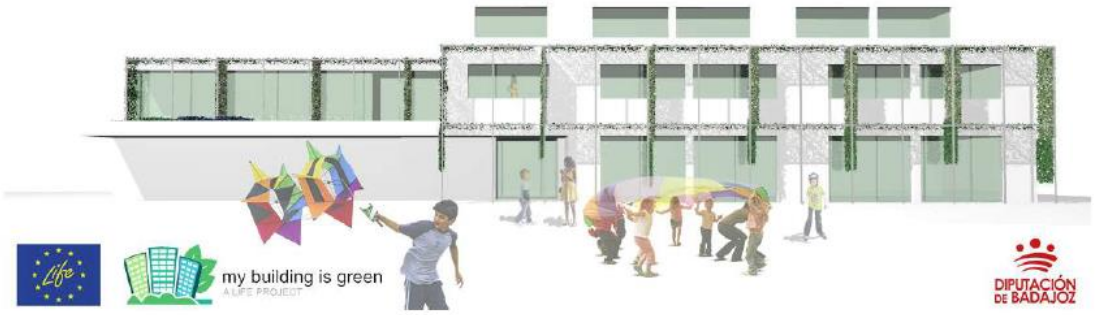
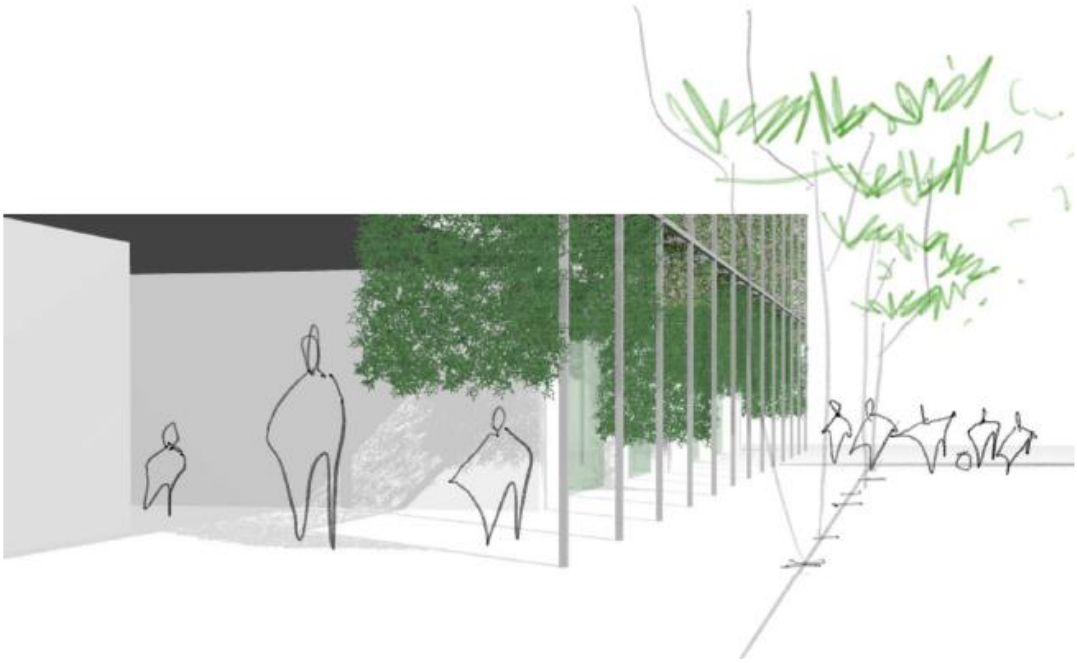




3. **mBiGFAC**. Prototype for creating vertical green surfaces.

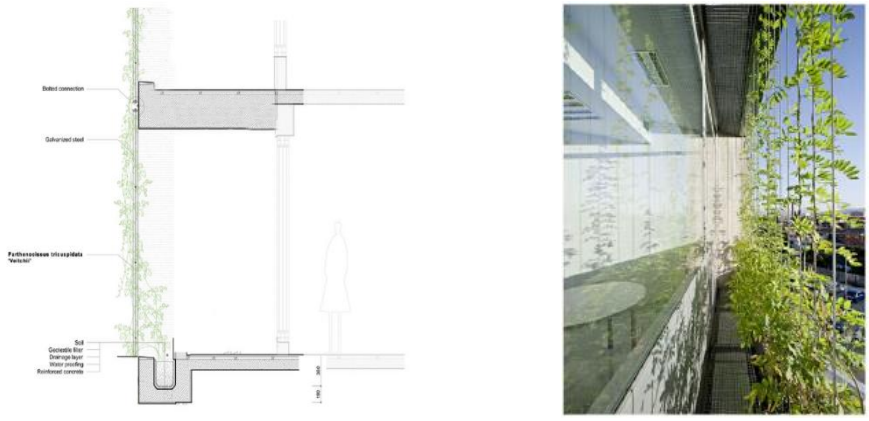
The façades have been the target of constant evolution, being a fundamental component of the building. The walls are also strongly exposed to natural elements, especially the sun, wind, and rain, so the installation of green walls allows to mitigate the impact of these elements on the structure, while 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.



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

PLAYGROUNDS OR OUTDOOR SPACES

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

General description

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 winter time and to shadow in summertime. The structure will have variable translucent areas in the cover according the location.

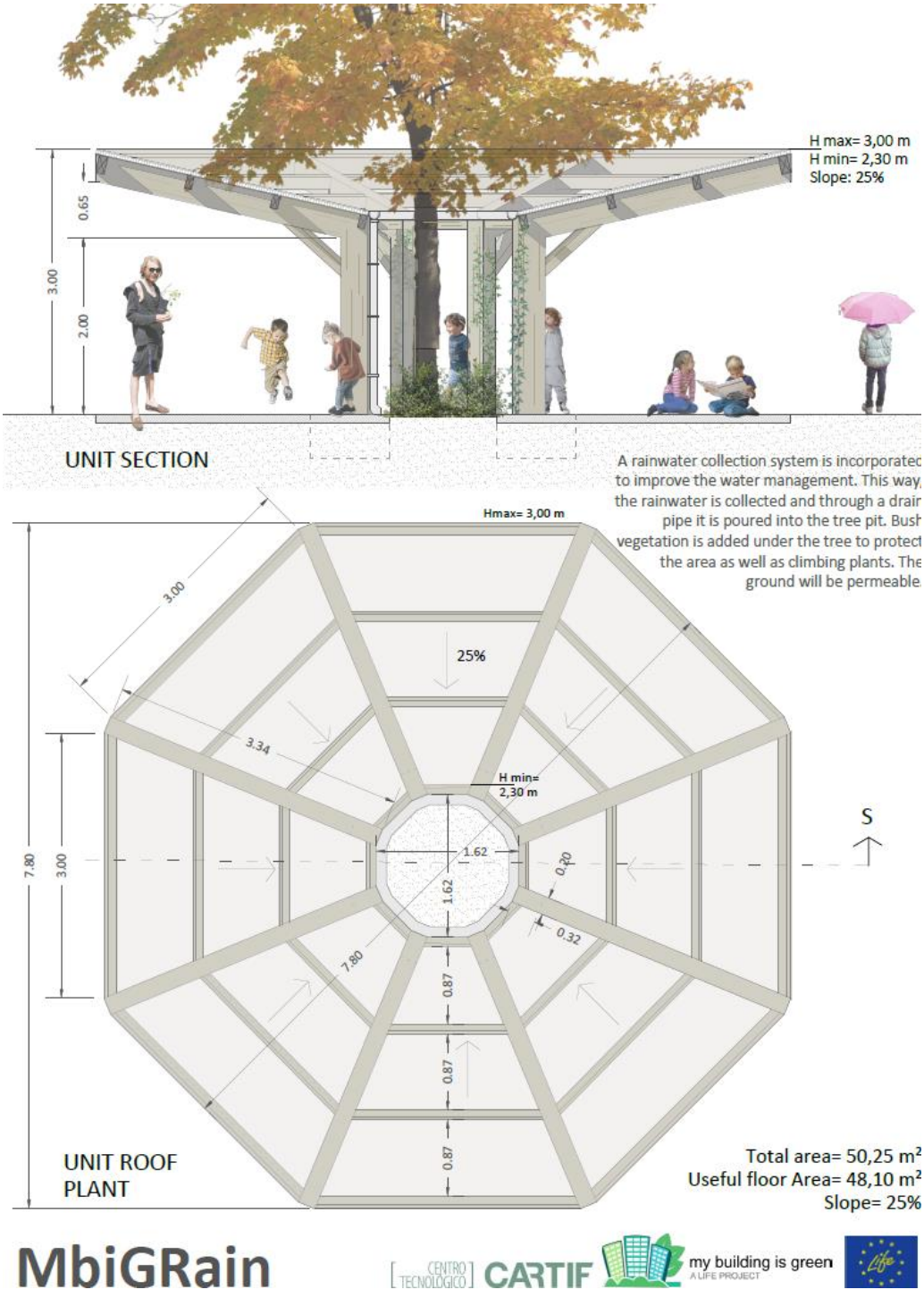
mBiGRain can be located with an existing old tree or with a new tree. mBiGRain can be created in isolated modules or can be connected to create different spaces.

mBiGRain is currently under development in collaboration with LIFE EcoTimberCell[16]for creating a sustainable solution promoting certified local wood.

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.

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

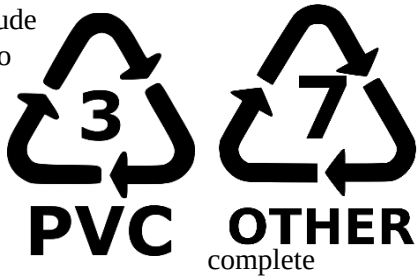
Dimensions



MbiGRain

Sustainability

mBiGRain main material is certified local wood. It can also include translucent ceiling panel made with PVC or PC. Using SimaPro software and following the method for impact assessment of ReCiPe Endpoint (H), PVC (223mPt) will be more environment friendly than PC (654mPt)[17].



mBiGRain is currently under development following eco-design methodology. When the design phase finish it will be presented a complete sustainability study of the solution.

SPECIFICATIONS (50 units 2x2m, 100 m^2)

mBiGRain is currently under development. When the design phase finish it will include complete specifications.

[17] [PlasticsEurope, 2005]: Eco-profiles of the European Plastics Industry. Plastics Europe, 2005.

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

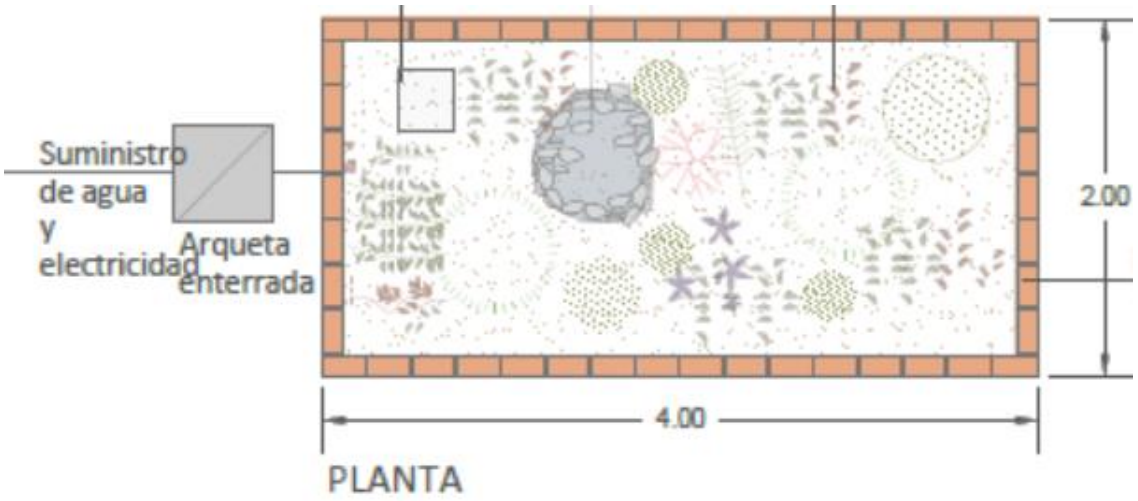
General description

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 element for citizens.

Urban areas are the refuge of numerous pollinators, for instance 83% of butterflies live in an urban area and they are disappearing faster from towns and cities than the countryside, 2/3 of butterfly species are declining. However, one garden could attract more than 18 species of butterfly, to this end it is necessary: to choose a sunny sheltered spot with flowers throughout pollinators season with a source of water and avoid peat using peat-free compost. Source: Butterfly Conservation.

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.



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.

Example of compacted pollinator's modules in the city centre of Ath (Belgium). Source: google maps

This green space attracts pollinators and biodiversity through flowers and plants. To achieve that a favourable sequence of flowering permit 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 (like 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 (take into account 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.
    - It includes a water reservoir or rainwater harvesting which storing part of drainage water (extra water should run off by a drainage system). It is possible to connect these modules to rain gutters in nearby buildings.
    - An irrigation system could be installed to supply needs if necessary.
    - It will have a drainage system to avoid the flooding of the roots.
    - It is necessary provide a water source for pollinator, with a spot land to not drown into the water. (This is why they often fly around clothesline or near to a fountain. Is their way of drinking water safely)
- **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 (e.g. 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.
    - **Design criterion**. Two different classes of modules. One of them with high diversity of flowering plants and the other one for monitoring purposes. It is necessary to create "big" areas containing the same structure of plants (amount and species) (at least 5-10 m2).
- Urban Landscape architecture criteria in the city must be taken into consideration.

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

General description

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.

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 permit 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.

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.

- It could include a rain garden (see VAc10) that contributes to the management of water; because it is a bioretention shallow basin designed to collect, store, filter and treat water runoff.
- An irrigation system could be installed to supply needs if necessary.
- It will have a drainage system to fill the rain garden or collect the water to Urban orchards or floodable park.
- It is necessary provide a water source for pollinator, with a spot land to not drown into the water. (This is why they often fly around clothesline or near to a fountain. Is their way of drinking water safely)

- **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.

4. **UGUVegetablesGardens**. Solution for creating vegetables gardens.

General description

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.

Different variants existing:

Two main kinds can be identified, depending on the type of garden:

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 less 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 has the most popular vegetables. For instance tomato, lettuce, courgette…

Garden with only lettuces and cabbage and parsley type)

© CARTIF

Garden with aromatic plants (Salad and herb) © 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.

Integrated and soil garden. © CARTIF

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.

Orchard in regular furrows © CARTIF

Orchard 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.

Orchard in terrace © CARTIF

Orchard in terrace © CARTIF

Growing tables: the cultivation is on tables.

Photo: www.gardeners.com

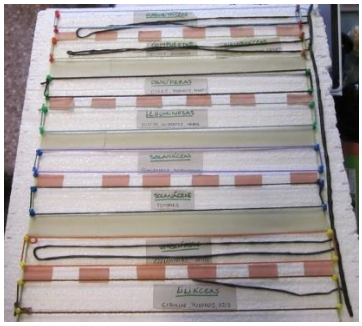
Keyhole or African orchard: it is a growing table with a composting basket in the centre.

Key hole 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.

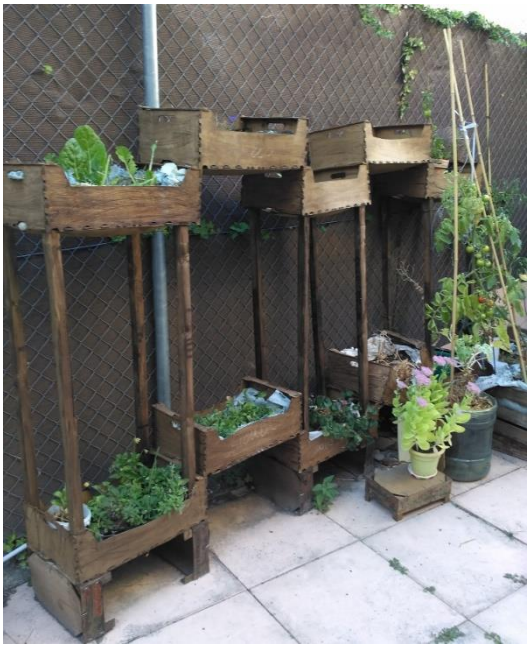
Parades crestall © CARTIF



Parades crestall scheme © 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

5. **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.

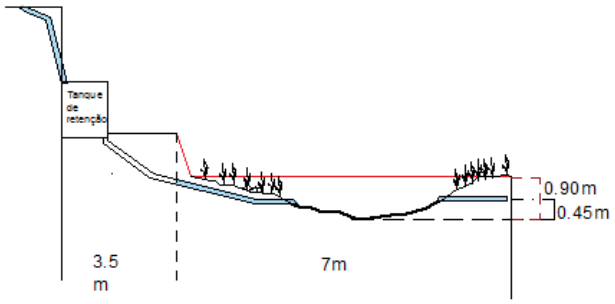


Figure 1. Transversal scheme of the mBiGPond prototype.