Best Practices Guide - LIFE

myBUILDINGisGREEN

LIFE17 CCA/ES/000088

2018 - 2024

my building is green
A LIFE PROJECT

PROJECT DATA

Locations	Solana de los Barros (Extremadura, Espanha) Évora (Alentejo Central, Portugal) Porto (Norte, Portugal)
Start date	01/09/2018
End date	29/02/2024
Duration	66 meses
Total budget	2.854.102 €
EU contribution	1.697.369 €
(%) of eligible costs	59,99 %
Coordinating Organisation	Consejo Superior de Investigaciones Científicas
Beneficiary Organisations	Fundación CARTIF, Diputación de Badajoz, Município do Porto Comunidade Intermunicipal do Alentejo Central
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Document date: February 2024

SUMMARY

LIFE-myBUILDINGisGREEN project consists of the design, development and implementation of innovative Nature-Based Solutions (NBS) and is based on the need to increase the resilience of educational and social buildings to extreme climatic phenomena, namely heat waves and changes in annual and seasonal rainfall patterns, improve bioclimatic comfort and promote the well-being of their users.

The main aim of this Best Practices Guide is to bring together the lessons learnt during the project, to identify the positive points of the solutions implemented, the difficulties encountered and how they were resolved, and to highlight the problems that still need to be solved.

The results of the project point to the potential of NBS to speed up the process of adapting buildings to climate change, making them more resilient. The results also constitute a robust contribution to the creation of evidence capable of promoting building intervention policies and strategies that integrate NBS.

The results of the project, together with the lessons learnt and systematised in this document, can shed light on a set of best practices for the implementation of NBS to be taken into account in future intervention projects in educational and social buildings, or others, boosting the dissemination of knowledge and the replicability of the prototypes developed in this LIFE – myBUILDINGisGREEN project.

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1. INTRODUCTION

The LIFE-myBUILDINGisGREEN project arises in a context in which climate change is recognised as one of the most serious environmental, social and economic challenges facing current and future populations, and is at the top of the European and world political agendas.

Climate change in Spain and Portugal

The regions of Spain and Portugal have been suffering the effects of climate change in a significant way.

The climate profile and trends recorded in the areas covered by the LIFE - myBUILDINGisGREEN project, the Diputación de Badajoz in Extremadura, Spain, and the Alentejo Central and the Municipality of Porto, both in Portugal, reveal an upward trend in average annual temperatures, an increase in extreme heat days and heat wave days per year, as well as a decrease in the percentage of annual precipitation associated with occasional but extreme rainfall phenomena.

The RCP4.5 and RCP8.5[1] climate scenarios were also analysed, and the three regions under study are expected to see a further increase of the trends. In the case of the Extremadura region, the projections indicate that maximum temperatures could rise by up to 6°C by 2100, and that the duration of heatwaves could increase by 20 days a year. In the case of Alentejo Central, there is an increase in the average annual temperature of 2.7°C, an increase in the number of heatwave days of 12 or 24 more days per year, respectively, for RCP 4.5 and RCP 8.5, by the end of the century, and a decrease of around 18% in annual rainfall. With regard to the Porto region, the future scenarios predict an increase in temperatures of up to 5°C per year and an average annual decrease in precipitation of up to 22% by the end of the 21st century.

The reduction in precipitation, the increase in the number of days of drought, and also the increase in heatwaves are risks with future impacts and vulnerabilities in the various sectors of human activity, which require the adoption of measures to adapt to and mitigate climate change.

[1] *"RCP scenarios (Representative Concentration Pathways) refer to the portion of the concentration levels that extend to 2100, for which the integrated assessment models produce corresponding emissions scenarios [IPCC, 2013]" (Portal do Clima, Clima - Alterações Climáticas em Portugal. Available at:*http://portaldoclima.pt/pt/o-projeto/glossario/c/ [09.02.2024]).

LIFE-myBUILDINGisGREEN project – framework

The Intergovernmental Panel on Climate Change, in its 5th Report, identifies urban areas as those that concentrate most of the global risks arising from climate change. It also states that the process of adapting to climate change can be accelerated by implementing measures to improve resilience and promote sustainable development.

In Europe, buildings with educational and social functions will face multiple challenges in the coming decades, including a strong impact from climate change. In particular, heatwaves and changes in annual and seasonal rainfall patterns significantly affect the health and well-being of children and the elderly, the main users of these facilities. These effects are being experienced more and more severely in southern Europe.

In this context, a group of partners from the Iberian Peninsula designed the LIFE-myBUILDINGisGREEN project, applying for the European Union's LIFE programme, with the aim of designing, developing and implementing a set of innovative Nature-Based Solutions (NBS) in order to increase the resilience of buildings to increasingly recurrent extreme weather events, promoting improved bioclimatic comfort and the well-being of their users.

The project consequently aims to contribute to the creation of evidence to promote policies and intervention strategies in buildings that integrate NBS, reducing the use of active air conditioning systems and thus reducing the associated energy consumption.

Adaptation to climate change in the construction sector

The project focuses on the construction sector, specifically buildings that house the population most vulnerable to the effects of climate change, using three pilot buildings: the Gabriela Mistral Elementary School, located in Solana de los Barros, Badajoz (Spain); the Horta das Figueiras Elementary School, in Évora (Portugal); and the Falcão Elementary School, in Porto (Portugal).

The construction sector has seen rapid evolution, both in materials and in construction techniques and methods, with an increase in innovative solutions, many of them of a technological nature. In terms of adapting to and mitigating climate change, this sector has been integrating the concept of circularity into the processes of designing, constructing, maintaining and dismantling or demolishing buildings. At the same time, more and more mechanical means of regulating the interior temperature of buildings are being adopted, using more efficient equipment and renewable energies. However, although equally promising steps have been taken with regard to integrating passive and NBS measures into the refurbishment and construction of new buildings, in Portugal and Spain they are still not part of the mainstream construction sector. There is a general lack of knowledge on the part of professionals in the construction sector (developers, designers, architects and engineers, construction companies and those responsible for building management and maintenance), as well as a shortage of qualified labour. Against this backdrop, the costs associated with implementing innovative NBS are currently characterised as high, which is a deterrent to their use.

The LIFE-myBUILDINGisGREEN project was therefore designed to directly address the construction sector and its professionals, with the three pilot buildings constituting real case studies. The assessment of the construction status of the pilot buildings in terms of structure, load-bearing capacity, waterproofing and energy efficiency made it possible to gather valuable data for the design of nature-based prototypes, such as resilience and climate adaptation measures to be implemented in these buildings. In turn, the NBS implemented, their monitoring and evaluation, makes it possible to verify their real application in rehabilitation and construction, and to assess their viability as alternative solutions for climate adaptation.

In this project, NBS were explored for buildings, with the aim of promoting sustainable and climate-efficient construction. The focus was on innovative solutions for implementing green roofs, ceilings and façades. The prototype solutions, which were implemented and tested in the three pilot buildings, made it possible to set up testing and learning laboratories for later replication.

The Best Practices Guide

The main aim of this Best Practices Guide is to bring together the lessons learnt during the project, to identify the positive points of the solutions implemented, the difficulties that have arisen and how they have been resolved, as well as the problems that still need to be solved.

In order to achieve its objectives, this Best Practices Guide has a three-part structure: this introduction, a development chapter entitled "The three pilot buildings under the LIFE-myBUILDINGisGREEN project", and the conclusion, where the main results of the project will be discussed, highlighting the main lessons learnt and future recommendations. The development chapter is organised into three sub-chapters, each dedicated to one of the project's pilot buildings. In turn, each of these sub-chapters is structured according to the following items: "The NBS prototypes implemented", describing the nature-based solutions designed and installed in each building; and, "Results: positive aspects and problems identified", which describes the "Best practices and positive aspects", the " Identified problems and respective solutions " and the " Flaws and unsolved problems " in each of the implementation phases of this LIFE project, "Planning", " Implementation" and "Results". In other words, the aim was to bring together the lessons learnt, with a focus on the NBS prototypes, from their conception, installation on site, respective maintenance and results achieved, highlighting the main challenges, success factors and recommendations for the dissemination of knowledge and replicability.

2. THE THREE PILOT BUILDINGS OF THE LIFE-myBUILDINGisGREEN PROJECT

NBS, as defined by the European Commission, are "nature-inspired and nature-supported solutions that deliver economic, environmental and social benefits while helping to build resilience. These solutions bring more diversity of nature and natural resources and processes into cities, landscapes and wetlands through systemic, efficient interventions that are adapted to the local context".

In the urban context, NBS are beginning to gain prominence as a measure for adapting to climate change, being implemented both in public spaces and in buildings.

At the building level, the prevalence of NBS implementation has been at the level of green roofs and façades. The commitment to creating green roofs that has been seen in many European cities has its origins in a growing tendency in new construction to opt for flat or low-slope roofs, which make it easier to fix the substrate to the roof slab, a necessary condition for the growth and development of plant species. Both green roofs and green façades enable gains in terms of energy efficiency as a result of their multiple layers, which has contributed to greater thermal protection of building materials and ensures a lower temperature range inside the building. In addition, there is a growing demand for more sustainable materials and resources.

The LIFE-myBUILDINGisGREEN project, as mentioned above, aims to design and develop innovative NBS, focusing on their implementation in social and educational facilities, as these are the ones that house the populations most vulnerable to extreme weather events.

To this end, a series of construction, environmental, social and economic criteria were defined for the selection of the three pilot buildings for this project. To summarise, at a constructive and environmental level, priority was given to buildings with flat, horizontal roofs (or with a slight slope, with a maximum of 5 to 10%), in good condictions, with no need for work prior to the installation of the NBS, with an area available for the installation of a green façade, as well as outdoor space for creating a shaded area, planting trees and installing drainage and permeable paving. At the same time, priority was given to choosing buildings with more thermally demanding construction features, in order to monitor and measure the results of installing NBS. Buildings from the 1970s were also prioritised, when there was a construction boom, namely schools with similar characteristics, which will increase the potential for replicability.

Three schools were chosen: the Gabriela Mistral School (Badajoz, Spain); the Horta das Figueiras School (Évora, Portugal); and the Falcão School (Porto, Portugal).

Architectural and speciality projects were developed for these buildings, including the design of NBS prototypes, which aim to improve well-being and thermal comfort inside, reduce the energy consumption for cooling, optimise water consumption for irrigation, improve air quality and increase biodiversity.

2.1. GABRIELA MISTRAL SCHOOL (BADAJOZ, SPAIN)

After a selection process, the Diputación de Badajoz, through the Rural Development and Sustainability Area, chose the Gabriela Mistral School in Solana de los Barros as the pilot building for the implementation of prototypes and solutions for adapting to the consequences of climate change, specifically those resulting from heatwaves, which have a greater impact on the most vulnerable users of buildings, in this case children.

The school in question has characteristics considered ideal for testing and experimenting with the implementation of NBS, as well as a set of passive shading and ventilation measures. The school consists of an older central building with a pitched roof and a new body, built in 2006, with flat roofs at different levels, capable of accommodating NBS in order to create green roofs. The two buildings are interconnected by a glazed corridor, which had no sun protection whatsoever and which the school dubbed the "corridor from hell", given the high temperatures that were reached inside as a result of the greenhouse effect, requiring an intervention capable of mitigating the extreme heating inside.

THE IMPLEMENTED NBS PROTOTYPES

Green roof | Extensive and cool roof prototypes

The project established different typologies to be tested on the building's various roof levels. Extensive green roof solutions were combined, with improved substrates, using recycled aggregates as part of the substrate, or rock wool, and solutions consisting of raised decks to create "cool roofs".

The refurbishment consisted of removing the existing inverted roof system (gravel, geotextile blanket, thermal insulation and the last geotextile separation blanket), uncovering the waterproofing, which was also replaced.

Thus, the new extensive green roof solution consists of a waterproofing layer made of synthetic PVC film, to which is superimposed a drainage layer with specific characteristics to ensure the solution works, and anti-root screens. The solution also includes metal profiles separating the different types of green roof to be implemented and tested. Finally, the substrate is laid out with a minimum thickness of 10-12 centimetres, the depth required for the roots of the plant species to develop. In some of the areas of the roof not filled with substrate, raised planted trays were laid out, creating an air gap, which makes it possible to create so-called "cool roofs".

The different levels of the school's roof also include the necessary walkways for maintenance and use as a teaching resource.

Figure 1 Application of PVC film waterproofing.

Figure 2 Metal spacer profiles.

Figure 3 Implementation of the irrigation system.

Figure 4 Implementation of "cold roofs".

Figure 5 Extensive green coverage.

Figure 6 Planted terraces. "Cool roofs".

Façade shading | FAVE prototype

The Vegetal Façade (FAVE) prototype was conceived as a substructure fixed to the façade that supports the planting of deciduous plant species (in this case, virgin vines of the tricuspidata and quinquefolia varieties were chosen), allowing sunlight in during the winter and providing shade in the summer. It is a modular, removable system made up of a three-dimensional structure, with metal profiles of standardised dimensions and bolted fixings, which makes it easy to reproduce and use in different buildings. The FAVE system was implemented on the ground floor façades, but also on the first floor façades on the roof of the lower floor. In these situations, the system supports were placed on top of the separating metal profiles, above the waterproofing.

Figure 8 FAVE prototype. Metal profiles.

Figure 7 FAVE prototype built on the ground floor.

Figure 9 FAVE prototype based on a roof.

Figure 10 FAVE prototype.

Figure 11 FAVE prototype.

Indoor green wall | Vertical garden prototype

A prototype vertical garden has been installed inside the so-called "corridor of hell", which connects the two volumes of the school building, with the aim of cooling the environment through the evapotranspiration of the plants. This type of installation also absorbs CO_2 from the environment, improving air quality. There is also an aesthetic component, visually, since the presence of nature as wall cladding inside buildings is known to have positive psychological effects on their occupants.

Figure 12 Indoor vertical garden.

Outdoor shading | PEVE prototype

Outside, shading modules were implemented using green pergolas, known as the PEVE system. The PEVE prototype consists of a modular metal structure that supports the growth of climbing vegetation, using the same deciduous species as the FAVE system.

Figure 13 PEVE prototype.

Permeable pavements | SUVE prototype

The SUVE prototype was designed to create draining vegetated soils, with the aim of minimising the flow of rainwater directly discharged into municipal sewage systems and increasing its infiltration into the ground.

At the school in Solana, continuous areas of porous concrete and areas with paving made of "filtering" stones were combined. In both cases, rainwater is filtered into the ground via a ditch and a filtering well, alleviating discharge into the sewage system and avoiding unnecessary treatment of this water, as well as the corresponding energy consumption.

Figure 14 SUVE prototype.

RESULTS: POSITIVE ASPECTS and IDENTIFIED PROBLEMS

Best practices and positive aspects

Planning

⇒ Adequate prior planning, defining priority activities and their maximum completion time, made it possible to obtain the necessary permissions and authorisations well in advance.

⇒ The correct identification of those involved in the project, especially those who had the power to make decisions to realise the project, made it possible to involve them beforehand and speed up decision-making. No less important are the stakeholders who, even though they don't have direct decision-making powers in the project, can delay or hinder it, or jeopardise relations between the parties and therefore harm the project, so it was important to involve them in the early stages. In this stakeholder involvement process, the building's daily users were involved from the outset, ensuring their commitment to the project's success throughout its life cycle.

⇒ The correct design of architectural and speciality projects is fundamental to construction. The greatest degree of detail contributes to the success of the construction work. The time allotted for drawing up the architectural and speciality project should not be underestimated. Greater investment in this phase will minimise unforeseen events in the subsequent construction phase. The specific nature of the work (green roofs and shading systems with NBS) requires prior and exhaustive market research during the preparation of the project. Contacting professionals in the field makes it possible to obtain, in advance, conditions and budgets for execution that will have to be integrated into the project, along with the other interventions needed to carry out the work. In this way, it is possible to avoid possible deserted tenders, as well as minimise unforeseen events during the implementation of the NBS and consequent budget overruns.

⇒ The implementation of green roofs requires a load capacity study for each case. In the case of the school in Solana de los Barros, the added load on the building's roof as a result of the new solution, namely the introduction of the substrate, was compensated for by removing the existing protective layer of gravel. If the structure has the capacity for the increased load, greater thicknesses of substrate can be used, making it possible for other larger species to grow.

Implementation

⇒ The choice to use PVC has advantages over asphalt sheeting, since the latter has organic components in its composition that attract plants. In the medium to long term, the roots of the plants, in search of the organic components of the asphalt fabric, could penetrate the anti-root fabric and end up spreading horizontally across the roof, especially near the drains, where the water is concentrated, ending up obstructing the roof's drainage system with the consequent risks of overloading, leaks and other construction pathologies.

⇒ All the prototypes, on roofs, façades and outdoor pergolas, require a drip irrigation system, designed according to the planned distribution of the plants. The irrigation system is a fundamental element in the entire NBS ensemble, especially in the local climate of Badajoz. Although plants with low water requirements were sought, in order to guarantee the growth of the species, an adequate supply of water that does not depend exclusively on rainfall is necessary, especially in the first few years. The system implemented is programmable and allows for the incorporation of fertilisers to facilitate plant growth. The installation also has a system for collecting and storing rainwater and surplus irrigation water for reuse.

⇒ In accordance with the regulations, the waterproofing must be tested by flooding with the drains temporarily covered for at least 48 hours to check for leaks or problems before proceeding with the next layers of the roof.

Figure 15 Waterproofing test by flooding.

⇒ The first moments after planting species are exceptionally delicate. Depending on the season in which they are to be planted, special care must be taken to ensure that the irrigation systems are fully implemented and fully functional, guaranteeing the survival of the newly planted species, especially in hot seasons.

⇒ Monitoring the construction work at least weekly, following the established work plan, makes it possible to observe deviations and take appropriate actions.

Results

⇒ After the NBS implementation work was completed at the school, in the first year of monitoring the building, temperature drops of between 8 and 11 per cent were observed in relation to the original temperatures measured inside. Thermographic images also showed considerable surface temperature differences between the conventional roofs with a gravel finish, where temperatures reached up to 48°C, and the green roofs, where surface temperatures dropped to 29°C.

⇒ The aesthetic result of the different applications is very appealing, changing the appearance of the façade.

⇒ The building also has the particularity that the roofs can be visited by children, so they can be used as an environmental education resource to show the different NBS, as a measure of adaptation to climate change.

⇒ The FAVE façade shading prototype is a modular, removable and flexible system that can be replicated in other buildings.

Identified problems and respective solutions

Implementation

⇒ One of the problems identified was the lack of local companies specialised in implementing NBS on building roofs, and the solution is to survey this type of company nationwide.

⇒ There was a lack of involvement on the part of the construction company during the implementation of the NBS, a problem which, in order to be overcome, required regular meetings to guarantee their commitment to the successful completion of the project.

⇒ There was a lack of maintenance companies specialising in NBS irrigation control, which is crucial for implementing automated systems. This control, whether remote or on-site, requires specialised knowledge of how the systems work and programming equipment, which only installers authorised by the brands have. This limitation requires in-depth market research throughout the country of companies specialising in NBS maintenance, which will also make it possible to tailor public procurement procedures to the specifics of the subject of the contract.

Results

⇒ The success of NBS requires constant monitoring and specialised maintenance, especially during the hot seasons, to ensure adequate irrigation and the presence of the necessary water. Inaccurate forecasting of deadlines for contracting subsequent maintenance services can create constraints. Similarly, the work and maintenance plans need to be reworked to make them more realistic and thus realisable.

⇒ The problems of adaptation to the environment and location in the building of some of the species selected could be solved by replacing them, using municipal nurseries or purchasing other plant species from external companies in the sector.

Flaws and unsolved problems

Implementation

⇒ Relationship problems between the contractor and subcontractors can result in losses for the building owner, the end consumer. The problem related to the subcontractor who installed the "closed irrigation control" is highlighted. Due to non-payment by the contractor to the subcontractor, the latter used irrigation control as coercion to resolve the dispute, resulting in losses for the owner who was unable to obtain irrigation control. This type of issue requires closer relations between subcontractors and contractors, in order to unblock access to the irrigation controller. In this context, the need to contract for the implementation of a meter to monitor water consumption, as well as future maintenance services, is yet to be resolved, ensuring that these include irrigation control.

Results

⇒ The performance of the pot made for the FAVE façade shading system, and the species selected (virgin vines), is not working as expected. The plants are not growing properly. This situation is still being assessed, in particular with the advice of the Royal Botanical Garden, in order to propose measures to solve this problem.

⇒ The installation of the green canopies (sprayed with a mixture of substrate and seeds) was unsuccessful. The failures identified were due to the unsuitability of the system for the local climate, the supplier's inadequate execution of the system or the design of the prototype itself, which was not adapted to the existing conditions. It should be emphasised that the vegetation dried out right at the start of the installation, over a weekend, probably due to failures in the irrigation installed. This is a solution that is very sensitive to a lack of water, especially during its initial development. The problem remains unsolved. We therefore need to assess the solution to be adopted: insist, testing a new species on the awnings; or dispense with their naturalisation, allowing them to continue carrying out the shading work on their own, without the need to incorporate plant species, avoiding this water consumption.

Figure 16 “Dry" green canopies.

2.2. HORTA DAS FIGUEIRAS SCHOOL (ÉVORA, PORTUGAL)

The Horta das Figueiras School, located in the city of Évora, was the pilot building selected by CIMAC from a series of other buildings in the Évora district, following the respective multi-criteria analysis for the implementation of innovative NBS.

Figure 17 Location of Horta das Figueiras School.

Figure 18 South façade before NBS implementation.

Figure 19 East façade before NBS implementation.

In order to carry out the intervention at the school, a public procurement procedure was carried out for the necessary architectural and speciality design services, which would accommodate the NBS prototypes developed by CARTIF. The project includes NBS interventions on the roof and façades of the building, as well as a series of interventions on the school's outdoor playground.

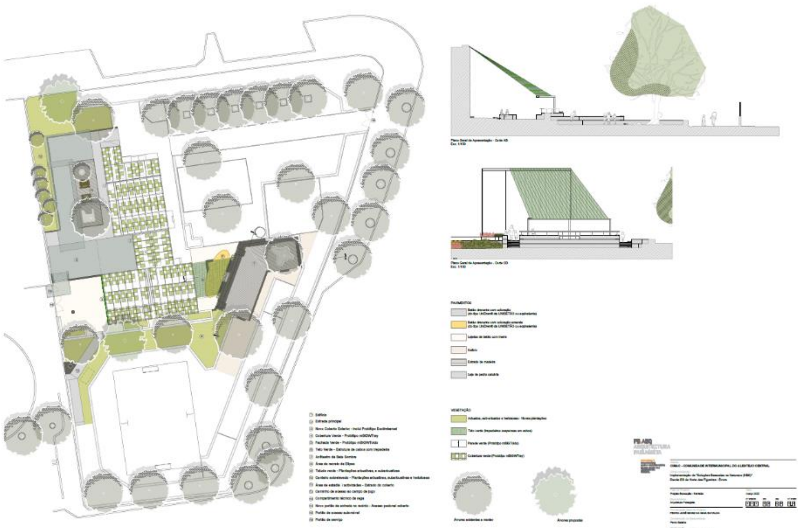

Figura 20 Project designed by P.B-Arquitetura Paisagista, Lda.

THE IMPLEMENTED NBS PROTOTYPES

Green roof | mBIGWTray prototype

To implement the green roof, the mBIGWTray prototype was designed, to be installed on a raised metal structure supported by the building's structure. This solution ensures that the additional loads resulting from the installation of the prototypes do not directly demand the roof covering, allows for better drainage, avoiding possible water accumulation and overloading of the structure, and also ensures the existence of an "air gap" between the prototypes and the roof of the building, which offers benefits from a thermal point of view.

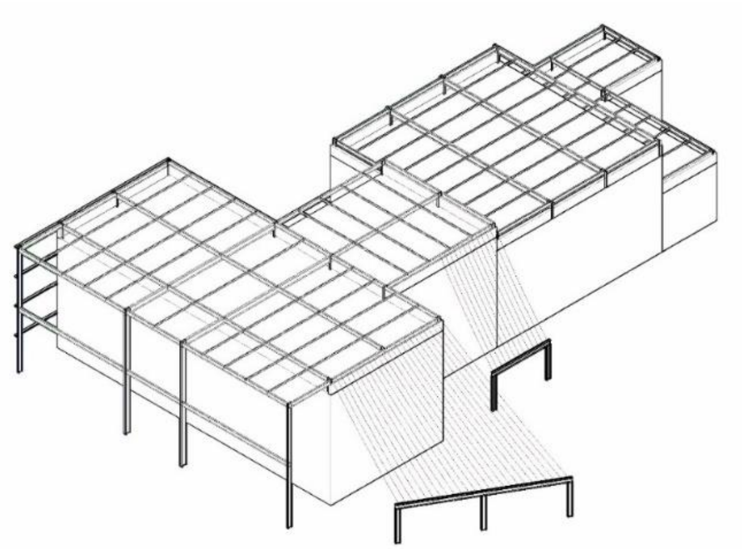

Figure 21 3D model of the metal structure supporting the green roof.

Figure 22 Metallic structure. South façade.

Figure 23 Metallic structure. Roof.

The mBIGWTray prototype consists of modular units. Each module consists of a bag (glass fibre-reinforced PVC sheet), which is filled with several layers: a drainage tray (made of high-density polyethylene), a retention blanket (a non-woven geotextile made of recycled polyester and recycled polypropylene fibres, mechanically coupled by a sharpening process), a geotextile sheet (high-strength anti-soil), and a garden cover substrate. At the top of the "bag" there are openings for planting the plant species which, in the case of the school in Évora and given the climate of the Alentejo, are of the sedum type. The system allows rainwater to be collected through the bag's raised side flap and retained inside the bag, reducing the need for auxiliary irrigation. The bags of the mBiGWTray system are distributed over the entire roof, in a percentage of approximately 40 to 50 per cent, so as to form a checkerboard pattern of full and empty green, but which, in the medium term, is expected to be almost entirely completed in a continuous green blanket.

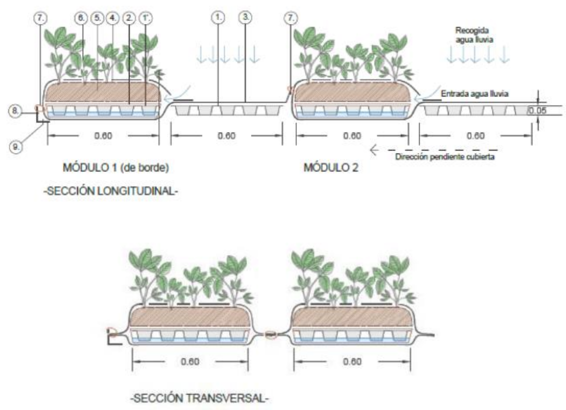

Figure 23 Schematic of the mBIGWTray module developed by CARTIF.

Figure 22 mBIGWTray test module.

Figure 25 Green roof. mBIGWTray prototype.

Figure 24 Green roof. mBIGWTray prototype.

For the west façade, the mBiGToldo prototype was designed, supported by a metal structure in tandem with the roof structure. This prototype was designed to create vertical surfaces with very thin vegetation. The system consists of a waterproof sheet, to which a non-woven felt is attached and onto which a seeded substrate is projected. Due to the low thickness of the substrate, hydroponic irrigation is integrated and distributed by gravity over the surface. A channel is integrated at the bottom to collect excess water, which is returned to the watering station, thus avoiding wasting water.

Figure 26 West façade. Installation of metal structure to support the mBIGToldo prototype.

Figure 27 Testing the mBIGToldo prototype.

Green Roof | Steel cable structure with climbing vine

On the east façade, the solution adopted consists of creating a green roof, made up of a system of steel cables that connect the beams installed on the roof with the beams of the porticos installed outside. These cables support the vines.

Figure 28 Steel cable structure.

OTHER NBS

In order to increase water infiltration in the soil, areas of outdoor paving were created with suspended wooden decking that allows the soil to permeate and areas with porous concrete. At the same time, the existing flowerbed areas were maintained and new planting was carried out, particularly with native species.

Figure 29 Permeable exterior paving. Installation of a suspended wooden platform.

Figure 30 Permeable exterior flooring. Suspended wooden platform.

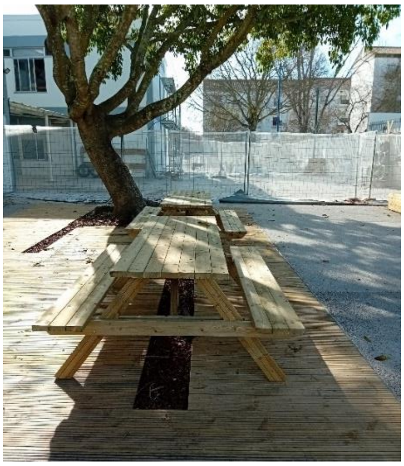

Figure 31 Permeable exterior flooring. Suspended wooden platform.

Figure 32 Replanting existing flowerbeds with native species.

RESULTS: POSITIVE ASPECTS and IDENTIFIED PROBLEMS

Best practices and positive aspects

Planning

⇒ The involvement of the school community with the integration of environmental issues into extracurricular activities, as well as co-design sessions, have allowed its users to take ownership of the project.

⇒ The design of the green roof, specifically the reticulated steel cable system, will provide better support for the climbing vegetation as it grows. However, considering that it will take several years for the climbing vegetation to completely cover the entire surface generated by the cable system, the installation of micro-perforated screens (in a chequered pattern) was considered to ensure the immediate shading of the associated exterior space and façade. As the vegetation develops, the screens will be removed.

Implementation

⇒ The involvement and motivation of the contractor in carrying out the work, as well as his investment in specialised training, is an added value for the successful execution of the prototypes.

Results

⇒ The interventions carried out and the implementation of the different NBS prototypes have resulted in an aesthetic and environmental enhancement of the school building, giving it a more attractive appearance.

Identified problems and respective solutions

Planning

⇒ CIMAC is the promoter of the project at the school, but the Évora municipality is the property owner. This requires close and attentive liaison and communication between the two organisations, which was not the case at the start of the project. As a result, when the architectural and speciality project for the implementation of the NBS was completed, it was found that the intervention being proposed for the school clashed with a previous project by the municipality to extend it. For this reason, the project had to be altered, taking into account the constraints of integrating other municipal projects and the requirements of the respective teams. Although the issue was resolved and the projects for the school were made compatible, the situation resulted in a 12-month delay in completing the design of the NBS implementation project and increased costs for its realisation (new public procurement procedure with the design team to draw up the amendment to the initial project).

⇒ The difficulties in contracting public works contracts that have arisen in various situations require procedures to be planned and deadlines to be set that are more accurate and coincide with reality. In the case of the work on the school in Évora, these difficulties led to procedures being deserted and cancelled, culminating in a delay in the start of the work and its completion. The difficulty in contracting this work was due to a number of cumulative reasons, namely:

- The financial crisis of 2008, the SARS-CoV-2 pandemic, and the subsequent outbreak of war in Ukraine, with consequences for the construction sector, from the lack of labour to the exponential rise in raw materials and building materials, with the base price for launching the procedure being inadequate in relation to the reality of the market and not proving to be attractive.
- In addition, there is a lack of companies specialised in implementing innovative NBS solutions on the domestic market.
- Furthermore, the deadline set out in the specifications was not sufficient to carry out the work in question.

⇒ The lack of an accurate diagnosis of the state of conservation of the building was reflected in unforeseen events on site, which led to the need to contract additional work, with consequent delays in the execution of the contract.

Implementation

⇒ There were initial difficulties in managing the expectations of educational guardians, particularly with regard to the planning of the work, the relocation of two of the four classrooms to another school during a school term, the delimitation of the construction site and the execution of the work at the same time as school activities. This issue was addressed with information sessions for parents about the timetable for the work and the positive results expected from the implementation of NBS.

Results

⇒ The project did not take into account accessibility to the roof in the safe conditions needed to carry out maintenance work. The solution identified on site was to install a lifeline fixed to the metal structure of the roof, to be used during maintenance work.

⇒ The project did not include an irrigation system on the roof for budgetary reasons, but in order to minimise the problem, a water point was left on the roof itself, which will allow a hose to be connected for later manual irrigation. The Municipality of Évora was also sensitised to the issue of maintenance and irrigation of the NBS on the roof, which will include the necessary drip irrigation system in the future.

⇒ The delay in carrying out the NBS implementation work meant that the corresponding impact could not be monitored. This action will be carried out during the After-LIFE Plan, and it is expected that measurable data will be obtained on the impact of the solutions implemented at the school in Évora, which will corroborate the respective benefits..

Flaws and unsolved problems

Results

⇒ The roof's difficult accessibility makes it impossible to use it as a practical teaching resource for children.

2.3. FALCÃO SCHOOL (PORTO, PORTUGAL)

The Falcão Basic School was selected as the pilot building in the city of Porto. The Municipality selected this school in the context of implementing a policy of upgrading the municipally-run school park, based on two main assessment criteria, namely the characterisation of the building and the area of insertion in the city, seeking to highlight areas of the city with more vulnerable economic and social conditions, while at the same time suffering a greater impact from the worsening of climate change.

In terms of buildings, the school is made up of two buildings. As a result of its configuration, location and surroundings, the building has a wide temperature range inside, being very cold in winter due to the excessive humidity and shade, and very hot in summer due to the southern orientation of the glazed façades.

For this project, only the main building was considered, which houses the classrooms, the area where the children spend the most time.

Given the selection of the Falcão School for the project, the opportunity arose to renovate the entire building with the intervention of the Municipal Directorate of Education. Thus, the intervention process had two different stages, the first for structural and functional upgrading, including solving the problems of poor waterproofing and insulation of the building's roof, and the installation of NBS, incorporated into the methodology and implementation of LIFE-myBUILDINGisGREEN.

The NBS prototypes designed for this school were then incorporated, resulting in the creation of 700 m^2 of permeable area on the roof and the installation of 60 photovoltaic panels to produce electricity for self-consumption in order to reduce energy bills.

To complement the roofs, a two-storey green façade was created to reduce sun exposure during the summer.

Figure 33 Falcão Elementary School.

THE IMPLEMENTED NBS PROTOTYPES

Green roof | Bio Roof Solar Prototype

The Solar Bio Roof prototype is a classic green roof adapted to accommodate photovoltaic panels. The inclusion of the panels in the design is the result of an initiative by the Municipality of Porto, together with the Porto Energy Agency and the Municipal Housing Company, Domus Social, to install renewable energy production systems in municipally-run buildings.

This prototype comprises the following layers, from the base of the slab to the vegetation cover: waterproofing layer and anti-root blanket; drainage element; filter to prevent substrate leaks and clogging of the drainage channels; gravel to facilitate drainage; substrate and vegetation.

Figure 34 Bio Roof Solar Prototype.

Figure 35 Bio Roof Solar Prototype.

Green roof | mBiGUL prototype

The mBiGUL prototype is a solution adapted from the system developed as part of the Green Urban Living project. The mBiGUL solution has a more simplified structure than the classic green roof, as it uses cork agglomerate as a drainage element. By using this porous, natural material, the use of natural resources is maximised and the carbon footprint and impact of the green roof is reduced. The use of agglomerate eliminates the need to lay gravel, which can help reduce the roof's load on the slab structure.

Figure 36 mBiGUL prototype.

Figure 37 mBiGUL prototype.

Green roof | mBiGUL prototype - sloping roof

The mBIGUL prototype, in its sloping version, is made up of several varieties of sedum, which are low-growing and resistant to extreme weather conditions. The inclined shape of this solution means that a mesh has to be placed over the substrate to prevent the substrate from draining and sliding and the resulting deformation of the cover. The vegetation is placed in the openings of the mesh and as the roots mature, they end up supporting the substrate, but initially this mesh is essential for the installation of sloping roofs.

Figure 38 mBIGUL prototype - sloping roof.

Green façade | Steel cable structure

The vegetation will be planted in the ground and the growth will be guided by a set of cables that follow the façade along the two floors. The balcony on the top floor creates an air gap between the green wall and the window. To achieve the desired effect, deciduous species will be planted in order to create areas of shade only in the summer months. During the winter, the absence of foliage allows natural light to pass through.

Figure 39 Steel cable structure.

Other NBS

Given the school's proximity to Horta da Oliveira, a community space for organic food production and cultivation, a pond was designed to utilise rainwater collected on one of the green roofs. The intention is that the water collected on the roof, and retained in the pond, will contribute to greater irrigation of the garden soil, increasing the availability of water in the soil and biodiversity. The pond has a pedagogical perspective and reflects the integrative component of the systems, with rainwater collected at the school being used for the vegetable garden. With this system, students will be able to see the water drainage channels and recognise ways of using rainwater as essential measures for efficient management of the urban water cycle.

RESULTS: POSITIVE ASPECTS and IDENTIFIED PROBLEMS

Best practices and positive aspects

Planning

⇒ Combining the implementation of NBS with the school's general works and the installation of photovoltaic panels has allowed the design and testing of the bio-solar roof, which in theory increases the productive efficiency of the panels.

⇒ The opportunity to link the implementation of the NBS to the school's general works also made it possible to overcome some construction barriers (e.g. the load-bearing capacity of the roofs, the reorganisation of spaces and the location of classrooms...), allowing the benefits of the implemented NBS to be maximised.

⇒ The involvement of different actors and stakeholders in the school led to the creation of a multidisciplinary group made up of elements from the various municipal units involved, from education, to environmental management, to water, to construction management, who, together with the team of architects, were able to create a school building that was practical and better organised from the point of view of school management, but also innovative and adapted to meet the challenges posed by climate change, particularly in terms of resource efficiency, energy and water, and comfort for all users.

⇒ The survey of the building's shortcomings and "defects", which had the valuable collaboration of the school's coordinator, allowed the project to consider more practical and pressing aspects of school management, which the project would otherwise not have known about, nor could they have been addressed in the prototype planning phase.

⇒ The collaboration with the National Association of Green Roofs, a partner of the Municipality of Porto in various municipal projects for natural-based solutions, was an asset in adapting the prototypes, not only to the needs envisaged, but essentially provided fundamental know-how to ensure their success (e.g. adapting to the local climate, specific location, type of vegetation used, irrigation needs...).

Implementation

⇒ The involvement of the school coordinator in the process from the outset has contributed to the success of its results, particularly in terms of raising awareness of environmental topics.

⇒ The possibility of implementing the NBS after the school's general works had been completed made it possible to create a blank canvas for the application of the prototypes.

⇒ The use of easily accessible and available materials ensured that there were no delays in supplying them or the plants to be used, given the context of shortages of some materials and resources that occurred during the school's general works.

⇒ The absence of schoolchildren during the work gave greater freedom of action and fewer constraints in the management of the project.

Identified problems and respective solutions

Planning

⇒ The system of cables to support the green surface to be created by climbing vegetation is not developing as expected. This may be due to the design of the structure itself, with only vertical cables, and the temperature that these acquire when exposed to direct sunlight, factors that will condition the plants' adherence. The problem could be solved by integrating horizontal elements to reinforce the vegetation growth support mesh (forming a quadricula similar to the solution designed for the school in Évora). The use of a support system using natural materials instead of steel could also be considered, in order to obviate issues related to the temperature of the materials.

⇒ The need to reconcile the design of the prototypes with the “Porto Solar” project and the school's redevelopment works became challenging from a planning point of view, which led to some delays in the conception, design and execution project. The need to articulate and integrate different visions and needs led to delays in finalising the execution projects.

⇒ The intention to promote and maximise the use of rainwater raised some licensing issues with Águas e Energia do Porto. Licensing doubts, and some fears due to the perception of parents and the rest of the school community about the use of rainwater for sanitary purposes, led to the abandonment of some initial proposals (e.g. using rainwater for flushing toilets).

Implementation

⇒ There was a delay in the execution of the school's requalification works, which impacted on the NBS implementation schedule. The SARS-CoV-2 pandemic and the lack of resources and materials resulting from the outbreak of the conflict in Ukraine led to delays in the supply of raw materials and construction materials, and the rise in prices had an impact on the duration of the project's implementation.

⇒ The delay in execution, and in the actual start-up of the construction works, led to a long period of monitoring downtime which, as it was a more complex project, conditioned the monitoring periods and subsequent evaluation of the results.

⇒ The school community had to be relocated and found itself confined to temporary premises for two school years, creating constraints for the entire community and the children's parents.

Results

⇒ As this is the first green roof for a school, there are difficulties associated with the lack of practice and scarce knowledge of the municipality's construction management teams, which will be worked on in order to resolve existing management and maintenance doubts.

⇒ The lack of time to properly evaluate not only the prototypes, giving them adequate time to consolidate and develop, but also to assess their impact on comfort and indoor air quality, can impact the success of the project, as it reduces the possibility of adjustments or corrections, and does not allow for the normal operation of the school during the four seasons of the year to be taken into account.

Flaws and unsolved problems

Planning

⇒ The decision not to use rainwater for sanitary purposes represents a missed of opportunity to test this solution as an interesting measure from the point of view of efficient water use and management, which, in a context of climate change and considering the water problems in many municipalities in the south of the Iberian Peninsula, would be seen as an attractive alternative for dealing with water shortages.

Results

⇒ Hiring a team specialised in green roof maintenance has been difficult to achieve (with delays in the process). The Municipal Company Domus Social is the manager of all the infrastructures built by the Municipality of Porto and has delayed this process.

⇒ The green roof has been "invaded" by seeds from many tree-like plants, such as plane trees, willows and even acacias, which could jeopardise the future functioning of the waterproofing screens, requiring increased maintenance care.

⇒ During the execution phase, the installation of various types of sensors (temperature, humidity, among others) was requested, but it has not yet been possible to verify that all the equipment requested has in fact been installed and to guarantee regular data collection (this process is ongoing).

⇒ Irrigation has proved difficult to manage, so we are still trying to identify whether there are technical problems with the rain gauge.

⇒ The initial idea of transporting water from the roof to the school's sanitary facilities was abandoned because it was impossible to implement.

3. CONCLUSION: LESSONS LEARNT AND BEST PRACTICES

NBS have the potential to accelerate climate change adaptation processes. Their implementation in the three pilot buildings of the LIFE-myBUILDINGisGREEN project aimed, on the one hand, to design and test innovative solutions, to validate them as measures to improve the resilience of buildings to extreme climatic phenomena and to promote sustainable development by monitoring parameters and quantifiable data and, on the other hand, to contribute to the creation of evidence to promote policies and intervention strategies in buildings that integrate NBS.

This document seeks to bring together the lessons learnt during the implementation of NBS, taking into account the previous phases of designing the prototypes and construction projects, obtaining administrative licences, public procurement of the respective works, as well as the life cycle of these solutions, the maintenance of the prototypes and the results obtained. The positive aspects and problems identified in each pilot building were analysed, including specific limitations in each situation as well as technical problems inherent to each solution. By systematising the lessons learnt, it is hoped to shed light on a set of best practices for the implementation of NBS to be taken into account in future NBS implementation projects.

Benefits and best practices

The advantages of implementing NBS in buildings translate into improved indoor thermal comfort, greater energy efficiency in the building, optimised water management for irrigation, better rainwater management and reduced urban runoff, benefits that can be proven by quantifying data such as temperature, humidity, CO2 levels, energy consumption and water consumption. These benefits have a direct economic impact on building management. In addition to these benefits, there are other benefits of a social and environmental nature, such as the attractive aesthetic characteristics that these solutions provide, the improvement in landscape value, the increase in living educational resources, the increase in biodiversity, the improvement in air quality and the improvement in the health indicators of their users. These benefits, in turn, make it more complex to quantify and measure their economic impact.

The results of this project, specifically those achieved through the implementation of NBS in the Gabriela Mistral Elementary School in Solana de Los Barros, have made it possible to validate the benefits of these solutions with measurable data, reflecting, in particular, greater energy efficiency in the building, optimisation in water consumption and management, reduction in the effects of extreme heat phenomena, through the reduction in indoor temperature achieved, generation of more oxygen and filtering of a significant amount of harmful gases per year, promoting an improvement in air quality.

We hope to corroborate and strengthen these results by monitoring the performance of the NBS in the other two pilot buildings: the Horta das Figueiras Elementary School in Évora and the Falcão Elementary School in Porto. The After-LIFE Plan, to be implemented between 2024 and 2028, will allow the prototypes to be monitored in their full operational phase, i.e. with the vegetation fully developed, both in the Solana de Los Barros School and in the two Portuguese schools.

As well as emphasising the advantages offered by the NBS prototypes, it's important to consider a number of best practices arising from the experience gained that could increase the project's chances of success. In this context, the following stands out:

⇒ Planning in advance and in an appropriate manner, establishing the key activities to be carried out and their maximum completion date, makes it possible to obtain the necessary licenses and permits, as well as the contracting of services and works inherent to the execution of the project, avoiding or minimizing any delays and budget overruns.

⇒ Identify and involve project stakeholders, including decision-makers, the user community (in this case the school community), but also those involved in building and installing the NBS prototypes.

⇒ Involving the beneficiary organizations (schools or other entities responsible for the buildings) in the planning process gives a more pragmatic view of the needs and requirements of the spaces, which is an essential contribution to making the solutions designed more easily accepted by the organizations and for the benefits to be real and effective.

⇒ Create broader multidisciplinary groups than the consortium, involving local organizations with recognized know-how, as a way of enhancing the validation of solutions, minimizing the risks and failure of prototypes.

⇒ It is equally important, prior to the development of the architectural and specialties project, to carry out the necessary studies to accurately characterize and diagnose the state of conservation of the building, allowing any construction and structural pathologies to be dealt with beforehand.

⇒ When necessary, it is advantageous to associate the implementation of the NBS with the general maintenance works of the school, allowing construction barriers to be overcome.

⇒ The specialization of the construction work, due to the implementation of green roofs and façades, NBS shading systems and the experimental and innovative nature of the prototypes, requires an increased investment in the study and preparation time of the architectural and specialty projects, as well as in the design of the solutions to be implemented. Investing in the detail of the project has the potential to minimize unforeseen problems on site. At the same time, it is advisable to carry out prior, exhaustive research into the materials and companies on the market in order to better design the solutions to be adopted. Likewise, this investment makes it possible to obtain more assertive execution conditions and budgets in advance, which should be transferred to the project along with the other necessary works, thus avoiding unforeseen implementation problems or budget shortfalls, and possible deserted or abandoned tenders.

⇒ The specific nature of the construction work and its innovative nature require an investment in execution time that is compatible with reality, which is why an adequate and realistic execution deadline must not be overlooked, avoiding changes and delays compared to the initially defined deadline.

⇒ Prepare an initial maintenance plan duly adjusted to ensure the survival of the newly planted species, which should be adjusted as the species develop and consolidate.

⇒ If the new green areas of the building are to be used, specifically on the roof, either for leisure or as a teaching resource, the project design must take into account and safeguard the respective accessibility in conditions of comfort and safety.

⇒ Select species that are perfectly adapted to the local climate, as well as to the conditions in which they are located in the building, without neglecting the use of expert advice on this matter.

⇒ For the purposes of monitoring and verifying the results obtained by the NBS, it is necessary to allow adequate time for the development and consolidation of the prototypes, in order to systematically extract and validate the results of the project.

Constraints

The results achieved by the project, explored, substantiated and justified throughout its implementation, represent a significant contribution to the knowledge of NBS and their corresponding performance as a measure to adapt buildings to climate change.

In this document, we have tried to build an efficient tool to help implement NBS in buildings and evaluate their performance.

Despite the results achieved, the NBS performance monitoring component has yet to be implemented in two of the pilot buildings, especially in the case of Évora, whose construction work ended coincidentally with the end of the LIFE-myBUILDINGisGREEN project.

In fact, the monitoring and results assessment periods must be long enough to ensure that they can take into account the most diverse variables, particularly in terms of the seasons and their impact on the solutions, and these moments are often sacrificed or shortened due to the limitations of the schedules.

It is expected that the results achieved in this phase will be overcome over the next five years, when the After-LIFE Plan will be in force.

The lack of knowledge of NBS and the innovative nature of the prototypes associated with this type of solution were also limitations identified during the course of the project.

In particular, there was a lack of companies specializing in NBS, either for the supply of materials or for the supply and installation of green roof and façade systems, irrigation systems for this type of solution, as well as construction companies with specialized technical capacity and skilled labour, and maintenance companies with experience in NBS. The scarcity of such suppliers on the market is still a barrier to the implementation of NBS in buildings. In addition, there is a general lack of knowledge on the part of other professionals in the construction sector, such as developers, designers, architects and engineers. Against this backdrop, the costs associated with implementing innovative NBS are high, and often a deterrent to their use.

In this context, the purpose of the LIFE-myBUILDINGisGREEN project was to overcome this limitation with actions to share and disseminate knowledge. These actions will continue, with various activities planned for different target audiences by the various consortium partners in the After-LIFE Plan.

At the same time, the growing amount of knowledge in NBS will enable barriers to be overcome with regard to public procurement and the organization and adequacy of the corresponding procedures.

Conclusion

The main result of this project is the design and implementation of several NBS prototypes, in the form of green roofs and façades, as well as new green areas planted with native species, in three pilot buildings: the Gabriela Mistral School, located in Solana de los Barros, in Badajoz (Spain); the Horta das Figueiras School, in Évora (Portugal); and the Falcão School, in Porto (Portugal).

With the results achieved, the project has also shown that these solutions have an impact on improving the thermal conditions and comfort inside the buildings, energy efficiency, water consumption control and the use of water, as well as making a significant contribution to adapting these buildings to climate change. Despite the monitoring and collection of quantifiable climate data already carried out at the Badajoz school, monitoring has yet to be carried out at the Porto and Évora schools with fully functioning NBS. In order to assess the evolution of the effects of the NBS on improving the bioclimatic conditions of the building, corroborating the preliminary results of the Badajoz school, and to robustly validate the NBS as measures for adapting to climate change, it is urgent to carry out the monitoring and evaluation actions planned for the two portuguese schools, over a period that includes the optimal development of the solutions implemented.

Considering that NBS are a viable and robust measure for adapting buildings to climate change, this Best Practices Guide culminates in a set of considerations to be taken into account when implementing NBS in future projects. This Best Practices Guide is also a useful tool for the replicability of the prototypes designed and tested in the LIFE-myBUILDINGisGREEN project, making a further contribution to the knowledge and understanding of NBS.