my building is green
A LIFE PROJECT

LIFE my building is green

LIFE17 ENV/EN/000088

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

Action: Monitoring of the impact of project indicators
Deliverable: Intermediate scoreboard.
Date: 30/03/2022

LIFE my building is green - LIFE17 ENV/ES/000088

Deliverable: **Report and results of the monitoring and evaluation of the proposed impacts on the pilot buildings.**

Date: **06/30/2022**

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

Data Beneficiary

Name Beneficiary:	STATE AGENCY CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
Contact person:	Miguel Vega
Postal address:	C/Serrano,117
Telephone:	34914203017
E-mail:	miguel.vega@rjb.csic.es
Project Website:	www.mybuildingisgreen.eu

Data Deliverable Responsible

Name Beneficiary:	CARTIF FOUNDATION
Contact person:	Jose Ramón Perán González
E-mail:	pedropombeiro@cm-porto.pt

Index

1. SUMMARY EN ESPAÑOL

This deliverable includes the mid-term evaluation (as of May 2022) of the status of the indicators and of some of the impacts resulting from the Project's actions, considering the baseline previously defined in Action C1.

To measure the impact of the project, monitoring of the effects produced by the project's action and the effectiveness of the technical actions has been carried out in accordance with the established indicators. These indicators have been previously determined in coherence with the environmental and climatic problems faced by the pilot buildings, as well as with the different Nature-based Solutions implemented. A series of indicators have also been selected that allow the evaluation of the socio-economic impact of the project, thus having a global and complete vision of the consequences of the technical actions implemented in the buildings.

At the time of carrying out this intermediate evaluation, at CEIP Gabriela Mistral in Solana de los Barros, the intervention has been completely completed since the end of 2021, at Escola EB1 Mello Falcão de Oporto, the works are in progress and at Escola EB1 Horta das Figueiras de Évora are about to start.

The state of calculation of the indicators is therefore different in each one of the schools. In the Solana de los Barros school, the impact evaluation period has begun and not yet for the other two. On the other hand, the degree of development of the technical indicators is greater than those proposed for social evaluation since it is becoming more complicated to collect the necessary information.

2. ENGLISH SUMMARY

This deliverable includes the intermediate evaluation (as of May 2022) of the status of the indicators and some of the impacts resulting from the Project's actions, taking into account the baseline previously defined in Action C1.

To measure the impact of the project, the effects produced by the project's actions and the effectiveness of the technical actions have been monitored in accordance with the established indicators. These indicators have been previously determined in coherence with the environmental and climatic problems faced by the pilot buildings as well as with the different Nature Based Solutions implemented. A series of indicators have also been selected to evaluate the socio-economic impact of the project, thus having a global and complete vision of the consequences of the technical actions implemented in the buildings.

At the time of this interim evaluation, at CEIP Gabriela Mistral in Solana de los Barros, the intervention has been fully completed since the end of 2021, at Escola EB1 Mello Falcão in Oporto, the works are in progress and at Escola EB1 Horta das Figueiras in Évora, the works are about to begin.

The state of calculation of the indicators is therefore different in each of the schools. In the Solana de los Barros school, the impact evaluation period has begun, while for the other two schools it has not yet begun. On the other hand, the degree of development of the technical indicators is greater than those proposed for the social evaluation, since it is more complicated to collect the necessary information.

3. RESUMO EM PORTUGUÊS

This deliverable includes the intermediate evaluation (as of May 2022) of the status of the indicators and some of the impacts resulting from the actions of the Project, taking into consideration the baseline previously defined in Action C1.

To measure the impact of the project, the effects produced by the action of the project and the effectiveness of the technical actions were monitored according to the established indicators. These indicators were previously determined in coherence with the environmental and climatic problems faced by the pilot buildings, as well as with the different Nature-Based Solutions implemented. A set of indicators was also selected to evaluate the socioeconomic impact of the project, thus having a global and complete vision of the consequences of the technical actions implemented in the buildings.

At the time of this interim evaluation, at CEIP Gabriela Mistral in Solana de los Barros, the intervention has been fully completed since the end of 2021, at EB1 Mello Falcão School in Porto, the works are in progress and at EB1 Horta das Figueiras School in Évora are about to begin.

The state of calculation of the indicators is, therefore, different in each of the schools. In the Solana de los Barros school, the impact evaluation period has already begun and not yet for the other two. On the other hand, the degree of development of the technical indicators is greater than those proposed for the social evaluation, because it is increasingly complicated to collect the necessary information.

4. INTRODUCTION

An important part of the project is to determine both the environmental and social impacts that have resulted from the implementation of the prototype nature-based solutions in order to assess the improvements and changes that have occurred.

To this end, an evaluation methodology has been established to define the data required for monitoring. The European project EKPLISE (http://www.eklipse-mechanism.eu/), adapted to the demonstration proposed in LIFE myBUILDINGisGREEN, has been used as a basis. In this way, the chosen indicators will serve on the one hand to integrate the results obtained in databases at European level (such as the OPPLA platform (http://www.oppla.eu/) and also be comparable with other experiences that can be carried out in other projects.

The scheme chosen for this action is shown in Table 1. It includes the environmental and social challenges to be addressed with the proposed actions, the indicators that will allow us to see the impact of the actions and the metrics considered appropriate for their evaluation. The complete description of the methodology for each of the indicators has already been included in deliverable C1 of the baseline.

Table 1. Outline of the pre-established impact assessment for LIFE myBUILDINGisGREEN.

ENVIRONMENTAL AND SOCIAL CHALLENGES	IMPACT
Adaptation and mitigation CC	**Interior temperature of the building.** In particular, it will be evaluated that the maximum comfort temperatures (27 ºC) are not exceeded during the summer months. **Building envelope temperature.** Evaluate facade behavior in different seasons and how it affects. It decreases in summer, stays the same in winter... **External environmental conditions of the building in** terms of humidity and temperature, evaluating if the implemented solutions improve the external thermal comfort. **Estimate of the energy savings achieved** thanks to the solutions implemented in refrigeration. **Estimated heating savings.**
Water management	**Estimated savings related to water consumption** that have

Table 1. Outline of the pre-established impact assessment for LIFE myBUILDINGisGREEN.

CHALLENGES ENVIRONMENTAL AND SOCIAL	IMPACT
	produced by the NBS implemented in green areas **Estimated savings in rainwater management through** rainwater harvesting from green roofs and the amount of water avoided going to sanitation.
Management of green areas	**Increased plant and animal biodiversity**. **Number of native plant species recovered that are suitable (non-allergenic, non-poisonous, etc.) for integration into green areas.**
Air quality	**Carbon dioxide concentration levels inside the classroom.** **Noise reduction levels from the outside**. **Levels of contamination** via installation of bioindicator species and training in their observation.
Urban regeneration	**Energy efficiency measures.** **Increase in green area (m^2 and in %)**.
Governance and participation	**Citizens' perception of urban nature**. **Learning policies and strategic plans for adaptation to CC**. **Open participatory processes. Citizen participation in open processes to define the recreational area / park to be installed.**
Social cohesion	**Number of agreements and disagreements**.
Public health and welfare	**Reduction in the number of absences and absences of students and teachers**.
Economic opportunities and employment	**Number of jobs created**. **Creation of new capacities in self-employed and companies in the area related to the NBS**. **Reduction of absenteeism among school personnel**.

5. INDICATORS AND DEVELOPMENT STATUS

This section refers to the indicators used to calculate the impact with respect to the baseline, based on the information in Deliverable C1 - Pilot Buildings Baseline Report.

5.1 Climate change adaptation and mitigation

The solutions proposed by the LIFE myBUILDINGisGREEN project to adapt buildings to climate change and mitigate its consequences are related to green roofs and different types of façade revegetation. Vegetation helps lower ambient temperatures by increasing air humidity through transpiration and soil irrigation. The decrease in outdoor temperatures is also related to the increase in the surface area that is protected from direct solar radiation by generating shade (Salvo et al, 1993). This improves environmental thermal comfort at high temperatures, alleviating the heat island effect. This type of solution also has an influence on the reduction of the interior temperature of buildings, since the vegetation and the related construction system act as insulation, increasing the passive energy savings of buildings and reducing the energy consumption required for heating and air conditioning. This energy saving leads to a reduction in greenhouse gas emissions from buildings.

The evaluation of the impacts that the actions in the pilot buildings have and will have on the adaptation and mitigation to climate change of the pilots is carried out based on indicators. In the following, a review of the current state of evaluation will be made and for some of them preliminary results observed will be shown.

I1.1 Indoor building temperature.

As an indicator of thermal comfort, the temperature and humidity inside the classrooms are being monitored. The reference values taken to evaluate thermal comfort are not to exceed 25ºC maximum in summer (RITE) and to maintain humidity levels between 30-70%.

The impact on the interior T&H of the classrooms will be related to those NBS that can have a positive effect on the classrooms, roofs, facades and green canopies. In order to know their impact, other classrooms that have not been affected by the interventions in principle will be used as a reference.

From the information collected, the ten-minute values of T and RH, only the values during the school period (9-14 h, Monday to Friday) are taken into account, excluding the non-school months of July and August.

The current status of the indicator is as follows:

Figure 1. Current status of indicator I1.1.

I1.2 Building envelope temperature.

By taking thermal images of the surface of the school façade before and after the interventions and comparing them with a reference building, it is shown whether the actions generate temperature reductions in the building envelope in high temperature situations. This is a general comparison, for communication purposes, a quantitative analysis is not established.

Figure 2. Current status of indicator I1.2.

I1.3 External environmental conditions of the building.

The impact on the outdoor environmental conditions of T and H due to the implementation of NBS and its ability to reduce the intensity of heat waves and the heat island effect is measured.

Figure 3. Current status of indicator I1.3.

I1.4 Modeling of the energy savings produced

The savings in energy consumption from the installation of commercial refrigeration equipment is calculated based on the reduction in indoor temperatures achieved by the measures implemented. This indicator has been initially estimated using simulation software and will be calculated at the end of the project based on the records of the sensors installed in the schools. The current state of the interventions does not make it possible to calculate this indicator at this time.

Figure 4. Current status of indicator I1.4.

I1.5 Estimated heating savings.

The current energy consumption savings compared to the situation prior to the interventions are evaluated. The time period for data collection is intended to include as a baseline the average value of the last 10 years of activity in the years prior to the interventions and at least 1 year after the interventions. The data to calculate this indicator are still being compiled among the administrations.

Figure 5. Current status of indicator I1.5.

5.2 Water management

The impact of the application of green roofs and permeable pavements on the improvement of rainwater management in the pilot buildings is measured, in terms of their capacity to collect and store rainwater, for its subsequent reuse or filtering to the ground, reducing the contribution of rainwater to the supply network and avoiding its collapse in episodes of heavy rainfall, as well as flooding. At the same time, savings in irrigation water consumption due to water reuse and the use of closed circuits are also measured.

The evaluation of the impacts that the actions in the pilots have had on the improvement of water management are as follows:

I2.1 Savings in water consumption for irrigation of green areas in the pilot buildings.

The savings from the implementation of NBS in irrigation water consumption are being calculated. For this purpose, the amount of water consumed (m^3) in the green areas of the pilot buildings before and after the implementation of the NBS is being estimated. For the calculation, the irrigation water consumption data of the historical green areas up to the present time are being collected.

Figure 6. Current status of indicator I2.1.

I2.2 Savings in rainwater management.

In order to know the savings produced by the NBS in water management, the volume of runoff entering the sewerage system before and after the implementation of the prototypes has been calculated. In this way, the capacity of the NBS to accumulate and/or filter rainwater is evaluated, avoiding its evacuation to the city's sewerage system and the resulting savings.

Rainfall data for the area are used for the calculation, and with the characteristics of the roofs and surfaces of the school, before and after the interventions, the impact of the interventions on each one is estimated.

Figure 7. Current status of indicator I2.2.

5.3 Management of green areas

By implementing nature-based solutions, the positive impact on biodiversity and ecosystem services will be measured, due to the increase in plant species present, as well as the animal species associated with them. Improved management of urban natural areas improves the management of urban natural areas and increases the quality and quantity of green spaces, providing ecological as well as recreational, social and welfare benefits.

The evaluation of the impacts of the actions in the pilots for the improvement of the management of green areas is carried out on the basis of the following indicators:

I3.1Increased plant and animal biodiversity.

This indicator seeks to identify the animal and plant species that appear after the implementation of the NBS or those that existed and are promoted due to the ecosystem services they provide. Basically, they consist of making periodic counts and identifying by functionalities and thus evaluating the impact of the NBS. In general, what is sought is an increase in plant and animal biodiversity under sustainability criteria, one of the most important of which is the promotion of native species.

Figure 8. Current status of indicator I3.1.

I3.2 Number of native plant species

This indicator is a complement to the one mentioned above. It assesses the impact of the NBS implemented on the number and promotion of native plant species. Direct promotion (planting) and indirect promotion generates spaces that are more adapted to the climate and that are also in balance with the rest of the area's biodiversity.

Figure 9. Current status of indicator I3.2

5.4 Air quality

The impact of the LIFE myBUILDINGisGREEN interventions on air quality has been measured in 3 aspects: indoor air quality - measuring CO concentrations$_2$; indoor noise pollution - measuring sound absorption and indoor noise levels (dB); and outdoor air quality based on the impact on bio-indicator species. Consequently, the comfort and well-being of school users is increased.

The evaluation of the impacts of the actions in the pilots for the improvement of air quality is carried out based on the following indicators:

I4.1 Carbon dioxide concentration inside the classroom.

The evolution of CO concentration levels$_2$ inside classrooms, the effect of ventilation protocols and whether good indoor air quality is maintained below 800 - 1,200 ppm have been evaluated. Exceeding these levels can cause discomfort, headaches and fatigue among others, depending on the duration of exposure. These symptoms can be aggravated in the case of children.

It should be noted that following the COVID19 pandemic, the recommended CO values$_2$ have been updated to 700-800 ppm in order to reduce the risk of one person breathing the air exhaled by another. In this consideration, of course, the aim is to avoid contagion of diseases transmitted by aerosols produced by breathing.

Figure 10. Current status of indicator I4.1.

I4.2 Noise reduction levels from outside.

Two annual measurements of interior and exterior noise levels, before and after the interventions, are used to determine whether the sound insulation of the building against exterior noise has improved. An interior space not affected by the interventions will also be measured as a reference value. The method provides an approximate value of the noise attenuation that can be provided by the prototype solutions implemented.

As reference values, according to the WHO, any sound above 65 dB is considered noise, and if it exceeds 75 dB it is considered harmful to health. The desirable upper limit is set at 50 dB. Green roofs and walls can function as an effective sound insulation layer, mitigating between 5-10-15 dB of sound for medium frequencies (G. Pérez et al., 2018).

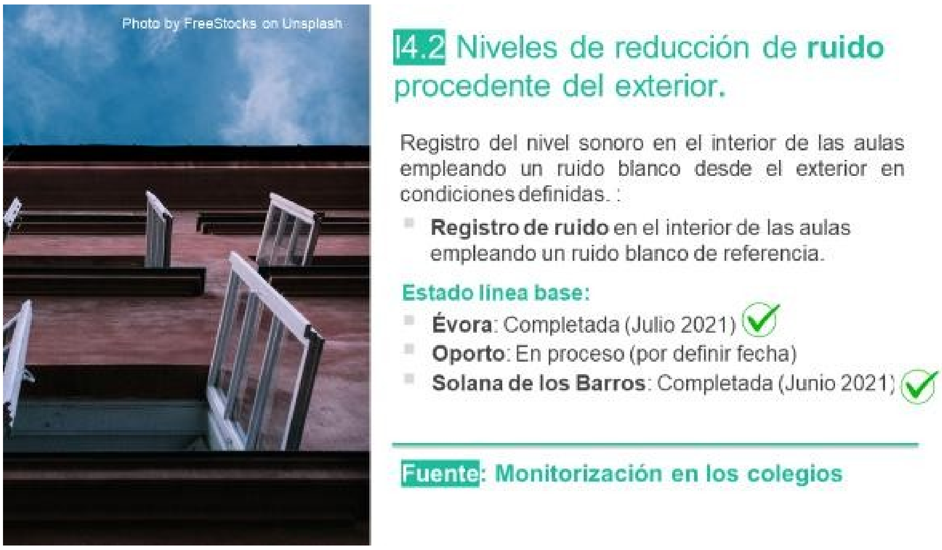


Figure 11. Current status of indicator I4.2.

I4.3 Number of bioindicator species

This indicator basically consists of planting bioindicator species of air pollution and evaluating the environmental pollution of the area, both around the school and in its vicinity, but without the influence of the NBS.

Figure 12. Current status of indicator I4.3.

5.5 Urban regeneration

Through the implementation of climate change mitigation and adaptation measures in the LIFE MyBUILDINGisGREEN project, it is expected to contribute to urban regeneration, moving towards new models of sustainable and resilient cities that contribute to an efficient use of resources, reducing energy consumption. The impact of NBS as energy efficiency measures for existing buildings is measured. It is also expected to contribute to improving universal access to green areas and public spaces in accordance with the SDGs (Goal 11 Sustainable Cities and Communities).

The evaluation of the impacts of the actions in the pilots for urban regeneration are as follows:

I5.1 Energy efficiency measures.

For the calculation of this indicator, the different measures that schools have implemented during the LIFE myBUILDINGisGREEN project to improve their energy efficiency have been taken into account. Energy efficiency measures are considered to be those that reduce the energy demand, in this case, of existing buildings. All those measures that influence the energy efficiency of the building will be collected, covering different types of interventions.

First, interventions related to the improvement of the building envelope will be included, taking into account measures to improve insulation (considering green roofs and facades as effective insulation systems) and the replacement of existing carpentry with new carpentry with thermal break and double glazing. Shading and solar protection elements are also considered an effective measure to improve thermal and lighting comfort by reducing the impact of direct insolation on buildings (Q. Vargas-Gómez et al., 2014). The adoption of ventilation protocols is also considered an effective measure to reduce temperatures in summer seasons. Measures that include improvements in the performance of heating, cooling, domestic hot water and lighting installations and/or the installation of renewable energies such as the installation of solar or photovoltaic panels are also included.

The impact of the implemented solutions in improving energy efficiency will be measured by evaluating the reduction in heating and electricity energy consumption.

Figure 13. Current status of indicator I5.1.

I5.2 Increase in green area

To calculate the impact achieved in increasing green areas, the green areas in the action area (m^2) and the percentage with respect to the total area of the plot (%) before and after the implementation of the actions have been measured. Green areas were considered to be all those interventions that generate a green surface, including new forms of urban greenery such as green facades and green roofs.

Figure 14. Current status of indicator I5.2.

5.6 Governance and participation

I6.1 Citizens' perception of urban nature.

To evaluate citizens' perception of the solutions implemented, surveys have been designed for students at the centers. The surveys will be distributed after the interventions, without a baseline.

Figure 15. Current status of indicator I6.1.

I6.2 Learning policies and strategic plans for adaptation to climate change.

This indicator will be used to evaluate the number of events and their impact, in terms of number of attendees, impact on social networks, press appearances, etc. It will serve to evaluate the effectiveness of the examples promoted by the project and its form of communication.

This indicator is currently under development, collecting data from the various events and other events in which the partners participate, especially the participating public administrations.

Figure 16. Current status of indicator I6.2.

I6.3 Open participatory processes.

This indicator will assess the number of events in which the project has collaborated with external agents for the execution of actions, both for the design and implementation of the BSS and for dialogue events open to the collection of suggestions and impressions from the general public.

The indicator is currently in the phase of collecting information on the processes and events carried out by the project partners. The information collected at the end of the project will be used to evaluate how citizen participation has been promoted.

Figure 17. Current status of indicator I6.3.

5.7 Social cohesion

I7.1 Number of agreements and disagreements.

This indicator measures the number of agreements reached by the project partners on the promotion of BSS as an adaptation measure. It will be valued on the total number of interactions carried out. A limit of agreements will be established as a target value. The impact will be measured by the percentage of agreements reached over the target.

Figure 18. Current status of indicator I7.1.

5.8 Public health and welfare

I8.1 Reduction in the number of absences and sick leaves of students and teachers.

Based on the information provided by the administrations, the number of absences (categorized according to the detail of the information received) before and after the interventions will be assessed to establish the impact of the interventions on comfort and health in the school spaces. It will be studied whether some kind of direct correlation can be established when presenting the conclusions.

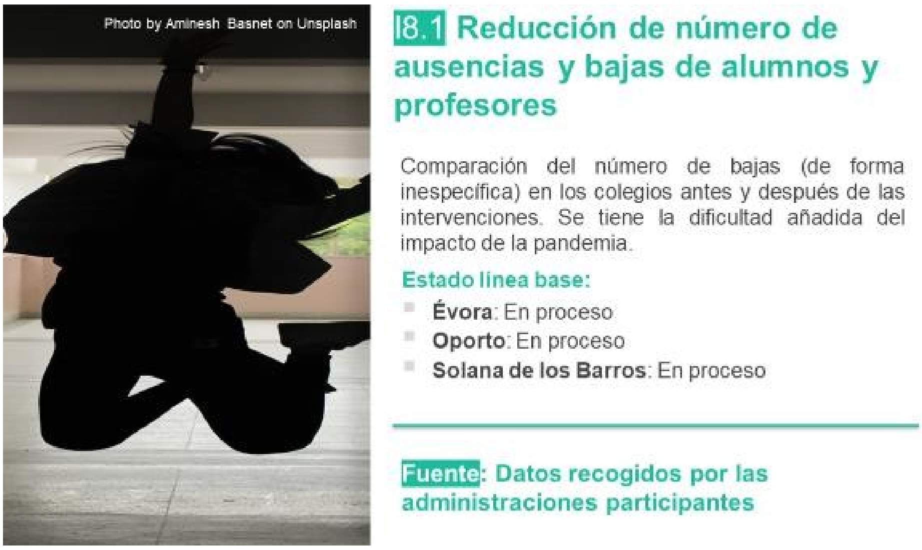


Figure 19. Current status of indicator I8.1.

5.9 Economic opportunities and employment

I9.1 Number of jobs created.

This indicator will measure the number of direct jobs created by the project, both in the direct execution of the LIFE by the partners and in the works carried out through tenders.

Information is currently being collected for evaluation at the end of the project.

Figure 20. Current status of indicator I9.1.

I9.2 Creation of new capacities in the self-employed and companies in the area

Assess the number of local and regional companies and self-employed that have participated in the bidding processes or have shown interest in the NBS. In addition, those that have been interested and participated in the courses carried out by the project will be counted.

Figure 21. Current status of indicator I9.2.

I9.3 Reduction in absenteeism

Based on the information provided by the administrations, the number of absences of school staff (categorized according to the detail of the information received) before and after the interventions will be assessed to establish the impact of the interventions on comfort and health in school spaces. Whether any direct correlation can be established when presenting conclusions will be explored.

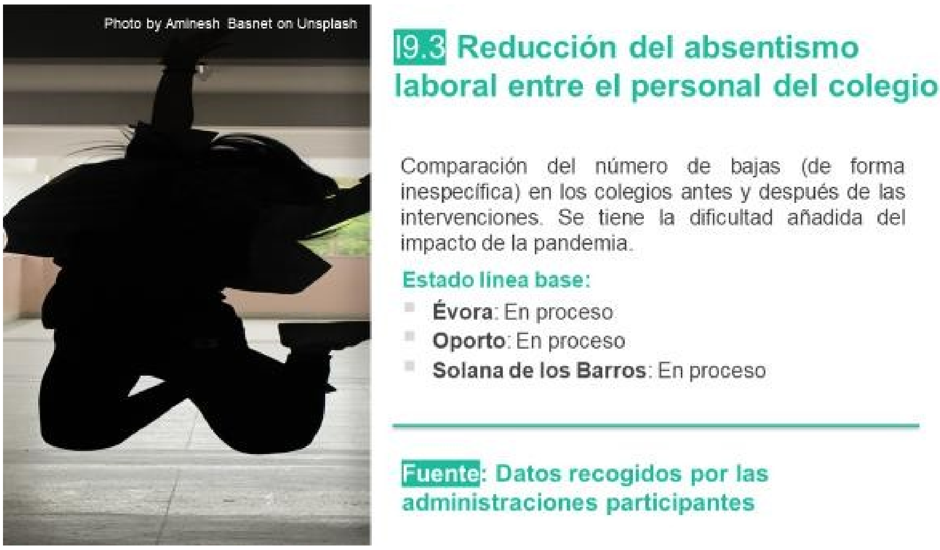


Figure 22. Current status of indicator I9.3.

6. IMPACTS ON BUILDINGS

6.1 Évora

INTRODUCTION

The implementation of Nature-based Solutions has focused on improving the thermal comfort of school users, increasing the green area in a sustainable way, reducing the carbon footprint, improving water management, recovering and promoting local biodiversity in the urban environment and raising awareness of the value of nature and the ecosystem services it provides.

The installation of green facades is intended to reduce the impact of solar radiation on the building envelope and its direct entry through the openings, generating a circulation of air inside the building in summer with naturally "cooled" air. In addition, the air renewal achieved with these actions should reduce carbon dioxide levels inside the classrooms and increase thermal comfort. Increased outdoor shaded areas are expected to improve outdoor environmental conditions of temperature and humidity. These impacts are expected to improve the health and well-being of students and teachers. The installation of draining floors and green roofs with the capacity to capture rainwater allows for a reduction in runoff water assumed by the public sewage system.

Participatory processes of co-design and co-development of solutions have also been integrated with the educational community to improve governance and social cohesion processes.

First, the actions implemented in the building and their relationship with the indicators will be briefly described. Subsequently, a review of the status of the proposed impact assessment indicators will be made. In this intermediate document there is still a lot of information to be included because the interventions have not yet been carried out.

The baseline data collection period is from January 2020 until work begins in 2022. The post-intervention data collection period is from the end of the works in 2022 until December 2023, which is the end of the project.

PRELIMINARY - STATUS AS OF MAY 2022.

ACTIONS - DESCRIPTION OF THE BUILDING

Generally speaking, all actions contribute to indicators I9.1; I9.2; I9.3

Covers

Installation of green roof with the mBiGWTray prototype on the 4 roofs. To maintain the original roof structure and avoid overloads that could affect the fiber cement encapsulation, the green roof is installed on a new independent metal structure.

Drip irrigation is installed to irrigate the green roof. Although the initial design did not include the need for the installation of drip irrigation, its incorporation was at the request of both CIMAC and the Municipal Chamber of Évora.

Plant species:

Relation to indicators I1.1; I1.3; I1.4; I1.5; I2.1; I2.2; I3.1; I4.2; I5.1; I5.2; I6.1; I8.1

Deck 1.

- Plant surface
- Accessibility
- Photo

Monitoring

Two sensors (CO_2 , T and RH) in classrooms 3 and 4, upstairs classrooms.

Deck 2.

- Plant surface
- Accessibility
- Photo

Deck 3.

- Plant surface
- Accessibility
- Photo

Monitoring

A sensor (CO_2 , T and RH) has been installed in this space.

Deck 4.

- Plant surface
- Accessibility
- Photo

South façade

Shading of the south façade by cantilevering the green roof.

- Description
- Plant species
- Irrigation system
- Plant surface
- Photo

Relationship to indicators I1.1; I1.2; I1.3; I1.4; I1.5; I2.1; I3.1; I4.1; I4.2; I5.1; I5.2; I6.1; I8.1

Monitoring

Four sensors (CO_2 , T and RH) have been installed in the four classrooms on the façade, two on the first floor and two on the upper floor.

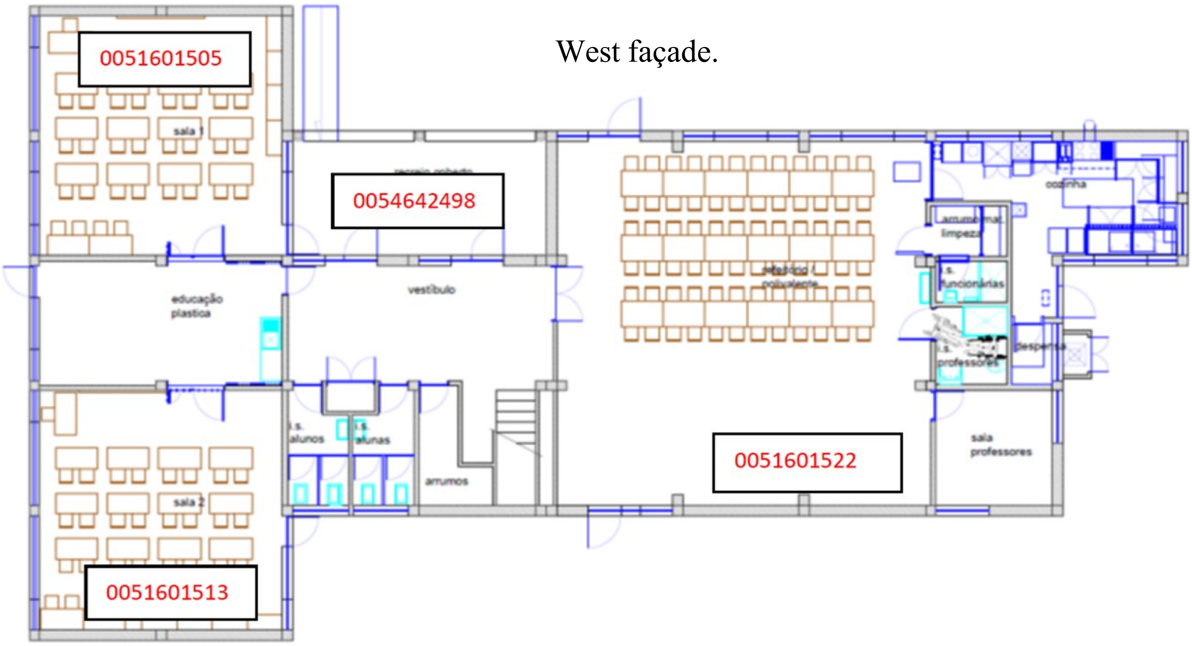


Figure 23. Location of sensors on the first floor of the building, including the exterior sensor on the west façade.

Figure 24. Sensors installed in the classrooms on the second floor and the one located outside on the south façade.

East façade

Installation of two wired structures to support the growth of climbing vegetation to shade the east façade.

- Description
- Plant species
- Irrigation system
- Plant surface
- Photo

Relationship to indicators I1.1; I1.2; I1.3; I1.4; I1.5; I2.1; I3.1; I4.1; I4.2; I5.1; I5.2; I6.1; I8.1

Monitoring

An exterior east façade sensor (T and RH) has been installed to implement the natural induced ventilation formulas.

West façade

Installation of the mBiGToldo prototype on the blind wall of the west façade.

- Description
- Plant species
- Irrigation system
- Plant surface
- Photo

Relationship to indicators I1.1; I1.2; I1.3; I1.4; I1.5; I2.1; I3.1; I4.1; I4.2; I5.1; I5.2; I6.1; I8.1

Monitoring

Installation of an outdoor sensor (T and RH) to assess fresh air intake for induced natural ventilation formulas.

Intervention abroad

- Shading canopies

Relation to indicators I1.3

- Permeable pavement

Relationship to indicators I2.2

- Change of pavement

Relationship to indicators I2.2

- Tree planting - vegetation

Relationship to indicators I1.3; I2.1; I2.2; I3.1; I4.2; I4.3; I5.2; I6.1; I8.1

CURRENT SITUATION INDICATORS - IMPACT

Climate change adaptation and mitigation.

I1.1 Indoor temperature of the building.

At the temperature evaluation level, the baseline is being recorded. As can be seen in the image, the indoor temperatures (monthly averages for each sensor only on school days and in the school period from 8 am to 3 pm) evolve in a similar way. In addition, it can be observed that in general the temperatures in the southern exterior zone of the

The building is higher, as expected, and in the western area, which is already more shaded, they are lower than in the interior of the building.

To analyze the effect of the roofs, we will study the evolution of the data from the upper floor classrooms compared to the data from the lower floor classrooms, which are less affected by the installation of the green roofs.

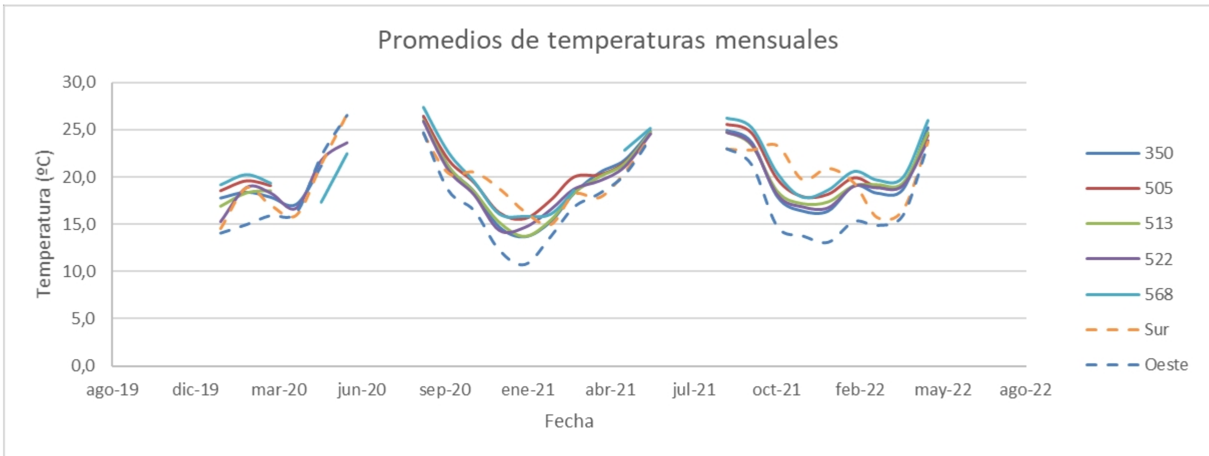


Figure 25. Evolution of monthly average temperatures of the sensors installed in the classrooms and outdoors in Évora.

I1.2 Building envelope temperature

In relation to the envelope temperature, thermal images were taken of the current situation before the interventions with the NBS. As an example, a detail of the east façade of the building and the surface temperatures depending on its color is shown. This façade will be shaded with climbing vegetation driven by metallic tensors.

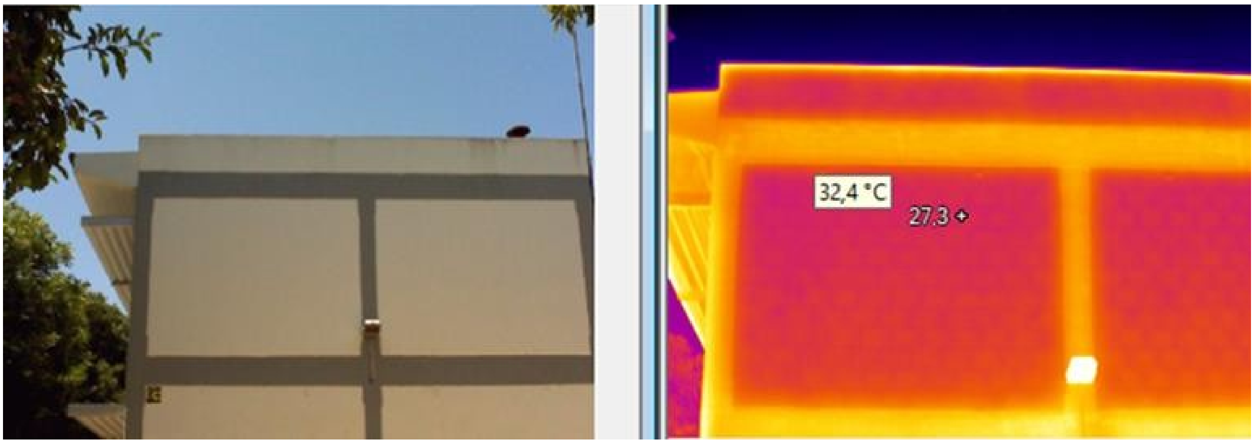


Figure 26. Visible and thermal images of a piece of the east façade.

Indicators I1.3, I1.4 and I1.5 are also in progress, gathering information to configure the building's baseline status.

Water management

These indicators are still in process.

Management of green areas

These indicators are still in process.

Air quality

I4.1 Carbon dioxide concentration inside the classroom.

For this indicator, the baseline of the current situation has been configured. It should be noted that indoor air quality, and in particular the carbon dioxide parameter, has been affected by the situation caused by the pandemic. Firstly, because there have been several months in which the confinement and the cancellation of classroom classes meant that the measurements were not representative of a normal school period. The values recorded were those corresponding to empty classrooms. On the other hand, the change in habits upon returning to classes due to the ventilation protocols promoted to avoid COVID19 contagion caused a very pronounced decrease in CO concentrations$_2$ compared to the pre-pandemic situation. However, it must be said that since the beginning of the 21-22 school year, it seems that the protocols have been relaxed and the average levels have risen again.

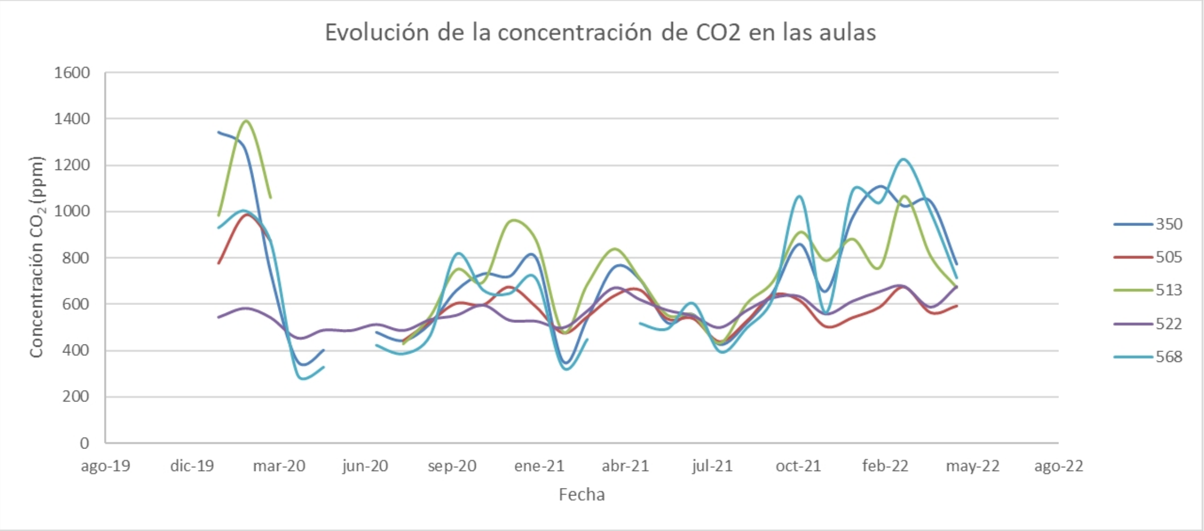


Figure 27. Graph of the evolution of the monthly average CO concentrations₂ in the different classrooms of the Évora school.

Indicators I4.2 and I4.3 are currently under development.

Urban regeneration

These indicators are still in process.

Governance and participation

These indicators are still in process. However, it should be noted that in Évora a day has already been organized with local agents to publicize the planned interventions in the school. In addition, a co-design action has been carried out with the school in which the children, in collaboration with the teachers and their families, have proposed solutions to have an outside area of the building with more vegetation and in compliance with their demands to improve their quality of life.

Social cohesion

Indicator in progress.

Public health and wellness

Indicator in progress.

Economic opportunities and employment

Indicators in progress.

6.2 Porto

PRELIMINARY - to be completed when more information is available.

6.3 Solana de los Barros

INTRODUCTION

The implementation of Nature-based Solutions has focused on improving the thermal comfort of school users, increasing the green area in a sustainable way, reducing the carbon footprint, improving water management, recovering and promoting local biodiversity in the urban environment and raising awareness of the value of nature and the ecosystem services it provides.

The installation of green facades is intended to reduce the impact of solar radiation on the building envelope and its direct entry through the openings, generating a circulation of air inside the building in summer with naturally "cooled" air. In addition, the air renewal achieved with these actions should reduce the levels of carbon dioxide inside the classrooms. Increased outdoor shaded areas are expected to improve outdoor environmental conditions of temperature and humidity. These impacts are expected to improve the health and well-being of students and teachers. The installation of draining floors and green roofs with rainwater harvesting capabilities reduces runoff water assumed by the public sewer system and promotes more natural water management.

Through participatory co-design and co-development processes with the educational community, the aim is to improve governance and social cohesion processes.

First, the actions implemented in the building and their relationship with the indicators will be briefly described. Subsequently, a review of the status of the proposed impact assessment indicators will be made.

The baseline data collection period is from May 2019 to December 2021. The period of data collection after the interventions is from January 2022 until the end of the project in December 2023, thus fulfilling the minimum two years of monitoring foreseen.

ACTIONS - DESCRIPTION OF THE BUILDING

The actions that have been carried out have affected the roofs and facades of the 'annex' building and the exterior spaces, pavements and plant areas. Both the façade system and the roofs and pergolas have irrigation systems.

Generally speaking, all actions contribute to indicators I9.1; I9.2; I9.3

Covers

Three types of green roofs have been installed (CUVE-SUS; CUVE-1 and CUVE-2), for a total of 420 m^2 of green roof.

Relationship to indicators I1.1; I1.2; I1.3; I1.4; I1.5; I2.1; I2.2; I3.1; I4.2; I5.1; I5.2; I6.1; I8.1

Deck 1

Three types of green roof have been installed on roof 1. On the one hand, the CUVE-1 system with elevated trays and extensive cover; and the CUVE-2 system with elevated trays with pots and climbers distributed at 50% over a total area of 58 m^2 . On the other hand, a CUVE-SUS system has an area of 85 m^2 of extensive cover, with perennials and sedum type plants. An access door to the roof has been installed from the +1 floor lobby.

Type: CUVE-SUS; CUVE-1 and 2.
Surface area: 143 m^2 .
Access: Yes.

Monitoring

By means of sensors (CO_2 , T and RH) in primary 2 and 4 classrooms.

Deck 2

Three types of green roof have been installed on roof 2. On the one hand, the CUVE-1 system with elevated trays and extensive cover; and the CUVE-2 system with elevated trays with planters and climbers distributed at 50% over a surface of total of 27 m^2 . On the other by hand, a CUVE-SUS means of area of system 60 m2 fr there is a extensively, with plants covered perennials and sedum type. Deck m2 was already accessible from the gallery, prior to the work.

Type: CUVE-SUS; CUVE-1 and 2.
Surface area: 87 m^2 .
Access: Yes.

Deck 3

Type: CUVE-SUS
Surface area: 200 m^2 .
Access: Yes.

An extensive CUVE-SUS cover has been installed on deck 3, with perennials and sedum type plants, covering a total area of 200 m^2 . A ladder has been installed for maintenance access to deck 3.

Facade

The FAVE-1 system has been installed at different levels and on different facades with climbing plants and planters. In turn, the FAVE-2 system has been installed on part of façade 3 with vegetated awnings on the vertical sunshades and climbing plants on the horizontal sunshades. A total of 400.5 m^2 of green facade has been installed.

Relation to indicators I1.1; I1.2; I1.3; I1.4; I1.5; I2.1; I3.1; I4.1; I4.2; I5.1; I5.2; I6.1; I8.1

East façade

On level -1, the FAVE-1 system has been installed on façade 1 in the vertical sunshades with a total surface area of 19.20 m^2 .

On level 0, a total of 138.45 m^2 of green façade has been installed. On façade 2, the FAVE-1 system has been installed on the vertical sunshades with a total surface area of 42 m^2 . On façade 1, the FAVE-1 system has been installed on the vertical and horizontal sunshades with a total surface area of 96.45 m .^{2}

On level +1, a total of 139.7 m^2 has been installed. On façade 3, the FAVE-1 system was installed on the horizontal and vertical sunshades with a total surface area of 116.5 m^2 and the FAVE-2 system on the vegetated awnings with a surface area of 23.2 m^2 .

On the roof level, the FAVE-1 system has been installed on façade 3 in the horizontal substructure with an area of 48.15 m^2 .

Monitoring

Two sensors (CO_2 , T and RH) have been installed in primary 2 and 4 classrooms and a T and RH sensor in primary 2 and 4.

the exterior of the facade. A photographic report of thermal images of façade 1 has been made.

West façade

The FAVE-1 system has been installed next to the new roof maintenance staircase, w i t h a 55 m surface area[2] of green façade.

Monitoring

A T and RH sensor has been installed outside.

Interior

On level 0, in the gallery connecting the old building with the annex, an 18.55 m interior green wall[2] has been installed.

Outdoor area

Two types of intervention were carried out in the outdoor area: pergolas with climbing plants and pots (PEVE 1 and 2 system) and outdoor plant areas with a total surface area of 707.3 m^2 and permeable paving (SUVE 1 and 2), with a total surface area of 456.7 m^2 .

In the main entrance courtyard, the PEVE-1 system has been installed with a surface area of 54.8 m^2 . In the children's playground, an outdoor area of 534 m^2 has been vegetated and the PEVE-2 system has been installed with an area of 118.5 m^2 , increasing the available shaded areas.

Relationship to indicators I1.3; I2.1; I3.1; I3.2; I5.2; I6.1; I8.1

In the patio corresponding to the north façade, the SUVE-1 system has been installed, a porous draining pavement, covering an area of 351 m^2 . On the perimeter, the SUVE-2 system has been installed, draining tiles (105.7 m).[2]

Relationship to indicators I2.2

FINAL SITUATION INDICATORS

Climate change adaptation and mitigation.

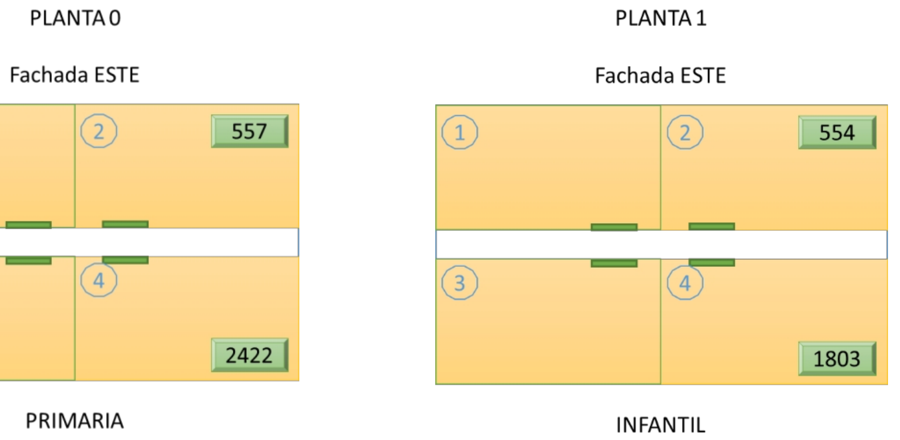
I1.1 Indoor temperature of the building.

The following table shows the location of the sensors installed in CEIP Gabriela Mistral, the classroom, the façade on which the classroom is located and the number of students in the classroom during the 2020/2021 academic year. Each classroom is also related to the NBS implementation that influences the interior temperature of the classroom.

Status of sensors and classroom occupancy at CEIP Gabriela Mistral.

Sensor	502	554	557	977	1803	2422
Plant	Floor 1 Old Building	Floor -1 Childre n's	Ground Floor	Ground Floor	Floor -1 Childre n's	Ground Floor
Facade	South	This	This	This	West	West
Students	12	14	19	Normally empty.	15	18
NBS	-	FAVE-1	FAVE-1 CUVE	FAVE-1 CUVE	-	-

Three sensors are located on the first floor, two of them in classrooms with windows facing the east façade and one in another classroom with windows facing the west façade.



Two sensors have been installed on the second floor, one in a classroom with windows facing the east façade and the other in another classroom with windows facing the west façade. On the other hand, a sensor has also been installed in a classroom of the old building on the south façade and two other sensors on the exteriors of the east and west façades.

The evolution of monthly average temperatures only considering school days and school hours shows the important seasonal variation. The temperature inside the classrooms follows a similar evolution in all of them, but with certain variations that make some classrooms have more comfortable temperatures than others when analyzed in detail. In the initial state of the building, the classrooms located on the west façade were found to have a vegetal barrier that shaded them and would also receive insolation from the

In the afternoon and after school hours, they had lower average temperatures than the classrooms on the east façade, which were fully exposed to the sun throughout the morning.

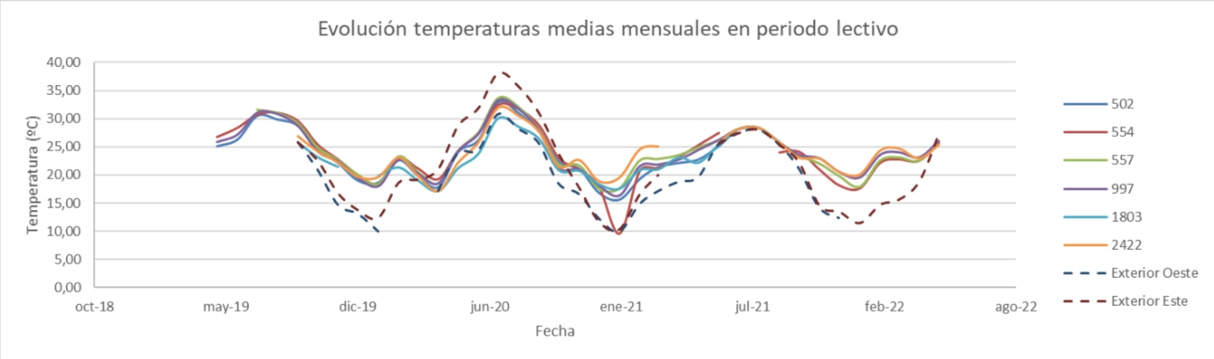


Figure 28. Evolution of monthly measured temperatures in the different classrooms during school hours.

Some studies have been carried out with the records collected so far, but the bulk of the impact assessment is expected to be carried out with the two data from the summer season of 2023. At that time the vegetation will be at its maximum development (within the project implementation period) and its impact can be assessed more adequately. However, it is expected that, in the following years, with the full development of the shading by the vegetation on the east façade of the building, the proposed beneficial impacts will be achieved.

However, with the data collected, interesting preliminary studies have been carried out. The period of nighttime opening of the automatic windows has been established in order to cool the interior of the building during the night.

The following figure shows the evolution of temperatures in two classrooms, one facing east (with greater variation and higher maximum values during the school period) and the other facing west. In addition, the evolution of the outside temperature is shown. As can be seen, the temperatures reached in May 2022 during the school period are exceptionally high, exceeding 27ºC on many days and reaching up to 31ºC inside the classrooms. It can also be seen how the minimum temperatures in some weeks do not drop below 25 ºC, which means starting the school day with very high temperatures. Analyzing the outside temperatures, it is possible to find a suitable period for opening windows in order to cool the inside of the building.

This programming, carried out with the information recorded in May, may also be valid for use in June, September or October, but its effectiveness will depend fundamentally on the weather and above all on the occurrence of heat waves associated with tropical nights (minimum temperature above 25ºC). If these situations become too frequent, other measures to reduce temperatures should be evaluated.

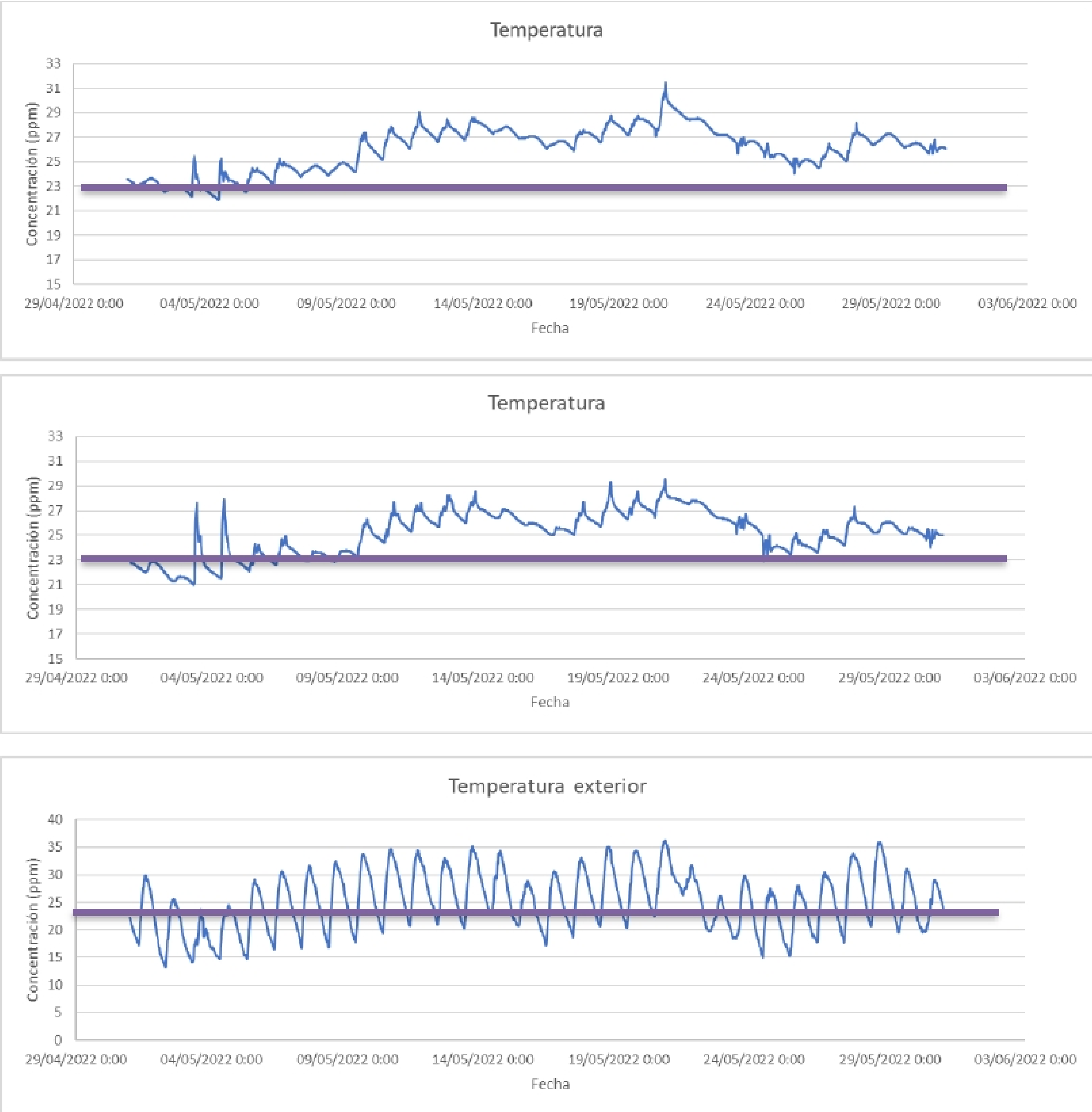
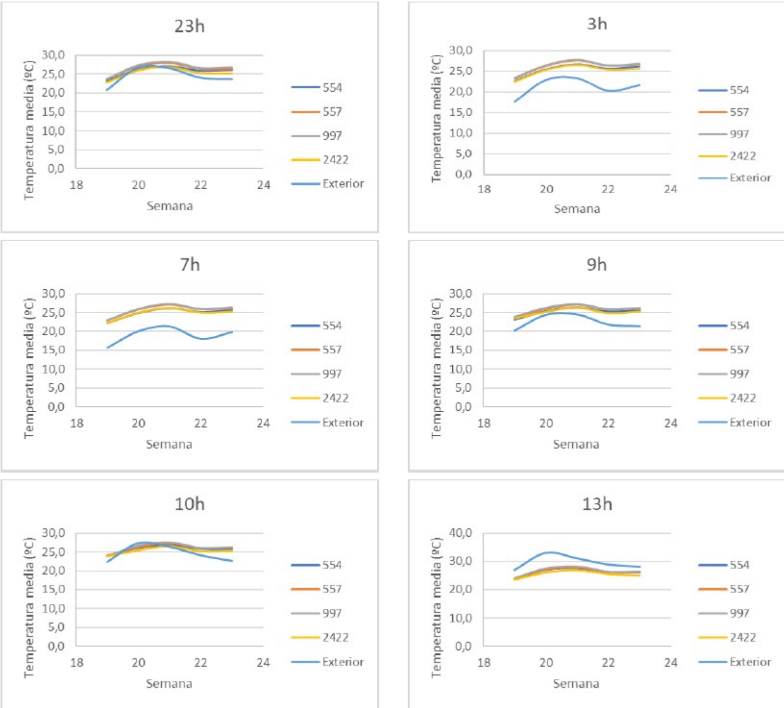


Figure 29. Temperature profile in a classroom facing east (top), west (center) and outside (east).

The figure below shows the differences in temperatures between the inside and outside of the school. It can be seen how opening the windows at night can circulate cooler air from the outside to the inside of the building, partially cooling it. This action can already be carried out. The proposed period is between 3:00h and 9:00h.

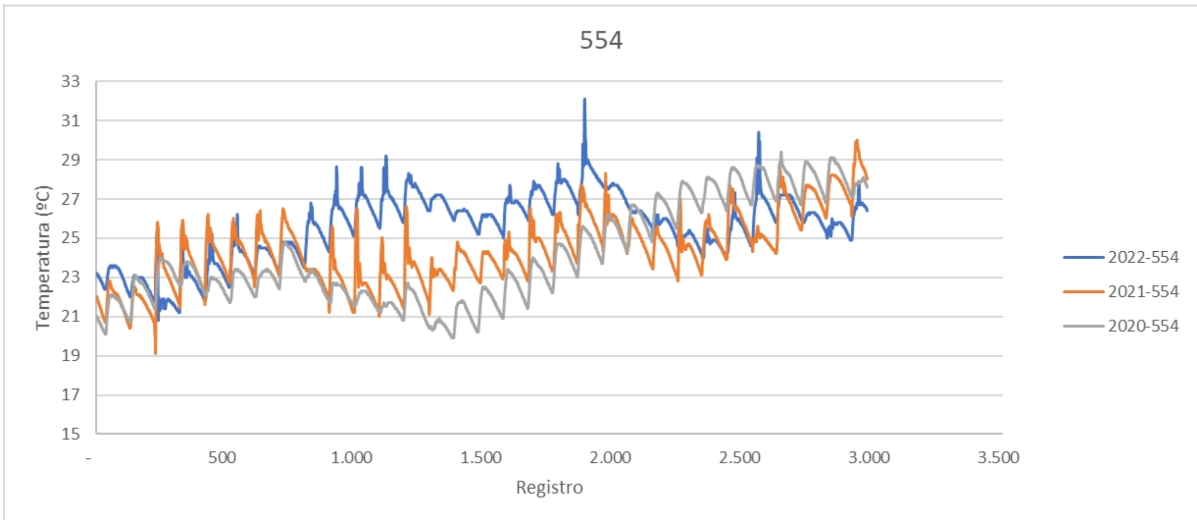


Perfil de las temperaturas medias en las distintas aulas a las horas indicadas.

Entre las 3 a.m. y las 9 a.m. la diferencia de temperaturas hace interesante abrir las ventanas para enfriar el interior del colegio.

Fuera de ese intervalo la temperatura exterior es igual o mayor que la interior. El intervalo se puede ajustar más según avanza el verano.

On the other hand, a study of the impact of the installation of the green roofs has begun. By way of introduction, with the data recorded in May, the indoor temperature values of two classrooms have been compared. One of them is on the second floor and has a green roof over it (554) and the other one is on the first floor (557), which in principle has not suffered any variation.



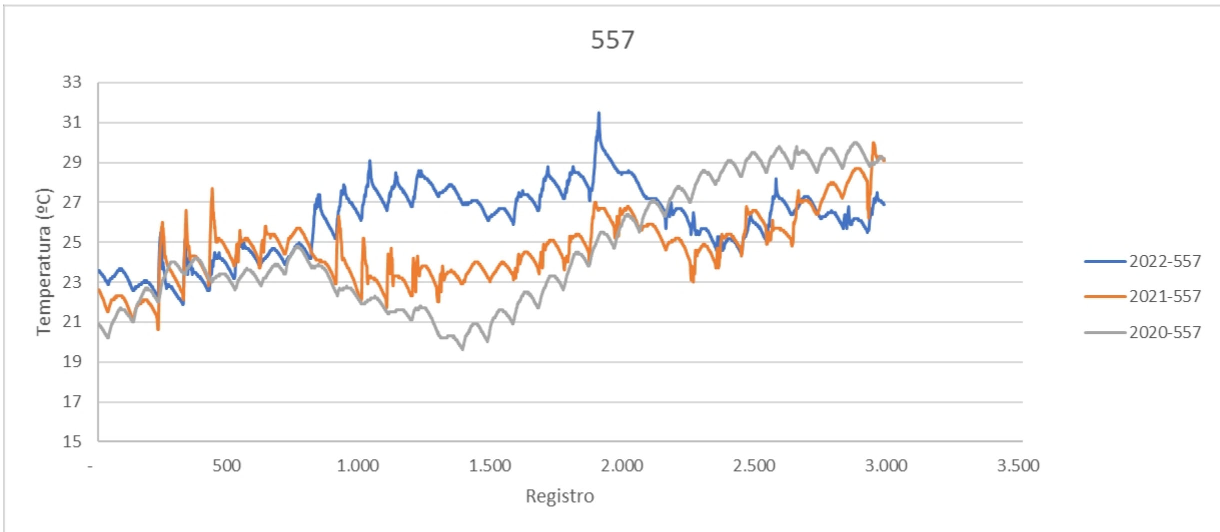


Figure 30. Temperature records at the highest in classroom 554 (second floor) and in classroom 557 (first floor).

Average temperatures in May for the following years 2020, 2021 and 2022 in classrooms 554 and 557.

SENSOR	**554**	**557**
FLOOR	1	0
FACADE	THIS	THIS
2020	24,1	24,5
2021	24,4	24,7
2022	25,6	26,1
Difference 22 - Avg.(20-21)	1,3	1,5

As can be seen in Figure 30 in the classroom, temperatures in May 2022 have been much higher than the temperatures recorded in the two previous years (average values between 24 and 25ºC). This month has been abnormally warm. However, in classroom 554, smaller differences have been recorded between May 2022 and May 2020 and May 2021. These are still small differences, but it is expected that with the development of vegetation in the coming years and especially with the combined effect on the protection of the
considerable reductions can be achieved.

I1.2 Building envelope temperature

In relation to the temperature of the building envelope, the thermal images of the situation prior to the implementation of the NBS are available. Periodically, those of the situation after the implementation of the NBS will also be collected, although it is believed that the images will start to show the benefits of the facades especially as early as 2023 when the vegetation is already visible.

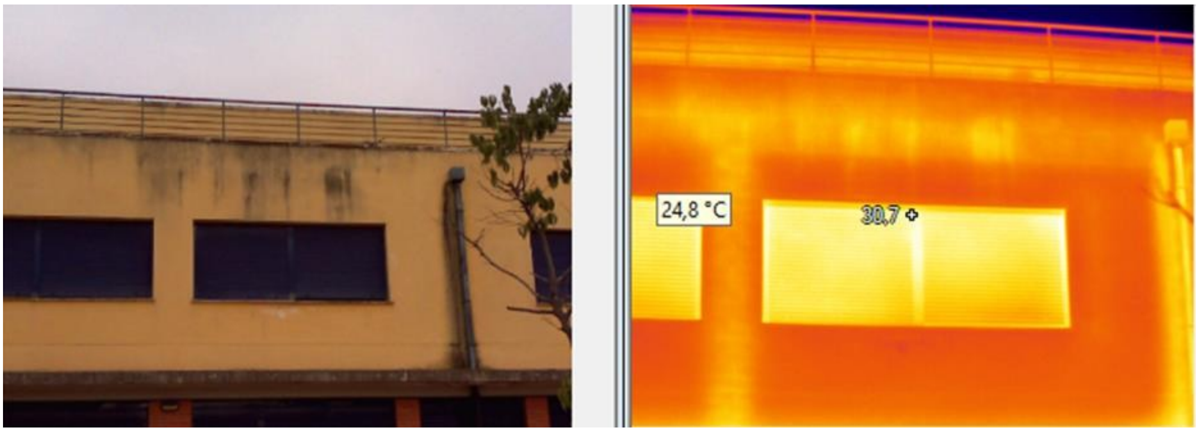


Figure 31. Visible and thermal images of a detail of the east façade of the CEIP Gabriela Mistral in Solana de los Barros prior to the installation of the SbN (Badajoz).

In the previous figure it can be seen how the temperature in the windows is higher than the facade due to the color and material of the protections. The proposed FAVE system will shade the facade avoiding the entrance of solar radiation through the openings, even with the shutter up, and thus they will have diffused natural light.

Indicators I1.3, I1.4 and I1.5 are also in progress, gathering information to configure the building's baseline status.

Water management

I2.1 Savings in water consumption for irrigation of green areas in the pilot buildings.

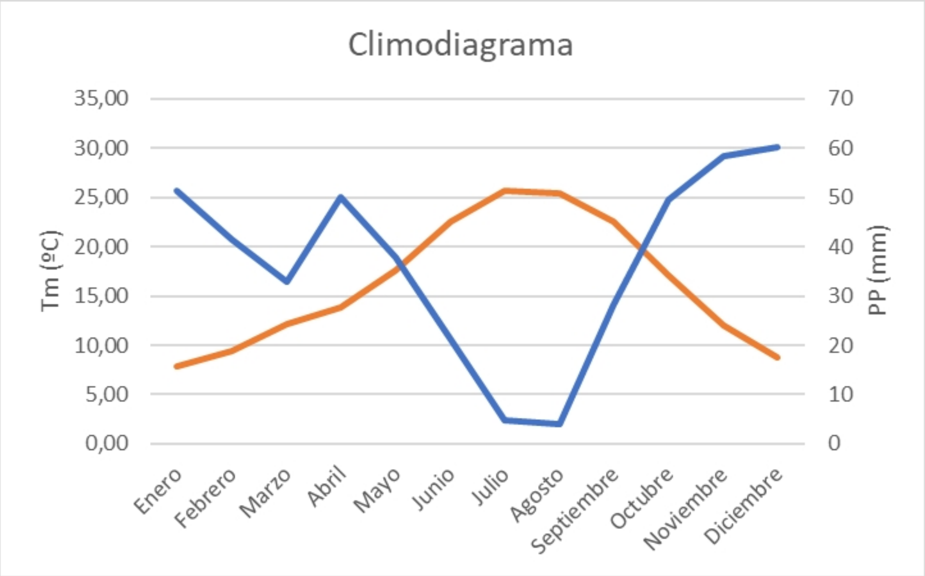
Indicator in process.

I2.2 Savings in rainwater management.

Rainwater management savings have been estimated indirectly using the curve method. This method takes into account the hydrological regime, the infiltration capacity of different surfaces, and the vegetation cover.

<u>Temperature and rainfall regime</u>

The climodiagram corresponding to the data from the Badajoz-Doña Teresa station is presented below. As can be seen, there is a period of **drought** during the summer months, starting early at the **end of May and extending through September**.



The presence of artificial irrigation guarantees the availability of water during the dry season. Considering the species planted on the roofs (*Sedum* type), it can be assumed that the phenology of this species includes a period of **vegetative growth** during the warm months (**April to September**), and a **resting period during the cold months.**

For the estimation of the humidity condition, meteorological data provided by AEMET corresponding to the Badajoz station (identifier 4410X), from September 2019 to June 2022, have been used. For each day, the humidity conditions corresponding to the sum of precipitation of the previous 5 days have been estimated, according to the following table.

CONDITION	VEGETATION PERIOD	REST PERIOD
I - Dry soil above the p.m.p.	< 13 mm	< 36 mm
II - Soil with medium humidity	13-28 mm	36-53 mm
III - Heavy or light rainfall and low temperatures during the 5 days prior to the given storm.	> 28 mm	> 53 mm

Table 4. Moisture conditions (based on Azagra, A. 1996)

With this table and the consideration of the vegetative period, the humidity condition was calculated for the entire period studied. As can be seen, the most frequent humidity condition is I, although the other two conditions also occur during the period studied.

	JAN	FEB	SEA	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DEC
I	16	10	21	33	6	4	1		7	17	23	31
II	8	5	3	2							9	4
III	3	3	6		3				1	5	8	8

Table 5. Humidity conditions during the period studied.

Types of surfaces

For this section, only the horizontal surfaces intervened are considered. The data on surface areas were obtained from the project for the construction of the Solana de los Barros school.

RESUMEN SUPERFICIES (ver anexo 4.5):

NIVEL -1 COTA -2.87		NIVEL 0 COTA +0.00		NIVEL 1 COTA +3.17		NIVEL PC COTA +6.34		TOTALES	
FACHADAS VEGETALES	19,20	FACHADAS VEGETALES	193,45	FACHADAS VEGETALES	139,70	FACHADAS VEGETALES	48,15	**FACHADAS VEGETALES**	**400,50**
SUELOS DRENANTES VEGETALES	451,70							**SUELOS DRENANTES VEGETALES**	**451,70**
ZONAS VEGETALES EXTERIORES (*)	709,00							**ZONAS VEGETALES EXTERIORES**	**709,00**
CUBIERTAS		CUBIERTAS VEGETALES	87,00	CUBIERTAS VEGETALES	143,00	CUBIERTAS VEGETALES	200,00	**CUBIERTAS VEGETALES**	**430,00**
TOTAL	**1.179,90**	**TOTAL**	**280,45**	**TOTAL**	**282,70**	**TOTAL**	**248,15**		**1.991,20**

(*) 259,00 m2 mediante zonas vegetales (plantación de jazmin) y pérgolas en el presente Proyecto. El resto hasta **706,30 m2** en zonas exteriores, (450 m2), mediante plantaciones de especies vegetales que realizará el socio coordinador del proyecto LIFE (CSIC) según acción C.2.5. Se estiman 150 uds / 3 colegios del proyecto LIFE= 50 uds de arbolado a plantar en este edificio. Con una superficie estimada de 3x3 = 9 m2 por cada árbol, se obtendrán 50 uds x 9 m2/ud = 450 m2, mediante la actuación del CSIC. Todo ello según el siguiente apartado del PRESUPUESTO del proyecto LIFE:

Table 6. Surface areas of action according to construction project

Of these action areas, those corresponding to the **vegetated draining soils (451.70 m^2) and green roofs (430.00 m^2)** are considered to have a significant impact on rainwater management.

Prior to the works, the area of the draining soils was composed of a layer of surface sand on compacted soil, while the roofs were composed of a layer of surface gravel on an insulated roof.

According to the classification table of hydrological soil groups shown below, these soils can be classified in **group D**, with a slow or very slow infiltration capacity. Although the surfaces considered have a layer of sand and gravel respectively, these layers are thin and lie on a compacted or artificial bed that prevents the passage of water.

Grupo hidrológico del suelo	Infiltración cuando están muy húmedos	Características	Textura
A	Rápida	Alta capacidad de Infiltración > 76 mm/h	Arenosa Arenosa-limosa
B	Moderada	Capacidad de infiltración 76-38 mm/h	Franca Franco-arcillosa-arenosa Franco-limosa
C	Lenta	Capacidad de infiltración 36-13 mm/h	Franco-arcillosa Franco-arcillo-limosa Arcillo-arenosa
D	Muy Lenta	Capacidad de infiltración<13 mm/h	Arcillosa

Hydrological classification of soils (SCS, 1964 in Bradbury et al., 2000).

After the actions, these soils have a higher water infiltration capacity, and it can be assumed that the infiltration rate increases to soil type B or C, although empirical studies are required for each of the surfaces. For this model a change to **surface B** will be assumed.

Performance	Surfaces (m2)	Geological type Ex - Ante	Ex - Post geological type
Vegetable draining soils	451.70	D	B
Covers	430.00	D	B
TOTAL	**881.70**		

Table 8. Ex-ante and ex-post surfaces

As for the type of vegetation installed, we started from a bare soil situation, and moved to intensive vegetation. In the actual situation of the school, these soils resemble firm roads and permanent meadows respectively according to the general table for the determination of the curve number.

VEGETATION TYPE	GROUND A	GROUND B	GROUND C	GROUND D
Roads on firm ground	74	84	90	**92**
Permanent meadows	30	**58**	71	78

General table for the determination of the curve number for situation II (adapted from Azagra, A. 1996).

Therefore, we start from a situation with a curve number of 92 and after the actions we move to a curve number of 58. This calculation is only valid for humidity situation II. The curve numbers for situations II and III are calculated based on the following formulas:

$$N_I = \frac{4,2 * N_{II}}{10 - 0.058 * N_{II}}$$

VEGETATION TYPE	GROUND A	GROUND B	GROUND C	GROUND D
Roads on firm ground	54	69	79	**83**
Permanent meadows	15	**37**	51	60

General table for the determination of the curve number for situation I (adapted from Azagra, A. 1996).

$$N_{III} = \frac{23 * N_{II}}{10 + 0.13 * N_{II}}$$

VEGETATION TYPE	GROUND A	GROUND B	GROUND C	GROUND D
Roads on firm ground	86	91	94	**95**
Permanent meadows	50	**76**	85	89

General table for the determination of the curve number for situation III (adapted from Azagra, A. 1996).

Taking into account all the factors analyzed, we have estimated the infiltrations Determination of the catchment

The installation and commissioning of the NBS marks the beginning and the end of the ex-ante monitoring.
- The following table shows the ante- and ex-post results for the period under study.

	HOME	FIN
BASELINE (ex - ante)	2019-09-01	2021-10-31
NBS (ex - post)	2021-11-01	2022-06-01 (current)

Table 12. Monitoring period considered

P_0 is calculated as the runoff threshold, i.e., the rainfall height above which surface runoff occurs (N is the curve number calculated above):

$$P_0 = \frac{5080 - 50.8 * N}{N}$$

Once this value is calculated, the runoff due to actual rainfall can be estimated.

$$ES = \frac{(P - P_0)^2}{P + 4 * P_0}$$

The difference between these two values is the catchment, i.e., the mm of rainwater that can be retained by the installed NBS. With these formulas, it has been estimated that theoretically, the installation and commissioning of the NBS during this time has meant the capture of 16.88 mm of rainwater.

Year	Month	Ex-ante capture	Ex-post capture	Difference
2021	NOV	5,80	6,00	0,20
	DEC	48,17	55,80	7,63
2022	JAN	2,20	2,20	0,00
	FEB	0,60	0,60	0,00
	SEA	80,11	89,00	8,89
	ABR	34,43	34,60	0,17
	MAY	0,00	0,00	0,00
	JUN	0,00	0,00	0,00
Grand total		**171,32**	**188,20**	**16,88**

Table 13. Volume of water captured (mm)

As can be seen in the following graph, the highest uptake occurred during the month of March 2022.

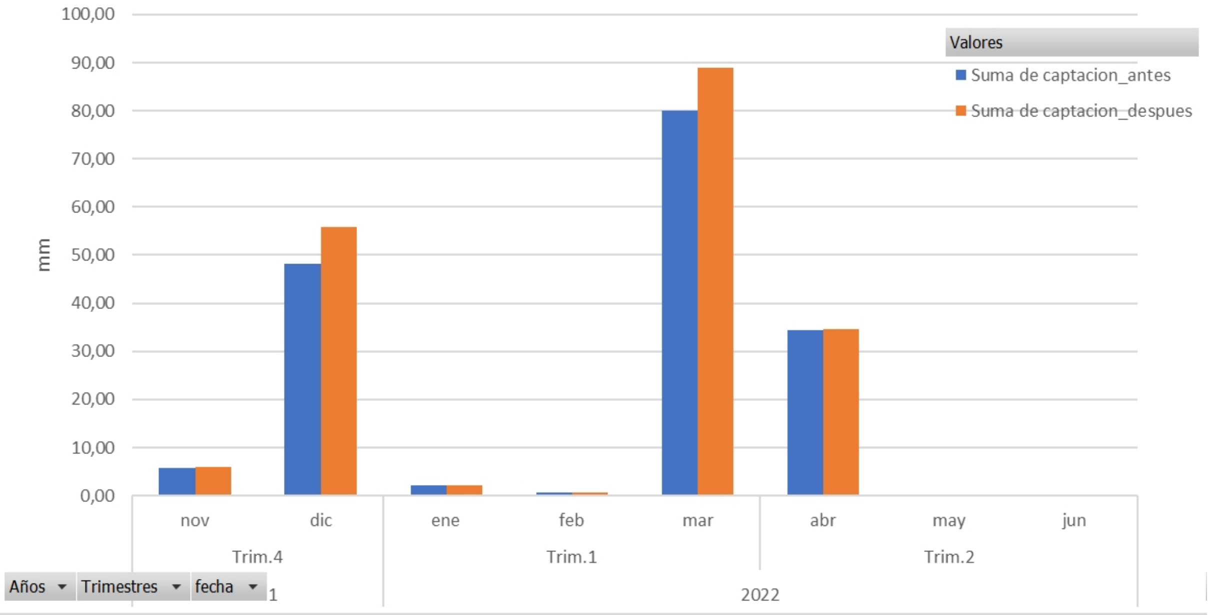
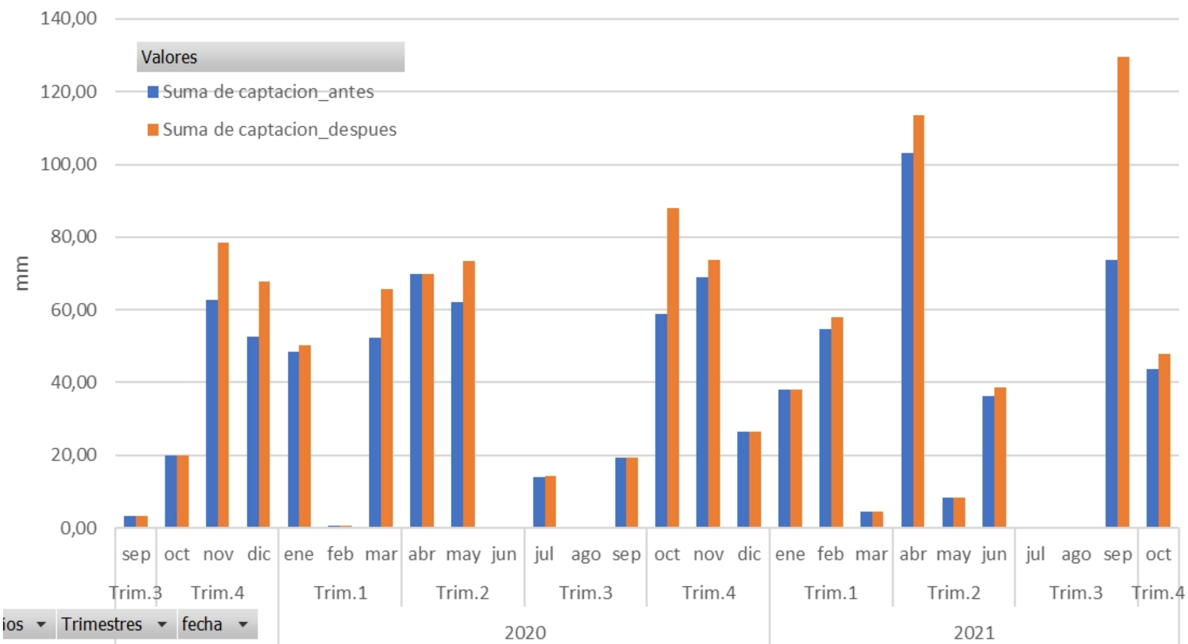


Figure 32. Evolution of the volume of water collected (mm) and comparison with the current situation.

This data will be updated as the monitoring period progresses.

If we consider a longer simulation period (ex-ante situation for the whole period studied), we can see the infiltration potential of the installed NBS.



The spring and fall months are expected to see the best capture rates.

Management of green areas

These indicators are still in process.

Air quality

I4.1 Carbon dioxide concentration inside the classroom.

The profile of average CO2 concentrations in classrooms, which gives an idea of the indoor air quality and the level of renovation that exists, has been modified very significantly as a result of the change in habits after the COVID pandemic19. As can be clearly seen in Figure 33, concentrations after the return from confinement have been very significantly reduced by the implementation of anti-COVID protocols in schools. However, in recent months there seems to have been a relaxation in the application of measures during the winter season.

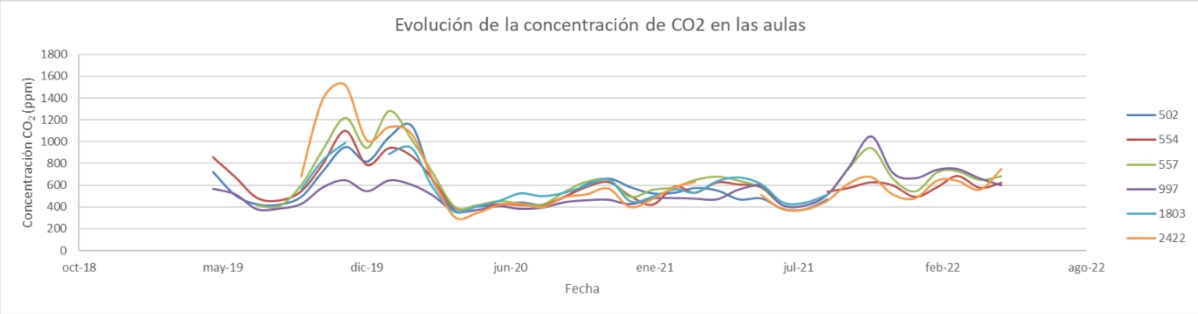


Figure 33. Evolution of average monthly CO concentrations₂ during school hours.

With the data collected, it has already been possible to carry out studies on the best time to open windows in the winter, seeking to optimize the times of ventilation for air renewal with those of the maximum outside temperature. In this way, it is possible to improve air quality in the most energy-efficient way possible. It should be noted that air renewal times are usually much shorter than those required to reduce the thermal load of the building, as is the case in summer at night. To this end, first of all, the CO concentration profiles$_2$ were analyzed in each classroom. There are significant differences between classrooms due to the number of students and the ventilation habits of the teachers. In some classrooms the recommended values were already exceeded as early as 9:30 am (school start time 9:00 am) and in others it took a little longer. Another significant aspect was that in some classrooms, after the school day, the values did not reach the outdoor basal values. This means that the air was not properly ventilated after the end of classes.

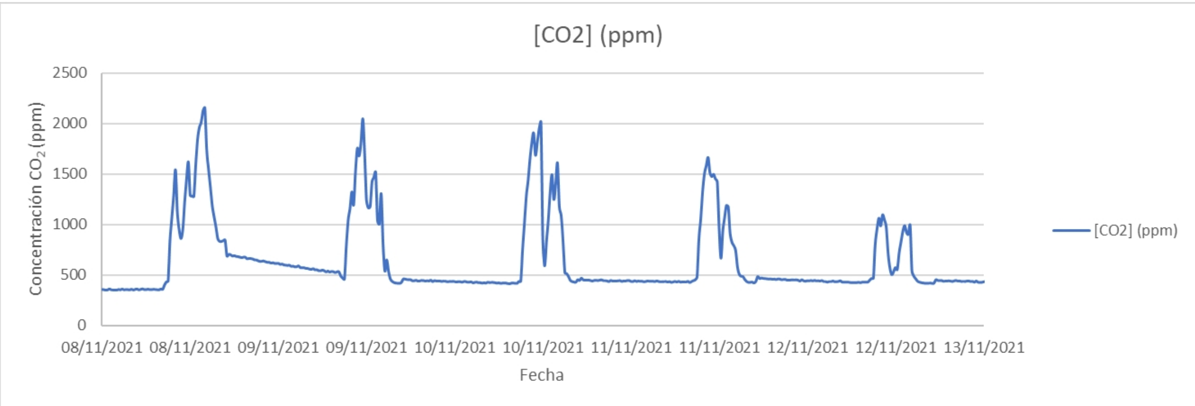


Figure 34. CO concentration profile$_2$ of the classroom with highest levels the week with the highest averages.

In parallel, the temperature profiles in the classrooms and outdoors were studied to maximize thermal comfort and energy efficiency. In addition, an attempt was made to find a schedule that would improve air quality in most of the classrooms for a significant part of the time. Finally, the schedule selected was opening from 9:30 to 10:00h, from 12:30 to 13:00 and then from 15:00 to 16:00h combining this last schedule with an instruction to the cleaning staff to open the windows as much as possible.

As a result, it was found that the average and maximum values for all classes comparing key weeks in November (before the scheduling of the windows) and December were lower after applying the new protocol. However, continuous evaluation and final assessment will be performed using longer time series. In addition, in order to optimize air quality while maintaining thermal comfort, it is necessary to train and raise awareness among the teaching staff.

Table 14. Average CO concentration₂ during school hours for one week before the modification of the window schedule (46) and one week after (49) in the year 2021.

	554		557		997		2422	
Week	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**	**Average**	**Maximum**
46	522	895	963	1813	1081	2153	651	1146
51	718	1782	730	1744	824	2305	620	1202

The evaluation of indicators I4.2 is in process and will be assessed when the implementation of vegetation is more visible and can have an adequate impact on it.

Urban regeneration

I5.1 Energy efficiency measures.

The measures taken to improve the school's energy efficiency are detailed below.

- Improved thermal insulation of the envelope through the installation of green roofs (430 m).[2]
- Replacement of 5 units of existing exterior carpentry to generate automatic ventilation, replacing the fixed window sashes with a motorized tilt-and-turn sash. The new windows have a solar factor of 50 compared to the 65 factor of the existing windows.
- Installation of façade shading systems using FAVE. Floor -1 includes horizontal shading systems and floors 0 and +1 include both horizontal and vertical shading systems.

The replacement of windows and the installation of shading systems reduce the radiation absorbed by the façade openings, minimizing interior heat gain. In some cases, these solutions are combined and in other cases they are isolated solutions. The different changes in the solar factor of the openings due to the implementations are shown below.

Table 15. Comparison of the Solar Factor of the façade openings

	Previous solar factor	Current solar factor	Impact
Window change	0,65	0,5	- 23%
FAVE P -1	0,48	0,4	- 16 %
FAVE P -1 + change window	0,48	0,29	- 40 %
FAVE P0/P1	0,65	0,30	- 53 %
FAVE P0 / P1 + window change	0,65	0,22	- 66 %
FAVE P0*	0,65	0,33	- 50 %

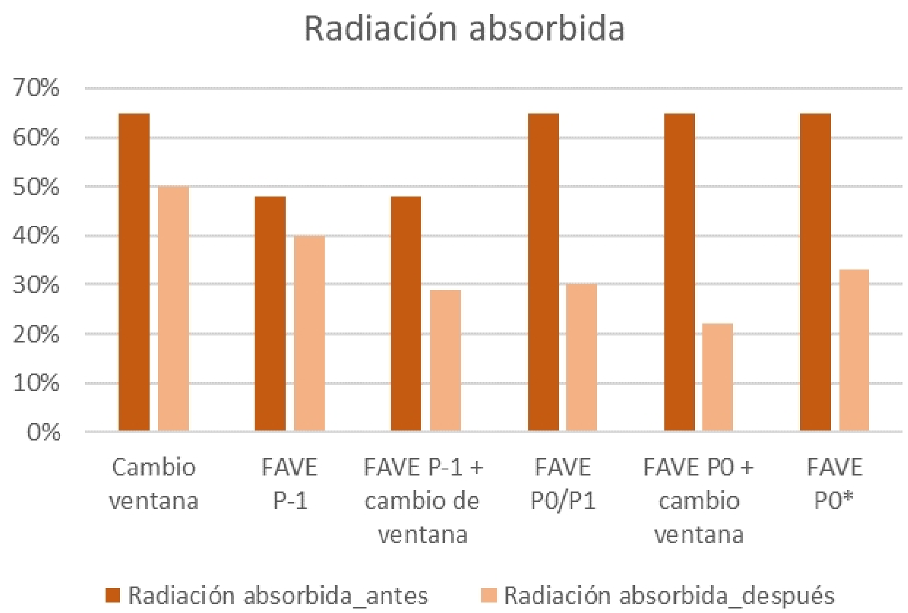


Figure 35. Percentage of radiation absorbed by the openings of the east façade before and after the intervention.

It is observed that the absorbed radiation is reduced to a greater extent when the FAVE system is combined with the replacement of carpentry.

The installation of green roofs implies an improvement in the thermal resistance (m²K/W) of the roof that will vary according to the green roof system used. In the Solana de los Barros school, 3 types of green roofs have been used. To calculate the thermal resistance of the green roof, the simplified method of the DA DB-HE / 1 (CTE) was used. The CUVE-1 and CUVE-2 system generates a ventilated roof, so the thermal resistance of the green roof materials is disregarded and a thermal resistance equal to the interior surface resistance of the roof (DA DB-HE / 1) is added. The CUVE-SUS system consists of a 10 cm thick substrate layer that improves the final thermal resistance, being the most effective system to improve the insulation of the roof.

Table 16. Thermal resistance before and after installation of the green roof.

	Initial R (m²K/W)	**R actual (m²K/W)**	**Impact**
CUVE-1	2,22	2,32	+ 5 %
CUVE-2	2,22	2,32	+ 5 %
CUVE-SUS	2,22	3,16	+ 42 %

The consumption of heating oil and electricity by surface area before and after the actions are shown below.

Table 17. Compilation of heating oil consumption for CEIP Gabriel Mistral.

	Heating oil - CEPSA Invoices			
	Volume (L)	Price	Cost (excluding VAT)	with VAT 21%.
xx-2021				
2022-2023				

Table 18. Compilation of electricity consumption in CEIP Gabriel Mistral

	Electric power - ENDESA				
	Energy (KWh)	Price (c€)	Cost (excluding VAT) taxed	Total cost (€)	Period (days)
xx-2021					
2022 - 2023					

I5.2 Increase in green area

The actions of the project have had a great impact on increasing the green areas of CEIP Gabriel Mistral. The following table shows the green areas implemented and the total compared to the baseline situation. Currently the school has 2577.77 m² of green area, **145.52%** more than the previous situation.

Table 19. Green surfaces implemented

(m)²	FAVE facade	Pergol to PEVE	Covere d	Vege taria n zone	Interventio n green area	Surface and previous green	Final green surface	Increase or % Increas e or % Increas e
Surfaces and	400,50	173,3	420	534	1991,2	1049,9	2577,7	145,52 %

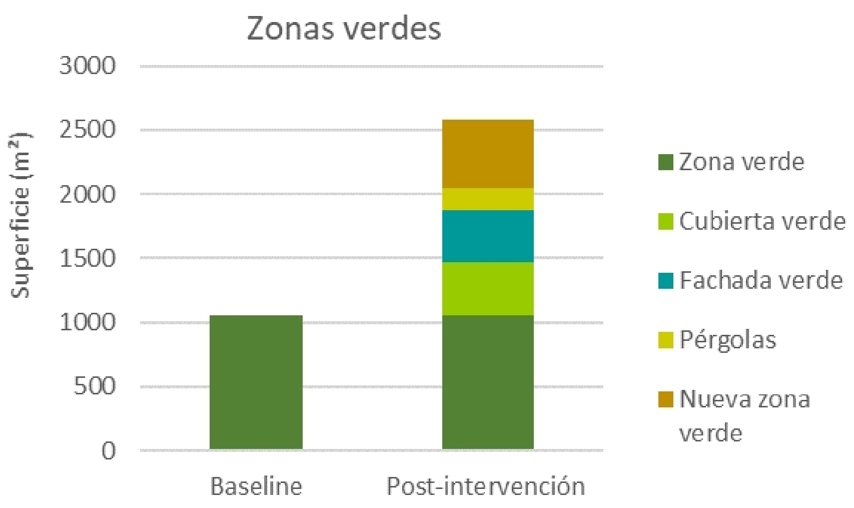


Figure 36. Increase in green areas

7. REFERENCES

- Supporting Document to Basic Document DB-HE Energy Saving Technical Building Code https://www.cgate.es/hit/Hit2015-1/DA-DB-HE-1-Calculo_de_parametros_caracteristicos.pdf
- Perez G., Perini K. Nature Based Strategies for Urban and Building Sustainability. Butterworth Heinemann. 2018
- Salvo A.E., Rubio A., Páez de la Cadena F., Escámez A., García J.C., Ballester J.F., Sánchez J.M., Valdés M.R. Naturaleza urbanizada. Studies on greenery in the city. Secretary of Publications and Scientific Exchange of the University of Málaga. 1993.
- Vargas-Gómez, O., & Molina-Prieto, L. (2014). Urban arborizations: strategy to mitigate global warming. REVISTA NODO, 8(16), 99 - 108.

8. ANNEX I. MONITORING DATA