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: Integration and transferability at local, national and European level

Deliverable: Design of 15 Natured-based Solutions projects

Date: 02/08/2023

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

Deliverable: Design from 15 Natured-based Solutions projects

Date: **02/08/2023**

Project location:	Spain
Project start date:	01/09/2018
Project end date:	31/12/2023
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(%) of eligible costs:	59,99 %

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1. SUMMARY EN ESPAÑOL

This document is part of Action C5, "Integration and transferability at the local, national, and European level". It presents 15 NBS (Nature-Based Solutions) projects for educational centres in the four main EU regions at risk of climate change. This document includes projects designed for 15 schools in 9 European countries: Spain, Portugal, France, Italy, Croatia, Greece, Austria, the Netherlands, and Finland.

Each project includes an assessment of each school and its geographical and climatic context, with general data for each centre and a climate analysis with supporting information to determine the most suitable NBS for the educational centre. For each school, the most suitable NBS prototypes have been determined based on the previous evaluation. Different prototypes developed in the myBUILDINGisGREEN project are included, covering NBS for roofs, facades, and outdoor spaces, as well as ventilation protocols. Each project defines the type of solution to be implemented, its location and surface area, suitable vegetation type, estimated cost, and its impact on various environmental indicators.

2. ENGLISH SUMMARY

This document is part of action C5. "Integration and transferability at local, national and European level". It presents 15 NBS projects for schools in the 4 main EU climate risk regions. In this document projects have been designed for 15 schools in 9 European countries: Spain, Portugal, France, Italy, Croatia, Greece, Austria, Netherlands, Finland.

Each project includes an assessment of each school and its geographic and climatic context, with general data on each school and a climate analysis with supporting information to determine the most appropriate NBS for the school. For each school, the most appropriate NBS prototypes have been determined depending on the previous evaluation. Different prototypes developed in the myBUILDINGisGREEN project have been included, covering NBS for roofs, facades and outdoor spaces, as well as ventilation protocols. Each project defines the type of solution to be implemented, its location and surface, the type of suitable vegetation, the estimated cost and the impact on different environmental indicators.

3. RESUMO EM PORTUGUÊS

This document is part of Action C5, "Integration and transferability at local, national and European level". It presents 15 projects of Solutions Based on Nature (SBN) for schools in the four main regions of the EU at risk of climate change. This document includes projects designed for 15 schools in 9 European countries: Spain, Portugal, France, Italy, Croatia, Greece, Austria, the Netherlands and Finland.

Each project includes an evaluation of each school and its geographical and climatic context, with general data for each school and a climate analysis with supporting information to determine the most appropriate SBNs for the school. For each school, the most suitable SBN prototypes were determined based on the previous evaluation. Different prototypes developed in the myBUILDINGisGREEN project are included, covering SBNs for roofs, facades and external spaces, as well as ventilation protocols. Each project defines the type of solution to be implemented, its location and surface, type of suitable vegetation, cost estimate and its impact on several environmental indicators.

4. INTRODUCTION

This document aims to define the most appropriate bioclimatic strategies to achieve thermal comfort in 15 schools located in different parts of southern Europe (some schools in central and northern Europe are included for comparison).

The strategies to be implemented in the project are aimed at reducing the cooling energy demand during the warm period. However, the strategies required for the whole year are analyzed in order to avoid introducing improvements for the summer that would mean a worsening of the building's energy performance during the winter.

The general information of each educational center was obtained through Google Maps and the cadastre in the case of schools in Spain.

As for the passive bioclimatic strategies, the starting point is the analysis of the climate at each of the locations. These data have been obtained from stations close to the school locations (EPW data, EnergyPLus). For each case, annual temperature and solar radiation graphs are provided as basic climate indicators.

To define the comfort criteria, the parameters corresponding to the "ASHRAE 55" standard have been chosen:

ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model (select Help for definitions)

1. COMFORT: (using ASHRAE Standard 55)

1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)
90.0	Predicted Percent of People Satisfied (100 - PPD)
20.3	Comfort Lowest Winter Temp calculated by PMV model(ET* C)
24.3	Comfort Highest Winter Temp calculated by PMV model(ET* C)
26.7	Comfort Highest Summer Temp calculated by PMV model(ET* C)
84.6	Maximum Humidity calculated by PMV model (%)

2. SUN SHADING ZONE: (Defaults to Comfort Low)

23.8	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

8.3	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

16.7	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
6.6	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

50.0	% Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:

2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)

8. FAN-FORCED VENTILATION COOLING ZONE:

0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C)
	(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):

12.8	Balance Point Temperature below which Heating is Needed (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION OF OUTDOOR SPACES:

8.5	Velocity above which Wind Protection is Desirable (m/s)
11.1	Dry Bulb Temperature Above or Below Comfort Zone (°C)

13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)

Illustration 1. ASHRAE Comfort Criteria

To support the selection of the most appropriate strategies for each of the locations, hourly climate data (T and H) were plotted on the psychrometric abacus. Climate Consultant 6.0 software (UCLA, 2008) was used.

The diagram shows the hourly points of temperature and humidity throughout the year, and places the thermal comfort (blue area) based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity and average radiant temperature. According to the ASHRAE standard, this zone meets the appropriate comfort parameters in which most people are comfortable. It is calculated using the PMV (Predicted Mean Vote) model.

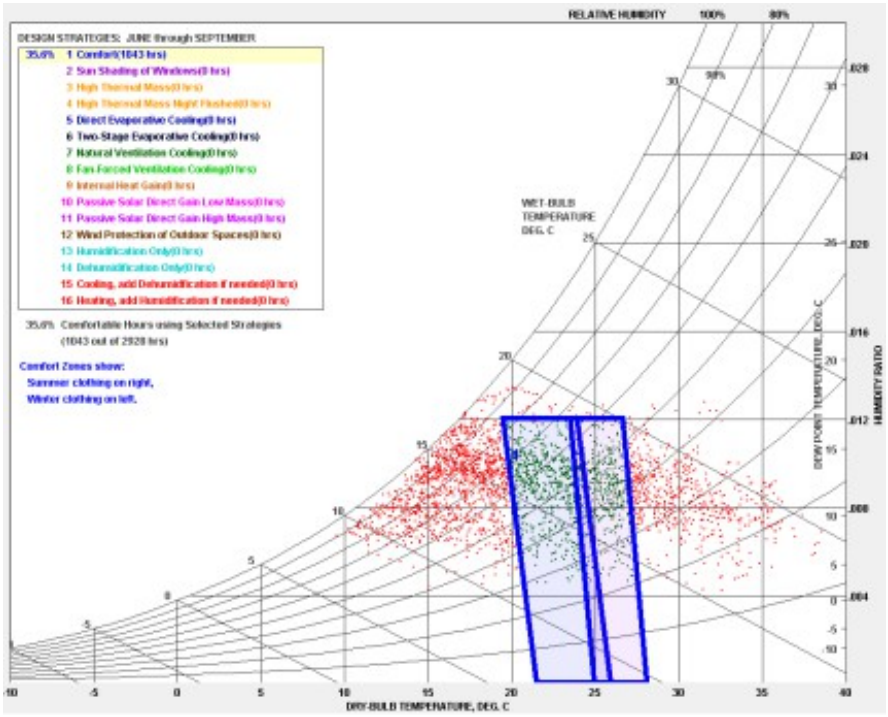


Illustration 2. Example of a psychrometric abacus. Defined comfort zones (blue) and comfort (green) and discomfort (red) time points.

The various passive strategies are proposed in order to correct the hours of discomfort and move them within the defined areas. Some of them are designed for summer and others for winter:

1- Comfort zone; 2- Shading of openings; 3- Thermal mass increase; 4- Thermal mass discharge at night; 5- Direct evaporative cooling; 6- Two-stage evaporative cooling; 7- Cooling by natural ventilation; 8- Cooling by forced natural ventilation; 9- Internal gains; 10- Direct solar gain at low thermal mass; 11- Direct solar gain at high thermal mass; 12- Protection against wind; 13- Direct solar gain at high thermal mass; 13- Wind protection

humidification; 14-Dehumidification; 15-Cooling (active system); 16-HVAC heating (active system).

Next, the NBS and passive strategies and their most appropriate location to improve the thermal discomfort previously identified are determined. These solutions are part of the NBS prototypes developed in the project. Deliverables C2.4 Technical Manual for NBS implementation, C2.2 Guide for the selection of plant species adapted to climate change and Annex 1. mBiG NBS prototypes - Deliverable A2. Elaboration of NBS Databases and Working Matrix have been used to support the selection of the most appropriate solutions.

The NBS prototypes for green roofs that are proposed are: mBiGCUVE roof, mBiGCUVE - SUS roof, mBiGUL roof, mBiGBIOSOL roof and mBiGSECAR roof. The NBS prototypes for green facades proposed are: mBiGFAC Facade and mBiGFAVE Facade. The prototypes for outdoor spaces that are proposed are: permeable pavements, trees and pond. Night ventilation protocols are also proposed.

To define the budget estimate for each solution, the budgets for the implementation of NBS in schools CEIP Gabriela Mistral, Solana de los Barros (Spain) and EB1 Falção, Oporto (Portugal) were taken as a reference.

5. COLLEGE PUBLIC SAN JOSÉ DE CALASANZ (CÁDIZ, SPAIN)

Climate risk zone 1: Southern Europe and Mediterranean basin

Location: C. Inmaculada Concepción, 6 (municipality: Rota, province: Cádiz, Autonomous Community: Andalucía)

Coordinates: 36.6223435918517, -6.359311835650813 (link Google maps) Height: 3

floors (main building, including first floor) + 1 floor (gymnasium) Year of

construction (according to land registry): 1940 (renovated: 1970)

Orientation:

SO: this orientation includes the main façade of the school where the main entrance door is located. It has a tree line right in front of the entrance.

NO: it is one of the sides of the school that adjoins other buildings, so that facade is not accessible from Google Maps.

NE: this is where the schoolyard is located and, together with the SW façade, it is the most exposed façade. There are no trees or any type of solar protection. There are no photos because there are other buildings between the school and the street where the Google car passes.

SE: there is a part of the main building that is exposed to insolation in this orientation without any solar protection (photo: "Fachada_SE2"). The gymnasium in this orientation would also be exposed to insolation, but it is not visible in the photos. There are no trees in the courtyard.

Photographs of the school: Annex 2. Photographs of the schools Types

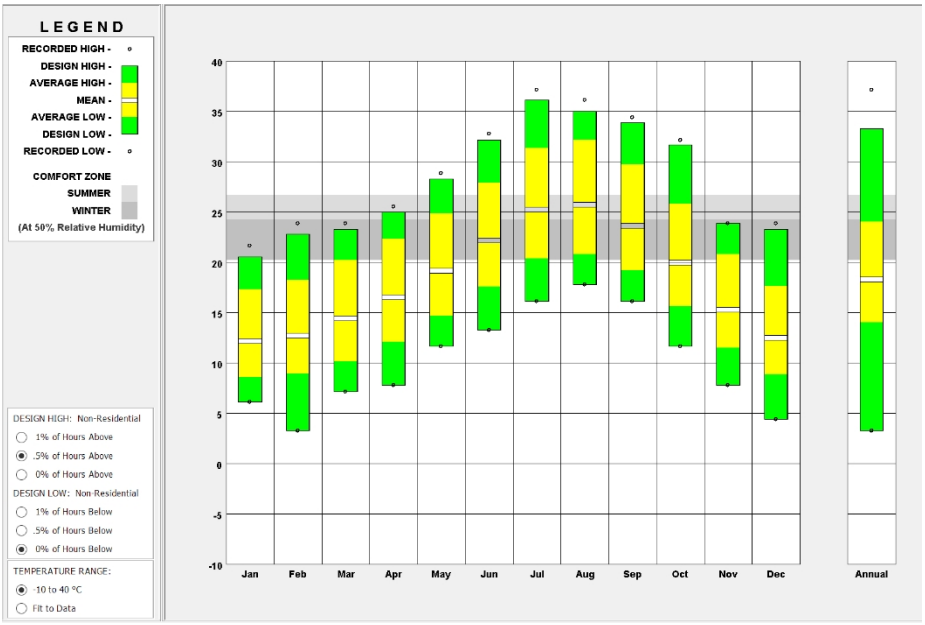
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area (according to cadastre): 2.408 m^2
- Gross floor area: 2,956 m^2 (956 + 817 + 817 + 817 + 366 (gymnasium))
- Gross floor area: 1,086 m^2 (2,408 - 956 (floor0) - 366)
- Green surface (according to "measure distance" of Google maps): 0 m^2
- Surface area with pavement (according to "measure distance" of Google maps": 1,086 m^2

5.1 Climate analysis

Climatic data (Nearest station Huelva)



Average, maximum and minimum temperatures (months)

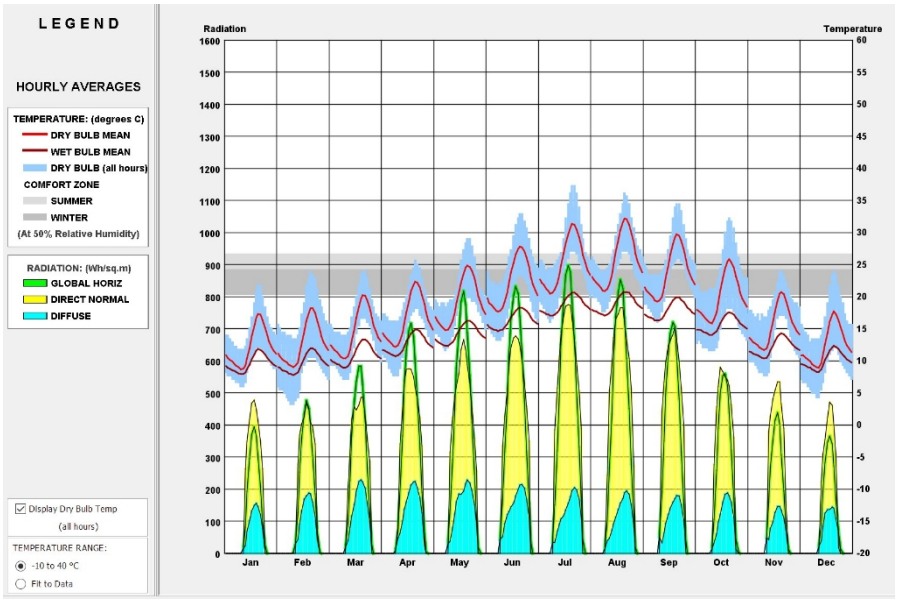


Illustration 4. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies

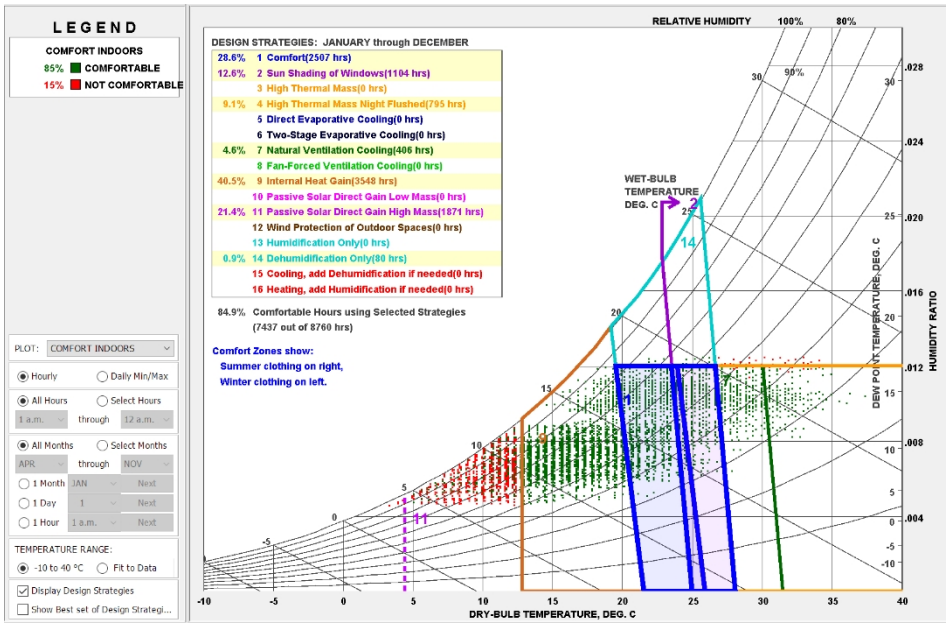


Illustration 5. Psychrometric diagram with incorporation of optimal passive improvement measures

Percentage of hours of comfort in the climate: 28.6%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Shading of hollows in summer (12.6%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (9.1%)

5.6- Evaporative cooling systems (not applicable) 7-

Night ventilation (4.6%)

9- Management of internal loads: lighting, equipment, people, etc. (40.5%)

10,11- Solar collection (21.4%)

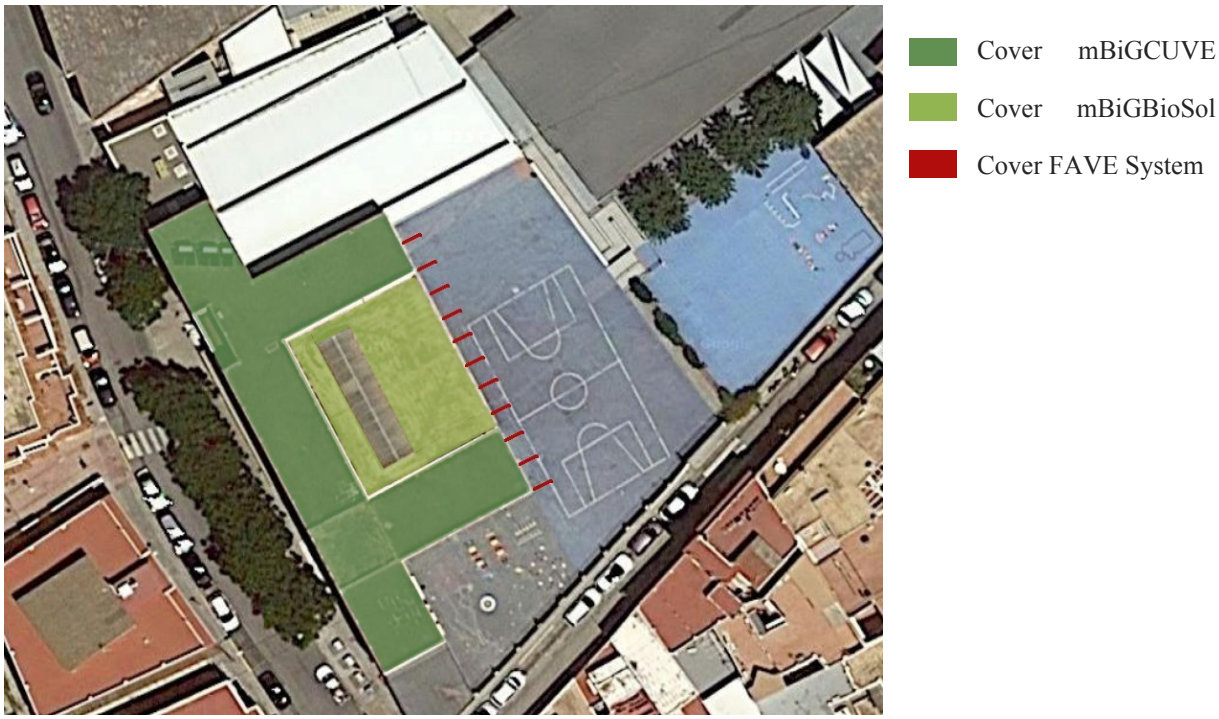
12- protection against external winds (not applicable)

Percentage of comfort hours with the application of bioclimatic strategies: 85%.

Need for Climate System (percentage of hours): 15% HEAT.

5.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the San José de Calasanz school: mBiGCUVE green roof, mBiGBIOSOL green roof and FAVE system. The following illustration shows the distribution of the solutions in the school.



General plan of the implementation of NBS at San José de Calasanz School (Cádiz, Spain).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 550 m^2**.

The type of vegetation recommended is the *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum album, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

This type of solution mainly impacts on the improvement of the thermal discharge of the building (9.1%).

Green cover - type mBiGBIOSOL

Installation of an mBiGBIOSOL green roof on the main building, covering an area of **surface area of 240 ^{m2}**.

The type of vegetation recommended is of the *Sedum* genus*, including* the following species: *Sedum album, Sedum album, Sedum acre, Sedum lydium, Sedum sexangulare, Sedum hispanicum, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu.*

This type of solution mainly impacts on the improvement of the thermal discharge of the building (9.1%).

Green façade - FAVE system

Installation of the FAVE system on the northeast facade, protecting the openings of one of the main and most unprotected facades. It covers a length of 30 m of façade and an area of **225 ^{m2} of vegetation shading**.

The type of vegetation recommended is deciduous climbing species, to allow solar gain in winter. Among these species are the Virgin Vine (*Parthenocissus Quinquefolia* and *Parthenocissus Tricuspidata*), *Trachelospermun Jasminoides*, or Lonicera.

This type of solution mainly impacts the shading of openings in summer (12.6%).

Ventilation protocol:

It is proposed to install motorized casement windows on opposite facades, preferably north/south or in the direction of the prevailing winds at night during the summer season.

Standard windows with motorized tilt-and-turn sash and two additional sliding sashes are included.

Installation of motorized casement windows: **6 windows** on the SW façade and **4 windows** on the NE façade to create cross ventilation.

Budget estimate

With the proposed interventions and using as a reference the costs associated with each SbN listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 1. Budget estimate for proposed interventions

Intervention	***Cost*** ***(€/m²)***	***Surface area*** ***(m²)***	***Estimated budget***
mBiGCUVE	175,79	550	96.686,26 €
mBiGBIOSOL	301,83	240	72.439,71€
FAVE	105,51	225	23.739,75 €
Windows	2.862,04	10	28.620,35 €
Total			**221.486,00 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact relative to the green area indicator. The green area increases 42% and the permeable area 33%.

Table 2. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	2408	-	-
Initial green area	0	0 %	-
Final green area	1014	42 %	**42 %**
Initial permeable surface	0	0 %	-
Final permeable surface	789	33 %	**33 %**

6. CEIP CERVANTES (ALBACETE, SPAIN)

Location: C. Sta. Quiteria, 39 (municipality and province: Albacete, CC.AA.: Castilla-La Mancha)

Coordinates: 38.99048868098227, -1.8504109333777665 (link Google maps)

Height: 2, 3 and 4 floors (including first floor)

Year of construction (according to cadastre): 1970

Orientation:

N: this orientation includes the main entrance to the school, although it represents the least extensive façade. It has a landscaped area in front with some large shrubs and trees.

E: is one of the sides of the school that includes another of the school entrances. It has some solar protection due to a building in front of it that protects part of the façade.

S: is where one of the school's courtyards is located and receives high solar radiation since it has no protection from buildings in front of it. The south courtyard is not included in the cadastral plot.

O: this façade is very well protected by a building in front of it of a similar height to the school that allows shading on most of the façade. Another of the school's courtyards is located here.

Photographs of the school: Annex 2. Photographs of the schools Types

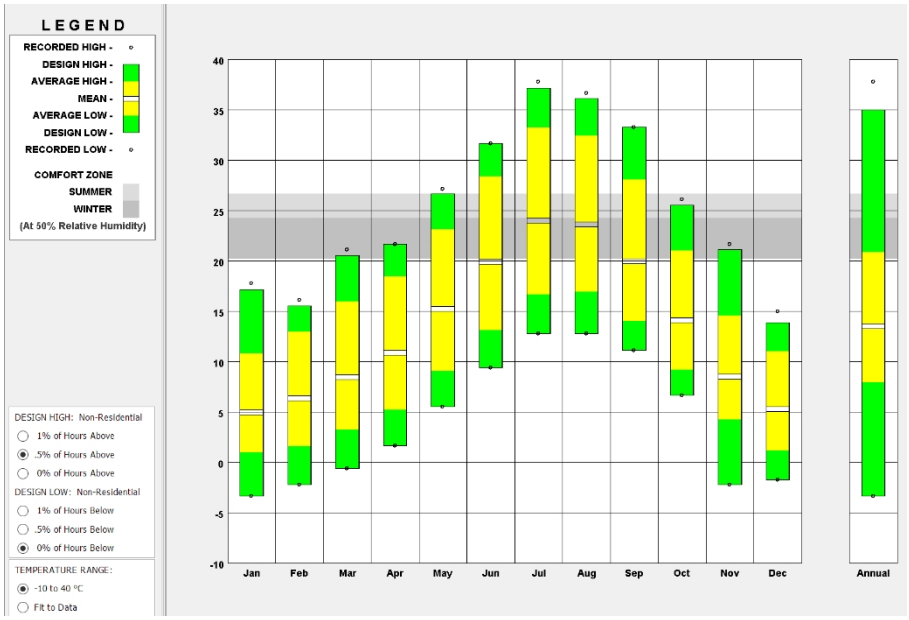
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area: 996 m^2 (according to cadastre) + 304 m^2 (south courtyard not included in cadastre and measured according to "measure distances" of Google maps) = 1,300 m^2
- Built-up area: 2,048 m^2 (594 + 620 + 478 + 356)
- Unbuilt area: 402 m^2 (996 - 594 (floor0)) + 304 m^2 (south courtyard) = 706 m^2
- Green area (according to Google maps "measure distance"): 70 m^2 (north entrance)
- Surface with pavement (according to "measure distance" of Goolge maps): 332 m2 + 304 m^2 (south patio) = 636 m^2

6.1 Climate analysis

Climate data



Average, maximum and minimum temperatures (months).

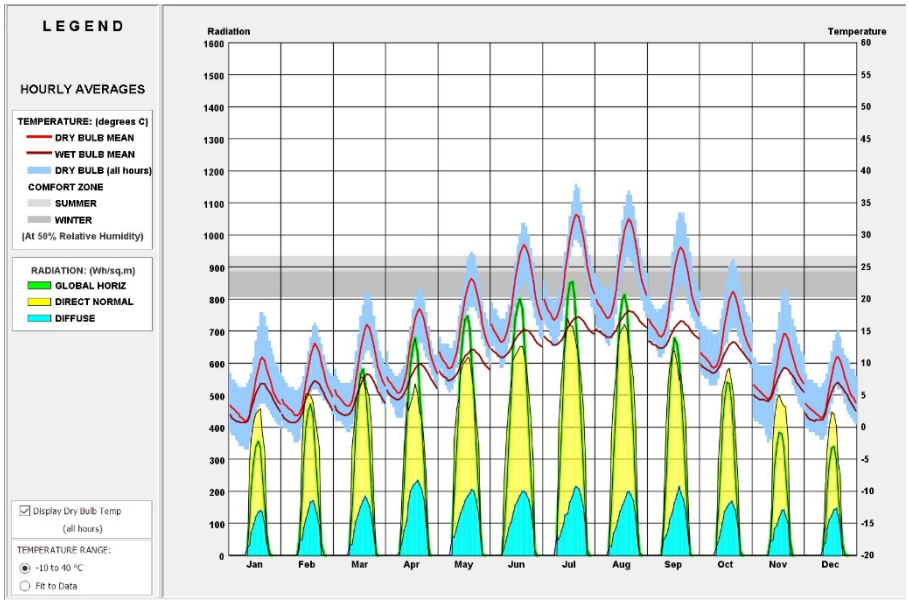
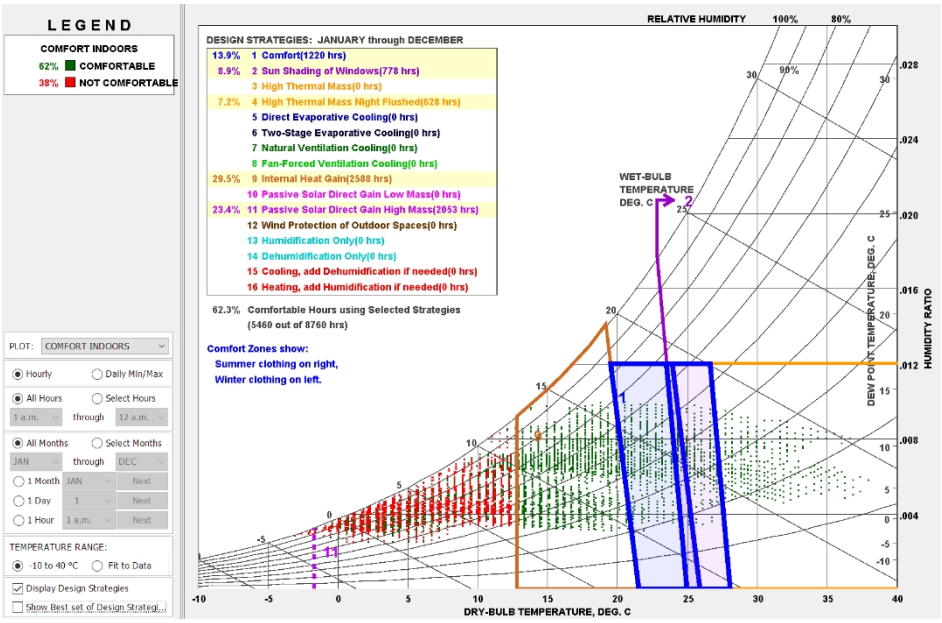


Illustration 8. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures.

Percentage of hours of comfort in the climate: 13.9%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (8.9%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (7.2%)

5,6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (29.5%)

10,11- Solar collection (23.4%)

12- protection against external winds (not applicable)

Percentage of comfort hours with the application of bioclimatic strategies: 62%.

Need for Climate System (percentage of hours): 38% HEAT.

6.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the CEIP Cervantes school: mBiGCUVE green roof, mBiGCUVE-SUS green roof, mBiGCUVE-SUS green façade, mBiGFAC green façade. Figure 10 shows the distribution of the solutions in the school.



General plan of NBS implementation at CEIP Cervantes school (Albacete, Spain).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 359 m^2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly improves the thermal discharge of the building (7.2%).

Green cover - type mBiGCUVE-SUS

Installation of an mBiGCUVE-SUS green roof on the main building, **covering an area of 235 m2**.

The type of vegetation recommended is the *Sedum* genus, within which we highlight the following species: *Sedum album, Sedum album, Sedum acre, Sedum lydium, Sedum sexangulare, Sedum hispanicum, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu, Sedum kamschaticum, Sedum kamschaticum, Sedum hybridum, Sedum spurium, Sedum spurium, Sedum spurium and Sedum spurium.*

Impact: this type of solution mainly improves the thermal discharge of the building (7.2%).

Green facade - mBiGFAC

Installation of the mBiGFAC system on the south façade, protecting the openings of one of the main and most unprotected façades. It covers a length of 20 m and 7 m and a total **plant shading** area **of 201 m2**.

Vegetation type: *Parthenocissus tricuspidata "Veitchii"*.

Impact: this type of solution mainly favors solar gain (23.4%).

Ventilation protocol

It is proposed to install two windows on opposite facades, preferably north/south or in the direction of the prevailing winds at night during the summer season. Standard windows with motorized tilt-and-turn sashes and two additional sliding sashes are included.

Installation of motorized casement windows: **7 windows on the SW façade** and **4 windows on the NE façade** to create cross ventilation.

The implementation of a night ventilation protocol in the school's classrooms favors cooling in an efficient way to improve the thermal environment in the buildings and reduce indoor temperatures. During the night, the accumulated heat is conducted to the outside through the open windows.

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 3. Budget estimate for proposed interventions

Intervention	***Cost*** ***(€/m2)***	***Surface area*** ***(m2)***	***Estimated budget***
mBiGCUVE / mBiGCUVE-SUS	175,79	594	104.421,16 €
mBiGFAC	88,59	201	17.807,01 €
Windows	2.862,04	11	31.482,39 €
Total			**153.710,56 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 67% and the permeable area by 60%.

Table 4. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total surface area	996	-	-
Initial green area	594	60 %	-
Final green area	865	87%	**80%**
Permeable surface initial	70	7%	-
Final permeable surface	664	67 %	**60 %**

7. CEIP VIRGEN DEL CARMEN-LA PLATA (PONFERRADA, CASTILLA Y LEÓN, SPAIN)

Location: C. Valencia, 5 (municipality: Ponferrada, province: León, CC.AA.: Castilla y León)

Coordinates: 42.5495689332854, -6.629926503284258 (link Google maps)

Height: 1 and 2 floors (including first floor)

Year of construction (according to cadastre): 1970 + 2nd plot of the gymnasium and west patio (according to cadastre): 2006

Orientation:

N: this orientation includes the access to the school and is the least extensive of the entire building, with no solar protection whatsoever.

E: is where the official entrance to the building is located, but not the access to the enclosure. It is one of the largest facades without any solar protection and has the main schoolyard located in this orientation, including the soccer field.

S: it is a small facade without any solar protection.

O: is the other façade with the largest extension that includes the sports pavilion. This area is located in another different parcel of the cadastre that for the analysis of areas has been joined to the main one.

Photographs of the school: Annex 2. Photographs of the educational centers

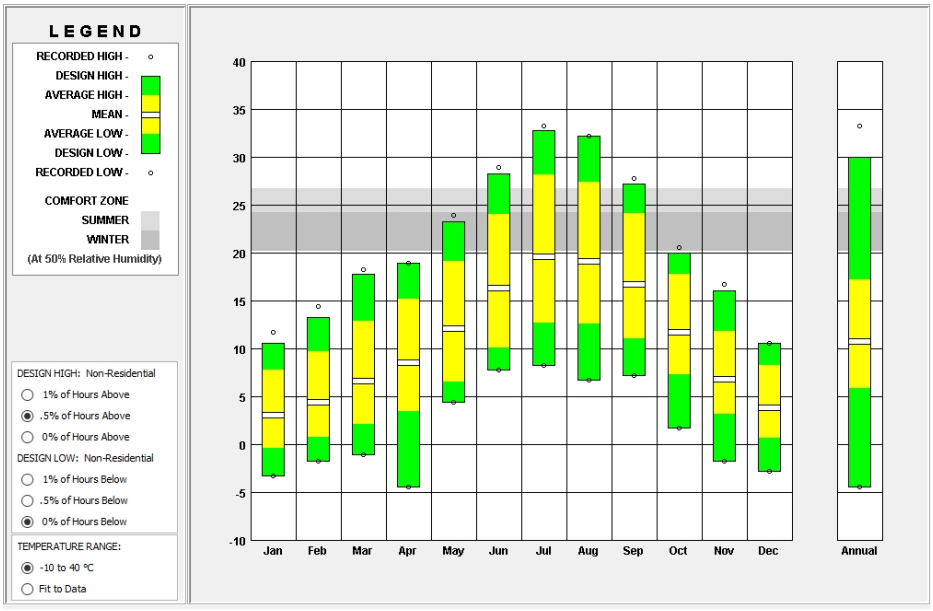
Roof types: pitched, except for the sports pavilion on the west side, which has a flat roof.

Areas in m^2 according to type of surface:

- Plot area: 2,714 m^2 (according to cadastre 1 and 2)
- Constructed area: 1,262 m^2 (452 + 240 + 94 + 77 + 141 + 51 + 207)
- Gross floor area: 1,692 m^2 (2,714 - 1,022 (floors0))
- Green surface (according to "measure distance" of Google maps): 0 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 1.692 m^2

7.1 Climate analysis

Climatic data (Nearest station LEON)



Average, maximum and minimum temperatures (months).

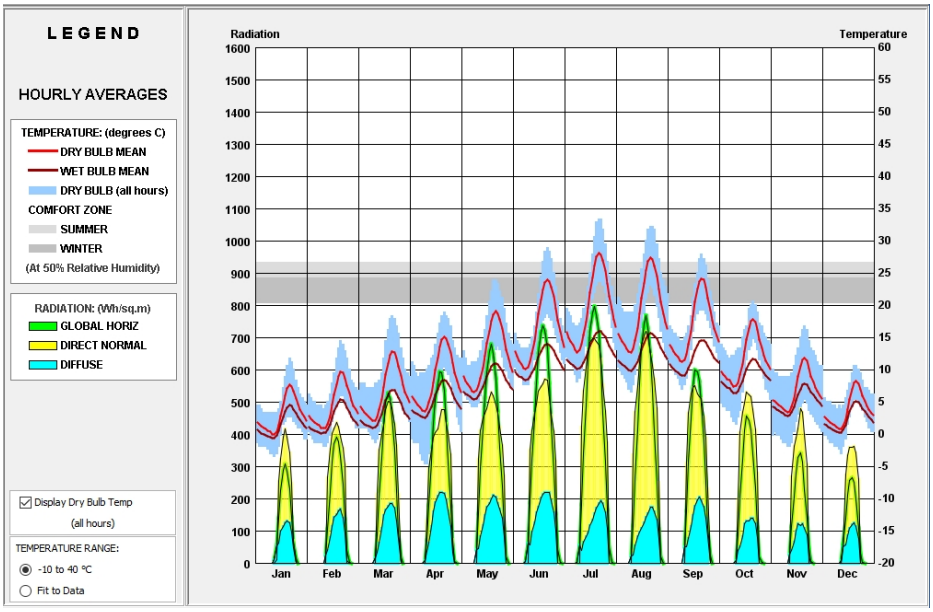
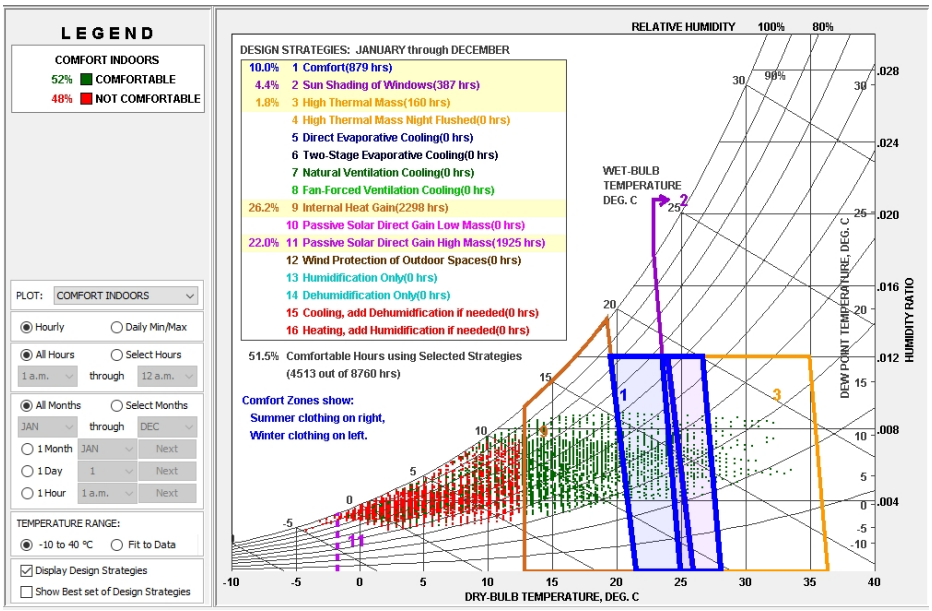


Illustration 13. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of comfort hours in the climate: 10.0%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (4.4%)

3- Exploitation of thermal inertia (1.8%)

4- Thermal discharge of building mass (not

applicable) 5.6- Evaporative cooling systems (not

applicable) 7- Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (26.2%)

10,11- Solar collection (22.0%)

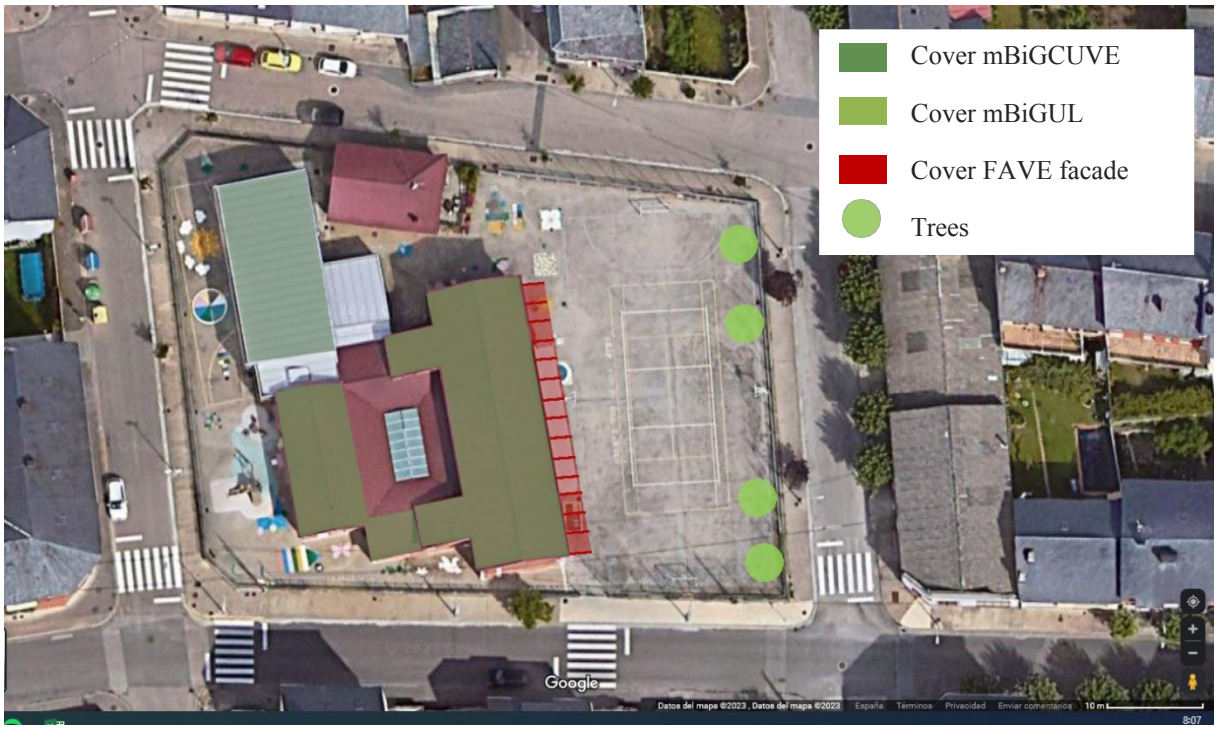
12- protection against external winds (not applicable)

Percentage of comfort hours with the application of bioclimatic strategies: 52%.

Need for Climate System (percentage of hours): 48% HEAT.

7.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the CEIP Virgen del Carmen school: mBiGCUVE green roof, mBiGUL green roof, FAVE system and trees arranged along the east courtyard to create shaded spaces. Figure 8 shows the distribution of the solutions in the school.



General plan of the implementation of NBS in the school CEIP Virgen del Carmen - La Plata (Ponferrada, Spain).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 470 m^2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (22%).

Green cover - type mBiGUL

Installation of an mBiGUL green roof on the main building, covering an **area of 180 m^2**.

Vegetation type: *Allium schoenoprasum, Carex buchananii, Festuca amesthystina, Limonium vulgare, Satureja montana, Saponaria ocymoides, Sedum album, Sedum floriferum, Sedum sediforme, Sedum spurium, Petrorhagia saxifraga.*

Impact: this type of solution mainly favors catchment (22%).

Green façade - FAVE system

Installation of the FAVE system on the northeast facade, protecting the openings of one of the main and most unprotected facades. It covers a 95 m long façade and a **plant shading** area **of 217.5 m^2**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the shading of openings in summer (4.4%).

Trees

Four trees will be planted in the east courtyard, with more sunlight, to create a shaded area, with a surface area of 52 m².

Type of vegetation: *Quercus ilex*

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 5. Budget estimate for proposed interventions

Intervention	***Cost*** ***(€/m²)***	***Surface area*** ***(m²)***	***Estimated budget***
mBiGCUVE	175,79 €	470	82.622,81 €
mBiGUL	130,40 €	180	23.472,00 €
FAVE	105,51 €	217,5	22.948,35 €
Trees	400,00 €	4	1.600,00 €
Total			**130.643,16 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 34% and the permeable area by 26%.

Table 6. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	2714	-	-
Initial green area	0	0 %	-
Final green area	920	34%	**34%**
Initial permeable surface	0	0 %	-
Final permeable surface	703	26 %	**26 %**

8. ESCOLA BÁSICA DE 1º CEB DE RIO DE MOINHOS (ABRANTES, PORTUGAL)

Location: R. de Estremoz (municipality: Abrantes, Intermunicipal Community: Médio Tejo, District: Santarém)

Coordinates: 38.77190330774062, -7.50360002981262 (link Google maps) Height:

1 and 2 floors (including first floor)

Year of construction without data

Orientation:

N: totally exposed to radiation, it is the main access to the school.

E: fully exposed to radiation, contains the main door of the school building.

S: exposed to radiation, includes a newly constructed runway.

O: The west side of the school is planted with trees, shrubs and vegetable garden, although the distance to the building and the small size of the trees do not protect the west façade from radiation.

Photographs of the school: Annex 2. Photographs of the schools Types

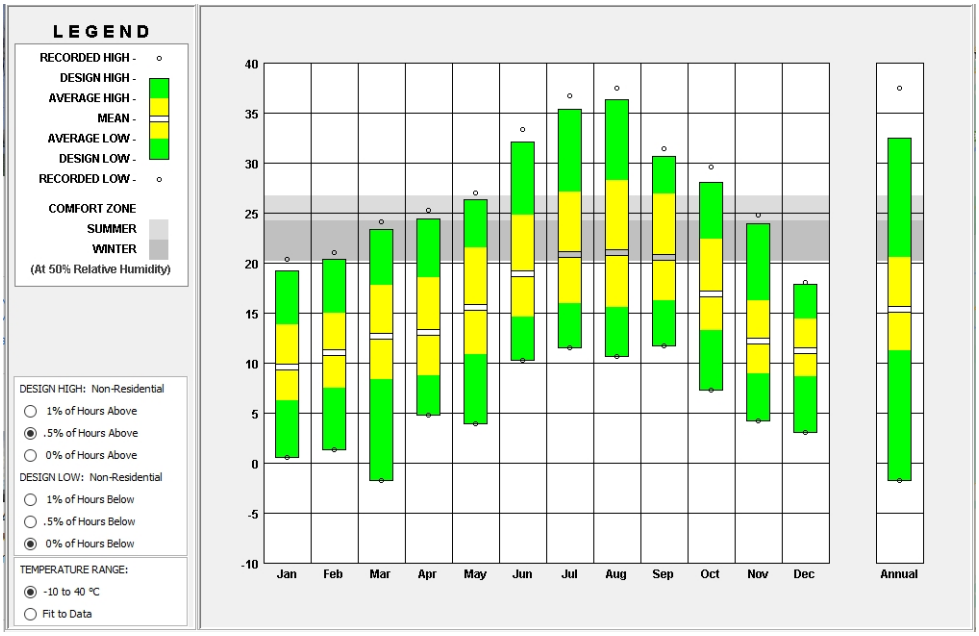
of roofs: pitched roofs

Areas in m^2 according to type of surface:

- Plot area: 4,526 m^2 (according to "measure distance" of Google maps)
- Built area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built meters between floors): 832 m2 (280 + 276 + 276)
- Gross floor area: 3,694 m^2 (4,526 - 832 (floors0))
- Green area (according to "measure distance" of Google maps): 666 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 3,028 m^2

8.1 Climate analysis

Climatic data (Nearest station COIMBRA)



Average, maximum and minimum temperatures (months)

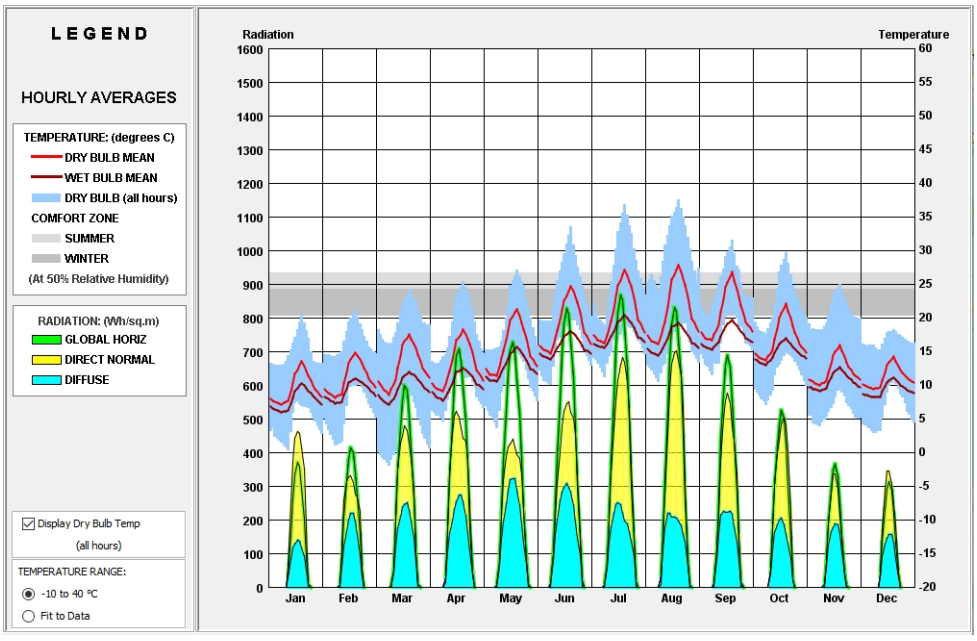
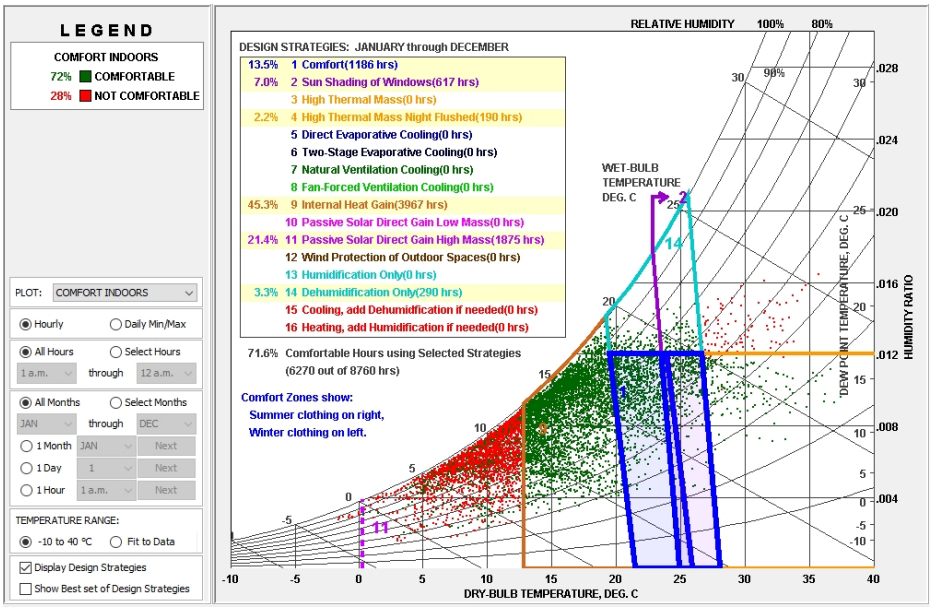


Illustration 17. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures

Percentage of hours of comfort in the climate: 13.5%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer void shading (7.0%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (2.2%)

5,6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (45.3%)

10.11- Solar collection (21.4%)

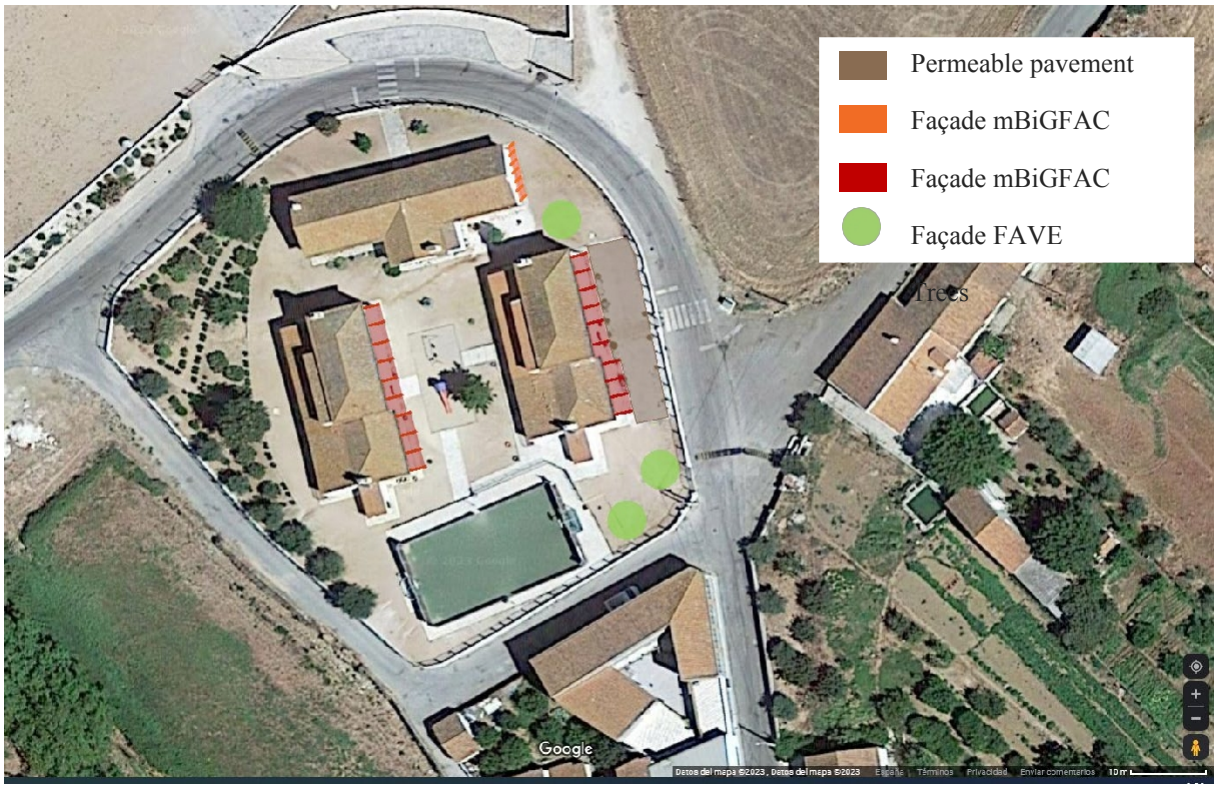
12- protection against external winds (not applicable)

Percentage of hours of comfort with the application of bioclimatic strategies: 72%

Need for Climate System (percentage of hours): 27.1% HEAT; 1.3% COOL.

8.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Escola Básica de 1º CEB De Rio de Moinhos school: wooded, a mBiGFAC type façade, FAVE system and a permeable pavement system. Figure 8 shows the distribution of the solutions in the school.



General plan of NBS implementation in Escola Básica de 1º CEB de Rio de Moinhos (Abrantes, PORTUGAL).

Green façade - type mBiGFAC

Installation of an mBiGFAC green façade on one of the buildings, covering an **area of 24 ^{m2}**.

Vegetation type: *Parthenocissus tricuspidata "Veitchii"*.

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Green façade - FAVE type

Installation of FAVE system in both buildings, covering an **area of 351 m^2**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution favors the thermal discharge of the building mass (2.2%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable mBiG_SUVE pavement on the east side of the school, covering an **area of 144 m^2**.

Type of vegetation: *Lolium perenne*, 10% *Poa pratensis*, 10% *Agrostis* spp, 70% *Festuca* spp.

Impact: this type of solution mainly favors solar gain (21.4%).

Trees

Three trees will be planted in the east courtyard, with more sunlight, to create a shaded area, with a surface area of 39 m².

Vegetation type: *Quercus suber*.

Impact: this type of solution mainly favors solar gain (21.4%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 7. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
mBiGFAC	88,59 €	24	2.126,21 €
FAVE	105,51 €	351	37.033,89 €
mBiG_SUVE	54,29 €	144	7.818,22 €
Trees	400,00 €	3	1.200,00
Total			**48.178,32 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 9% and the permeable area by 4%.

Table 8. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	4526	-	-
Initial green area	832	18 %	-
Final green area	1080	24%	**9%**
Initial permeable surface	666	15 %	**-**
Final permeable surface	849	19 %	**4%**

9. ESCOLA BÁSICA 1 DE SÃO MARTINHO DO BISPO (COIMBRA, PORTUGAL)

Location: Praceta Dr. José de Oliveira Firmo, 3 (municipality: Coimbra, District: Coimbra)

Coordinates: 40.21062198130003, -8.45669917662195 (link to Google maps)

Height: 2 floors (including first floor)

Year of construction no data Orientation:

N: it is a very small facade with two awnings to protect the first floor from sunlight.

E: it is the largest and most exposed facade, although half of it is protected by trees. This façade is where the main entrance to the enclosure is located, as well as the main entrance to the building. It is also where most of the courtyard is located, including a tennis court.

S: it is a very small facade with two awnings to protect the first floor from sunlight.

O: it is the other facade of greater extension, although very protected from the sun by the adjacent buildings. It contains a small patio.

Photographs of the school: Annex 2. Photographs of the schools Types

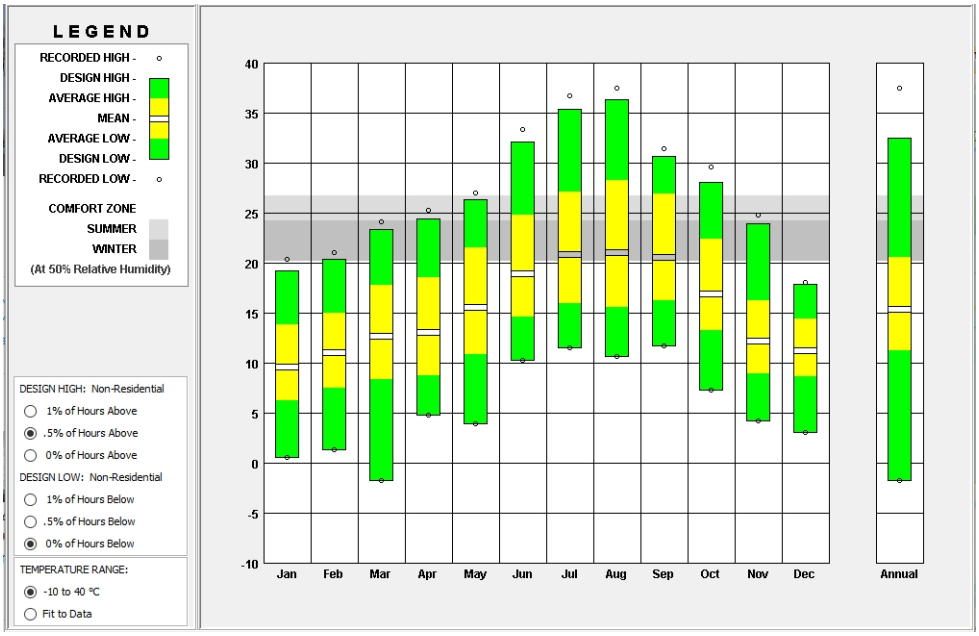
of roofs: pitched roofs

Areas in m^2 according to type of surface:

- Plot area: 1,300 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 523 m2 (455 + 90 + 78)
- Gross floor area: 777 m^2 (1,300 - 523 (floors0))
- Green area (according to Google maps "measure distance"): 240 m^2 (northeast woodland)
- Surface with pavement (according to "measure distance" of Goolge maps): 537 m^2

9.1 Climate analysis

Climatic data (Nearest station COIMBRA)



Average, maximum and minimum temperatures (months).

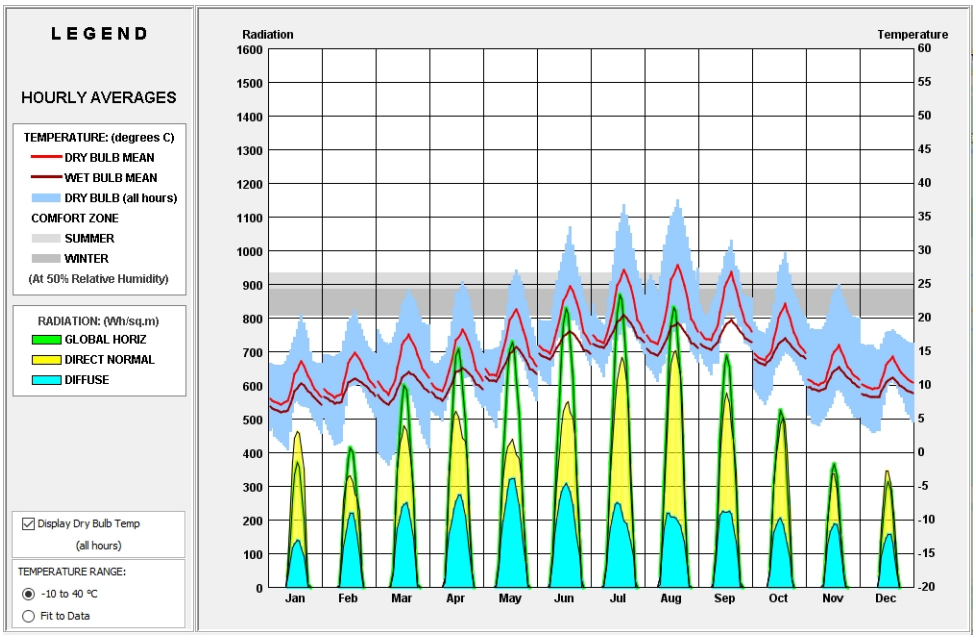
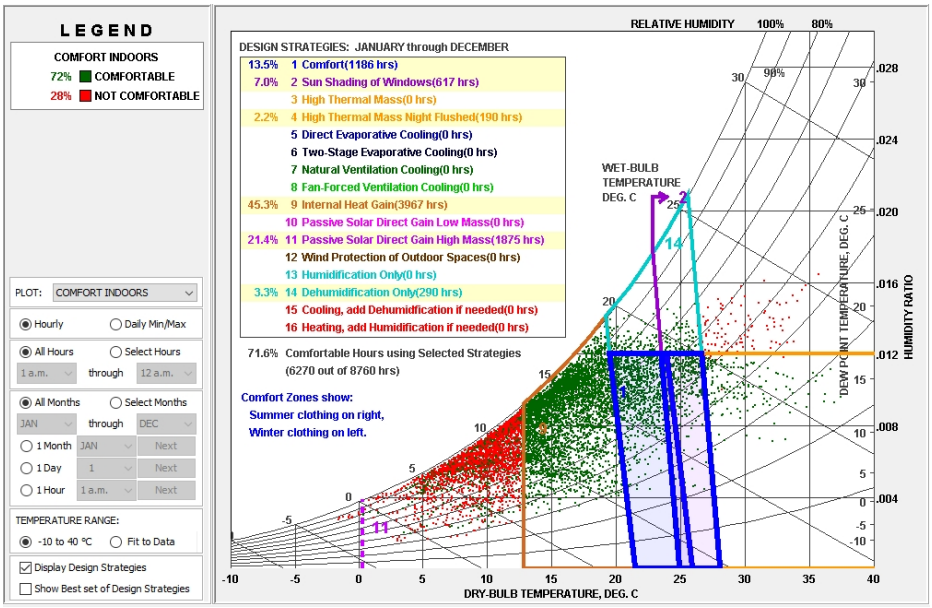


Illustration 21. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of hours of comfort in the climate: 13.5%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (7.0%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (2.2%)

5,6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (45.3%)

10,11- Solar collection (21.4%)

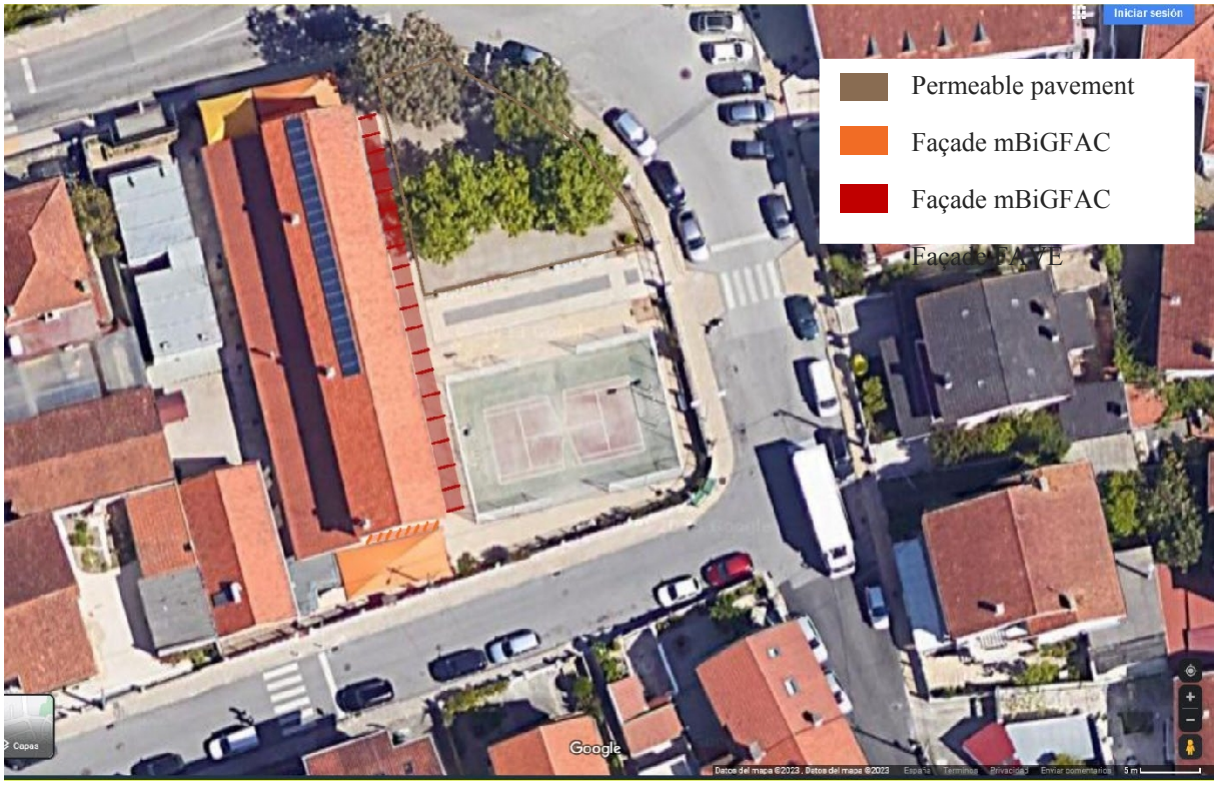
12- protection against external winds (not applicable)

Percentage of hours of comfort with the application of bioclimatic strategies: 72%

Need for Climate System (percentage of hours): 27.1% HEAT; 1.3% COOL.

9.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Escola Básica 1 school in São Martinho do Bispo: mBiGFAC green facades, a FAVE system and a permeable pavement. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Escola Básica 1 in São Martinho do Bispo (Coimbra, PORTUGAL).

Green façade - type mBiGFAC

Installation of an mBiGFAC green façade on the main building, covering an **area of 48 m2**.

Vegetation type: *Parthenocissus tricuspidata "Veitchii"*.

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Green façade - FAVE type

Installation of a FAVE system in the main building, covering an **area of 267 m2**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 258 m^2**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (21.4%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 9. Budget estimate for proposed interventions

Intervention	***Cost*** ***(€/m²)***	***Surface area*** ***(m²)***	***Estimated budget***
mBiGFAC	88,59 €	48	4.252,42 €
FAVE	105,51 €	267	28.171,08 €
mBiG_SUVE	54,29 €	258	14.007,64 €
Total			**46.431,15 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 24% and the permeable area by 20%.

Table 10. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	1300	-	-
Initial green area	523	40 %	-
Final green area	555	43%	**24%**
Initial permeable surface	240	18 %	**-**
Final permeable surface	498	38%	**20 %**

10. ÉCOLE ÉLÉMENTAIRE PUBLIQUE SYLVAIN DAURIAC (TOULOUSE, FRANCE)

Location: Rue Paul Lambert, 41 (municipality: Toulouse, region: Occitania, Province: Languedoc)

Coordinates: 43.57820444027022, 1.4138674139749907 (link Google maps) Height:

2 floors (including first floor)

Year of construction: no data Orientation:

NE: this is the façade with the main entrance to the school and with a wide extension. Although it is indicated NE, it dominates the north orientation. On the sidewalk of the street there are quite a number of trees planted in tree wells.

SE: the two main buildings of the school have a wide SE orientation, with East dominance. From Google, one can only access the façade of the easternmost building, where the soccer field and a large part of the schoolyard are located. There is not much protection against solar radiation.

SO: from Google it is not possible to access this façade, of southern dominance, although it has been possible to take a photo from this orientation of the easternmost part of the NE façade.

NW: the two main buildings of the school have a broad NW orientation, with west dominance. From Google, only the façade of the westernmost building, which faces the street and where no protection against solar radiation is visible, can be accessed.

Photographs of the school: Annex 2. Photographs of the schools Types

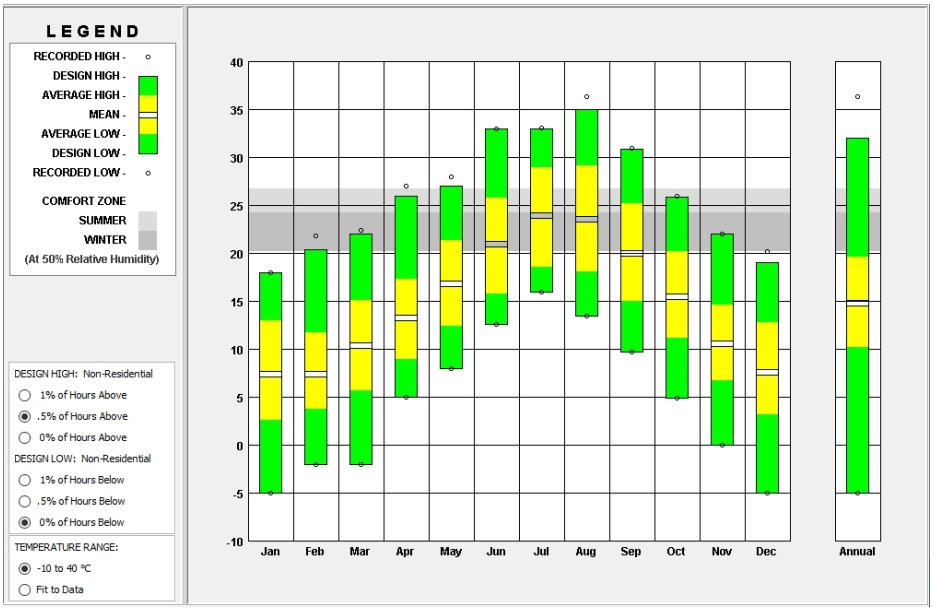
of roofs: flat roofs

Areas in m2 according to type of surface:

- Plot area: 7,035 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 2,691 m^2 (927 + 990
  + 774)
- Gross floor area: 4,344 m^2 (7,035 - 2,691 (floors0))
- Green area (according to Google maps "measure distance"): 1,678 m^2 (wooded)
- Surface with pavement (according to "measure distance" of Goolge maps): 2,666 m^2

10.1 Climate analysis

Climatic data (Nearest station MONTPELLIER)



Average, maximum and minimum temperatures (months).

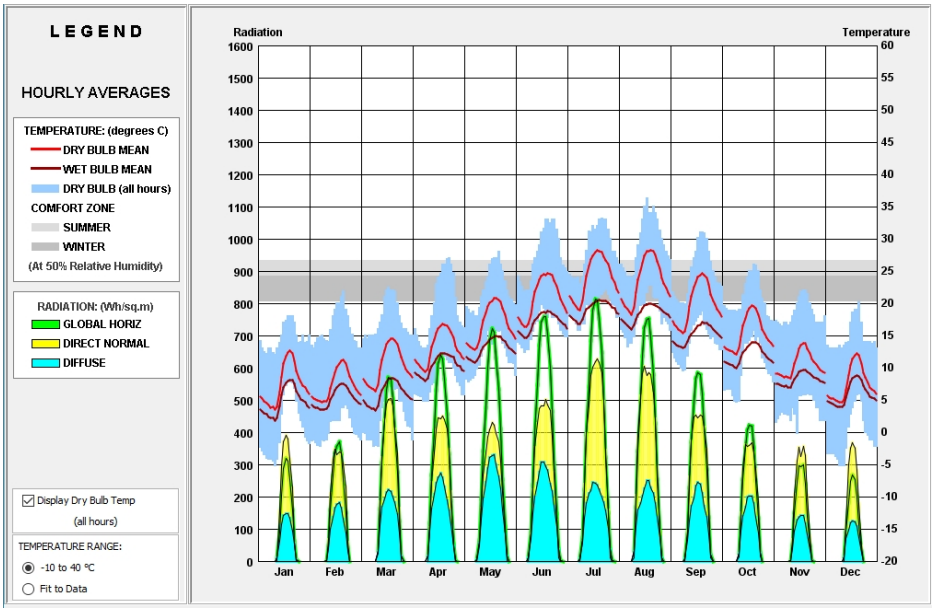
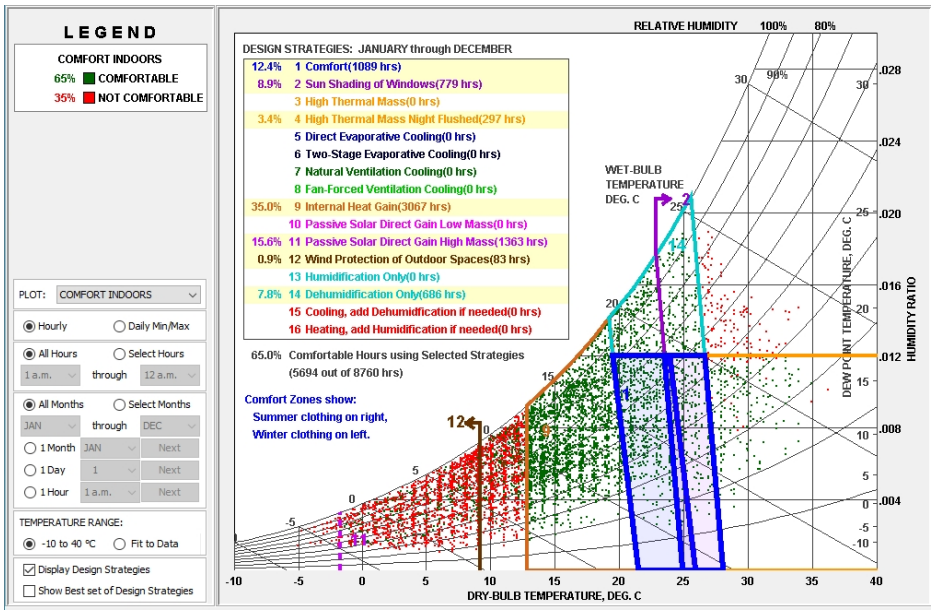


Illustration 25. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of hours of comfort in the climate: 12.4%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (8.9%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (3.4%)

5,6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (35.0%)

10,11- Solar collection (15.6%)

12- protection against external winds (not applicable)

Percentage of comfort hours with the application of bioclimatic strategies: 65%.

Need for Climate System (percentage of hours): 32.6% HEAT; 2.4% COOL.

10.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the École Élémentaire publique Sylvain Dauriac school: mBiGCUVE green roof, mBiGCUVE-SUS green roof, FAVE system arranged around the east courtyard to create shaded spaces. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at École Élémentaire publique Sylvain Dauriac (Toulouse, FRANCE).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on one of the main buildings, covering an **area of 1,076 ^{m2}**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (3.4%).

Green cover - type mBiGCUVE-SUS

Installation of an mBiGCUVE green roof on the main building, covering an **area of 692 ^{m2}**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (3.4%).

Green façade - FAVE type

Installation of an mBiGCUVE green roof on the main building, covering an **area of 418 ^{m2}**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the shading of openings in summer (8.9%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 11. Budget estimate for proposed interventions

Intervention	***Cost (€/m2)***	***Surface area (m2)***	***Estimated budget***
mBiGCUVE	175,79 €	1768	310.802,39 €
FAVE	105,51 €	418	44.103,04 €
Total			**354.905,43 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 31% and the permeable area by 25%.

Table 12. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total surface area	7035	-	-
Initial green area	1678	24 %	-
Final green area	3864	55%	**31%**
Initial permeable surface	1678	24%	**-**
Final permeable surface	3446	49 %	**25%**

.

11. SCUOLA MEDIA STATALE MASSARI GALILEI (BARI, ITALY)

Location: Via Daniele Petrera, 80 (municipality: Bari, region: Apulia)

Coordinates: 41.10949231088252, 16.865141776546125 (Google maps link)

Height: 3 floors (including first floor)

Year of construction without data

Orientation:

N: it is the facade with the main entrance of the school. It is well protected by large trees.

E: it looks like the facade of an auxiliary building that could be the gymnasium. It has no protection against solar radiation.

S: from Google it is not possible to access all of this façade, although some photos of the SW and SE ends are available. The part of the building located more to the W is more protected by trees than the E part.

O: these facades are protected by large trees. Photographs of the

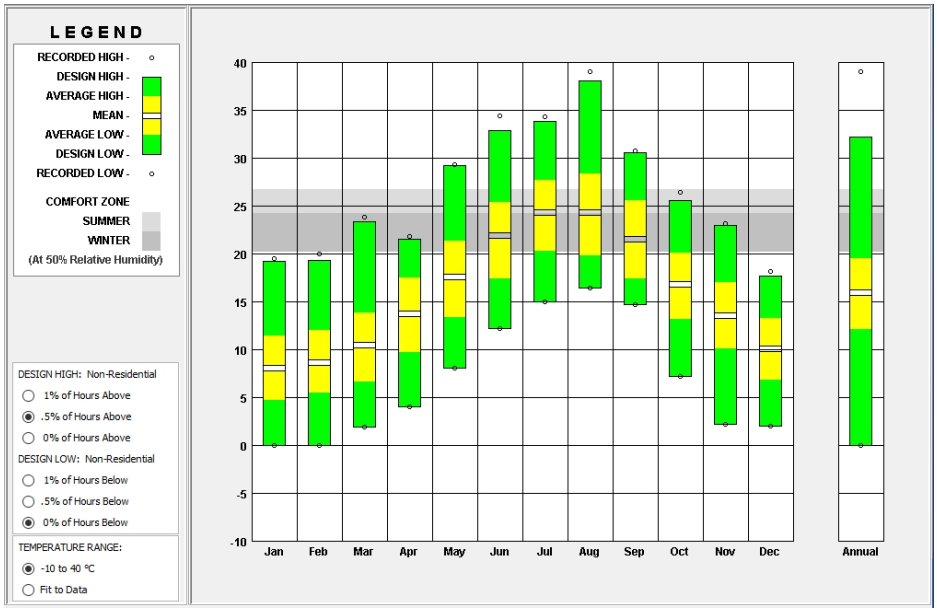
school: Annex 2. Photographs of the schools Types of roofs: flat (some

appear to have solar panels) Areas in m2 according to type of surface:

- Plot area: 5,192 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 1,919 m^2 (276 + 312
  + 198 + 280 + 462 + 391)
- Gross floor area: 3,273 m^2 (5,192 - 1,919 (floors0))
- Green area (according to Google maps "measure distance"): 515 m^2 (wooded)
- Surface with pavement (according to "measure distance" of Goolge maps): 2,758 m^2

11.1 Climate analysis

Climatic data (Nearest station, Bari)



Average, maximum and minimum temperatures (months).

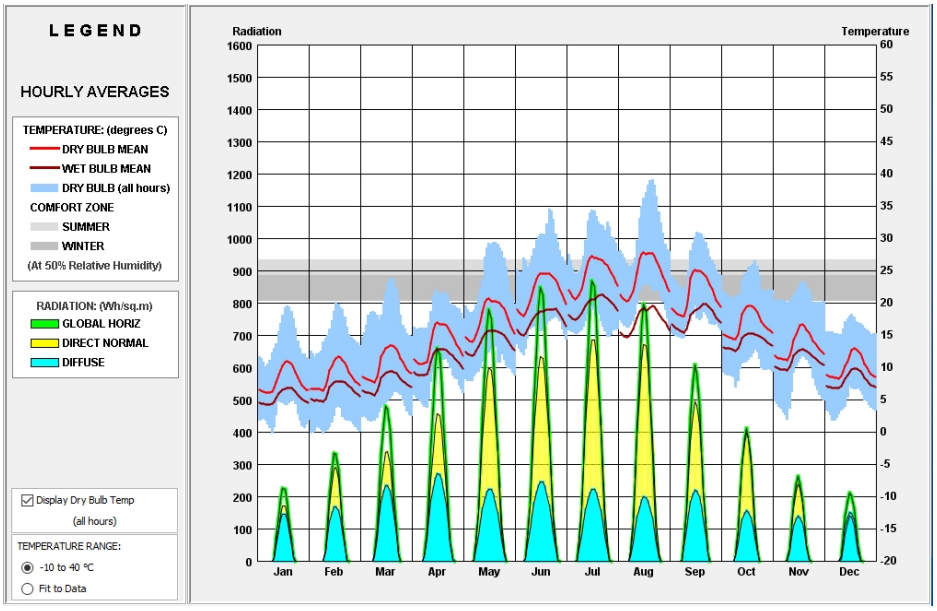
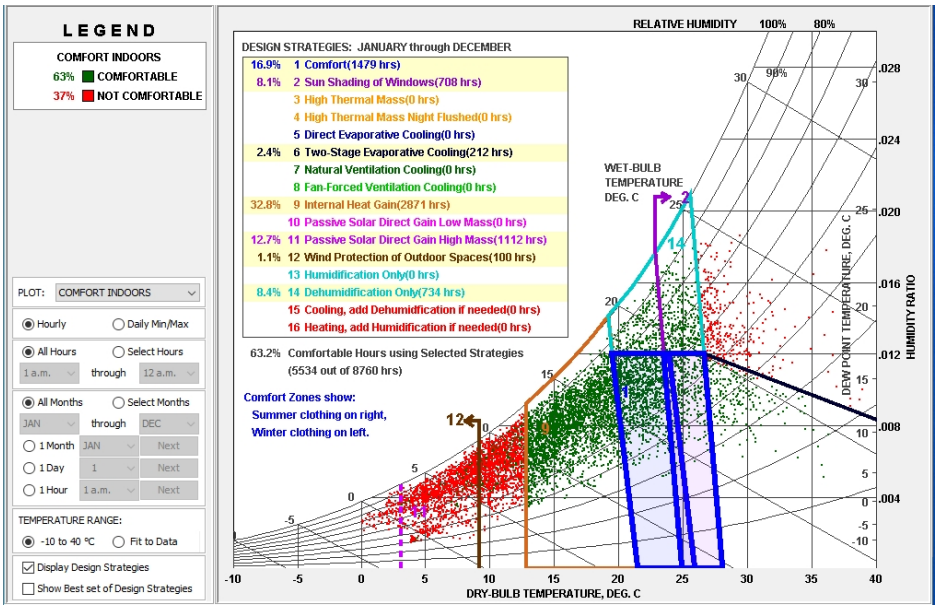


Illustration 29. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures

Percentage of hours of comfort in the climate: 16.9%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (8.1%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (2.2%)

5.6- Evaporative cooling systems (2.4%) 7- Night

ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (32.8%)

10,11- Solar collection (12.7%)

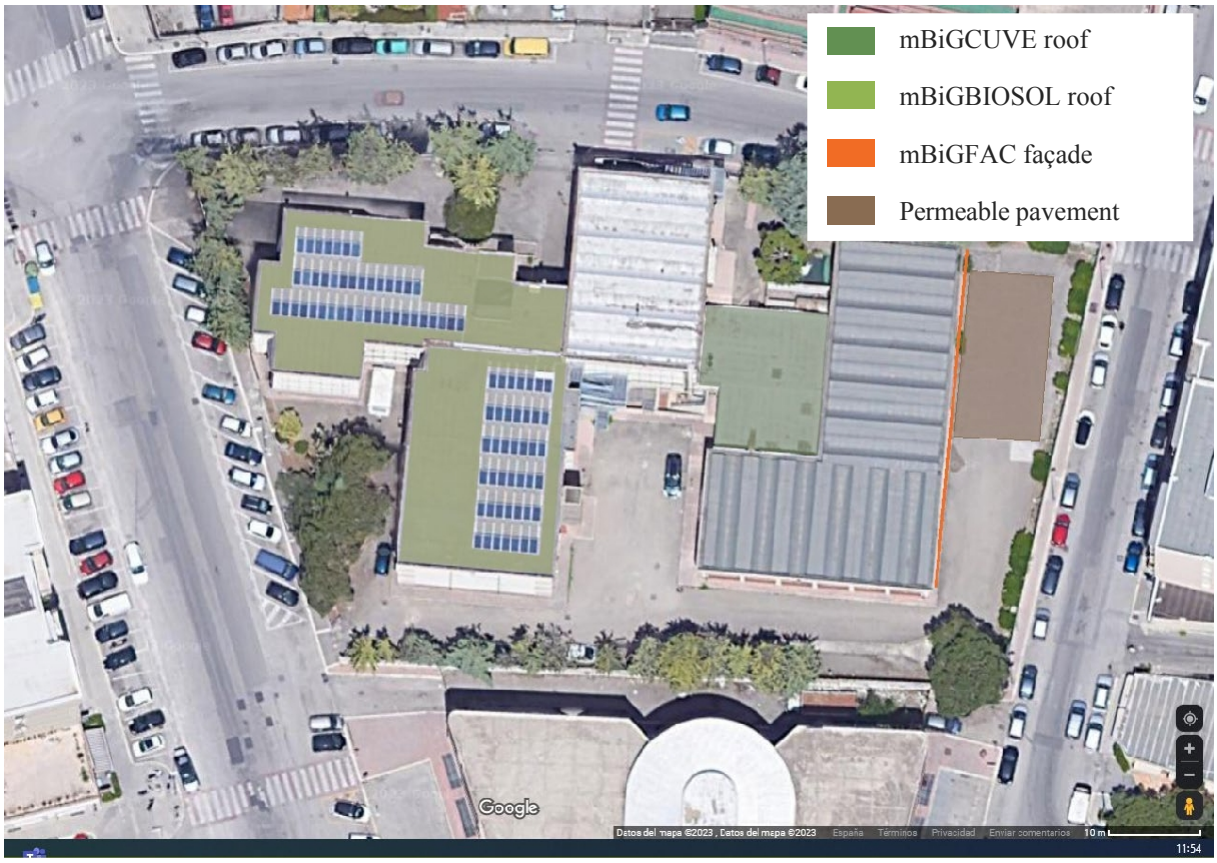
12- protection from external winds (1.1%)

Percentage of comfort hours with the application of bioclimatic strategies: 63%.

Need for Climate System (percentage of hours): 32.7% HEAT; 4.1% COOL.

11.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Scuola Media Statale Massari Galile school: mBiGCUVE green roof, mBiGBIOSOL green roof, mBiGFAC green façade and mBIG-SUVE pavement, arranged around the main buildings and in the eastern part of the school to create shaded spaces. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Scuola Media Statale Massari Galilei (Bari, ITALY).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 70 m^2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Green cover - type mBiGBIOSOL

Installation of an mBiGCUVE green roof on the main building, covering an **area of 832 ^{m2}**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Green façade - type mBiGFAC

Installation of an mBiGCUVE green roof on the main building, covering an **area of 208 ^{m2}**.

Vegetation type: *Parthenocissus tricuspidata "Veitchii".*

Impact: this type of solution mainly favors the thermal discharge of the building mass (2.2%).

Permeable pavement - type mBiG-SUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 167 ^{m2}**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain Ç (12.7%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 13. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
mBiGCUVE	175,79 €	70	12.305,52 €
mBiGBIOSOL	301,83 €	832	251.124,33 €
mBiGFAC	88,59 €	208	18.427,16 €
mBiGSUVE	54,29 €	167	9.066,96 €
Total			**290.923,97 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 21% and the permeable area by 21%.

Table 14. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	5192	-	-
Initial green area	515	10 %	-
Final green area	1625	31%	**21%**
Initial permeable surface	515	10 %	-
Final permeable surface	1584	31 %	**21 %**

12. ISTITUTO DI ISTRUZIONE SECONDARIA DI PRIMO GRADO G. GALILEI (GROSSETO, ITALY)

Location: Via Garigliano, 16 (municipality: Grosseto, region: Tuscany)

Coordinates: 42.763045375706724, 11.121728285844256 (Google maps link)

Height: 2 floors (including first floor)

Year of construction no data

Orientation: The school is cross-shaped, so there are facades in various orientations located on the N, S, E, and W walls. The E facing wall includes the main access to the enclosure and has trees, although less than the N and S walls, which have many large trees that shade the building.

Photographs of the school: Annex 2. Photographs of the schools Types

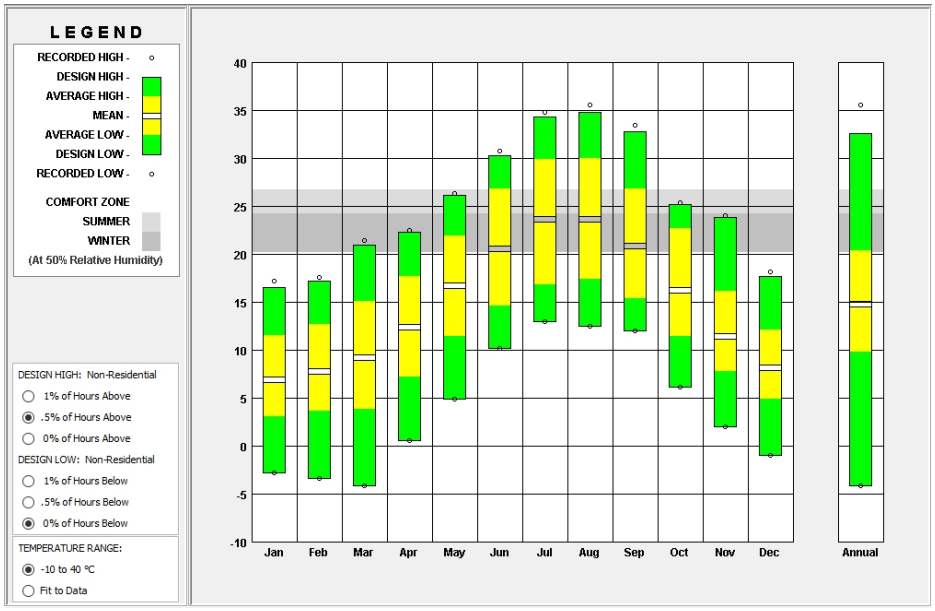
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area: 8,835 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 2,559 m2 (1,080 + 585 + 754 + 140)
- Gross floor area: 6,276 m2 (8,835 - 2,559 (floors0))
- Green area (according to Google maps "measure distance"): 4,627 m^2 (trees and garden)
- Area with pavement (according to "measure distance" of Goolge maps): 1,649 m^2

12.1 Climate analysis

Climate data (Nearest station, Bari)



Average, maximum and minimum temperatures (months).

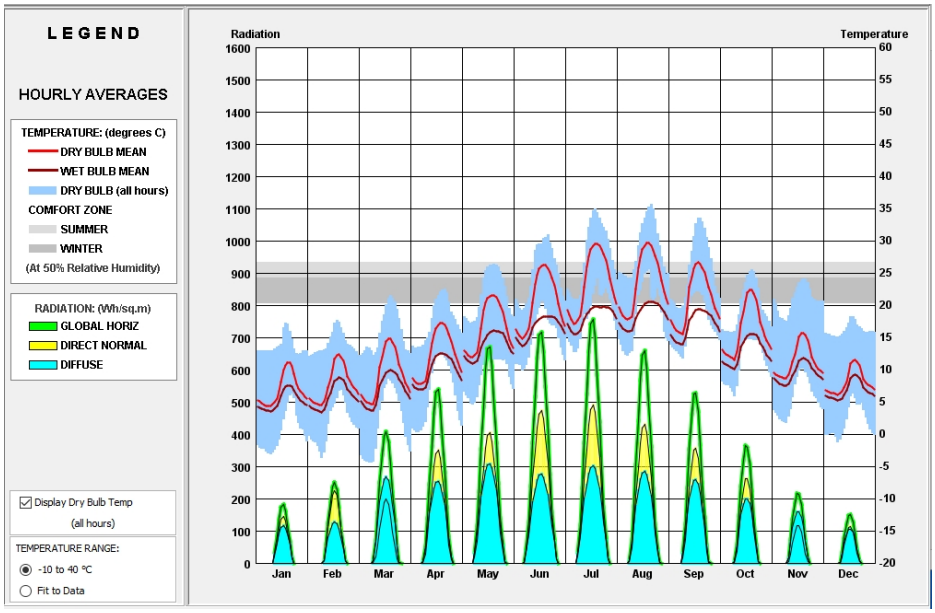
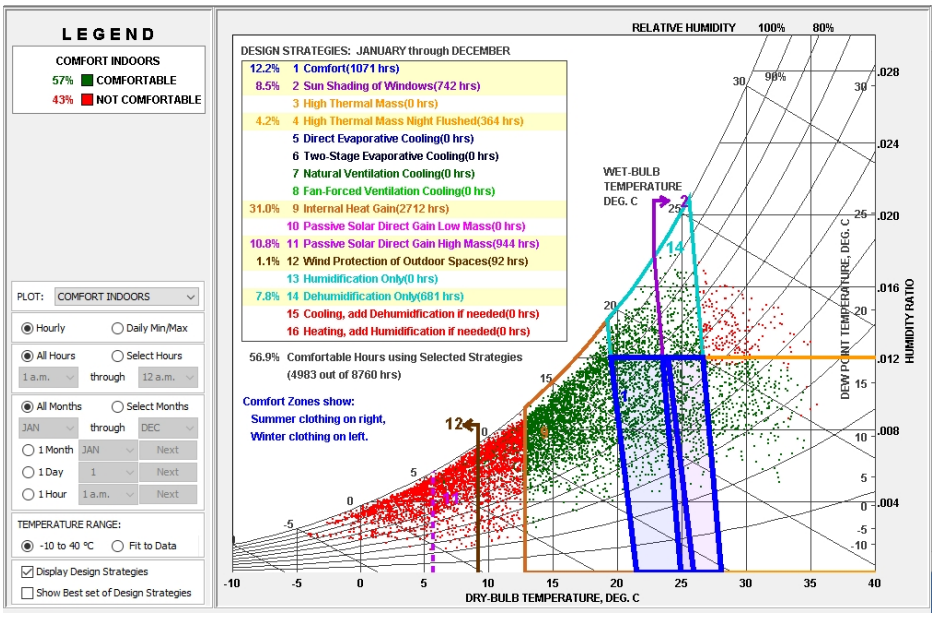


Illustration 33. Temperature and radiation (months with time range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures

Percentage of hours of comfort in the climate: 12.2%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (8.5%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (4.2%)

5.6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (31.0%)

10,11- Solar collection (10.8%)

12- protection against external winds (1.1%)

Percentage of comfort hours with the application of bioclimatic strategies: 57%.

Need for Climate System (percentage of hours): 40.2% HEAT; 2.9% COOL.

12.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Istituto di Istruzione Secondaria di primo grado G. Galilei school: mBiGCUVE green roof, mBiGCUVE- SUS green roof, two mBIGFAVE green facades arranged along the east courtyard to create shaded spaces. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Istituto di Istruzione Secondaria di primo grado G. Galilei (Grosseto, ITALY).

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 720 m2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (4.2%).

Green cover - type mBiGCUVE-SUS

Installation of an mBiGCUVE-SUS green roof on the main building, covering an area of **area of 583 m2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum album, Sedum album, Sedum acre, Sedum lydium, Sedum sexangulare, Sedum hispanicum, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu, Sedum spurium and Sedum spurium.*

Impact: this type of solution mainly improves the thermal discharge of the building (4.2%).

Green façade - FAVE type

Installation of two FAVE systems in the building, covering an **area of 267 m² and 203 m2** each.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (4.2%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 15. Budget estimate for proposed interventions

Intervention	***Cost (€/m2)***	***Surface area (m2)***	***Estimated budget***
mBiGCUVE	175,79 €	1303	229.058,55 €
FAVE	105,51 €	470	49.589,55 €
Total			**278.648,09 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 19% and the permeable area by 15%.

Table 16. Green and permeable surface before and after NBS installation.

	Surface area (m)^2	Percentage	Increase (%)
Total area	8835	-	-
Initial green area	4627	52 %	-
Final green area	6297	71%	**19%**
Initial permeable surface	4627	52%	-
Final permeable surface	5930	67 %	**15 %**

13. OSNOVNA ŠKOLA STOJA (STOJA PRIMARY SCHOOL) (PULA, CROATIA)

Location: Brijunska ul. 5 (municipality: Pula, county: Istria)

Coordinates: 44.859769817708255, 13.831328667018688 (link Google maps)

Height: 3 floors (including first floor)

Year of construction without data

Orientation:

N: it is one of the most extensive facades, where the main entrance of the building is located and which faces a narrow street without trees. It is oriented N with a slight inclination to W.

E: is a small unshaded facade with a slight slope to the N.

S: is the other larger side of the school that leads to the schoolyard. They have no protection against sunlight since the green area in front is far from the building. It is oriented S slightly inclined to E.

W: this façade is divided into two clear orientations, SW (with practically no protection from the sun) and NW (with a large tree protecting the façade from the sun).

Photographs of the school: Annex 2. Photographs of the schools Types

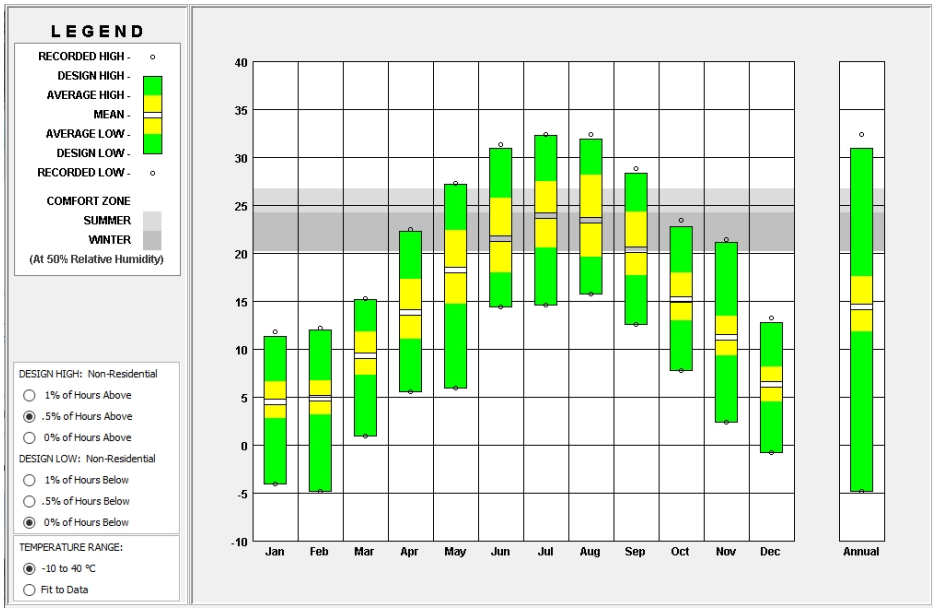
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area: 3,953 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 1,354 m2 (288 + 286 + 36 + 180 + 144 + 144 + 276)
- Gross floor area: 2,599 m^2 (3,953 - 1,354 (floors0))
- Green area (according to "measure distance" of Google maps): 1,242 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 1.347 m^2

13.1 Climate analysis

Climatic data (Nearest station, Trieste)



Average, maximum and minimum temperatures (months)

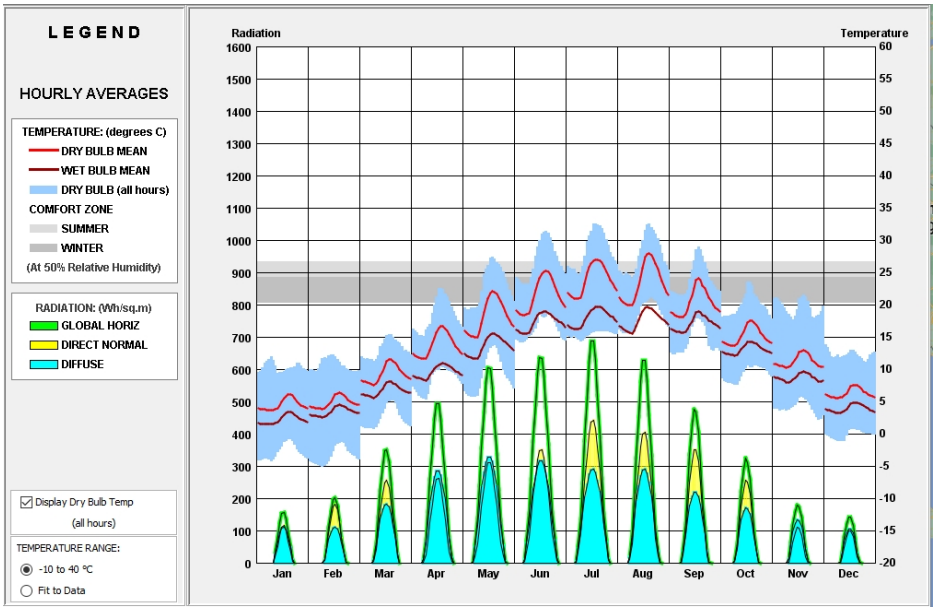
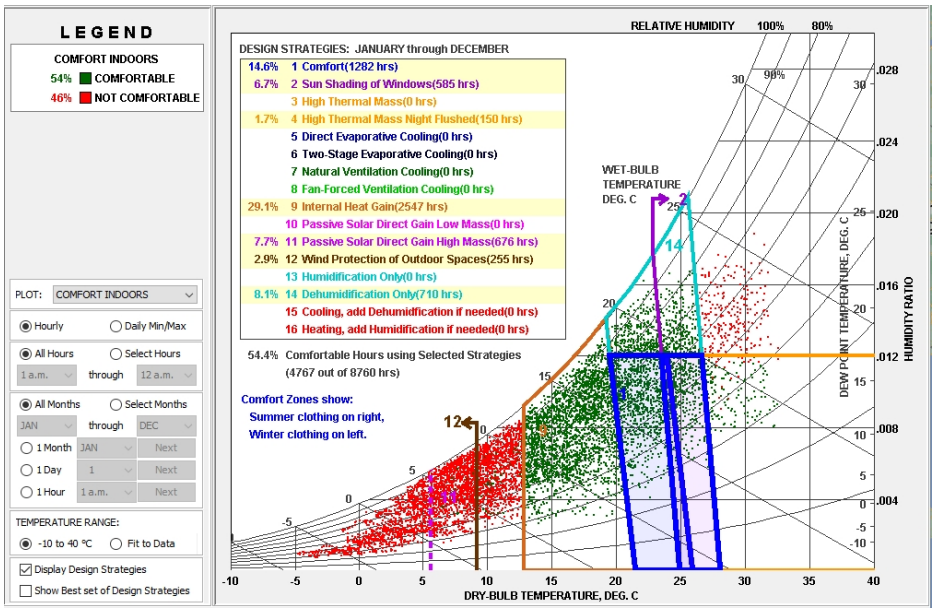


Illustration 37. Temperature and radiation (months with time range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures

Percentage of hours of climate comfort: 14.6%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Shading of hollows in summer (6.7%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (1.7%)

5.6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (29.1%)

10,11- Solar collection (7.7%)

12- protection against external winds (2.9%)

Percentage of comfort hours with the application of bioclimatic strategies: 54%.

Need for Climate System (percentage of hours): 42.3% HEAT; 3.3% COOL.

13.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Osnovna škola Stoja (Stoja Primary school): mBiGCUVE green roof, mBiGCUVE-SUS green roof, FAVE system and mBIG-SUVE permeable pavement arranged around the buildings and south-east façade and in the south courtyard, respectively. The following illustration shows the distribution of the solutions in the school.



General plan of the implementation of NBS in Stoja Primary school (Pula, CROATIA)

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 572 m^2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (1.7%).

Green cover - type mBiGCUVE-SUS

Installation of an mBiGCUVE-SUS green roof on the main building, covering an area of **surface area of 465 ^{m2}**.

Type of vegetation: *Sedum* genus, including the following species: *Sedum album, Sedum album, Sedum acre, Sedum lydium, Sedum sexangulare, Sedum hispanicum, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu.*

Impact: this type of solution mainly improves the thermal discharge of the building (1.7%).

Green façade - FAVE type

Installation of a FAVE system in the main building, covering an area of 147 m^2 .

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata, Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (1.7%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an area of 170 m^2 .

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (7.7%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 17. Budget estimate for proposed interventions

Intervention	***Cost (€/m2)***	***Surface area (m2)***	***Estimated budget***
mBiGCUVE	175,79 €	1037	182.297,55 €
FAVE	105,51 €	147	15.509,92 €
mBiGSUVE	54,29 €	170	9.229,84 €
Total			**207.037,32 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 30% and the permeable area by 31%.

Table 18. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	3953	-	-
Initial green area	1242	31%	-
Final green area	2426,65	61%	**30%**
Initial permeable surface	1242	31%	-
Final permeable surface	2449,5	62%	**31%**

14. OSNOVNA ŠKOLA KNEZA MISLAVA (MISLAVA PRIMARY SCHOOL) (KAŠTEL SUĆURAC, CROATIA)

Location: Ul. Braće Radić 6 (municipality: Kaštel Sućurac, county: Dalmatia)

Coordinates: 43.54720646499244, 16.422485394899553 (Google maps link) Height:

2 floors (including first floor).

Year of construction without data

Orientation:

N: is the façade of the main entrance to the building, with tree protection in some areas and a soccer field in the front.

E: it looks like the facade of a gymnasium type building, without much protection against solar radiation.

S: is an extensive glass façade with some protection by large trees. The eastern sun should shine well on this façade.

O: the O orientation is divided into 3 facades, two of them with tree protection and a very small one more exposed to solar radiation.

Photographs of the school: Annex 2. Photographs of the schools Types

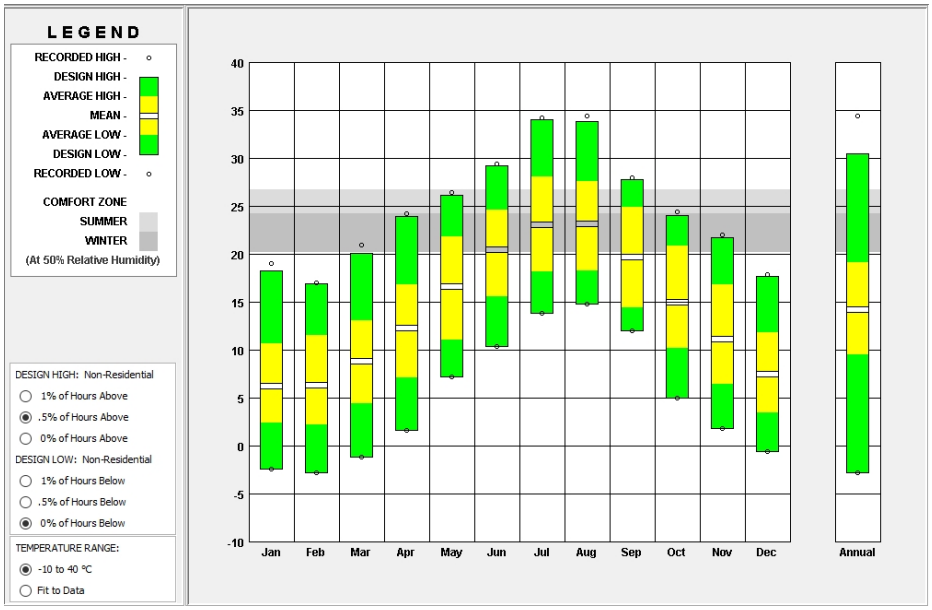
of roofs: flat roofs

Areas in m^2 according to type of surface:

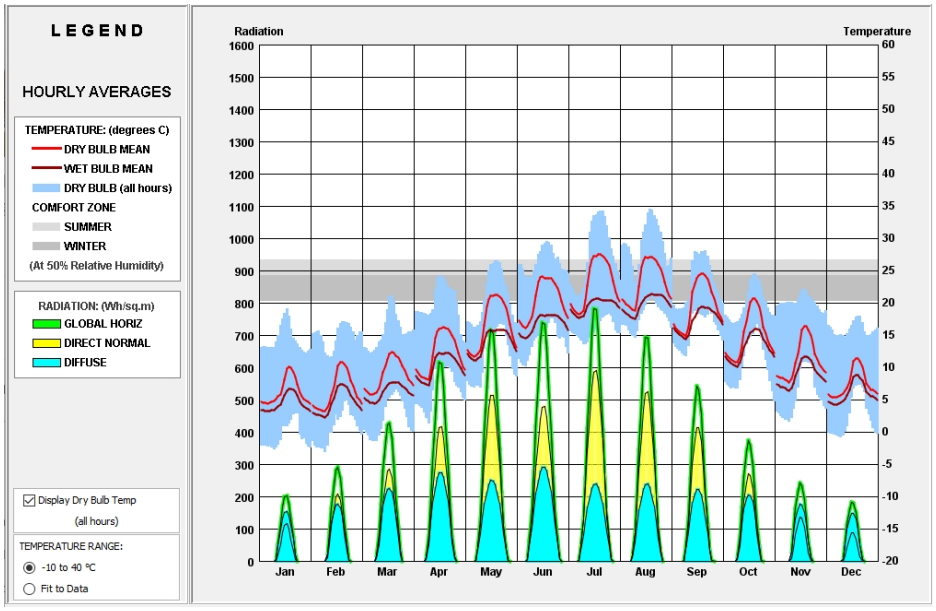
- Plot area: 9,240 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 1,970 m2 (682 + 506 + 782)
- Gross floor area: 7,270 m2 (9,240 - 1,970 (floors0))
- Green area (according to "measure distance" of Google maps): 5,028 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 2.242 m^2

14.1 Climate analysis

Climatic data (Nearest station, Pescara, Italy)

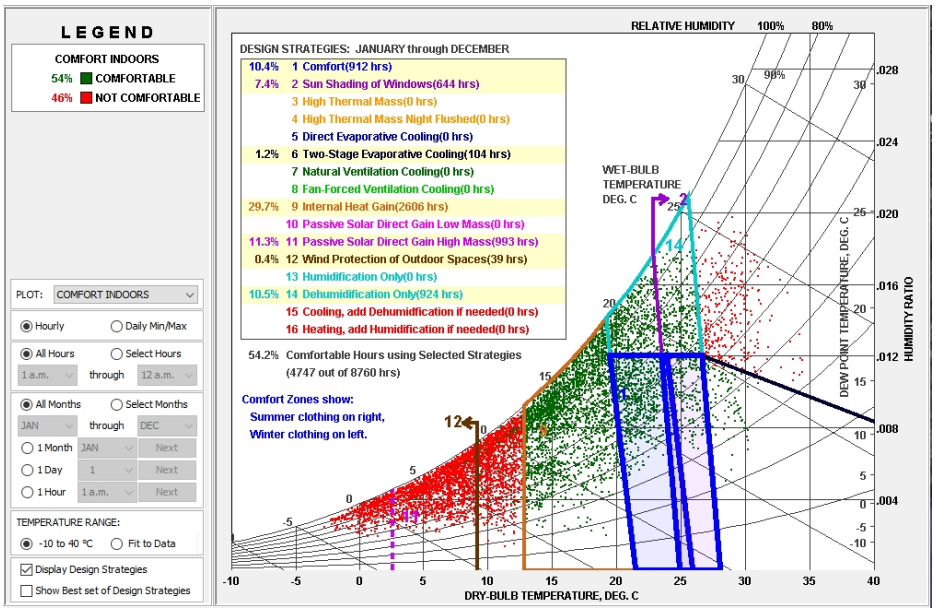


Average, maximum and minimum temperature (months)



Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of hours of comfort in the climate: 10.4%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Shading of holes in summer (7.4%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of building mass (not

applicable) 5.6- Evaporative cooling systems (1.2%)

7- Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (29.7%)

10,11- Solar collection (11.3%)

12- protection against external winds (0.4%)

Percentage of hours of comfort with the application of bioclimatic strategies: 54%.

Need for Climate System (percentage of hours): 41.9% HEAT; 3.9% COOL.

14.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Osnovna škola kneza Mislava school (Mislava Primary school) green roof mBiGCUVE , green roof mBiGUL and two facades with the mBiGFAC system on the east and south facades. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Mislava Primary school (Croatia)

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 783 m2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (11.3%).

Green cover - type mBiGUL

Installation of an mBiGUL green roof on the main building, covering an **area of 405 m2**.

Vegetation type: *Allium schoenoprasum, Carex buchananii, Festuca amesthystina, Limonium vulgare, Satureja montana, Saponaria ocymoides, Sedum album, Sedum floriferum, Sedum sediforme, Sedum spurium, Petrorhagia saxifraga.*

Impact: this type of solution mainly favors catchment (11.3%).

Green façade - type mBiGFAC

Installation of mBiGFAC green façades on the east and south side of the school, covering a **surface of 193m2 and 165 m²**.

Vegetation type: *Parthenocissus tricuspidata "Veitchii".*

Impact: this type of solution mainly favors solar gain (11.3%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 19. Budget estimate for proposed interventions

Intervention	***Cost (€/m2)***	***Surface area (m2)***	***Estimated budget***
mBiGCUVE	175,79 €	783	137.646,08 €
mBiGUL	130,40 €	405	52.812,00 €
mBiGFAC	88,59 €	358	31.715,98 €
Total			**222.174,06 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 17% and the permeable area by 13%.

Table 20. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total area	9240	-	-
Initial green area	5028	54%	-
Final green area	6573,7	71%	**17%**
Initial permeable surface	5028	54%	-
Final permeable surface	6216,2	67%	**13%**

15.13Ο ΓΥΥΜΝΆΣΙΟΠΕΡΙΣΤΕΡΊΟΥ (13TH HIGHSCHOOL OF PERISTERI) (PERISTERI, GREECE)

Location: Ferwn, Eth. Antistaseos, Peristeri 121 35 (municipality: Peristeri, periphery: Attica)

Coordinates: 38.01558126894932, 23.68282282423919 (link Google maps)

Height: 3 floors (including first floor)

Year of construction no data Orientation:

NO: it is the facade of the main entrance to the building, unprotected from the sun, but located on a narrow street.

NE: facade without sun protection on a street with no buildings in front.

SE: main façade of the school that receives the most intense insolation and where one of the school's playgrounds is located.

SW: this façade is divided into a southernmost part, which are windowless panels that protect the main building from the sun, and a northernmost part, which has no protection from the sun. Another playground is located in the southernmost SW orientation.

Photographs of the school: Annex 2. Photographs of the schools Types

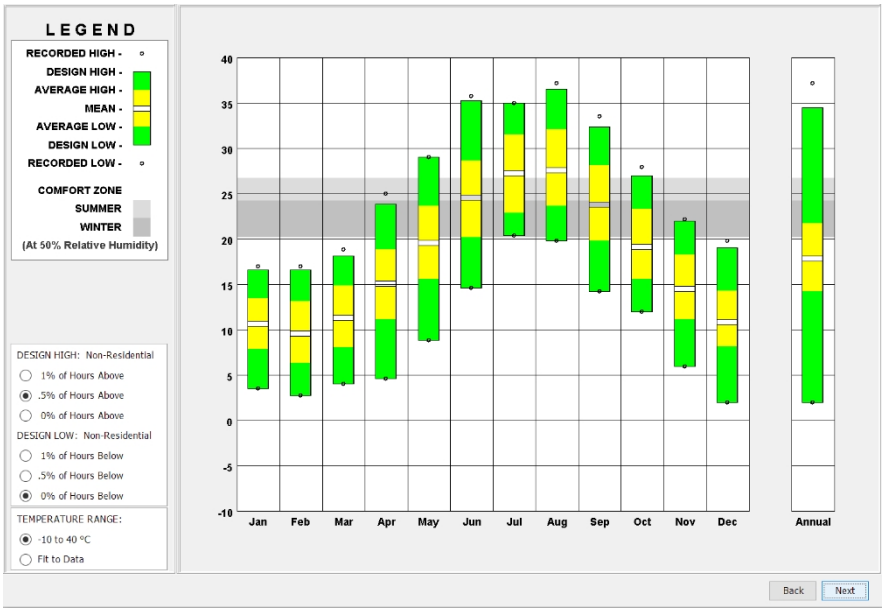
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area: 3,192 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate between floors): 984 m^2 (768 + 216)
- Gross floor area: 2,208 m^2 (3,192 - 984 (floors0))
- Green area (according to "measure distance" from Google maps): 95 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 2.113 m^2

15.1 Climate analysis

Climatic data (Nearest station, Athens)



Average, maximum and minimum temperatures (months)

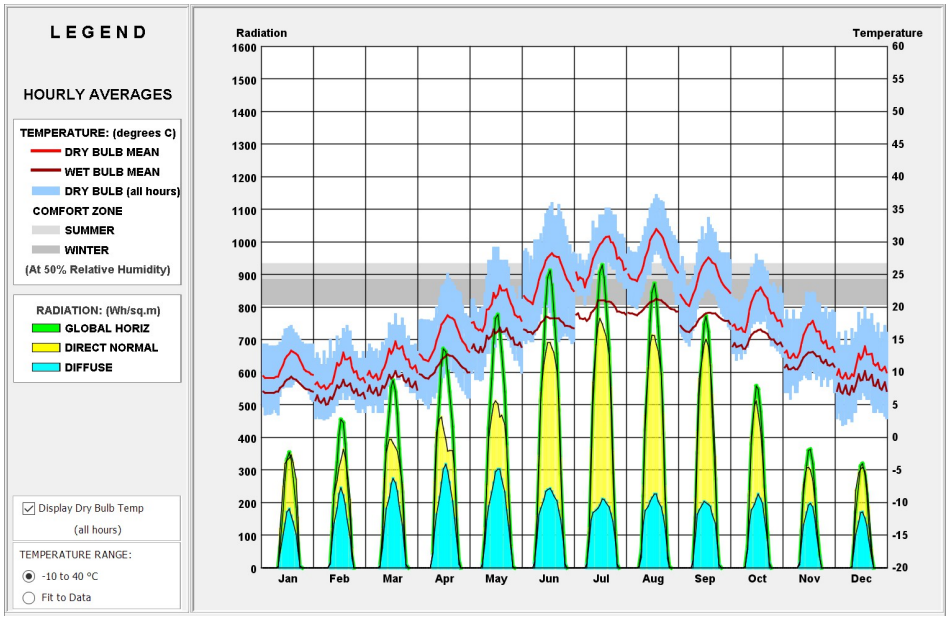
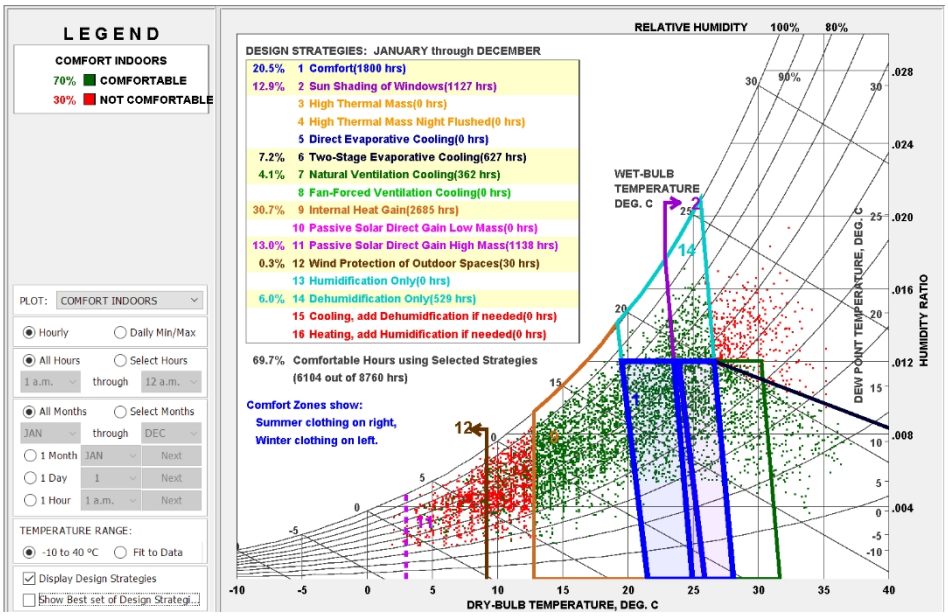


Illustration 45. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive enhancement measures

Percentage of hours of comfort in the climate: 20.5%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (12.9%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (not

applicable) 5.6- Evaporative cooling systems (7.2%)

7- Night ventilation (4.1%)

9- Management of internal loads: lighting, equipment, people, etc. (30.7%)

10,11- Solar collection (13.0%)

12- protection against external winds (0.3%)

Percentage of hours of comfort with the application of bioclimatic strategies: 70%.

Need for Climate System (percentage of hours): 24% HEAT; 6% COOL.

15.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the schoolΓυμνάσιο Περιστερίου (13th High School of Peristeri): mBiGCUVE green roof, mBiGCUVE-SUS green roof, mBiGFAVE green façade and mBiG-SUVE permeable pavement. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at 13th High School of Peristeri.

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 537 m^2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (13%).

Green cover - type mBiGCUVE-SUS

Installation of an mBiGCUVE-SUS green roof on the main building, covering an area of **surface area of 447 ^{m2}**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum album, Sedum album, Sedum acre, Sedum lydium, Sedum sexangulare, Sedum hispanicum, Sedum spurium, Sedum floriferum, Sedum kamschaticum, Sedum hybridum, Sedum reflexu.*

Impact: this type of solution mainly improves solar gain (13%).

Green facade - type mBiGFAVE

Installation of the mBiGFAVE system on the south façade, protecting the openings of one of the main and most unprotected façades. A length of 7 m of façade is covered and a **plant shading** area **of 42 ^{m2}**.

Vegetation type: *Festuca rubra, Agrostis stonolonifera, Sagina subulata or Cymbalaria muralis*.

Impact: this type of solution mainly favors the shading of openings in summer (12.9%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 100 ^{m2}**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (13%).

Ventilation protocol

It is proposed to install two windows on opposite facades, preferably north/south or in the direction of the prevailing winds at night during the summer season. Standard windows with motorized tilt-and-turn sashes and two additional sliding sashes are included.

Installation of motorized casement windows: **6 windows on the NW façade** and 6 **windows on the NE façade** to create cross ventilation.

The implementation of a night ventilation protocol in the school's classrooms favors cooling in an efficient way to improve the thermal environment in the buildings and reduce indoor temperatures. During the night, the accumulated heat is conducted to the outside through the open windows.

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 21. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
mBiGCUVE	175,79 €	984	172.980,51 €
FAVE	105,51 €	42	4.431,41 €
mBiG_SUVE	54,29 €	100	5.429,32 €
Windows	2.862,04 €	12	34.344,42 €
Total			**217.185,66 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 29% and the permeable area by 34%.

Table 22. Green and permeable surface before and after NBS installation.

	Surface area (m)^2	Percentage	Increase (%)
Total area	3192	-	-
Initial green area	95	3%	-
Final green area	1026	32%	**29%**
Initial permeable surface	95	3%	-
Final permeable surface	1179	37%	**34%**

16.5Ο ΓΥΜΝΆΣΙΟ ΕΥΌΣΜΟΥ (5TH HIGH SCHOOL OF PERISTERI) (EVOSMOS, GREECE).

Location: Pithagora 6, Evosmos 562 24 (municipality: Evosmos, periphery: Central Macedonia)

Coordinates: 40.66216851519196, 22.90105530410279 (link Google maps)

Height: 2 floors (including first floor)

Year of construction no data Orientation:

NO: facade more protected from solar radiation thanks to a line of trees attached to the building.

NE: façade with a lot of tree protection, but with some unprotected sections, where one of the accesses to the building is located.

SE: facade totally exposed to solar radiation. One part directly overlooks the street and the other part overlooks the school courtyard.

SO: most of this façade is exposed to solar radiation, except for the westernmost part of the building. All of it faces the school courtyard.

Photographs of the school: Annex 2. Photographs of the schools Types

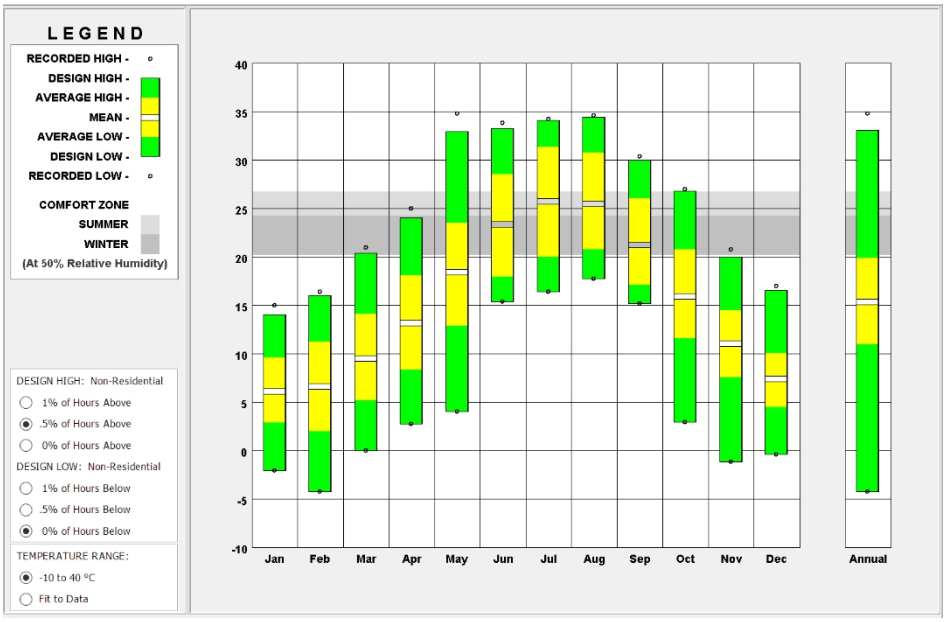
of roofs: flat roofs

Areas in m^2 according to type of surface:

- Plot area: 2,590 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 1,050 m^2 (731 + 319)
- Gross floor area: 1,540 m^2 (2,590 - 1,050 (floors0))
- Green surface (according to Google maps "measure distance"): 256 m^2
- Surface with pavement (according to "measure distance" of Goolge maps): 1.284 m^2

16.1 Climate analysis

Climatic data (Nearest station, Thessaloniki)



Average, maximum and minimum temperatures (months)

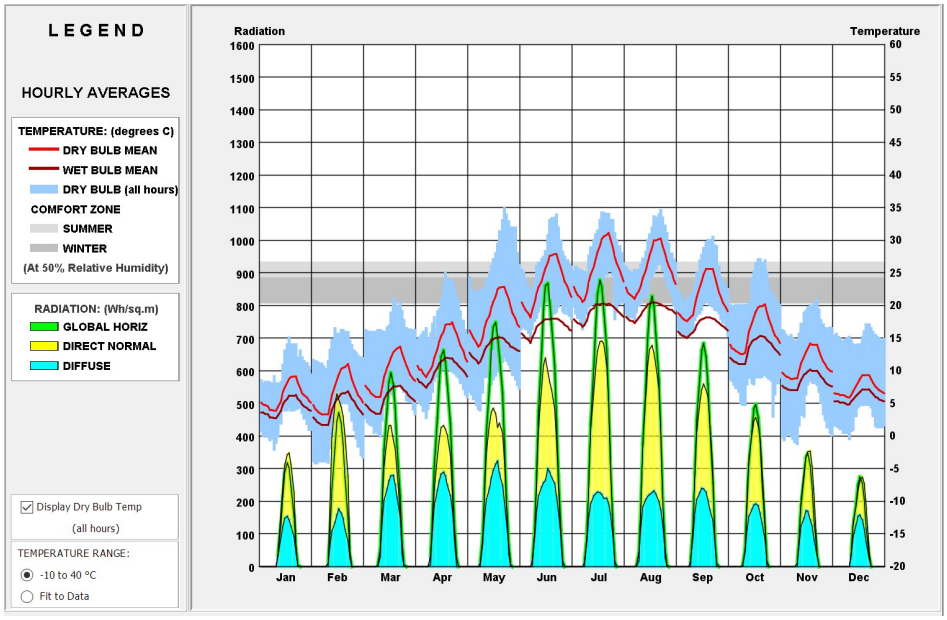
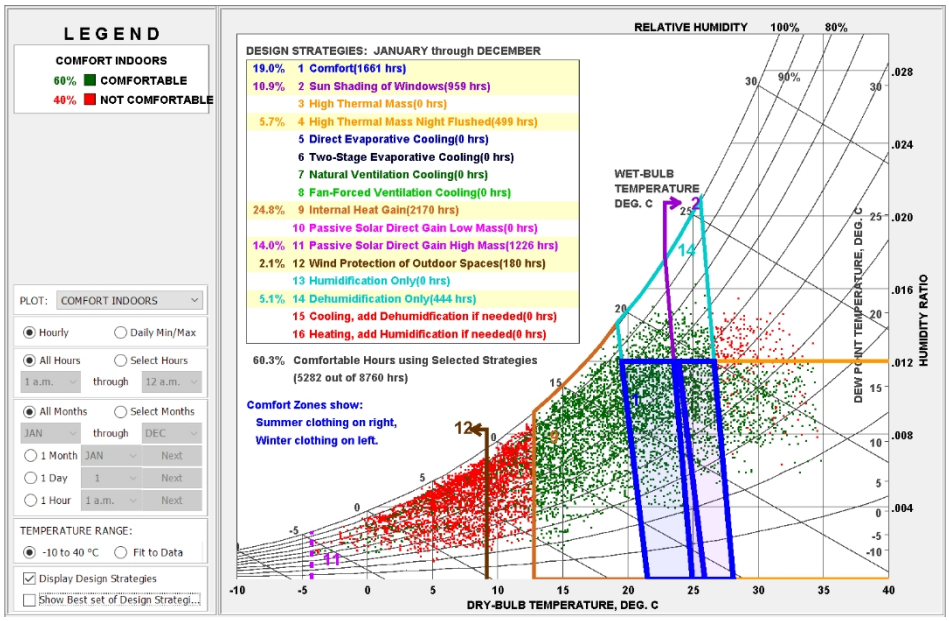


Illustration 49. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of hours of comfort in the climate: 19.0%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (10.9%)

3- Use of thermal inertia (not applicable)

4- Thermal discharge of the building mass (5.7%)

5.6- Evaporative cooling systems (not applicable) 7-

Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (24.8%)

10,11- Solar collection (14.0%)

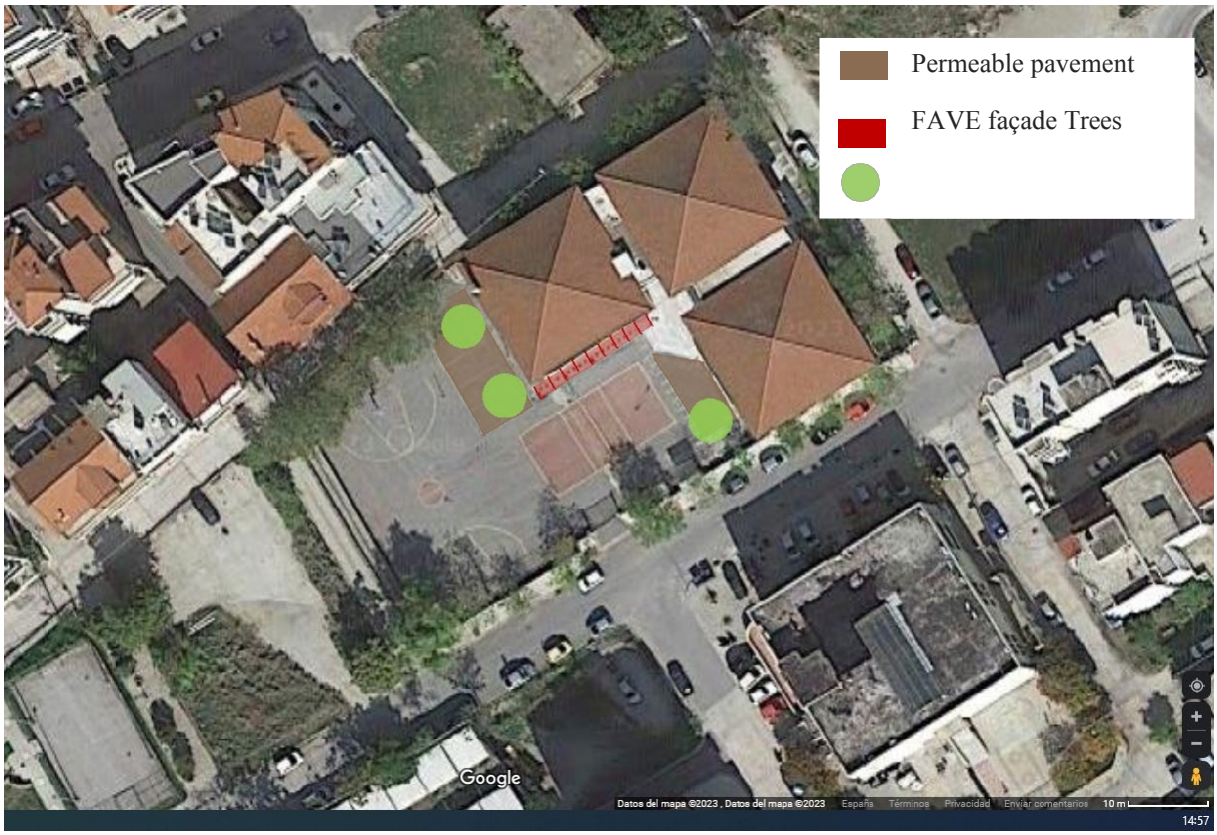
12- protection against external winds (2.1%)

Percentage of comfort hours with the application of bioclimatic strategies: 60%.

Need for Climate System (percentage of hours): 36.5% HEAT; 3.2% COOL.

16.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the school Γυμνάσιο Ευυόσμου (5th High School of Peristeri): trees, FAVE type green façade and mBiG-SUVE permeable pavement arranged along the east courtyard to create shaded spaces. In the NEXT illustration the distribution of the solutions in the school is shown.



General plan of NBS implementation at 5th High School of Peristeri.

Trees

Three trees will be planted in the east courtyard, with more sunlight, to create a shaded area, with a surface area of 39 m².

Type of vegetation: *Quercus ilex*

Impact: this type of solution mainly favors solar gain (14%).

Green façade - FAVE type

Installation of a FAVE system in the main building, covering an **area of 131 m2**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors the thermal discharge of the building mass (5.7%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 171 ^{m2}**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (14%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 23. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
FAVE	105,51 €	131	13.821,77 €
mBiG_SUVE	54,29 €	171	9.284,14 €
Trees	400,00 €	3	1.200,00 €
Total			**24.305,90 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 7% and the permeable area by 7%.

Table 24. Green and permeable surface before and after NBS installation.

	Surface area (m)^2	Percentage	Increase (%)
Total surface area	2590	-	-
Initial green area	256	10%	-
Final green area	426,25	16%	**7%**
Initial permeable surface	256	10%	-
Final permeable surface	426,5	16%	**7%**

17. VOLKSSCHULE MAXGLAN (ELEMENTARY SCHOOL MAXGLAN) (SALZBURG, AUSTRIA)

Climatic risk zone 2: Mountainous areas

Location: Siezenheimer Str. 14A (municipality: Salzburg, State: Salzburg)

Coordinates: 47.80390590901642, 13.01565420681302 (Google maps link) Height:

3 floors in the tallest building (including first floor)

Year of construction without data

Orientation:

N: the 2-story building and the 3-story building have exposed north facades, although the ground floor of the 3-story building is attached to a first floor solarium.

E: only the E side, which is more to the N, can be accessed with Google. The E façade is more exposed by the ends of the buildings, but somewhat protected by nearby houses. On the E façade there is a school playground area with picnic tables.

S: Google does not allow taking pictures of the south façade, although it is small and is protected by a building next to it. The greatest radiation on that façade is from the SE orientation.

O: is the main facade of the buildings, which is composed of a two-storey building, a ground floor solarium and a 3-storey building. It is totally exposed to radiation in autumn-winter, but in front of it there is the schoolyard with large deciduous trees that will protect the building in summer. There is a flower shop at the entrance to the school that does not belong to the school.

Photographs of the school: Annex 2. Photographs of the schools Types

of roofs: pitched roofs

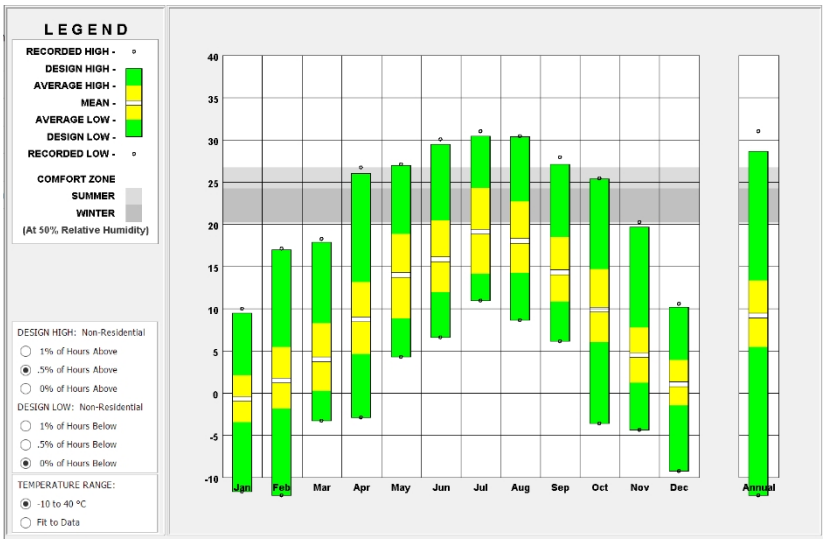
Areas in m^2 according to type of surface:

- Plot area: 2,600 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 767 m^2 (172 + 135 + 333 + 127)
- Gross floor area: 1,833 m^2 (2,600 - 767 (floors0))

- Green surface (according to "measure distance" of Google maps): 1,464 m^2 (I have considered green surface everything that is not pavement as I see in the aerial view of the school and approaching the type of soil of the main courtyard).
- Surface area with pavement (according to "measure distance" of Goolge maps): 369 m^2

17.1 Climate analysis

Climatic data (nearest station, Salzburg)



Average, maximum and minimum temperatures (months)

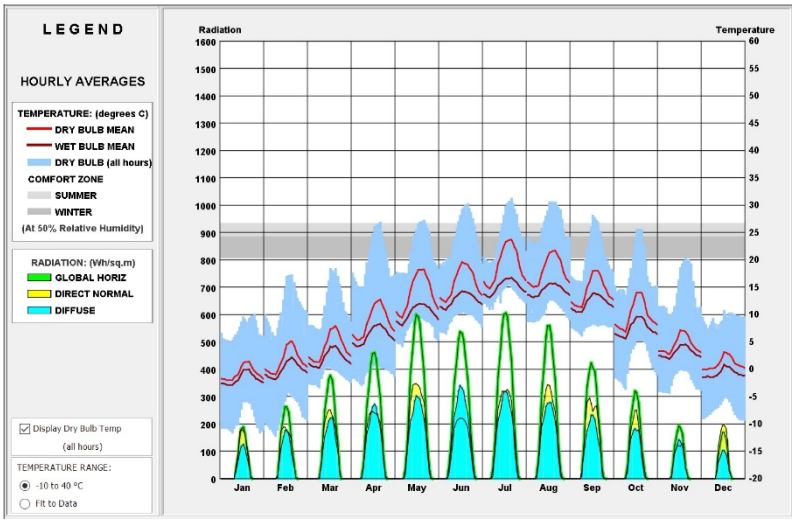
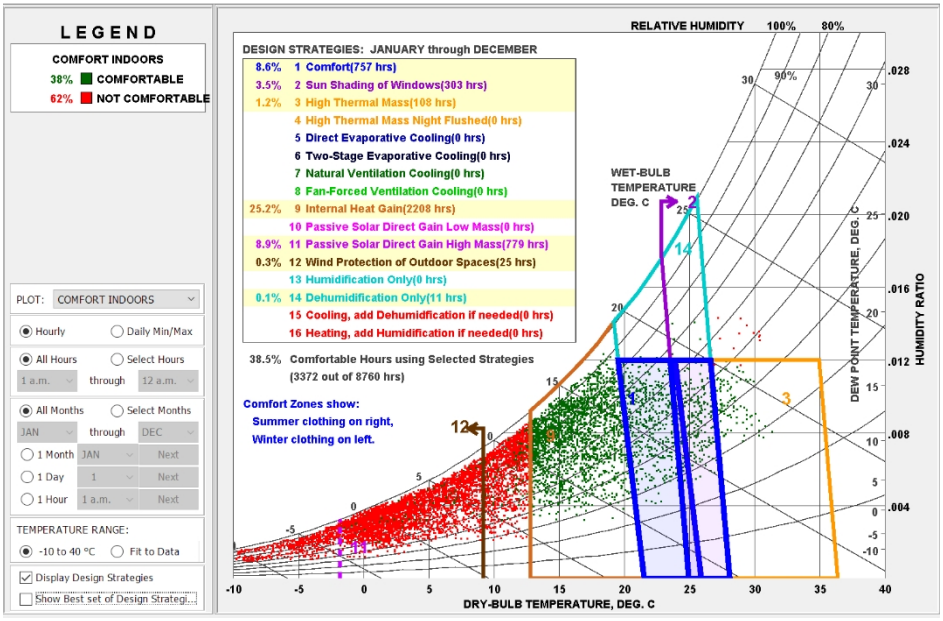


Illustration 53. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of optimal passive improvement measures.

Percentage of comfort hours in the climate: 8.6%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Shading of hollows in summer (3.5%)

3- Exploitation of thermal inertia (1.2%)

4- Thermal discharge of building mass (not

applicable) 5.6- Evaporative cooling systems (not

applicable) 7- Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (25.2%)

10,11- Solar collection (8.9%)

12- protection against external winds (0.3%)

Percentage of hours of comfort with the application of bioclimatic strategies: 38%

Need for Climate System (percentage of hours): 62% HEAT;

17.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Volksschule Maxglan (Elementary school Maxglan): BiGSECAR green roof, a FAVE system and a pond. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Elementary school Maxglan.

Green cover - type mBiGSECAR

Installation of an mBiGSECAR green roof on the main building, covering an area of **surface area of 454 m2**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (8.9%).

Green façade - FAVE type

Installation of a FAVE system in the main building, covering an **area of 217 m2**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors protection against external winds (0.3%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 20 m2**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (8.9%).

Pond - type mBiGPond

Installation of a permeable pavement, covering an **area of 20 m2**.

Vegetation type: *Iris pseudacorus*, *Nymphaea alba*, *Alisma lanceolatum*, *Potamogeton nodosus*, *Parthenocissus tricuspidata*.

Impact: this type of solution mainly favors solar gain (8.9%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 25. Budget estimate for proposed interventions

Intervention	***Cost (€/m2)***	***Surface area (m2)***	***Estimated budget***
FAVE	105,51 €	217	22.895,60 €
mBiGSECAR	200,17 €	454	90.877,80 €
mBiG_SUVE	54,29 €	20	1.085,86 €
mBiGPond	367,55 €	20	7.351,09 €
Total			**122.210,35 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 26% and the permeable area by 17%.

Table 26. Green and permeable surface before and after NBS installation.

	Surface area (m)^2	Percentage	Increase (%)
Total area	2600	-	-
Initial green area	1462	56%	-
Final green area	2133,15	82%	**26%**
Initial permeable surface	1462	56%	-
Final permeable surface	1915,65	74%	**17%**

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18. OPENBARE BASISSCHOOL HET VOGELNEST (PUBLIC ELEMENTARY SCHOOL HET VOGELNEST) (AMSTERDAM, NETHERLANDS)

Climate risk zone 3: Coastal areas, deltas and floodplains Location:

Mussenstraat 26 (municipality: Amsterdam, province: Noord-Holland) Coordinates:

52.386823845703134, 4.9170725230568255 (Google maps link) Height: 2 floors in

the tallest building (including first floor)

Year of construction without data

Orientation:

NO: it is the main façade of the school without protection against solar radiation. It faces a pedestrian street and bike path, as well as a square.

NE: very little extensive facade facing a wooded area of the school.

SE: rear façade of the school that overlooks an area with lush vegetation so it has plenty of shade.

SO: small façade of the school without protection from the sun and facing a street with a house in front whose shadow does not affect this façade.

Photographs of the school: Annex 2. Photographs of the schools Types

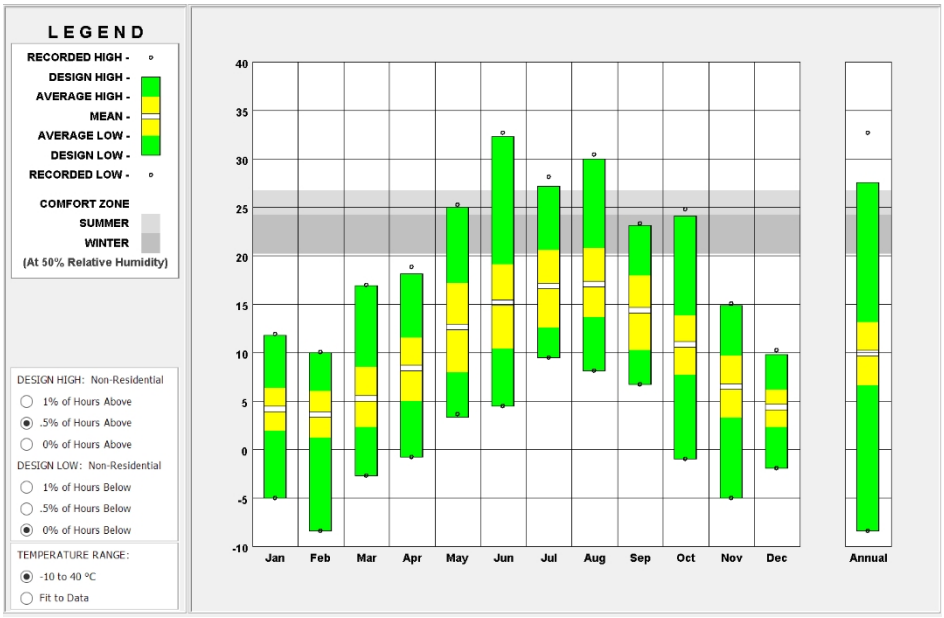
of roofs: pitched roofs

Areas in m^2 according to type of surface:

- Plot area: 1.621 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate between floors): 676 m^2 (623 + 53)
- Gross floor area: 945 m^2 (1,621 - 676 (floors0))
- Green area (according to Google maps "measure distance"): 610 m^2 (in this case, it is not easy to distinguish between green and paved areas).
- Surface with pavement (according to "measure distance" of Goolge maps): 335 m^2

18.1 Climate analysis

Climatic data (nearest station, Amsterdam)



Average, maximum and minimum temperatures (months)

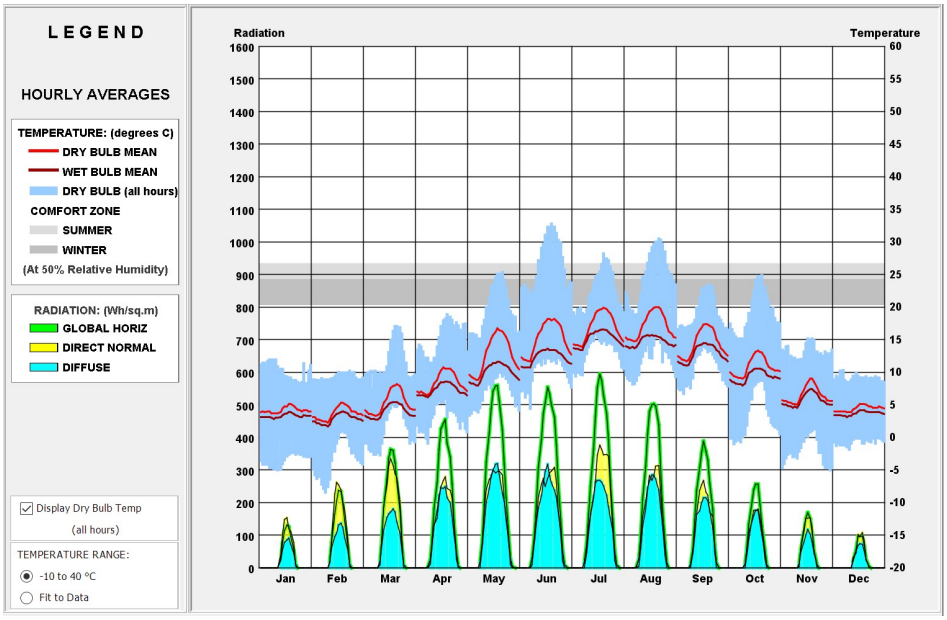
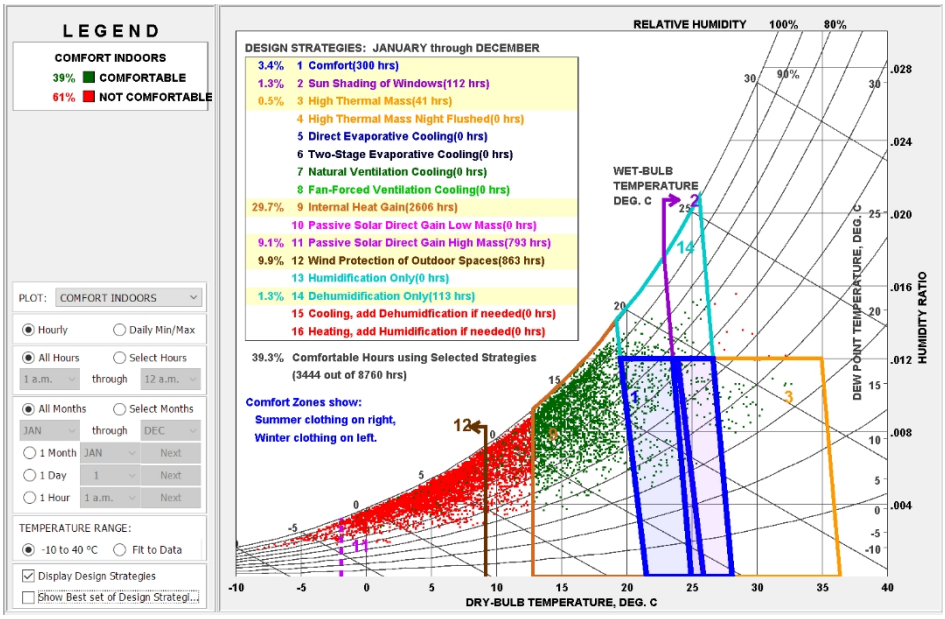


Illustration 57. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures

Percentage of hours of climate comfort: 3.4%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (1.3%)

3- Use of thermal inertia (0.5%)

4- Thermal discharge of building mass (not

applicable) 5.6- Evaporative cooling systems (not

applicable) 7- Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (29.7%)

10,11- Solar collection (9.1%)

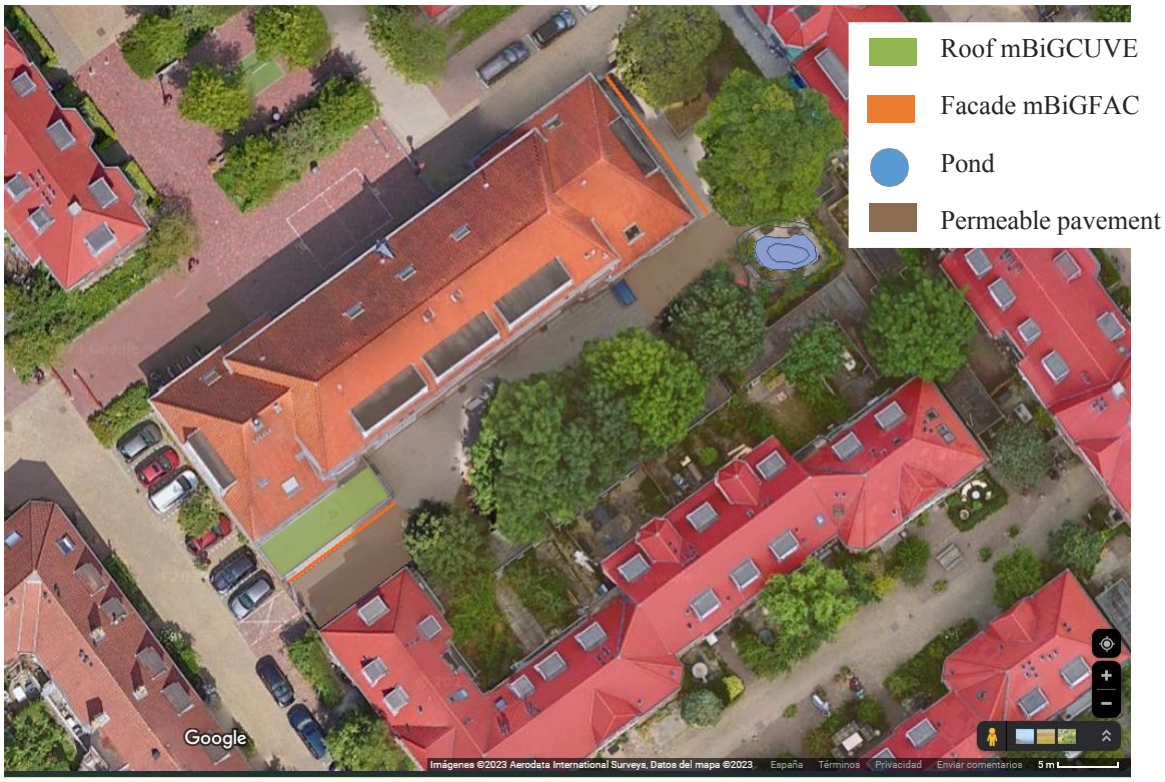
12- protection against external winds (9.9%)

Percentage of comfort hours with the application of bioclimatic strategies: 39%.

Need for Climate System (percentage of hours): 61% HEAT.

18.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Openbare Basisschool Het Vogelnest (Public Elementary School Het Vogelnest): mBiGCUVE green roof, two mBiGFAC green facades, a mBiGPond pond and a mBiG-SUVE permeable pavement arranged around the east courtyard to create shaded spaces. Figure 8 shows the distribution of the solutions in the school.



General plan of NBS implementation at Public Elementary School Het Vogelnest.

Green cover - type mBiGCUVE

Installation of an mBiGCUVE green roof on the main building, covering an **area of 37 m².**

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (9.1%).

Green façade - type mBiGFAC

Installation of two mBiGFAC green facades on the main building, covering a total **area of 77 m².**

Vegetation type: *Parthenocissus tricuspidata "Veitchii".*

Impact: this type of solution mainly favors protection against external winds (9.9%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 102 m2**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (9.1%).

Pond - type mBiGPond

Installation of a permeable pavement, covering an **area of 20 m2**.

Vegetation type: *Iris pseudacorus*, *Nymphaea alba*, *Alisma lanceolatum*, *Potamogeton nodosus*, *Parthenocissus tricuspidata*.

Impact: this type of solution mainly favors solar gain (9.1%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 27. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
mBiGCUVE	175,79 €	37	6.504,35 €
mBiGFAC	88,59 €	77	6.821,59 €
mBiG_SUVE	54,29 €	102	5.537,91 €
mBiGPond	367,55 €	20	7.351,09 €
Total			**26.214,94 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 7% and the permeable area by 9%.

Table 28. Green and permeable surface before and after NBS installation.

	Surface area (m)^2	Percentage	Increase (%)
Total surface area	1621	-	-
Initial green area	610	38%	-
Final green area	723,3	45%	**7%**
Initial permeable surface	610	38%	-
Final permeable surface	748,4	46%	**9%**

19. MALMIN PERUSKOULU (MALMIN ELEMENTARY SCHOOL) (HELSINKI, FINLAND)

Climate risk zone 4: Far North Europe and the Arctic Location:

Talvelantie 1 (municipality: Helsinki, province: Southern Finland) Coordinates:

60.25531297435535, 25.000724477563466 (Google maps link) Height: 2 floors

(including first floor)

Year of construction no data

Orientation: In general, the facades of this school have no protection from solar radiation, except for the SE facing facade which has a row of trees attached to that part of the building. The exterior of the NW and NE facing part of the building is landscaped, while the southern half of the campus is paved, where the playground is located. In addition, it has a building at the south end of the enclosure that appears to contain restrooms, locker rooms or something similar.

Photographs of the school: Annex 2. Photographs of the schools Types

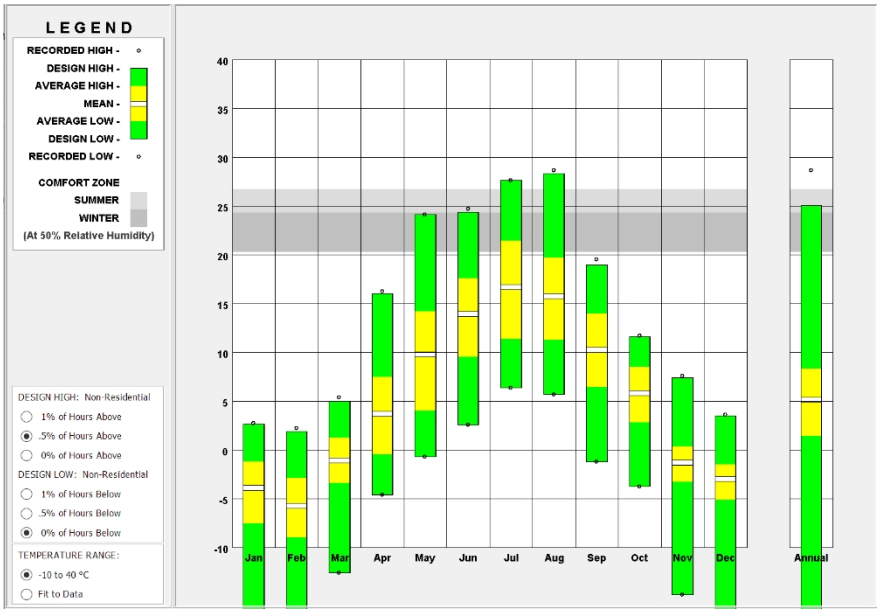
of roofs: slightly inclined.

Areas in m^2 according to type of surface:

- Plot area: 11,293 m^2 (according to "measure distance" of Google maps)
- Built-up area (measurement of building area according to Google maps "measure distances", it is not possible to differentiate built-up meters between floors): 3,190 m^2 (1,045 + 1,244 + 709 + 192)
- Gross floor area: 8,103 m^2 (11,293 - 3,190 (floors0))
- Green area (according to Google maps "measure distance"): 3,178 m^2 (in this case, it is not easy to distinguish between green and paved areas).
- Surface with pavement (according to "measure distance" of Goolge maps): 4.925 m^2

19.1 Climate analysis

Climatic data (Nearest station, Helsinki)



Average, maximum and minimum temperatures (months).

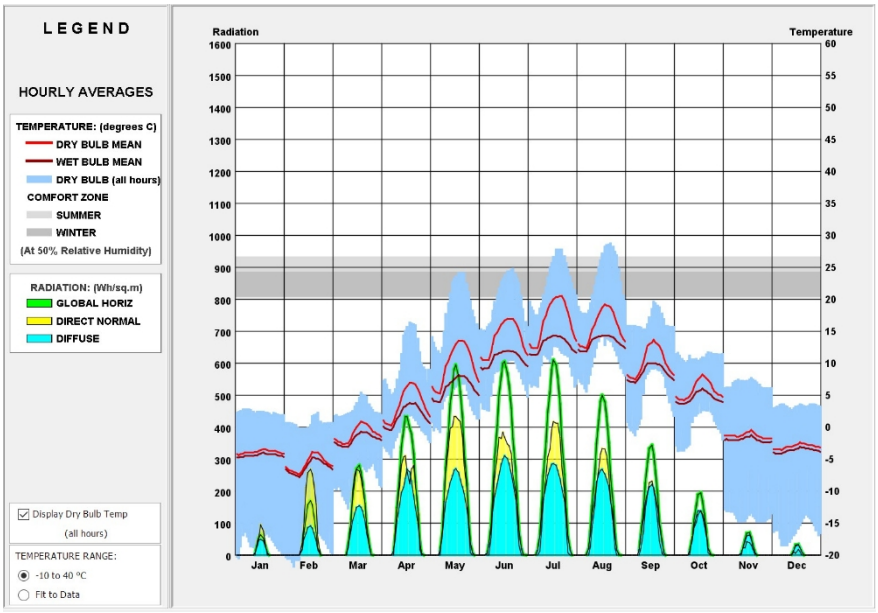
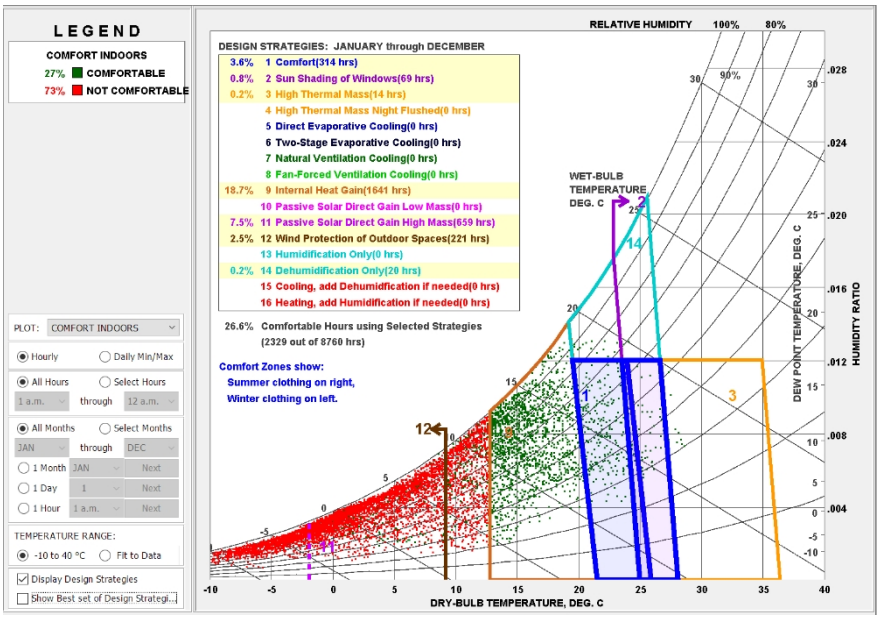


Illustration 61. Temperature and radiation (months with hourly range)

Adapted bioclimatic strategies



Psychrometric diagram with incorporation of the optimal passive improvement measures

Percentage of hours of climate comfort: 3.6%.

Bioclimatic measures possible with NBS according to diagram (percentage of hours resulting in comfort after its application):

2- Summer hole shading (0.8%)

3- Use of thermal inertia (0.2%)

4- Thermal discharge of building mass (not

applicable) 5.6- Evaporative cooling systems (not

applicable) 7- Night ventilation (not applicable)

9- Management of internal loads: lighting, equipment, people, etc. (18.7%)

10,11- Solar collection (7.5%)

12- protection against external winds (2.5%)

Percentage of comfort hours with the application of bioclimatic strategies: 27%.

Need for Climate System (percentage of hours): 73% HEAT.

19.2. NBS Project

The following NBS are proposed to improve the thermal comfort of the Malmin peruskoulu school (Malmin Elementary School): mBiGSECAR green roof, two FAVE systems and mBiGSUVE permeable pavement. The following illustration shows the distribution of the solutions in the school.



General plan of NBS implementation at Malmin Elementary School.

Green cover - type mBiGSECAR

Installation of an mBiGSECAR green roof on the main building, covering an area of **surface of 1518 ^{m2}**.

Type of vegetation: *Sedum* genus, within which we highlight the following species: *Sedum acre, Sedum álbum, Sedum floriferum, Sedum reflexum, Sedum sexangulare, Sedum spurium.*

Impact: this type of solution mainly favors solar gain (7.5%).

Green façade - FAVE type

Installation of two FAVE systems on the N and E façade, covering an **area of 143 ^{m2}**.

Type of vegetation: *Virgin Vine Parthenocissus Quinquefolia, Parthenocissus Tricuspidata Lonicera, Clematis or Clematis, Aquebia or Akebia, Trachelospermun Jasminoides.*

Impact: this type of solution mainly favors protection against external winds (2.5%).

Permeable pavement - type mBiG_SUVE

Installation of a permeable pavement, covering an **area of 245 ^{m2}**.

Vegetation type: *Lolium perenne, 10% Poa pratensis, 10% Agrostis spp, 70% Festuca spp.*

Impact: this type of solution mainly favors solar gain (7.5%).

Budget estimate

With the proposed interventions and using as a reference the costs associated with each NBS listed in Annex 1, this approximate budget for the interventions has been prepared. It should be borne in mind that this is an estimate and that the budget should be adjusted once the complete project has been sized.

Table 29. Budget estimate for proposed interventions

Intervention	***Cost (€/m²)***	***Surface area (m²)***	***Estimated budget***
FAVE	105,51 €	143	15.087,88 €
mBiGSECAR	200,17 €	1518	303.860,12 €
mBiG_SUVE	54,29 €	245	13.301,83 €
Total			**332.249,83 €**

Impact

By implementing the proposed BSS, a number of environmental, social and user welfare benefits are provided. The following indicators are positively impacted: building interior temperature, building envelope temperature, building exterior environmental conditions, energy savings, water consumption, rainwater management, plant and animal biodiversity, noise reduction levels from the exterior, energy efficiency measures, increased green space, citizens' perception of urban nature.

Specifically, the following table shows the impact related to the green area indicator. The green area increases by 15% and the permeable area by 16%.

Table 30. Green and permeable surface before and after installation of NBS

	Surface area (m)^2	Percentage	Increase (%)
Total surface area	11293	-	-
Initial green area	3178	28%	-
Final green area	4839,1	43%	**15%**
Initial permeable surface	3178	28%	-
Final permeable surface	4941,3	44%	**16%**

20. SUMMARY AND CONCLUSIONS

Bioclimatic strategies are proposed in order to adapt environmental parameters to comfort ranges. We have estimated those that can be applied through the use of NBS contemplated in the LIFE-mBiG project.

The following table shows a summary of those recommended for the different types of climates where schools are located.

Table 31. Summary table of recommended passive strategies for locations.

School zone	Weather. Temperature (ºC)		Comfort hours (%)	Passive strategies. Only those possible with NBS. Percentage improvement in comfort hours (%)									Hours required Clima System (%)	
	Range		Outdoor Climate	2	3	4	5 6	7	9	10 11	12	Total Appl. Appl. Passiv.	Heating (%)	Refrigeration (%)
	Annual	Months Heat May-Oct		Som-brea-do	Inerc. Term	Desc. Inerc. Term.	Enfr Evap	Vent Noct	Int.	Cap. sol.	Prot. wind			
Climate risk zone 1: Southern Europe and Mediterranean basin														
1. Rota, Cadiz	7-33	15-33	28,6	12,6	-	9,1	-	4,6	40,5	21,4	-	85	15	-
2. Albacete	2-33	10-33	13,9	9,2	-	7,2	-	-	29,5	23,4	-	62	38	-
3. Ponferrada	0-28	6-28	10,0	4,4	1,8	-	-	-	26,2	22,0	-	52	48	-
4. Abrantes	6-27	12-27	13,5	7,0	-	2,2	-	-	43,3	21,4	-	72	27,1	1,3
5. Coimbra	6-27	12-27	13,5	7,0	-	2,2	-	-	43,3	21,4	-	72	27,1	1,3
6. Toulouse	4-27	13-27	12,4	8,9	-	3,4	-	-	35,0	15,6	-	65	32,6	2,4
7. Bari	6-28	14-28	16,9	8,1	-	2,2	2,4	-	32,8	12,7	1,1	63	32,7	4,1
8. Grosseto	3-30	12-30	12,2	8,5	-	4,2	-	-	31,0	10,8	1,1	57	40,2	2,9
9. Pula	3-28	13-28	14,6	6,7	-	1,7	-	-	29,1	7,7	2,9	54	42,3	3,3
10. Dalmatia	3-28	12-28	10,4	7,4	-	-	1,2	-	29,7	11,3	0,4	54	41,9	3,9
11. Peristeri	6-33	15-33	20,5	12,9	-	-	7,2	4,1	30,7	13,0	0,3	70	24	6
12. Evosmos	3-32	13-32	19,0	10,9	-	5,7	-	-	24,8	14,0	2,1	60	36,5	3,2
Climate risk zone 2: Mountain areas														
13. Salzburg	-4-24	9-24	8,6	3,5	1,2	-	-	-	25,2	8,9	0,3	38	62	-
Climate risk zone 3: Coastal zones, deltas and floodplains														
14. Amsterdam	2-22	7-22	3,4	1,3	0,5	-	-	-	29,7	9,1	9,9	39	61	-
Climate Risk Zone 4: Far North Europe and the Arctic														
15. Helsinki	-8-22	4-22	3,6	0,8	0,2	-	-	-	18,7	7,5	2,5	27	73	-

For each school/location, the following is indicated:

- Outdoor temperature ranges. Annual (maximum and minimum) and warm months (May-October).
- The percentage of hours of the outdoor climate that is in comfort.
- For each passive measure, the percentage of hours it achieves comfort.

- The total percentage of hours that are incorporated into comfort after the application of all passive measures.
- The remaining percentage of hours in which the use of active systems (heating or cooling) is necessary to achieve 100% comfort hours.

The averages contemplated as passive strategies are:

2- Gap shading.

During hot summer months, the use of eaves, overhangs or any element that blocks unwanted direct sunlight incident on glazed areas will reduce cooling demand. These elements should be located above the glazed area (facing south) and their projection should extend approximately 1/3 of the height of the opening (at latitudes of 36° to 40°).

In this case, any of the devices developed in the project, such as FAVE or similar, could be used.

3- Exploitation of thermal inertia.

The idea is to use the thermal mass of the building as an accumulator of heat from external sources such as the sun. To do this, solar radiation must reach the interior walls and floors. This mechanism is capable of acting as a thermal regulator (day and night), damping the oscillations and reducing their amplitude.

4- Thermal discharge of the building mass.

The energy stored in the thermal mass of the building must be dissipated at night by means of cooling systems such as night ventilation.

5,6- Evaporative cooling systems.

The transfer of energy in the form of latent heat helps to reduce the indoor air temperature. Indoor plants with moist substrates could be used.

7- Night ventilation.

Low nighttime temperatures are used to cool the building and prevent accumulation and overheating in hot weather.

9- Management of internal loads, lighting, equipment, people.

Lighting equipment, computer equipment or people themselves are heat generators. The use of these sources is important in cold climates. In hot weather, their use should be avoided or reduced.

10,11- Solar gain (measured for cold season).

Increase the surface area of the openings and facilitate the entry of radiation to take advantage of the sun as a source of energy. Measure for the cold season.

12- Protection against external winds (measure for cold season).

Convective transfer coefficients are reduced and the thermal resistance of the envelope is improved.

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22. ANNEX

Annex 1. Calculation bases for infrastructure cost estimates

This annex presents the approximate implementation costs for each of the Nature-based Solutions that have been proposed in the different schools throughout this document.

These costs have been established based on the actual costs incurred in the implementations carried out in the project in the three demonstration schools: CEIP Gabriela Mistral in Solana de los Barros (Badajoz, SPAIN), EB1 Horta das Figueiras in Évora (Central Alentejo, PORTUGAL) and EB1 do Falcão in Porto (PORTUGAL).

To see the details of each of the solutions, please refer to the deliverables corresponding to the design of the SbNs proposed by the project and the implementation projects of the three pilot schools.

Facade solutions

mBiG FAVE Solution

Information gathered in the implementation project of the pilot construction project of the CEIP Gabriela Mistral school.

The cost presented includes the previous works for the adaptation of the façade and the realization of the foundations and supports for fixing the structure. Although in each case these previous works will have to be adjusted to the state of the facade and the circumstances of the building environment, it is assumed that the amounts required in the case of CEIP Gabriela Mistral (€ 50,876.78 base budget for 694 m^2 of implemented solution) will be similar to those of most of the buildings that consider similar solutions.

In this particular case a small piece was also added on the façade of a different prototype, mBiGToldo, which for this study has not been considered because this solution would only be recommended in very specific cases.

The cost of this solution used in this document is **€73.$^{28/m2}$** base and **$^{€105}$.51/m2** once the cost of general costs, industrial profit and VAT (21% in the case of Spain) are included.

mBiGFAC Solution

Information collected in the execution project of the construction project of the pilot of the EB1 do Falcão school. It is a façade covering with tensors and climbers.

The cost presented includes the previous works for the adaptation of the façade and the ground for the anchorages. It is assumed that the quantities required in the case of the EB1 do Falcão school are

(€8,859.21 base budget for 100m^2 of covered façade with this solution) will be similar to those of most buildings where similar solutions are considered.

The cost of this solution used in this document is **€88.$^{59/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

Roofing solutions

mBiG CUVE solution

Information gathered in the implementation project of the pilot construction project of the CEIP Gabriela Mistral school.

The cost presented includes the previous works for the adaptation of the roof and access and protection systems on the roofs for their use. Although in each case these previous works will have to be adjusted to the state of the roofs and the circumstances of the building, whether the roofs can be walkable or not, it is assumed that the amounts required in the case of CEIP Gabriela Mistral (€ 52,497.45 base budget for 430 m^2 of roofs made) will be similar to those of most of the buildings that consider similar solutions. In this case, the roofs were flat and walkable. Half of the surface area was also adapted for use for educational purposes so that children could access them.

The cost of this solution used in this document is **€122.$^{09/m2}$** base and **$^{€175}$.79/m2** once the cost of general costs, industrial profit and VAT (in the case of Spain 21%) are included.

mBiG Tray Solution

Information collected in the implementation project of the pilot construction project of the EB1 Horta das Figueiras school.

The cost presented includes the work of fixing the trays to the roof. Although in each case these previous works will have to be adjusted to the state of the roofs and the circumstances of the building, whether the roofs can be walkable or not, it is assumed that the quantities required in the case of EB1 Horta das Figueiras will be similar to those of most of the buildings where similar solutions are proposed in similar roofs. In this case the roofs were flat, but not walkable.

The cost of this solution used in this document is **€132.$^{47/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

mBiGUL Solution

Information gathered in the project for the implementation of the pilot construction project of the EB1 do Falcão school.

The cost presented includes the previous works for the adaptation of the roof and access and protection systems on the roofs for their use. Although in each case these previous works will have to be adjusted to the state of the roofs and the circumstances of the building, whether the roofs can be passable or not, it is assumed that the amounts required in the case of the EB1 do Falcão school (€53,464.92 base budget for 410 m^2 of roofs completed) will be similar to those of most buildings where similar solutions are considered. In this case the roofs were flat and walkable.

The cost of this solution used in this document is **€130.$^{40/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

mBiGSECAR Solution

Information gathered in the implementation project of the pilot construction project of the EB1 do Falcão school.

The presented cost includes the previous works of adaptation of the roof and access and protection systems on the roofs for its use. However, these amounts are important because it is a solution adapted to be placed on pitched roofs without major interventions. It is assumed that the amounts required in the case of the EB1 do Falcão school (€10,008.57 base budget for 50m^2 of roofs) will be similar to those of most of the buildings where similar solutions are considered.

The cost of this solution used in this document is **€200.$^{17/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

mBiGBioSol Solution

Information gathered in the implementation project of the pilot construction project of the EB1 do Falcão school.

The presented cost includes the previous works of adaptation of the roof, the access and protection systems on the roofs for its use and the installation of the photovoltaic panels. However, these amounts are important because it is a solution adapted to be placed on sloping roofs without major interventions. It is assumed that the amounts required in the case of the EB1 do Falcão school (€ 69,421.39 base budget for 230m^2 of roofing) will be sufficient for the installation of the photovoltaic panels.[2]

The roofs of the buildings will be similar to those of most of the buildings where similar solutions are considered.

The cost of this solution used in this document is **€301.$^{83/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

Other solutions

mBiG PEVE solution

Information gathered in the execution project of the construction project of the pilot project of the CEIP Gabriela Mistral school. It is a pergola with vegetation for outdoor seasonal shading.

The cost presented includes the previous works for the realization of the foundations and supports for fixing the structure. Although in each case these previous works will have to be adjusted to the state of the corresponding location, it is assumed that the quantities required in the case of CEIP Gabriela Mistral will be similar to those of most of the buildings where similar solutions are proposed.

The cost of this solution used in this document is **€175.$^{51/m2}$** base and **€252.$^{71/m2}$** once the cost of general costs, industrial profit and VAT (21% in the case of Spain) are included.

mBiG SUVE Solution

Information collected in the execution project of the construction project of the pilot project of the CEIP Gabriela Mistral school. It is an exterior paving slab built with drainage mortar and with space for the introduction of substrate and seeds.

The cost presented includes the preliminary works for site preparation and the construction of the corresponding water drainage structures. Although in each case these previous works will have to be adjusted to the state of the corresponding location, it is assumed that the amounts required in the case of CEIP Gabriela Mistral will be similar to those of most of the buildings where similar solutions are proposed.

The cost of this solution used in this document is **€37.$^{71/m2}$** base and **€54.29/m2** once the cost of general costs, industrial profit and VAT (21% in the case of Spain) are included.

mBiGPond solution

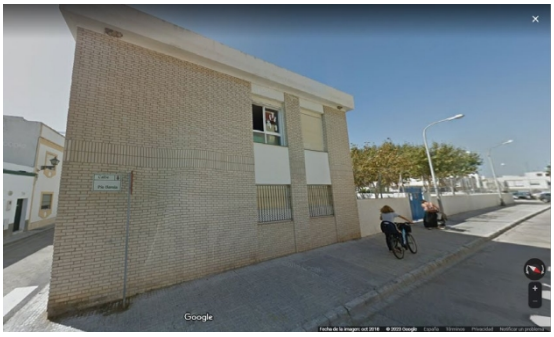
Information collected in the implementation project of the pilot construction project of the EB1 do Falcão school. This is an artificial pond to collect excess rainwater managed by the school's NBS. It allows the creation of an aquatic space with great plant biodiversity that attracts a great diversity of plants.

The cost presented includes the previous land adaptation works. It is assumed that the amounts required in the case of the EB1 do Falcão school (€3,307.99 base budget for a pond of 9m^2 surface area) will be proportional to those of most of the interventions that propose similar solutions.

The cost of this solution used in this document is **€365.$^{55/m2}$** final solution price. The cost has had to be updated slightly from the initial budget estimate because it was calculated prior to the pandemic. The cost would be increased for other general operations of this type of project, but would be included in the project total.

Annex 2. Photographs of the educational centers

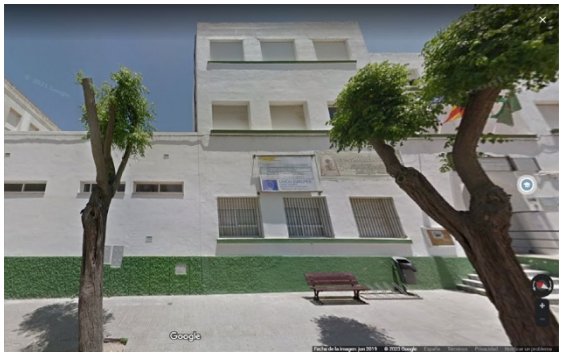
COLEGIO PÚBLICO SAN JOSÉ DE CALASANZ (Cádiz, SPAIN)




North - East façade (San José de Calasanz, Cádiz, Spain).



North - West façade (San José de Calasanz, Cádiz, Spain).




South - West façade (San José de Calasanz, Cádiz, Spain).



South - East façade (San José de Calasanz, Cádiz, Spain).

Photographs of the rest of the schools can be found in Annex "C5.7.annex School Photographs".