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A LIFE PROJECT

LIFE my building is green

LIFE17 CCA/EN/000088

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

Deliverable: Help document for "Prototype Design".

02- Bioclimatic strategies for the locations of Oporto, Évora and Badajoz.

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Proposal of bioclimatic strategies for the locations of Oporto, Évora and Badajoz.

1. OBJECTIVE

This document is part of the deliverable "Prototype Design". It aims to define the most appropriate bioclimatic strategies for each of the three locations of the LIFE My Building is Green project.

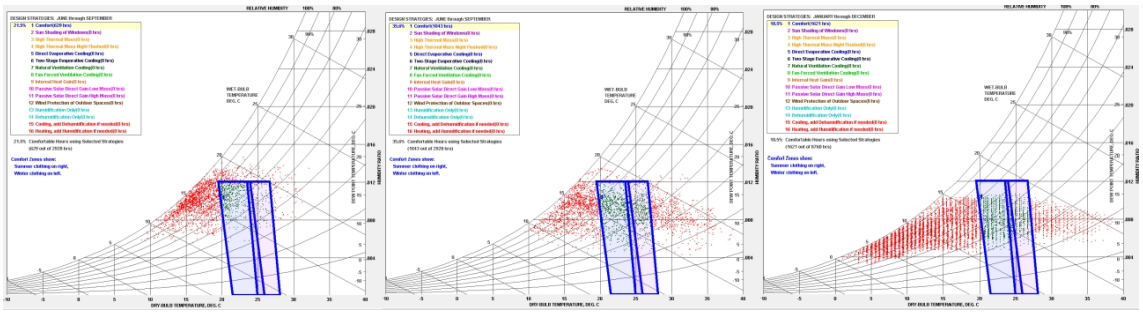
The strategies to be implemented in the project are aimed at reducing the cooling energy demand during the warm period. However, the strategies required for the whole year are analyzed in order to avoid introducing improvements for the summer that would mean a worsening of the building's energy performance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

2. PASSIVE BIOCLIMATIC STRATEGIES FOR THE 3 LOCATIONS

To support the selection of the most appropriate strategies for each of the locations, relevant hourly climatic data are plotted on the psychrometric abacuses for human comfort, in particular:

- Dry temperature (sensible heat)
- Relative and absolute humidity

Climate Consultant 6.1 software (UCLA, 2008) was used to plot the data in the psychrometric abacuses.



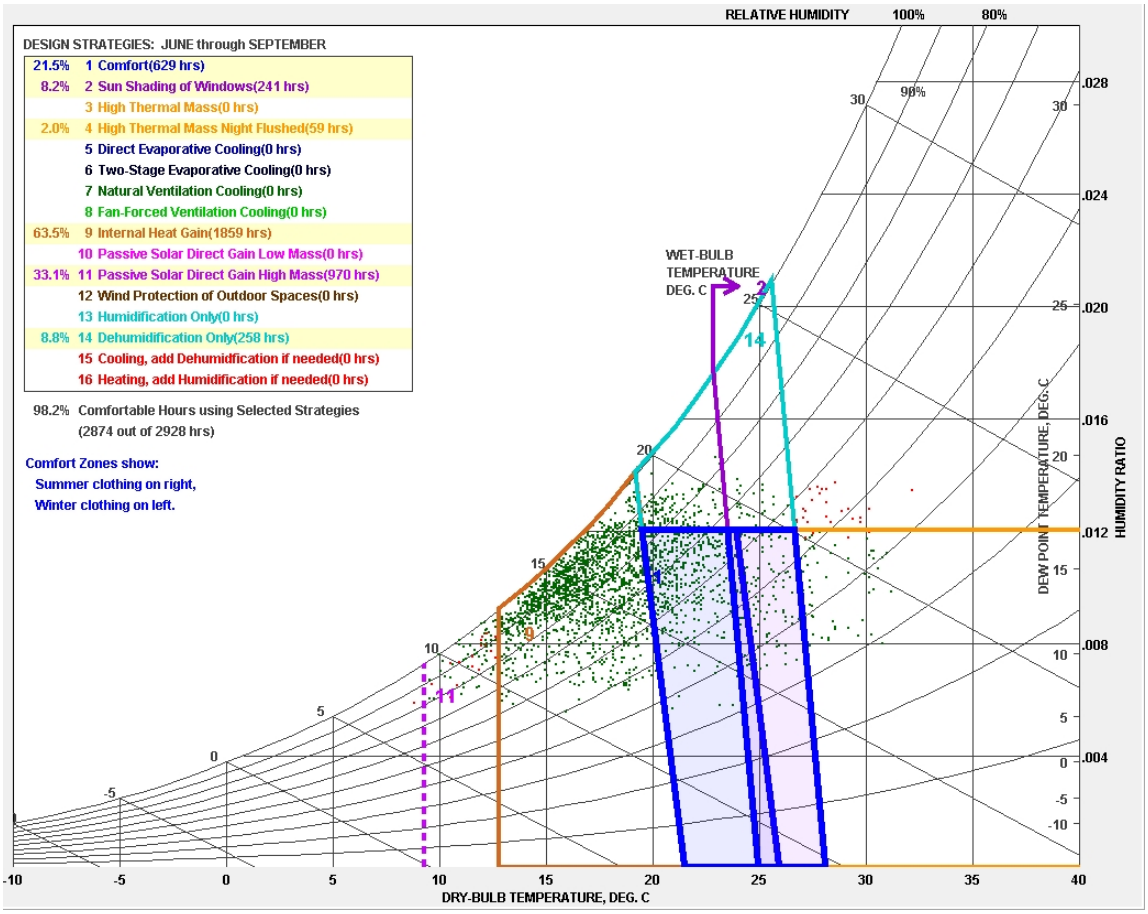
Psychrometric diagrams for the locations of Oporto, Évora and Badajoz during the summer period (June to September).

In the period analyzed (June to September), in the case of Oporto there were 21% of hours within the comfort range, 35.6% of hours in Évora and 37.2% in Badajoz.

The proposed bioclimatic measures are adapted to the climatic conditions of each situation and have been obtained from various sources (García Arroyo, 1983; Givoni, 1998; Mazei and Serra Florensa, 1985; Neila, 2009).

2.1. Porto

During the summer (June to September), it would be possible to achieve 98% comfort hours without using active air conditioning systems by incorporating appropriate passive measures.



Psychrometric diagram with incorporation of the most appropriate passive improvement measures during the summer at the Porto location (UCLA, 2008).

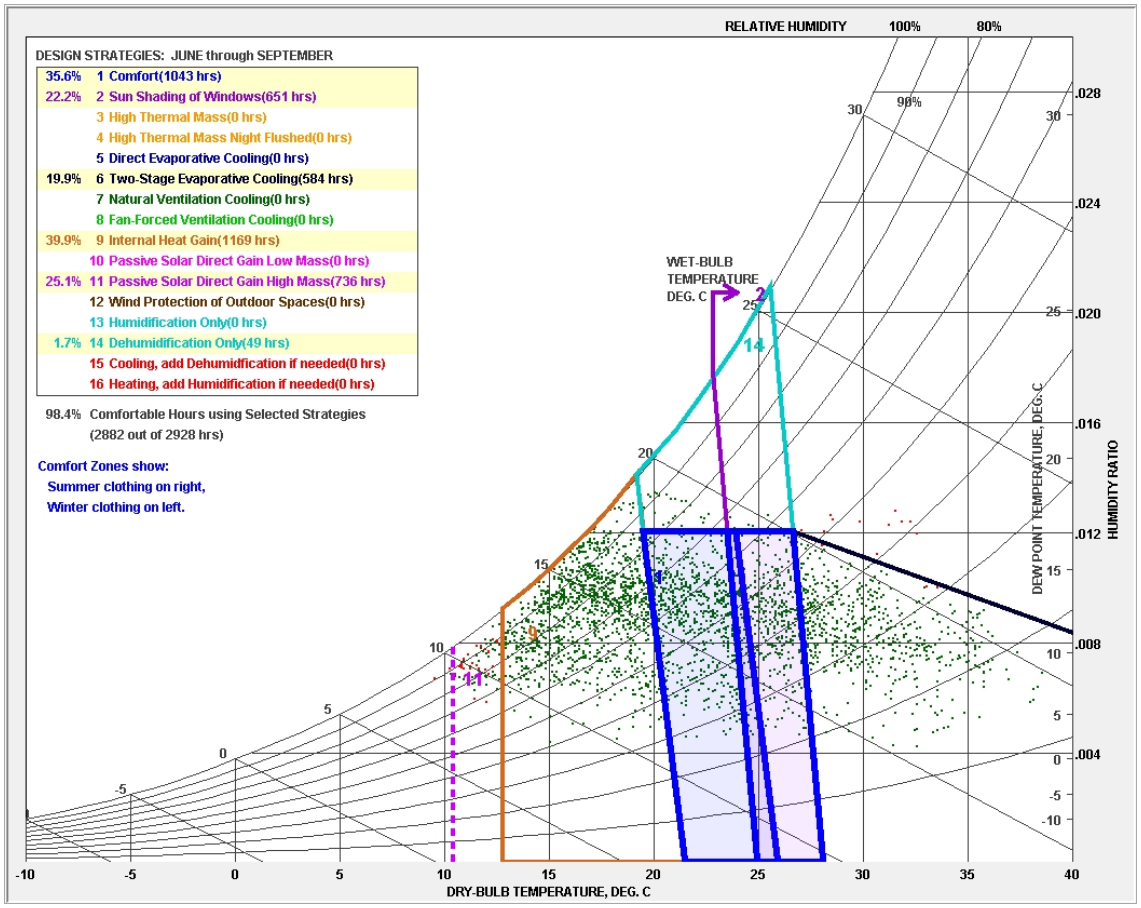
According to the analysis of the psychrometric diagram, the most suitable passive measures for the reduction of cooling demand during the months of June to September in the temperate and humid climate of Porto are the following:

- Gap shading to prevent overheating
- Cross ventilation
- Internal profit control
- Exploitation of thermal inertia
- Dehumidification

Measures should take into account their impact in winter so as not to penalize passive solar gain and heat conservation during the cold months.

2.2. Évora

During the summer, by incorporating appropriate passive measures, it would be possible to achieve 98% comfort hours without using active air conditioning systems.



Psychrometric diagram incorporating the optimal passive enhancement measures during the summer for the Évora location (UCLA, 2008).

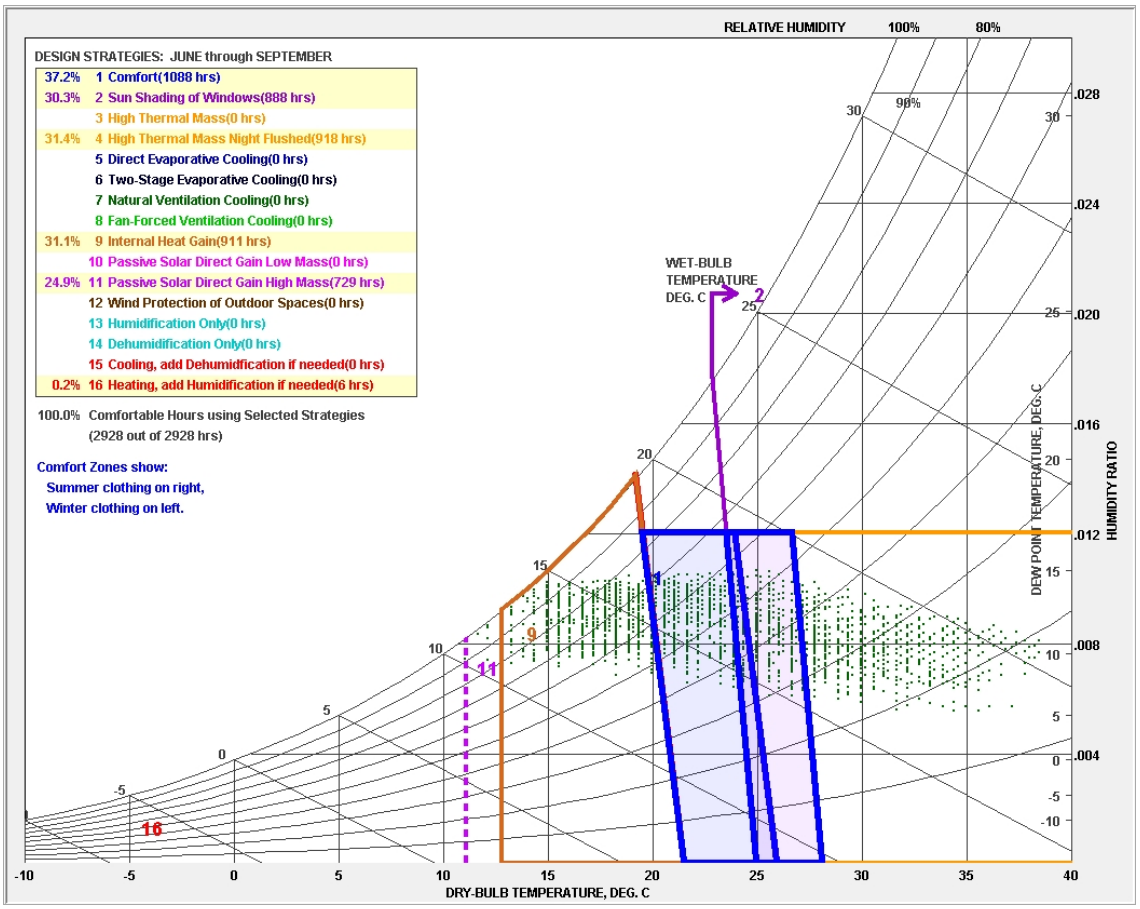
According to the analysis of the psychrometric diagram, the most appropriate passive measures for the reduction of cooling demand during the months of June to September in the temperate and dry climate of Évora are the following:

- Shading of openings and outdoor spaces during summertime
- Cross ventilation
- Evaporative cooling systems
- Management of internal loads
- Light colors and reflective coating

Measures should take into account their impact in winter so as not to penalize passive solar gain and heat conservation during the cold months.

2.3. Badajoz

During the summer, by incorporating appropriate passive measures, it would be possible to achieve practically 100% comfort hours without the need to use active air conditioning systems.



Psychrometric diagram incorporating the optimal passive enhancement measures during the summer for the Évora location (UCLA, 2008).

- Reflective flat cover
- Gap shading (maximum shading in summer and minimum shading in winter)
- Evaporative cooling systems
- Exploitation of thermal inertia
- Night ventilation
- Management of internal loads
- Use of ceiling fans

Strategies should be implemented without negatively influencing bioclimatic behavior in winter.

3. DESCRIPTION OF PASSIVE MEASURES

a. Reflective flat cover

Cool roofs are composed of surfaces that reflect sunlight and emit or discharge heat efficiently, keeping them cooler on sunny days. The two properties that determine the temperature of a roof are solar reflectance and thermal emissivity, measured on a scale of 0 to 1. The larger the two values, the cooler the roof temperature will remain. The optical characteristics of roofs should have the following properties:

- Solar reflectance (SR) > 0.7;
- Thermal emissivity (TE) > 0.75

b. Shaded outdoor spaces and patios

The shading of outdoor spaces with the inclusion of a fountain or sheet of water to increase humidity will reduce the temperature due to the effect of evaporative cooling.

c. Semi-buried buildings

Semi-buried buildings are protected from extreme changes in outdoor temperature, precipitation, wind and humidity. In addition to protecting the building from the elements, semi-burying helps preserve the natural habitat and reduce the transmission of outside noise.

d. Cross ventilation

Buildings can be ventilated and/or cooled by taking advantage of natural wind currents. Window openings should be oriented perpendicular to the prevailing winds. Coupled with openings on the opposite side of a space or building, they will provide natural ventilation by utilizing the fresh outside air. Proper use of cross ventilation can remove heat from the building by keeping the indoor air temperature approximately 1.5°C below the outdoor air temperature.

> *GUIDES: Orient air inlet openings perpendicular to (or within ± 45° of) the prevailing winds. Locate outlet openings on the opposite side of the inlet openings, ensuring that they are equal to or larger than the inlet openings. Maintain an unobstructed path between the inlet and outlet openings for adequate airflow (UCLA, 2008).*

e. Ceiling fans

Induced ventilation by ceiling fans can reduce the wind chill by up to 5°C on hot days.

f. Shading: solar facade

During the hot summer months, the use of eaves or overhangs blocks unwanted direct sunlight incident on the glazed areas, thereby reducing cooling demand. Eaves or overhangs should be located above the glazed area (facing south). The projection of eaves and overhangs shall extend approximately:

- 1/3 of the height of the glazed opening for latitudes from 36° to 40°.

Exterior horizontal louvers can also be used to shade south-facing glazed areas. Use the above guidelines to determine the dimension of the projection of horizontal louvers based on the distance between them.

g. Exploitation of thermal inertia

The energy rehabilitation for these climates can include a thermal insulation system on the exterior (SATE) so that the thermal mass existing in the enclosures is included in the interior and can take advantage of the inertia to dampen the temperature difference between day and night.

h. Evaporative Cooling

In hot, dry climates, the use of evaporative cooling helps to reduce air temperature. By distributing the cooled air into the interior of a space or building, its interior temperature can be reduced (see measure c).

An example of this would be the evaporative cooling tower. The evaporation of water at the top of a cooling tower creates a downdraft of cold air that can be distributed to a specific space or area. The amount of cold air produced by the tower depends on the humidity of the environment, the height of the tower, and the amount of water that evaporates. Configure the evaporative cooling tower with:

- A minimum height of two times the height of the space to be cooled, with
- A cross-sectional area of approximately:
    - 3 m2 for residential applications
    - 6 m2 for commercial applications

The higher the tower, the greater the amount of air cooled. The area of the outlet opening (which distributes the cooled air) should be as large as the cross section of the evaporative cooling tower.

i. Night ventilation

The thermal mass of a space cooled at night absorbs heat during the day, maintaining a cool temperature across its surface, and helping to create comfortable conditions during the day. In dry climates, with a day-night temperature difference of 11 C° or more, and where summer nighttime temperatures fall at least 5.5 C° below the desired daytime indoor temperature, cool nighttime air can be used to dissipate heat buildup in the space. The space will remain cool during the day without the use of energy sources.

To this end, the building must incorporate thermal mass in the interior walls, floors and/or ceilings:

- A minimum of 10.2 cm thick, with

- An exposed surface area of 1 to 3 times the area of the space to be conditioned.

The larger the exposed surface area of the mass in a space, the more stable its internal temperature will be. Cross or induced ventilation allows cooling the thermal mass at night.

j. Leveraging internal gains

Reducing lighting and equipment helps reduce cooling demand in summer during the hot hours. At times when the temperature is below freezing, it can help keep it within comfort.

k. Induced cross ventilation

The use of openings located at the bottom and top of a space, placed on opposite sides, produces a 'chimney effect' - warm indoor air escapes through the high openings, inducing the entry of cooler outdoor air through the low openings. The pushing force that occurs when air experiences a temperature difference - at least 1.7 C° difference between indoor and outdoor air - produces the 'stack effect' within a space or ventilation duct, inducing a draft that evacuates the accumulated warm air within the space or building. For the location of inlet and outlet openings:

- Commercial spaces - A minimum of 15 feet (4.6 meters) clearance between openings.

The greater the vertical separation between openings, the greater the air movement. Locate the inlet openings below the height of the occupants' torso - 0.76 m to 1.37 m above finished floor level.

l. Direct gain: glazed area

Glazed areas allow solar radiation to enter directly into the spaces to passively heat them in the winter. The south-facing glazed area should be sized to allow enough radiation to enter on a typical sunny winter day to heat the interior space for a 24-hour period. The sizing is done as a percentage of the area to be heated:

Cold climates *

- 16% for latitudes 28º - 40º.
- 20% for latitudes of 44º - 56º

Temperate climates

- 10% for latitudes 28º - 40º.
- 13% for latitudes of 44º - 56º.

GUIDELINES: Orient the solar glazed area within ±15º of the equator, and no more than ±25º from those orientations. Save some of the heat gained during the day for use at night by providing sufficient thermal mass within the space.

In very cold climates incorporate movable insulation to protect the glazed area at night (UCLA, 2008).

4. CONCLUSIONS

In this document we have identified the general lines that should be observed in the solutions to be incorporated in the buildings of the three project locations to improve comfort conditions during the summer (June to September). For the selection of the most appropriate measures, the impact on the number of hours of comfort of each of them has been ranked from highest to lowest, without assessing a priori whether their implementation is possible or not in the demonstrator buildings.

The decision of the measures that can be incorporated through nature-based solutions (NBS) should be made on the basis of the lines proposed in this document. As these are rehabilitation works, some measures will be easy to incorporate (such as the inclusion of shading elements in windows) and others will depend on the existing characteristics of the building to be intervened (for example, the use of thermal inertia depends on the existence of heavy enclosures in the building).

The major difference between the climatic adaptation of the architecture in the different locations is based on humidity, very high in Porto, low in Evora, and very low in Badajoz. Evaporative cooling systems will be very effective in Badajoz and counterproductive in Porto, where dehumidification may be necessary.

BIBLIOGRAPHY .

García Arroyo, A., 1983. Bases for passive solar design: energy saving equipment in buildings. Instituto Eduardo Torroja de la Construcción y del Cemento, Consejo Superior de Investigaciones Científicas, Madrid.

Givoni, B., 1998. Climate considerations in building and urban design. Van Nostrand Reinhold, New York.

Mazei, E., Serra Florensa, R., 1985. The book of passive solar energy. Gustavo Gili, Mexico.

Neila, F.J., 2009. Bioclimatic architecture in a sustainable environment. Editorial Munilla- Leria, Madrid.

UCLA, 2008. Climate Consultant, Energy Design Tools. Department of Architecture and Urban Design.