

Thermal Performance of Residential Buildings with Large Glazing Areas in Temperate Climate

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ABSTRACT: This work presents the results of an experimental and numerical study of a residential building, in a temperate climate, the particularity of these buildings is the large glazing areas around 65% to 85% of exterior façade. The thermal performance is presented and discussed. The study was developed taking into account the implementation of monitoring during the summer and winter for a housing unit in an intermediate floor with only one façade in contact with the exterior (south façade) without solar protection by the glass (glazing area 80% exterior façade) located in Lisbon, Portugal (Latitude 40 ° N); as well as detailed modeling of this unit using EnergyPlus for thermal simulation. The detailed model took into account the characteristics of the housing unit and the conditions under which it was monitored during the summer and winter. To simulate the detailed model under the monitored conditions the climatic data was carefully introduced in the thermal simulation (climate file), the data was obtained from the meteorological stations of the National Laboratory for Energy and Geology (LNEG, Lisbon) for the same periods of the monitoring. From the detailed model different parametric variations were performed (summer and winter). Thus we obtained a set of effects that let you check the parameters of major and minor influence on the thermal performance of housing units with large glazing areas situated in temperate climates. This work intends to provide tools and guidance to building designers with regard to the thermal performance of buildings

1 INTRODUCTION

The main heat exchange in a building usually occurs through the transparent elements (windows, skylights zenith, and other transparent elements). The exchange by conduction and convection in the glazing exhibit the similar behaviour to the opaque elements with the possibility of controlling the exchange of air between the interior and exterior - opening or closing. However, the radiation is the main factor because the portion directly transmitted through the glass into the interior.

The non-opaque envelope (glazing) can be considered a major factor in the control of radiation, ventilation and natural lighting (more dynamic, easier to adapt / adjust to obtain the desired interior conditions). Thus, the non-opaque envelope presents a greater degree of control and flexibility to adapt to climatic variations compared with the opaque envelope. It is the more flexible and interesting element of the building envelope.

In addition, glass and other transparent and translucent materials are considered essential for the successful implementation of most passive solar heating systems (when they have a proper solar orientation).

In Portugal, in the case of habitation, the needs in the winter season are easily satisfied by a correct orientation and scaling of the glass areas, thermal mass, thermal insulation (opaque envelope and thermal insulation of glazing areas at night). However in the summer season, the cooling needs are usually resolved with the proper design of the outer skin, night ventilation cooling, shading the windows and thermal mass inside.

At the same time the interest in glass materials in construction has increased in order to verify progress in the development of production of that material. The evolution of the glass production and progressive independence between skin and supporting structure, promoted the process of dematerialisation of the facades and the dilution between the wall and windows of buildings. A increase of glazing areas on the facades of residential buildings can also be noticed in the Portuguese built stock mainly in the buildings constructed over the past decades (see Figure 1). Thus verifying residential buildings with 65% -85% of façade in glazing.

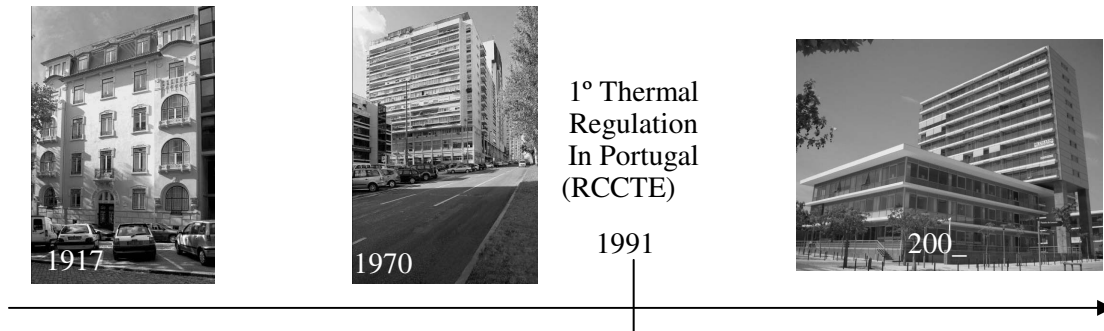


Figure 1. The increase of glazing areas on the facades of residential buildings in last few decades (Lisbon).

So, the thermal behaviour of buildings with large glazing areas will directly depend on a number of factors including: glazing control and protection systems, the thermal inertia within the environments and the degree of building insulation.

2 METHODOLOGY

2.1 Object of study

For the study in question was selected a housing unit located in a building chosen among others buildings identified in the Portuguese building stock. These buildings present important features to this study; in particular the glazing areas, because these are buildings with glazing areas over 65% of the main façade.

This housing unit keeps the features already mentioned (about the glazing areas), and these features are related to the construction and architecture practiced in recent years in Portugal.

This housing unit is located an intermediate floor (Lisbon, Latitude 40 ° N) with a single façade in contact with the outside (facing to the south) and without any protection device in the glazing areas (80% of the façade is glazed). This housing unit has a balcony (0.85m wide) over the entire glazing, so this balcony provides shading on the glazing under study.



Figure 2. Housing unit features.

2.2 Phases of the Study

The study was developed in different phases: monitoring during the summer and winter, the construction of the detailed modeling using EnergyPlus for thermal simulation, the simulations of the detailed model under the monitored conditions (summer and winter), the calibration of the detailed model and different parametric variations for the detailed model (summer and winter).

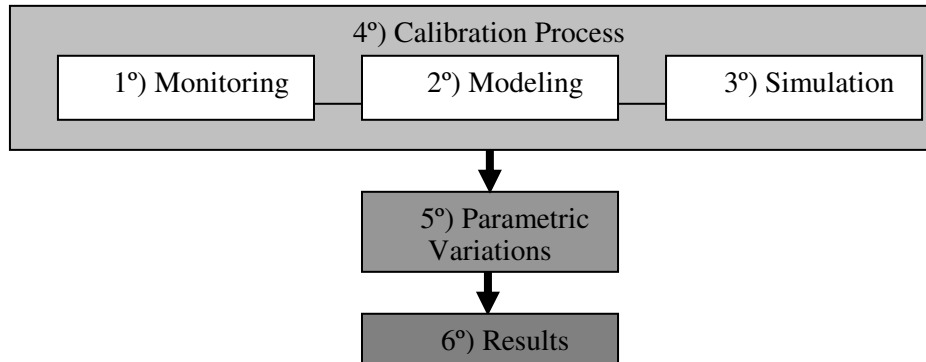


Figure 3. Study phases.

3 ANALYSIS

3.1 Summer and Winter Monitoring

Beginning with the selected housing unit, and with the support of the architectural projects, a more detailed assessment was performed. This made possible the site monitoring during both, summer and winter periods of 2007-2008.

Temperature and relative humidity (hygrothermal behaviour - mini dataloggers) sensors were installed in the selected housing unit (living room and bedroom). The use and occupancy pattern of housing unit was also recorded during the measurements, as well as the views of residents through a survey targeting the issues of thermal comfort. Thus, we obtained a set of data and other important information for understanding the thermal behaviour of the compartments of the study unit.

While the monitoring were performed the external conditions were obtained from the LNEG Meteorological Station (LNEG-National Laboratory for Energy and Geology, IP) installed in the Solar XXI Building, Lisbon.

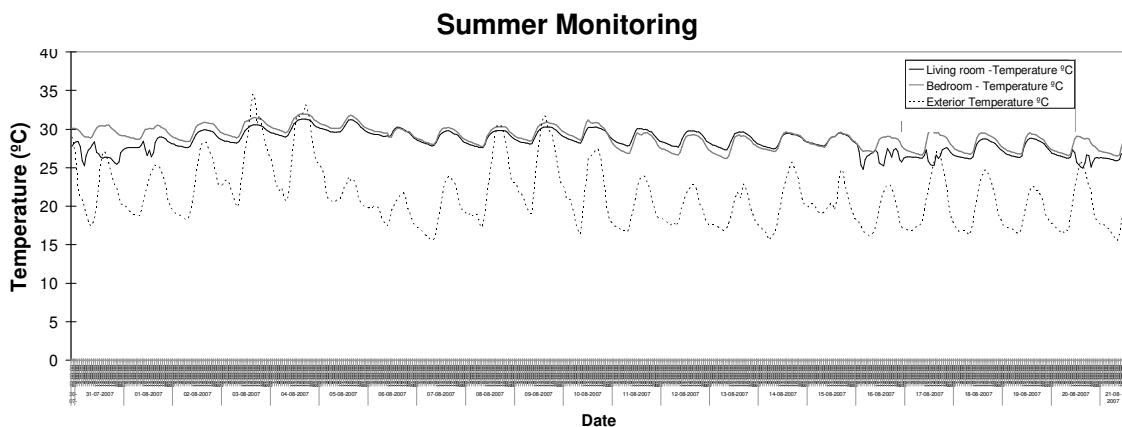


Figure 4. Summer Monitoring..

Summer Monitoring Period - 30 July to 21 August 2007:

Inside the flat were observed the mean temperature for the both compartments. In the living room the mean temperature was 28.5 °C, and for the bedroom was 29 °C.

The mean thermal amplitude was 6.5 °C in the living room and 6 °C in the bedroom.

Temperatures in the living room and bedroom were above 25 °C (temperatures above the comfort level) in 100% of the time. Temperatures in the living room were between 27 °C and 31 °C in 80% of the time and the temperatures in the bedroom were between 27 °C and 31 °C in 90% of the time. Approximately 84% of the time the outside temperatures were below 25 °C.

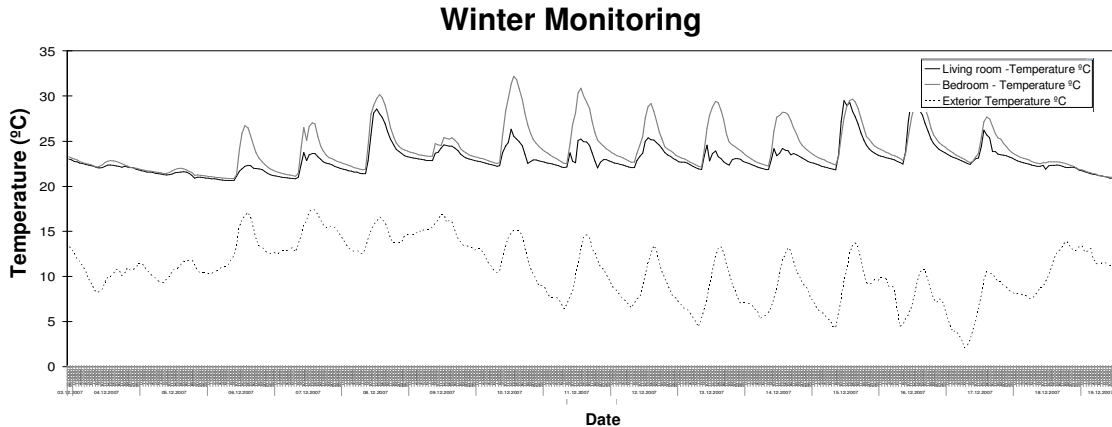


Figure 5. Winter Monitoring..

Winter Monitoring Period - December 30 to 19 December 2007:

Inside the flat the mean temperature for the living room was recorded in 23 °C and in the bedroom 24 °C. The mean thermal amplitude was 9 °C in the living room and 11 °C in the bedroom. Temperatures in the living room were between 20°C and 25 °C in 90% of the time and 73% of the time in the bedroom. Approximately 4.5% of the time temperatures in the living room were above 27 °C and in 6% of the time temperatures in the bedroom were above 29 °C. There were no temperatures below 20 °C in these compartments.

The outside air temperatures were below 15 °C in 85% of the time, and in 37% of the time the temperatures were between 5 °C and 10 °C.

3.2 Summer and Winter Simulation

Based on information obtained from the housing unit in question, a detailed model was constructed in the thermal simulation software EnergyPlus (E+) The detailed model took into account the features of the housing unit and the conditions under which it was monitored during the summer and winter (geometry, orientation, location, construction solutions, pattern of use and occupation, renewal rates by time, equipment ...). In order for the model to simulate under the monitored conditions special care was taken to introduce into the thermal simulation software the climatic data (climate file) obtained from the meteorological stations of the National Laboratory for Energy and Geology (LNEG, Lisbon) the same periods of monitoring.

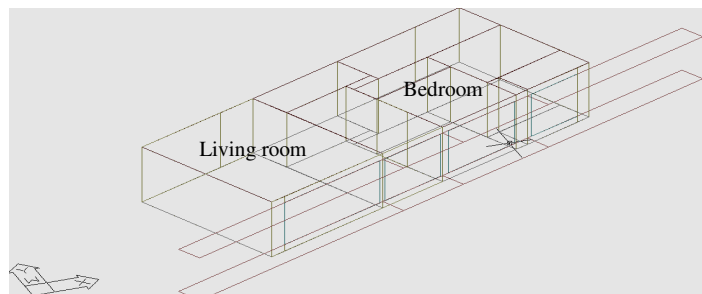


Figure 6.Housing unit Detailed Model in EnergyPlus (E+).

The results obtained from the simulations were compared with the results obtained from the monitoring (Detailed Model calibration), thus allowing to confirm that the detailed model presents results and thermal performance similar to that obtained in the real model.

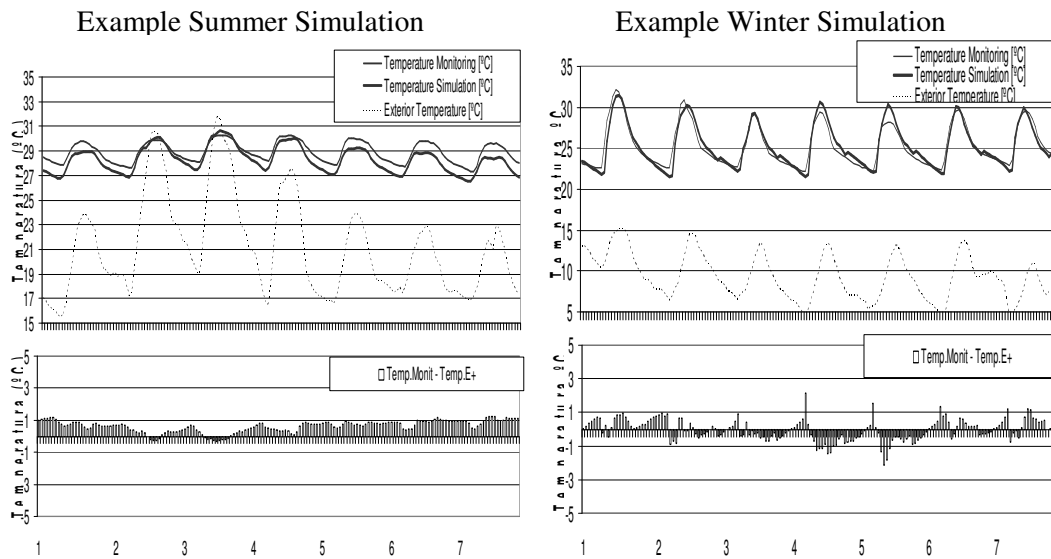


Figure 7. Calibration Detailed Model, monitoring and modeling.

The difference between the temperatures obtained during the monitoring and those obtained through simulations for the environment living room (during the seven days selected to represent the summer season) was on average $0.62\text{ }^{\circ}\text{C}$, and for the bedroom was $0.44\text{ }^{\circ}\text{C}$.

The difference between the temperatures obtained during the monitoring and those obtained through simulations for the environment living room (during the seven days selected to represent the winter season) was approximately $0.32\text{ }^{\circ}\text{C}$; and for the bedroom was $0.04\text{ }^{\circ}\text{C}$.

The manufacturer of the equipment uses a margin of error of $\pm 0.5\text{ }^{\circ}\text{C}$ and that the weather station is not located exactly on the building site studied. Thus, the results in terms of calibration can be considered satisfactory, taking into account the above observations and the mean differences obtained in both seasons (monitoring and simulations), which were no more than $\pm 0.62\text{ }^{\circ}\text{C}$.

3.3 Parametric Variations - Summer and Winter Simulation

The Detailed Model (calibrated) was used to perform different parametric variations (summer and winter). Thus, permitting to verify the parameters of major and minor influence on thermal behaviour of the unit in question.

The parametric variations were made in the detailed model as a whole (considering all zones in the model, which represent the different environments existing in the housing unit chosen). However, for this study was adopted an example room to demonstrate the influence of parametric variations performed and the thermal behaviour of the model.

Summer Parametric Variations:

The charts below demonstrates the importance of natural ventilation and the presence of sun protection devices near the windows to achieve a better thermal performance in housing units with characteristics similar to that adopted for this study.

The variations in the air change per hour (ACH), showed a great potential to reduce the indoor temperature, up to $3\text{ }^{\circ}\text{C}$. The changes made relative to the size of the horizontal shading (width) showed the possibility to reduce temperatures by up to $8\text{ }^{\circ}\text{C}$ on average, this possibility with the interior wood shutters were between $1\text{ }^{\circ}\text{C}$ and $3\text{ }^{\circ}\text{C}$, and with the exterior blinds were between $1.5\text{ }^{\circ}\text{C}$ and $4.5\text{ }^{\circ}\text{C}$. The variations on the degree of insulation on the outside elements (in this case the exterior walls, because it is an intermediate floor fraction), as well as on the type of cloth wall (single wall) had little influence on results.

Parametric Variations - Summer

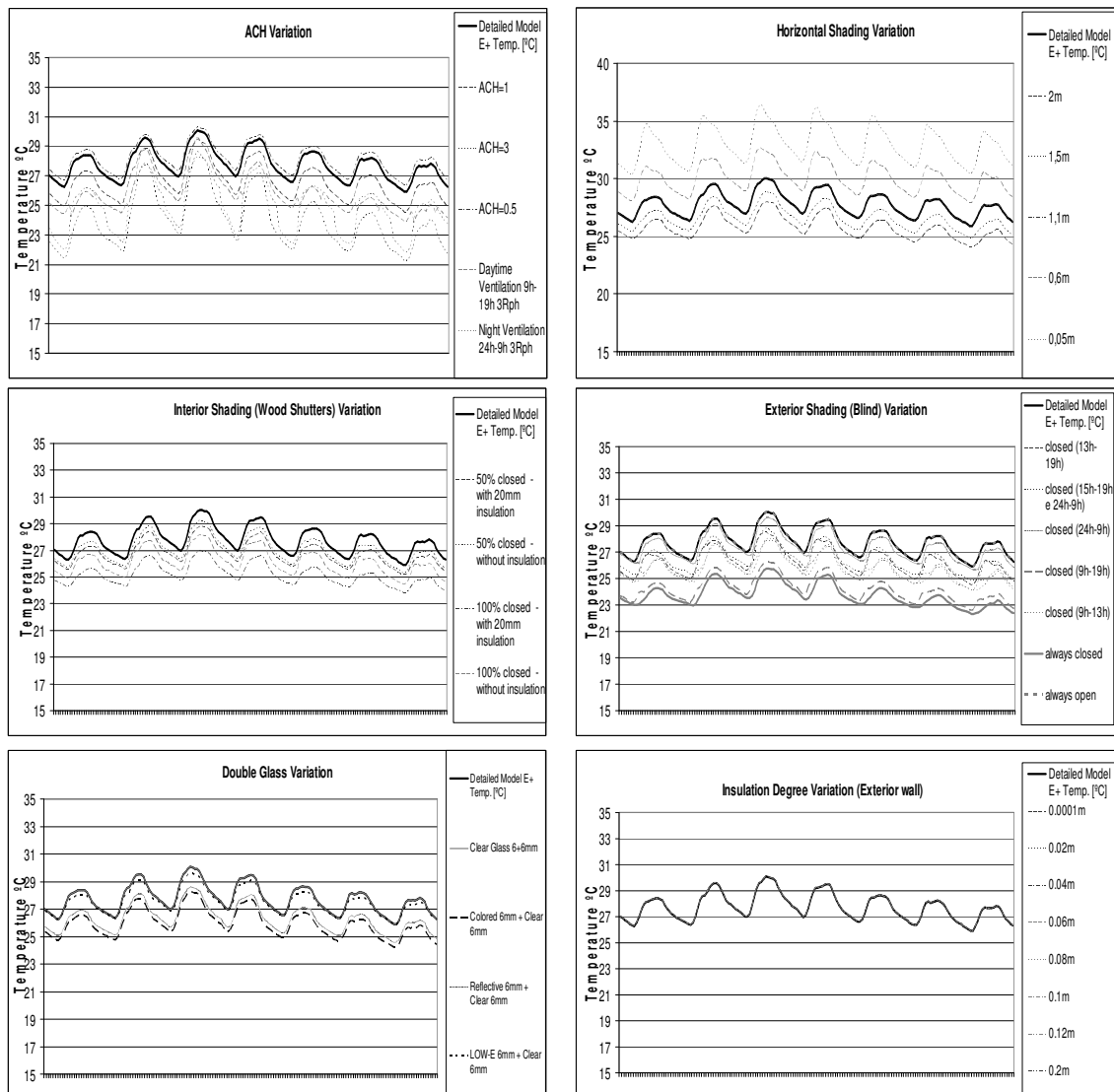


Figure 8. Summer parametric variations (Detailed Model).

Winter Parametric Variations:

Through the charts below we can see the infiltration influence, because the difference between the two situations (with 0.5ACH and 1ACH) in terms of temperature, can be of 4.5 °C on average,

The solutions between 0.6 ACH and 1.2 ACH are recommended in DL/80 2006 as winter conditions for all glazing (closed), and the ACH rate varies consonant with the wind exposure and the type of frames.

Regarding the types of protection, the solution that showed the best results for this season was the solution that considers the exterior blind closed between the 24h-9h (Night). The solution with blind closed 24 hours showed temperatures below the reference (Tsimulation) at 10°C on average.

The best glass type solution for this season was the clear double glass. This solution presented temperatures above the solution with coloured double glass (difference of 4°C on average).

As with the summer parametric variations, the degree of insulation and the type of cloth wall had little influence on the result.

Parametric Variations - Winter

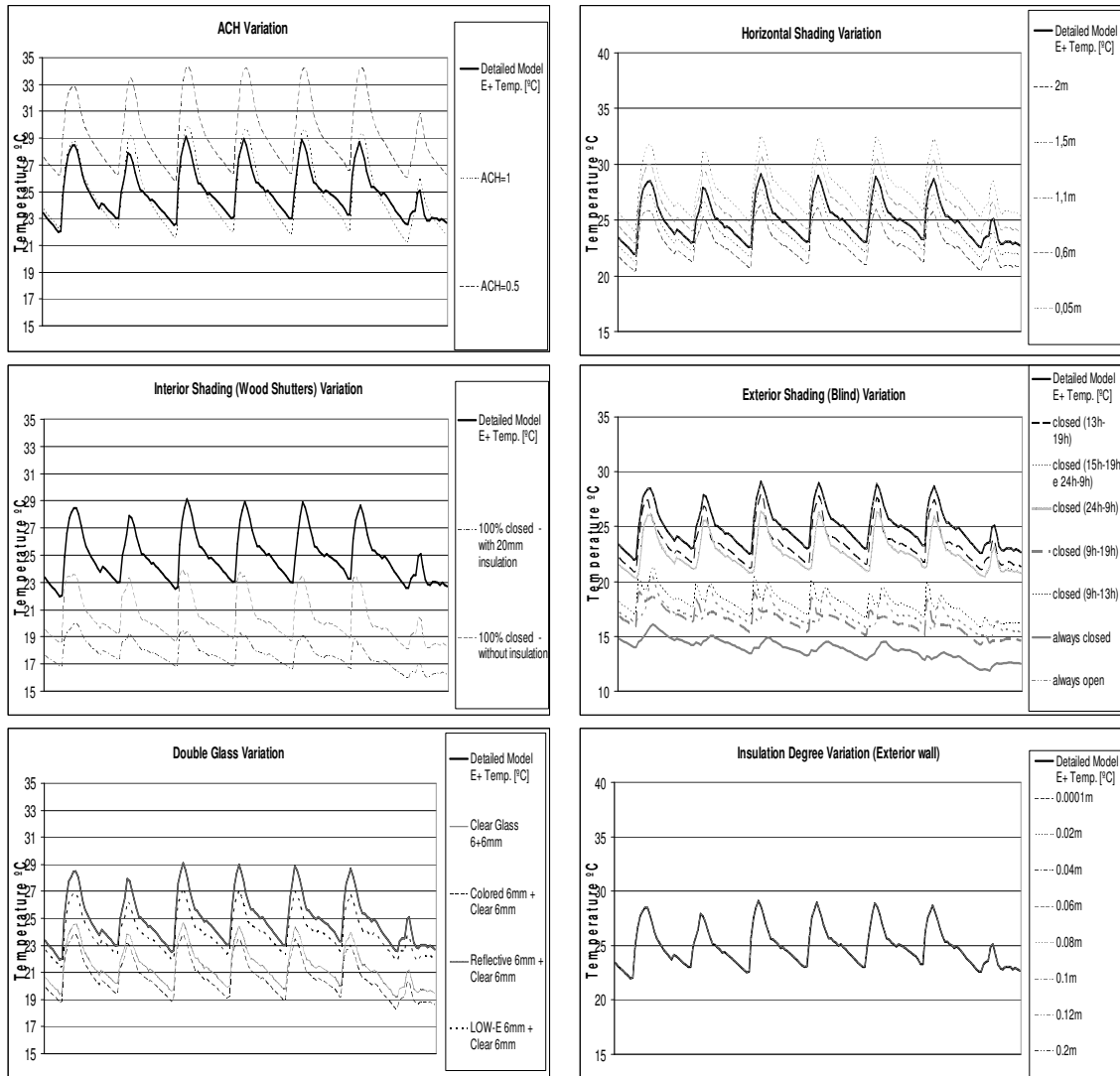


Figure 9. Winter parametric variations (Detailed Model).

4 FINAL REMARKS

This study showed the influence of various parameters on the thermal behaviour of housing units with large glazing areas. It was verified (within the range studied) that the interior temperatures ranged up to 8°C in summer and 10 °C in winter depending on the adopted solution.

During the summer, the natural ventilation and the type of protection contributed significantly to a better thermal behaviour of the model in question.

In winter the point of greatest care is the infiltration (reducing infiltration while maintaining levels of indoor air quality) as well as how to use the protection devices by the users (to provide better reception of solar radiation available).

Thus, this study aims to help and alert the professionals to some solutions that can be adopted for buildings with large glazing areas in temperate climates.

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