

Numerical simulation of the thermal response of a University Campus of the University of Algarve



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OBJECTIVES

- Numerical simulation of the University Campus thermal response.
- Application in the University of Algarve.
- Evaluation of environmental variables, thermal comfort level and consumption level.

NUMERICAL MODEL

- Integral energy balance equation (spaces, transparente and opaque bodies,

occupants and others):
$$mC_p \frac{dT}{dt} = \sum_i \dot{Q}_i$$

- Integral mass balance equation (air, water vapour, carbon dioxide and

others):
$$\frac{dm}{dt} = \sum_i \dot{m}_i$$

NUMERICAL MODEL

INPUT:

- Geometry (building and surroundings);
- Materials used;
- Building and its materials thermal properties;
- External geographical and environmental conditions: insolation, T_{air} , RH, V_{air} , D, etc.;
- Occupation cycle and occupant clothing and activity level.
- Ventilation topologies.



RESOLUTION PROCESS: Runge-Kutta-Fehlberg method with error control.



OUTPUT:

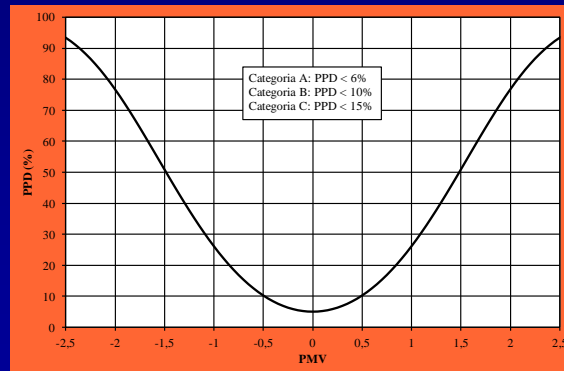
- Solar radiation;
- T_{air} , RH_{air}, V_{air} , MRT;
- CO₂;
- Thermal comfort and air quality;
- Consumption level.

Input and output data.

THERMAL COMFORT INDEXES

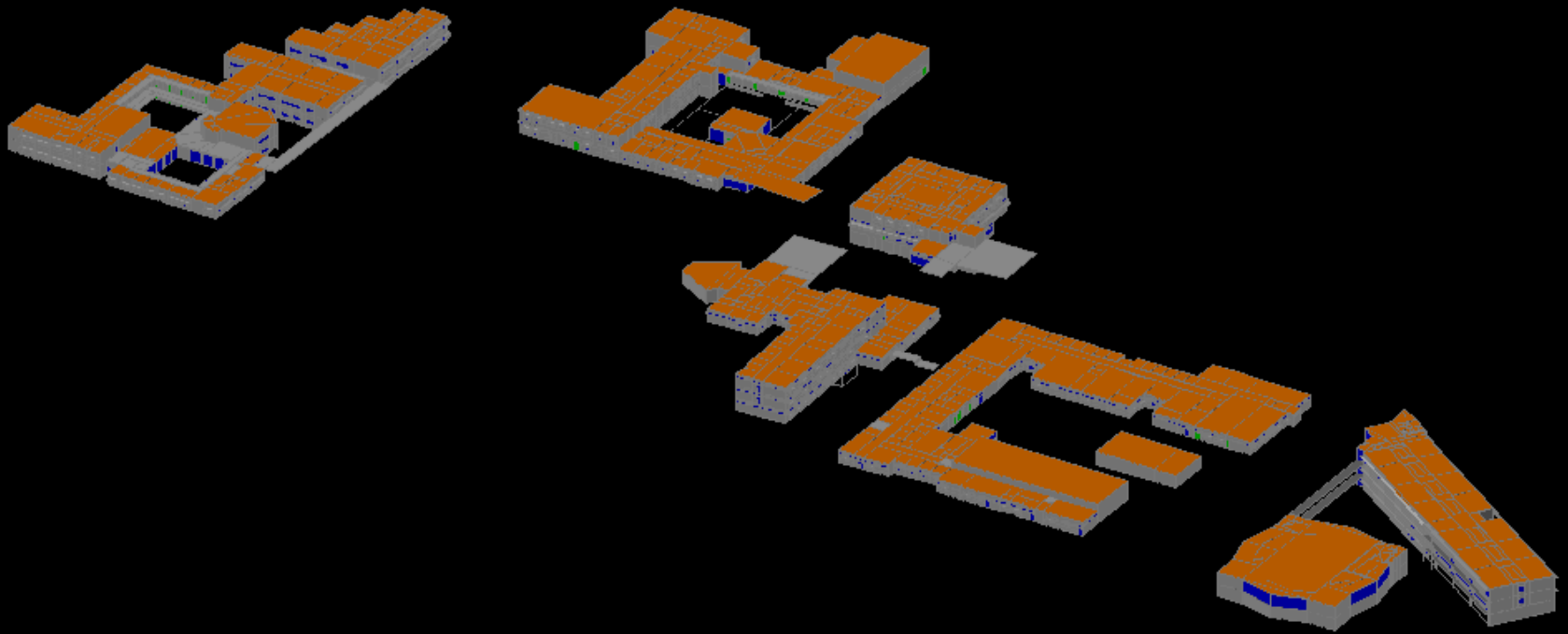
$$\begin{aligned} PMV = & (0,303e^{-0,036M} + 0,028) \\ & \times [(M - W) - 3,05 \cdot 10^{-3} \\ & \cdot (5733 - 6,99(M - W) - p_a) \\ & - 0,42((M - W) - 58,15) - 1,7 \cdot 10^{-5}M \\ & \cdot (5867 - p_a) - 0,0014M \times (34 - T_a) \\ & - 3,96 \cdot 10^{-8}f_{cl}((T_{cl} + 273)^4 - (MRT + 273)^4) \\ & - f_{cl}h_c \times (T_{cl} - T_a)] \end{aligned}$$

$$PPD = 100 - 95e^{-(0,03353PMV^4 + 0,2179PMV^2)}$$



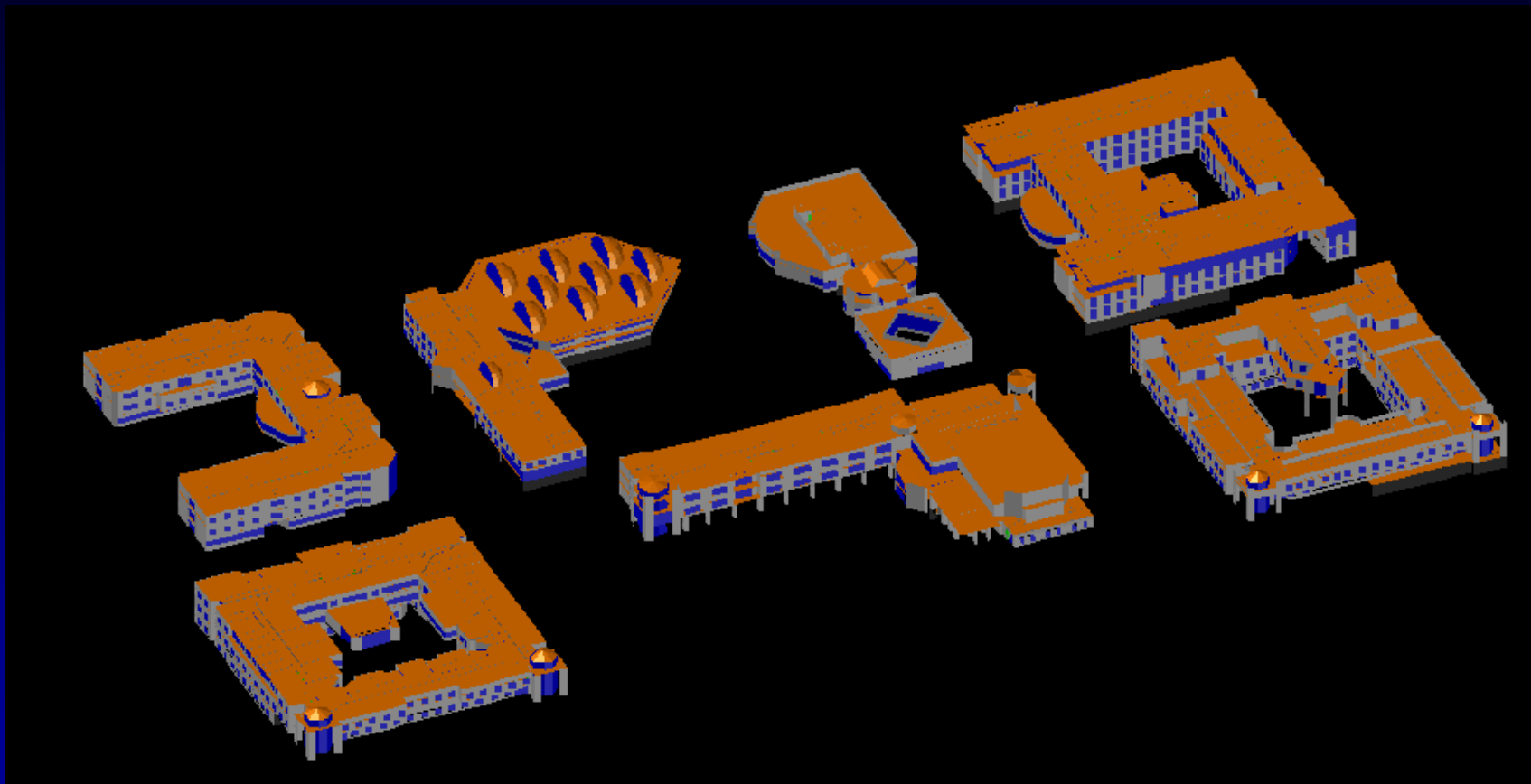
Predicted Mean Vote and Predicted Percentage of Dissatisfied People.

NUMERICAL METHODOLOGY



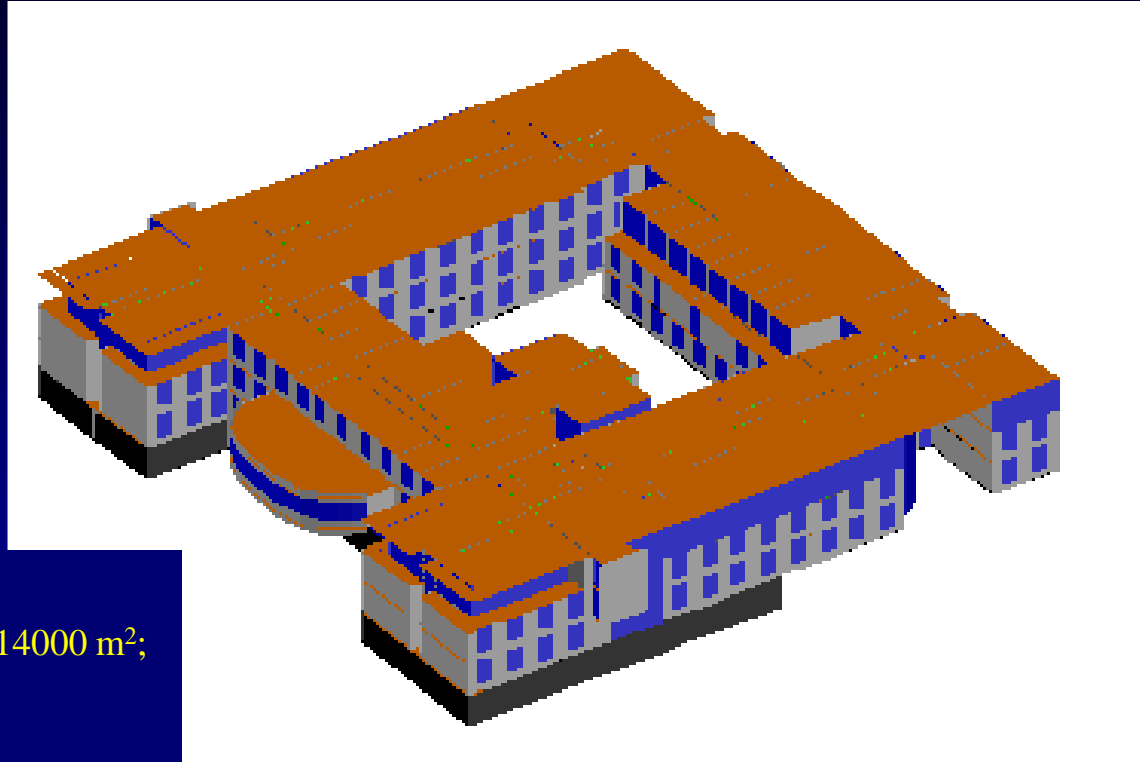
Campus da Penha, Faro.

NUMERICAL METHODOLOGY



Campus de Gambelas, Faro.

NUMERICAL METHODOLOGY



Constitution:

- 4 floors with an area of 14000 m²;
- 344 compartments;
- 171 compartment equipped with HVAC systems (occupied spaces).

University building identification (Campus de Gambelas, Faro).

NUMERICAL METHODOLOGY

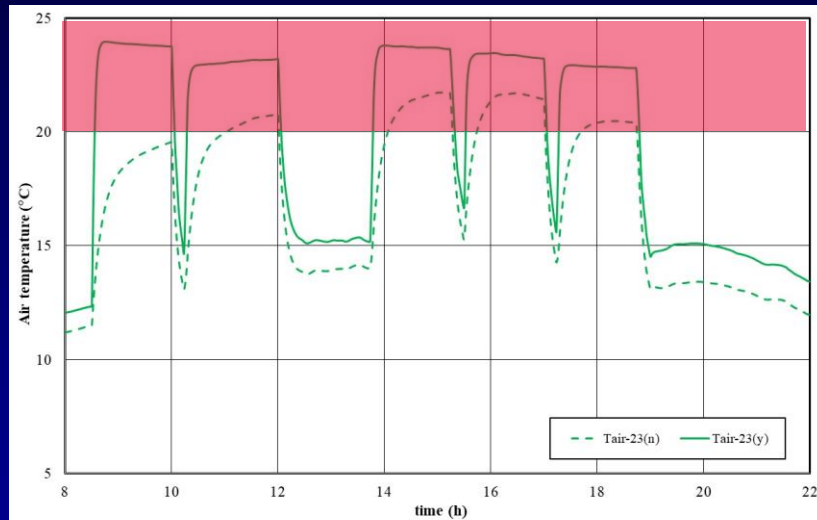
- Winter and Summer conditions.
- Activity level: 1.2 met.
- Clothing level: 0.5 clo (summer) e 1 clo (winter).
- Occupation cycle (number of occupants per room during each time period):

Time (hours)	0 to 8:30	8:30 to 10	10 to 10:15	10:15 to 11:45	11:45 to 12	12 to 13:30	13:30 to 13:45	13:45 to 15:15	15:15 to 15:30	15:30 to 17	17 to 17:15	17:15 to 18:45	18:45 to 19	19 to 20:30	20:30 to 24
Spaces															
23	0	50	0	50	0	0	0	50	0	50	0	50	0	0	0
108	0	35	35	35	35	35	35	35	35	35	35	35	35	35	0
313	0	45	0	45	0	0	0	45	0	45	0	0	0	0	0

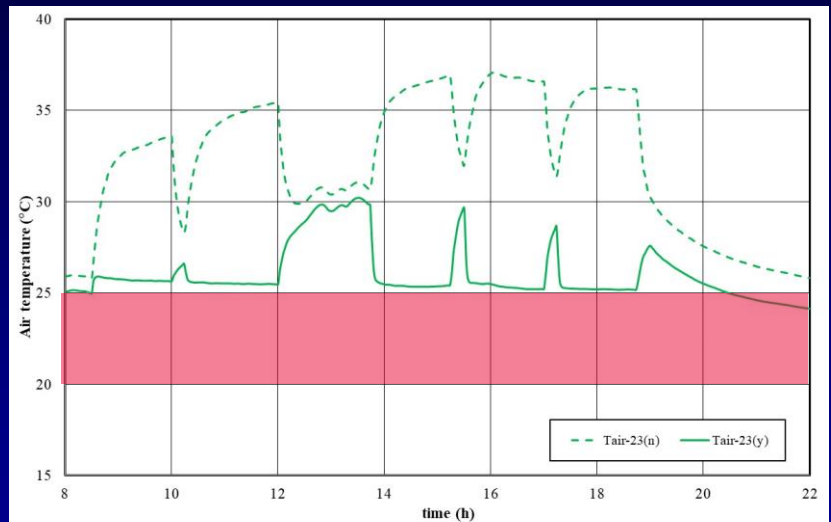
Input data.

RESULTS

Winter conditions



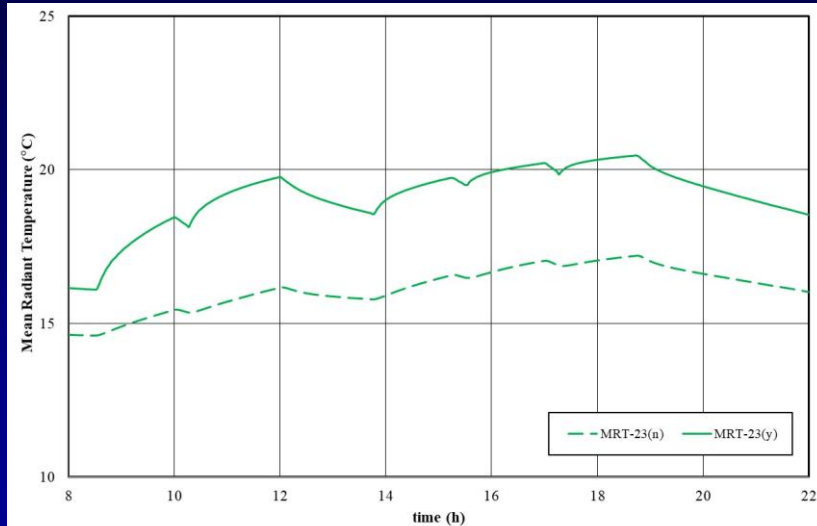
Summer conditions



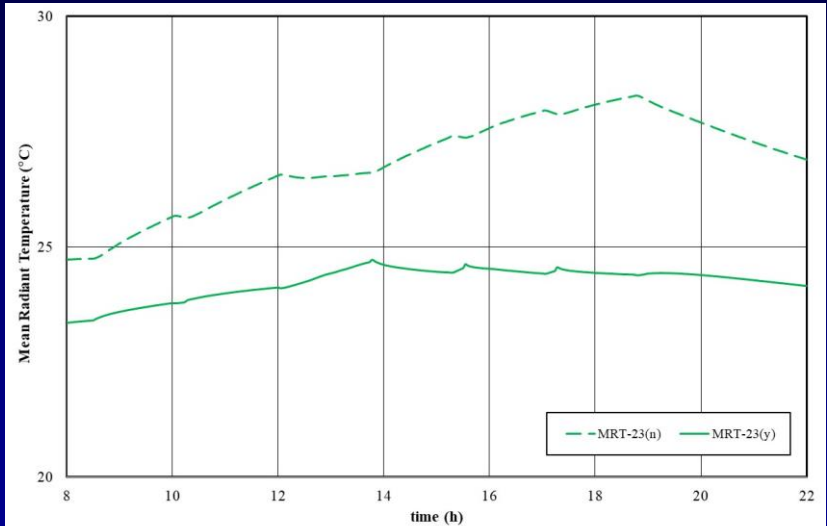
Evolution of indoor air temperature, T_{air} , with and without HVAC system.

RESULTS

Winter conditions



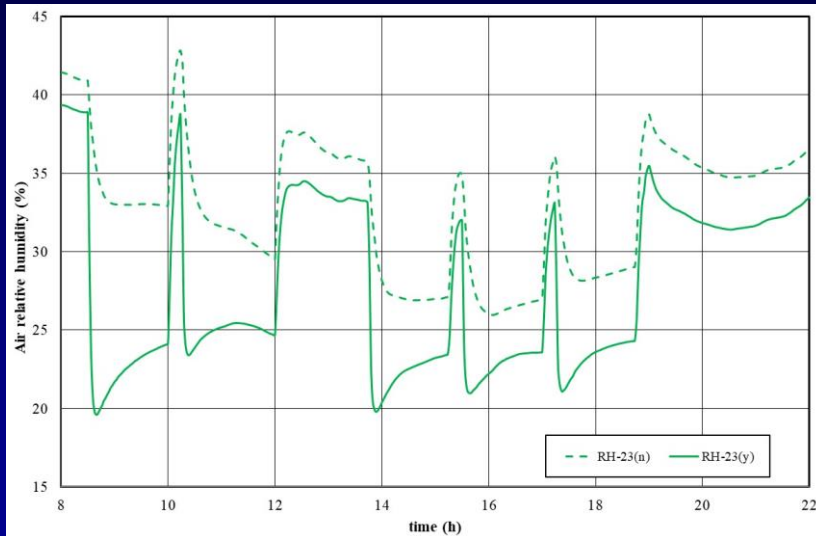
Summer conditions



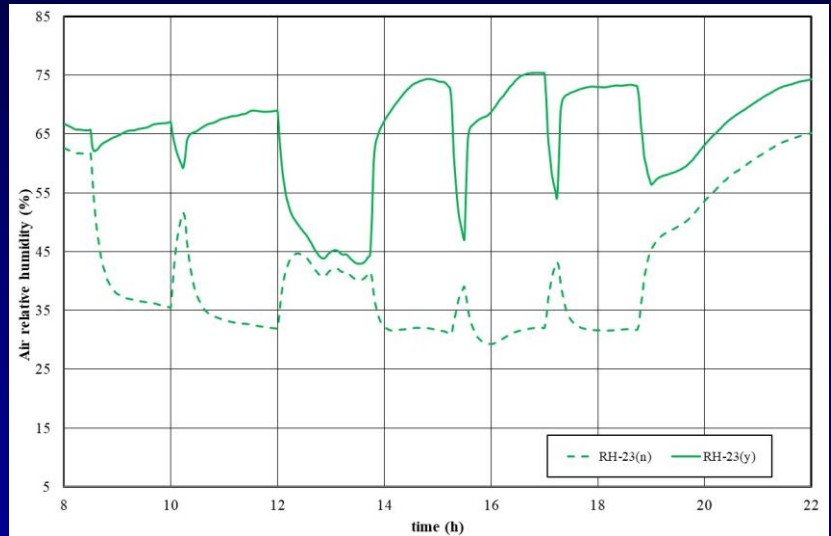
Evolution of mean radiant temperature, MRT, with and without HVAC system.

RESULTS

Winter conditions



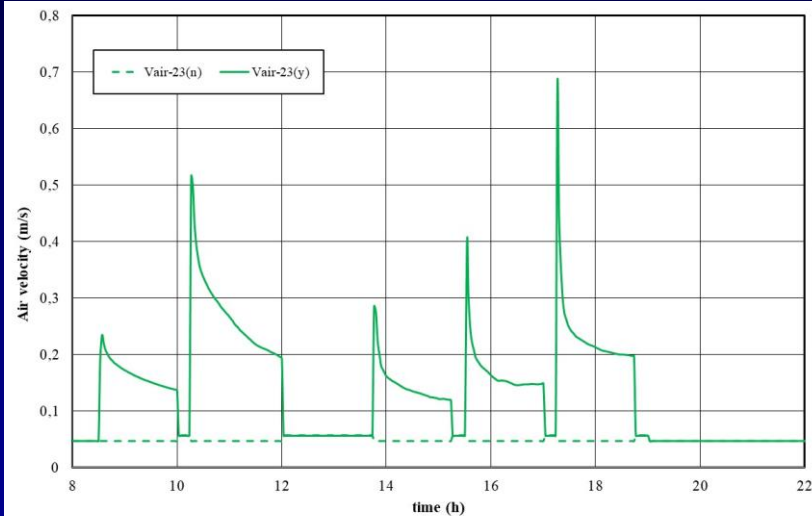
Summer conditions



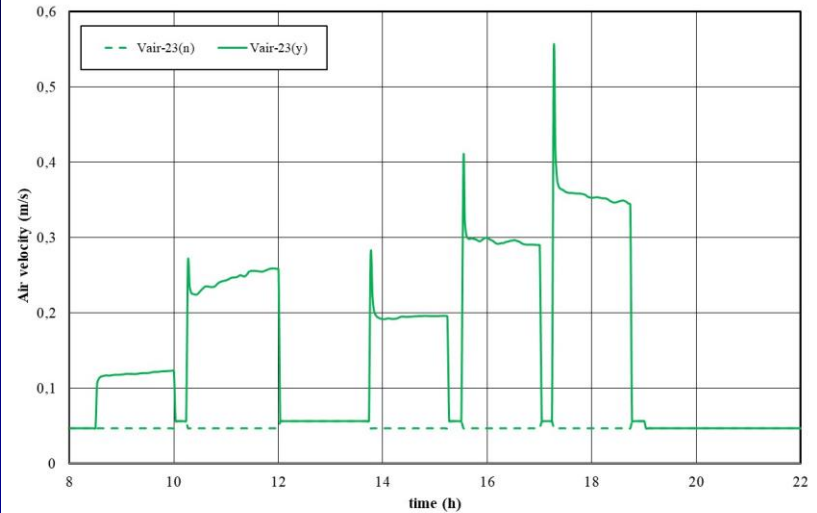
Evolution of air relative humidity, RH, with and without HVAC system.

RESULTS

Winter conditions



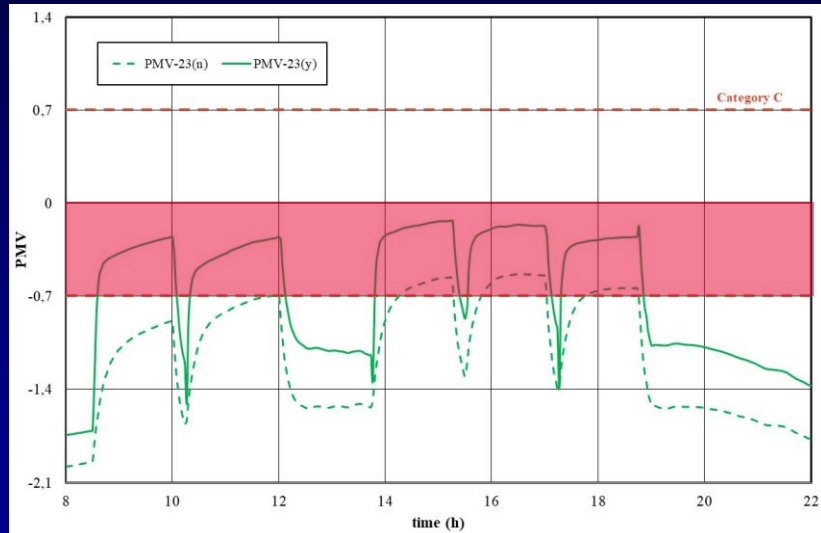
Summer conditions



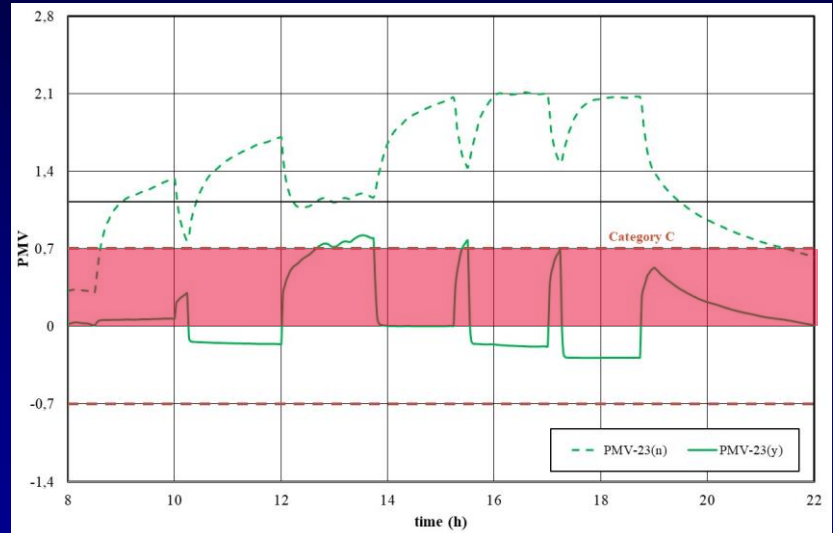
Evolution of air velocity, Vair, with HVAC system.

RESULTS

Winter conditions



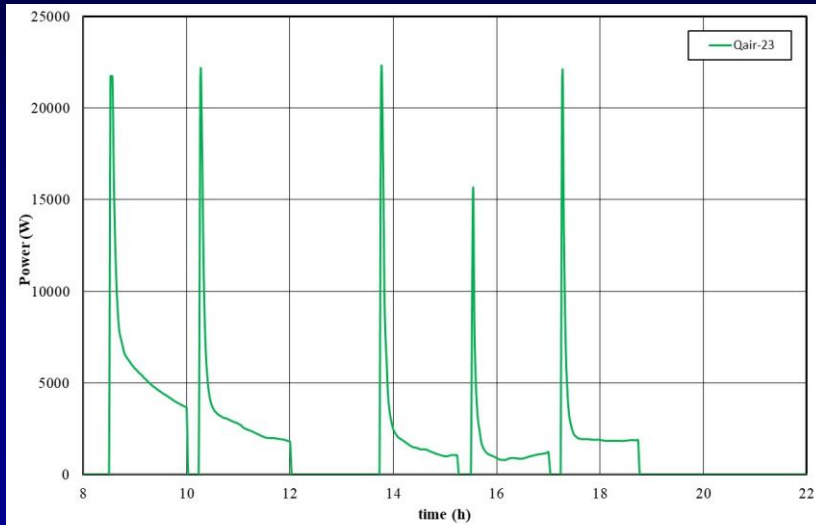
Summer conditions



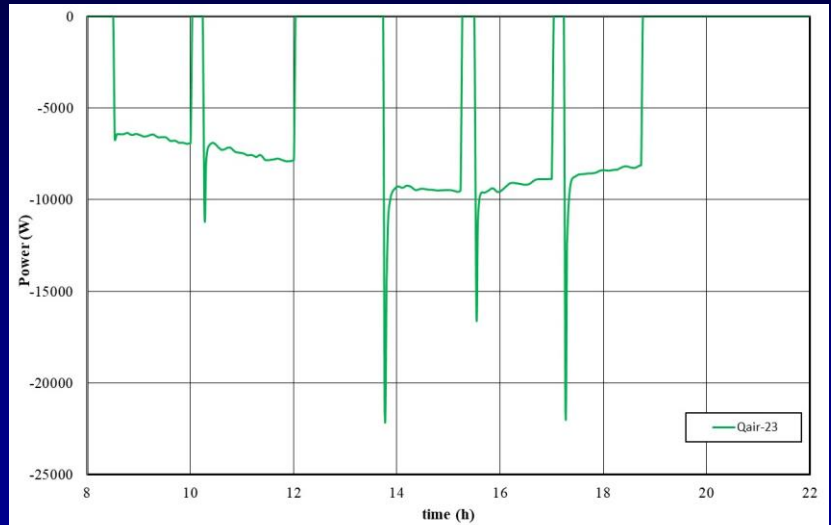
Evolution of PMV index with and without HVAC system.

RESULTS

Winter conditions



Summer conditions



Evolution of consumption level with and without HVAC system.

CONCLUSIONS

- When the PMV control is on, in general, the compartments are comfortable according to category C (ISO 7730).
- When the PMV control is on, the indoor air temperature values change between 20° (winter) and 25°C (summer), which are in accordance with the Portuguese standard.
- When the PMV control is on, the consumption level in summer is higher than in winter conditions.