

# **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:

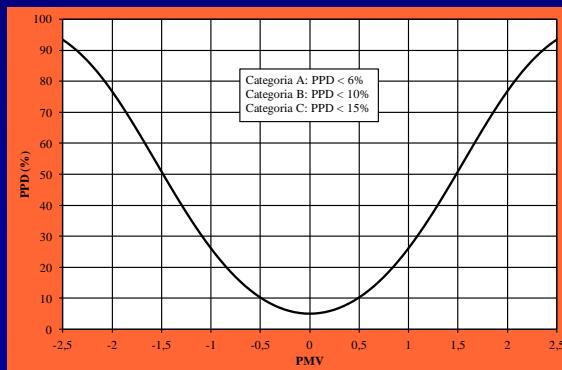
- Solar radiation;
- $T_{air}$ ,  $RH_{air}$ ,  $V_{air}$ , MRT;
- $CO_2$ ;
- Thermal comfort and air quality;
- Consumption level.

Input and output data.

# THERMAL COMFORT INDEXES

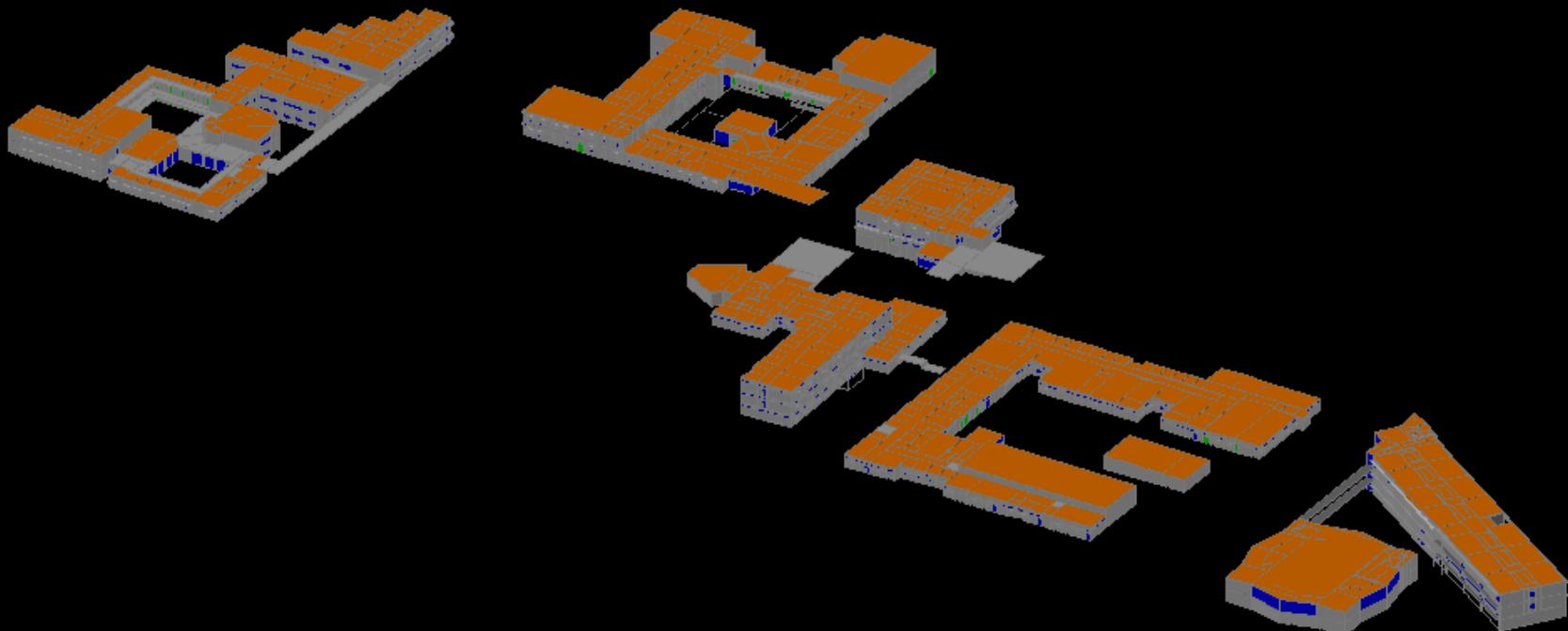
$$\begin{aligned} PMV = & (0,303e^{-0,036M} + 0,028) \\ & \times [(M - W) - 3,05 \cdot 10^{-3} \\ & \cdot (5733 - 6,99(M - W) - p_a) \\ & - 0,42((M - W) - 58,15) - 1,7 \cdot 10^{-5}M \\ & \cdot (5867 - p_a) - 0,0014M \times (34 - T_a) \\ & - 3,96 \cdot 10^{-8}f_{cl}((T_{cl} + 273)^4 - (MRT + 273)^4)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

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



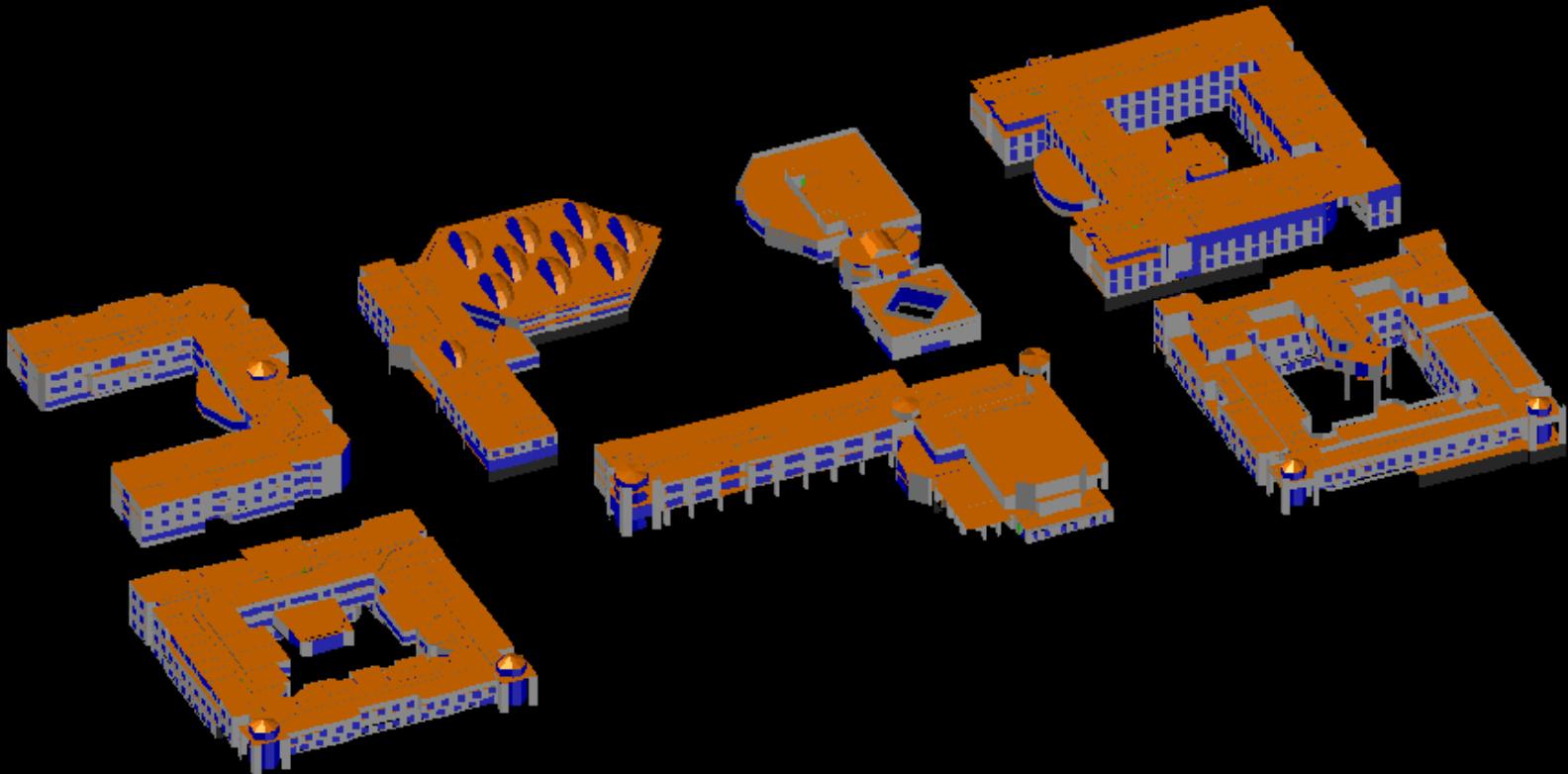
Predicted Mean Vote and Predicted Percentage of Dissatisfied People.

# NUMERICAL METHODOLOGY



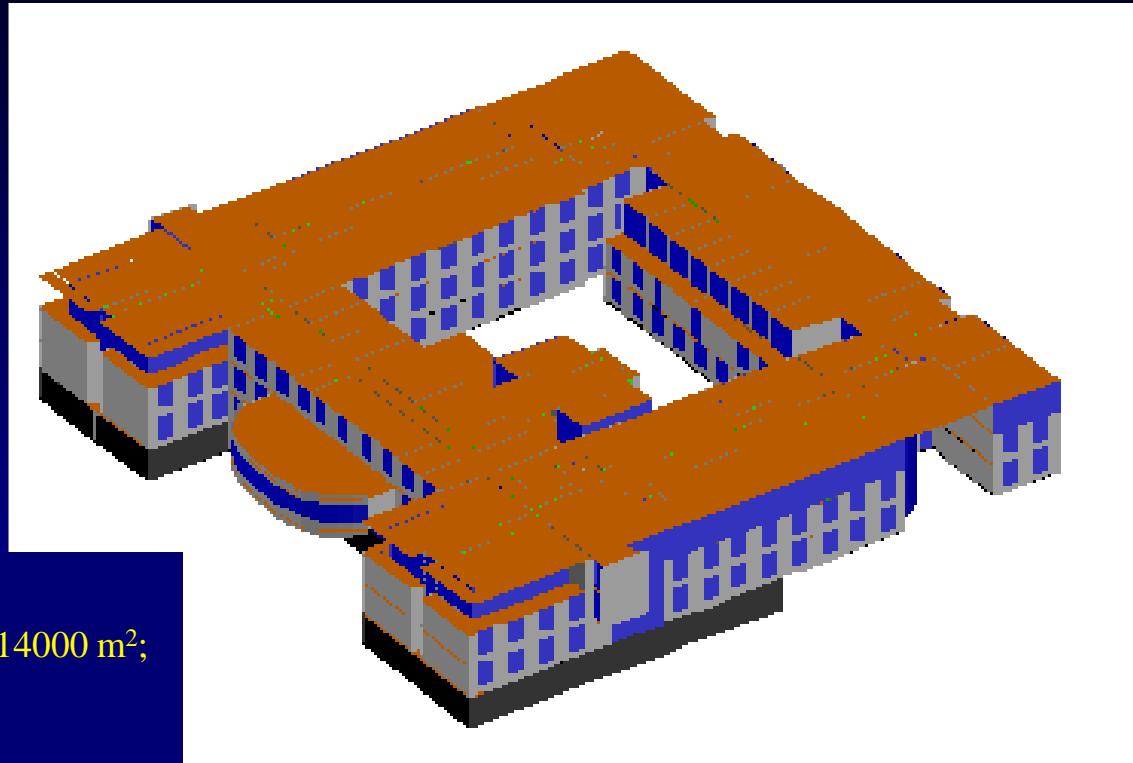
Campus da Penha, Faro.

# NUMERICAL METHODOLOGY



Campus de Gambelas, Faro.

# NUMERICAL METHODOLOGY



## Constitution:

- 4 floors with an area of 14000 m<sup>2</sup>;
- 344 compartments;
- 171 compartment equipped with HVAC systems (occupied spaces).

University building identification (Campus de Gambelas, Faro).

# NUMERICAL METHODOLOGY

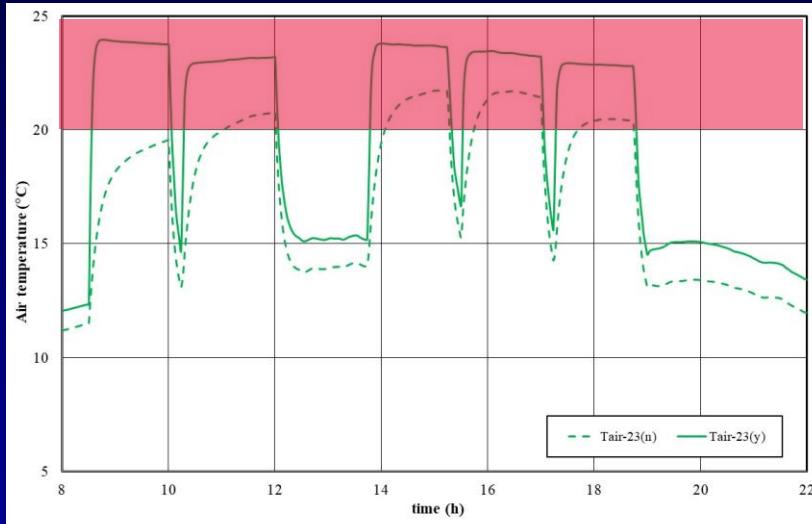
- Winter and Summer conditions.
- Activity level: 1.2 met.
- Clothing level: 0.5 clo (summer) e 1 clo (winter).
- Occupation cycle (number of occupants per room during each time period):

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	115:15 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

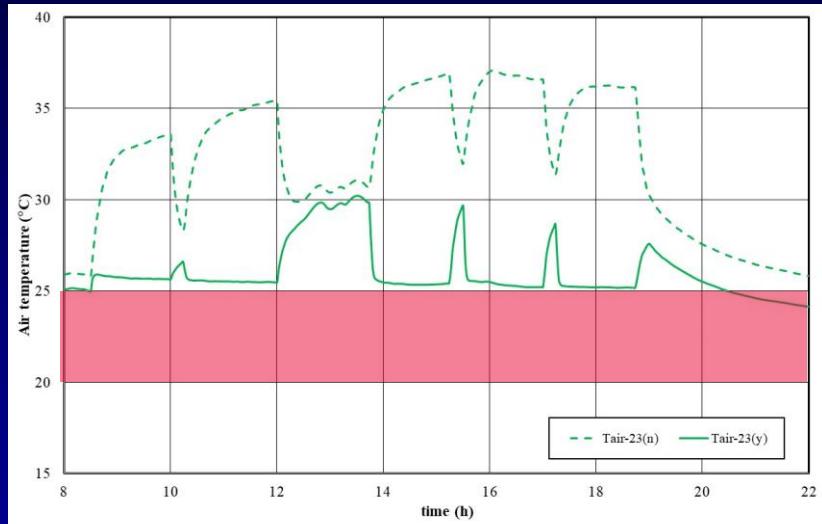
Input data.

# RESULTS

## Winter conditions



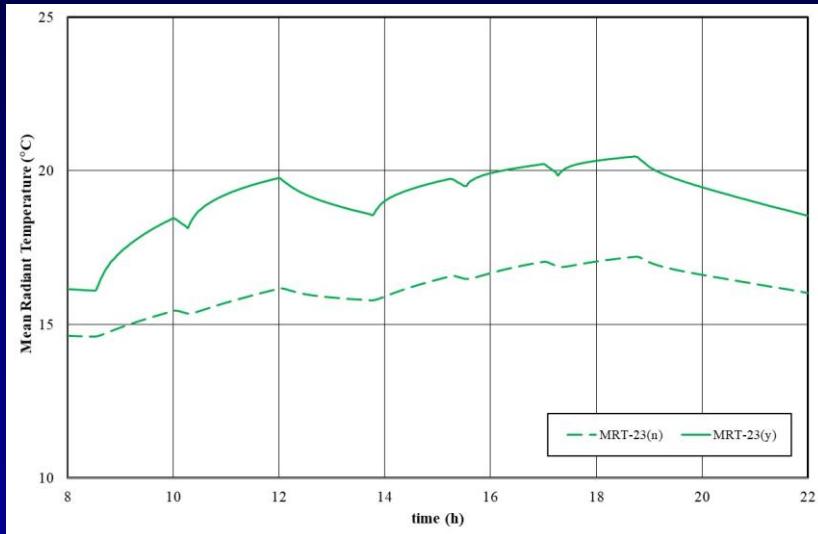
## Summer conditions



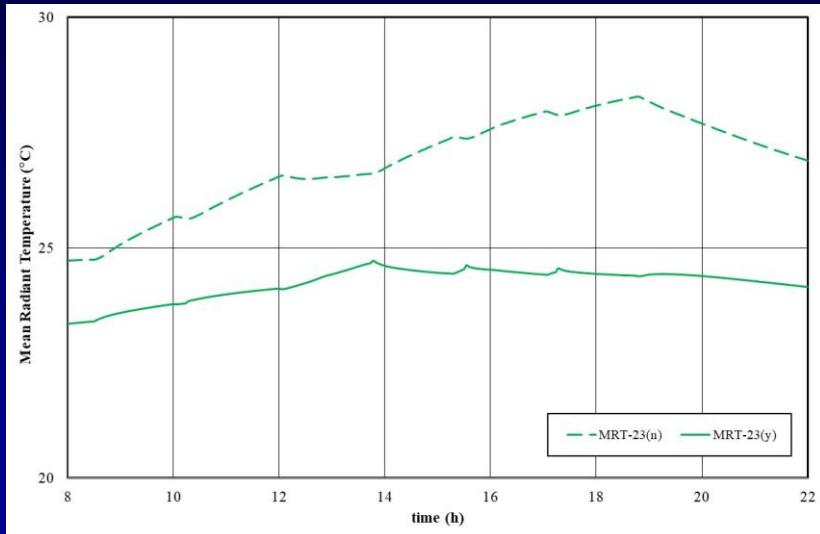
Evolution of indoor air temperature,  $\text{T}_{\text{air}}$ , with and without HVAC system.

# RESULTS

## Winter conditions



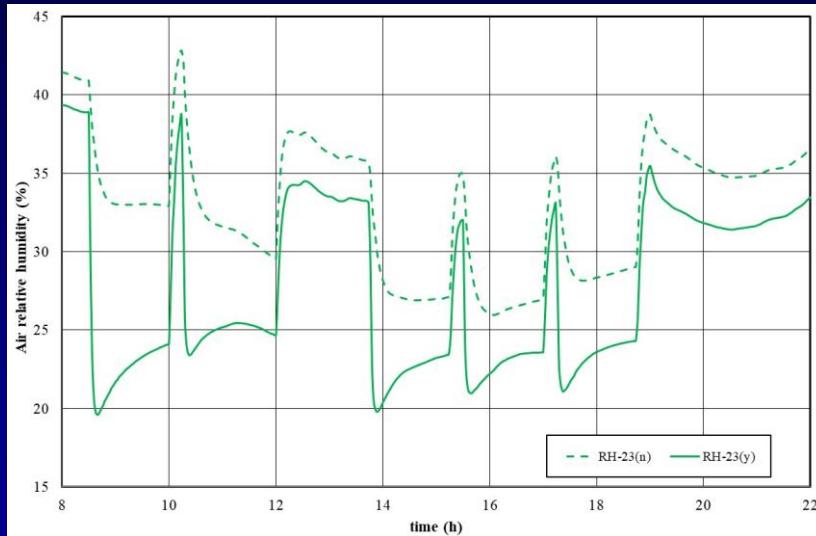
## Summer conditions



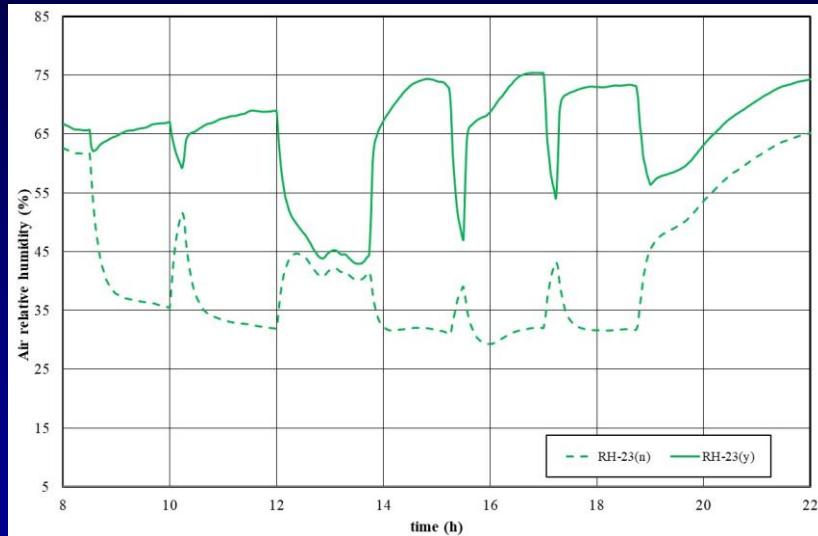
Evolution of mean radiant temperature, MRT, with and without HVAC system.

# RESULTS

## Winter conditions



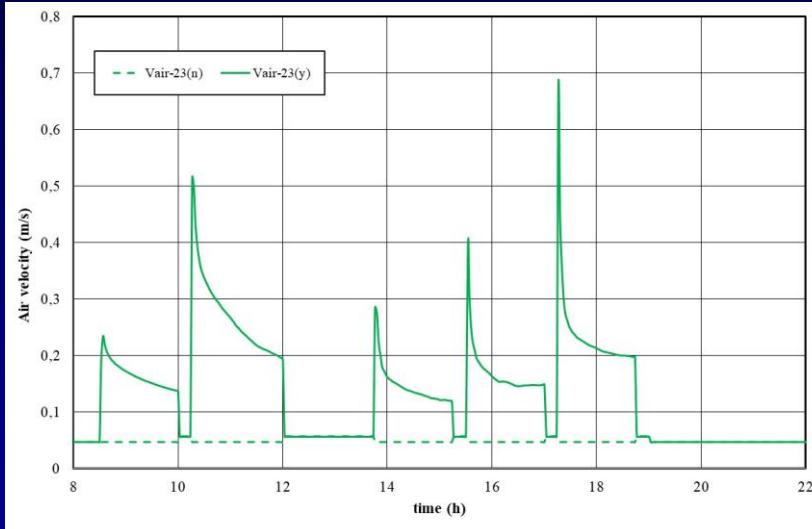
## Summer conditions



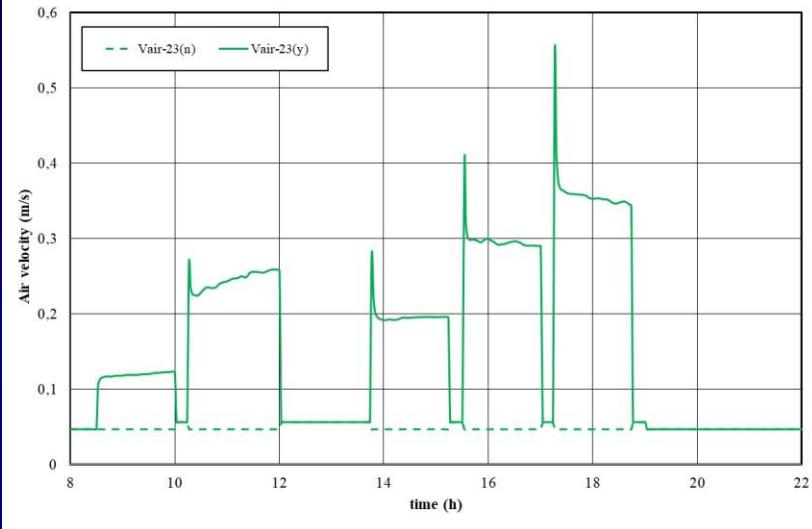
Evolution of air relative humidity, RH, with and without HVAC system.

# RESULTS

## Winter conditions



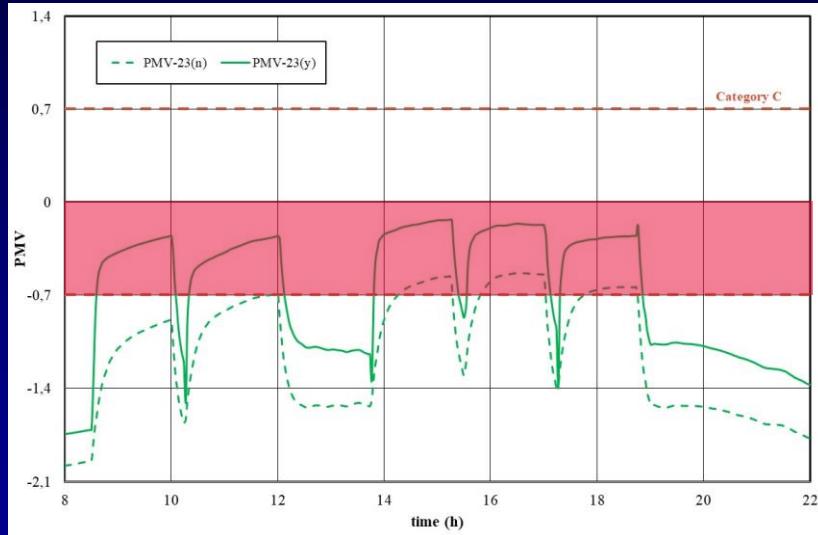
## Summer conditions



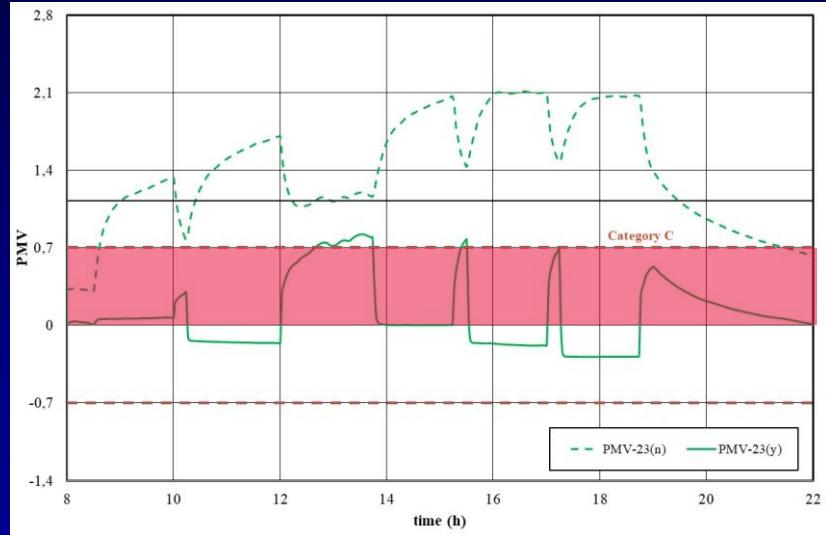
Evolution of air velocity, Vair, with HVAC system.

# RESULTS

## Winter conditions



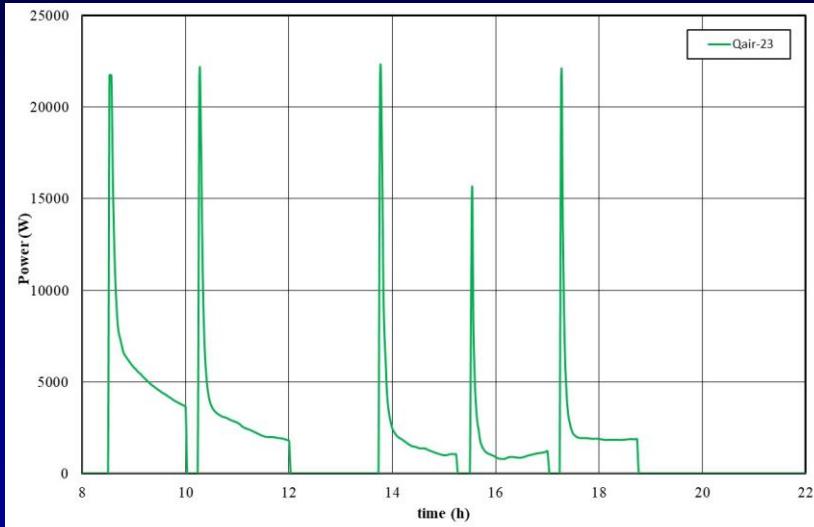
## Summer conditions



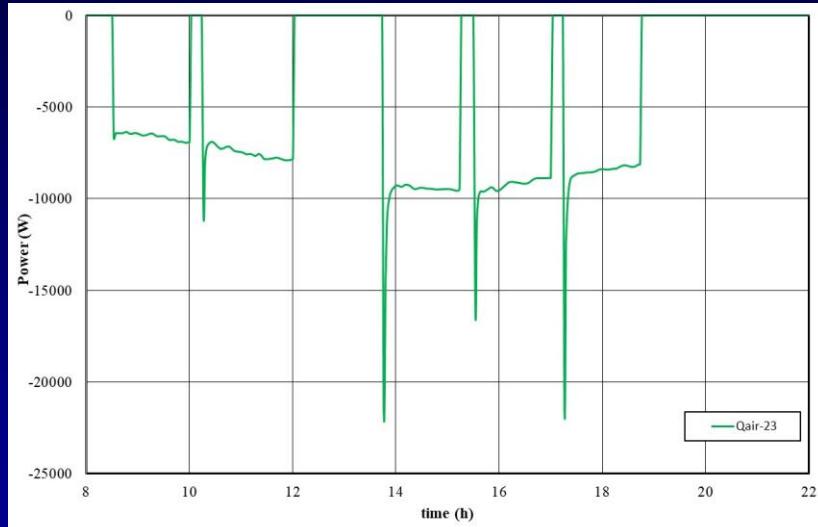
Evolution of PMV index with and without HVAC system.

# 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.