Energy and Comfort in School Buildings in the South of Portugal

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OBJECTIVES

- Application of a numerical model, in transient conditions, for Summer and Winter conditions.
- Evaluation of building solar radiation and internal environments variables.
- Application of a HVAC System with control based in the Human Thermo-Phisiology.

OBJECTIVES – SOFTWARE (Virtual)

- Module 1 - Buildings thermal response
- Module 2 - Human Thermal Response
- Module 3 - Evaluation of Thermal Comfort
- Module 4 - Flows inside the ducts
- Module 5 - CFD inside the compartments
- Module 6 - Evaluation of air quality
- Module 7 - Response human mechanical
- Module 8 - Acoustic (...)
- Module 9 - Lighting (...)

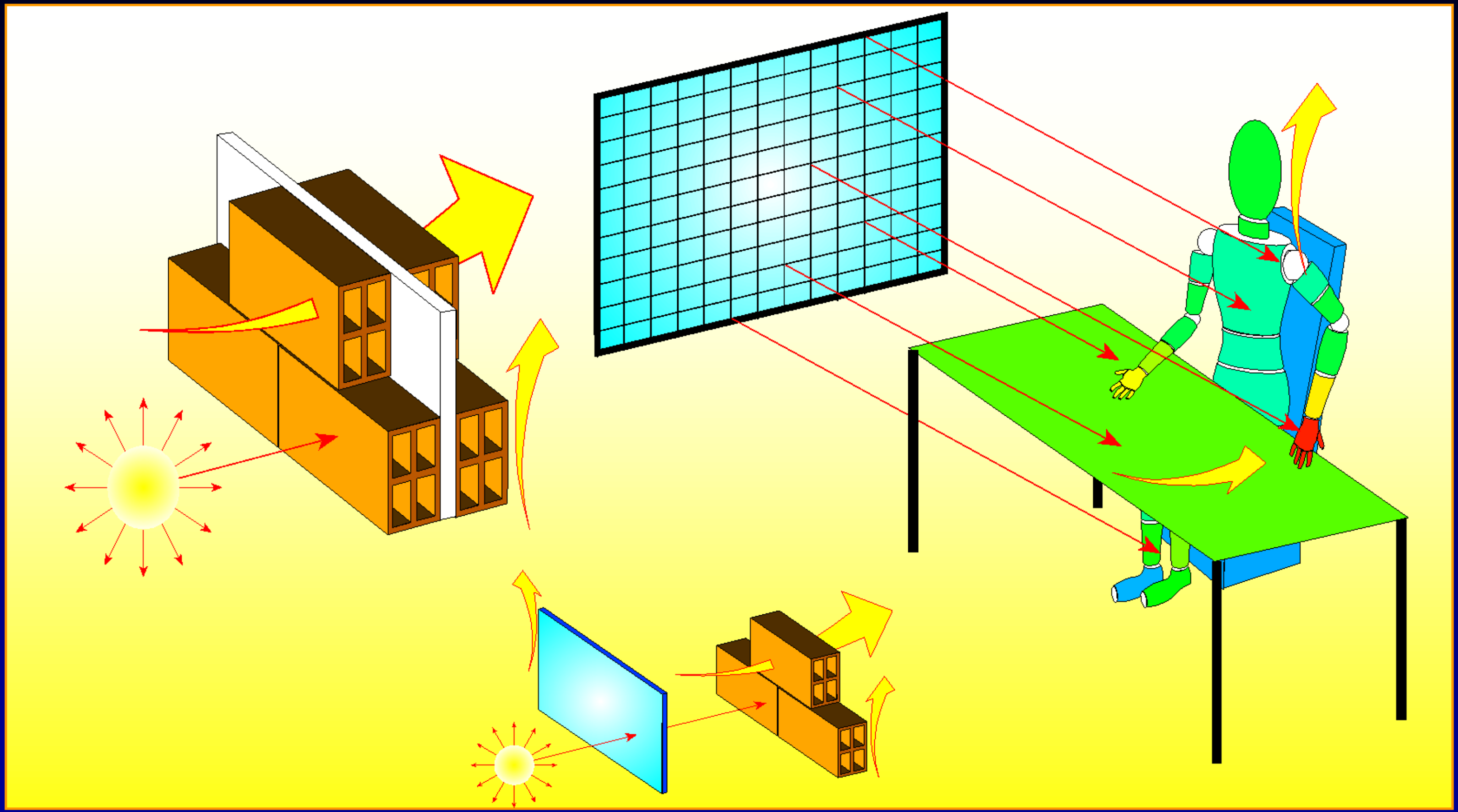
MATHEMATICAL MODEL

- BUILDING THERMAL RESPONSE
- Energy balance integral equations for:
  - air inside spaces and ducts;
  - windows glasses and interior bodies;
  - main bodies and ducts layers.
- Mass balance integral equations for:
  - water vapor and gases inside the spaces;
  - water vapor in building surfaces.
- Runge-Kutta-Fehlberg method

OUTPUT DATA

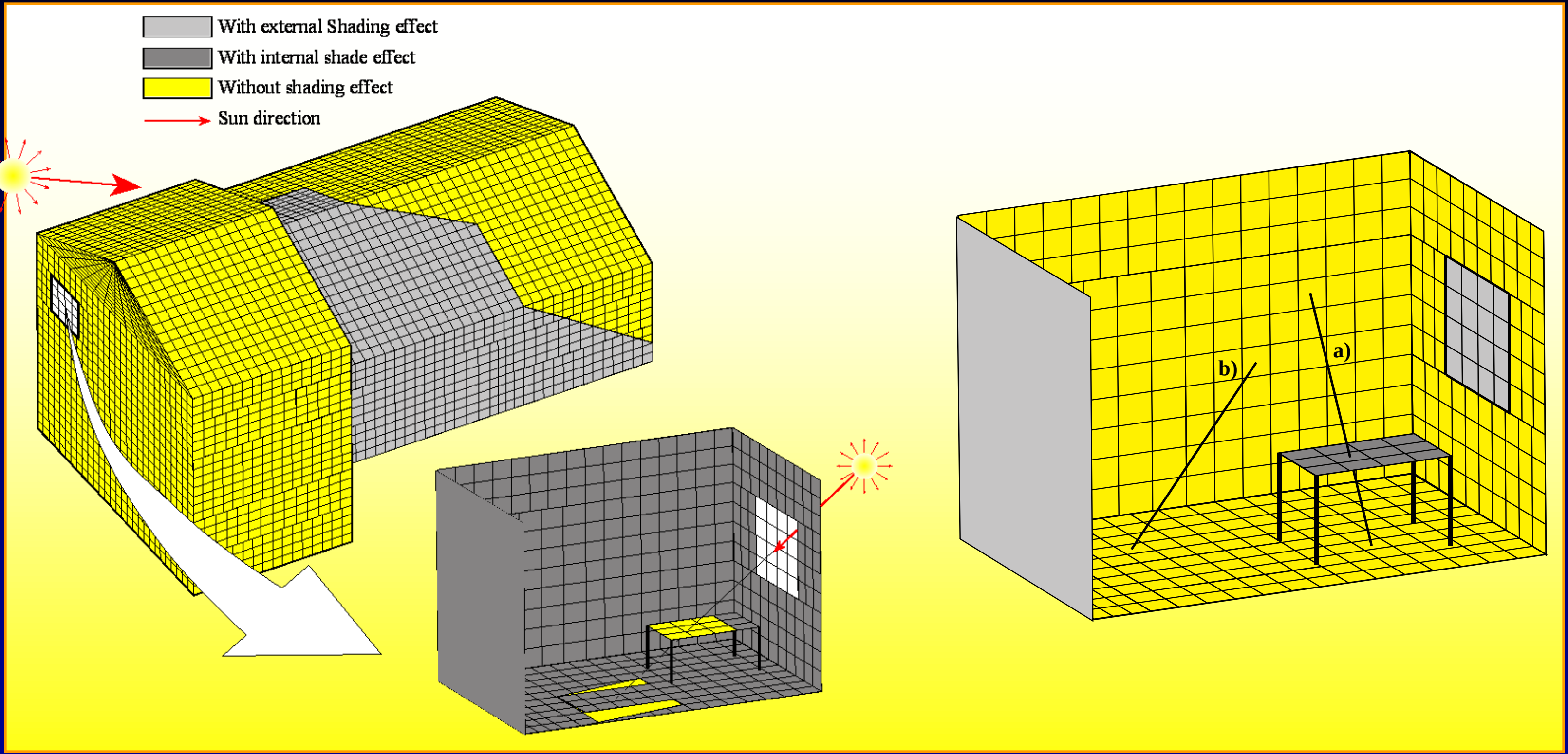
- The air temperature values;
- The opaque and transparent building temperature;
- The air water vapor and other gases mass;
- The building surface water vapor mass;
- The air relative humidity;
- The air velocity;
- , The radiant mean temperature;
- The air quality;
- The thermal comfort.

HEAT AND MASS EXCHANGE PHENOMENA



Convection, Conduction (main bodies), Heat Load (HVAC, human...), Mass Transfer (renovation, transpiration, respiration) and Radiation.

RADIATIVE PHENOMENA



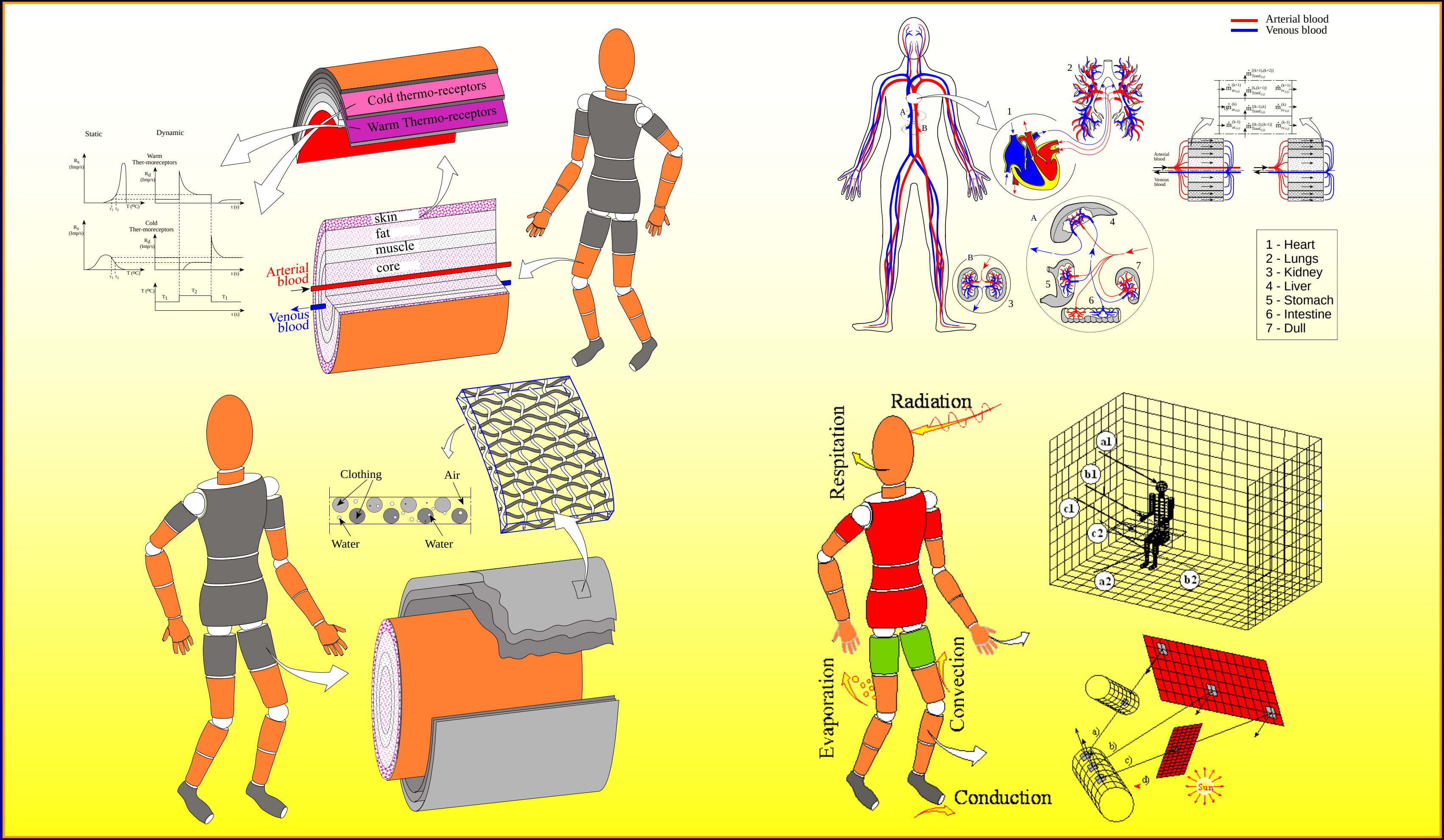
Short-wave radiation (Solar)

Distribution in external and internal surfaces (main and interior bodies and windows).

Long-wave radiation (diffuse)

Heat exchanges in external and internal surfaces.
Radiosity method / view factors.

VIRTUAL OCCUPATION

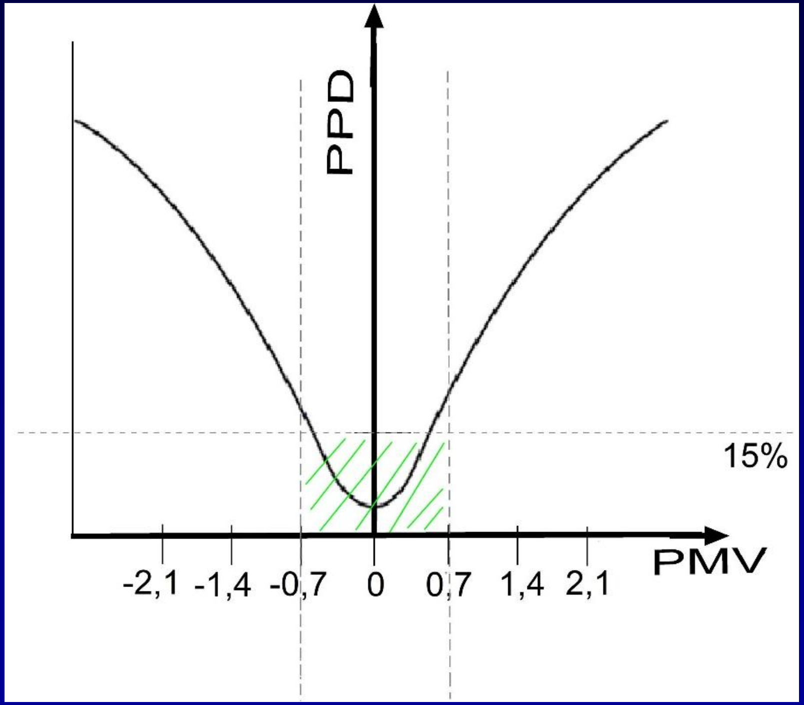


Human body divided in 35 elements and each one divided 12 layers.
Arterials, veins, capillaries and clothing.

Predicted Mean Vote

PMV=$f(Tar, Var, TMR, RH, clo, met)$

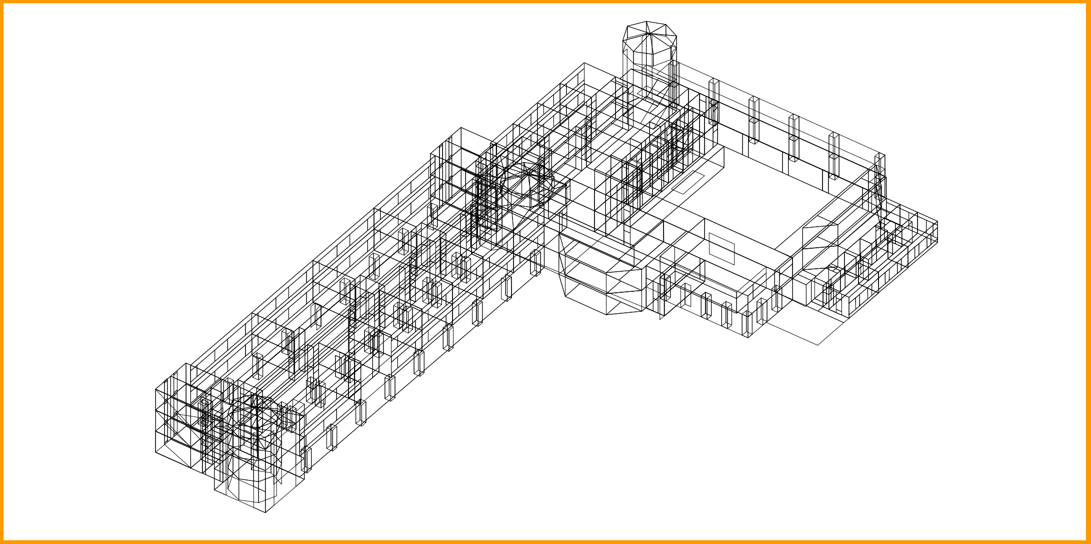
PMV: Predicted Mean Vote
PPD: Percentage of Dissatisfied People



Thermal sensation scale

-3= cold
-2= cool
-1= slightly cool
0= neutral
+1= slightly warm
+2= warm
+3= hot

VIRTUAL BUILDING



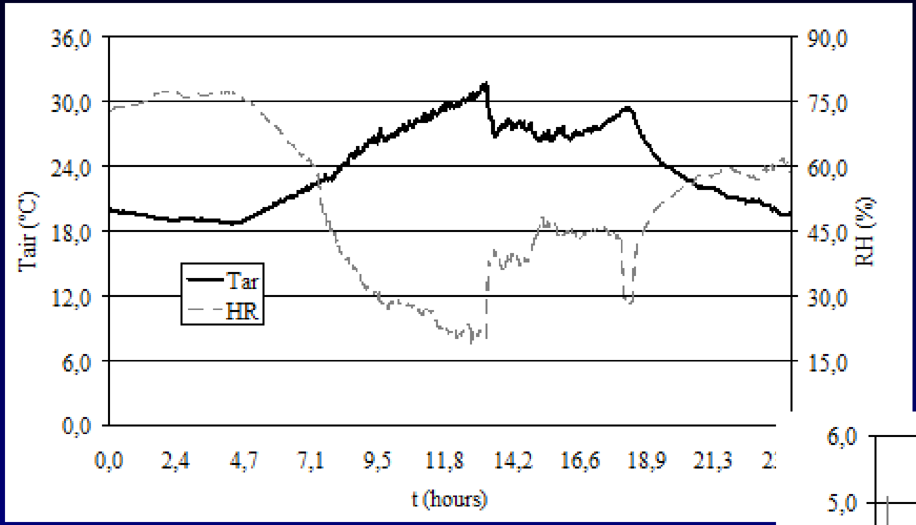
The study was made in summer and in winter conditions.

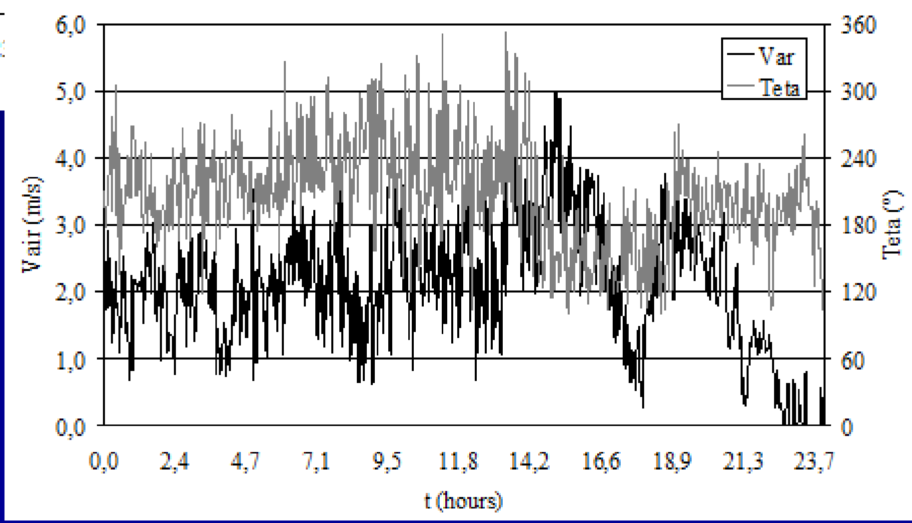
The airflow rate was considered.

The building, with three floors, is divided in 110 spaces, 122 transparent bodies (windows) and 1516 opaque bodies (interior and exterior walls, floors, roof and doors).

University building scheme and the discretization spaces.

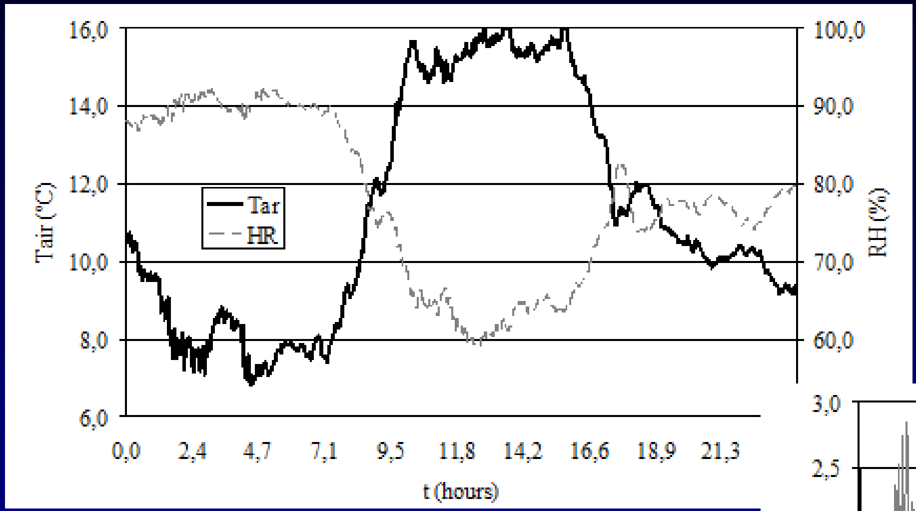
INPUT DATA

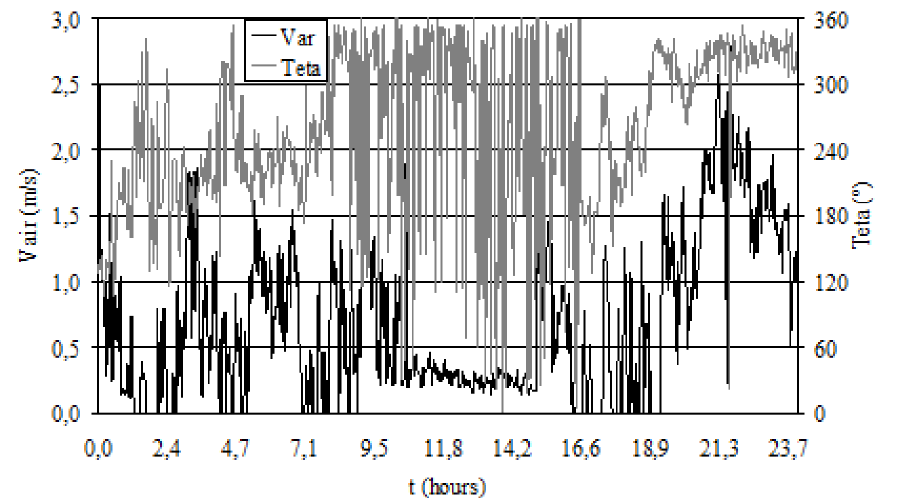




Measured outdoor air temperature, air relative humidity, air velocity and wind direction, for a typical summer day.

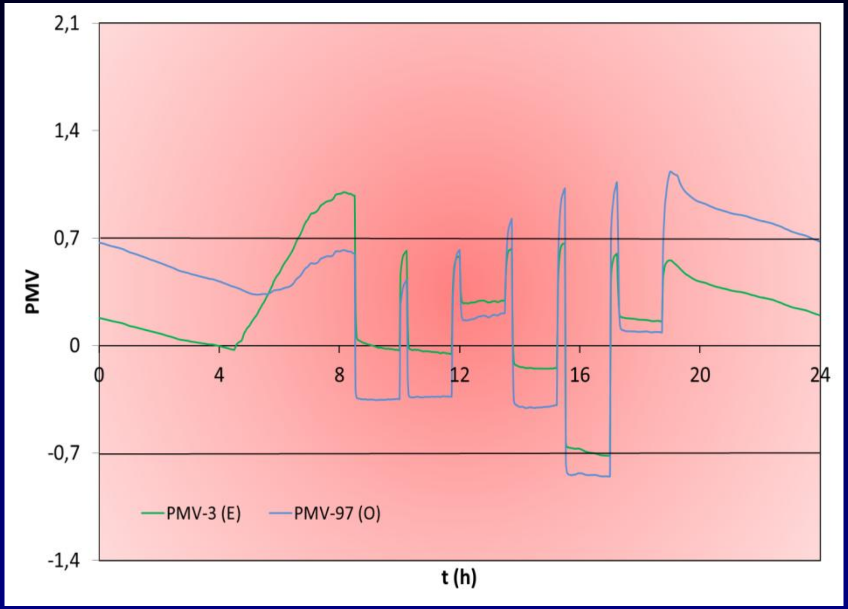
INPUT DATA



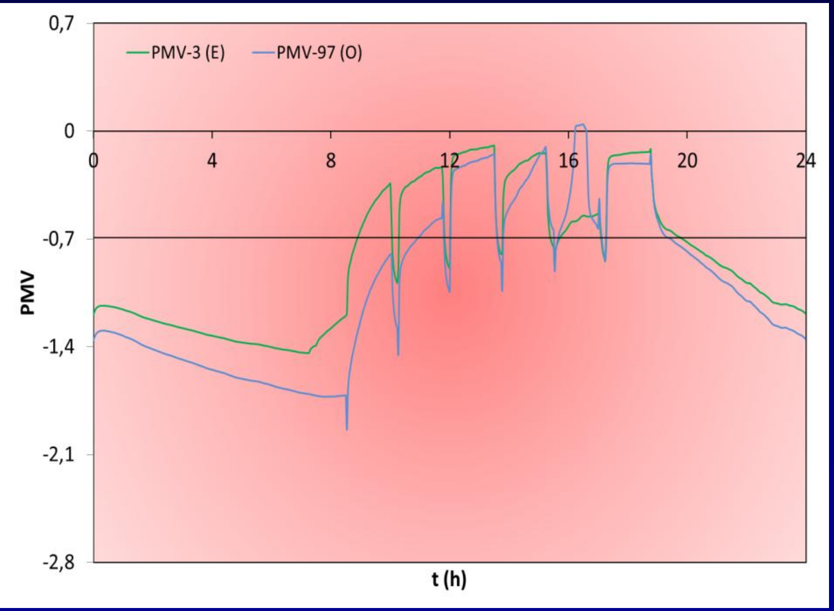


Measured outdoor air temperature, air relative humidity, air velocity and wind direction, for a typical winter day.

RESULTS – PMV in classrooms



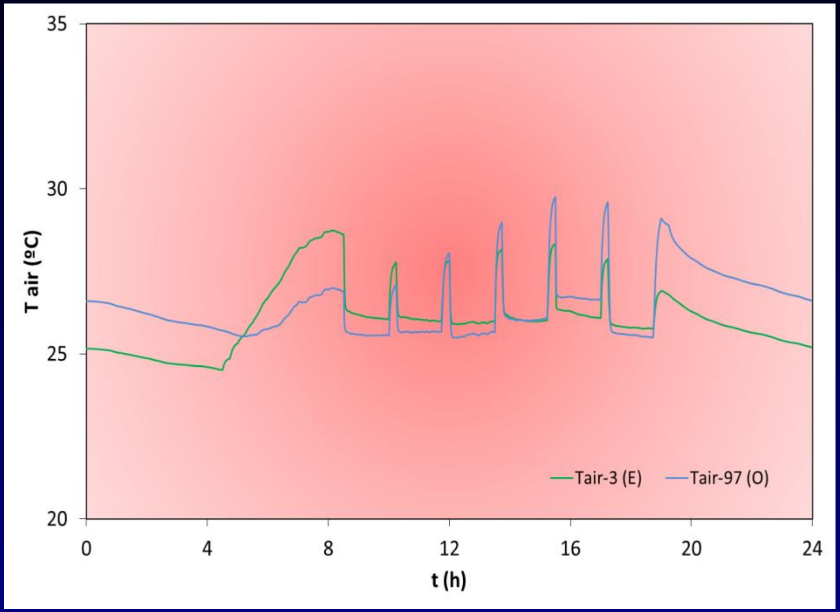
a)



b)

Evolution of the thermal comfort index (PMV) in classrooms with windows facing East (E) and West (O), in a) summer conditions and in b) winter conditions.

RESULTS – Indoor air temperature in classrooms



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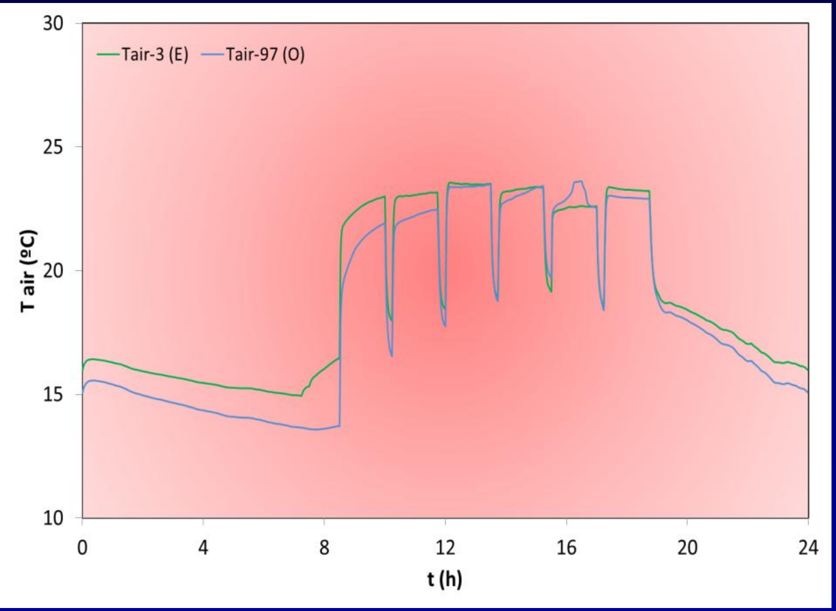
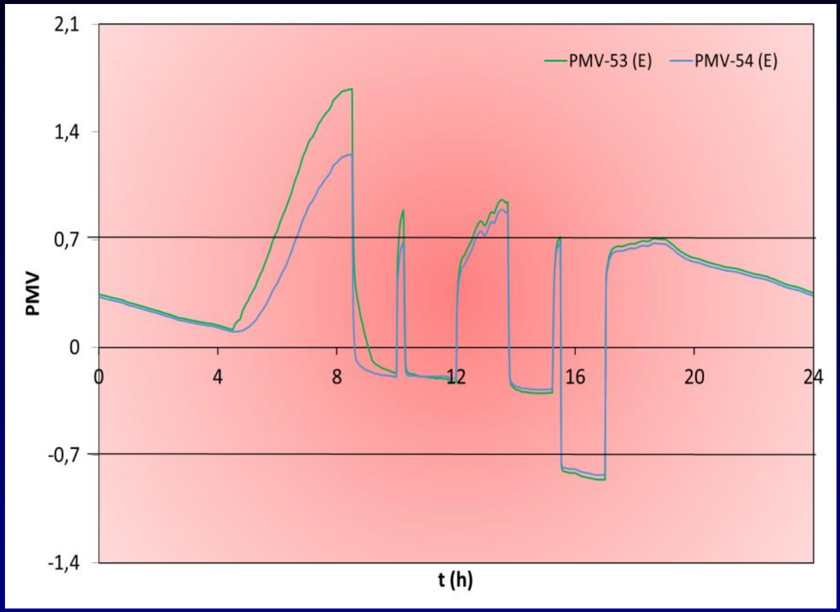


b)

Evolution of the air temperature (Tair) in classrooms with windows facing East (E) and West (O), in a) summer conditions and in b) winter conditions.

RESULTS – PMV in offices



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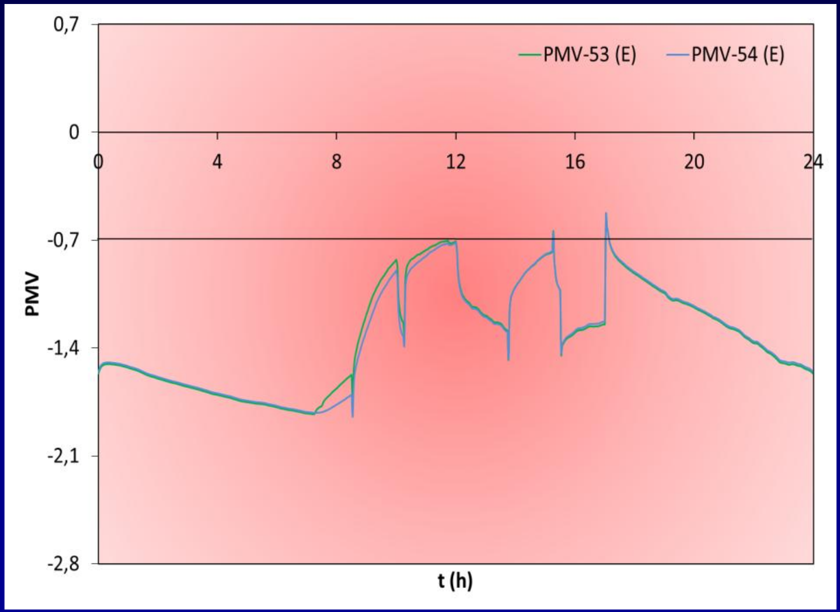
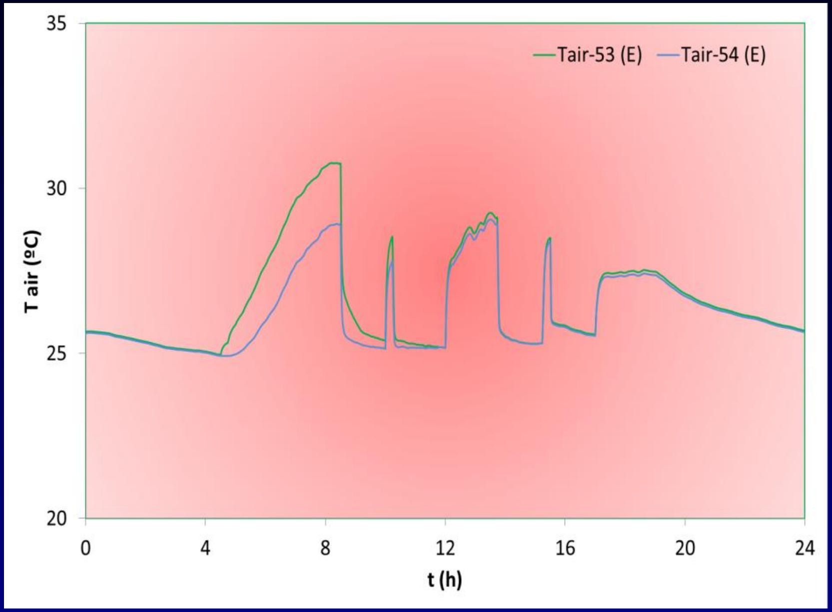


b)

Evolution of the thermal comfort index (PMV) in offices with windows facing East (E), in a) summer conditions and in b) winter conditions.

RESULTS – Indoor air temperature in offices



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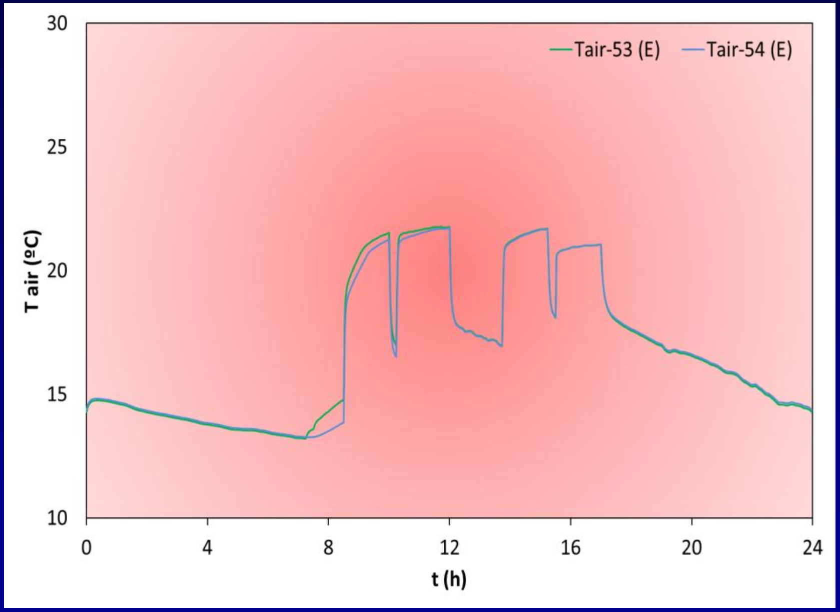

b)

Evolution of the air temperature (Tair) in offices with windows facing East (E), in a) summer conditions and in b) winter conditions.

CONCLUSIONS

- The thermal comfort has acceptable values according to category C. However, in many situations, this level is in accordance with category B or even category A.
- In order to improve the performance of HVAC systems with minor fluctuations and lower levels of energy consumption, it is suggested in future works to develop alternative PMV control algorithms.
- In future works, the geothermal and solar radiation energy sources with PMV control will also be developed.