BuildSim-Nordic 2017

Lund university

PV-PCM Integration in Glazed Building. Genetic Optimization Study

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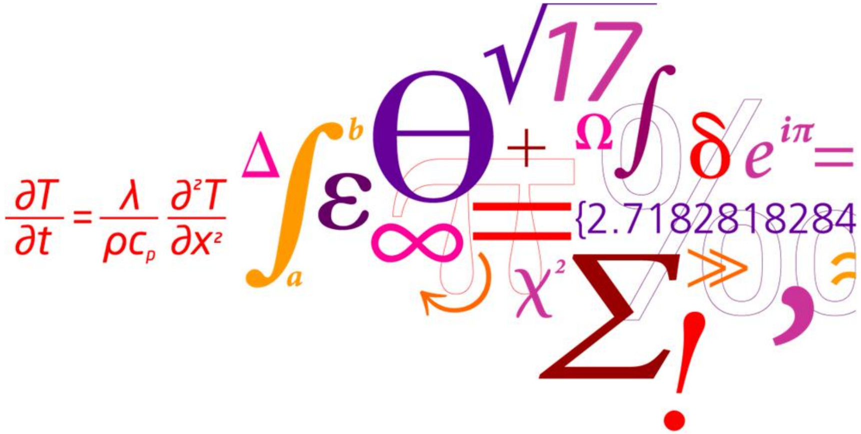
PostDoc



DTU Byg

Institut for Byggeri og Anlæg

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Outlines

- Integration PV-PCM Module inside a forced ventilated façade cavity.
  - ❖ PCM thermal and optical numerical simulation
  - ❖ Numerical transient model of a fixed nodal grid through MATLAB
  - ❖ Link the external façade to an office room built on TRNSYS

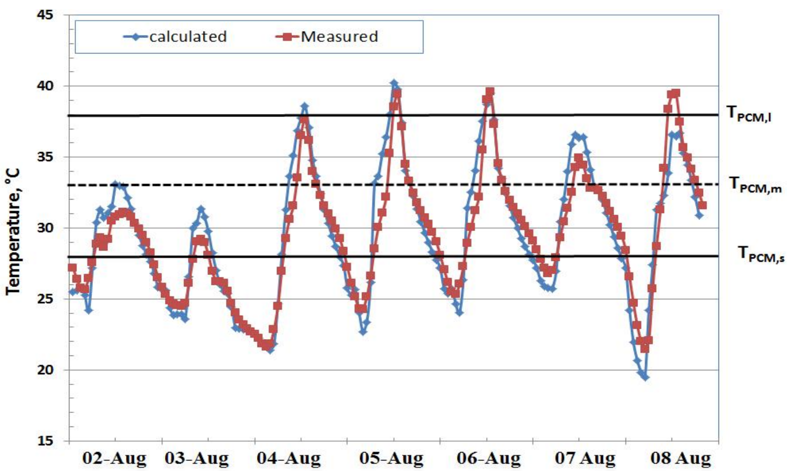
- The model has taken a step forward by implementing a multiple objectives genetic optimization algorithm.

- Overall energy performance and inside temperature deviation have been evaluated through the optimization algorithm.

PCM Numerical simulation

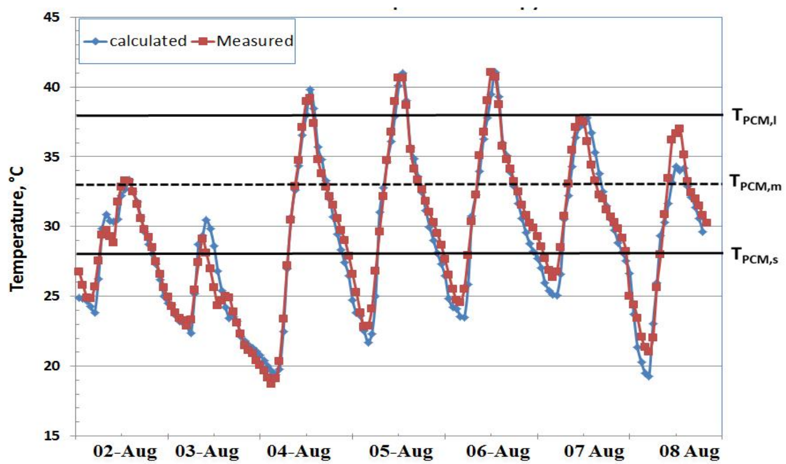
Enthalpy Method

This method was proposed by Voller and Swaminathan [1992] , its key feature to assume that phase change occurs over an arbitrarily thin temperature range. In this way the enthalpy can related to the temperature by a piecewise continuous function.



(a)

RMSE=1.7℃



(b)

RMSE=2℃

Numerical Model validation, calculated Vs measured ,(a) Inner glass surface, (b) Outer glass surface

Optical analysis aspect:

The PCM has a variable optical characteristics nature depending on the current physical status of the material.

When the PCM is in solid state, the dominant transmission mode is direct-to-diffuse and the scattering effect is prominent while in liquid phase, as the transparency increases,direct-to-direct transmission takes place. (Goia et al., 2015)

Glazed PCM Window , taken By F.Goia

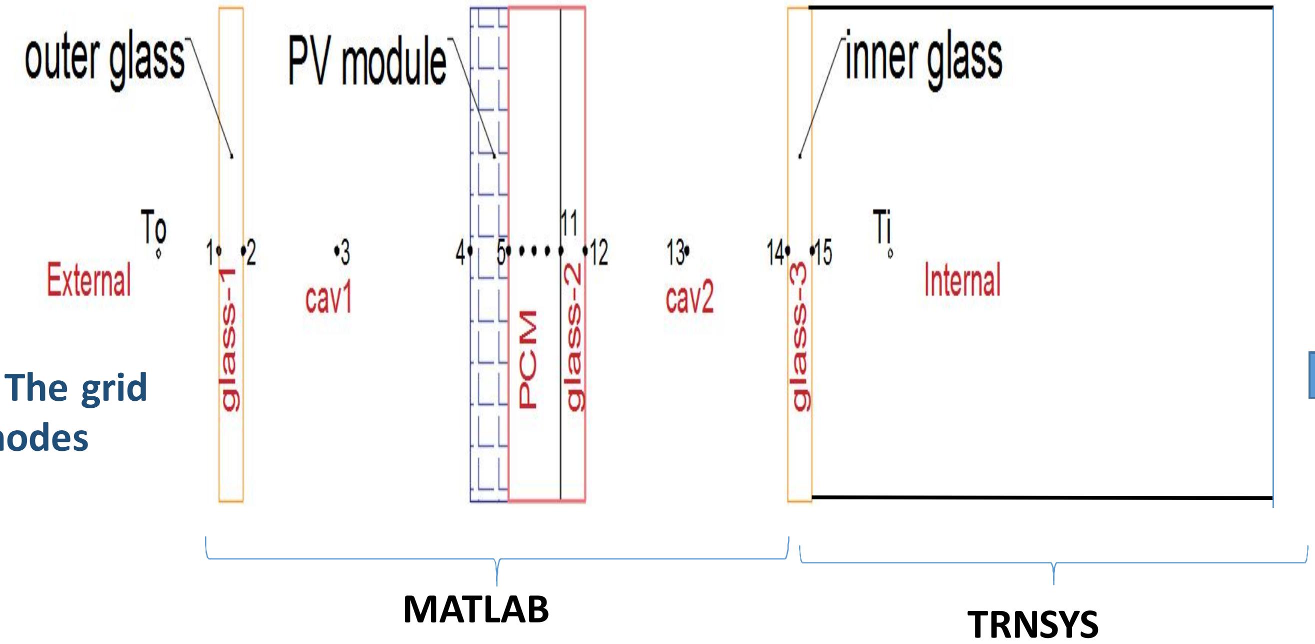
The solution is to correlate the PCM optical characterstics to the PCM nodal temperature.

Elarga H , Zarrella A, Francesco Goia, Andrea Dal Monte ,Ernesto Benini. Thermal and electrical performance of an integerated PV-PCM system in double skin facades. A numerical study. **Solar energy Journal (2016).**

PV/PCM Model Application

Link external PVPCM façade to an office room built on TRNSYS (type 56)

FDM, dynamic model. The grid consists of 15 thermal nodes

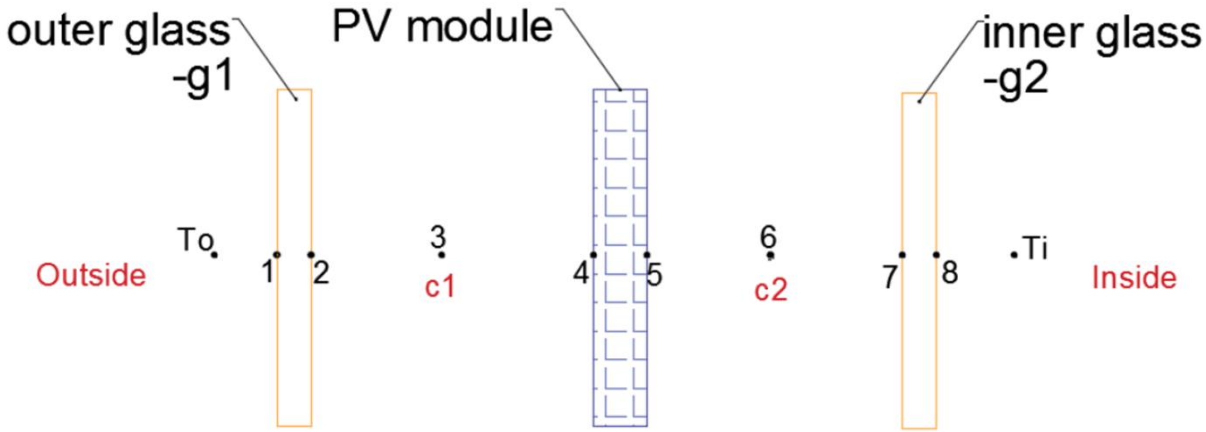


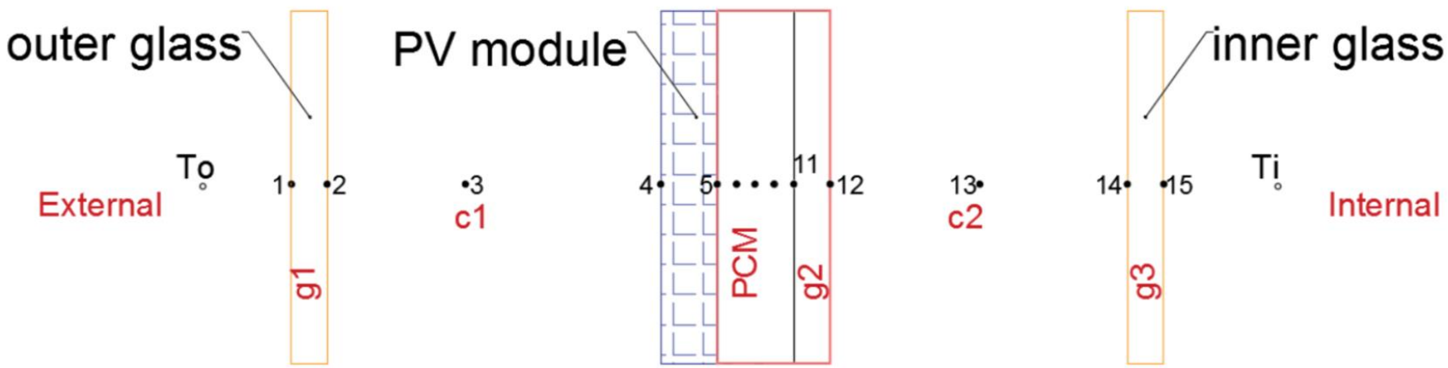
Optimization Algorithm

Elarga H , Zarrella A, Goia F, Dal Monte A , Benini E. Thermal and electrical performance of an integerated PV-PCM system in double skin facades. A numerical study. **Solar energy Journal (2016).**

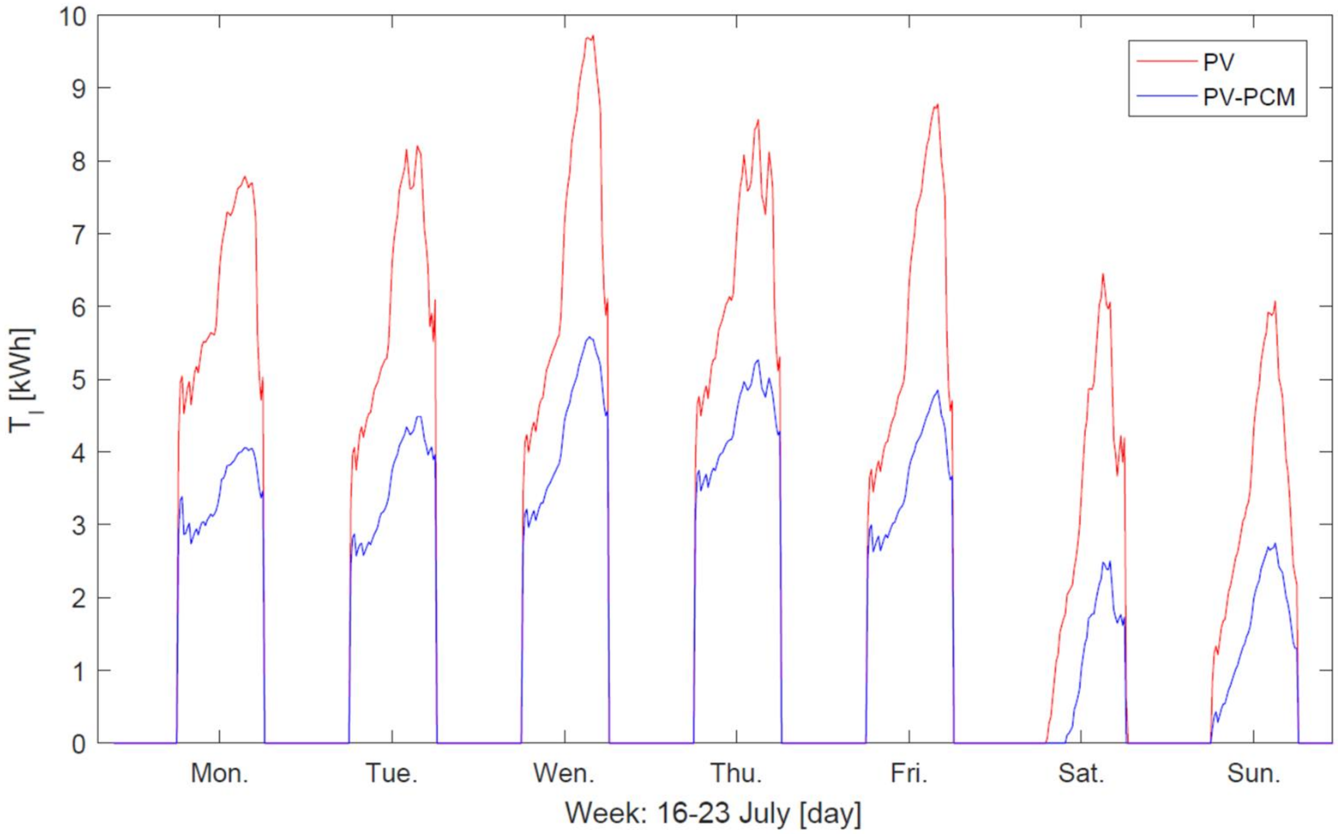
Elarga H , Goia F, Benini E. PV-PCM integration in glazed buildings. Numerical study through MATLAB/TRNSYS linked model. **Building simulation application Conferecne, Bolzano/Italy (2017).**

Exploratory case

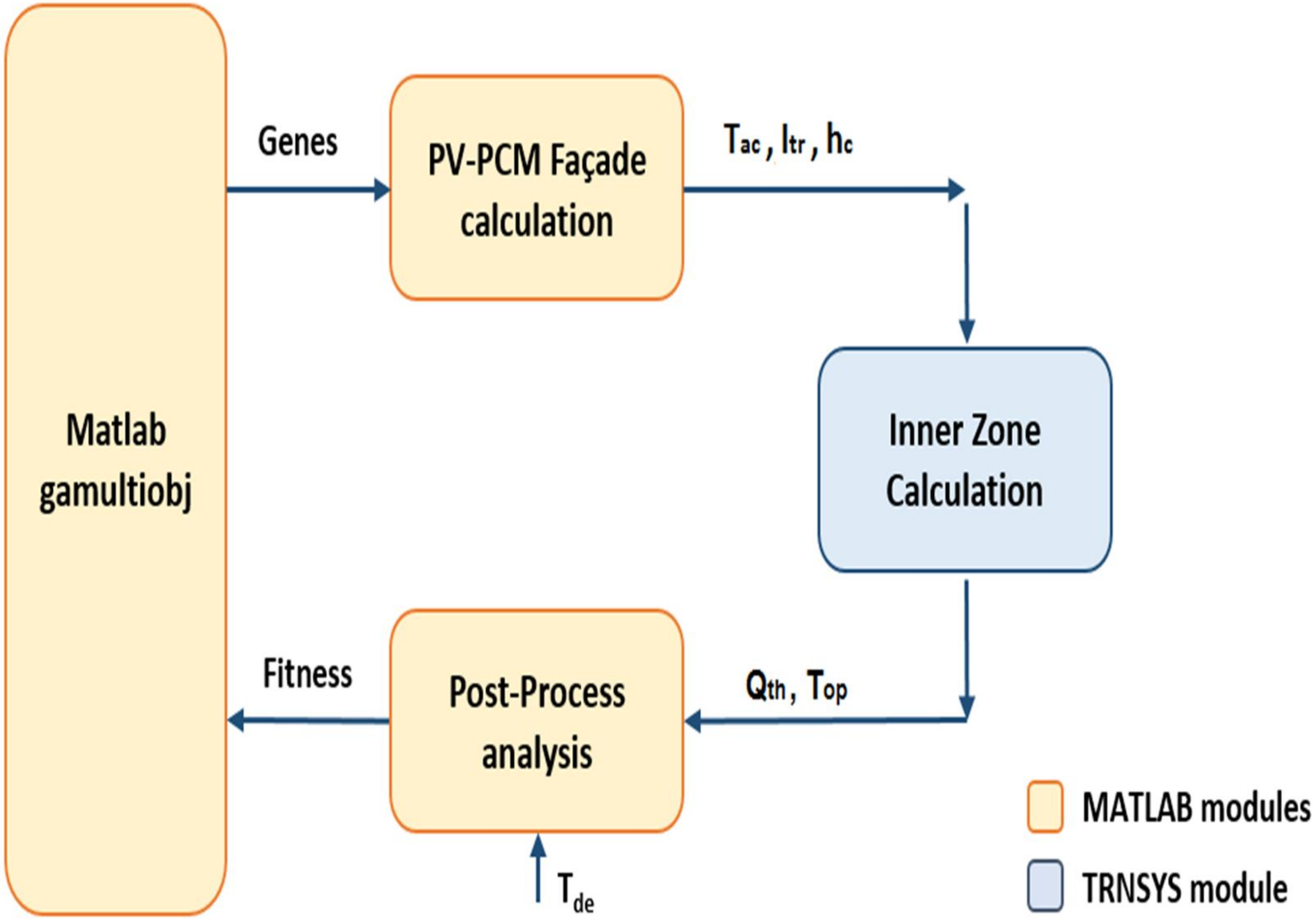




Cooling thermal loads comparison



GA-TRNSYS SCHEME



<u>Multi objectives genetic algorithm to optimize:</u>

- Thermal energy loads
- Deviation between operating and design temperatures for each time step.

<u>Variables are:</u>

Mass flow rate of cavity 1 and cavity 2
Ventilation starting time and intervals through winter, summer and heating seasons.

<u>The optimization algorithm is:</u>

Implemented in Matlab, its name is GA MULTI OBJECTIVE ,based on NSGH2

Genetic Algorithm

P1 | P2 | P3 | P4

Gene

Chromosome

Initial set of Individual

Population of Individuals

Evaluate Fitness of each individual

Ranking and Select Parents(SURVIVORS)

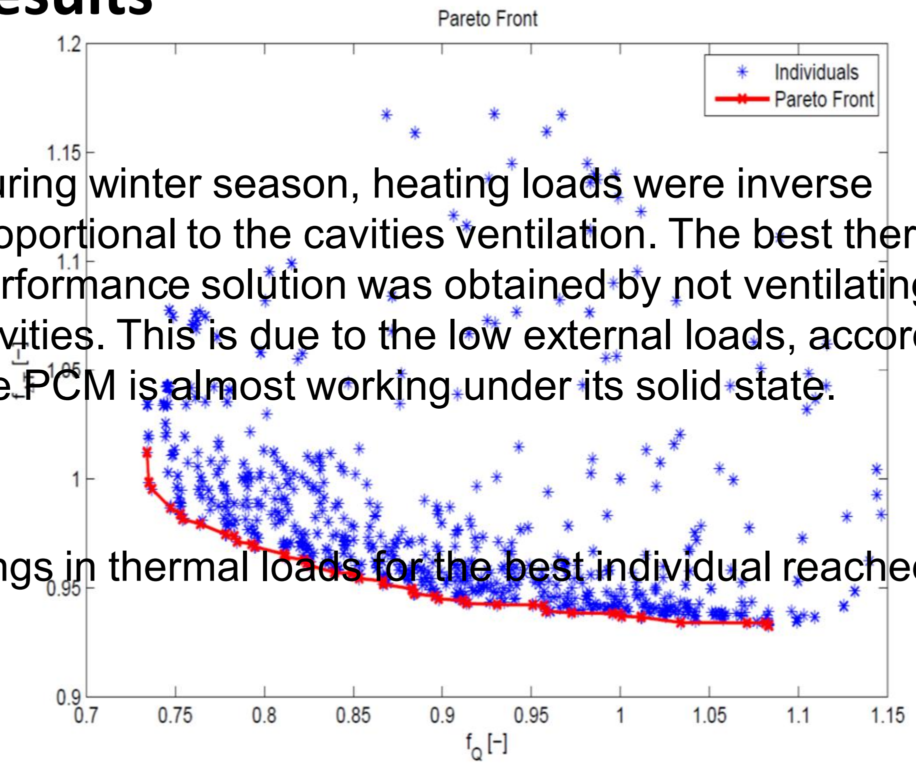
Create new Population

Iterative loop till constrains are obtained

Constrains:

- mc1+mc2 < 20 L/s per façade meter

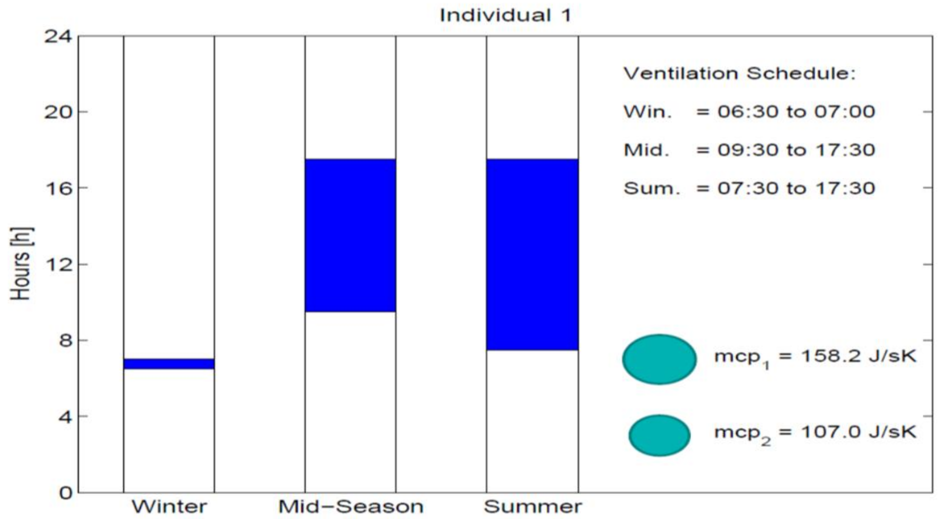
Results

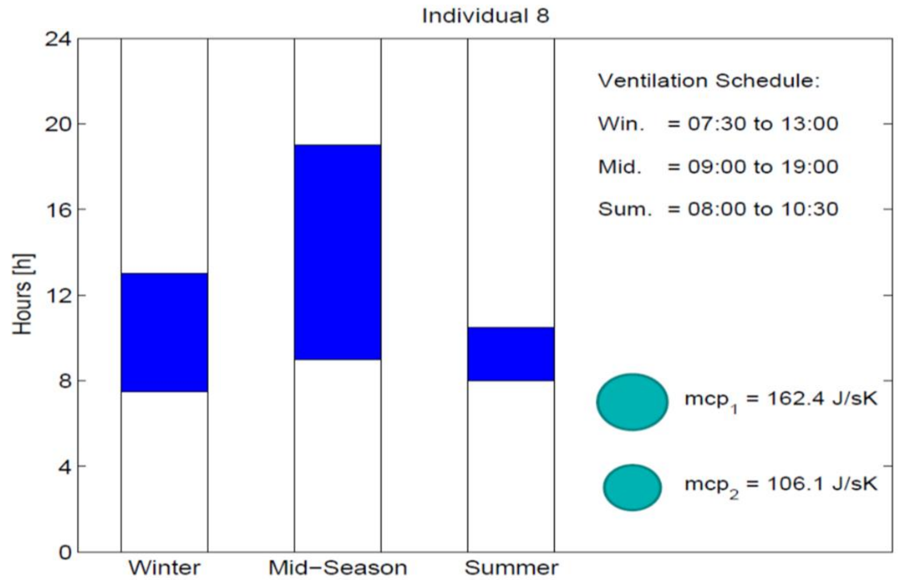


During winter season, heating loads were inverse proportional to the cavities ventilation. The best thermal performance solution was obtained by not ventilating the cavities. This is due to the low external loads, accordingly the PCM is almost working under its solid state.

Savings in thermal loads for the best individual reached 27%.

Thermal loads are proportional to ventilation starting hour and duration, especially during the Summer season. When the duration dropped below 7 hours, the required thermal loads started to increase. High solar radiation, intensity and external temperature need the ventilation system to support the PCM solidification process.





Conclusions

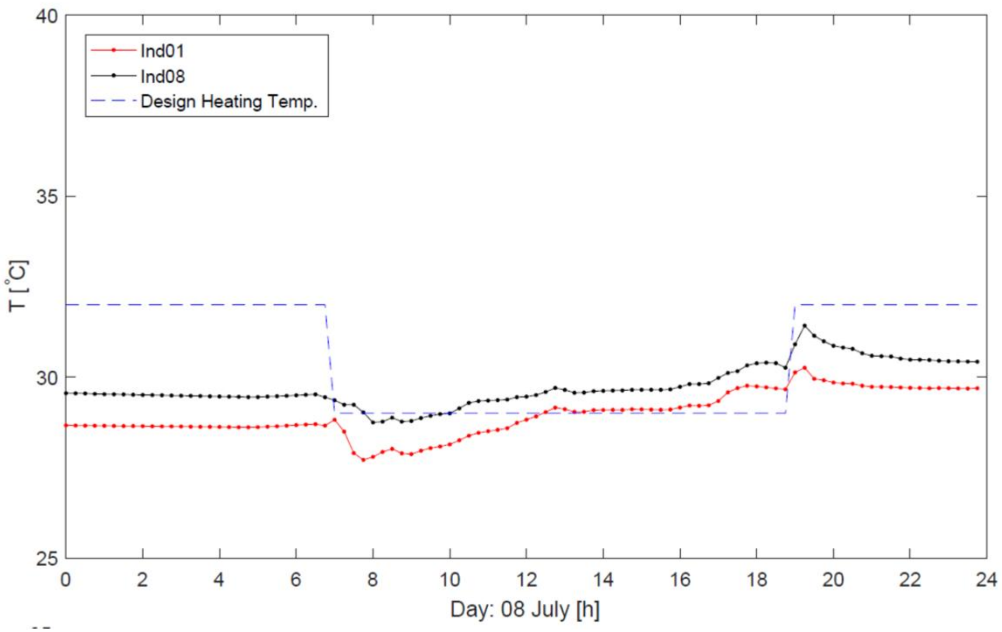
- The results demonstrates how both the schedule of ventilation and air flow rates represent key parameters for the optimization.

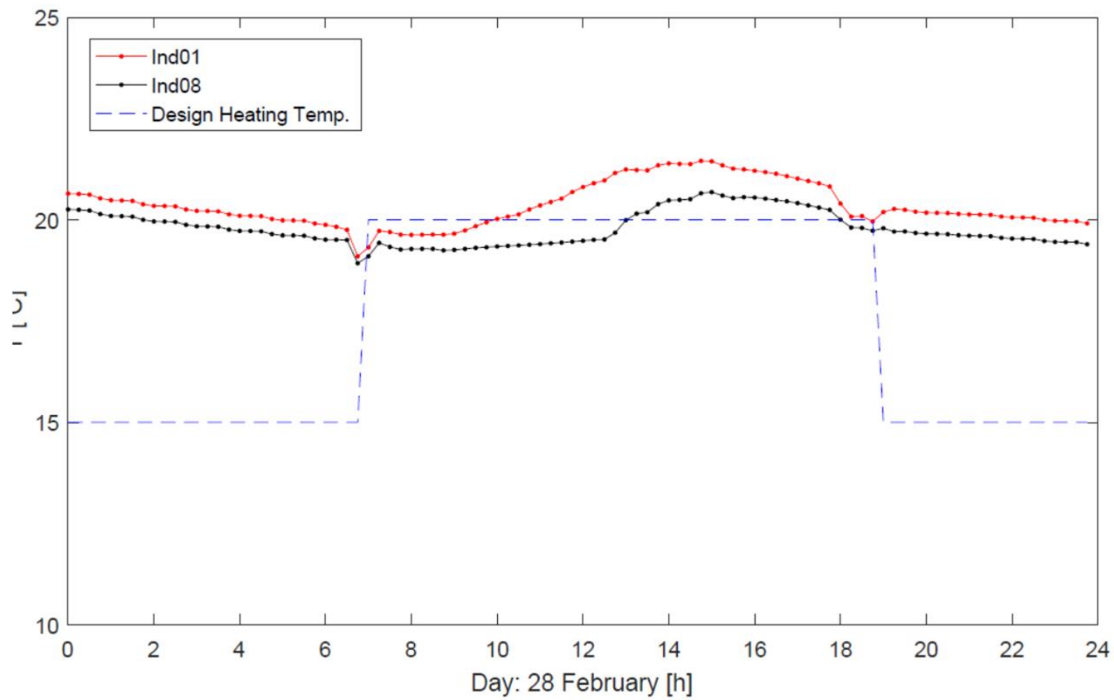
- The positive influence of ventilating cavity c1 is higher on the required thermal loads in comparing to cavity c2. The ventilation flow rate of cavity c2 is almost constant and equal to 4 to 5 L/s per facade meter in all seasons while in cavity c1 it ranged between 6 to 8 L/s per facade meter. This indicates that higher flow rates implemented to cool the PV surface is improving the overall energy balance of the inner zone.

- The PCM type has to be properly selected to suit the boundary conditions of each case under investigation.

Thanks for your attention

Results





On the other hand, the second fitness function concluded in the difference between design and the operating inside temperatures has a different trend. This temperature difference is inverse proportional to the cavities ventilation duration. In the summer season; not ventilating the cavity is delaying the PCM solidification phase. Thus, the PCM latent heat storage capability, which produce a more flatter temperature profile, is in its minimum level
i.e. specific heat capacity is $2kJ(kgK)^{-1}$