Thermal Storage in Smart PCM Walls:

An enhanced and controlled discharge power by forced convection

Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg

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Hes·so Haute Ecole Spécialisée de Suisse occidentale Fachhochschule Westschweiz

ENERGY Institute of Applied Research in Energy Systems

blue FACTORY Fribourg – Freiburg

smart living lab

lehmorange® moderne Lehm-Trockenbausysteme

butikofer de oliveira vernay architectes

Outline

- Description of the active PCM concept
- Testbed
  - Set-up
  - Measurements
  - Simulations

} concept validation

- Simulations of a reference building
  - PCM of 23°C and 26°C with day and night loading
  - Active and passive PCM
- Conclusion and outlook

Active PCM concept

- Electrical battery can be charged and discharged at every moment

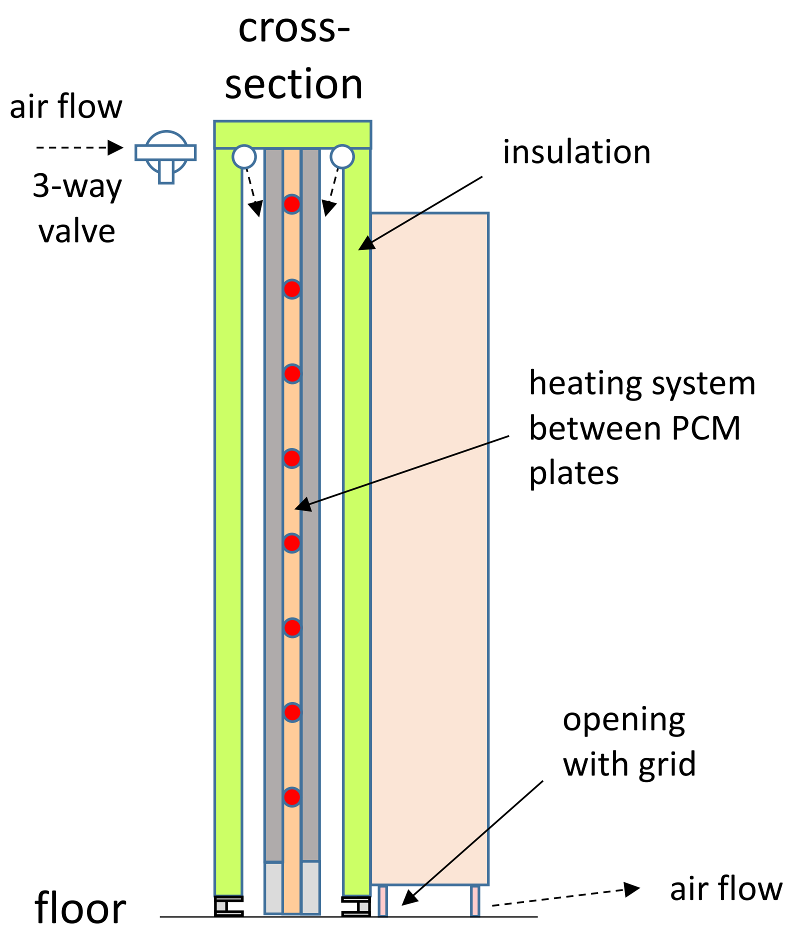
- Standard PCM (Phase Change Material):
  - can be loaded on demand (heating)
  - discharged as soon as $T_{int} < T_c$ → **Storage management not possible**

- **NEW CONCEPT**
  with on demand activation of the PCM discharge

- **Solution**

Charge	→	Heating an insulated PCM
Storage	→	PCM remains insulated
Discharge	→	Ventilation of the PCM

Concept of a ventilated PCM wall



- Heating with a water circuit
- Discharging with an air flow
- PCM:
  - micronal encapsulated paraffin with T_c = 23/26°C

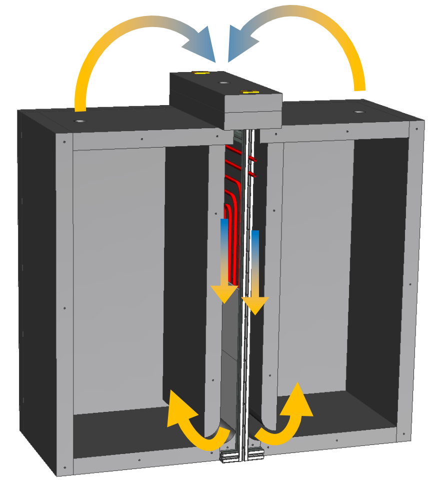
  - in «Lehmorange» plates
- Advantage:
  - discharge can be controlled
  - wall can be furnished

Testbed: PCM wall in the middle of two rooms

heating system

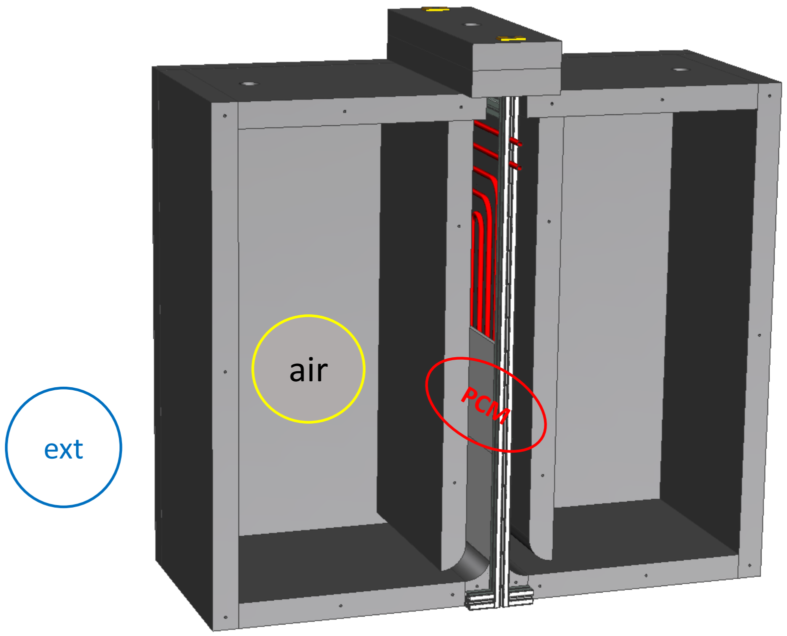
PCM-Plate

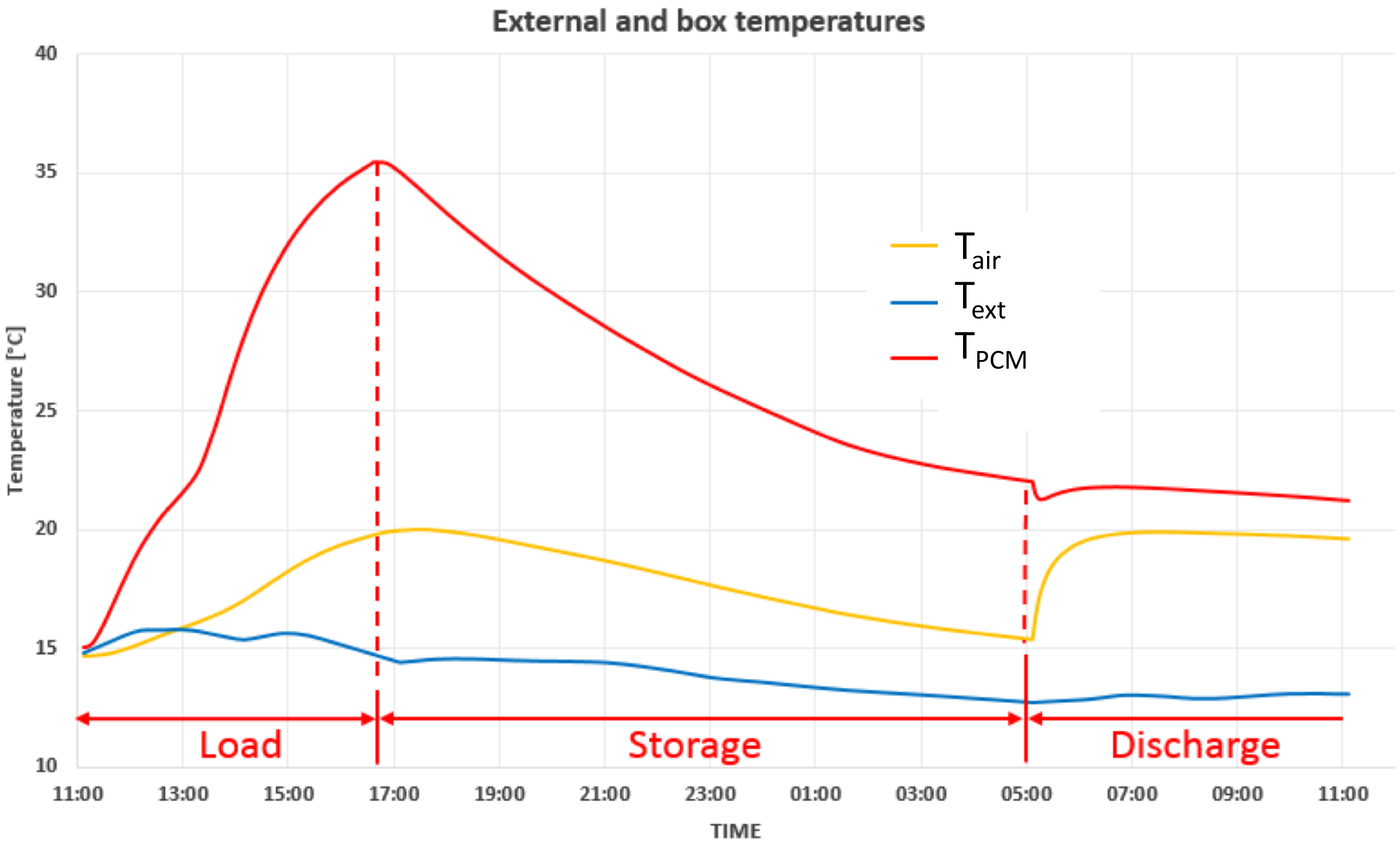
Active discharge



Smart PCM Walls : Simulation results

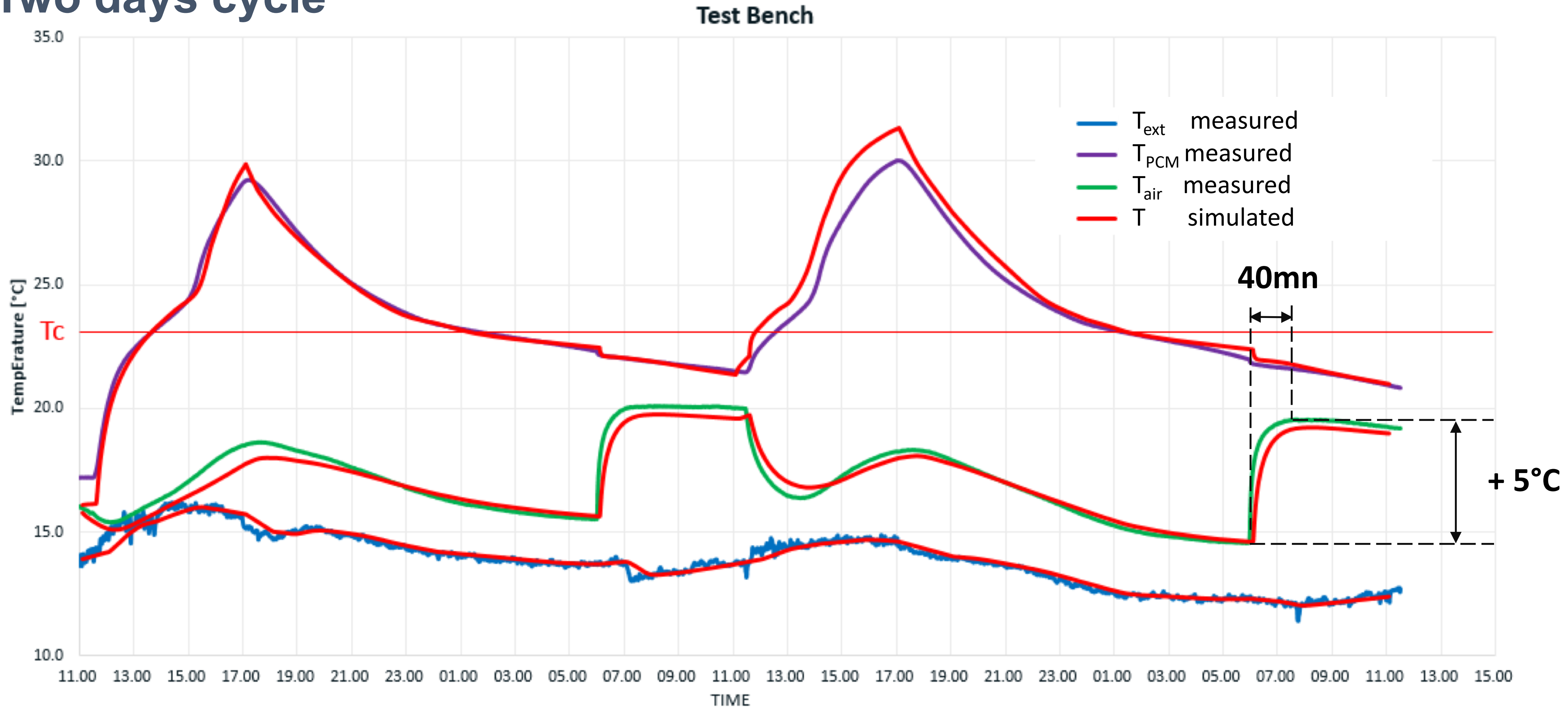
External and box temperatures



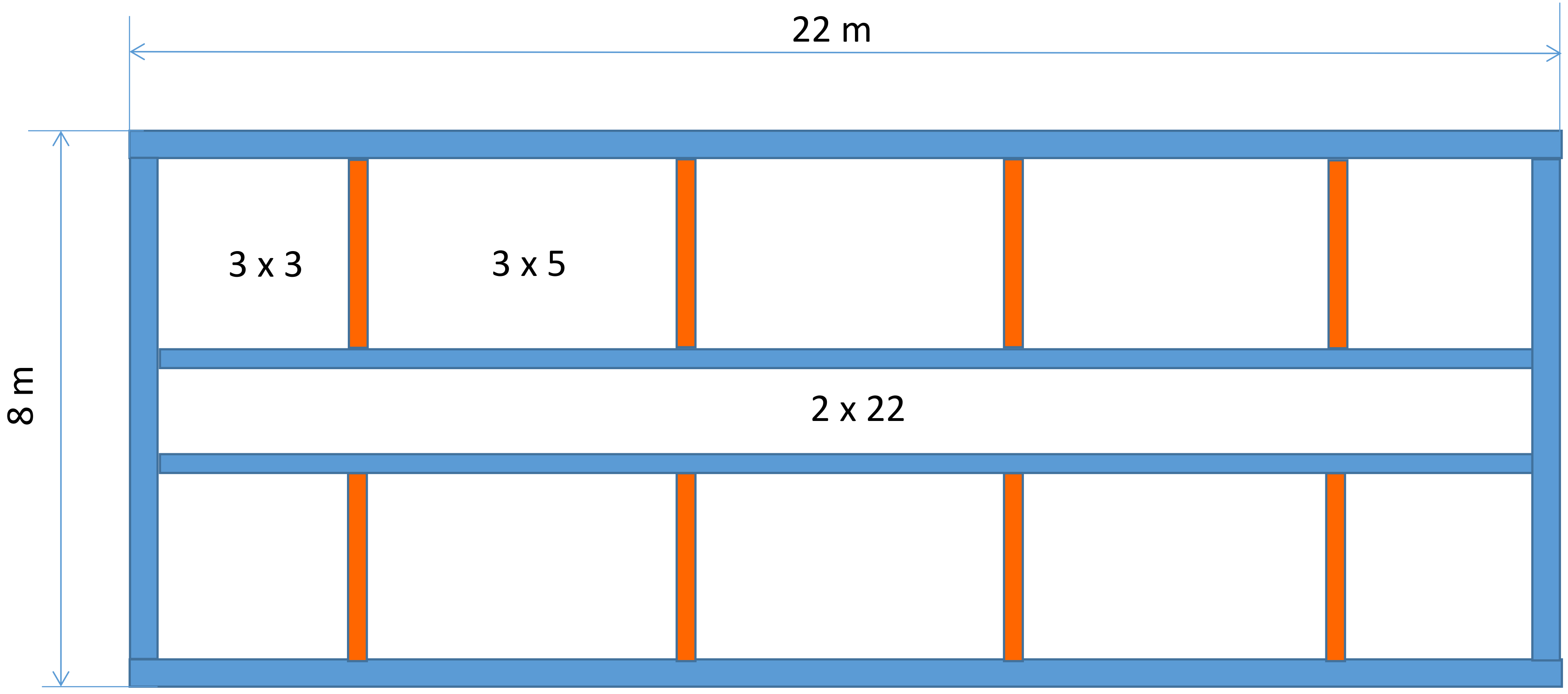


Smart PCM Walls : Comparison Measures-Simulations

Two days cycle



Simulations of a reference building



PCM walls

bearing walls

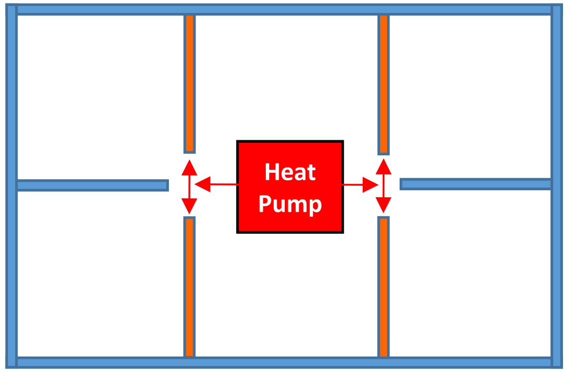
Height 3m per floor
Building has 2 floors
Total volume: 1'000 m^3

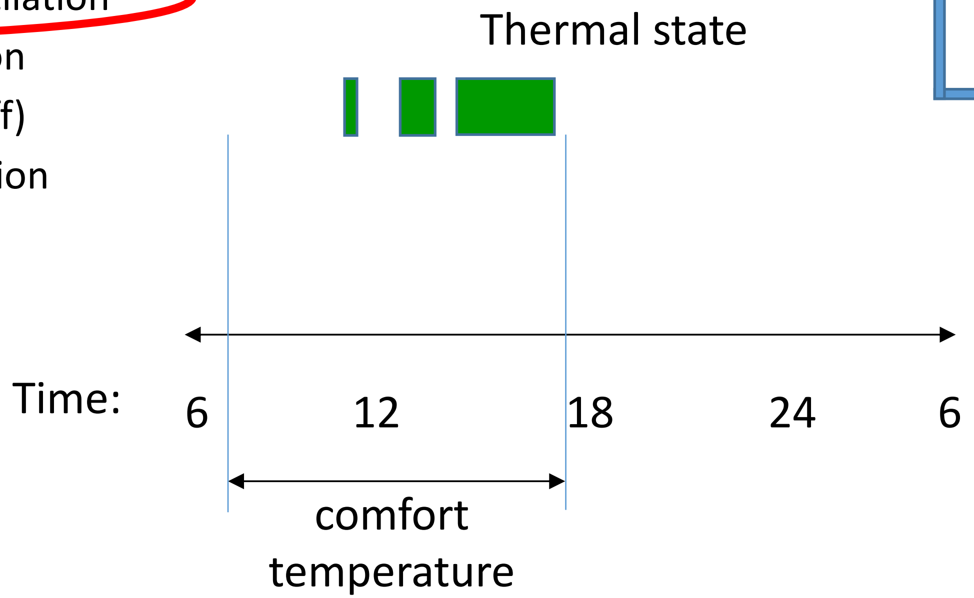
administrative building (not occupied at night and during week-ends)

Heating process with PCM walls

- **Goal**: increase the building autonomy and assure comfort temperature during building occupancy

- **4 states**:
  - **Loading**: Heat pump on without ventilation
  - **Storage**: no heating and no ventilation
  - **Discharge**: Ventilation (heat pump off)
  - **Heating**: Heat pump on with ventilation





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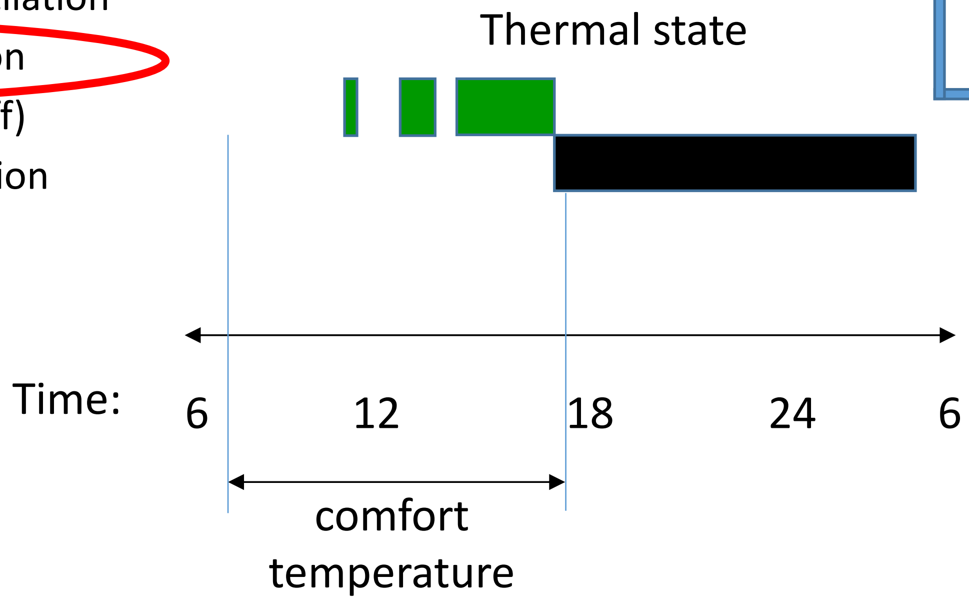

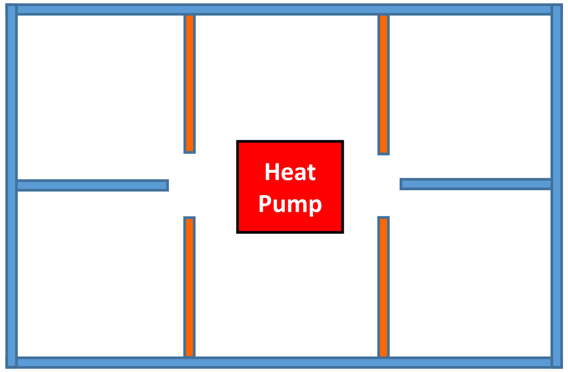

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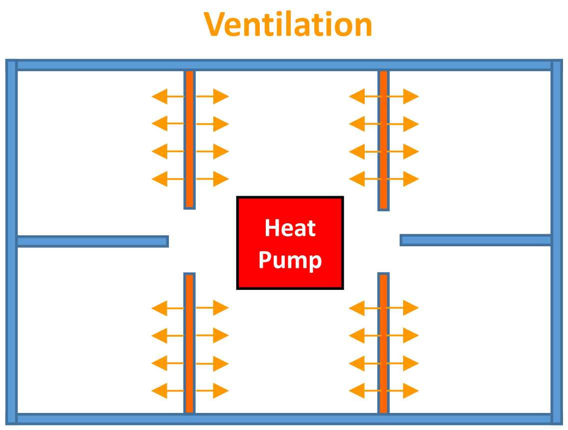

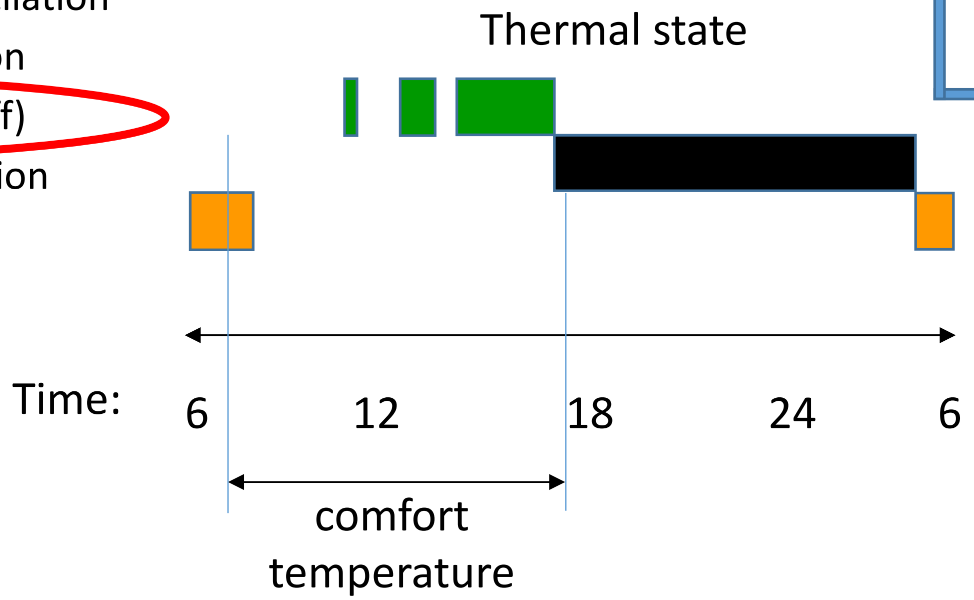

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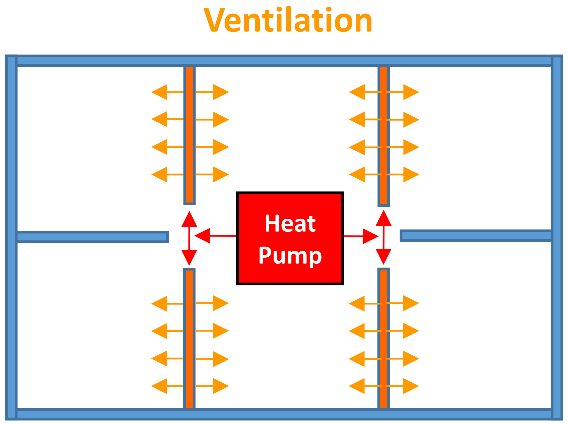
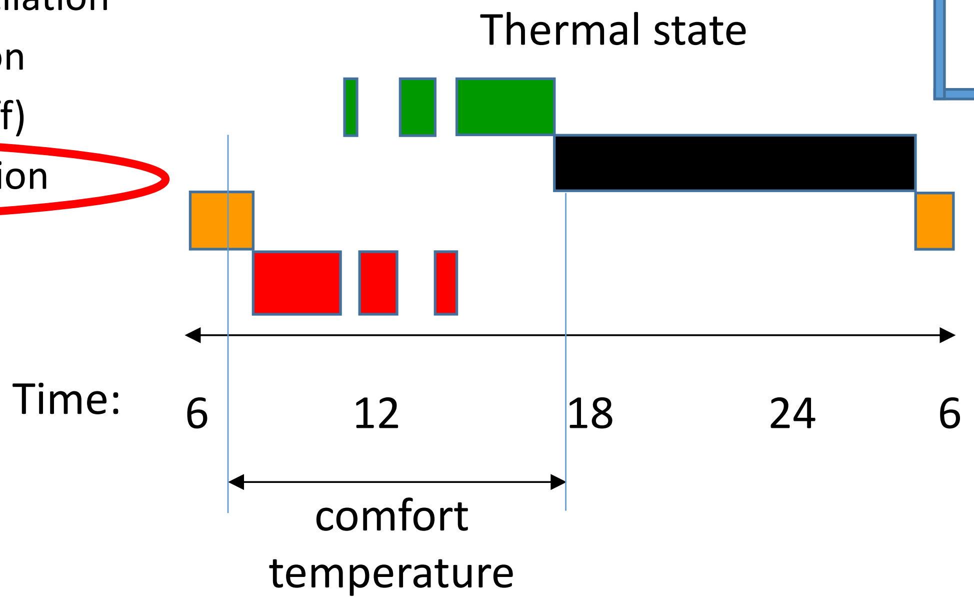




Simplified simulations

- T_{ext} constant the whole day all around the building
- Solar heating inside the building and wind effect are neglected
- U-value = 0.15 W/m^{2}K for the building envelope

- Comfort temperature of about **20.5°C** between **06h and 17h30**
- Air renewal: 0.5 Vol/hour from 7h to 18h with 90% heat recovery
- **PCM loaded with 12kW** either during the day or night
  - day: from 9h30 to 16h
  - night: before 6h

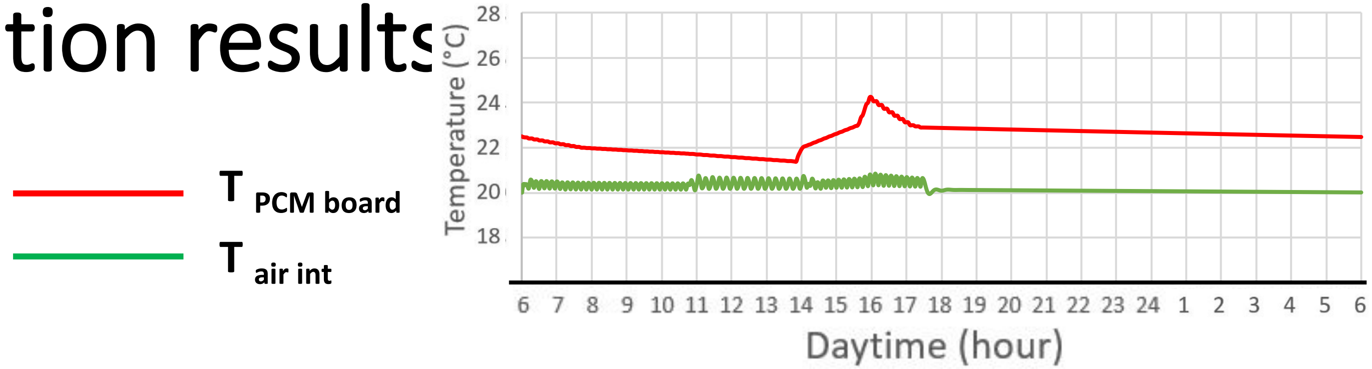
  } but no more than 6h30
- Simulation performed from **6h to 6h the next day** with goals:
  - recover the **same temperatures**: T_{int}, $T_{concrete}$, T_{PCM} and the **same PCM loading**
  - in case of insufficient heating time → study the drops of T_{int}, $T_{concrete}$, T_{PCM} and PCM loading

Day loading:

PV panels → Heat pump: 12KW → PCM

Day loading simulation results

$T_c = 23°C$



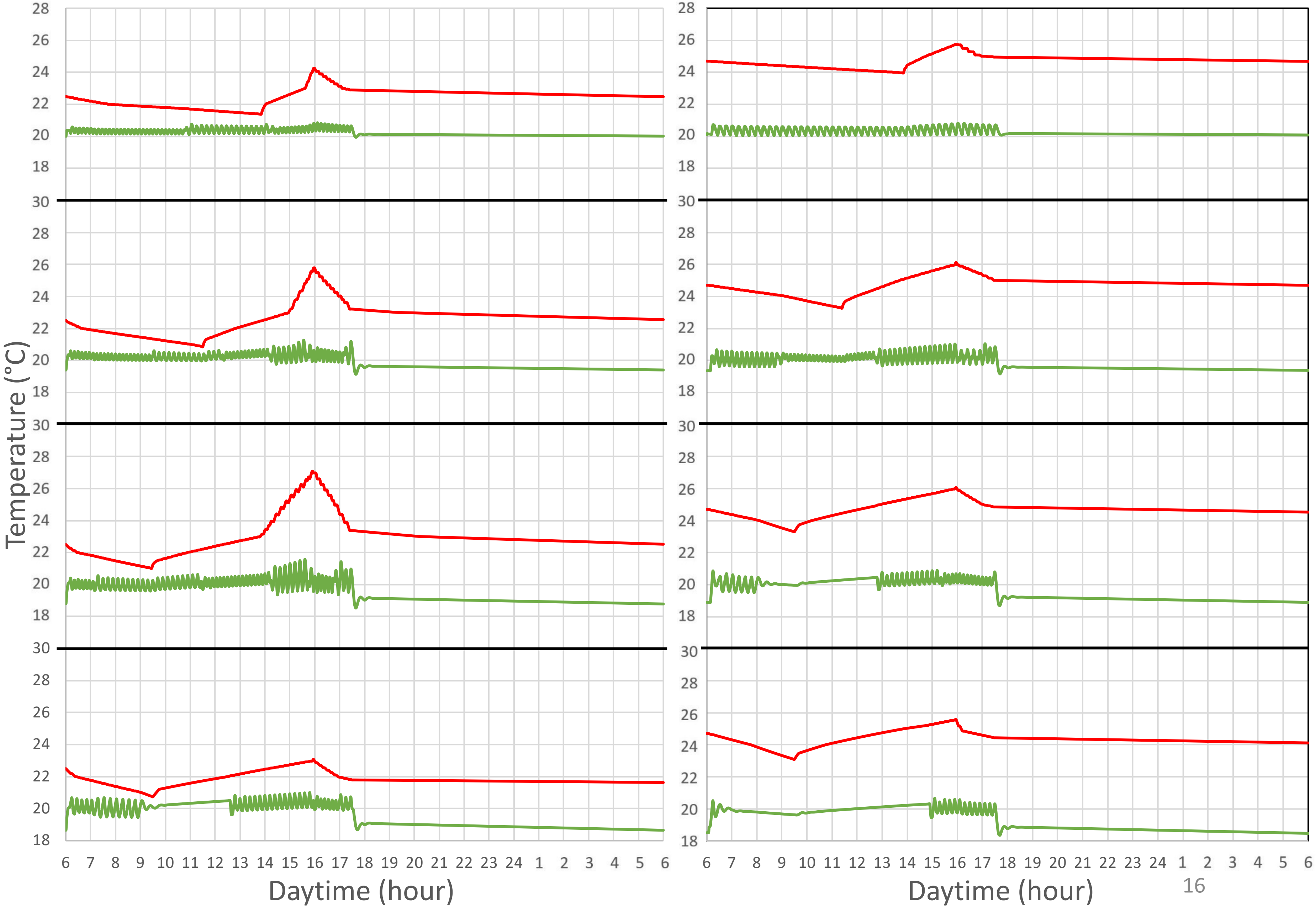
Day loading simulation result

$T_{PCM\ board}$

$T_{air\ int}$

T_c = 23°C

T_c = 26°C



PCM discharge:

- **T_c=23°C** → comfort temperature until **T_{ext} = -10°C**
- **T_c=26°C** → comfort temperature until **T_{ext} = - 5°C**
- superiority of 23°C PCM due to **lower overnight discharge** than 26°C PCM

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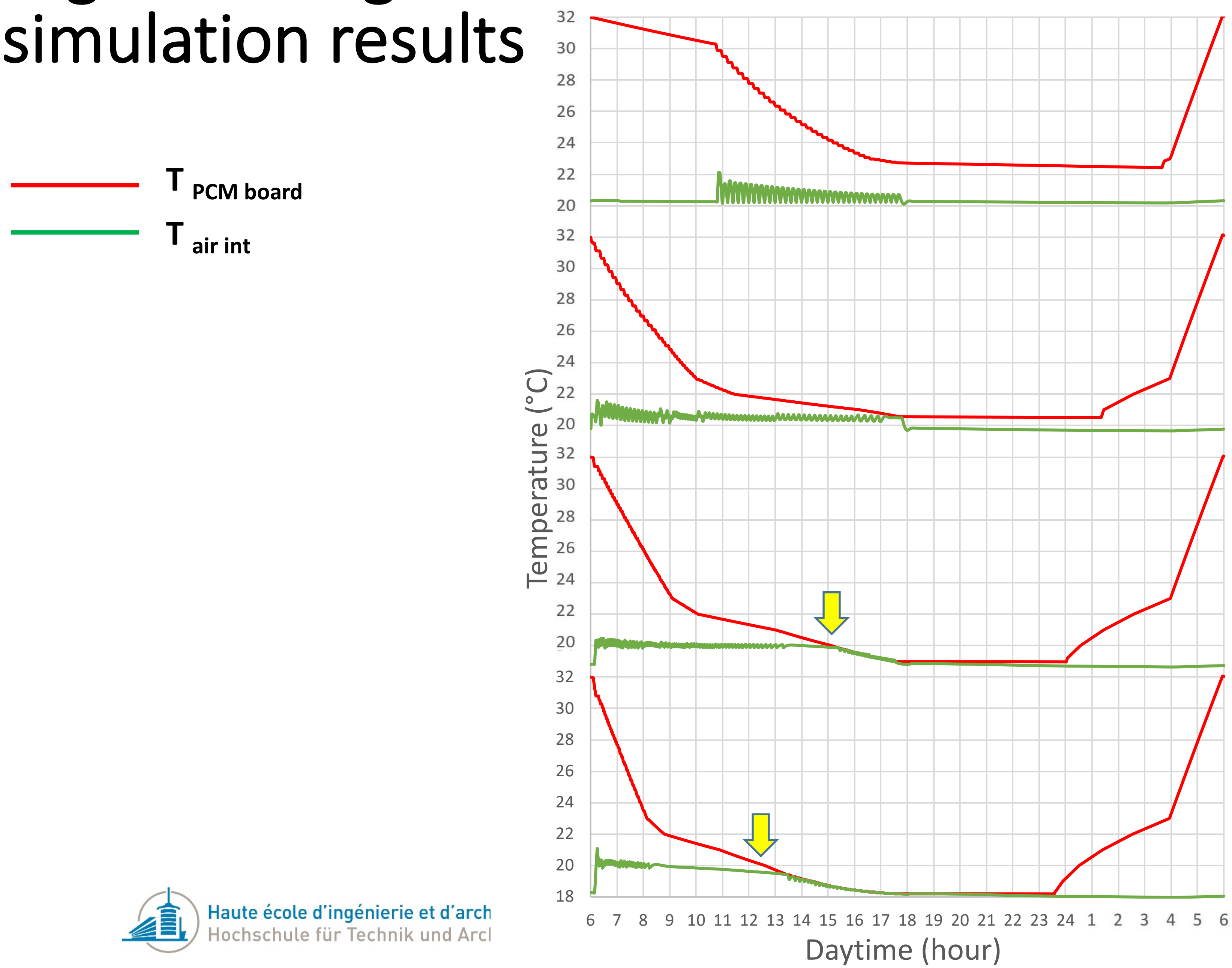
Night loading:

Electricity Network → Heat pump: 12KW→ PCM

Night loading simulation results

T_c = 23°C



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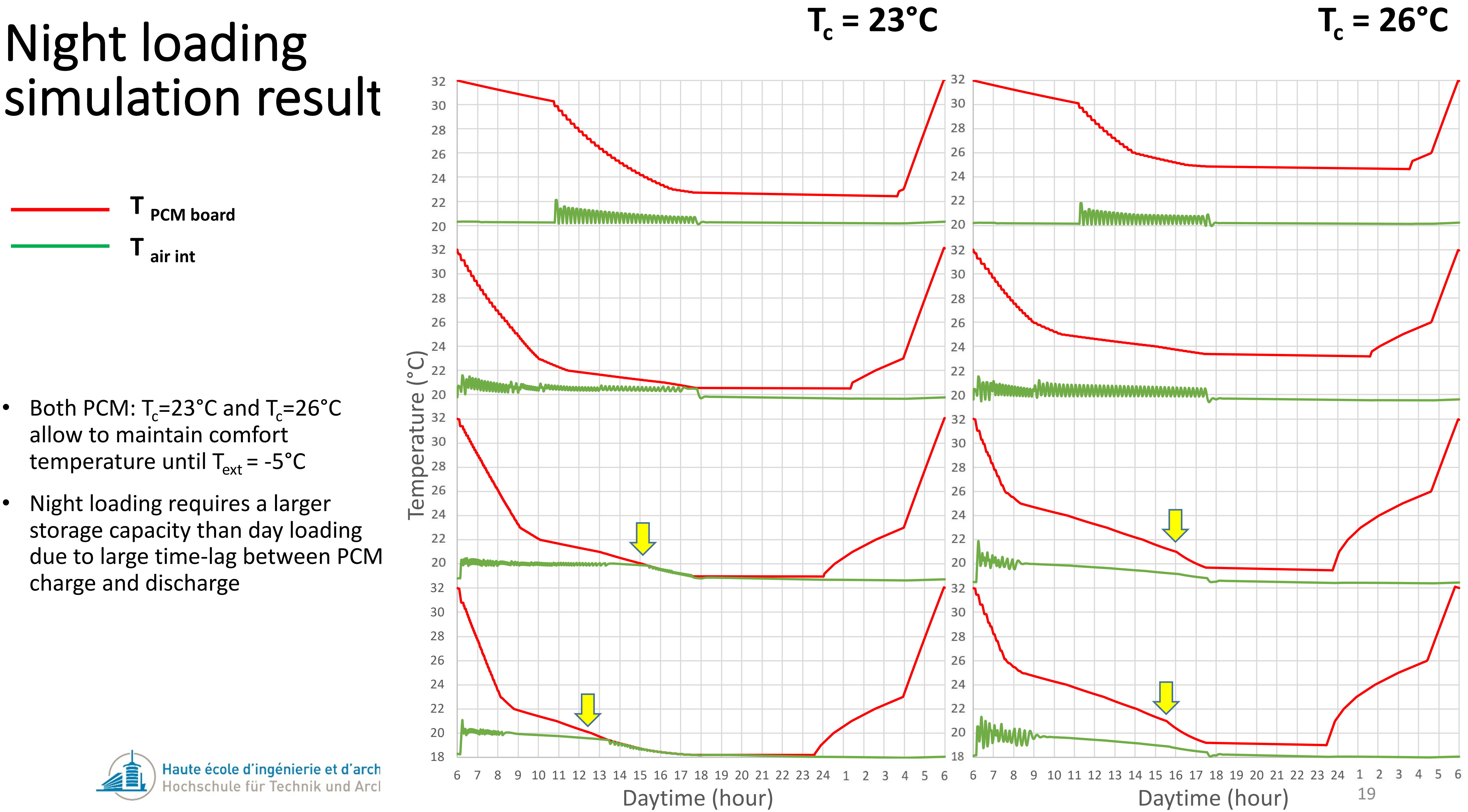
Night loading simulation result



- Both PCM: T_c=23°C and T_c=26°C allow to maintain comfort temperature until T_{ext} = -5°C
- Night loading requires a larger storage capacity than day loading due to large time-lag between PCM charge and discharge

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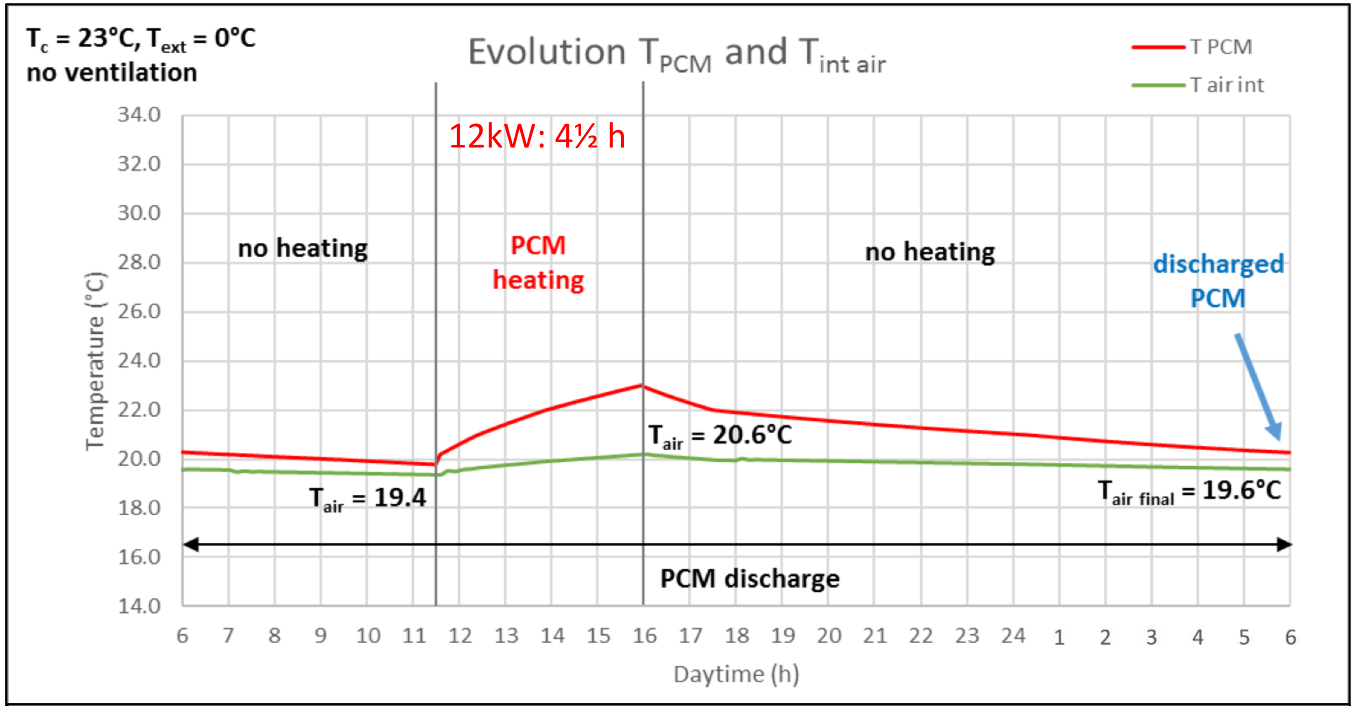
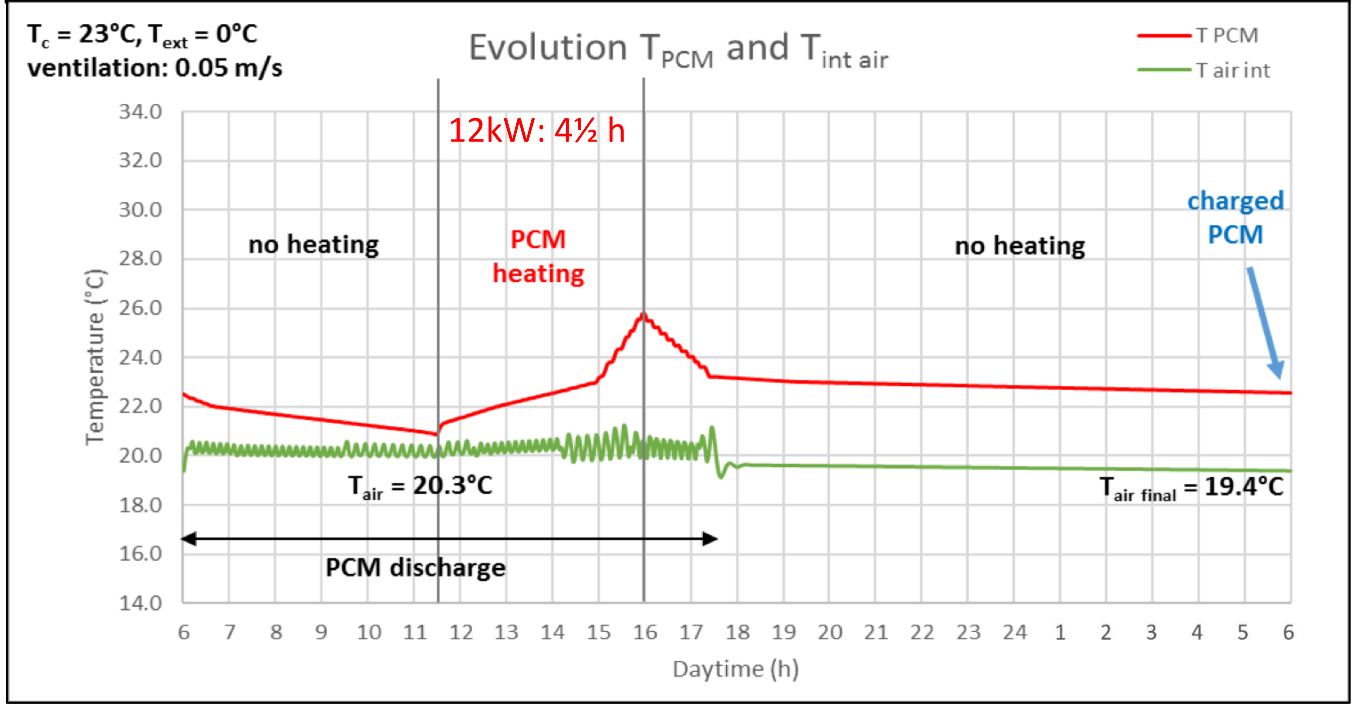
Passive versus active PCM comparison

day loading, T_{ext} = 0°C

passive PCM 23°C



active PCM 23°C



Conclusion

- **Concept of active PCM** walls for heating **validated** by lab tests and simulations:
  - **+ 5°C** in 40mn
  - Studied system suitable for outdoor temperatures between **-5°C and +10°C**
- **PCM with T_c =23°C has higher performances** compared to 26°C (due to lower overnight discharge) but requires ventilation
- **Day loading** requires lower storage capacity than night loading (due to lower heating-loading time-lag)
- **Active PCM has lower heat losses at night time** than passive PCM (continuous natural convection)

PERSPECTIVES and OUTLOOK

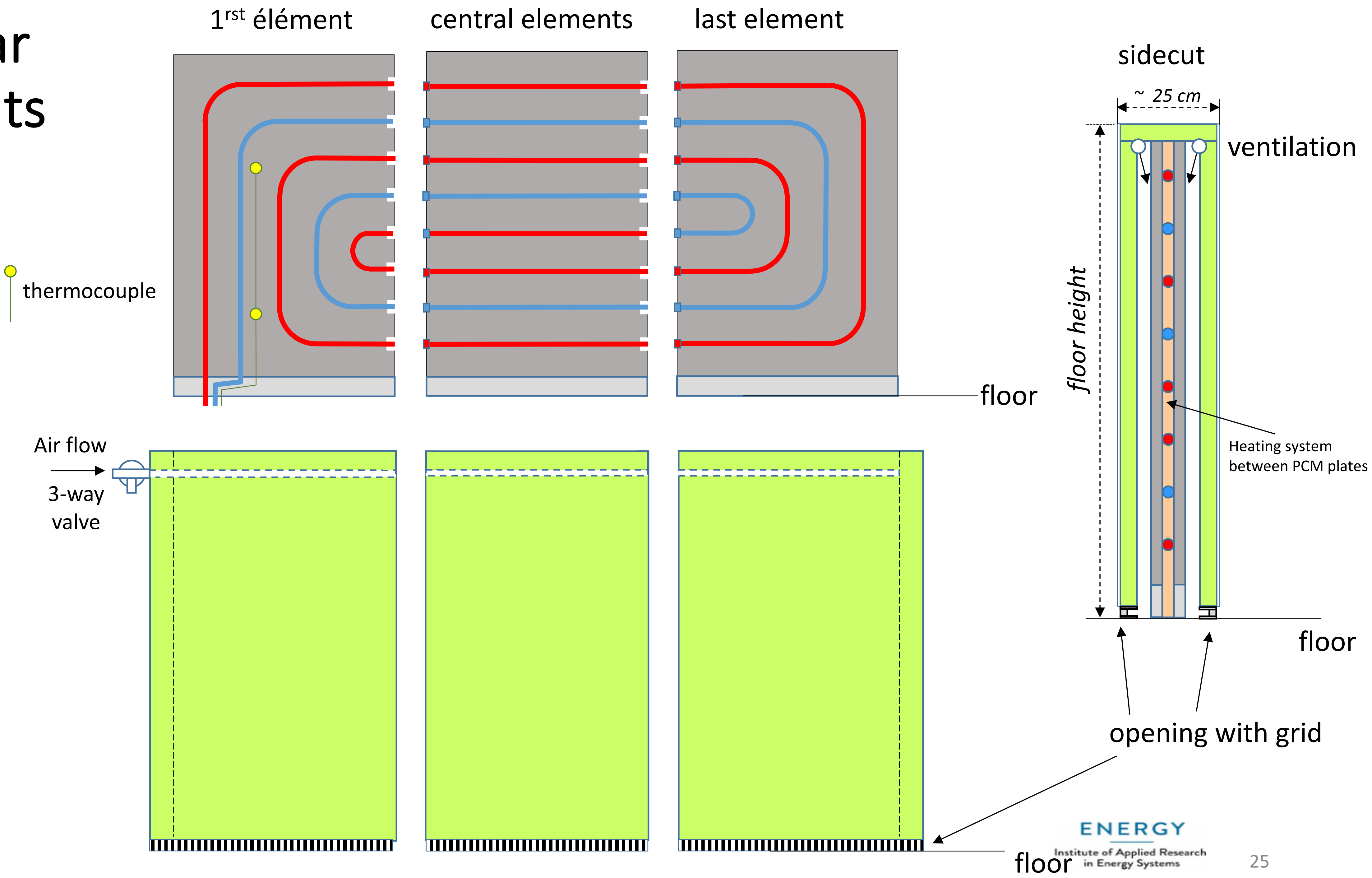
- For very cold days: combination of day solar power
  + the necessary night loading defined after weather forecast
- PCM with T_c of 23°C can also provide cooling
- Integration in real building / demonstrator

Thank you for your attention!

Questions?

Back-up slides

Modular elements



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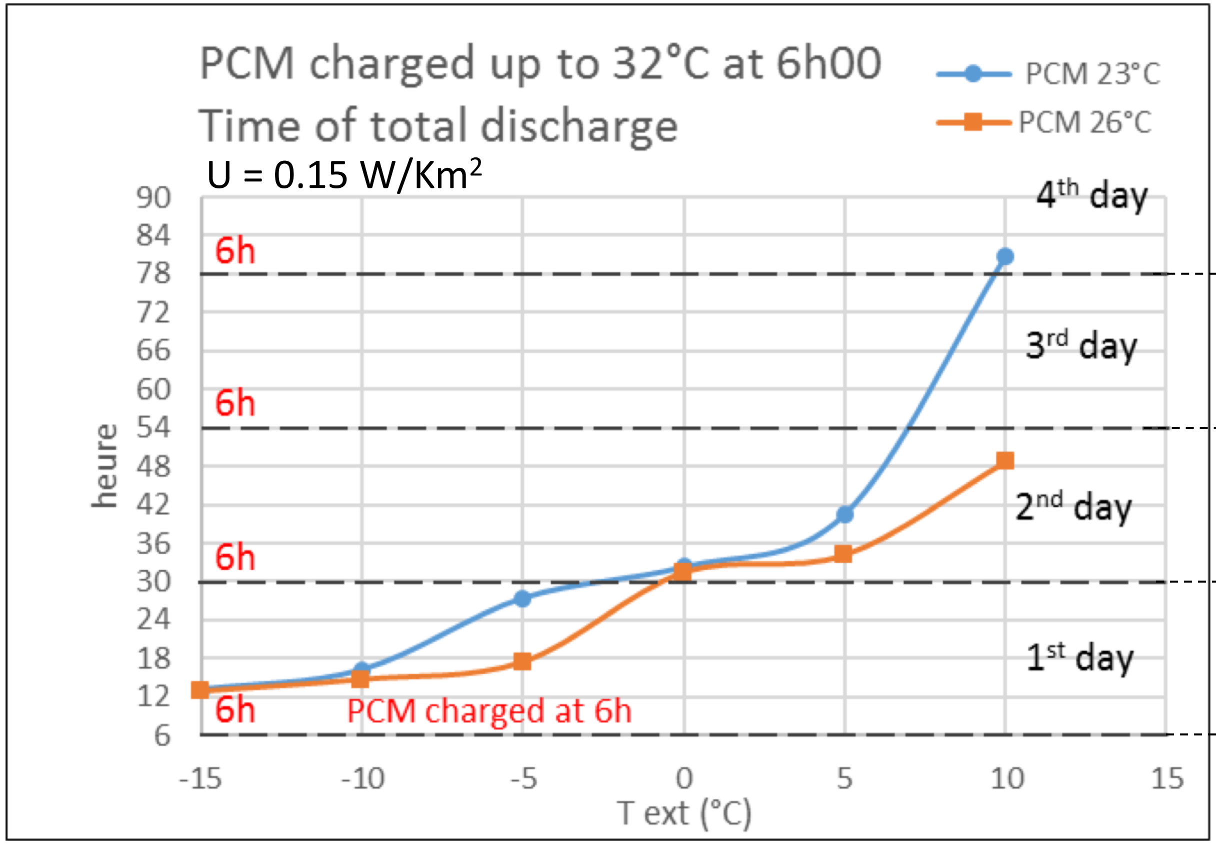
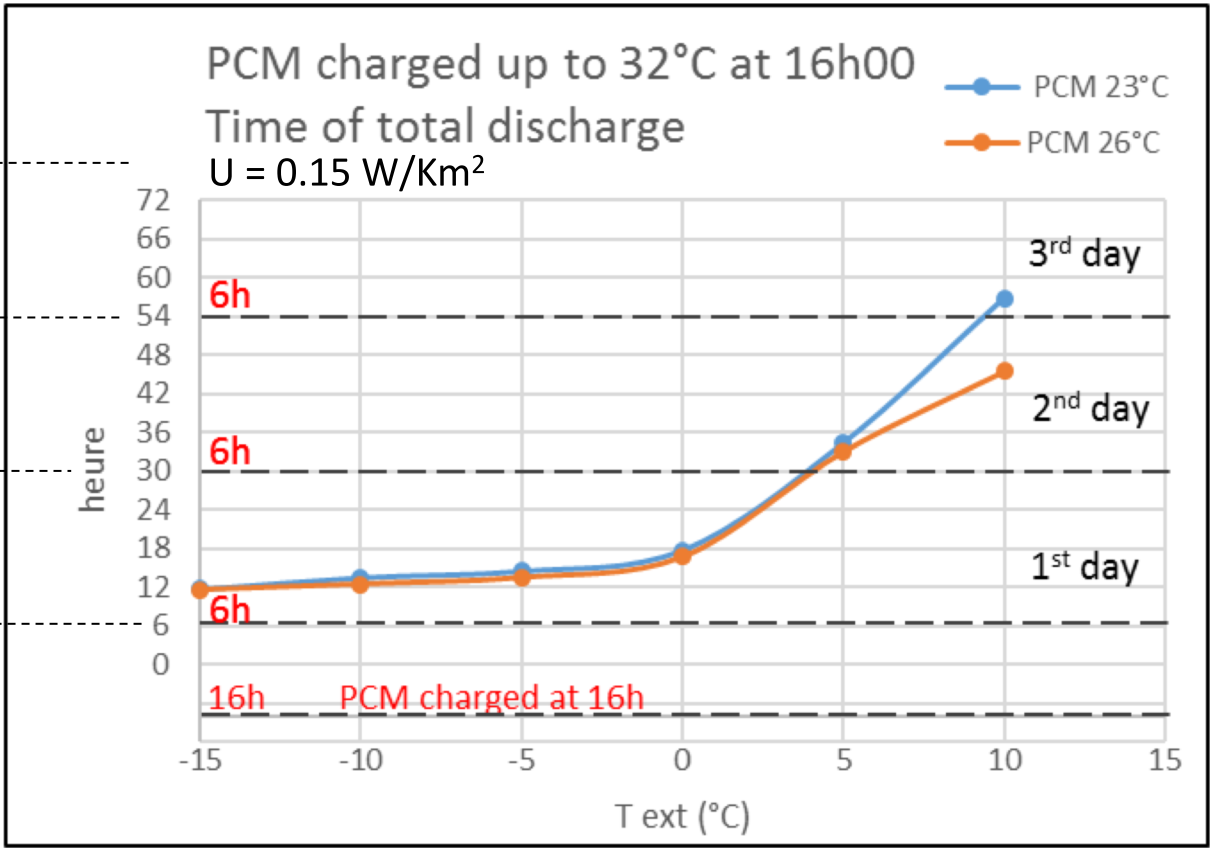
PCM loaded at 06:00 am / at 16:00 pm

with latent heat in a single step





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