HOW TO OPTIMISE ENERGY STORAGE IN BUILDINGS?

Which applications for phase change materials?

27/09/2017

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Research assistant (UCL-Architecture et Climat)

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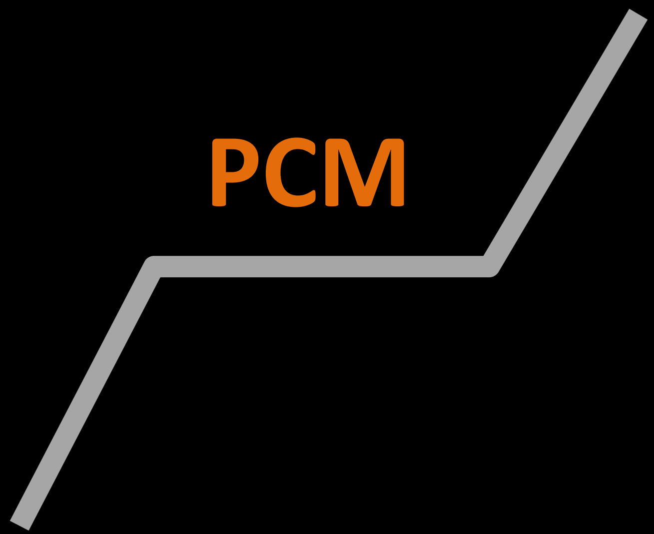
PCM

Phase Change Materials

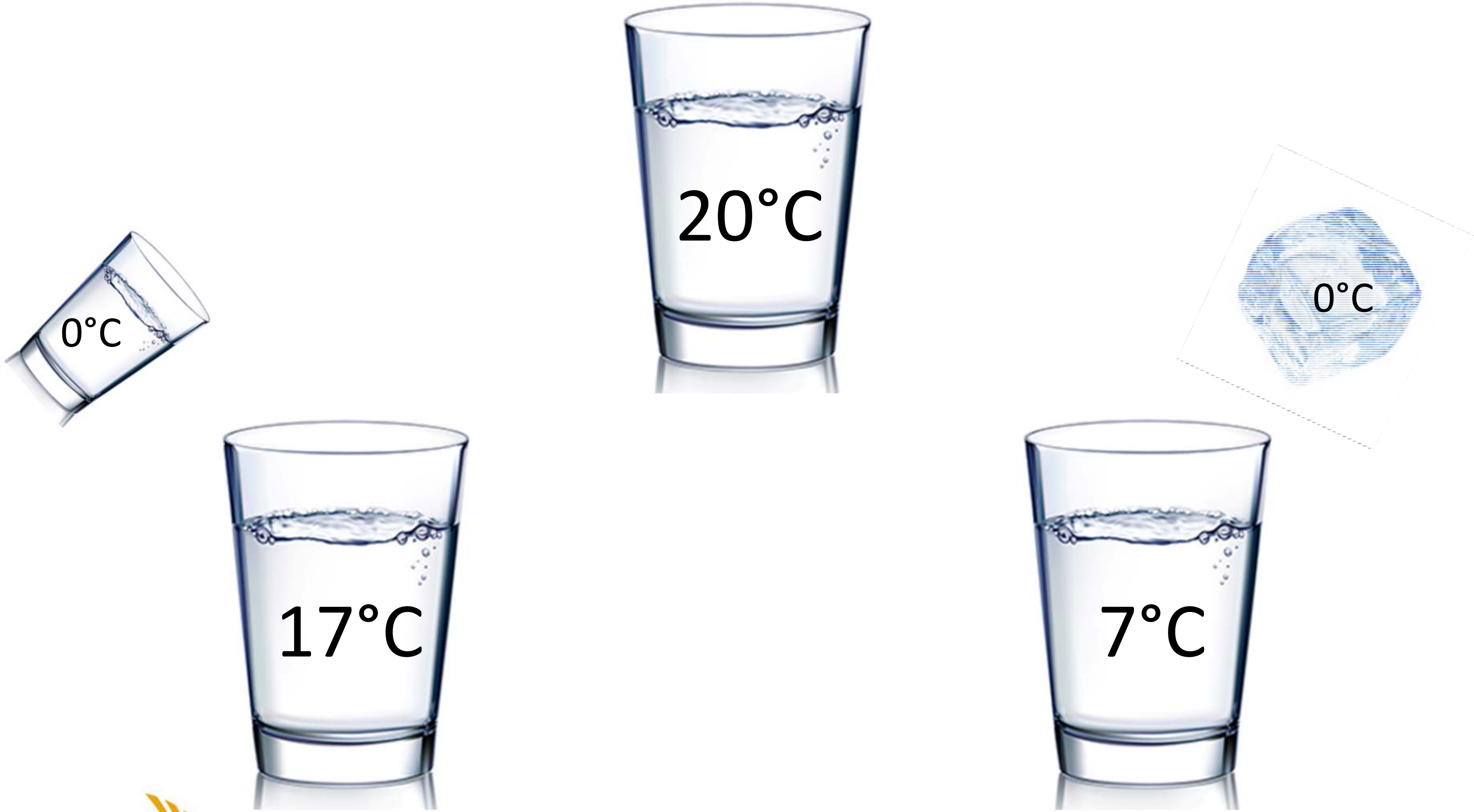
In Building Applications

To Optimise Thermal Mass

Phase Change Materials



Why is an ice cube more efficient to cool my glass than 0°C liquid water?



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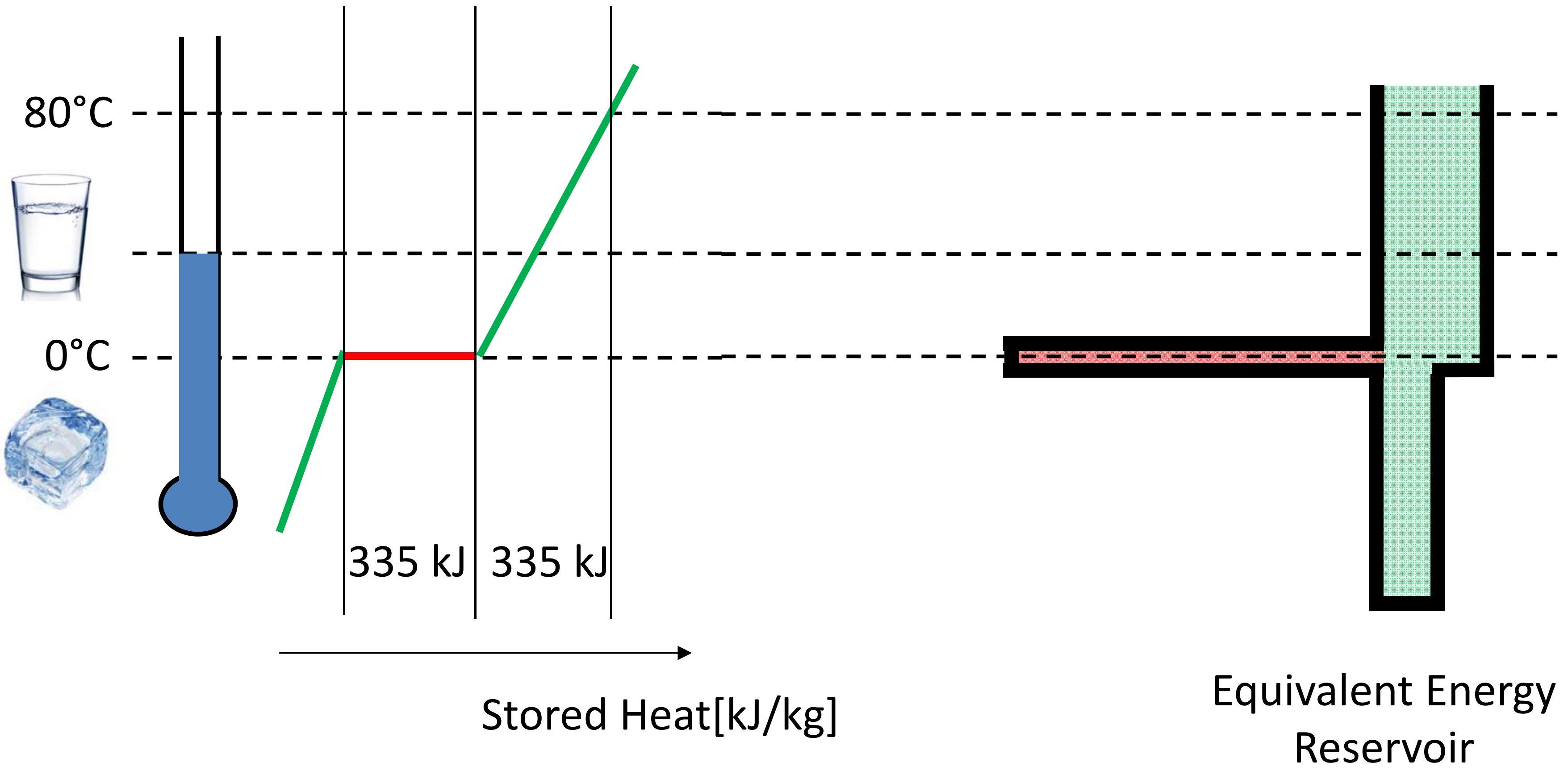
Temperature: an indicator of sensible and latent heat



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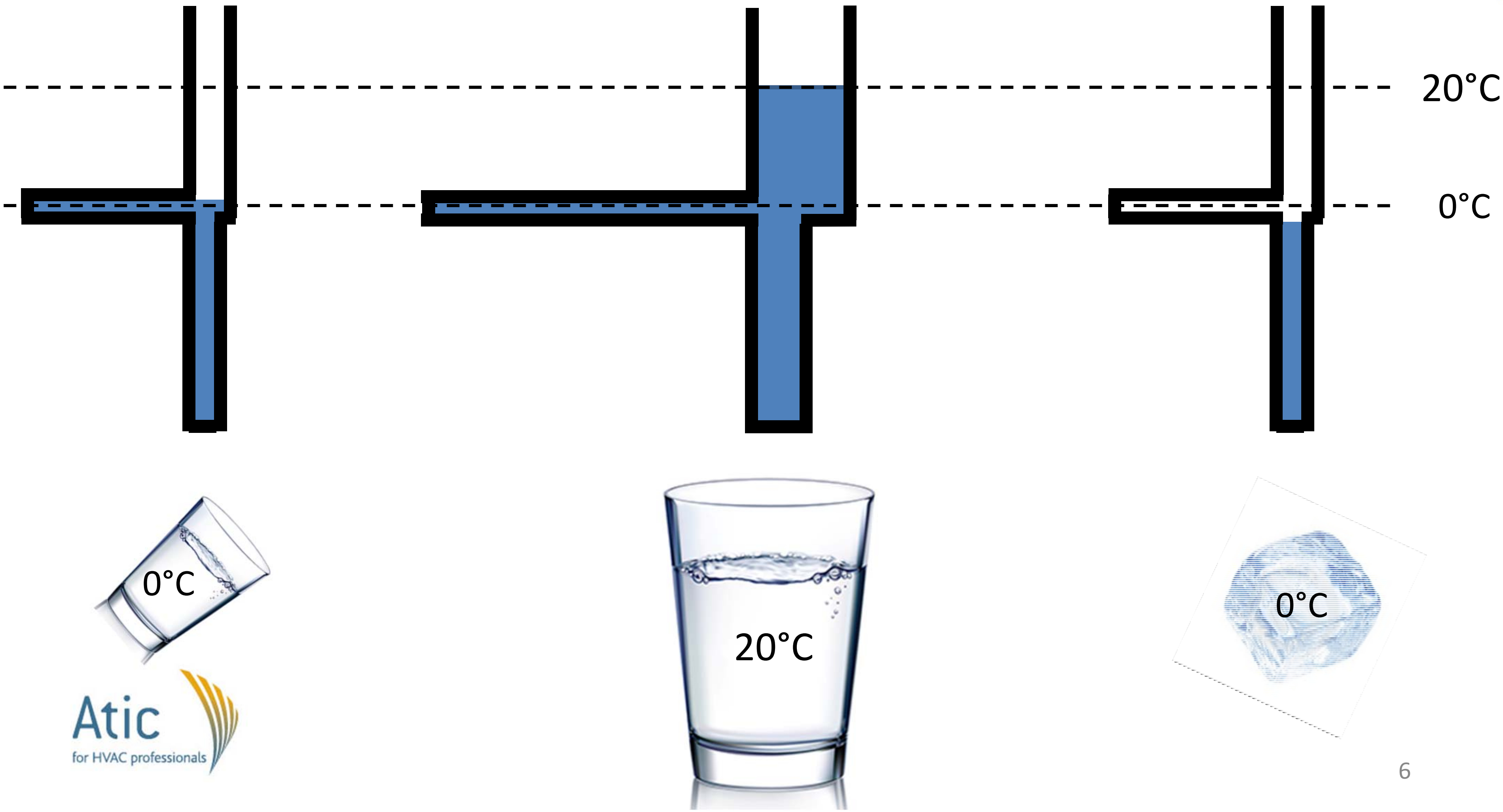
Unlike ice cube, latent reservoir of 0°C liquid water is already filled



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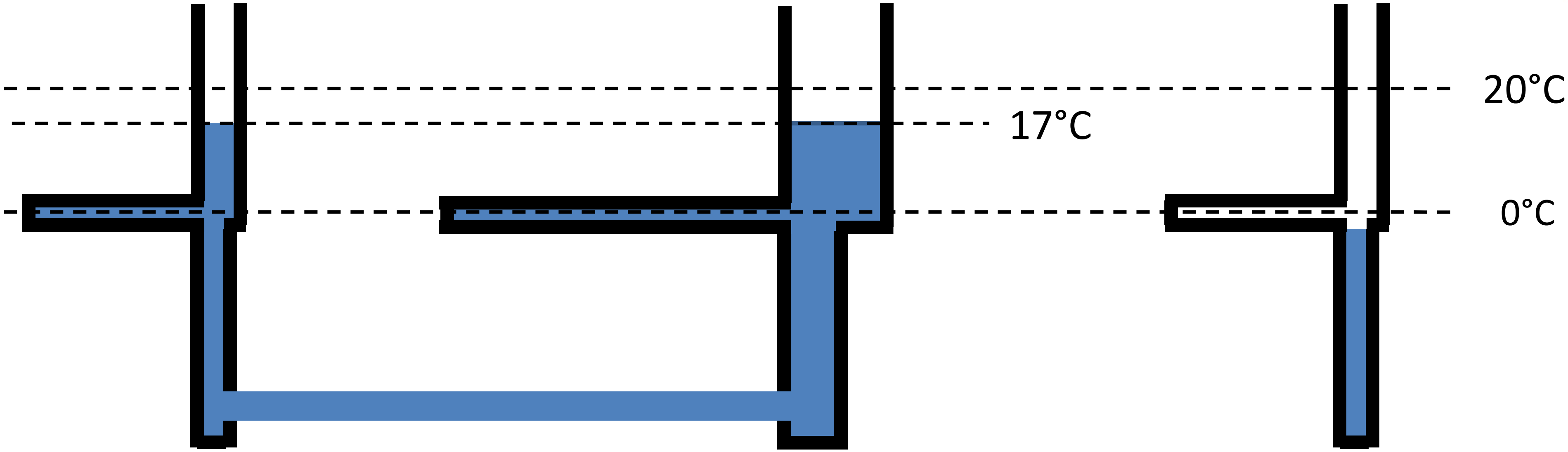
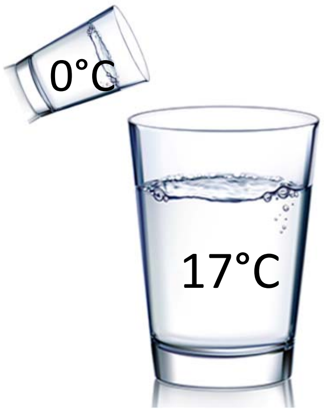
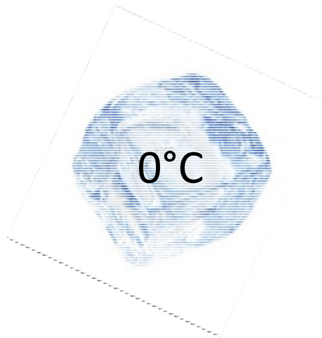
Equilibrium is achieved at 17°C with 0°C liquid water







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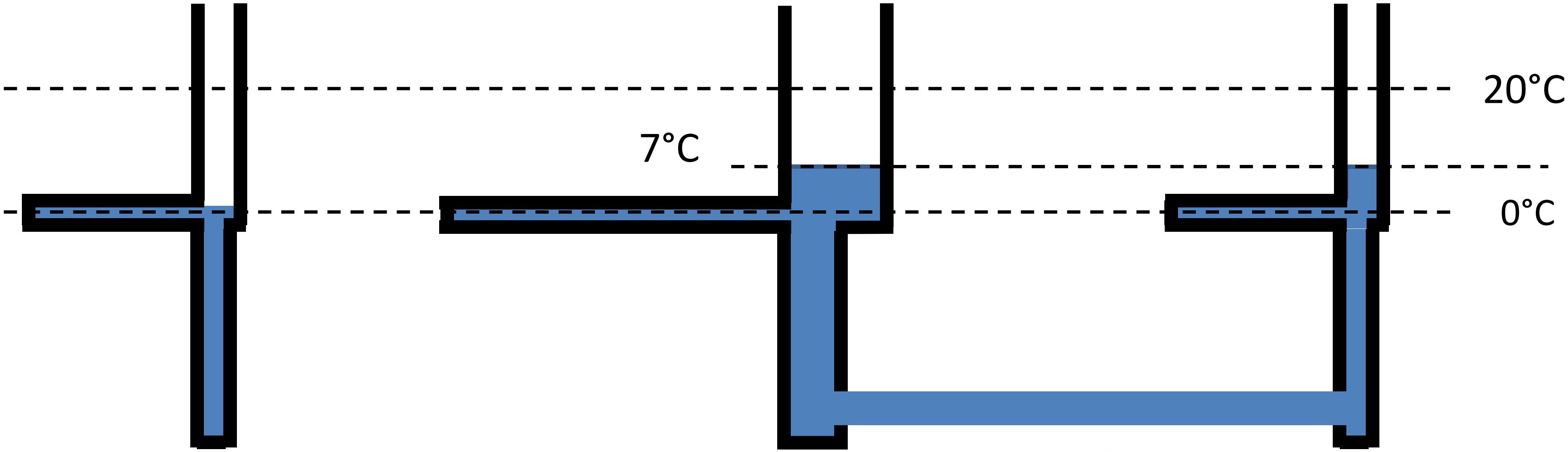
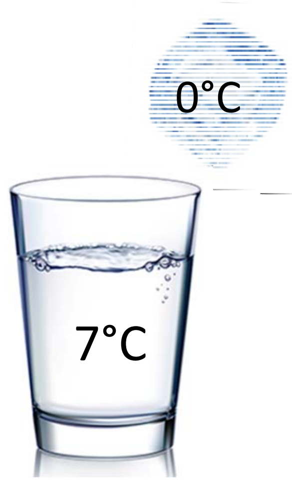
Equilibrium is achieved at 7°C with the ice cube





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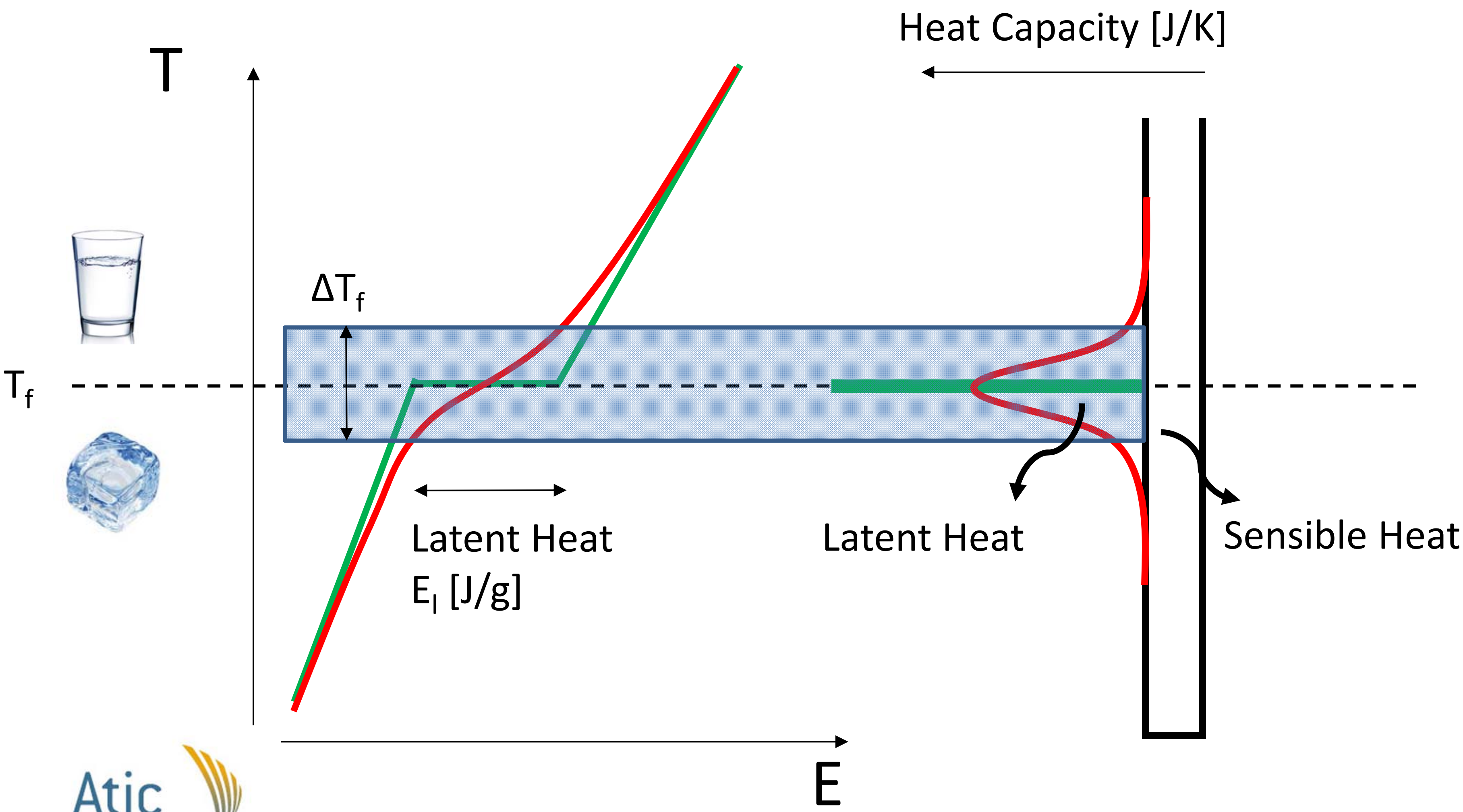
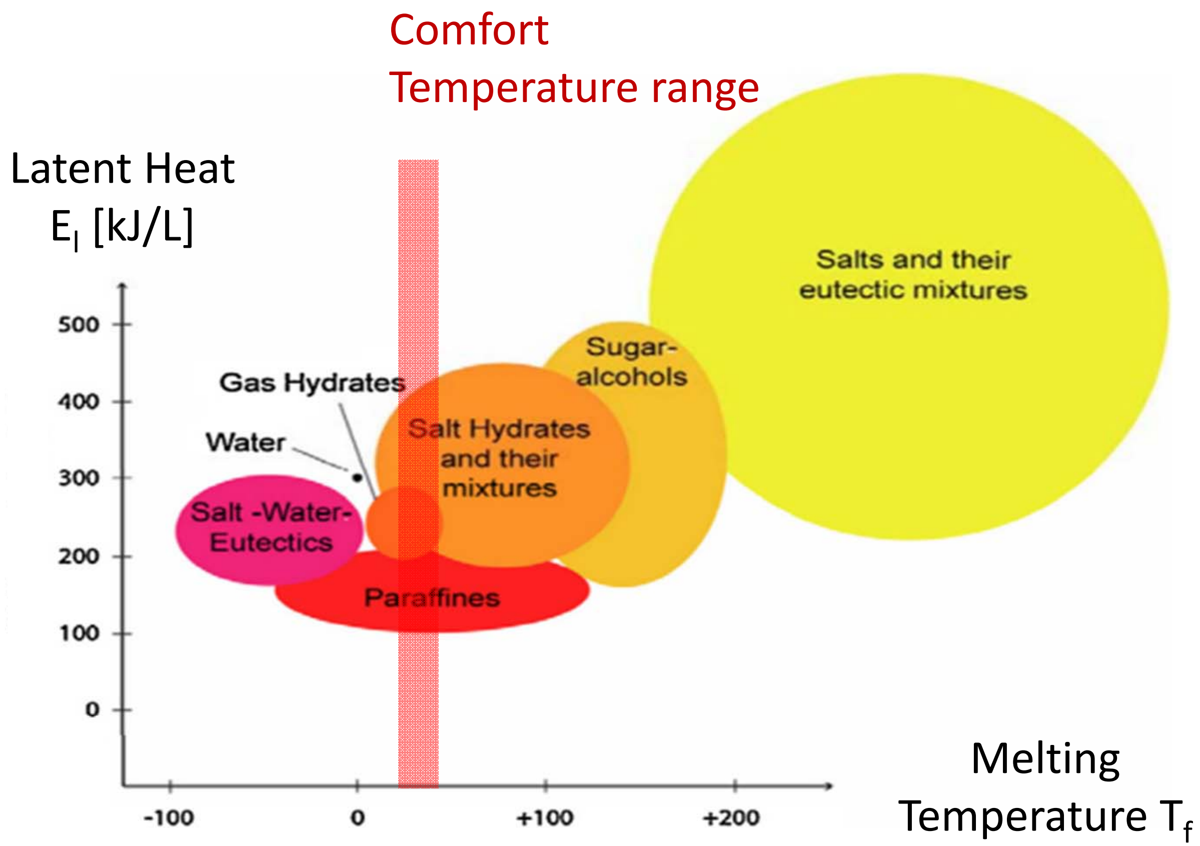
Main characteristics and differences between real PCMs and ideal PCMs



Phase Change Materials

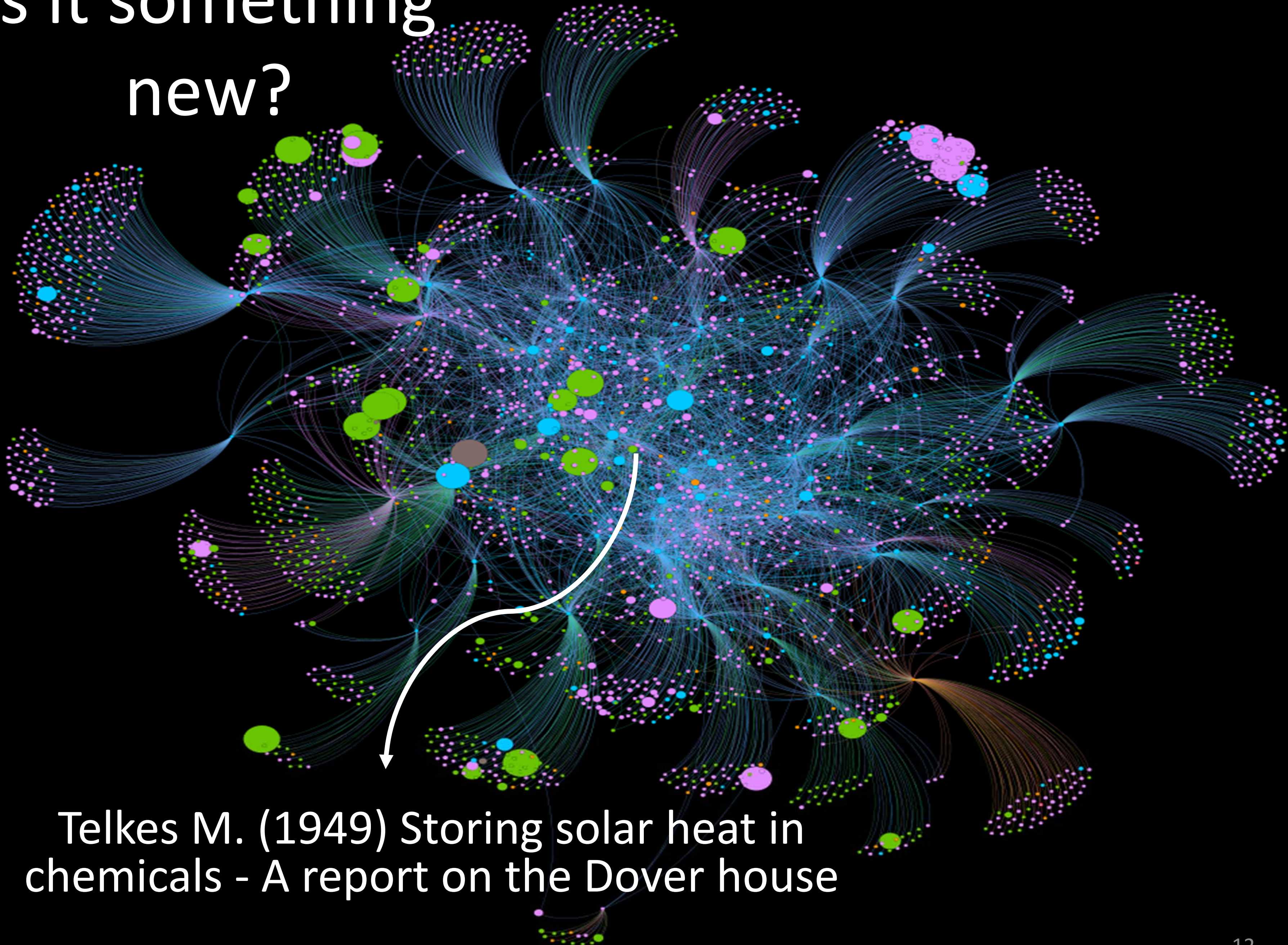
In Building Applications

Phase Change Materials… for building applications



1. Kalnæs, S.E. and B.P. Jelle, *Phase change materials and products for building applications: A state-of-the-art review and future research opportunities.* Energy and Buildings, 2015. **94**: p. 150-176.

Is it something new?



Telkes M. (1949) Storing solar heat in chemicals - A report on the Dover house

PCM for building applications: an historical perspective

P. Schossig (2005)
point of view

Kosny (2014)
point of view

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1949

± 1980

± 2000

2014

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Immersion

Micro-encapsulation

Macro-encapsulation

Shape-Stabilized PCMs

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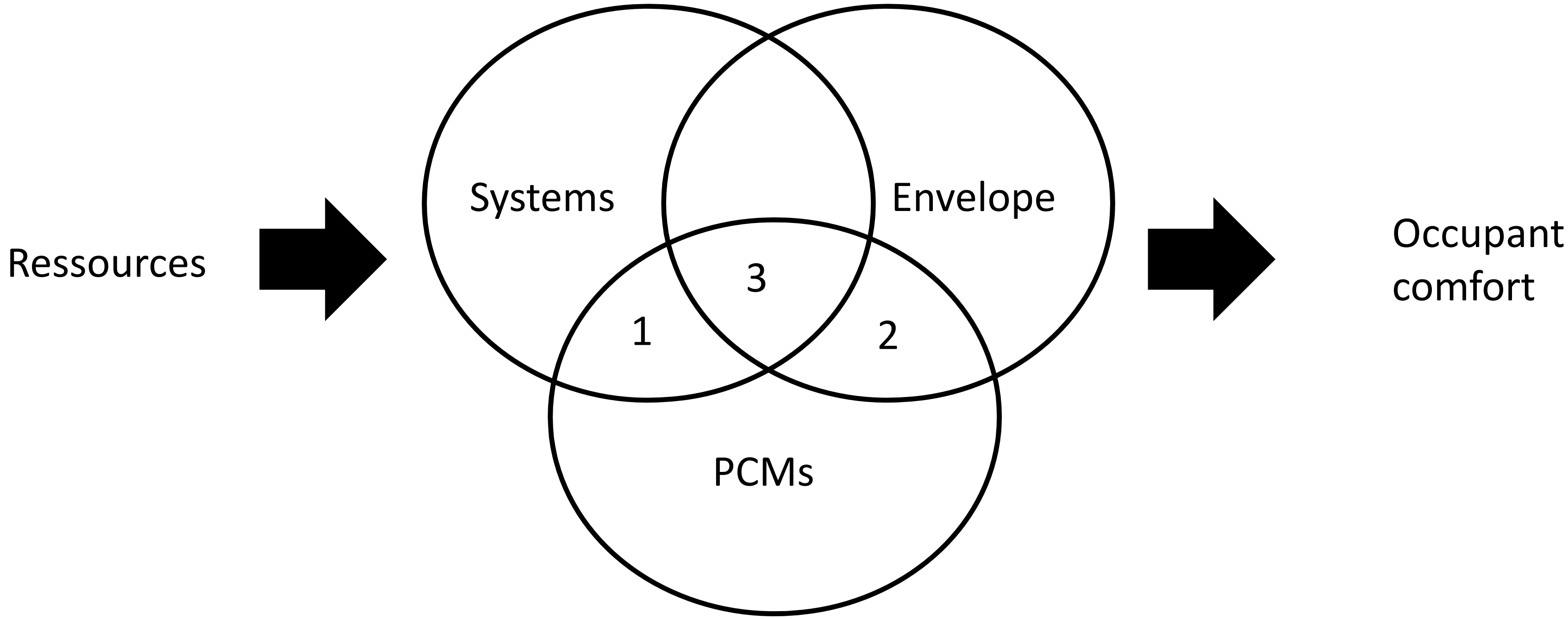
P. Schossig (2005) point of view: limitation of previous works

- *PCMs that are not encapsulated may interact with the building structure and change the properties of the matrix materials, or leakage may be a problem over the lifetime of many years.*
- *Macro- capsules have the disadvantage that they have to be protected against destruction while the building is used (no drilled holes or nails in the walls/ceiling).(…) Another problem with macro-capsules is the decreasing heat transfer rate during the solidification process when PCMs like paraffins are used, with poor heat transfer coefficients in the solid state. This may prevent the system from discharging completely overnight.*
- *Due to these limitations, none of the PCM products had a big market impact.*

Classification of PCMs integration in building



1. System applications
2. **Passive applications**
3. Active applications

Technical specifications for PCMs selection

Table 2
Main criteria that govern the selection of PCMs.

Thermal and physical properties	– Suitable phase-change temperature in the desired operating temperature range
	– High thermal conductivity and good heat transfer
	– High latent heat of transition per unit mass
	– High specific heat and high density
	– Congruent melting and long term thermal stability
	– Favourable phase equilibrium and no segregation
	– Small volume change on phase-change
	– Small vapour pressure at operating temperature
Kinetic properties	– High nucleation rate and little or no supercooling of the liquid phase
	– High rate of crystallization
Chemical properties	– Complete reversible melt/freeze cycles
	– Long term chemical stability and no degradation after a large number of melt/freeze cycles
	– No corrosiveness and capability with construction materials
	– Nontoxic, non-flammable and non-explosive
Economic properties	– Abundant and available
	– Cost effective
Environmental properties	– Low embodied energy
	– Separation facility from the other materials and recycling potential
	– Low environmental impact and non-polluting

1. Soares, N., et al., *Review of passive PCM latent heat thermal energy storage systems towards buildings' energy efficiency.* Energy and Buildings, 2013. **59**: p. 82-103.

Commercial PCM products for passive applications

Energain | ENRG Blanket | Knauf

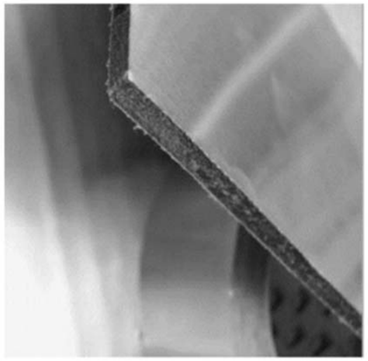
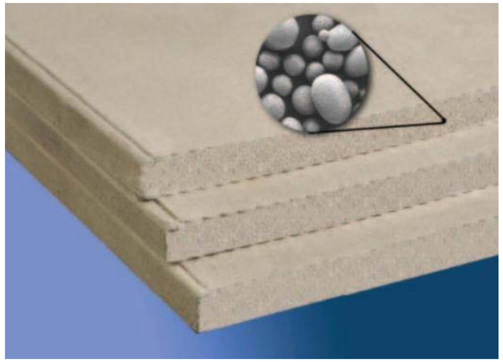


Fig. 3. Dupont de Nemours PCM composite wallboard, composed of 60% of microencapsulated paraffin [38].



SSPCM | Macro-encapsulation | Micro-encapsulation

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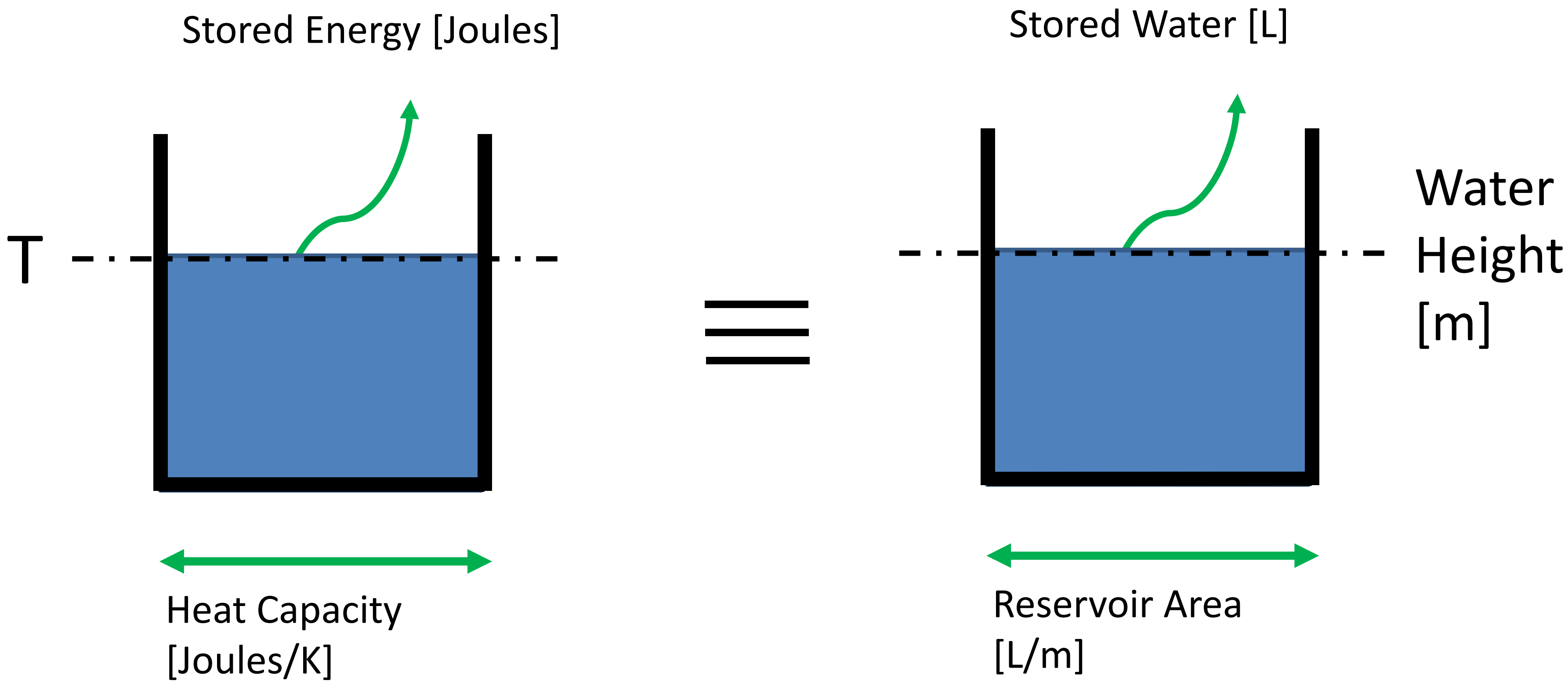
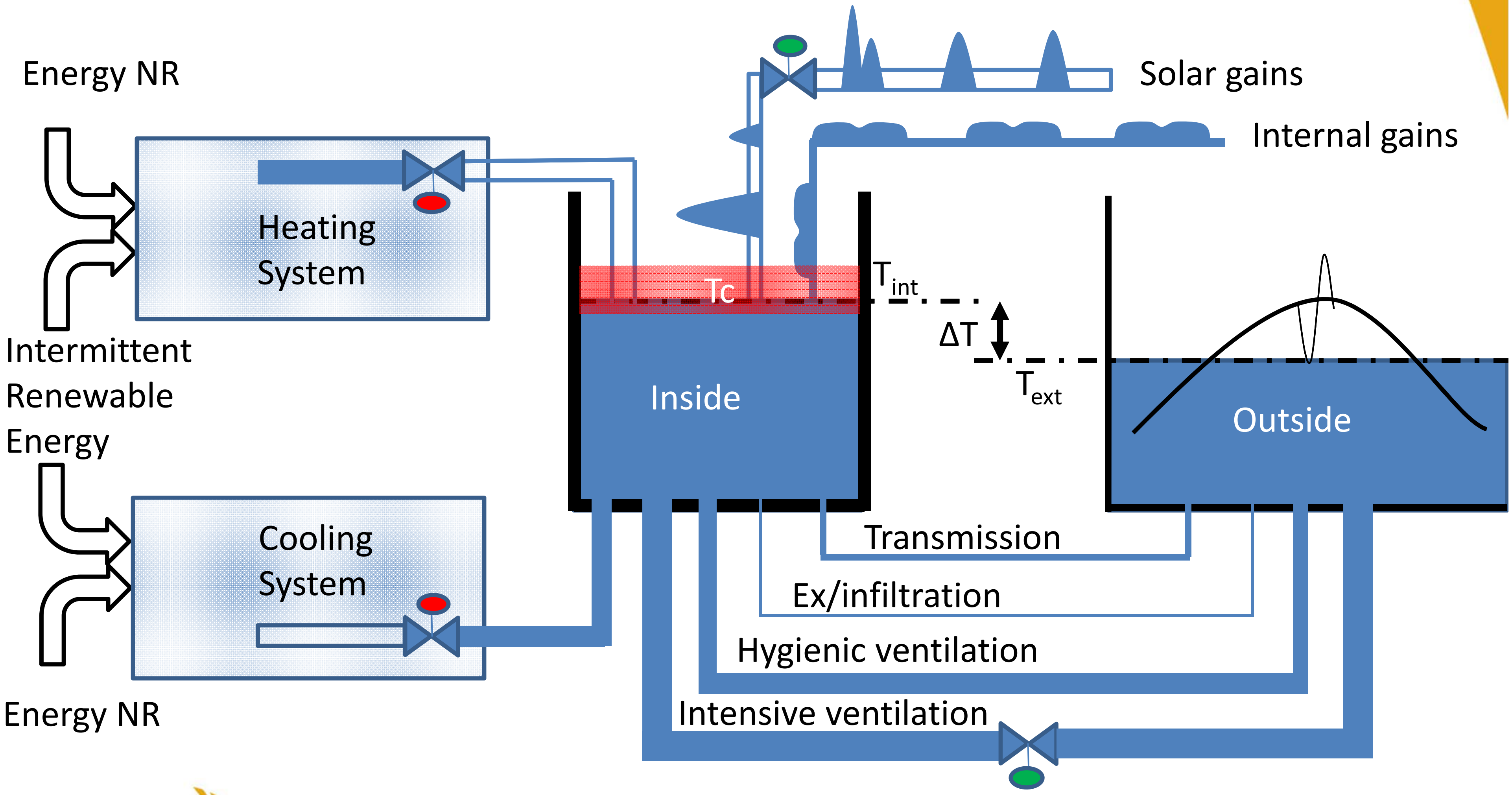
In Building Applications

To Optimise Thermal Mass

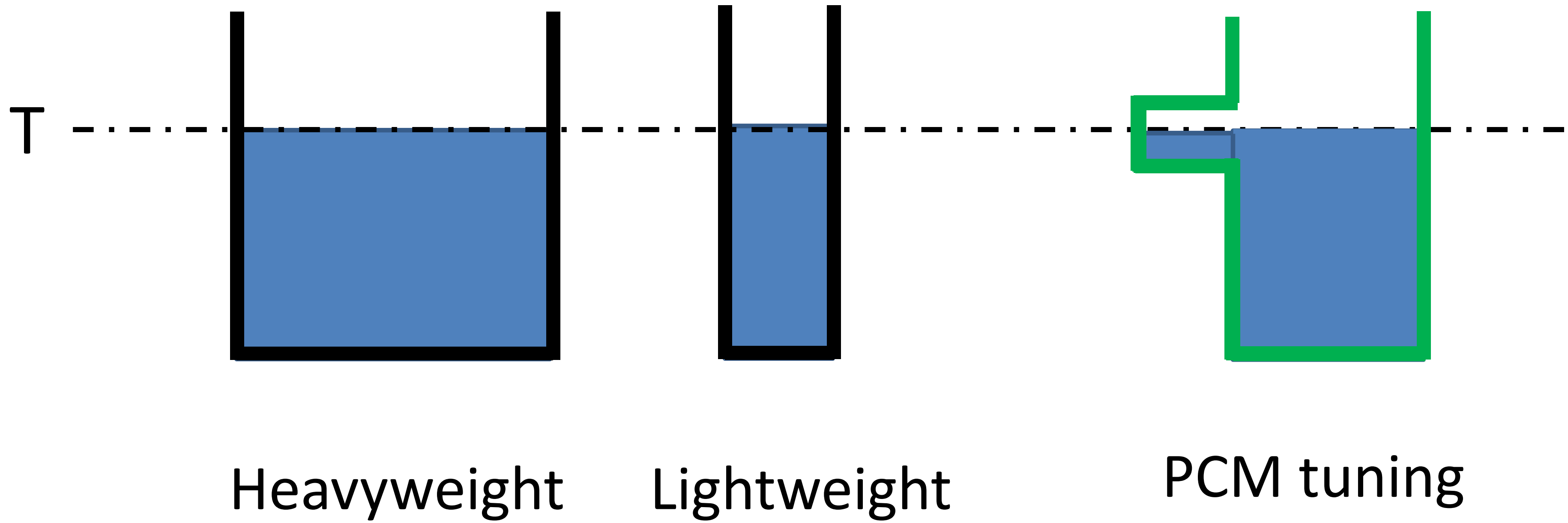
Thermal mass and water reservoir analogy



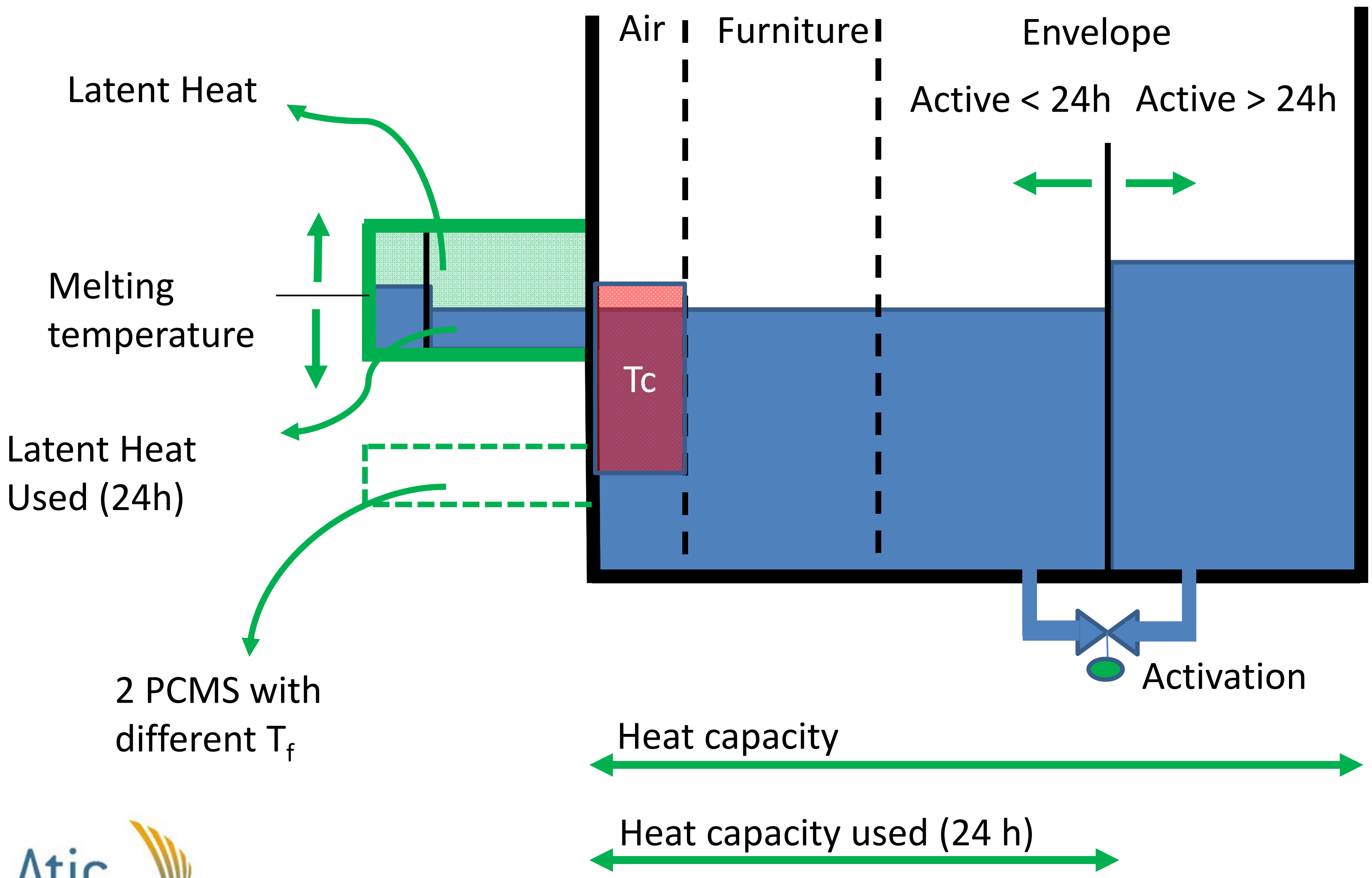
Thermal mass in the « building system »



PCMs change thermal mass shape



Levers for action to optimise thermal mass



Classical PCM use to increase thermal mass in lightweight buildings

« Lightweight » Building

PCM

PCM Envelope

+

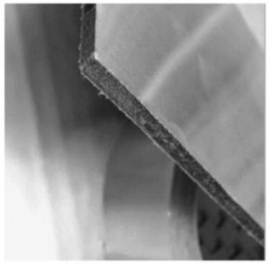


Fig. 3. Dupont de Nemours PCM composite wallboard, composed of 60% of microencapsulated paraffin [38].

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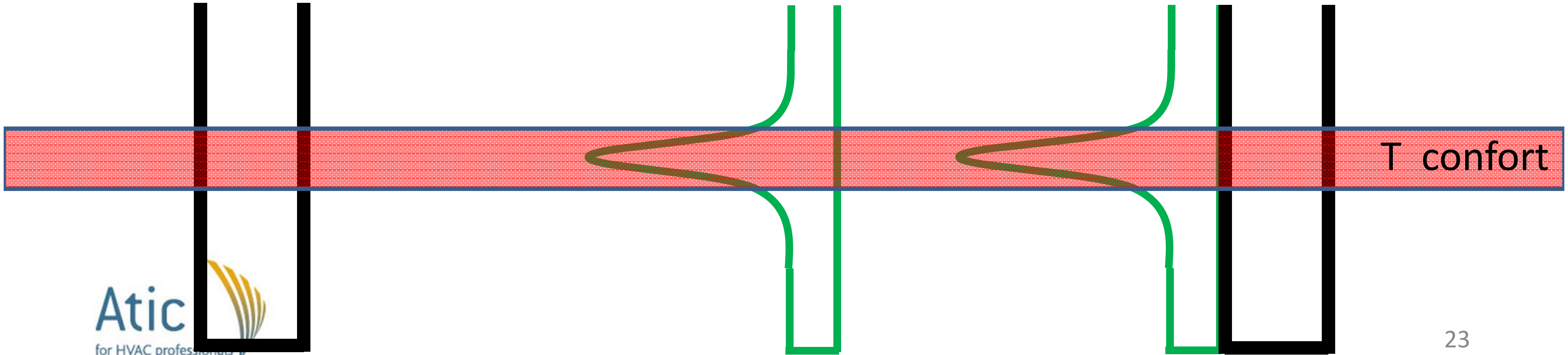

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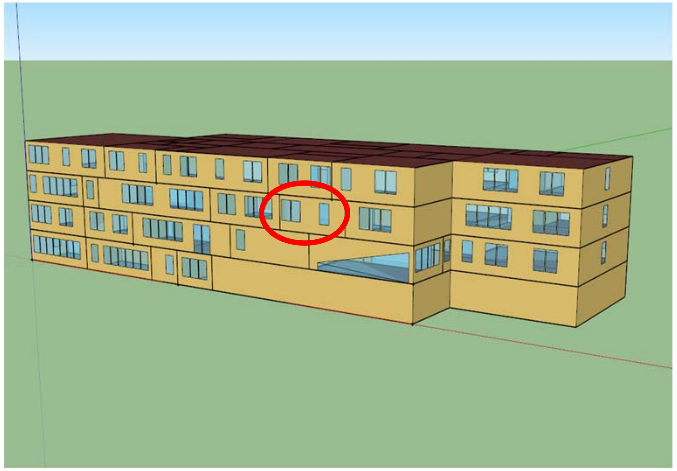
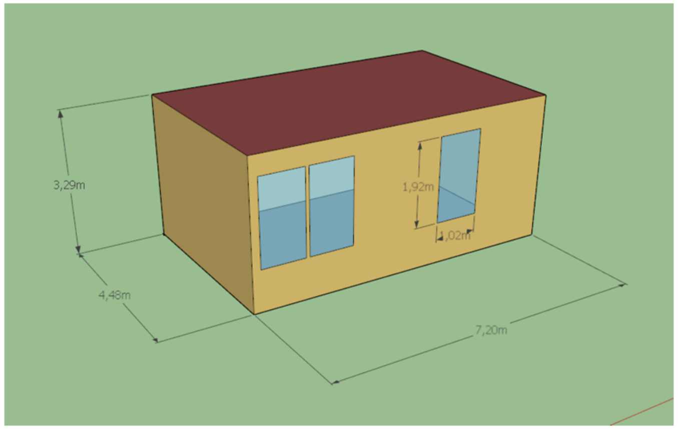
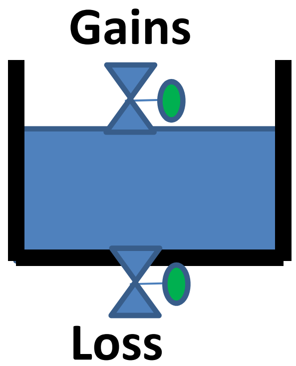
Case study: effect of thermal mass optimisation on cooling loads in a south-oriented office

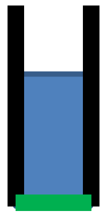




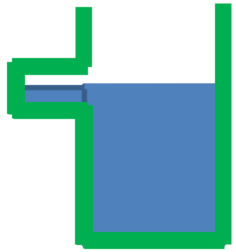
- Scenarios for cooling



- Thermal mass variation without PCM



- Thermal mass variation with PCM
  1 m2 PCM/m2 floor



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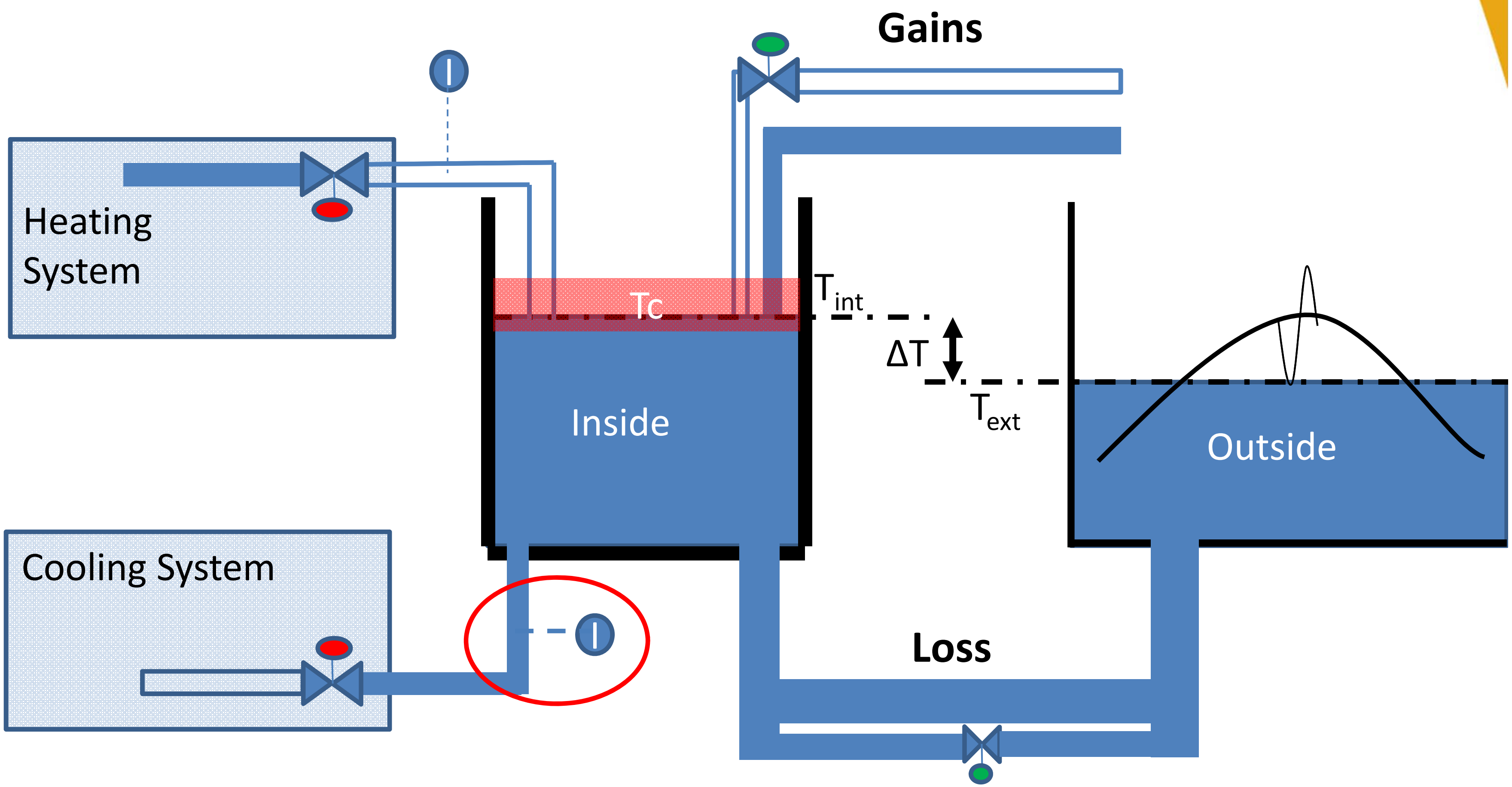
Effect of different scenarios on the annual cooling energy (kWh/m2 an)



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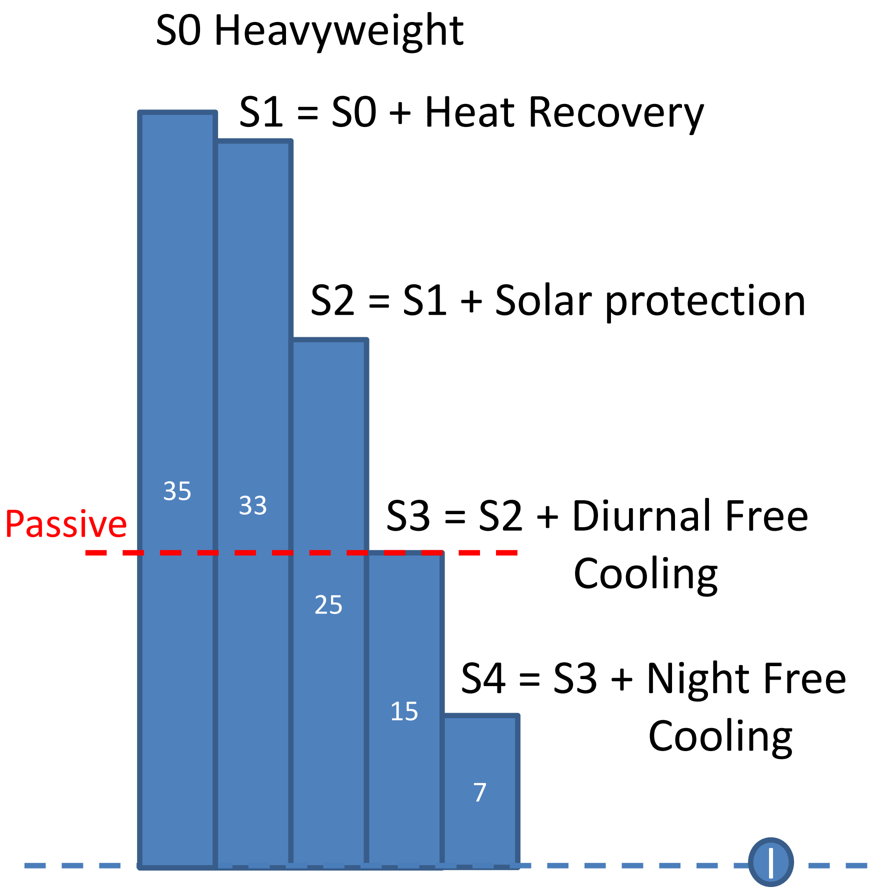

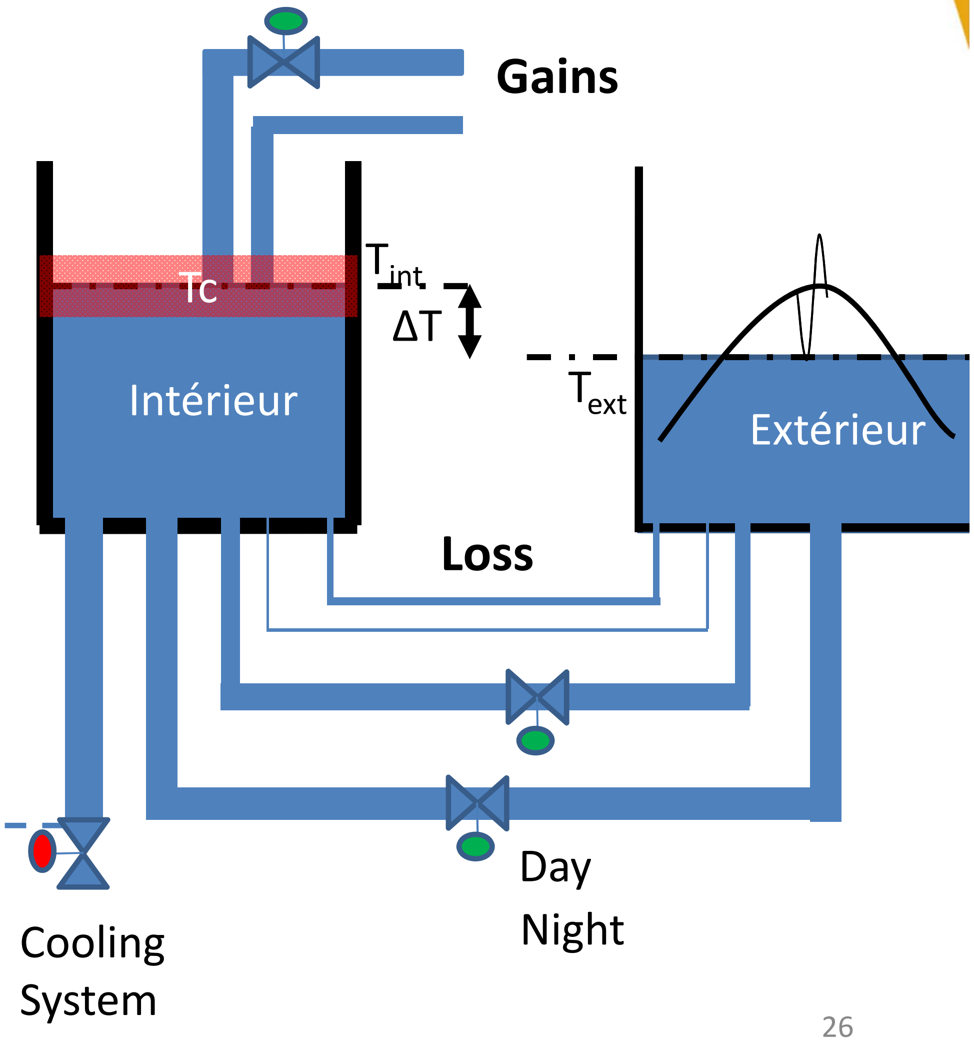

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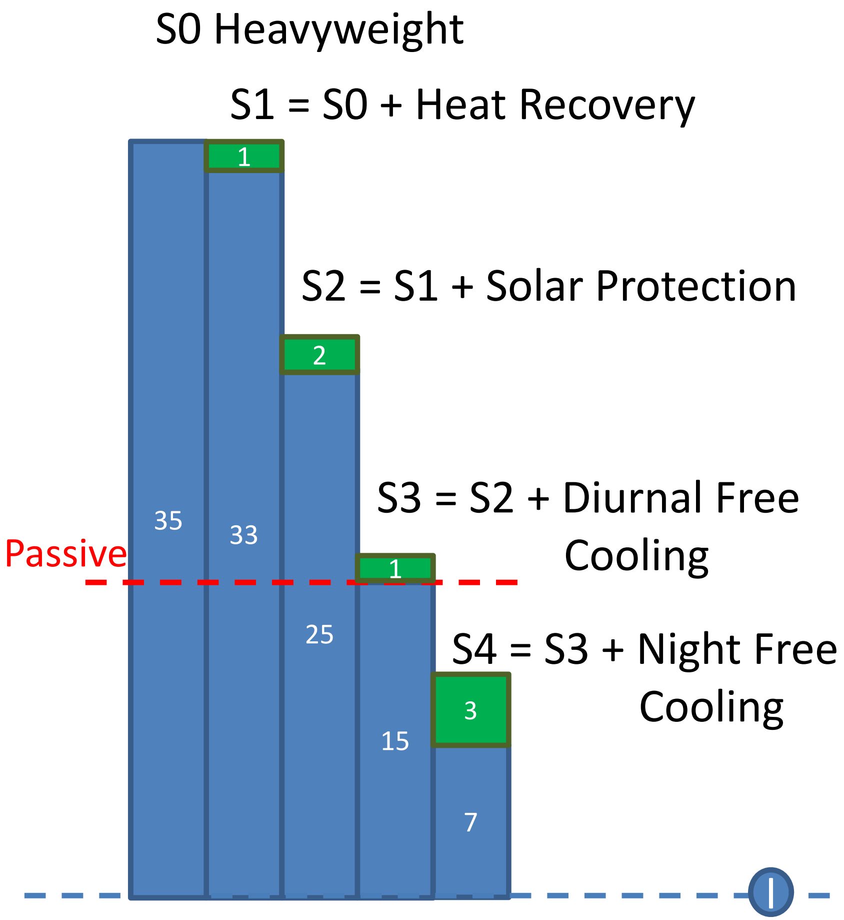
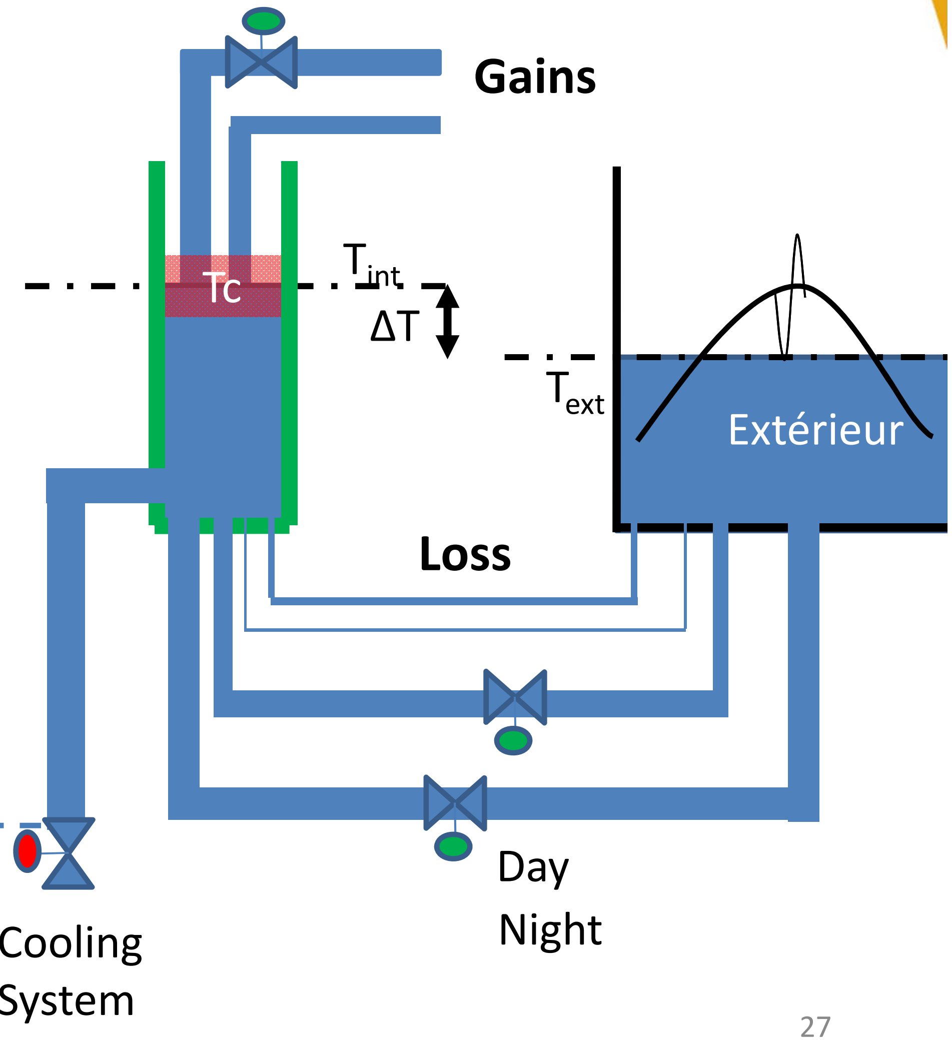
Effect of thermal mass on the annual cooling energy (kWh/m2 an)





Effect of thermal mass + PCM on the annual cooling energy (kWh/m2 an)

1 m2 exchange surface/ m2 floor

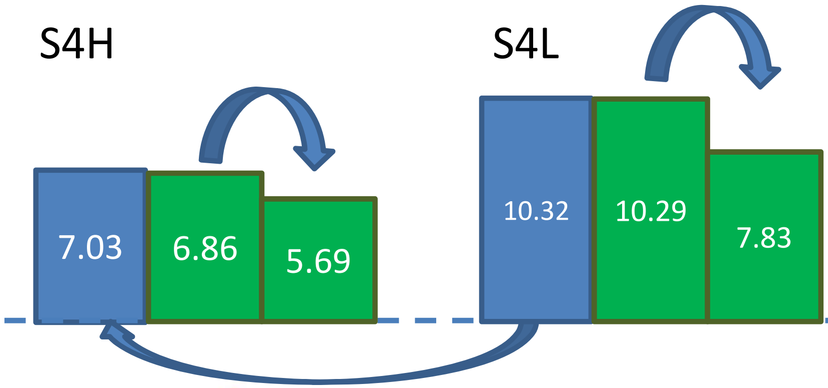
PCM effect:
E_l 110 J/g; T_f 23; ΔT_f 1
0,53 cm PCMs wallboard

ΔE_c 1.17 ; 17%

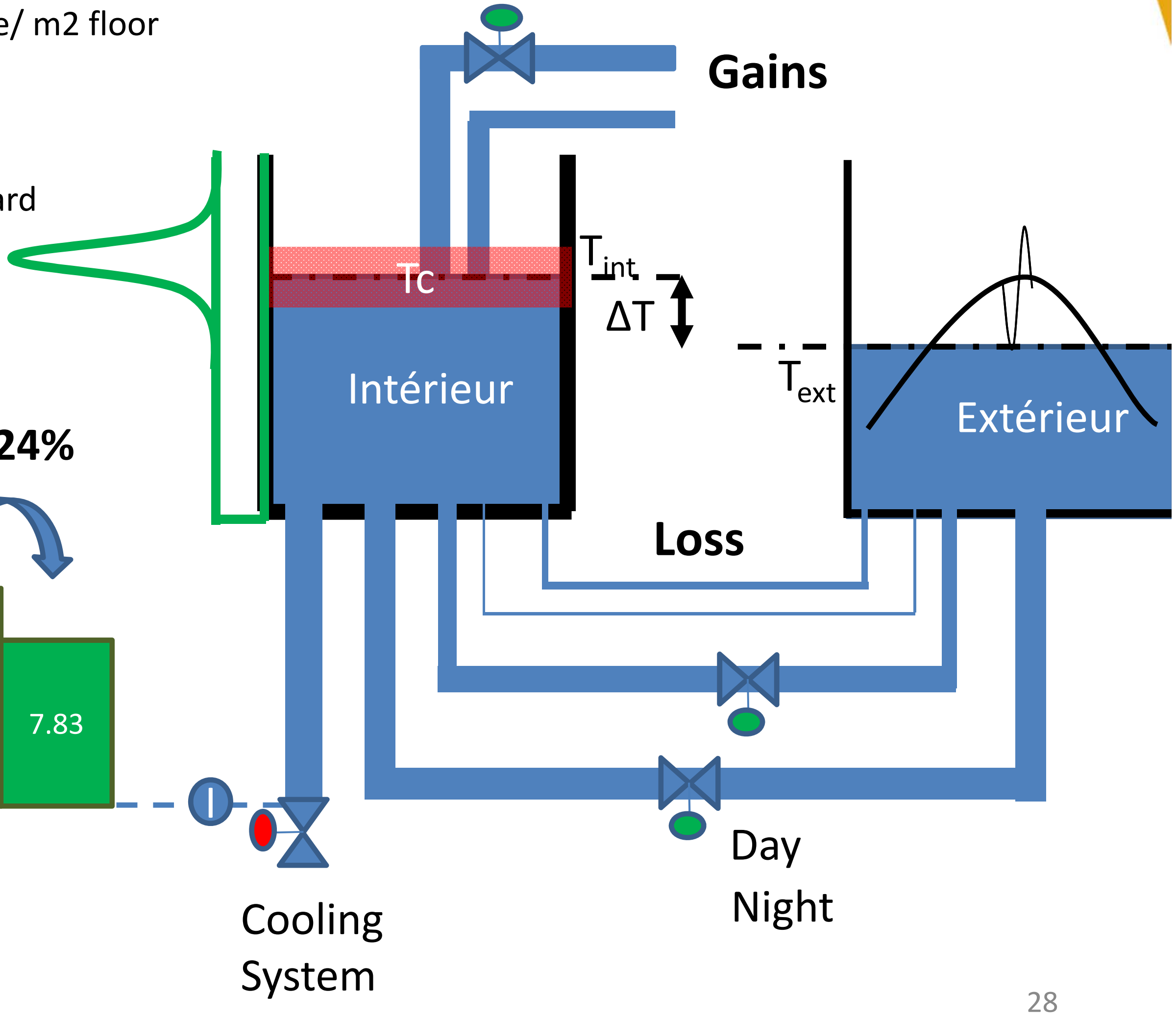
S4H

ΔE_c 2.46 ; 24%

S4L



1,3 m2/m2 floor
Exchange Surface



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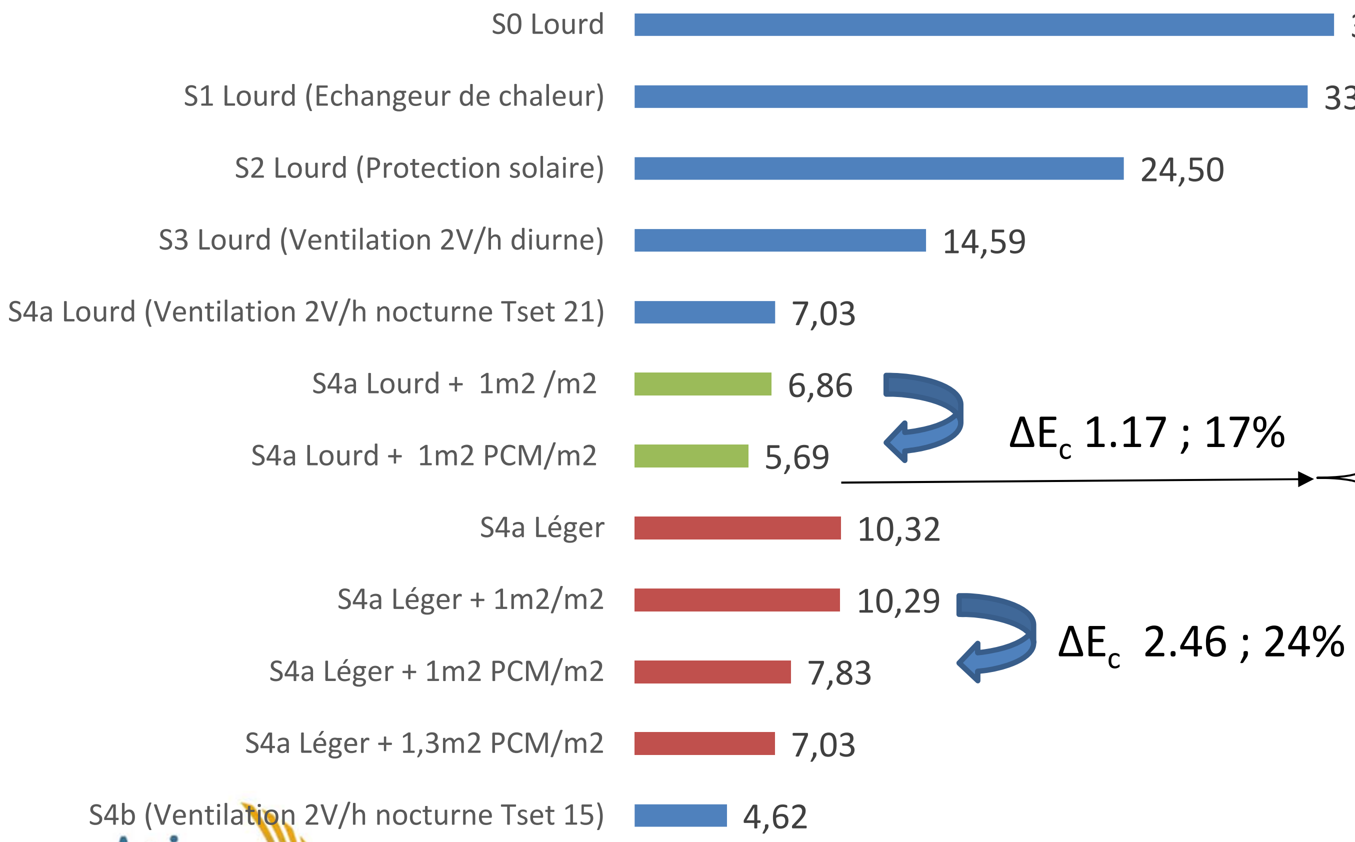
Cooling loads evolution (kWh/m2 an) in different scenarios



↗ Lambda

ΔE_c 0.1

↗ Exchance surface

ΔE_c 0.4

↗ PCM quantity

4 ep: ΔE_c 0.4

4 surf: ΔE_c 2.4

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1 m2 exchange surface/ m2 floor
E_l 110 J/g; T_f 23; ΔT_f 1
0,53 cm PCMs wallboard

STOCC

PCM in Building Applications to Optimise Thermal Mass

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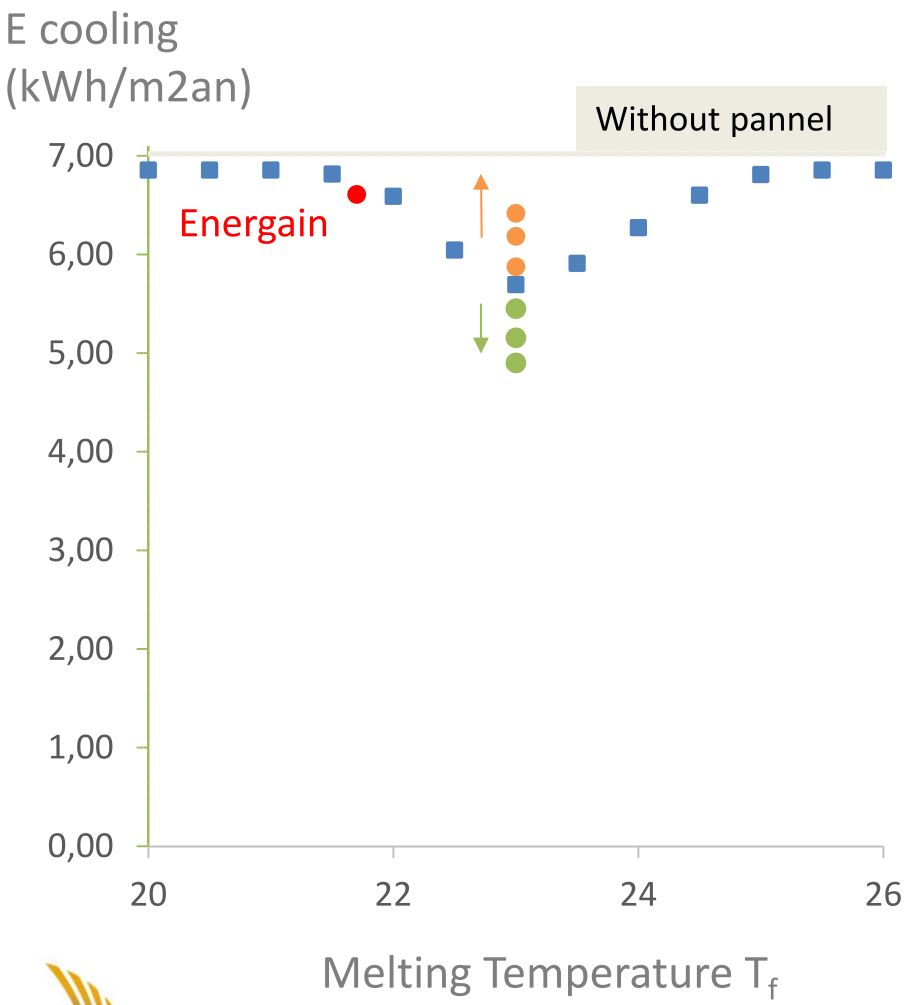
Architecture et Climat - UCL

Appendix 1: Ecooling in function of T_f, ΔT_f and E_l



Optimum T_f 23°C

↗ ΔT_f , ↗ E cooling

(1,3,6,10)

↗ E_l , ↘ E cooling

(110 ,220 (limite paraffine),550 (limite sels hydratés) ,1100 (cas extrême)

1 m2 exchange surface/ m2 floor
E_l 110 J/g; T_f 23; ΔT_f 1
0,53 cm PCMs wallboard

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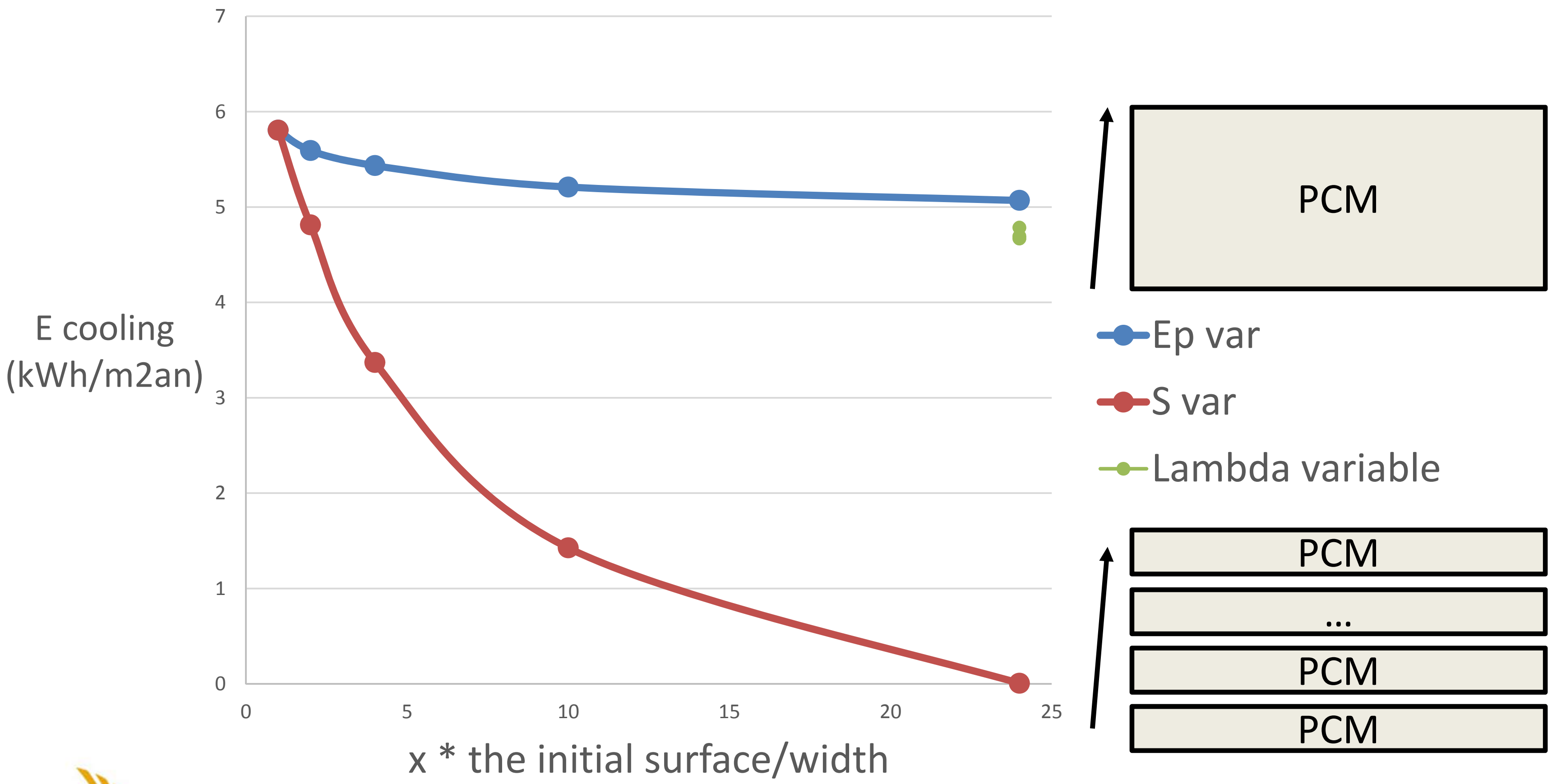
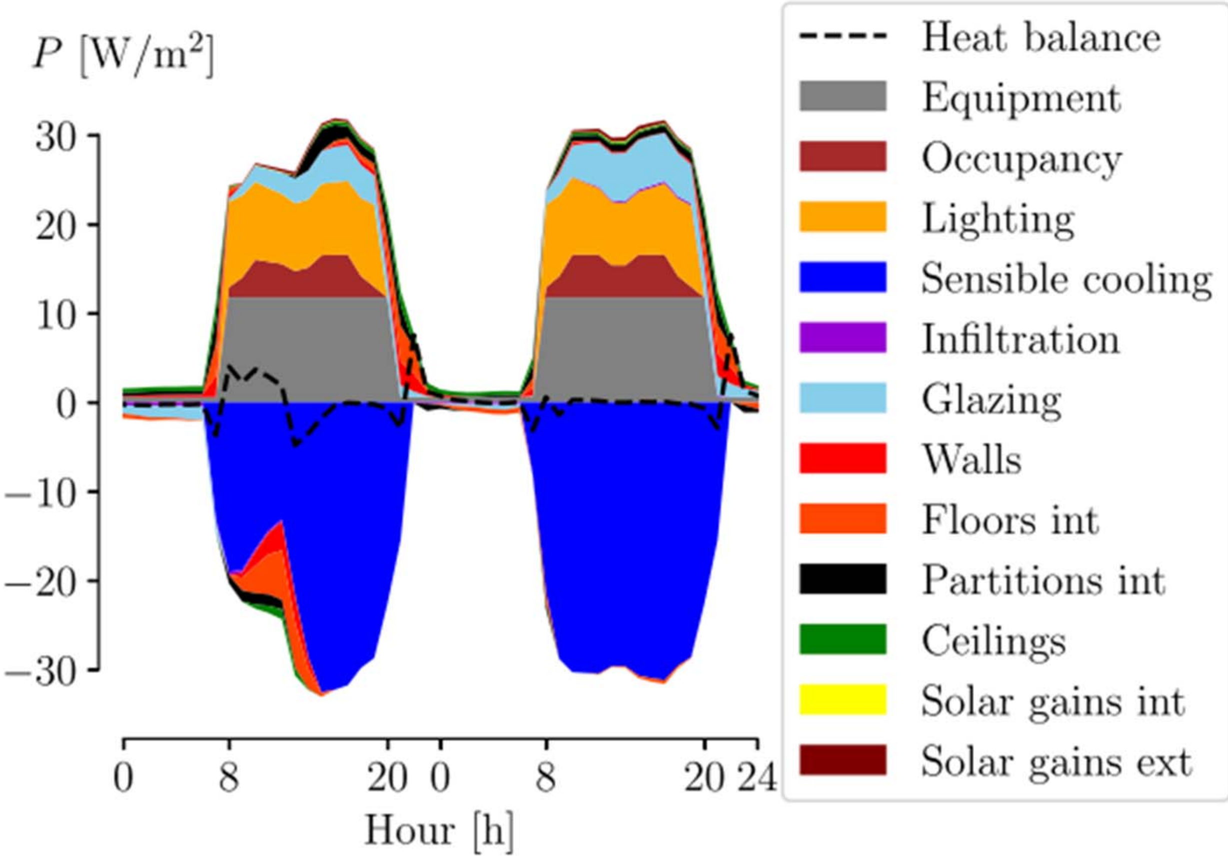
Appendix 2: Ecooling in function of PCM quantity: increasing of width and number of panels



Appendix 3: cooling loads in the south-oriented office



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