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Udnyttelse af betons termiske egenskaber til forbedret indeklima og reduceret energiforbrug

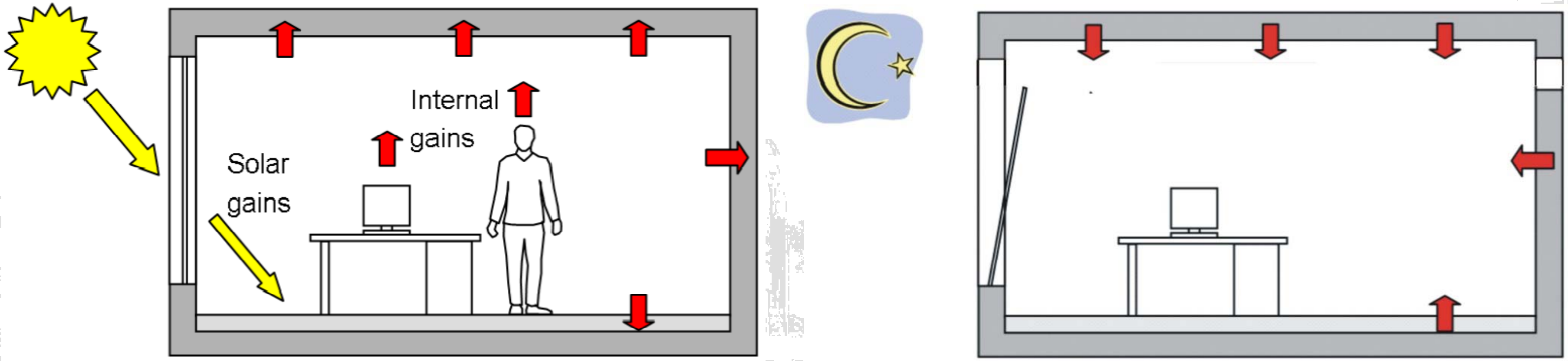
Per Heiselberg

Institut for Byggeri og Anlæg

Aalborg Universitet

Energi akkumulering – Hvad er den basale funktion?

- Varmemodulering (24 timers cyklus)
  - Absorbtion af overskudsvarme om dagen – tilbagelevering af varme om natten (reduktion af varmebehov)



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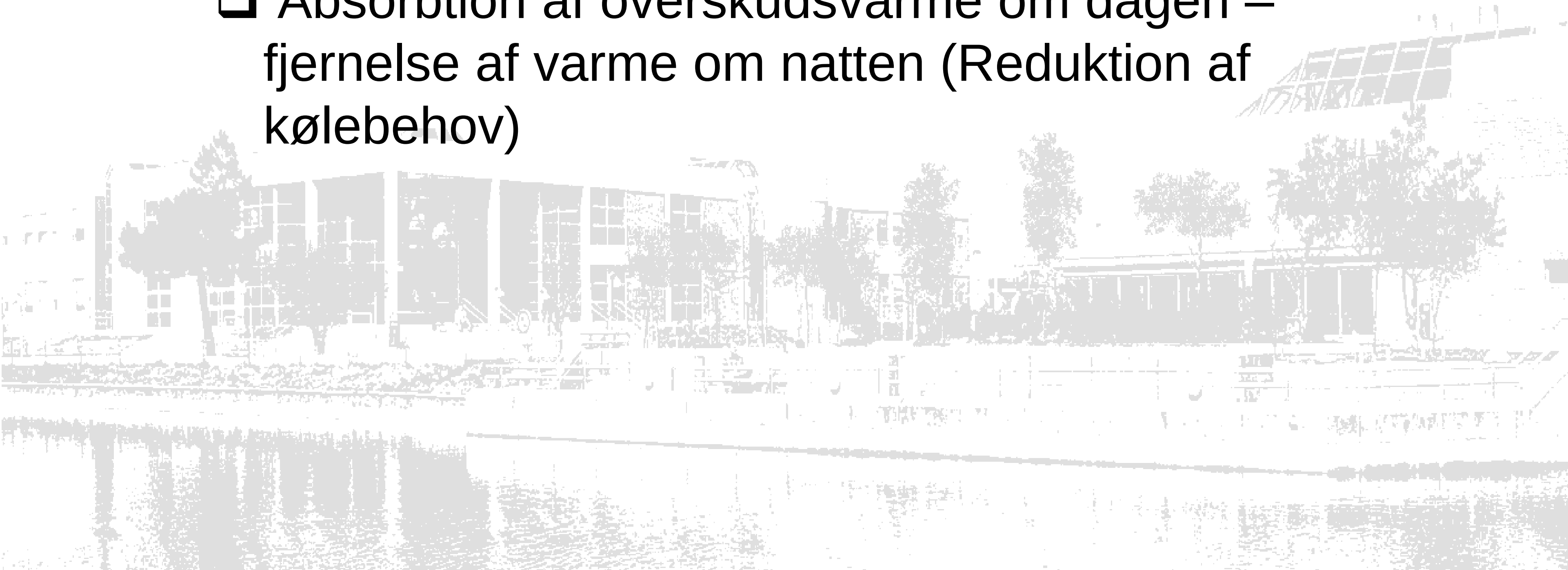
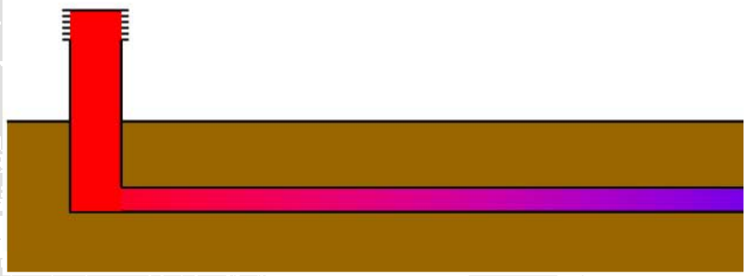
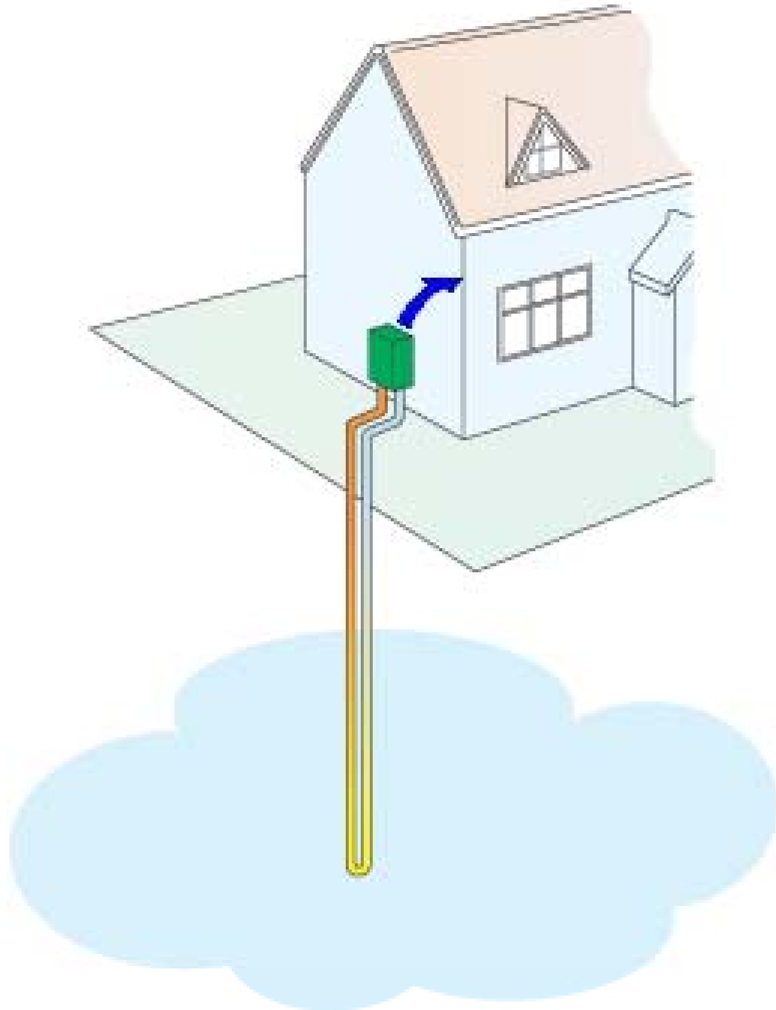


Natural heat sinks

- Night-time outdoor air
- Earth-to-air (water) heat exchanger
- Ground water





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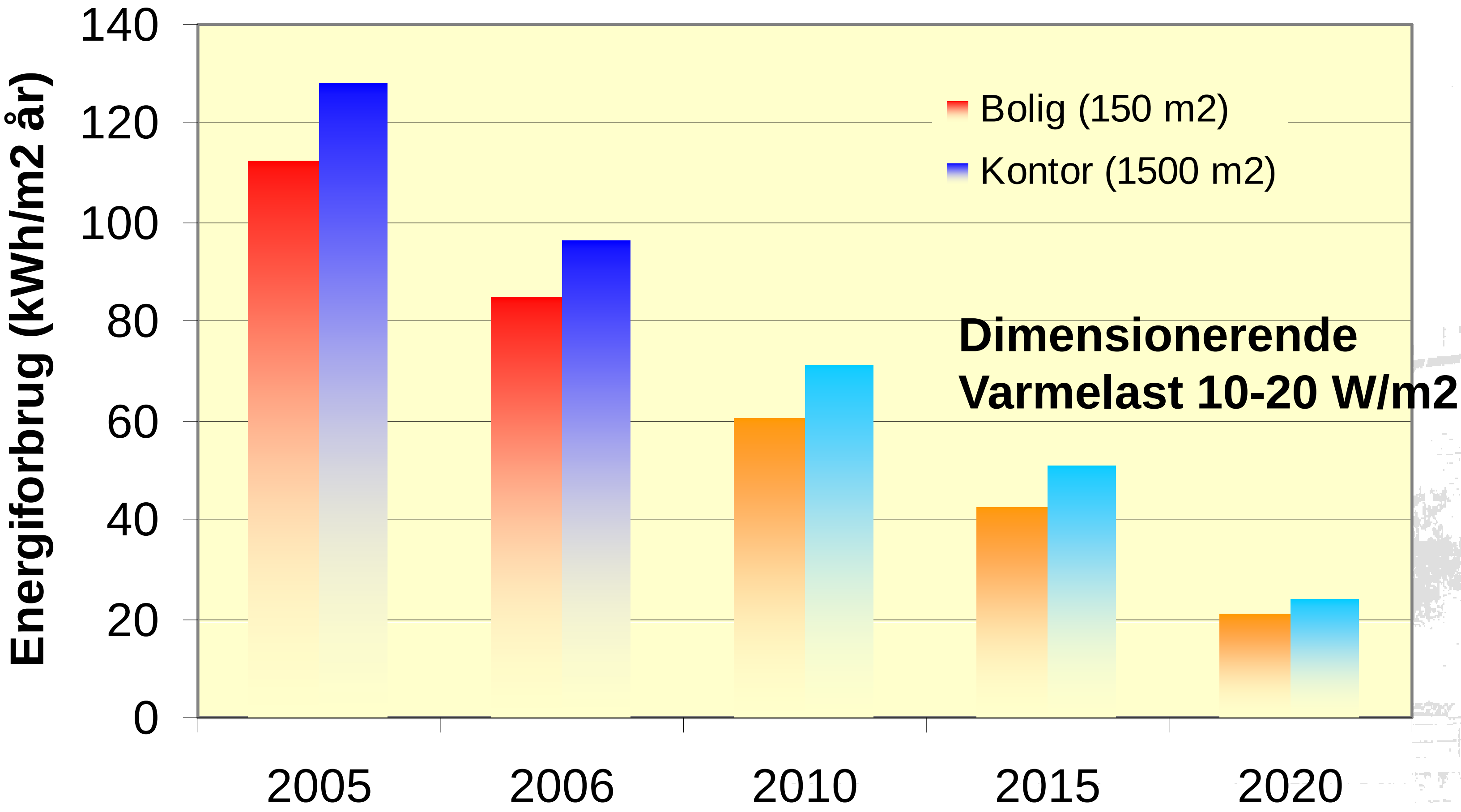
- Varmelagring (3-4 dages lagring)
  - Absorbtion af solenergi/overskudsvarme på solskinsdage – tilbagelevering af varme på overskyede dage

Udvikling i maksimalt energiforbrug i nye bygninger



Varmebehov/varmetilskud

- Varmebehov
  - Dimensionerende 10-20 W/m2
  - Gennemsnitlig i vintermånederne 6-12 W/m2
- Varmetilskud
  - Personer 100 W (kontor 5 W/m2)
  - Belysning 7-10 W/m2
  - Kontor udstyr 5-10 W/m2
  - Solindfald 20-40 W/m2

- I kontorbyggeri vil der altid være varmeoverskud i brugstiden
- I boligbyggeri vil der altid være varmeoverskud, når solen skinner

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Necessary Conditions for Success

- **It can make a difference** (replacement of heating system and/or air conditioning)

- A heat sink is available (low night-time outdoor air temperatures)
- The heat storage capacity of the building construction is adequate
- The excess heat gain can be absorbed and released within a 24 hour cycle

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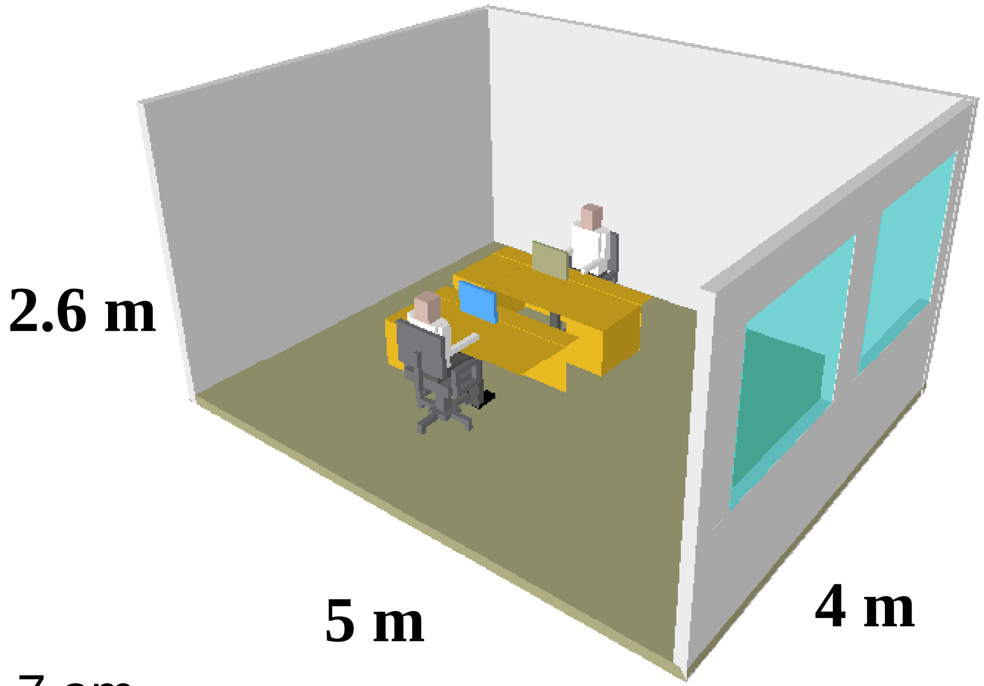
Parameter Study



Office room
Model in HELIOS

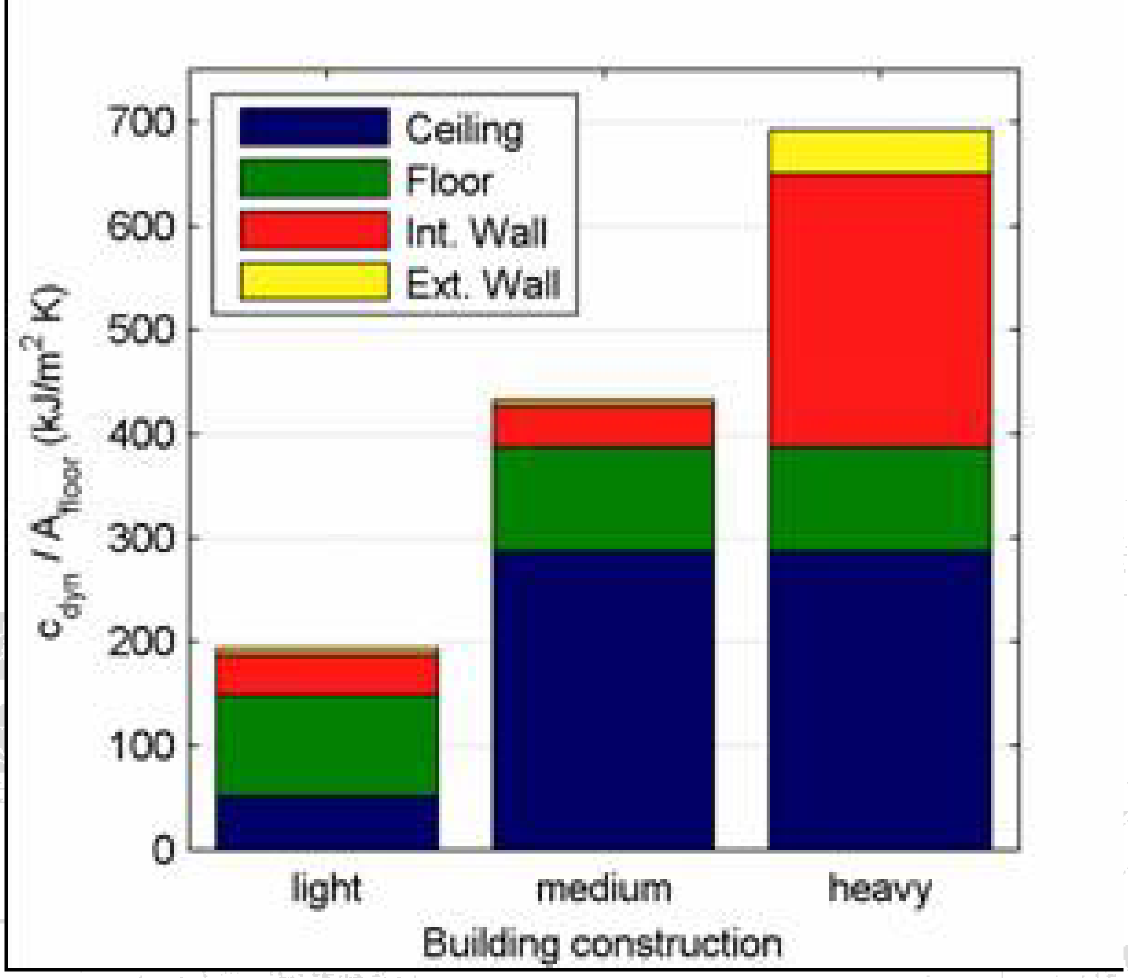
- Night-time ventilation
  - Air change rate: 6 ACH
  - Night ventilation from 7 pm to 7 am
  - Temperature difference, $T_{Surface}$ - $T_{Ambient}$ > 3 K
  - Termination if $T_{Surface}$ < 20 °C
- Thermal mass

  Light-, medium-, and heavy-weight building construction
- Internal heat gains

  Low, medium and high internal heat gains
- Climatic data
  - Measured data: Zurich SMA, ANETZ
  - Zurich Design Reference Year (DRY)

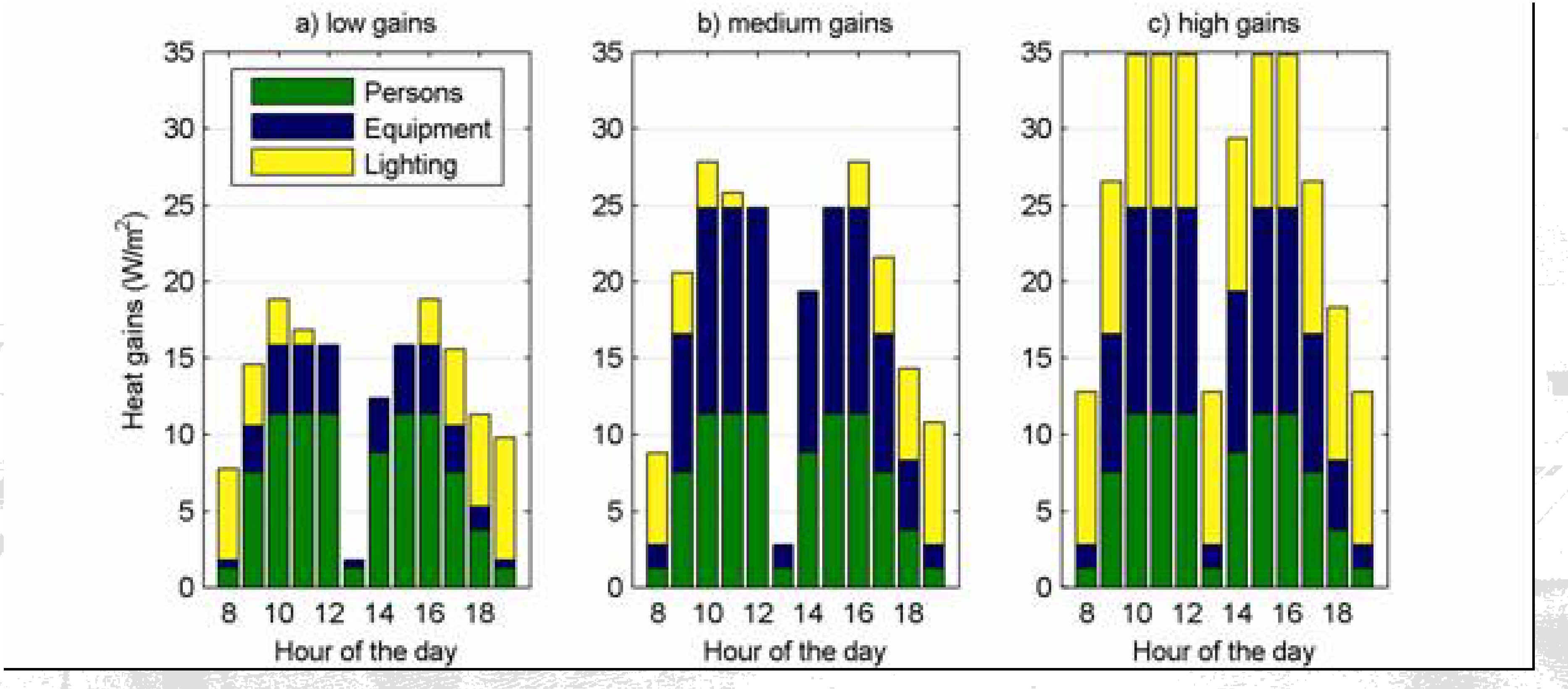
Thermal Mass

- Three different levels of thermal mass
  - light (suspended ceiling, gypsum board walls),
  - medium (exposed concrete ceiling, gypsum board walls)
  - heavy (exposed concrete ceiling, lime sand brick walls)



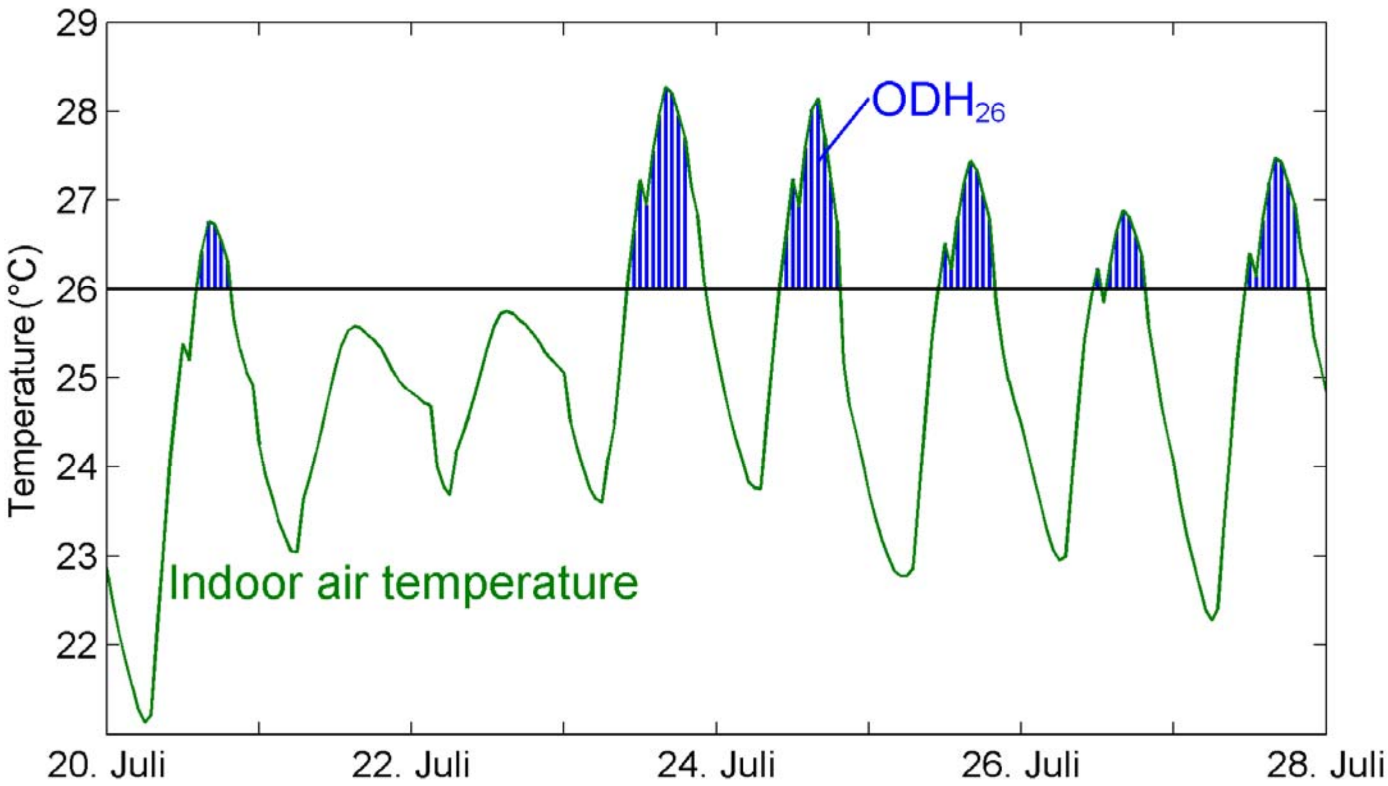
Internal heat gains in the course of a day.

- Low (159.2 Wh/m^{2}d, 13 W/m^2)
- medium (229.2 Wh/m^{2}d, 19 W/m^2)
- high (313.2 Wh/m^{2}d, 26 W/m^2)



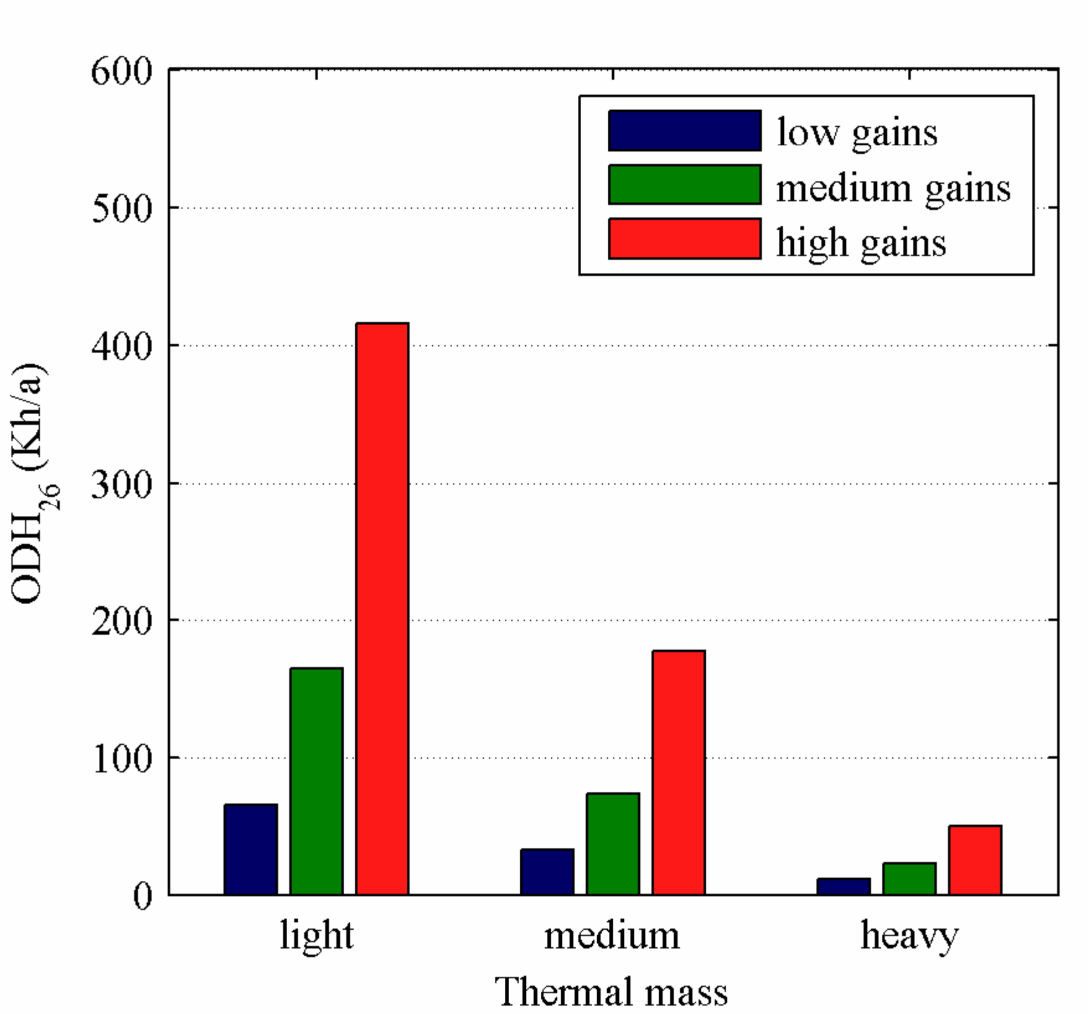
Thermal comfort evaluation

- Overheating degree hours above 26 °C (ODH_{26})
- International standards: ODH_{26} = 100 - 400 Kh/a



Overheating degree hours above 26 °C

- For Zurich climatic dat
  - ANETZ 1996-2005);



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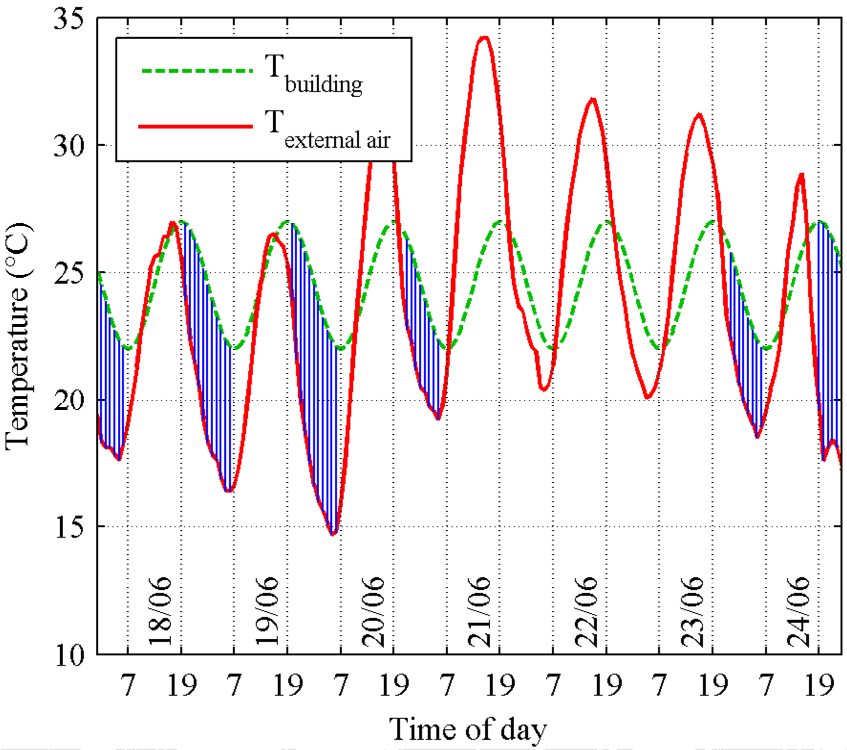
Climatic potential for night-time cooling

- Degree hours method to quantify the climatic cooling potential (CCP)
- Harmonically oscillating building temperature within a range of thermal comfort:
  $T_b = 24.5°C \pm 2.5°C$
- Ventilation period:
  7 pm – 7 am
- Minimum temperature difference: $\Delta T_{crit} = 3K$



Shaded areas show the climatic cooling potential during one exceptionally hot week in summer 2003 for Zurich SMA (ANETZ data)

➔ CCP (K h)

$$CCP_d = \sum_{t=t_i}^{t_f} m_{d,t} \left(T_{b(d,t)} - T_{e(d,t)}\right)$$

$$\begin{cases} m = 1\text{h} & \text{if } T_b - T_e \geq \Delta T_{crit} \\ m = 0 & \text{if } T_b - T_e < \Delta T_{crit} \end{cases}$$

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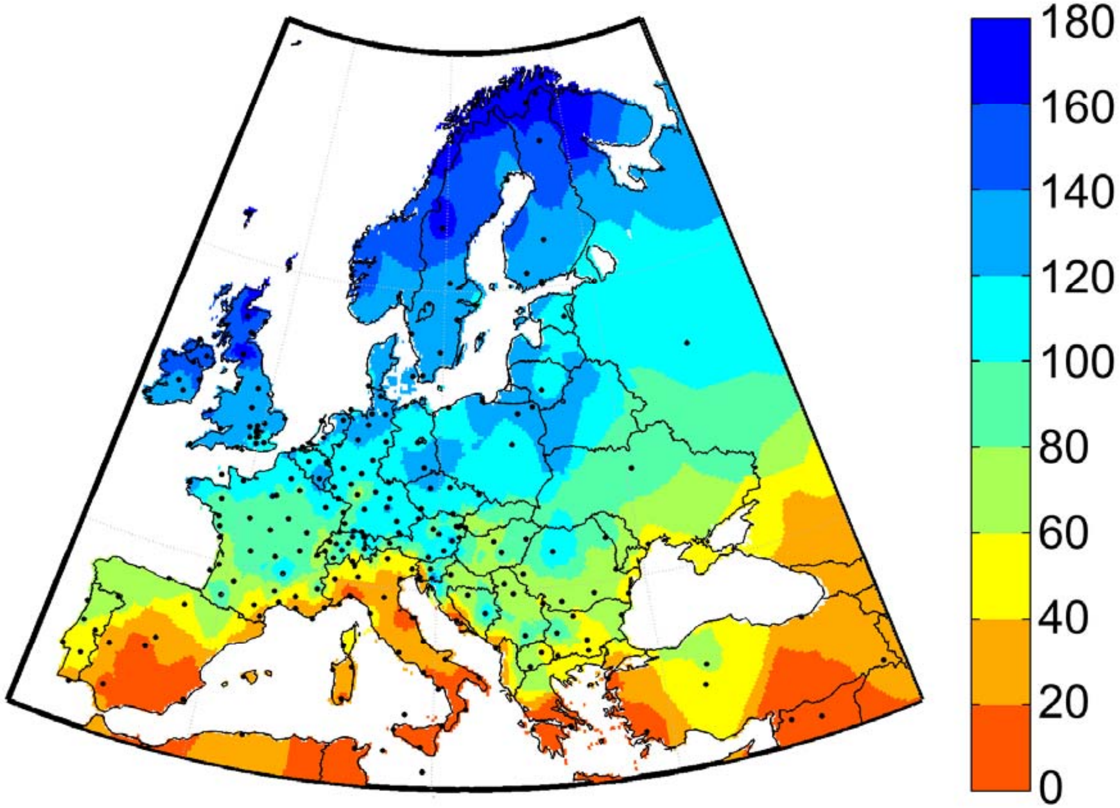
Local variability

Semi-synthetic data (Meteonorm) from 259 locations in Europe

- Very high potential of 120 – 180 K h in Northern Europe (incl. British Isles)
- High cooling potential (80 – 140 K h) in Central, Eastern and parts of Southern Europe
- Low cooling potential in Southern Europe: 0 – 80 K h



Map of mean climatic cooling potential (K h / night) in July (Meteonorm data)

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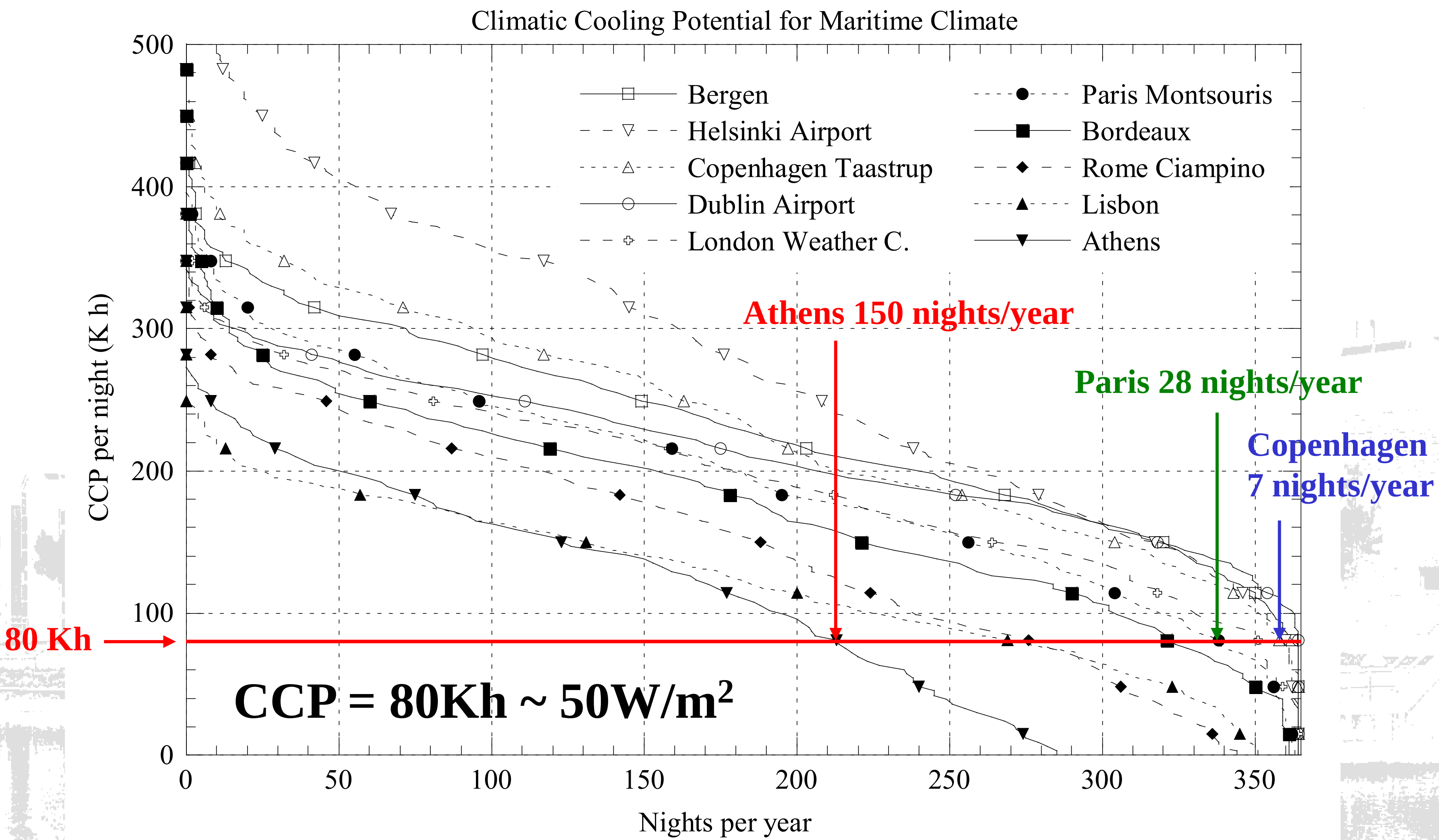
Cumulative frequency distribution of CCP



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Necessary Conditions for Success

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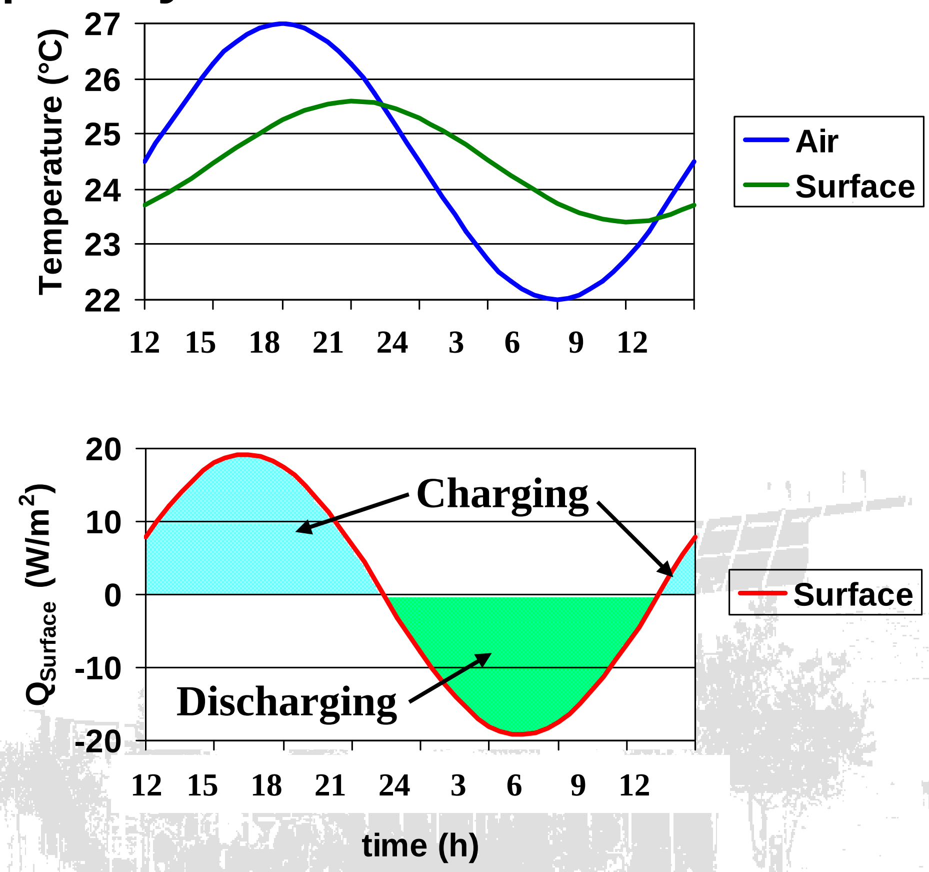
Dynamic heat storage capacity

- Integration of the charging or discharging surface heat flow over one periodic cycle

➔ Dynamic heat storage capacity c_{dyn} (kJ/m²K)



Definition in EN ISO 13786 (1991)
Thermal performance of building components – Dynamic thermal characteristics – Calculation methods

Temperature and surface heat flow profiles for a 100 mm thick concrete slab, h = 10 W/m²K.

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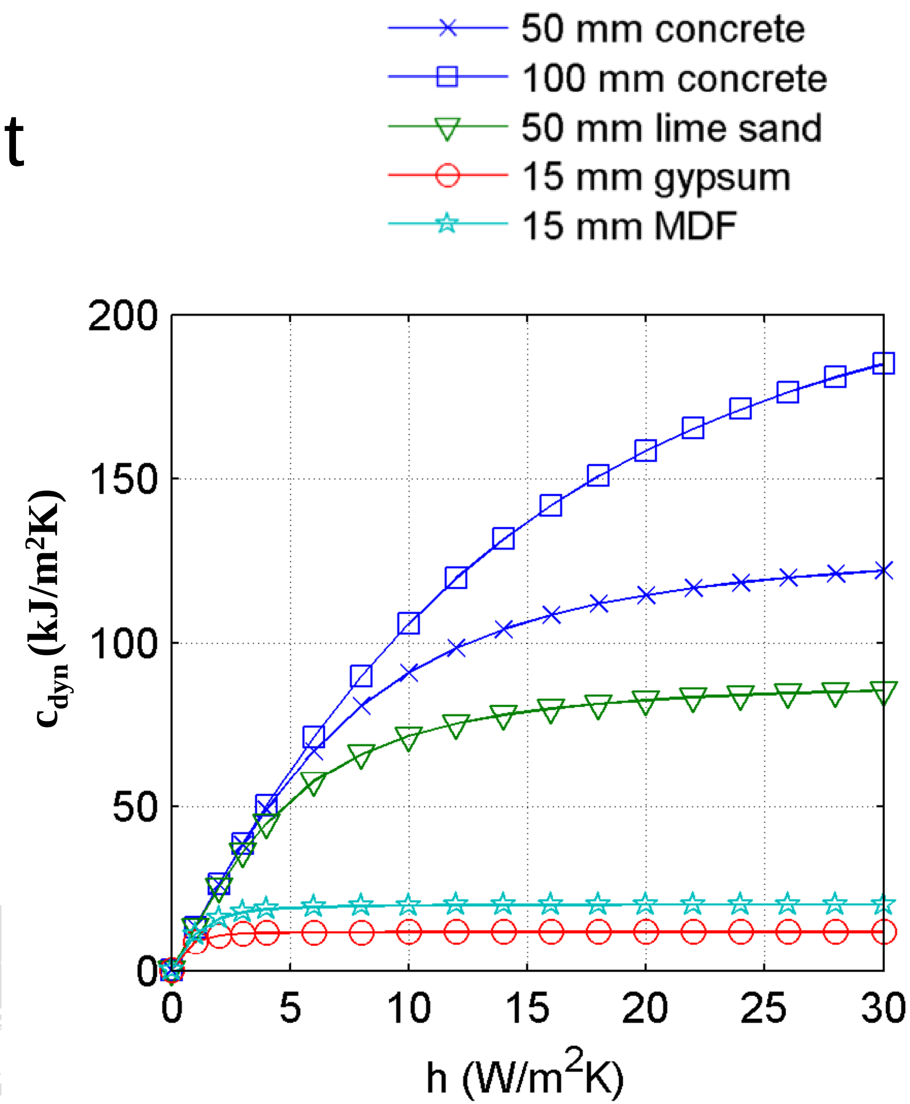
Heat transfer coefficient

- Thin slab / light-weight material: Constant heat storage capacity for $h > 3$ W/m²K
- Thick slab / heavy-weight material: Significant increase in heat storage capacity with increasing HTC up to $h = 30$ W/m²K

	λ W/mK	ρ kg/m³	c kJ/kgK
Concrete	1.80	2400	1.1
Lime Sand	1.10	2000	0.9
Gypsum	0.40	1000	0.8
MDF	0.18	800	1.7



Diurnal heat storage capacity, c_{dyn} depending on the heat transfer coefficient, h for different materials and slab thicknesses.

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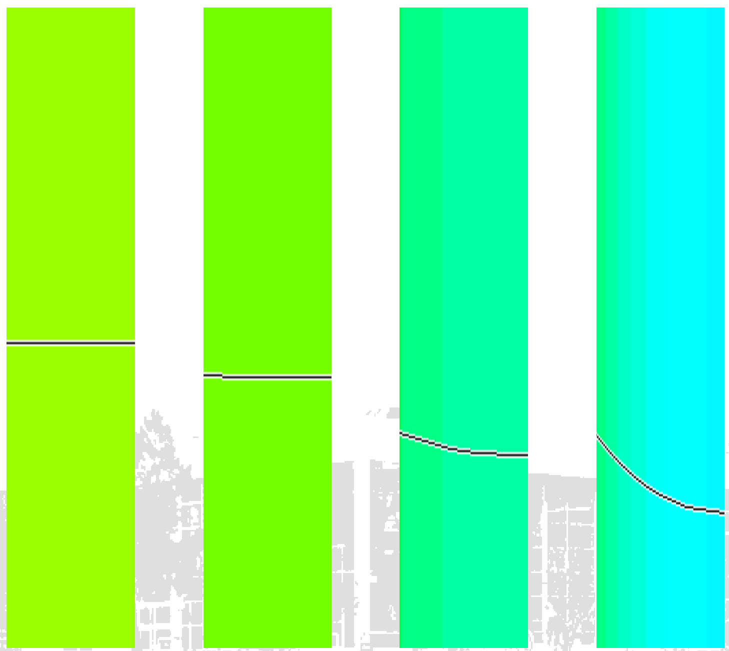
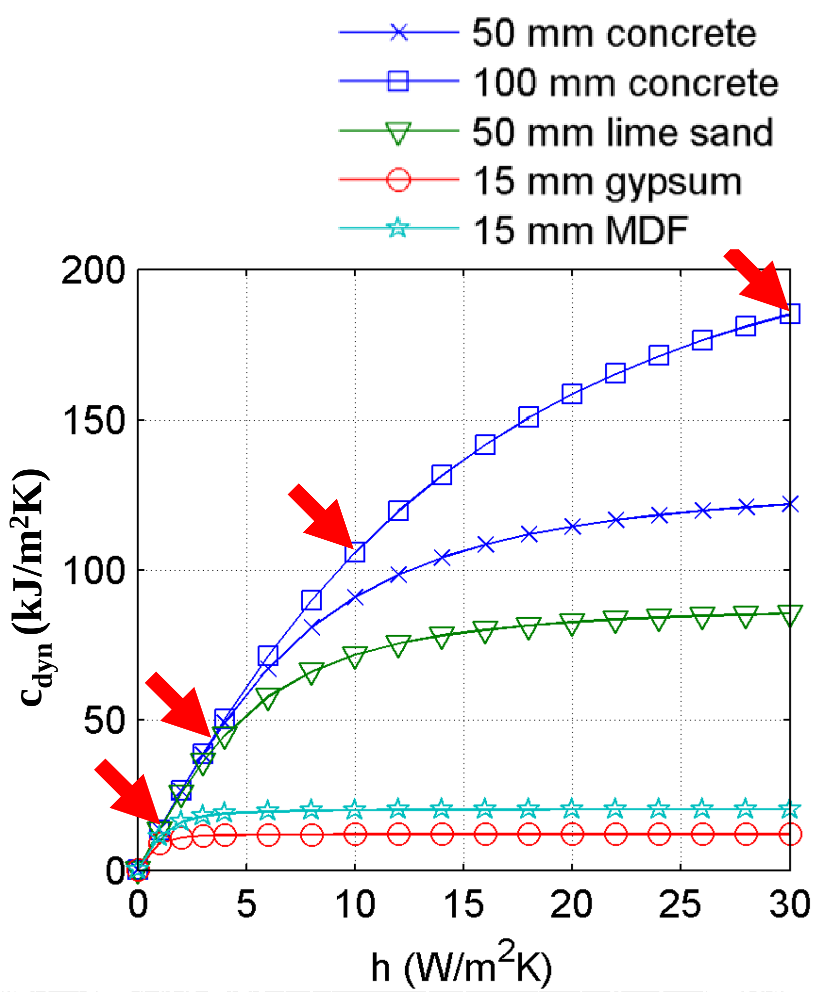
Heat transfer coefficient

Concrete, d = 100 mm



h = 1 .. 3 .. 10 .. 30 W/m^2K



Diurnal heat storage capacity, c_{dyn} depending on the heat transfer coefficient, h for different materials and slab thicknesses.

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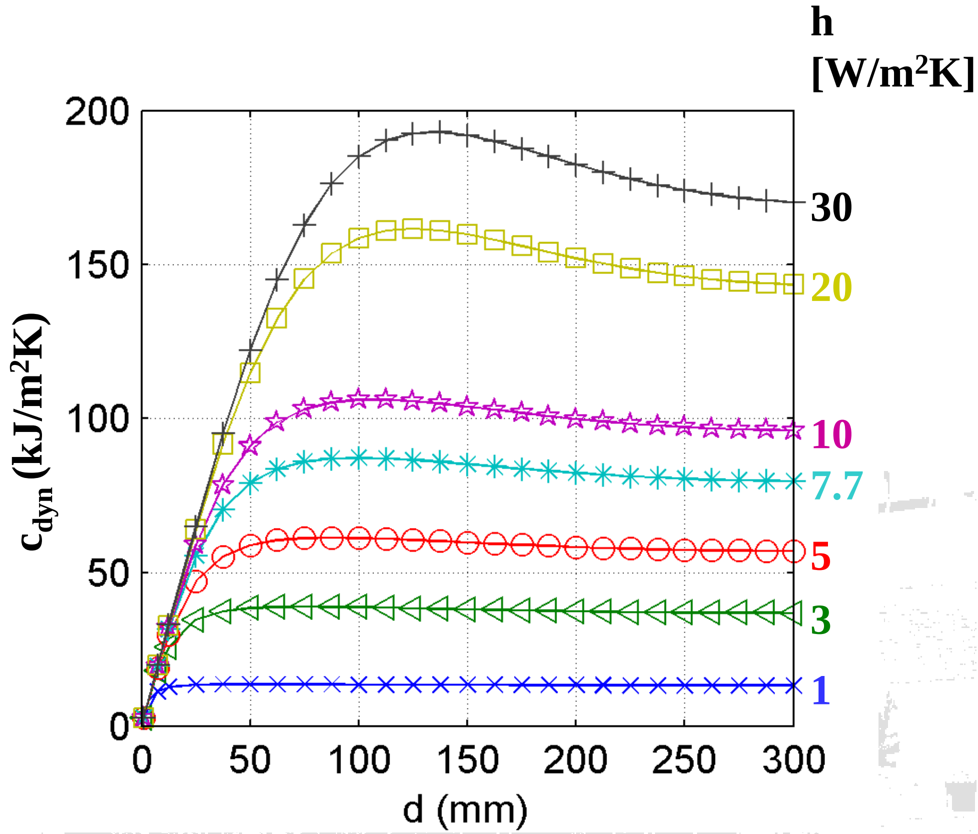
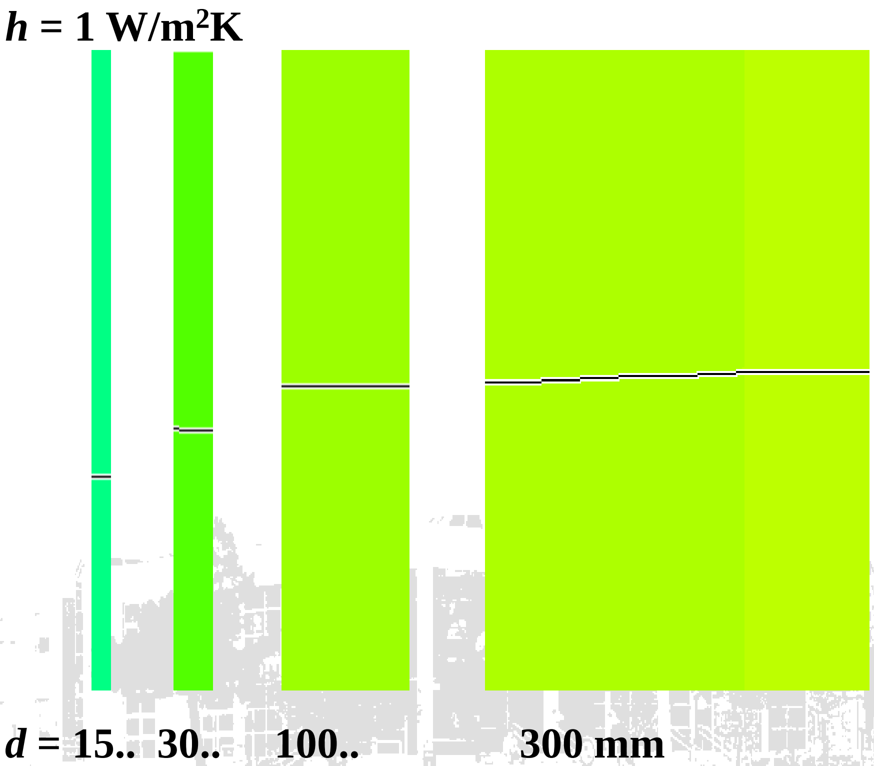
Slab thickness

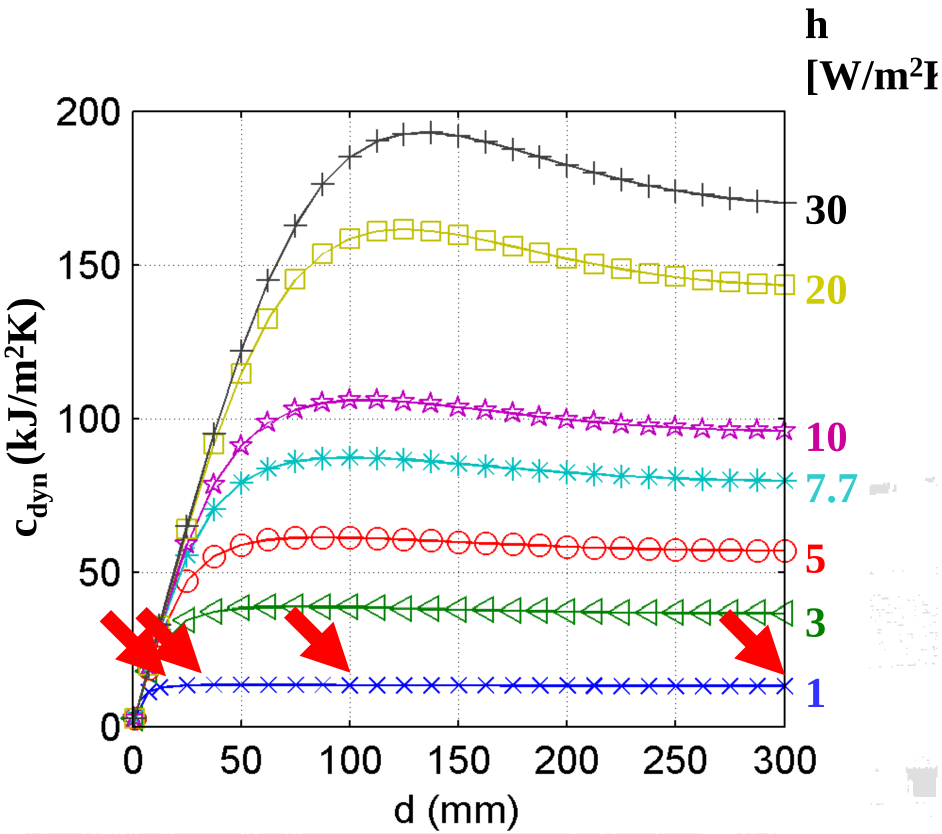
- **Low heat transfer coefficient: No increase in heat storage capacity for *d* > 30 mm**
- **High heat transfer coefficient: Increase in heat storage capacity until a maximum**
- **Optimum thickness depending on heat transfer coefficient**
  - **h = 5 W/m²K: d_{opt} = 90mm**
  - **h = 30 W/m²K: d_{opt} = 140mm**



Diurnal heat storage capacity, c_{dyn} of a concrete slab depending on the thickness, *d* for different heat transfer coefficients, *h*.

Slab thickness

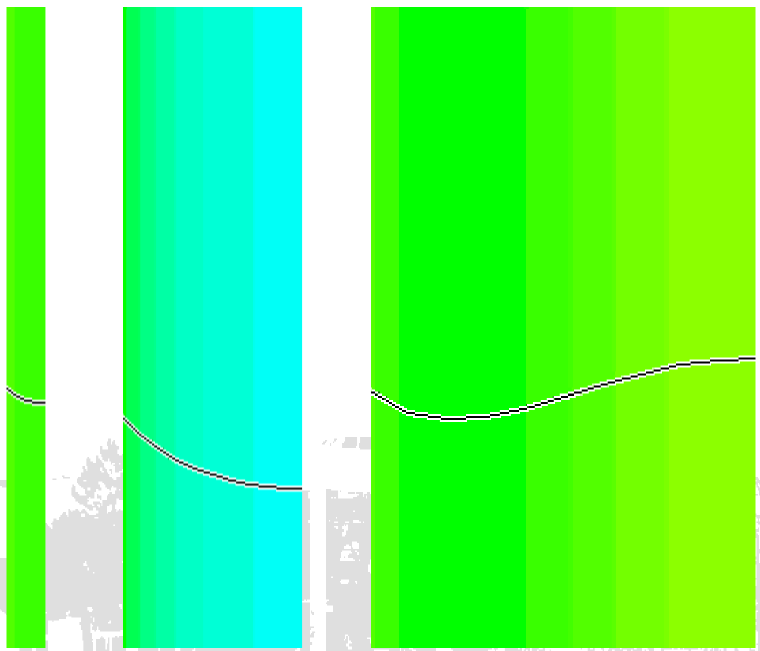




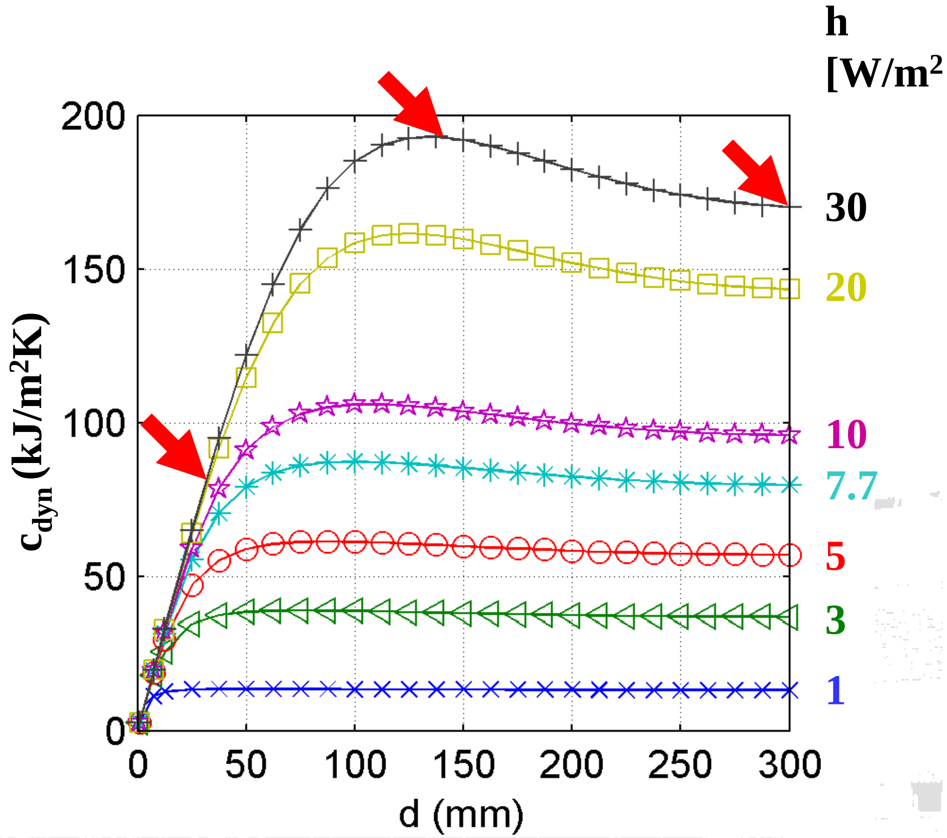
Diurnal heat storage capacity, c_{dyn} of a concrete slab depending on the thickness, *d* for different heat transfer coefficients, *h*.

Slab thickness

h = 30 W/m²K



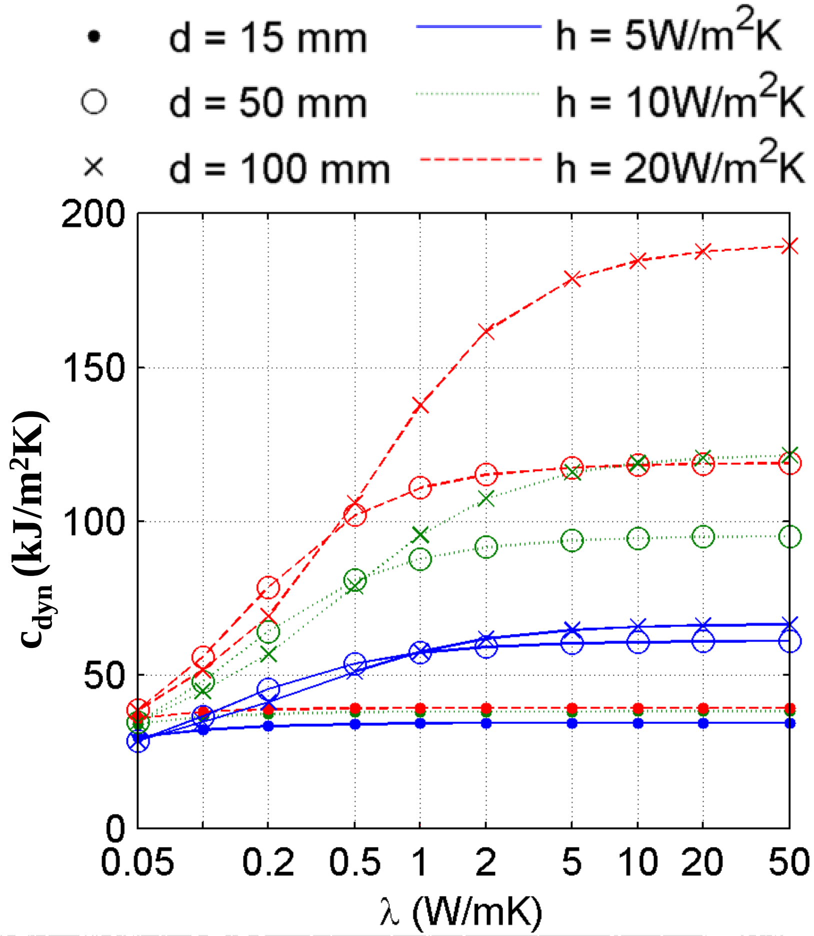
d = 30..   140..   300 mm



Diurnal heat storage capacity, c_{dyn} of a concrete slab depending on the thickness, *d* for different heat transfer coefficients, *h*.

Thermal conductivity

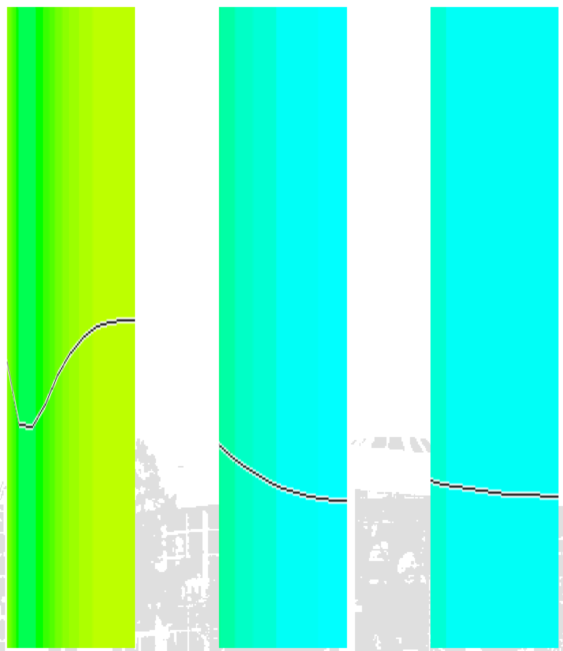
- Thin slab (d = 15 mm): No impact of the thermal conductivity, λ
- Thick slabs: Increase in heat storage capacity up to $\lambda \approx 1.8$ W/mK
- Above $\lambda = 1.8$ W/mK: Further increase only for thick slabs (d = 100 mm) and high HTC ($h = 20$ W/m^{2}K)



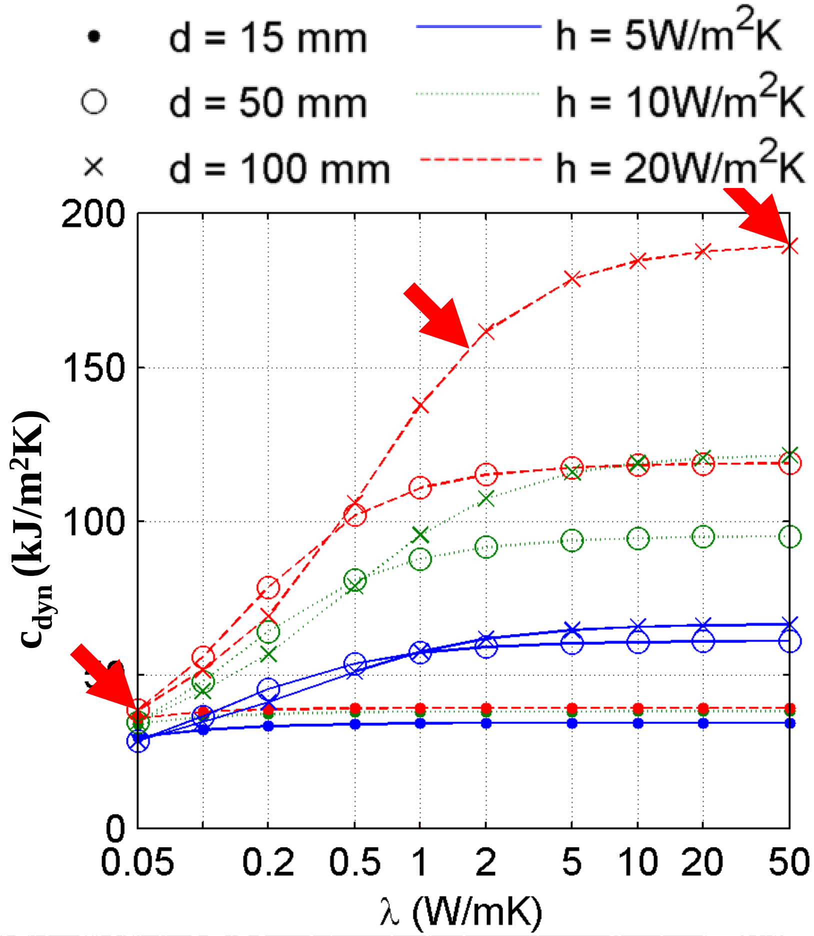
Diurnal heat storage capacity, *q* depending on the thermal conductivity, λ for different heat transfer coefficients, *h* and slab thicknesses, *d*; ρc = 2.6 MJ/m^{3}K.

Thermal conductivity

d = 100 mm; h = 20 W/m²K



λ = 0.05.. 1.8.. 50 W/mK



Diurnal heat storage capacity, c_{dyn} depending on the thermal conductivity, λ for different heat transfer coefficients, h and slab thicknesses, d; ρc = 2.6 MJ/m³K.

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Conclusions

Dynamic heat storage capacity can be limited by…

… the total thermal capacity of the element (*d*, ρc)

➔ Typically not problematic for concrete elements

… the heat transfer (*h*, λ)

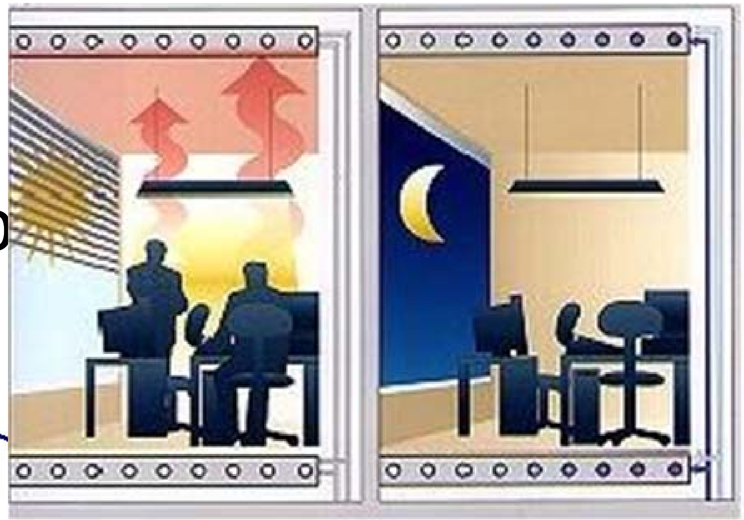
➔ In most cases the thermal conductivity of concrete (λ = 1.8 W/mK) is sufficient

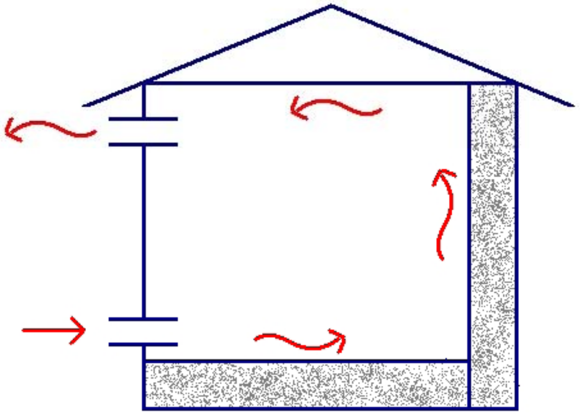
➔ The most typical limiting factor is the surface heat transfer

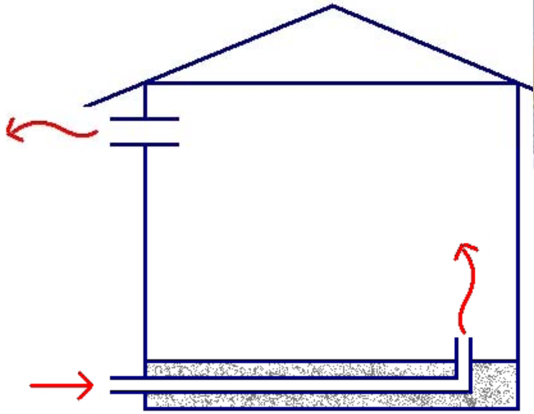
Solutions

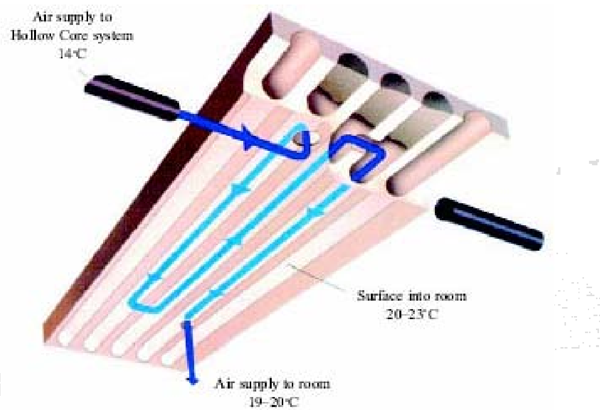
- Ensure large radiation exchange (solar radiation, cool surfaces in the view)
- Increase surface area
- Extract heat from construction core (one – way heat transfer, increases possible time for absorption and driving force (temperature difference)
- Increase heat capacity at room temperature (larger temperature difference with Phase Change Materials)

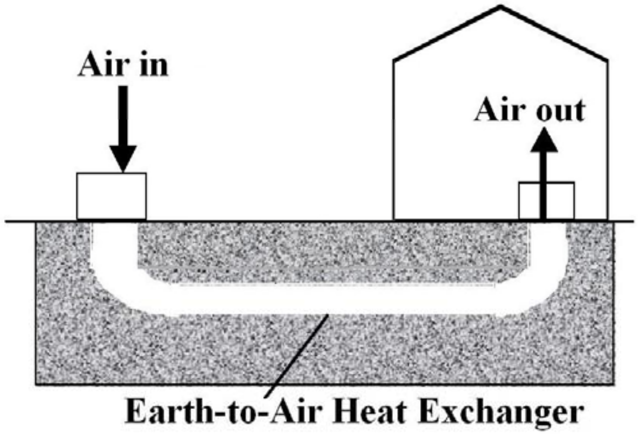
Examples of Air Based Solutio











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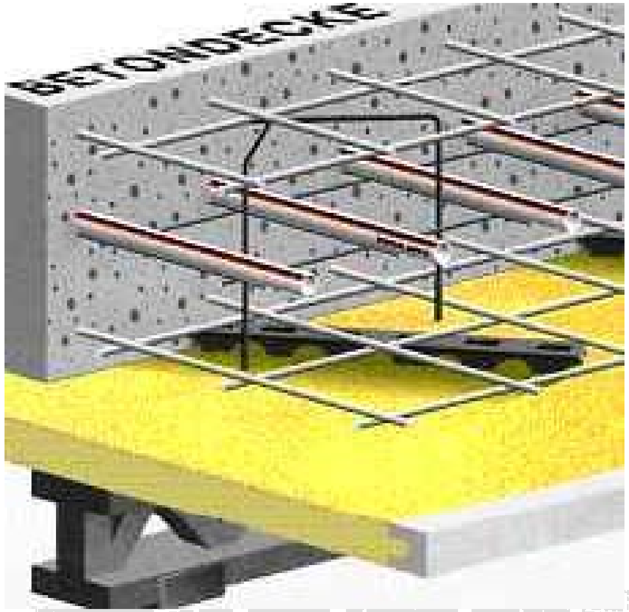
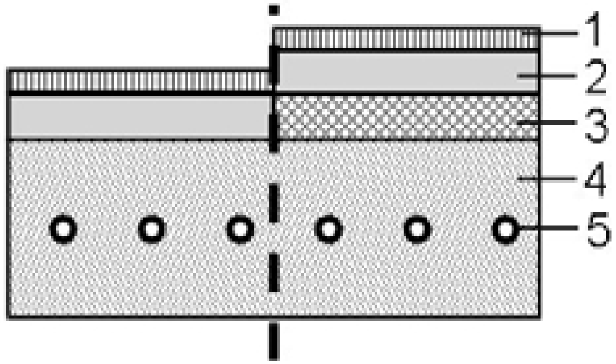
Water based system





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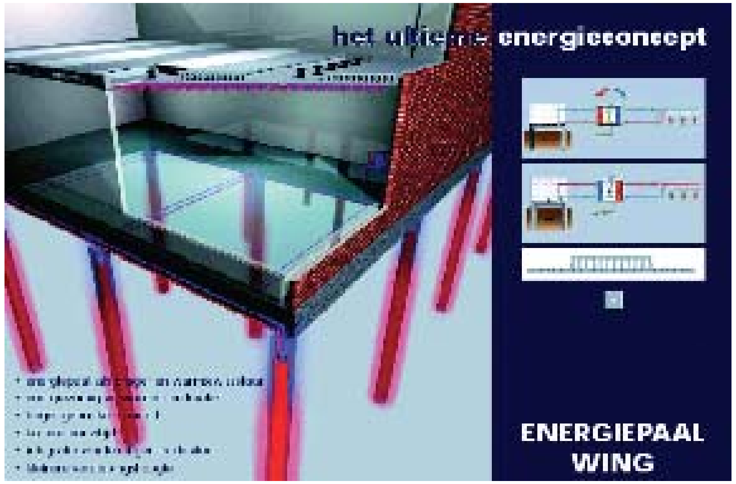
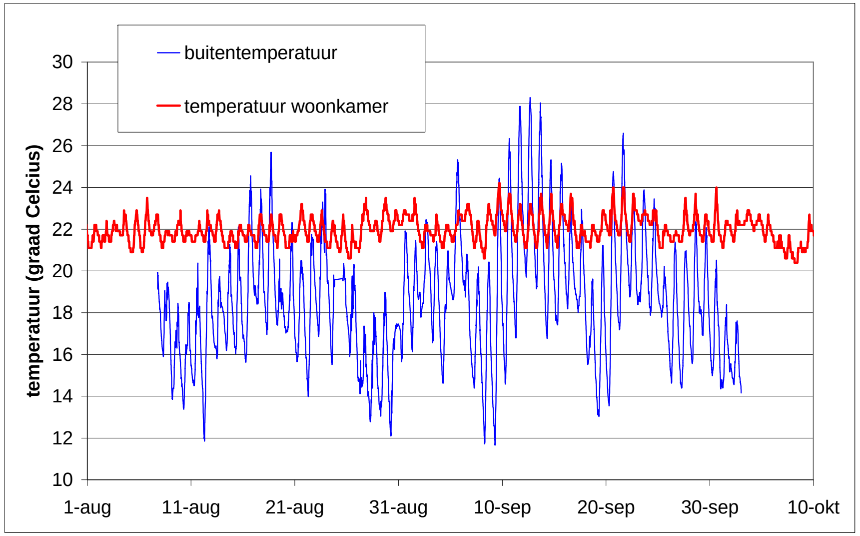
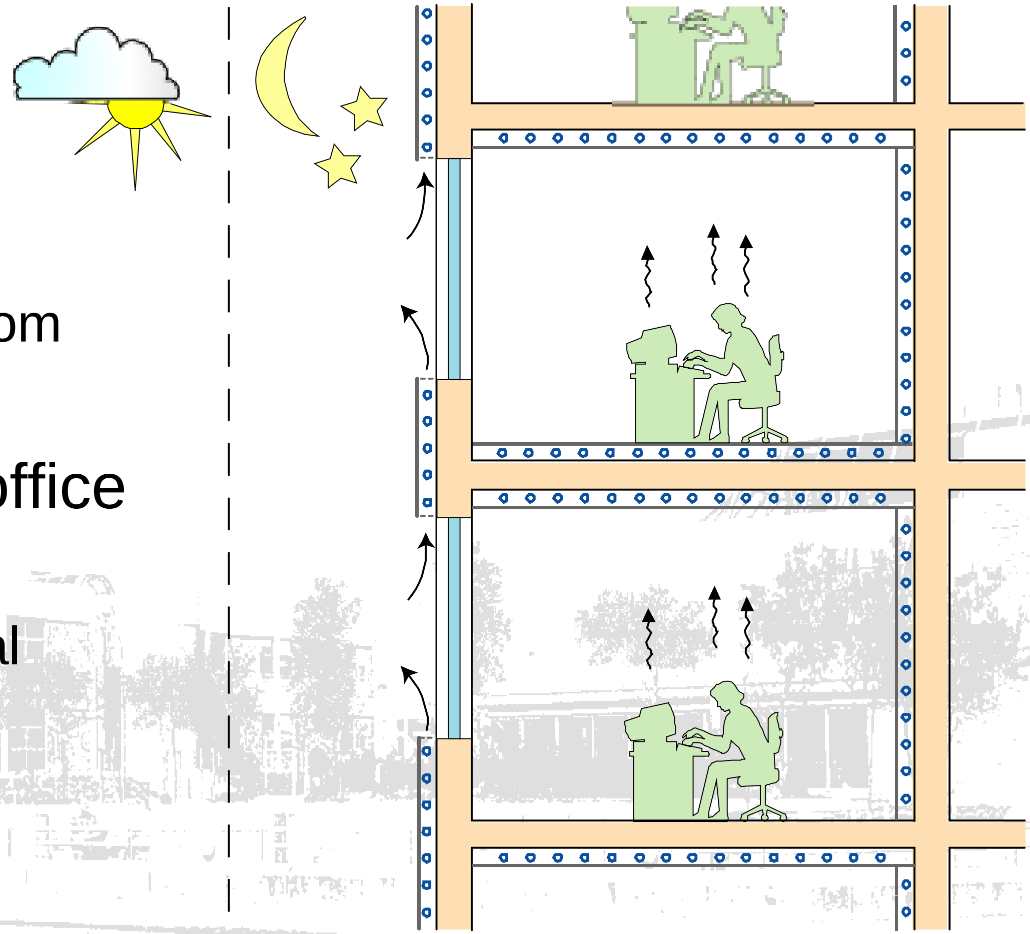
Energy piles with CCC





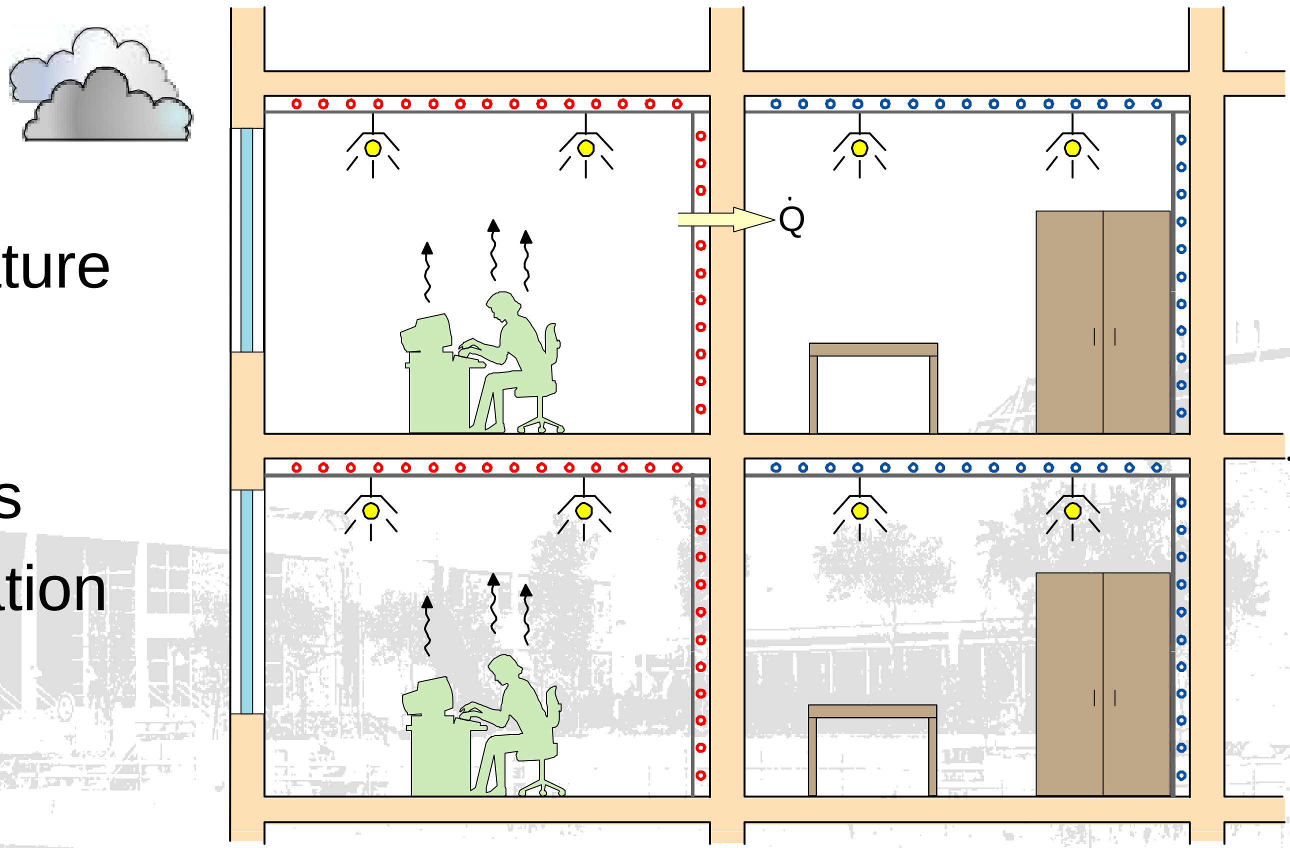
Energy Transfer from Rooms to the Façade

- Using temperature differences
  - between façade and room
  - between night and day
- Increased cooling for office building
  - combination with natural ventilation
  - high comfort standard



Energy Transfer between Rooms

- Using temperature and load differences between rooms
- Thermal activation of building basements



Conclusion

- Activation of thermal mass can make a difference
- Significant climatic cooling potential by night-time ventilation for most locations in Northern, Central and Eastern Europe
- The dynamic heat storage capacity of concrete can be increased by:
  - Focusing on radiation exchange of heat
  - Increasing surface area
  - Extract heat from construction core
  - Increase heat capacity at room temperature by phase change materials