Development of a quasi-steady-state assessment method of night cooling

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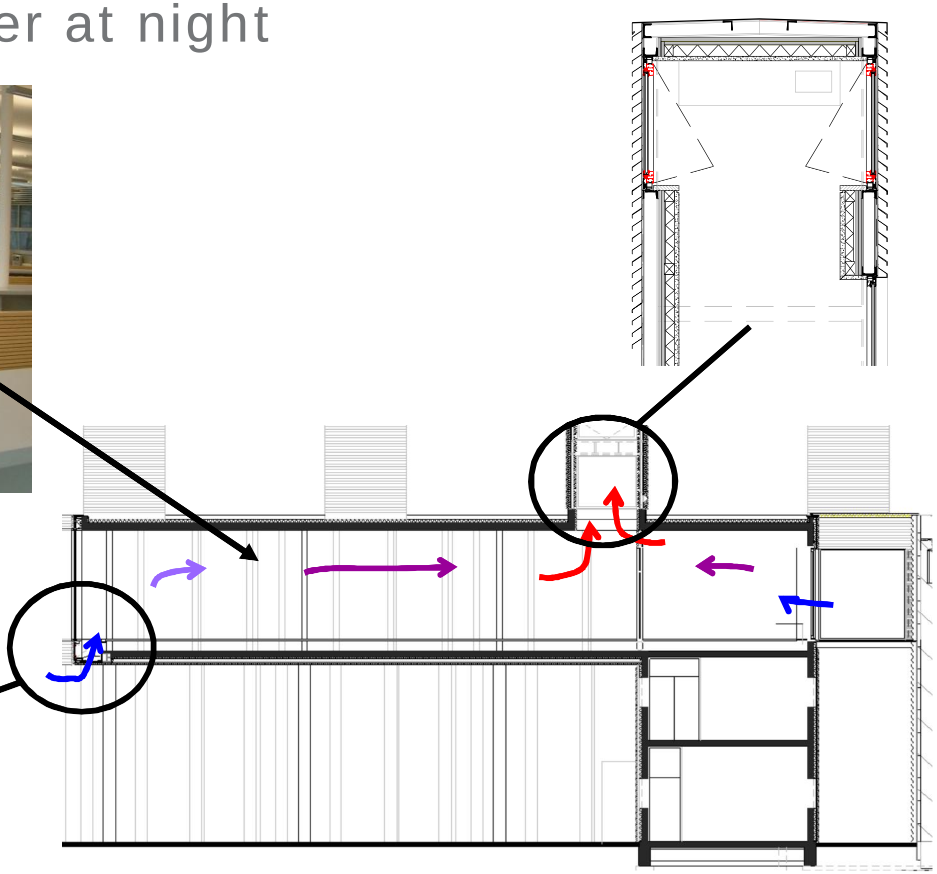
9th Nordic Symposium on Building Physics, Tampere – 2011, 29 May – 2 June

Night cooling

- Passive cooling technique
  - Accumulation heat gains in thermal mass by day
  - Convective heat transfer at night



Renson (Belgium)

Context

Assessment method night cooling?

- Directive on the Energy Performance of Buildings 2002/91/EC (EPBD)
- EN 13790: quasi-staedy-state < > detailed BES

⇒ new quasi-staedy-state assessment method in Flemish EPB

- cooling demand
- mechanical night cooling
- non-residential buildings

- Introduction
- Methods
  - Quasi-steady-state calculation
  - Type buildings
- Results
- Conclusions & further research

Quasi-steady-state calculation

- EN 13790
  - Cooling demand (MJ) $Q_{C,nd} = (Q_{int} + Q_{sol}) - \eta_{C,ls}(Q_{tr} + Q_{ve})$
  - Heat transfer by ventilation $Q_{ve} = H_{ve,adj}(\theta_{int,set,C,z} - \theta_e)\, t$

$$H_{ve,adj} = \rho_a c_a \sum_k b_{ve,k}\, q_{ve,k,mn}$$

- Temperature adjusment factor $b_{ve,k} = \frac{(\theta_{int,set} - \theta_{sup,k})}{(\theta_{int,set} - \theta_e)}$
- Extra air flow rate

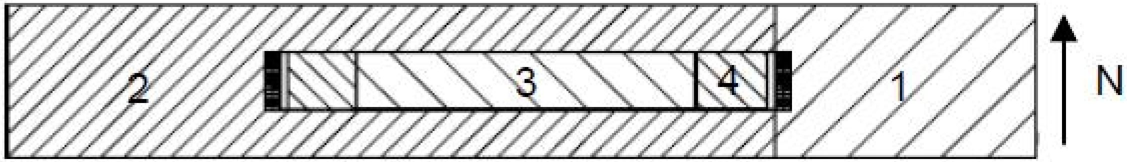
$$q_{ve,extra,mn} = c_{ve,eff,extra}\, f_{ve,t,extra}\, q_{ve,extra}$$

- Adjustment factor inertia
- Time fraction of operation

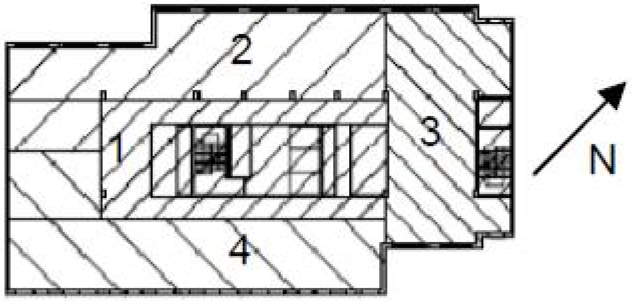
=> Define adjustment factors

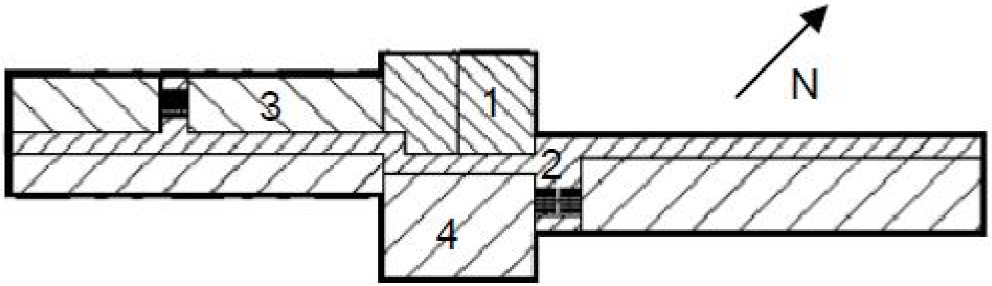
Type buildings

- Dynamic simulations in 3 non-residential buildings
  - Small office building: 3 floors
    1. Cafetaria /offices
    2. Lobby/offices
    3. Technical rooms /meeting room
    4. Sanitary



  - Large office building (10 floors) – school building (1 floor)
  - 3 quality levels: ACCeptable – GOOd – VERy good





Type buildings

- Internal heat gains: 12.5 – 100% default EPB
- Meteonorm Uccle (Belgium) ≈ weather 2004-2008
- Balanced mechanical hygienic ventilation
- Convective heating (<20°C) and cooling (>23°C)
- Night cooling
  - cafetaria, lobby, offices, meeting rooms, class rooms
  - Flow rate: 1 – 3 – 6 x hygienic flow rate
  - Control system

Daytime activation requirement	Night cooling activation requirements
$\theta_{i,max} > 23°C$	$22h < time < 6h$ $\theta_{s,ceiling} > 22°C$ (= heating set point + 1°C) $\theta_i - \theta_e > 2°C$ $v < 7$ m/s

θ_i : indoor temperature (°C)
θ_s : surface temperature (°C)
θ_e : exterior temperature (°C)
v: wind velocity (m/s)

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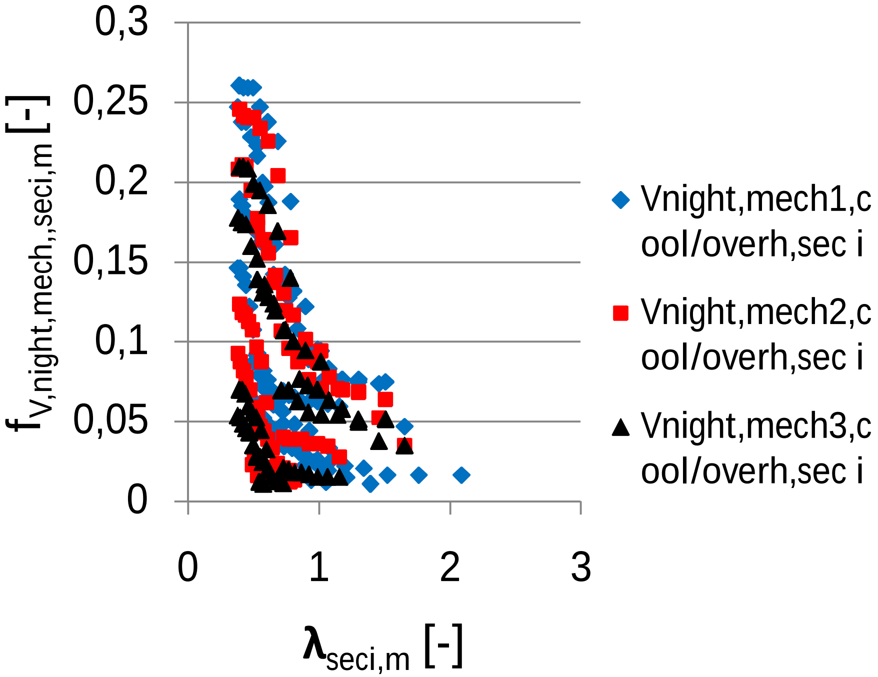
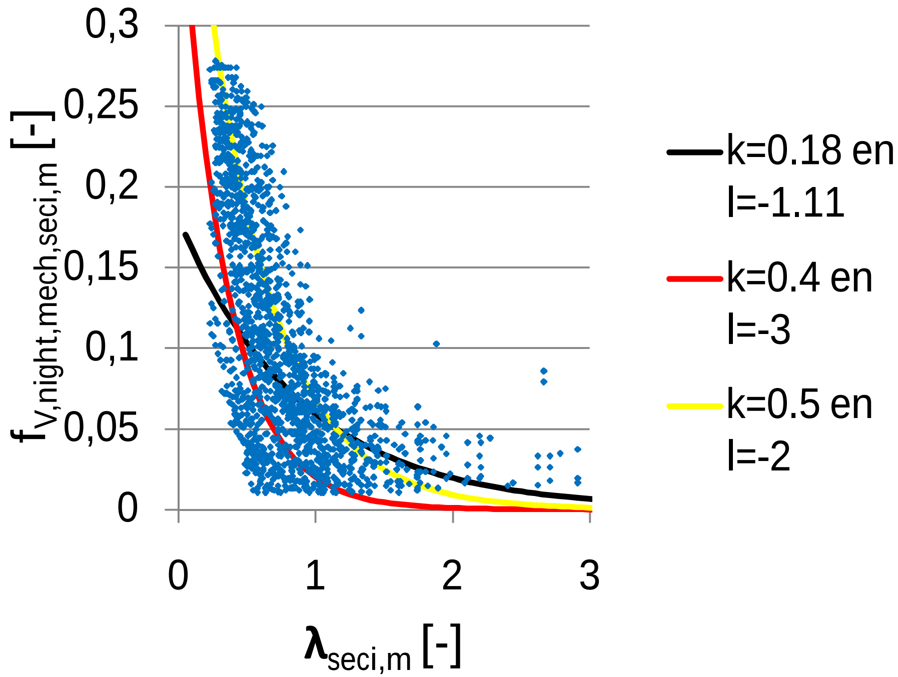
  - Determination of adjustment factors
  - Verification
- Conclusions & further research

Time fraction of operation f





- Function of losses to gains ratio λ

$$f_{V,night,mech,overh/cool,seci,m} = k \cdot e^{l \cdot \lambda_{seci,m}}$$

Best fit: k = 0.18 – l = -1.11

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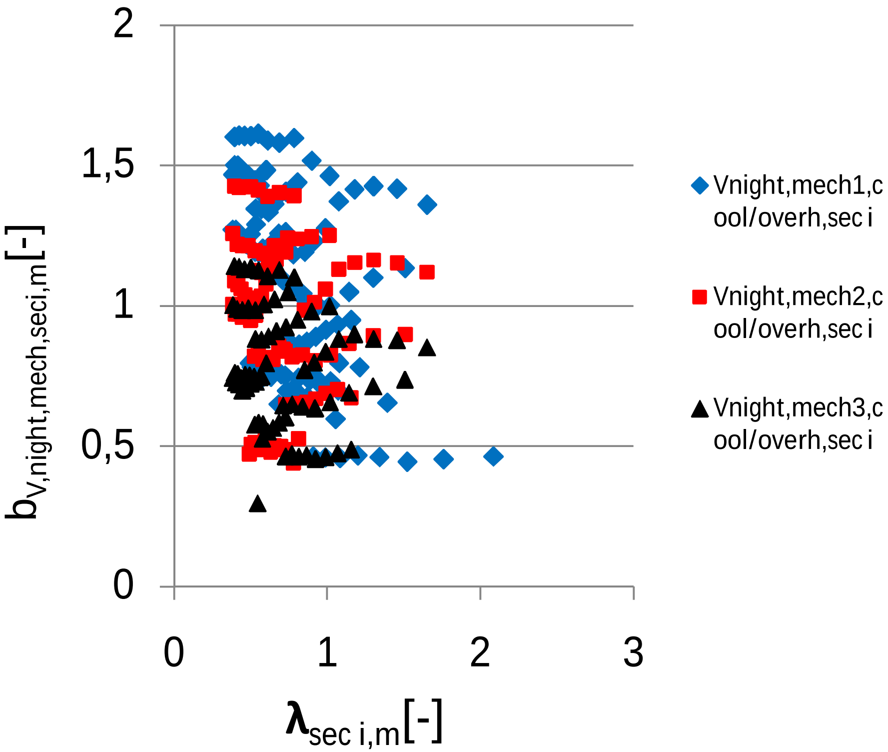
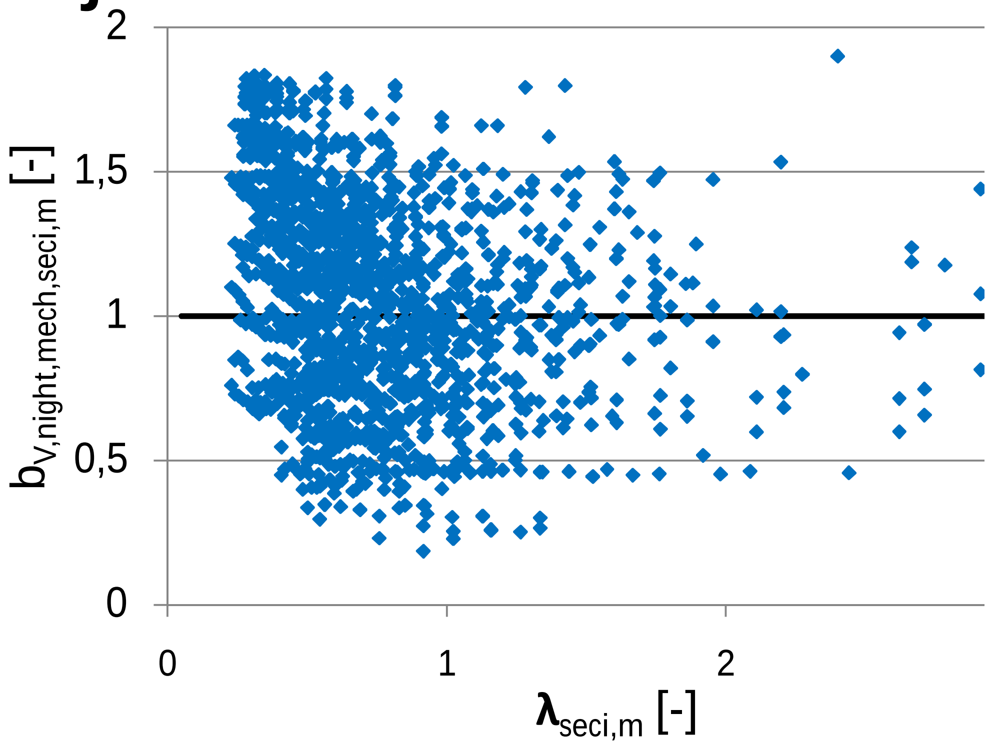
Temperature adjustment factor b





- No significant relation b – λ
- Temperature adjustment factor b = 1

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Adjustment factor inertia c

- 4 levels of thermal capacity
- Saved cooling demand compared to base case

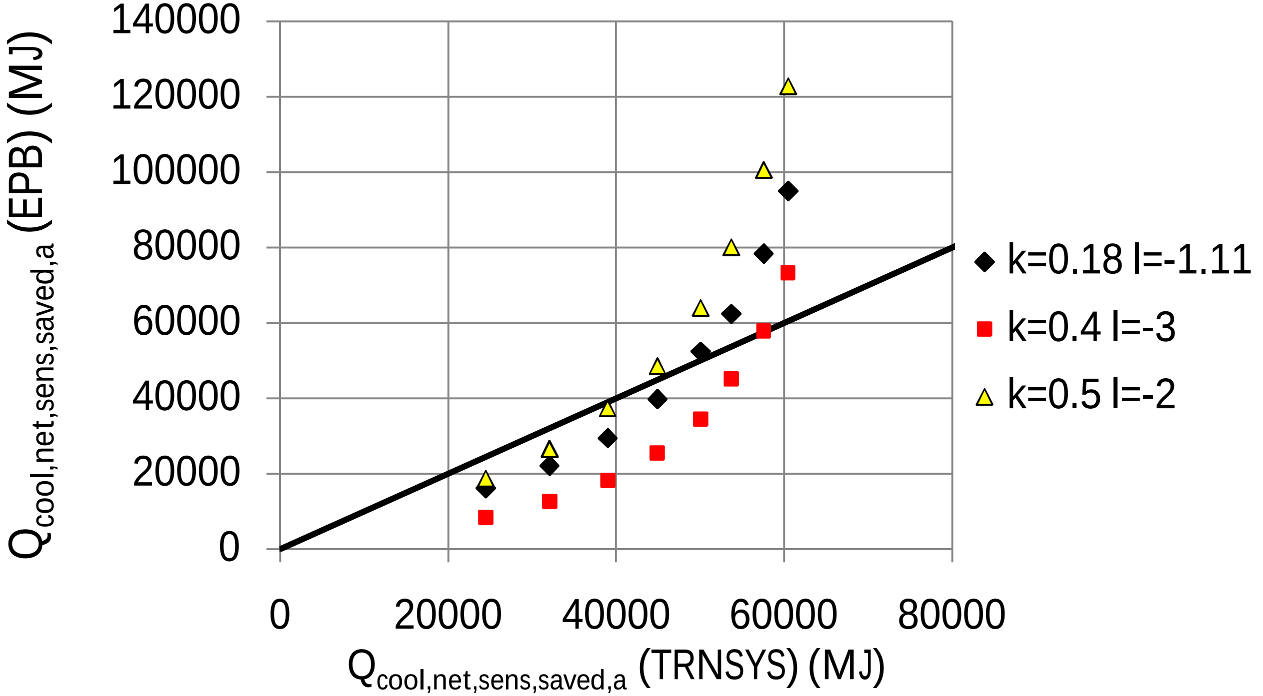
	D_j (kJ/m².K)	Saved cooling demand (% base case)		
		ACC	GOO	VER
Lowered ceiling + raised floor + heavy façade	60	0.63	0.66	0.69
No lowered ceiling + raised floor + light façade	194	0.64	0.71	0.76
No lowered ceiling + raised floor + heavy façade	256	0.96	0.93	0.92
No lowered ceiling + no raised floor + heavy façade	366	1.00	1.00	1.00

- Adjustment factor inertia
  - Raised floor: light – heavy structure: 0.7 – 1.0
  - Lowered ceiling: 0.7

verification

- Saved cooling demand

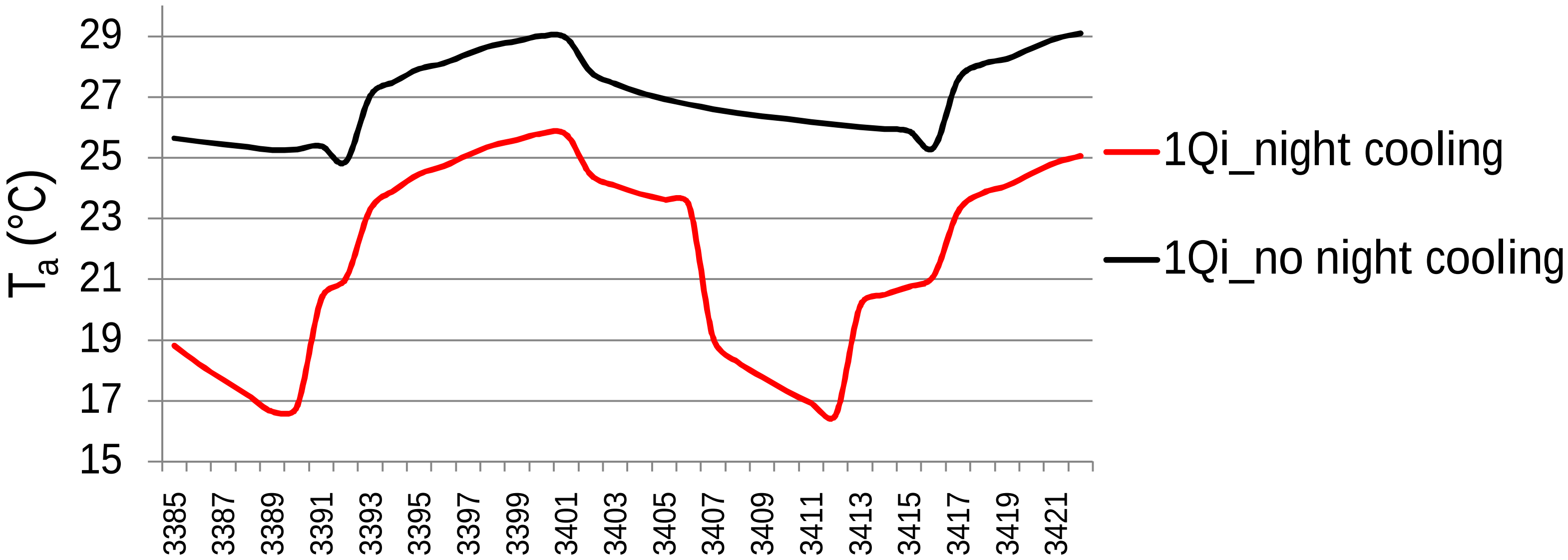
  Quasi-steady-state (EPB) <> dynamic (TRNSYS)



  – k=0.18, l=-1.11 overestimation high internal heat gains
  – Time fraction of operation: k=0.4, l=-3

verification

- Uncertain correspondence EPB < > dynamic
  - Difference thermal storage
- EN 13790 to assess night cooling questioned
  - Standard utilization factor η
  - Ventilation heat transfer coefficient
    extra flow rate -> temperature course is changed



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- Introduction
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Conclusions & further research

- New quasi-steady-state assessment method of mechanical night cooling
- EN 13790: ventilation heat transfer coefficient
  - Temperature adjustment factor = 1
  - Time fraction of operation ~ losses to gains ratio
  - Adjusment factor dynamic effects ~ thermal mass
- Dynamic simulations 3 non-residential buildings
- Quasi-steady-state <> dynamic
  - Non-linear & uncertain correspondence
  - Dynamic effects insufficiently considered
- Further research to assess effect of night cooling

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