Demand side management in district heating networks

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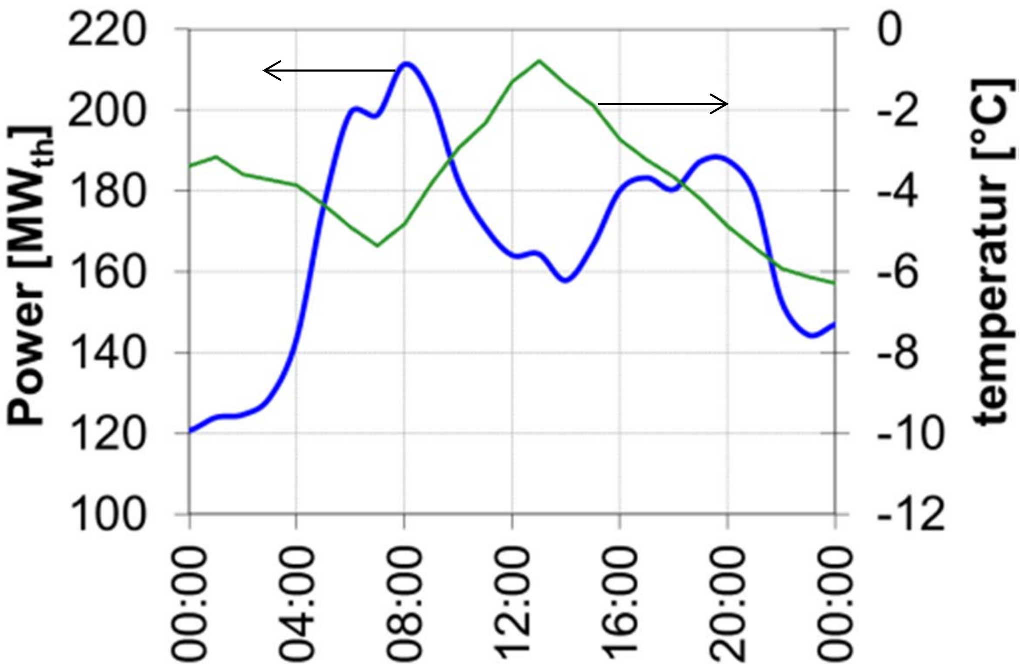
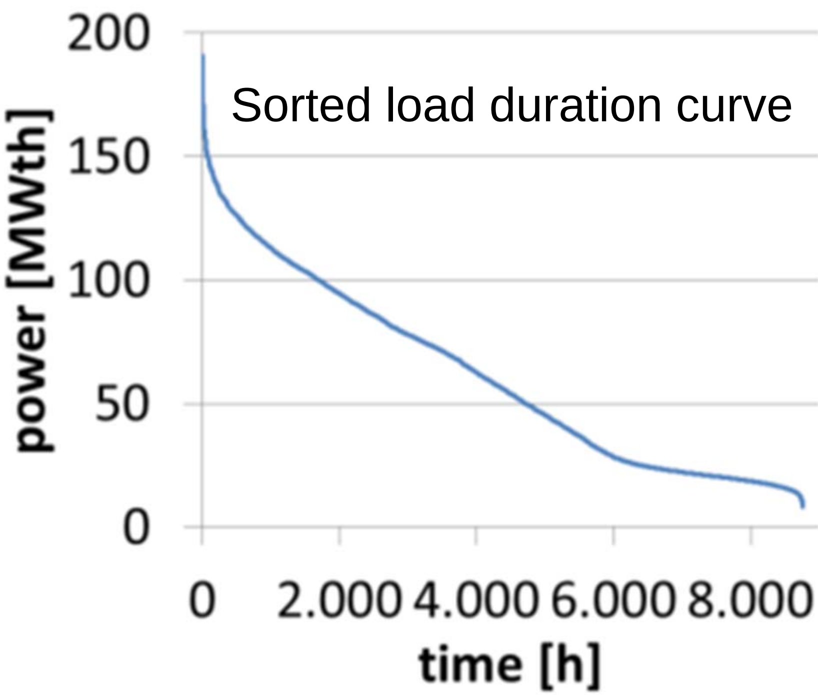
Motivation: peak loads in DH networks





- when a large number of buildings adopt **similar night setback settings**, **large peak loads** can occur thus requiring **peak boiler** to run at expensive **operational costs** and moreover with large **CO_2 emissions**

Literature survey: Night set-back and load shifting

- Significant **energy savings between 15 and 30%** are possible by applying night- and day-time setback strategies e.g. [1-10]
- In different publications the effect of **using the building thermal mass for load shifting** has been assessed and verified e.g. [11-17]
- BUT: none have been researching the potential of peak savings when the measure is **applied at large scale**, e.g. for a city wide DH network

References
[1] M.M. Manning, M.C. Swinton, F. Szadkowski, J. Gusdorf, K. Ruest, The effect of thermostat set-back and set-up on seasonal energy consumption, surface temperatures and recovery times at the CCHT twin house facility, ASHRAE Transactions 113 (1) (2007) 1–12.
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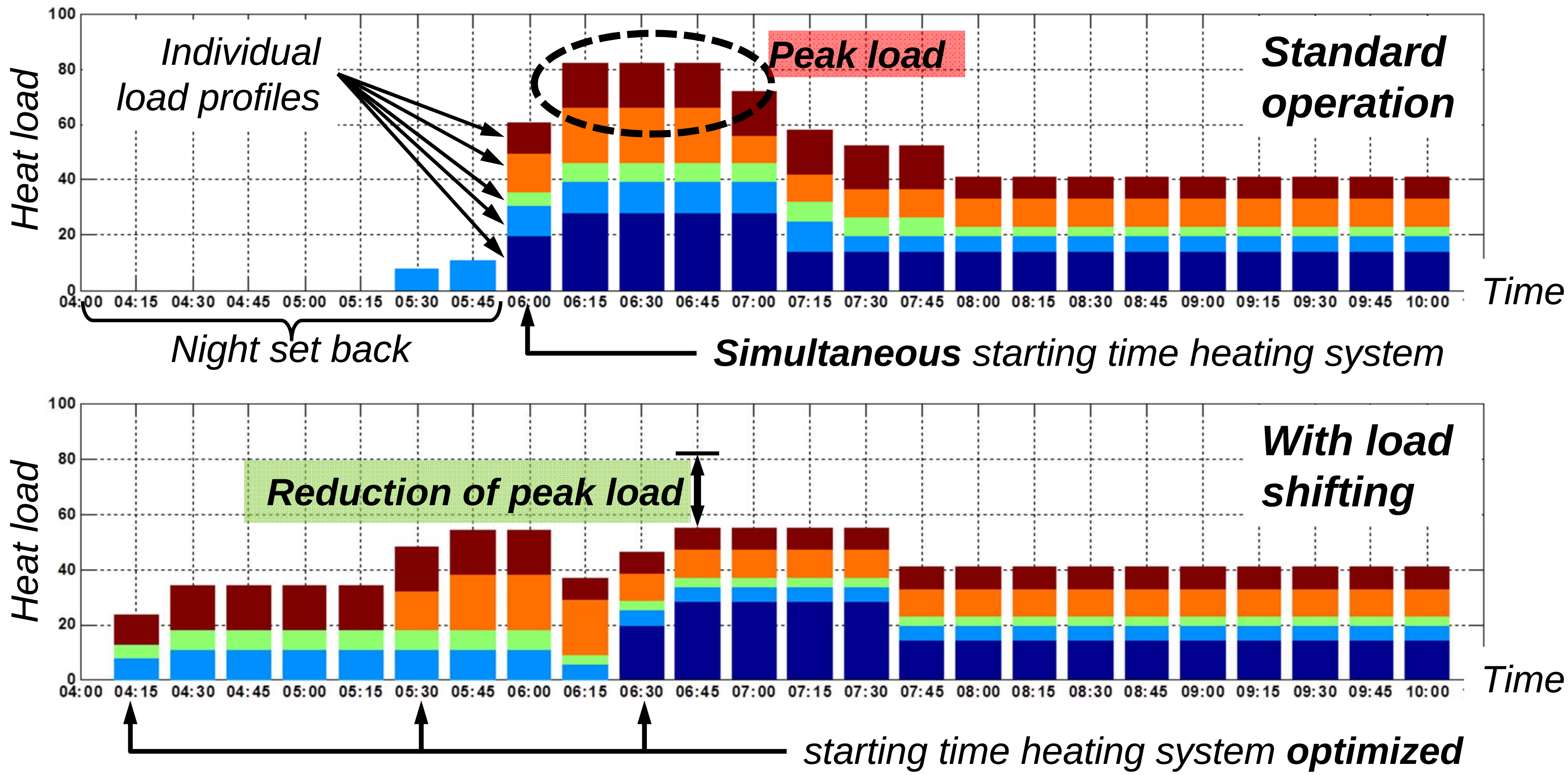
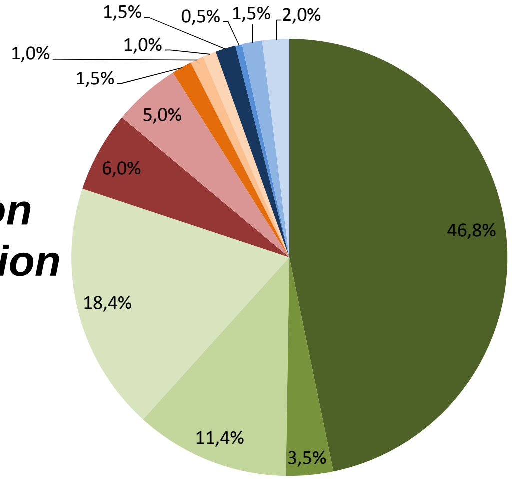
Load shifting: **principle** of the optimization algorithm



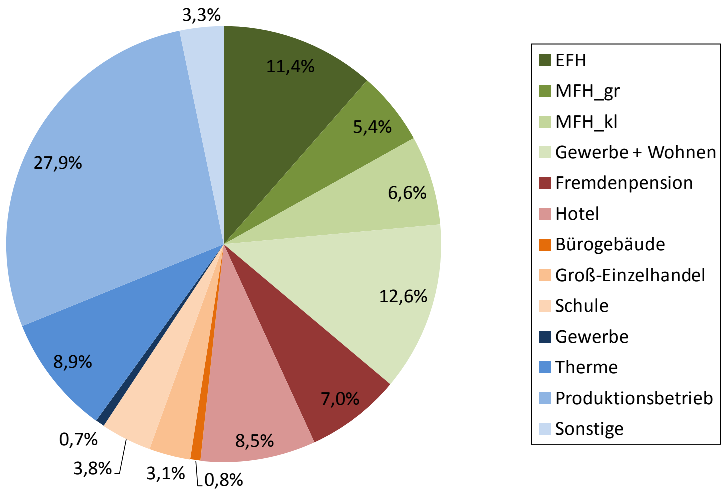
Case study: DH Altenmarkt (AT)

Region	Tourism region in the Alps (Salzburg)
Network length	ca. 10,3 km main network
Temp. levels	supply: ~95°C, return: ~55°C
customers	204 substations, ~14,6 MW capacity
Heat generation	• Biomass boiler 1 (base load 1): 5 MW (used by the DH network: 3,0 - 3,5 MW) • Biomass boiler 2 (base load 2): 2 MW • Fuel oil boiler (peak load): 5,2 MW

Distribution of substation number

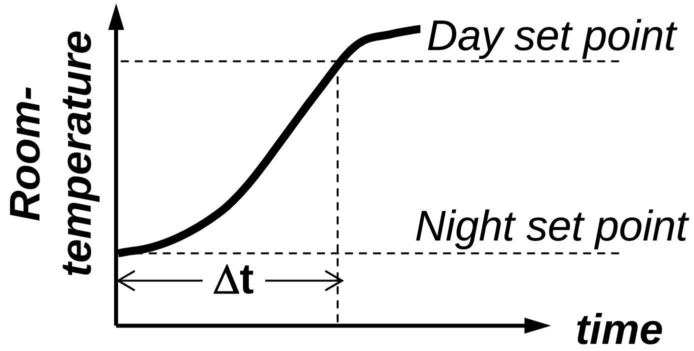


Distribution of substation capacities



Assessment of **load profiles**: building dynamics

- **Side survey** in a demonstration network to determine building properties
  - Age of the Building, Number of (heated) floors, Type of usage, Thermal renovation
- Dynamic **building simulation** to determine the heat up time (Δt)
  - Type of walls,
  - Air exchange rate,
  - Outdoor temperature,
  - start temperature,
  - Size of the building,
  - Heating system

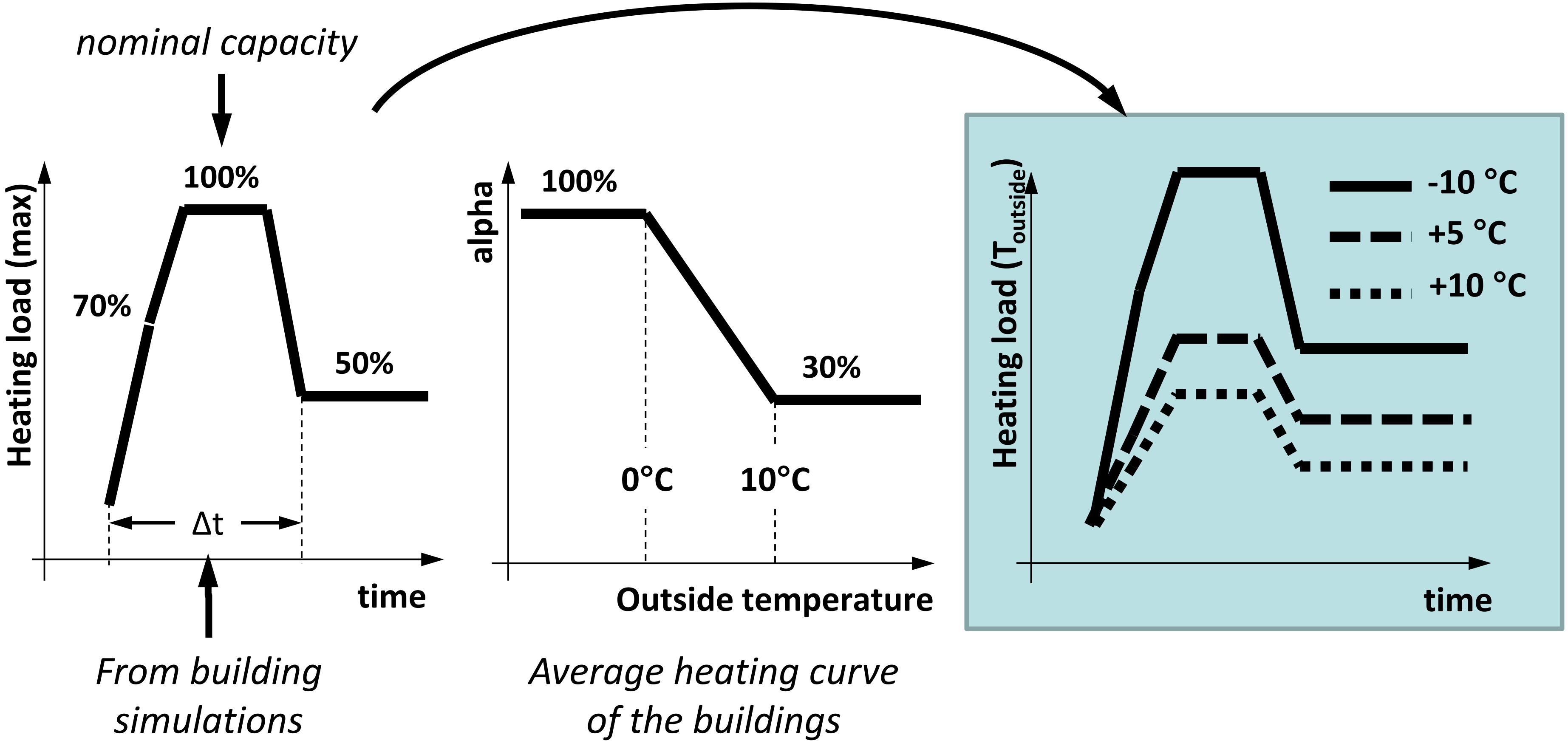


=> **multi parameter variation** in a simplified building model

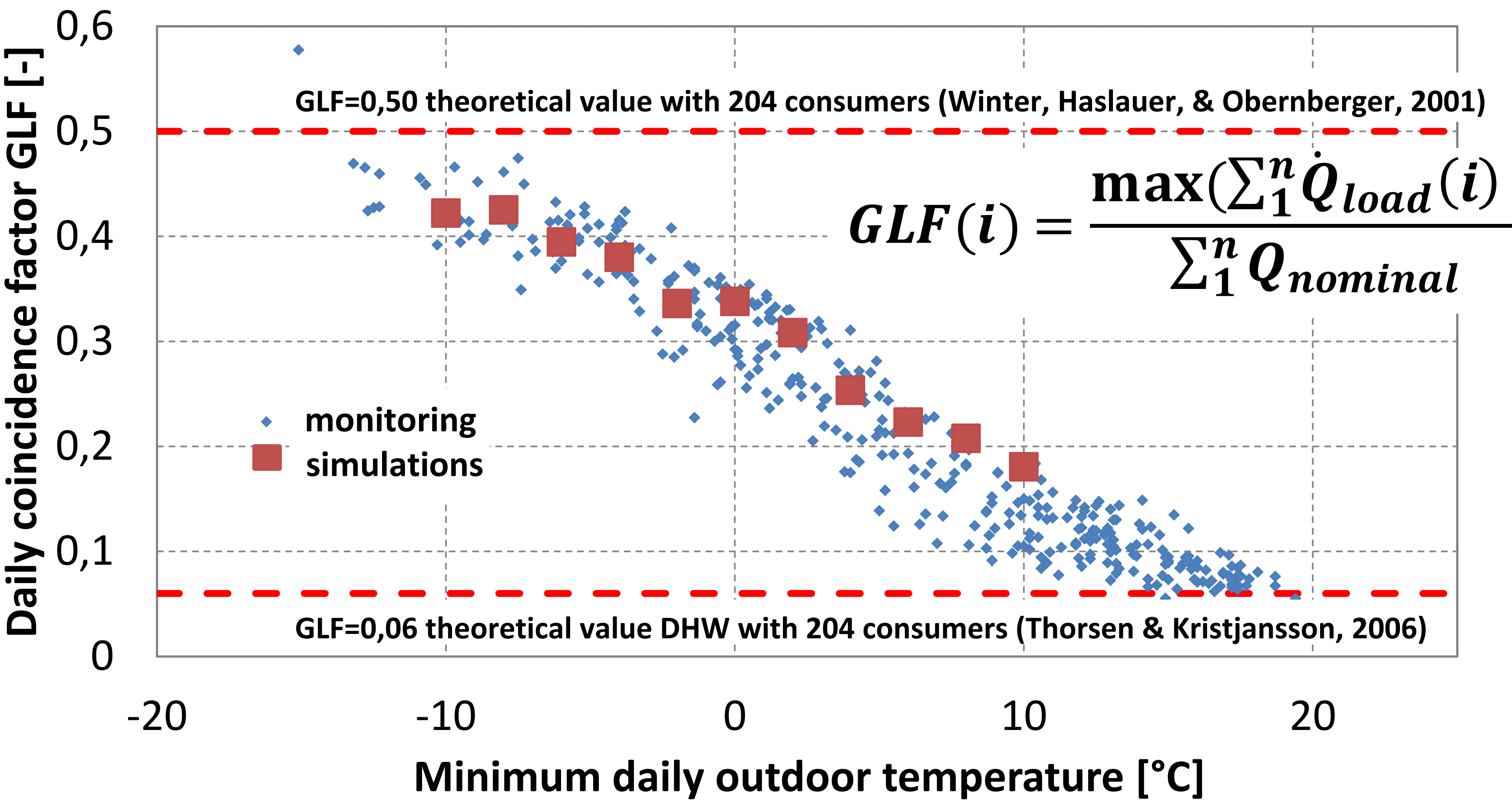
→ around 95,000 combinations

- Analyses of **building monitoring data** (heat load profiles of every substation, 15 min. resolution) and **calibration of simulations**

Assessment of **load profiles:** principle



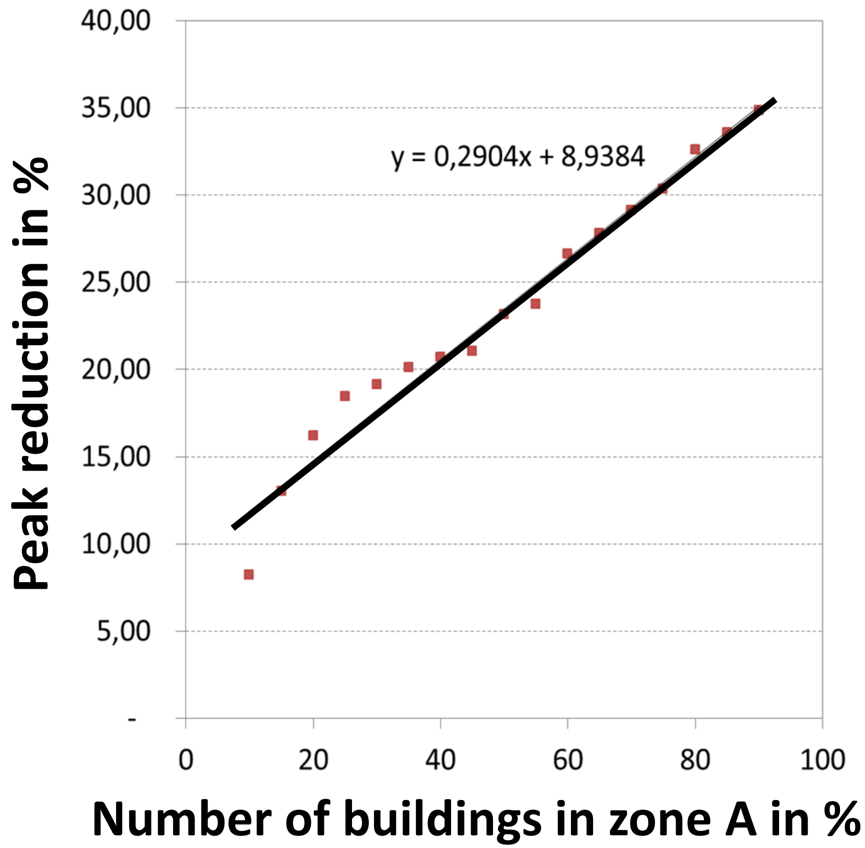
monitoring and simulation data **evaluation** (case study)



$$GLF(i) = \frac{\max\left(\sum_1^n \dot{Q}_{load}(i)\right)}{\sum_1^n Q_{nominal}}$$

Application of the load shifting algorithm: **General**

- **Boundary conditions**:
  - day set-point: to be reached between 6 – 8 am
  - start time heating system: as late as possible, 2 am earliest
- **Classification** of the buildings:
  - zone A: $\Delta t < 2$ h, zone B: $\Delta t > 2$ h
- **Parameter variation** for different DH networks
  - random combination of 1000 buildings
  - varying fractions of zone A
- Only ab. 2 % **additional heat load**



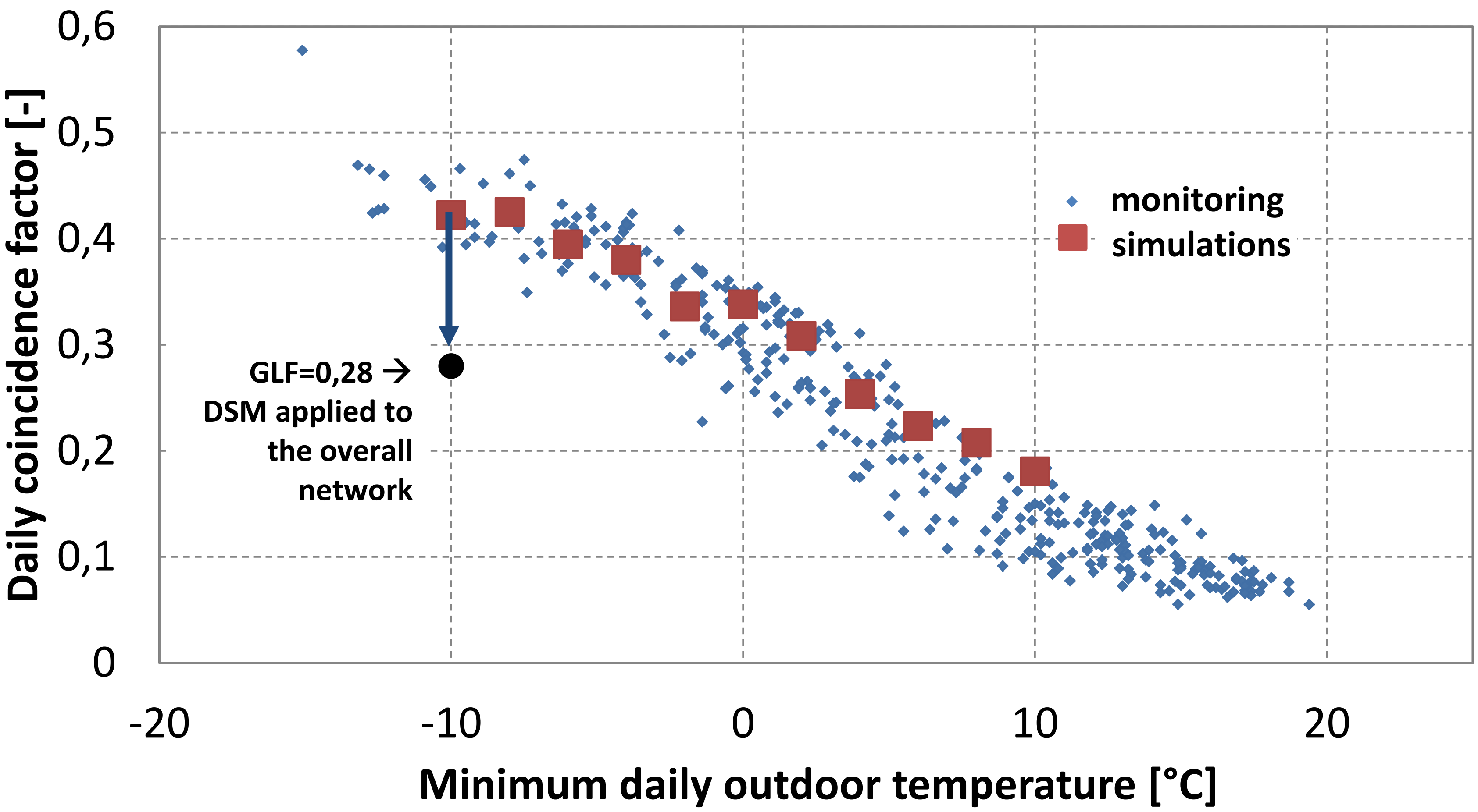
Application of the load shifting algorithm: **Conclusions**

- A high number of **buildings with low heat up time** (zone A) is beneficiary for demand side load shifting
- This is the case for
  - Buildings with a **low thermal mass**
  - Buildings with **oversized substation capacity** (wrong calculation of heat load/ no adaptation of the substation after thermal retrofitting)

=> retrofitted buildings (**without adaptation** of the substation capacity) have a **high flexibility** and are beneficiary for load shifting

=> retrofitted buildings (**with adaptation** of the substation capacity) have a **lower flexibility**, but also contribute less to the overall peak load

Application of the load shifting algorithm: **case study**



Considerations for **implementation** of load shifting

- **requirements** for the implementation:
  - the **accessibility** of the substation of the building and
  - the **possibility** to remote control
- Two possible **implementation**:
  - at **primary** side level (substation settings such as supply temp. set-point)
  - at **secondary** side level (set-points for heating systems via radiator valves).
- A **first implementation attempt** (using a small number of buildings in the Altenmarkt DH network via remote control of the supply temp.) was largely **unsuccessful** due to a secondary control in the buildings:

  →the room thermostats opened the regulating valves as soon as the secondary supply temperature was reduced.

Conclusions

- a simulation study is presented, exploiting the **implementation of load shifting** in a case study for reducing peak loads due to the night setback.
- a large database of **validated heating up time for different types of buildings** and outdoor conditions was developed
- an **optimization algorithm** considering certain flexibility in reaching the day set-point was developed and **applied for a large number of DH network**s with different building structures
  - A high number of buildings with low heat up time is beneficiary => a **reduction of the daily peaks of up to 35% possible** (about 2 % additional heat load)
  - Decreasing the substation capacity reduces the flexibility, but also the individual peak load
- The **practical implementation** of load shifting measures needs further investigations

Thank you for your attention!

Acknowledgment

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Night setback: Literature survey

source	Type of study	Maximum energy savings [%]
[Manning, 2007]	Experimental	13%
[Ingersoll, 1985]	Analytical investigations	-
[Beckey, 1981]	Experimental	16%
[Nelson, 1973]	Simulation results	15%
[Nelson, 1977]	Simulation results	20%
[Nelson, 1978]	Simulation results	20%
[Woo Moon, 2011]	Simulation results	20%
[Haiad, 2004]	Simulation results	**27%**
[Szydlowski, 1993]	Experimental	19%
[Kosny, 2001]	Literature review	-

References

[1] M.M. Manning, M.C. Swinton, F. Szadkowski, J. Gusdorf, K. Ruest, The effect of thermostat set-back and set-up on seasonal energy consumption, surface temperatures and recovery times at the CCHT twin house facility, ASHRAE Transactions 113 (1) (2007) 1–12.
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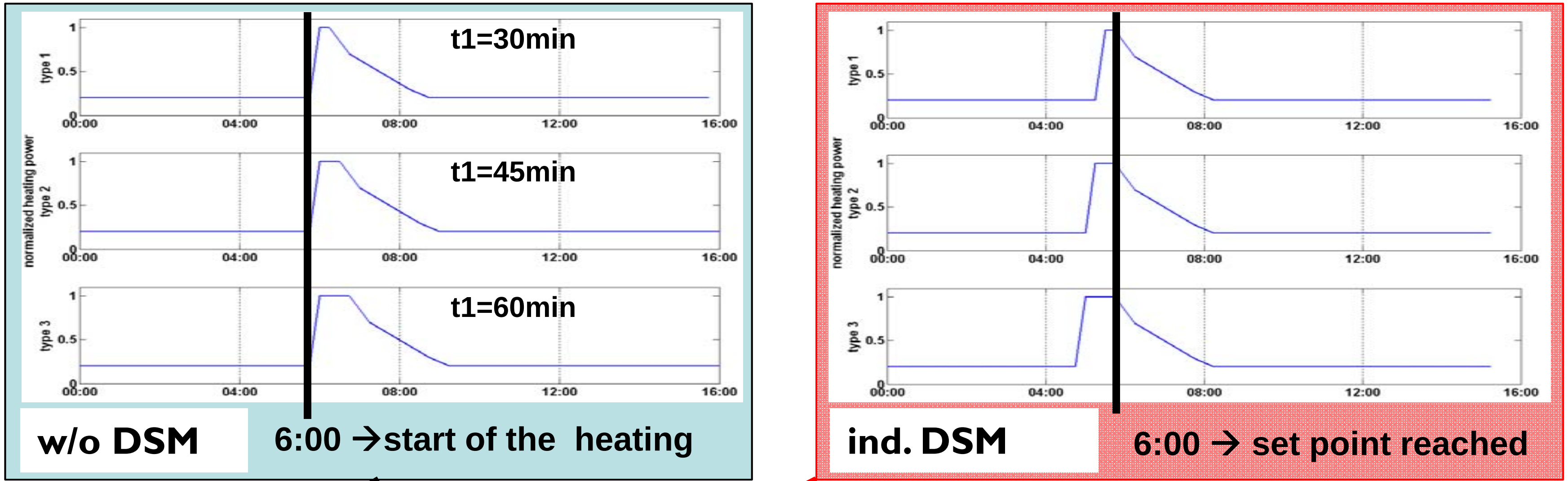
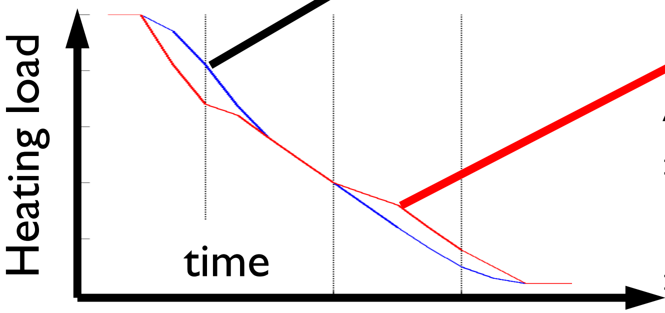
Individual DSM



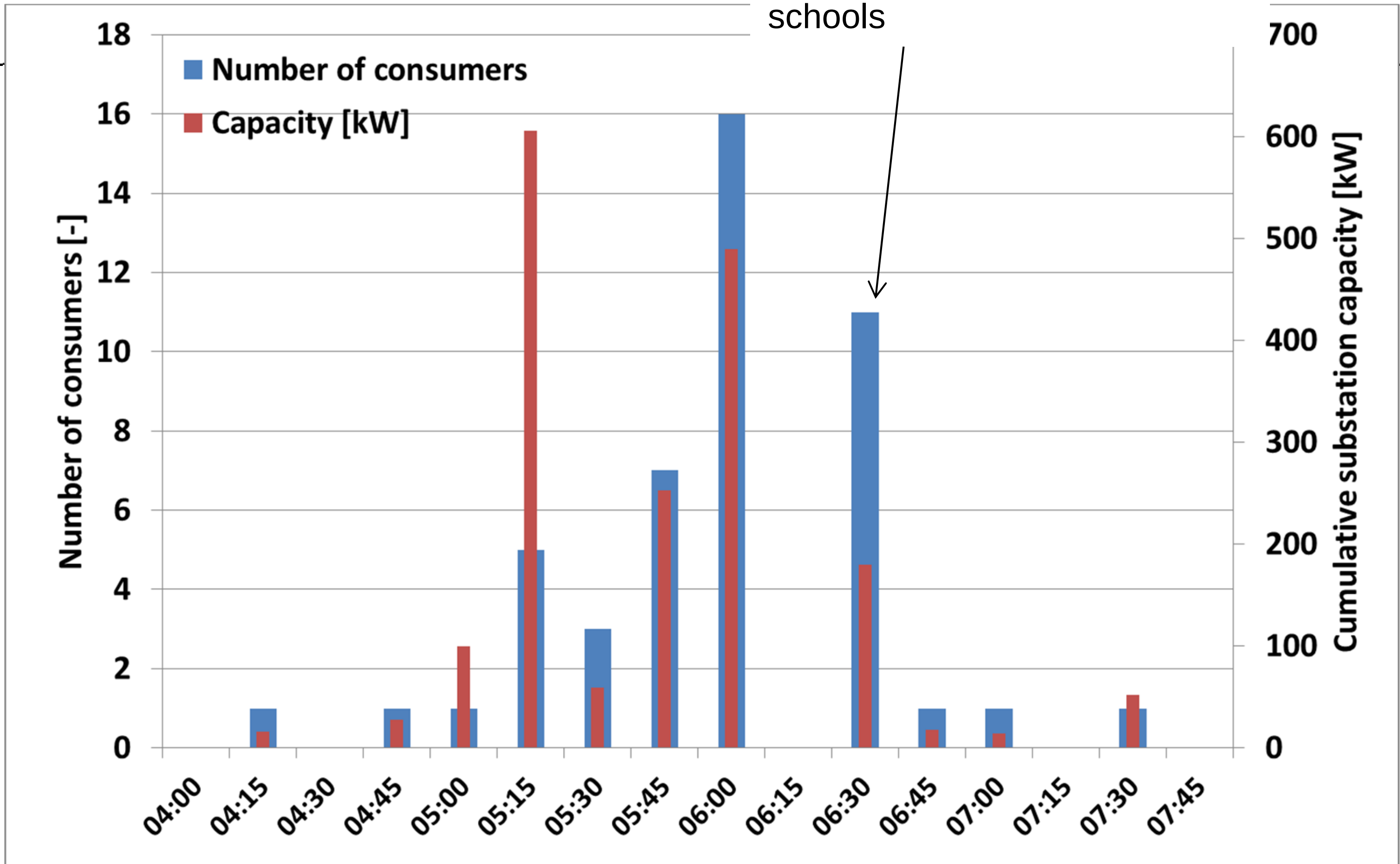


All customers reach the set point at the same time

⇒ **Risk of synchronisation: no reduction of the overall peak load due to individual DSM!**

⇒ **Implementation at selected customers could result in a peak loads reduction!**

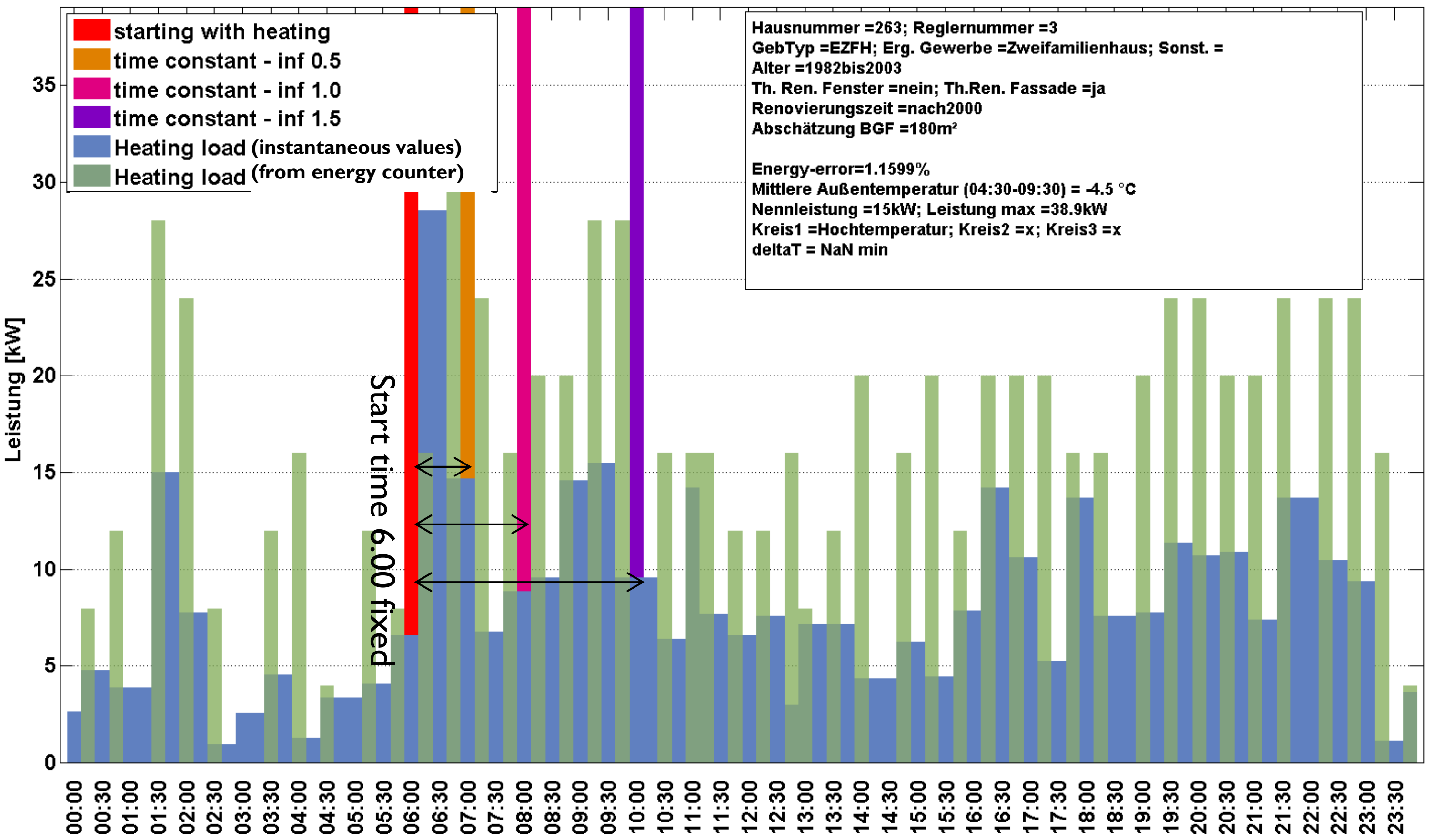
600 kW (10% of an average consumption peak load) **already shifted** → mainly two schools

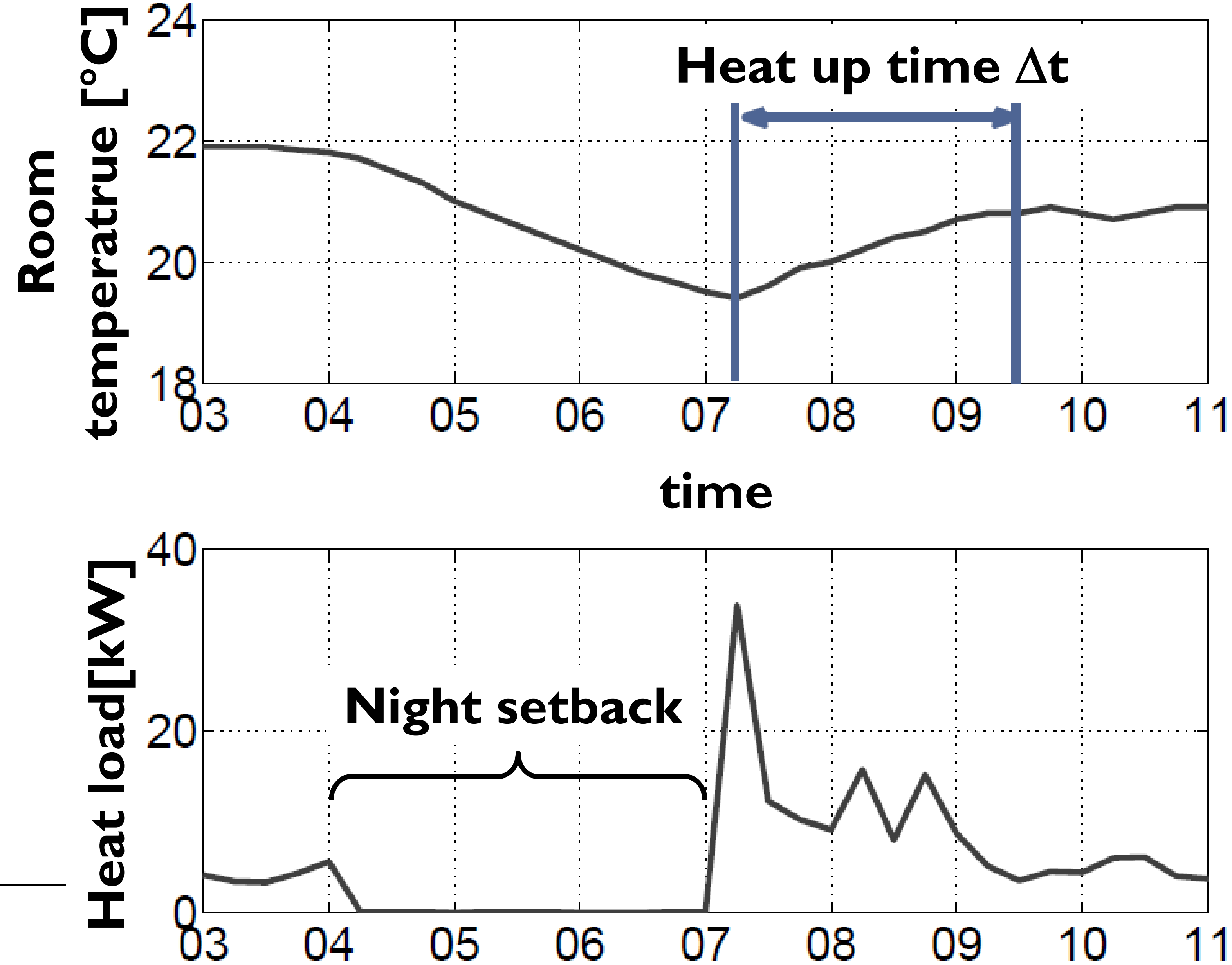


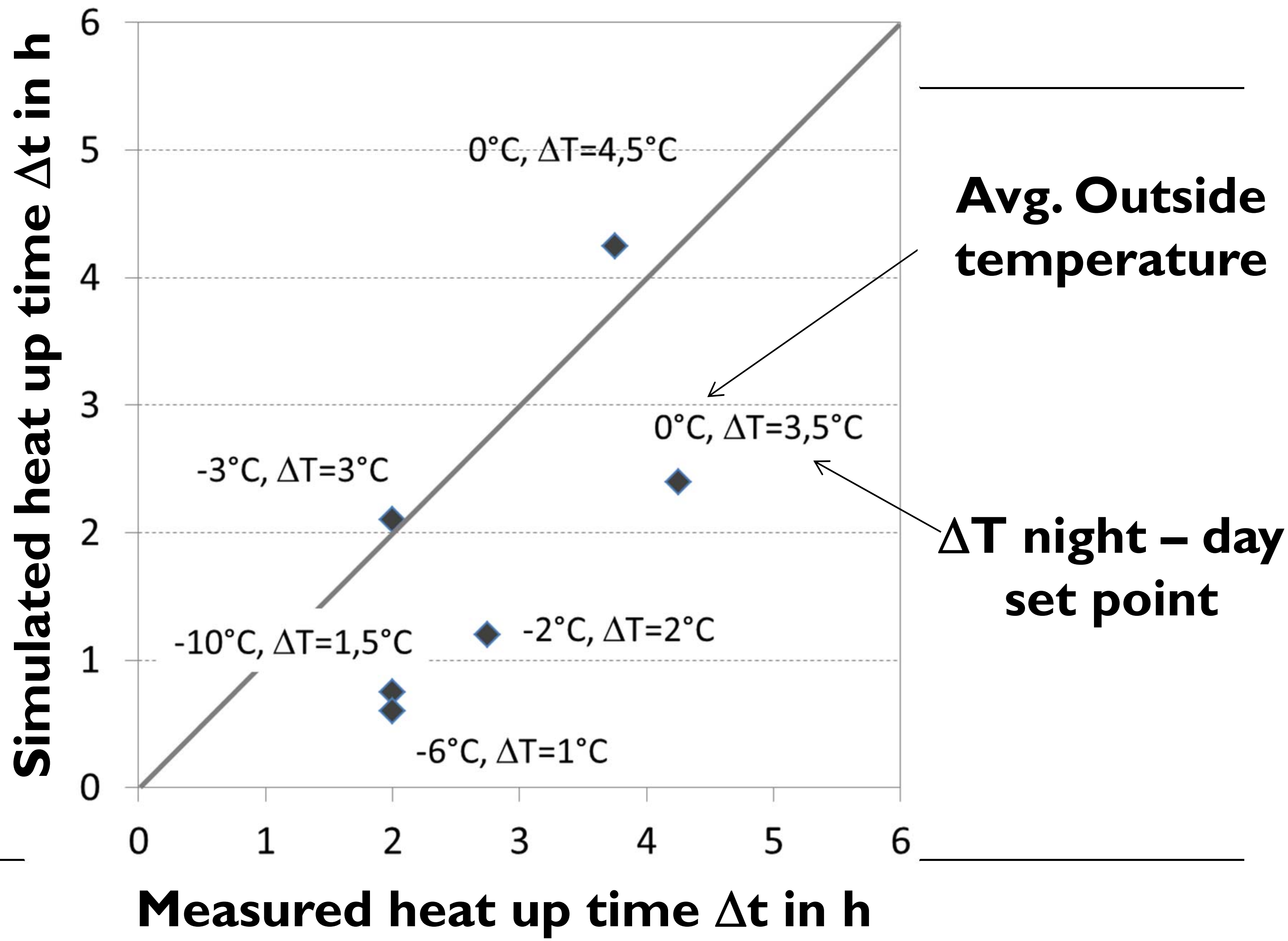
Start time heating system

Fitting of results:

- Visualisation of every heat load profiles per user and simulation results
- Definition of the infiltration rates per user by comparison with monitoring data




Room temperatrue [°C]
24
22
20
18
Heat up time Δt
03
04
05
06
07
08
09
10
11
time
Heat load[kW]
40
20
0
Night setback
03
04
05
06
07
08
09
10
11



Simulated heat up time Δt in h
0°C, ΔT=4,5°C
0°C, ΔT=3,5°C
-3°C, ΔT=3°C
-10°C, ΔT=1,5°C
-2°C, ΔT=2°C
-6°C, ΔT=1°C
0
1
2
3
4
5
6
Measured heat up time Δt in h
Avg. Outside temperature
ΔT night – day set point