Powered by

AALBORG UNIVERSITY DENMARK

energy CLUSTER DENMARK

sEEnergies

Innovation Fund Denmark

reINVEST

midt regionmidtjylland

DEN EUROPÆISKE UNION
Den Europæiske Fond for Regionaludvikling
Vi investerer i din fremtid

GRØN ENERGI

kamstrup

LOGSTOR

Ørsted

Aalborg Forsyning

6th International Conference on Smart Energy Systems
6-7 October 2020
#SESAAU2020

Heat load demand response experiment in social housing apartments

- using wireless radiator setpoint control

Presented by

Martin H. Kristensen
MSc.Eng, Ph.D.

AffaldVarme Aarhus
Business Development

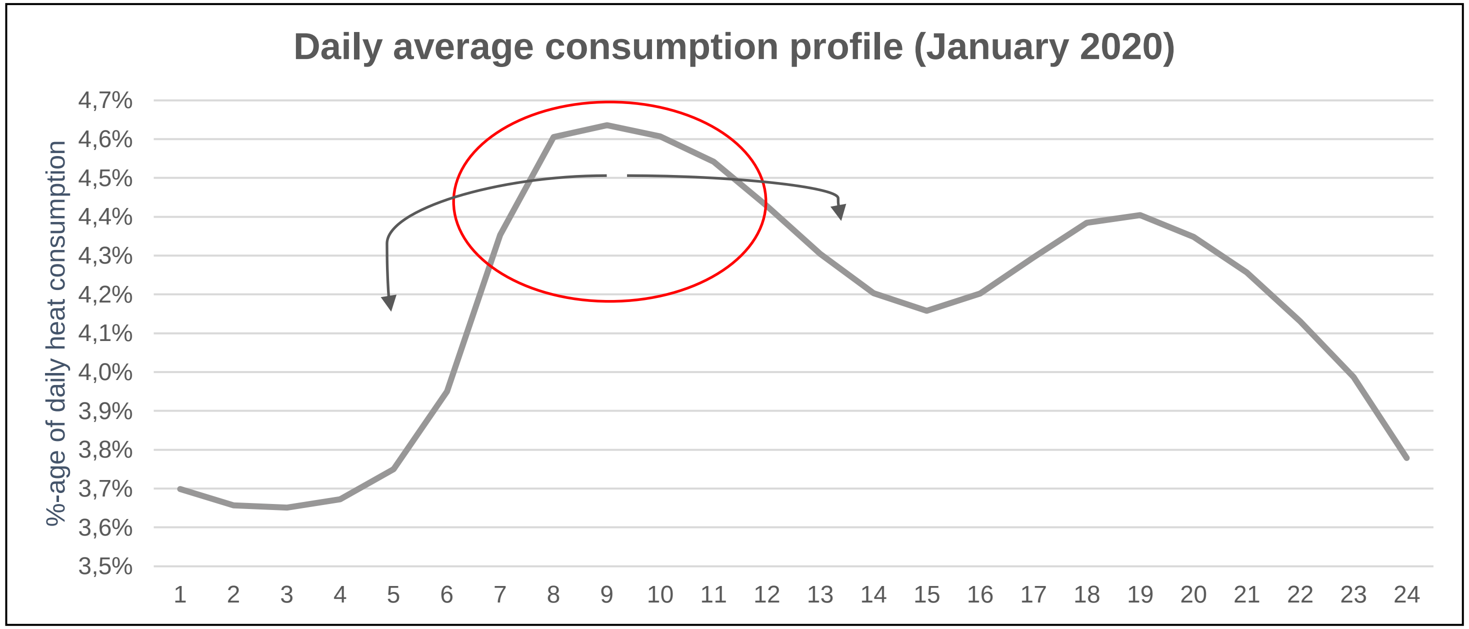
AFFALDVARME AARHUS

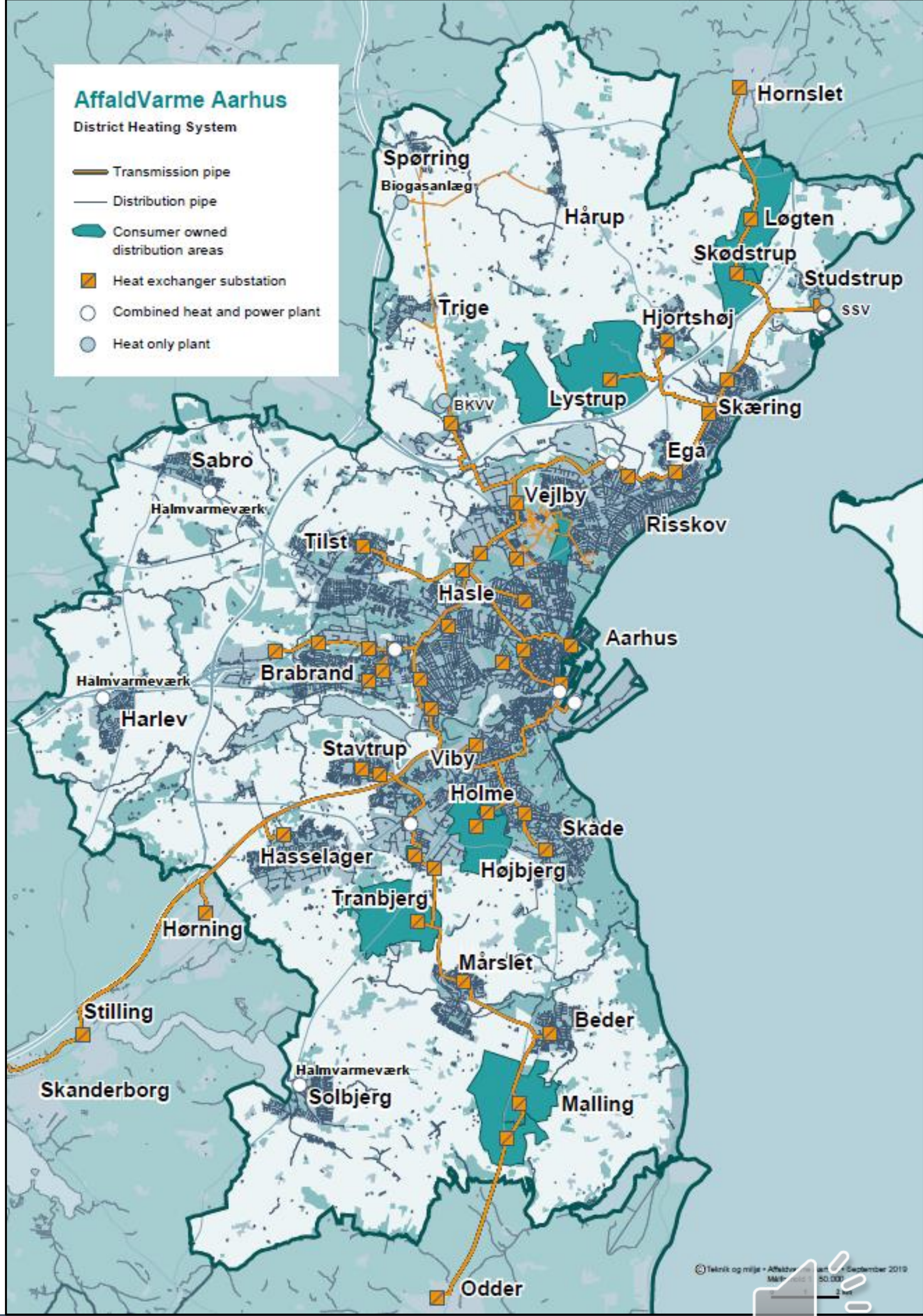
AD NYE VEJE AALBORG UNIVERSITET

AURA ALBOA

Background

- The district heating system in Aarhus is the 2nd largest in Denmark with more than 60,000 customers.
- Morning peak load makes up the main system bottleneck.
- Demand side management technologies may help balancing the load curve by mean of demand response.





Research objectives

In the context of demand side management in district heating, we wanted to:

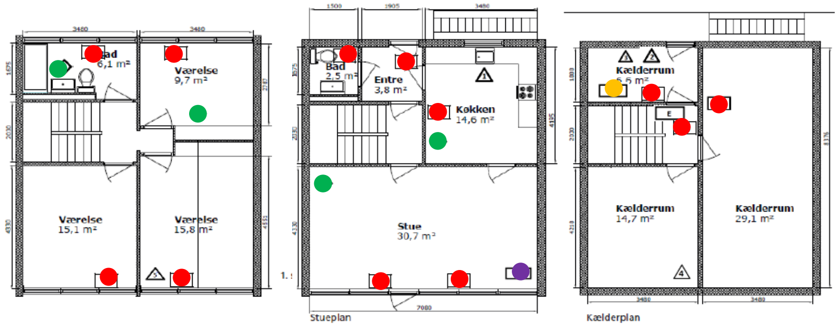
1. Investigate how district heating loads and room temperature conditions are affected by switching off radiator thermostats in shorter periods of time during morning hours.

2. Get insight into the practical challenges of implementing demand response technology in existing buildings.

Methodology

Test cases and measurement equipment

10 three-story social housing apartments in Aarhus were selected for experiments.



Equipment installed:

- District heating smart meter on space heating circuit [kW + °C]

- Room temperature sensors [°C]

- Wirelessly controlled radiator thermostats [setpoint]
  (11 out of 12 radiators, bathroom left out)

- IoT data hub [Zigbee, M-Bus, WLAN]

Methodology

Demand response schemes evaluated

During 10 weeks of measurements in 2020, we investigated three different demand response schemes.

Each scheme was tested every morning from Monday to Friday for two weeks in a row.

BASELINE: No interventions.

SCHEME 1: Radiators were **switched off for 1 hour** between 7:00 and 8:00.

SCHEME 2: Thermostat setpoints were **increased +1°C for 2 hours** between 4:00 to 6:00 whereafter radiators were **switched off for 3 hours** between 6:00 and 9:00.

SCHEME 3: Radiators were **switched off for 3 hours** between 6:00 and 9:00 (no preheating).

BASELINE: No interventions.

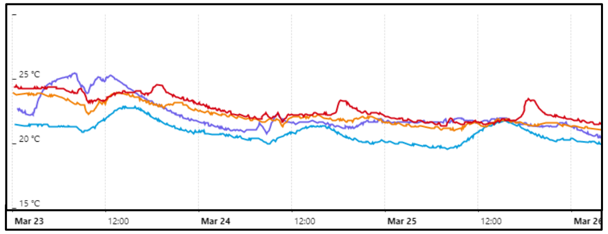
Methodology

Evaluation of thermal conditions

Experiments were conducted as **‘blind’ experiments**, meaning that the tenants did not know what was happening during the ten-week measurement period.

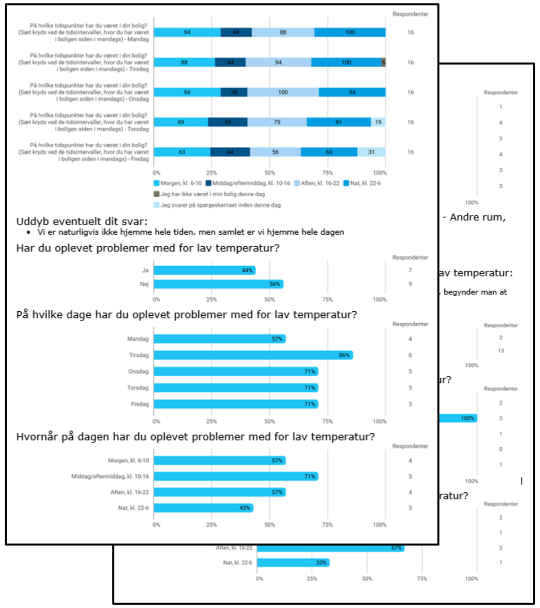
Objective evaluation of thermal conditions:

- Room air temperature



Subjective evaluation of thermal comfort and user satisfaction:

- Weekly online questionnaires
- Log book
- Post-experimental focus group interviews



Methodology

Practical evaluation of DR potential and the room temperature variations resulting hereof

Realized demand response:

$$\text{DR [\%]} = \frac{LOAD_{(\text{DRevent}-1\text{h})} - LOAD_{(\text{DRevent})}}{LOAD_{(\text{DRevent}-1\text{h})}} \times 100\%$$

Room temperature variations:

The standard deviation of room temperature measurements $STD(T_{\text{room}})$ is used as a measure of dynamic temperature conditions.

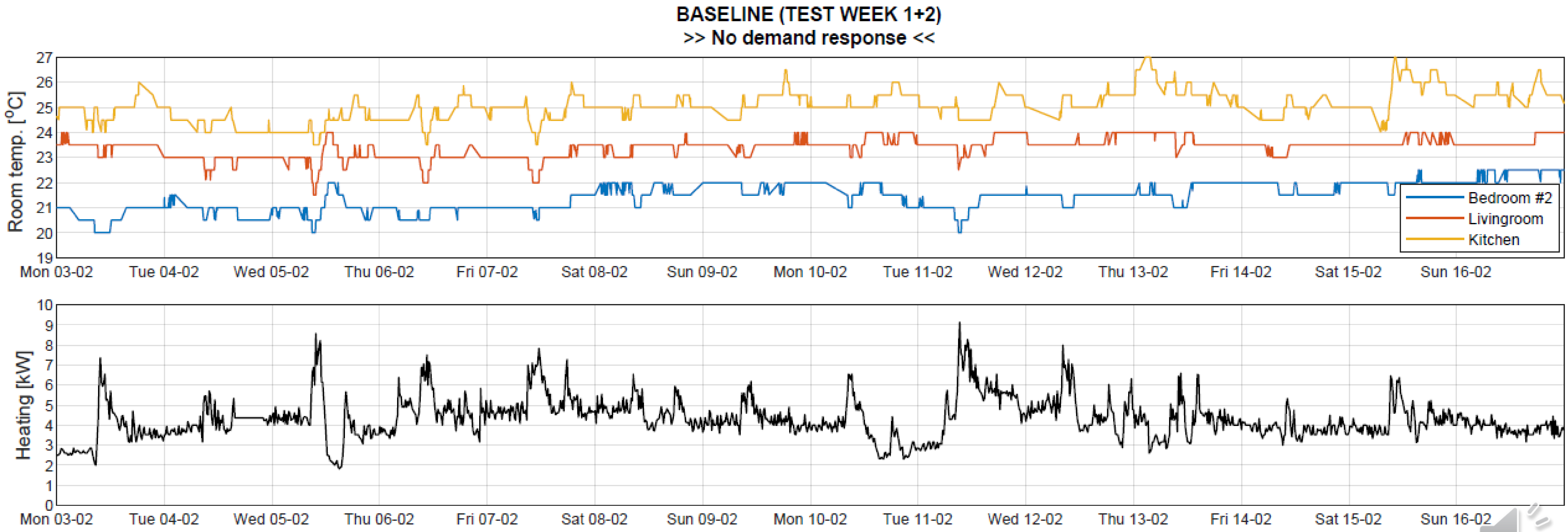
Hypothesis test (Two-sample right-tailed t-test):

H_0: $STD(T_{\text{room}})$ is the same on days with and without DR.

H_A: $STD(T_{\text{room}})$ is greater on days with DR than on days without.

Results

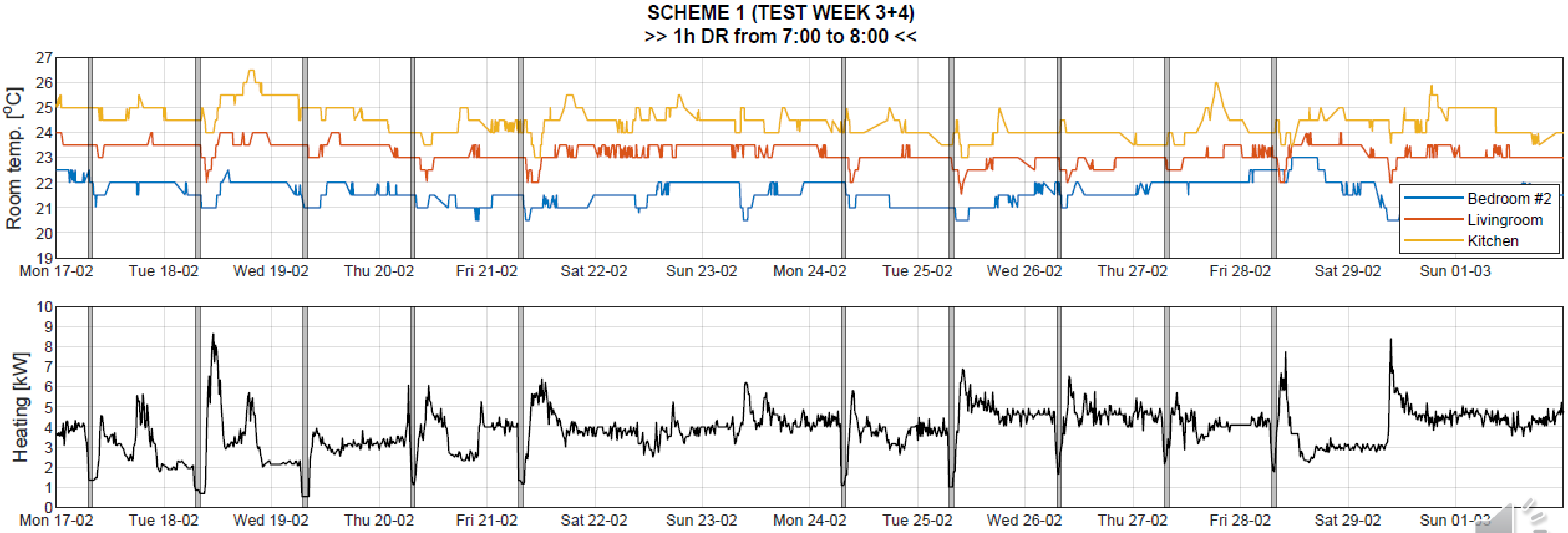
Two weeks of BASELINE



Results

Two weeks of SCHEME 1

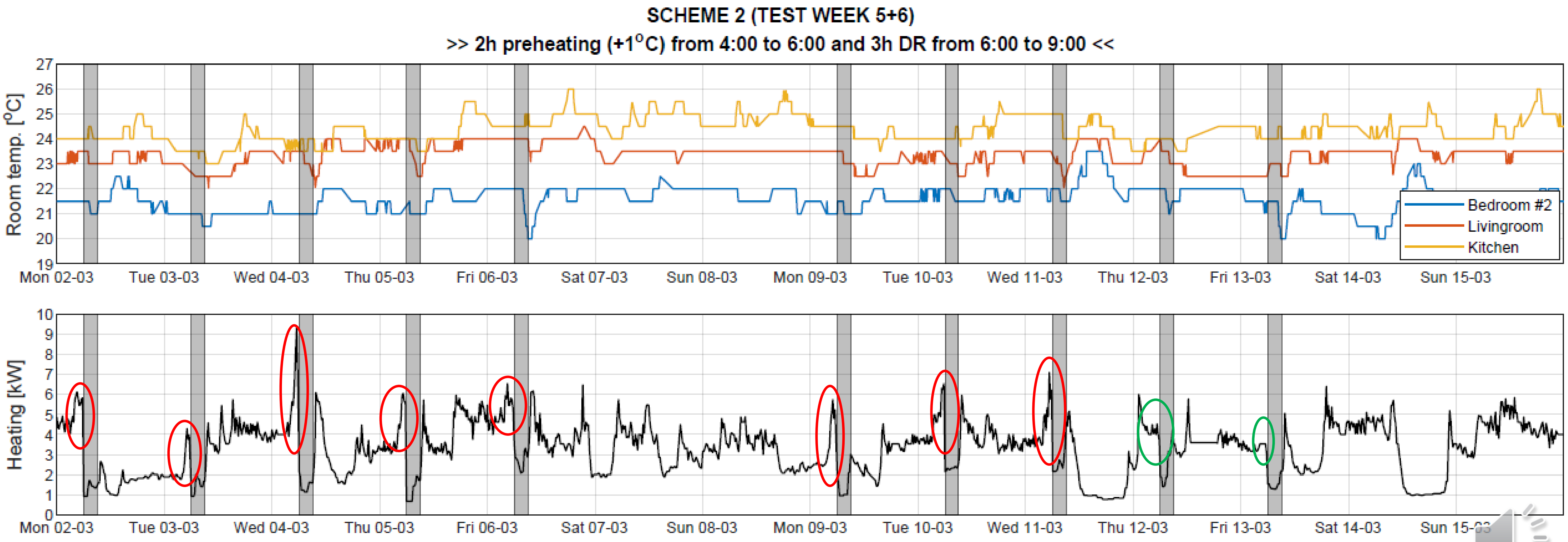
- DR events are visible in the heating profile, but the effect on room temperature is dubious.
- Realized DR: 30% to 68% of the heat load (54% in average across the two weeks).



Results

Two weeks of SCHEME 2

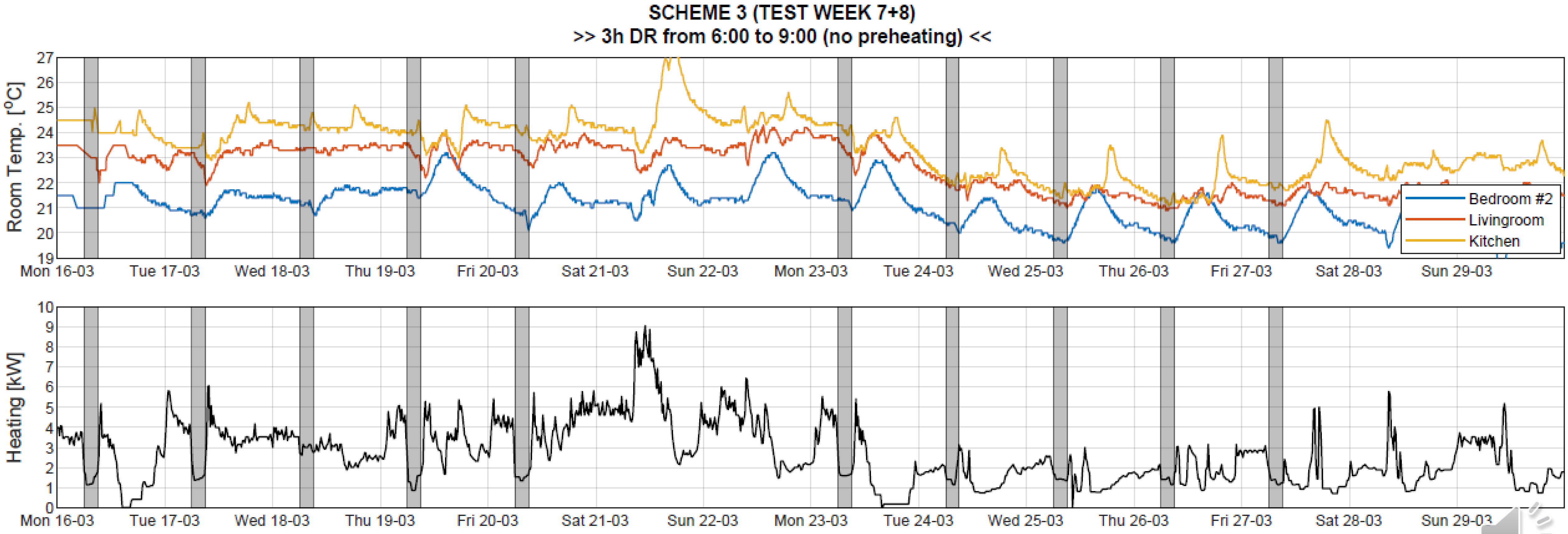
- New preheating peaks are introduced prior to the DR events!
- Realized DR: 21% to 72% of the heat load (50% in average across the two weeks).



Results

Two weeks of SCHEME 3

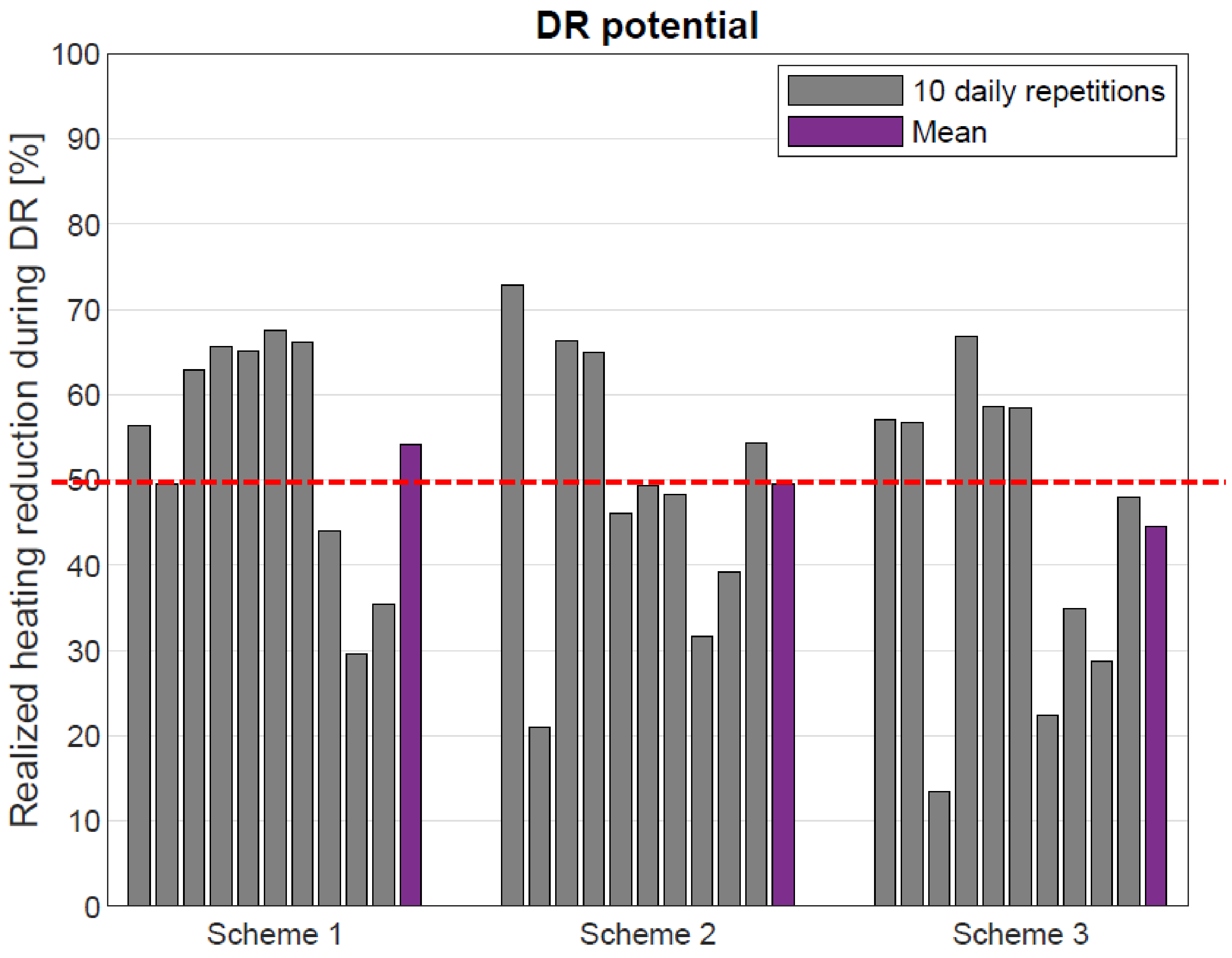
- Room temperature variations between DR events seem larger than any temperature drop during or immediately after the DR events.
- Realized DR: 14% to 66% of the heat load (45% in average across the two weeks).



Results

Summary

- 10 repeated observations per DR scheme (MON-FRI x2)
- Heat loads were reduced by approx. 50% in average during DR events compared to the heat load prior to the DR events.



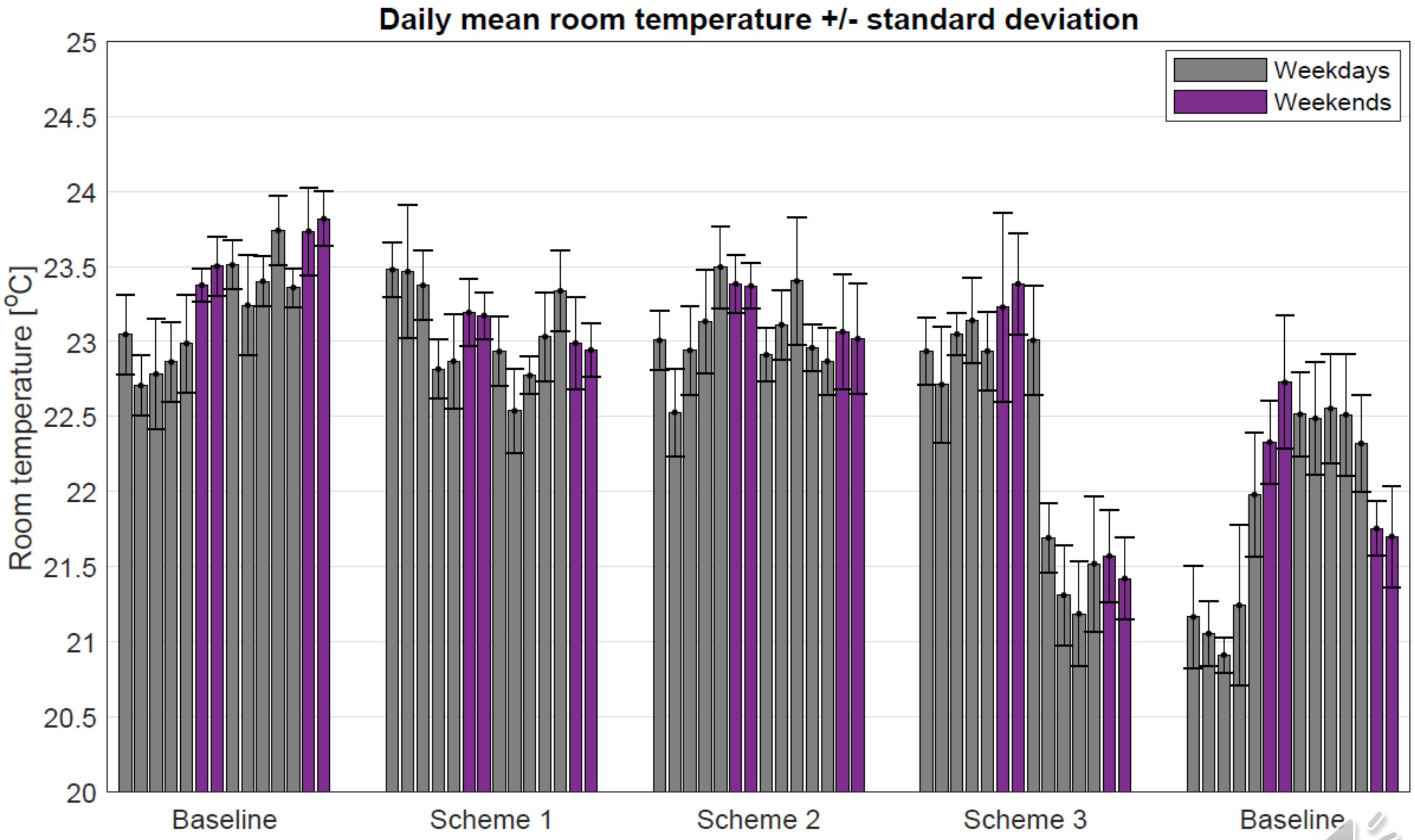
Results

Room temperature variations

- Daily mean room temperature varied across the measurement period (column height).

- The room temperature variation within each day is quantified by means of the standard deviation of the measurements (uncertainty bars).

- **Question:**
  Are the within-daily variations larger during Scheme 1, Scheme 2 and Scheme 3, than during the Baseline periods?



Results

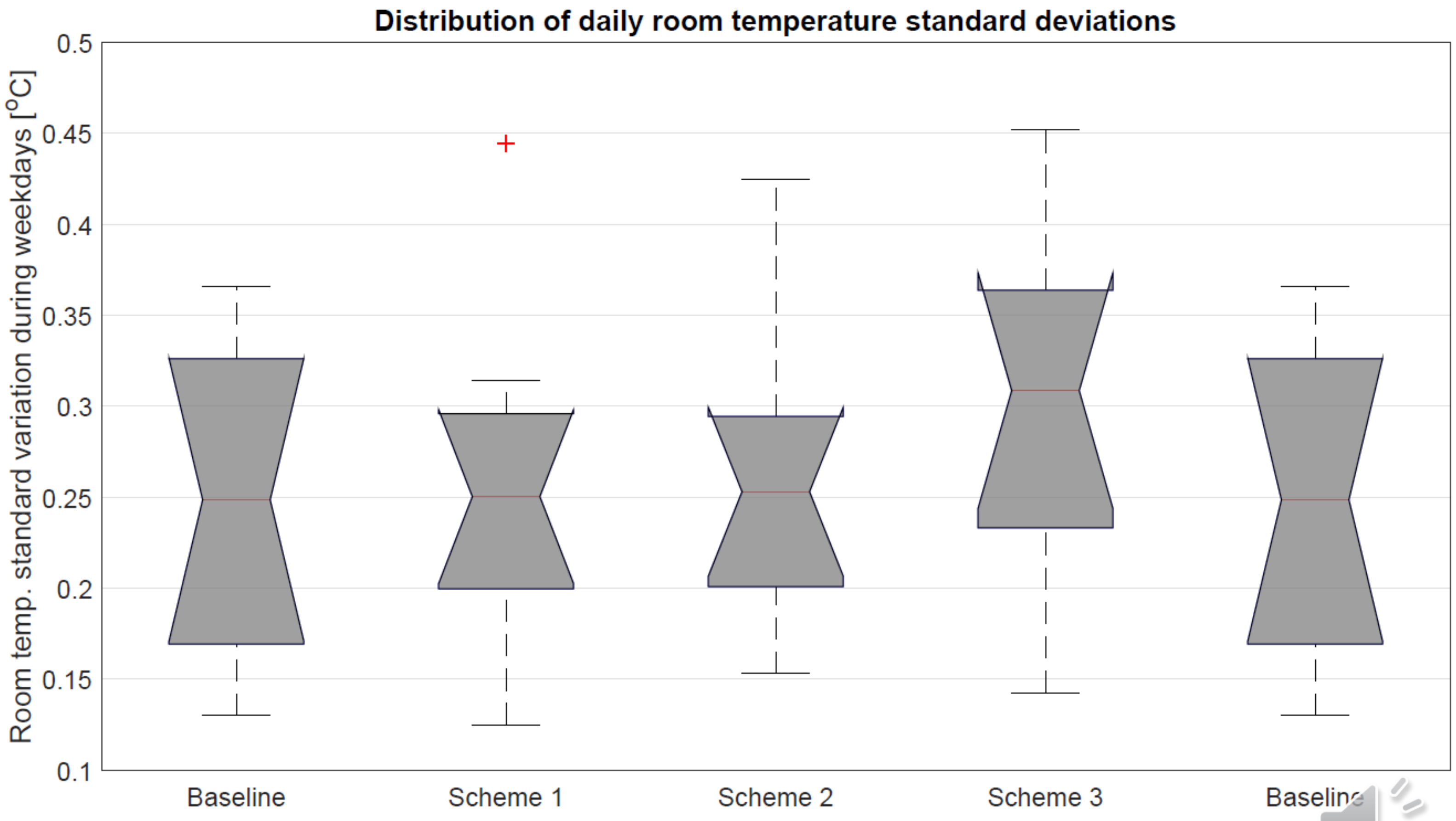
Hypothesis test of differences in room temperature standard deviations, $STD(T_{\text{room}})$

H$_0$: $STD(T_{\text{room}})$ is the same on days with and without DR.

H$_A$: $STD(T_{\text{room}})$ is greater on days with DR than on days without.

Result: Fail to reject H$_0$ in all cases

Interpretation: Room temperature dynamics are unaffected by DR event.



Summary

Conclusions:

- Wirelessly controlled radiator thermostats (11/12 radiators) were used to test the effect of heat load demand response.
- Three different schemes were tested (radiators shut-off from 1h to 3h in the morning, with and without preheating).
- Space heating load was reduced by appox. 50% in average during the three demand response events.
- Room temperature dynamics were unaffected by the presence of demand response events.

Future work:

- Analyze subjective thermal comfort evaluations (questionaires and interviews).
- Look into the effect of DR on the return temperature of district heating water.

Thank you for your attention

Martin Heine Kristensen
MSc.Eng, Ph.D.

AffaldVarme Aarhus
Business Development
mahkri@aarhus.dk

AFFALDVARME | AARHUS