energy management at the Kazán Community House

Benjamin Márkus, energy coordinator of the facilities team, ACRED

overview

- electricity: 36 kWp PV system since this year's start
- insulation state: poor, with slight improvements recently
- heating:
    - gas-fired central heating (with occasional space heating), plan to switch to a central heat pump in the future
    - smartified one year ago

planning and results so far

2022-23: energy task force, comprehensive long-term energy
development roadmap:
    1) first lessen heat need and consumption
    2) then switch to heat pumps run on PV (yearly net metered)

since then:
1) stalled PV installation pushed to finish line, in operation since Jan with
a dedicated energy improvement fund founded on the savings
2) smart heating system developed in house with comprehensive data
gathering and evaluation
3) localized improvements of insulation at points deemed the most critical
…4) currently applying for 0 interest loan to do a full insulation

PV system overview

- 36.08 kWp, 400 Wp Hyundai panels, 30 kW Huawei inverter
- E-W dual orientation to stretch out daily peak
- sized to produce just about the yearly consumption of the building
- yearly net metering for 10 years
  - (but at the mercy of energy traders)
- production, feed in, take up and overall consumption data for the past year with 15 mins granularity
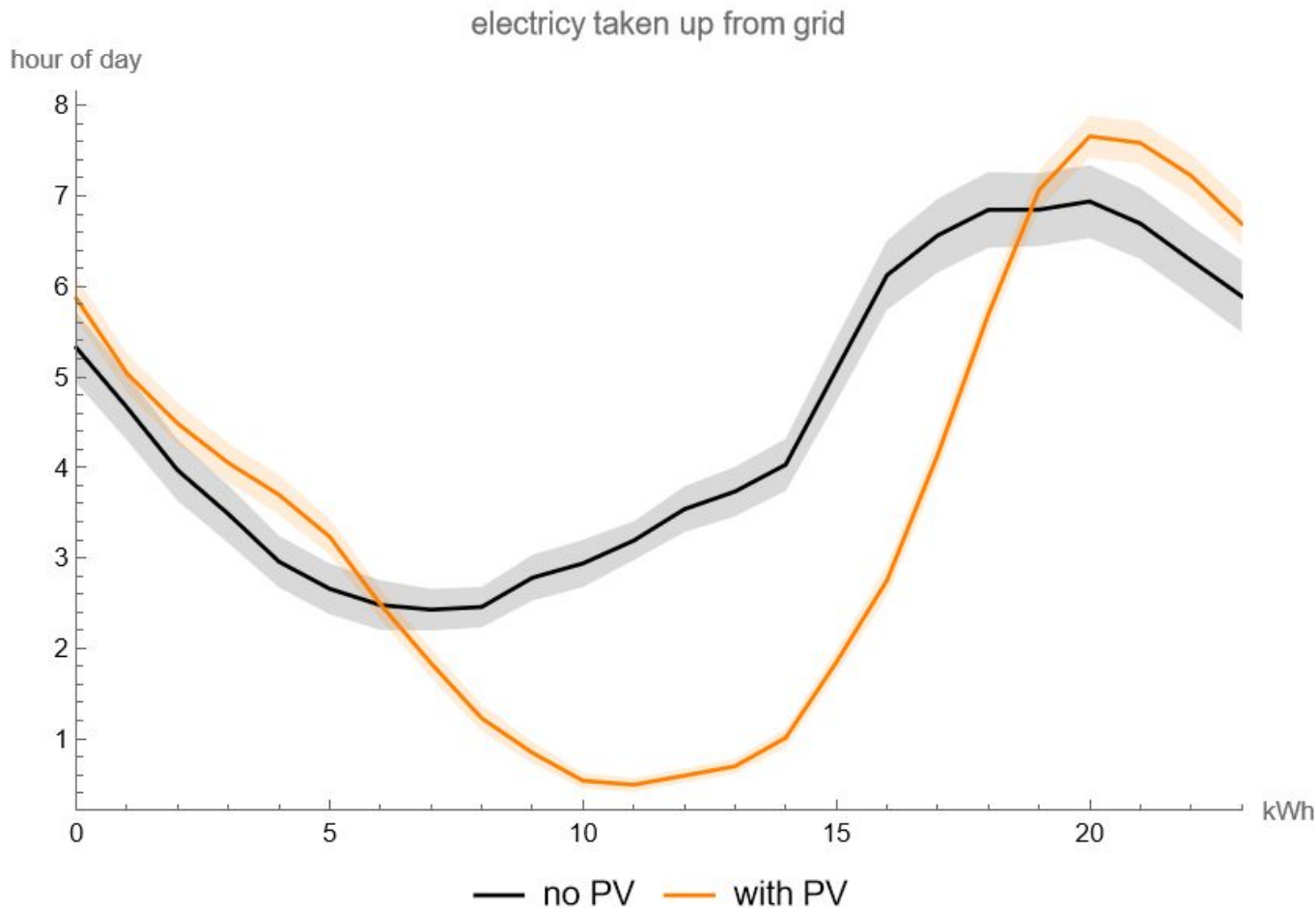
PV system overview

PV system: the first 10 months of operation

PV production

daily energy (kWh)

PV system: the first 10 months of operation

electricy taken up from grid
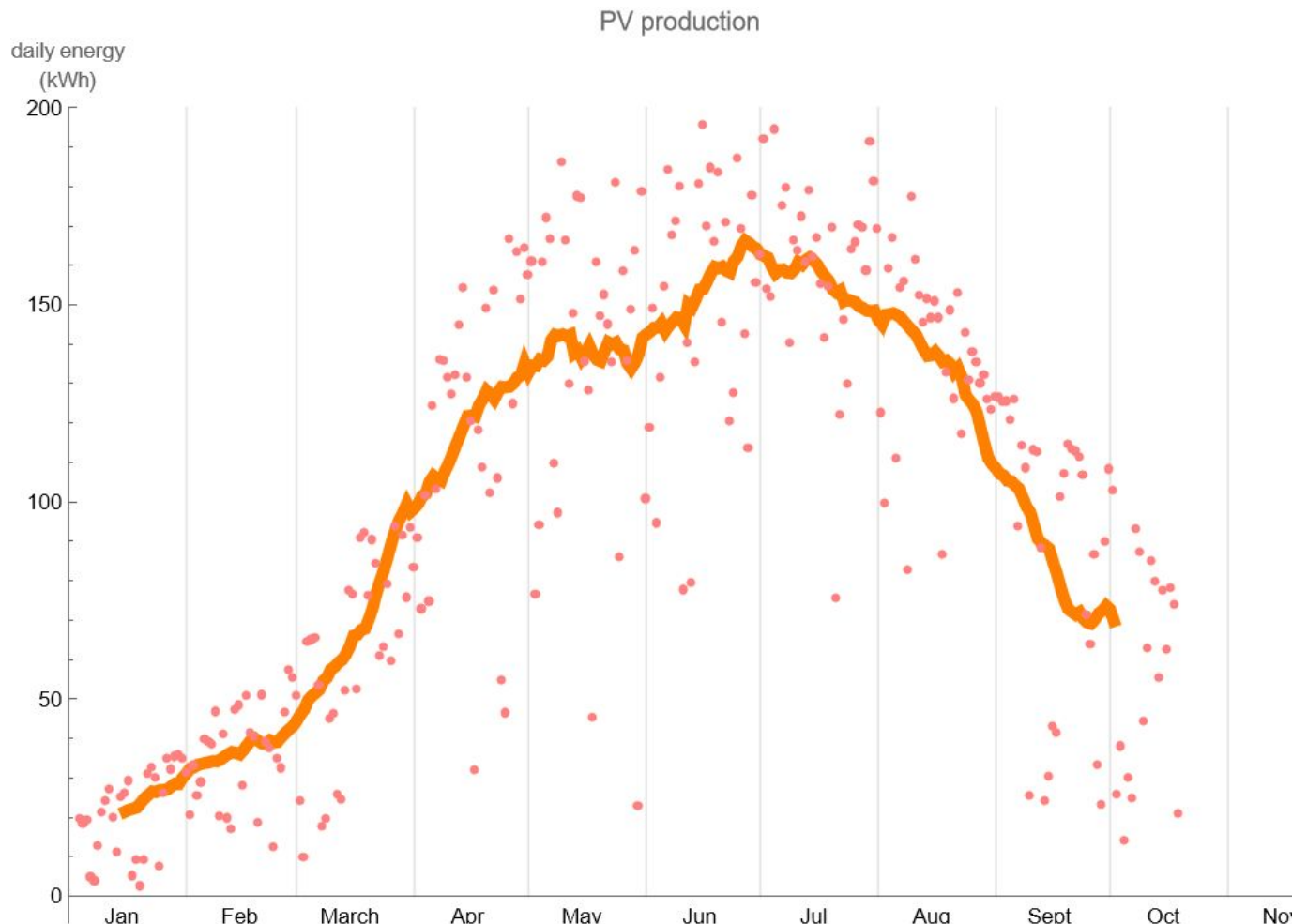
PV system: the first 10 months of operation

- yearly consumption so far: 44.5 MWh
- … production: 27.9 MWh
- … grid net: 16.6 MWh

- estimated income for the energy improvement fund this year:

    2.3-2.4M HUF ≈ 5700 - 6000 EUR

   (how? tenants chose to pay market price for electricity produced in house)

heating: smartified gas-fired central heating

- four heating cycles, about 1700 sq. meters heated, served by 2 Ariston gas boilers
- most of the rooms (10) are temperature-controlled:
  - smart thermometers and a central heating control logic running on a RasPi switching the boilers and cycles
  - web-based user interface and [dashboard](#)
  - intensive data gathering at each stage: gas, heating energy, heating state, temperatures
- but only the cycles can be switched → overheating of rooms

heating: analysis of first season's dataset

- aims:
  - determining the financial cost of various deficiencies at the most detailed level (room) and as precisely as possible
  - identification of hidden issues
  - general evaluation, comparison to previous seasons
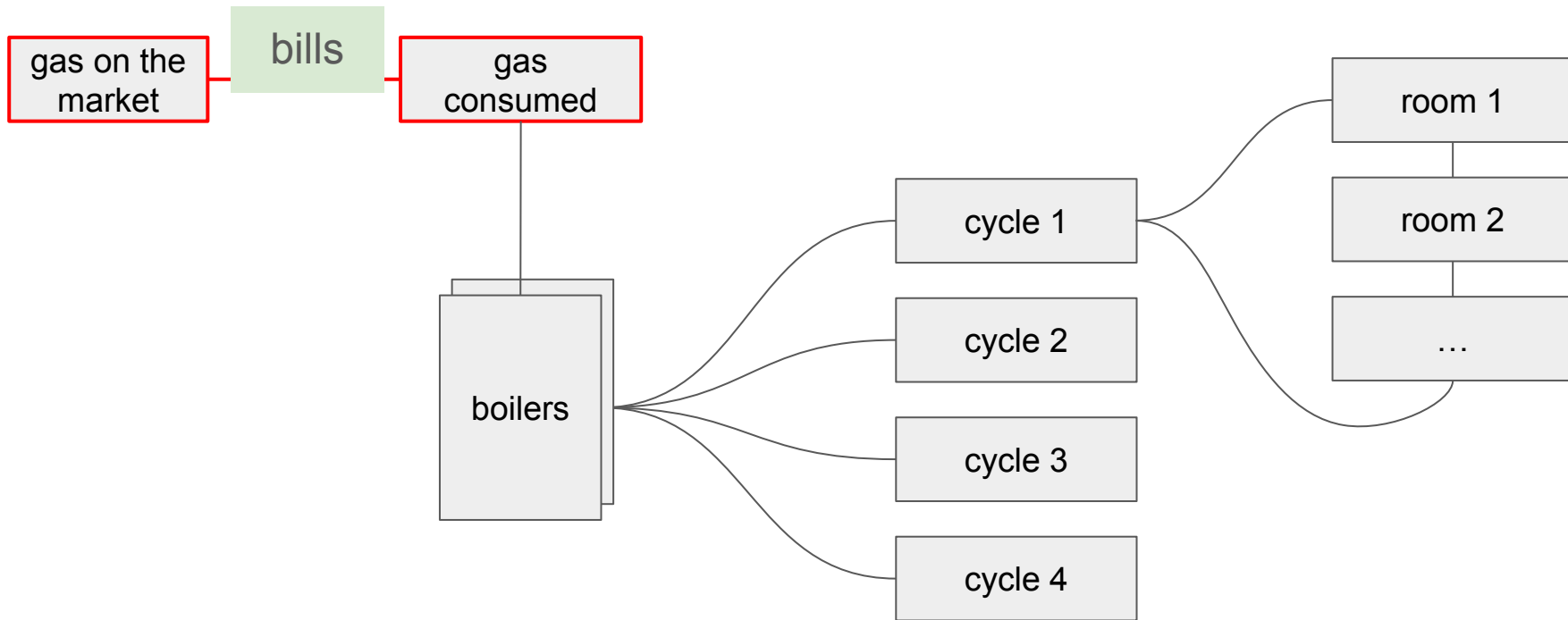 - smart heating evaluation

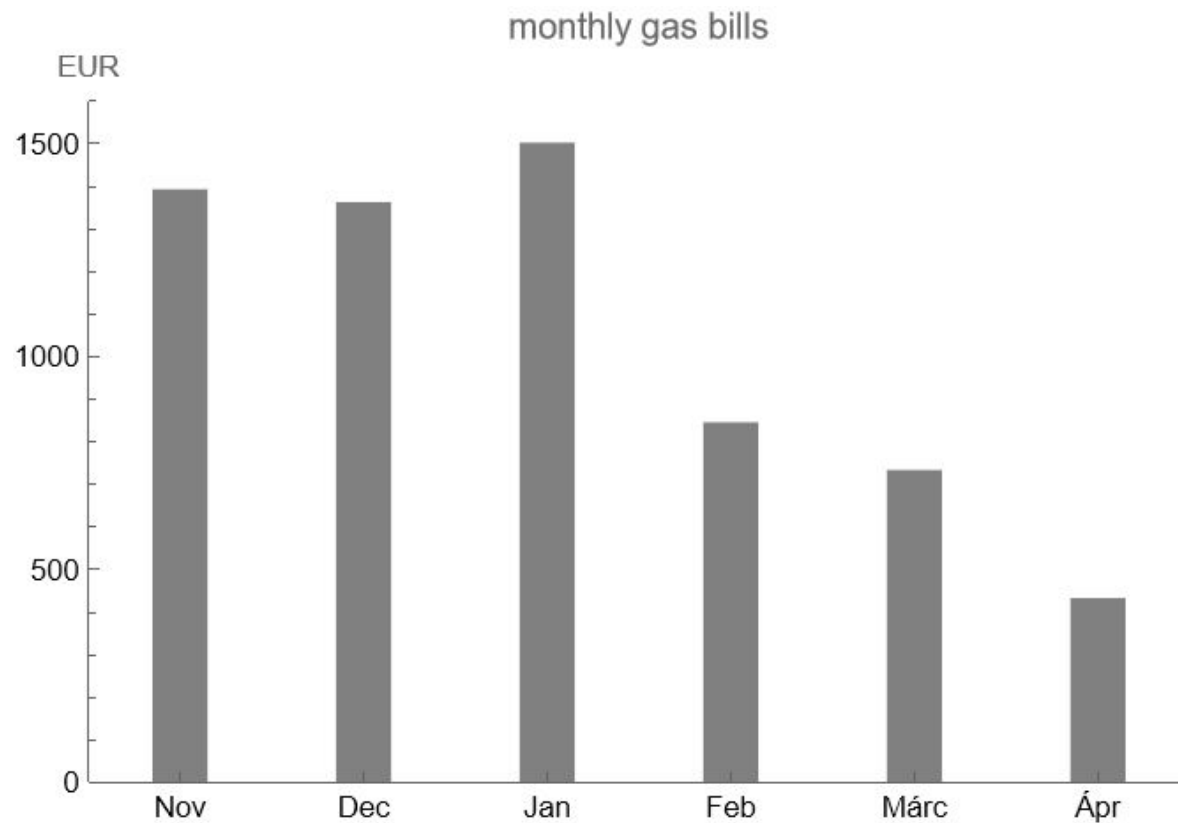# heating: analysis of first season's dataset - cost assignment
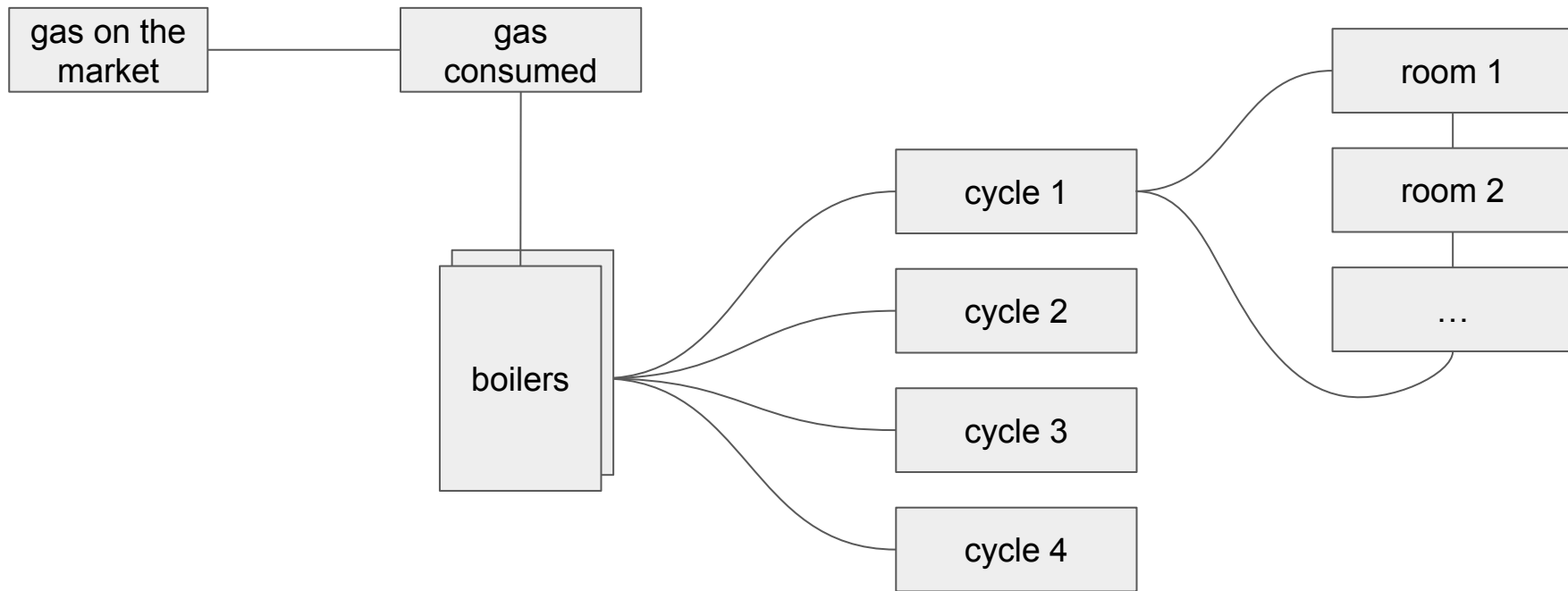
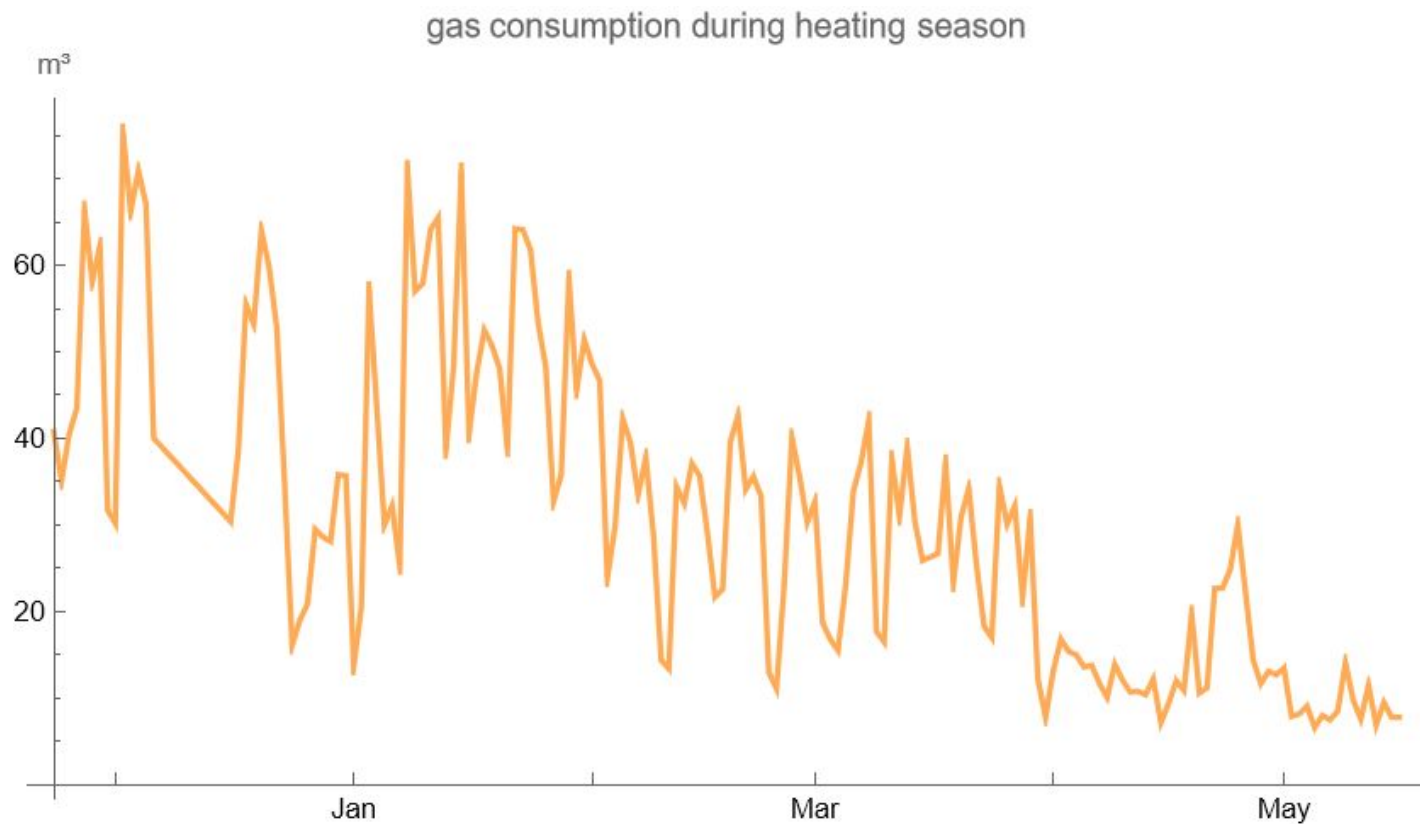# heating: analysis of first season's dataset - cost assignment
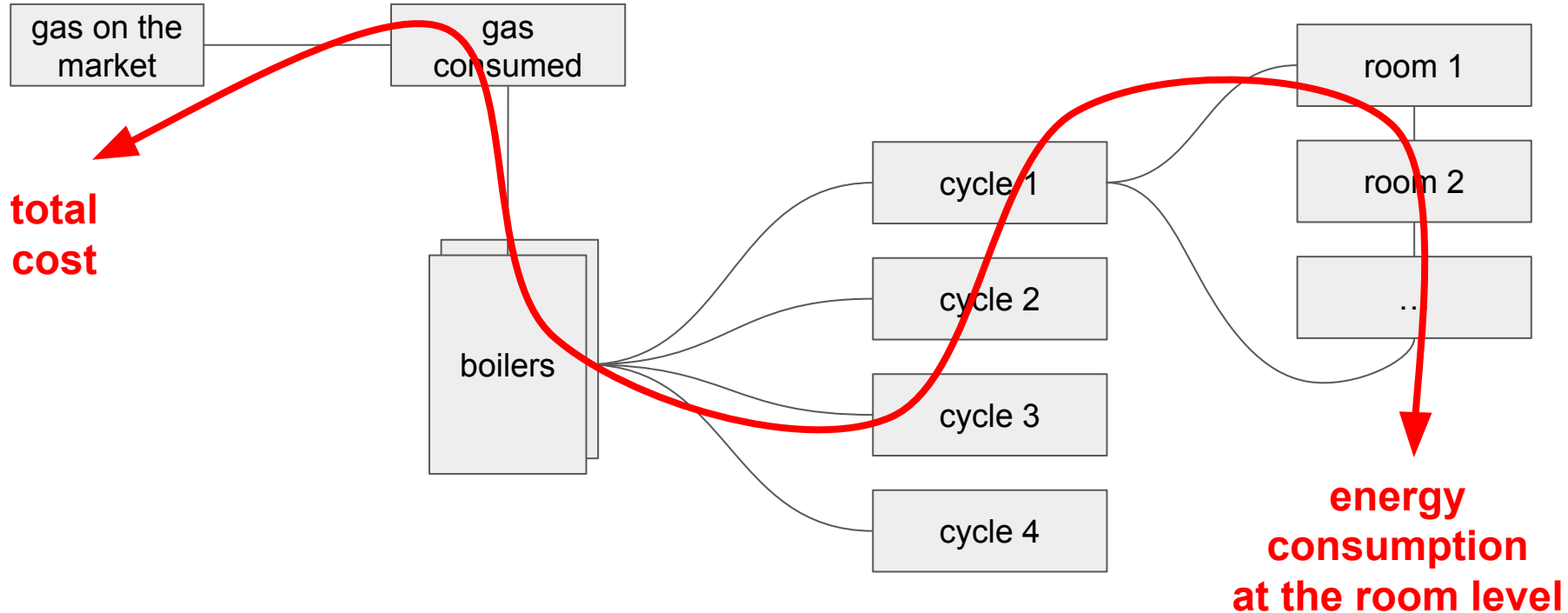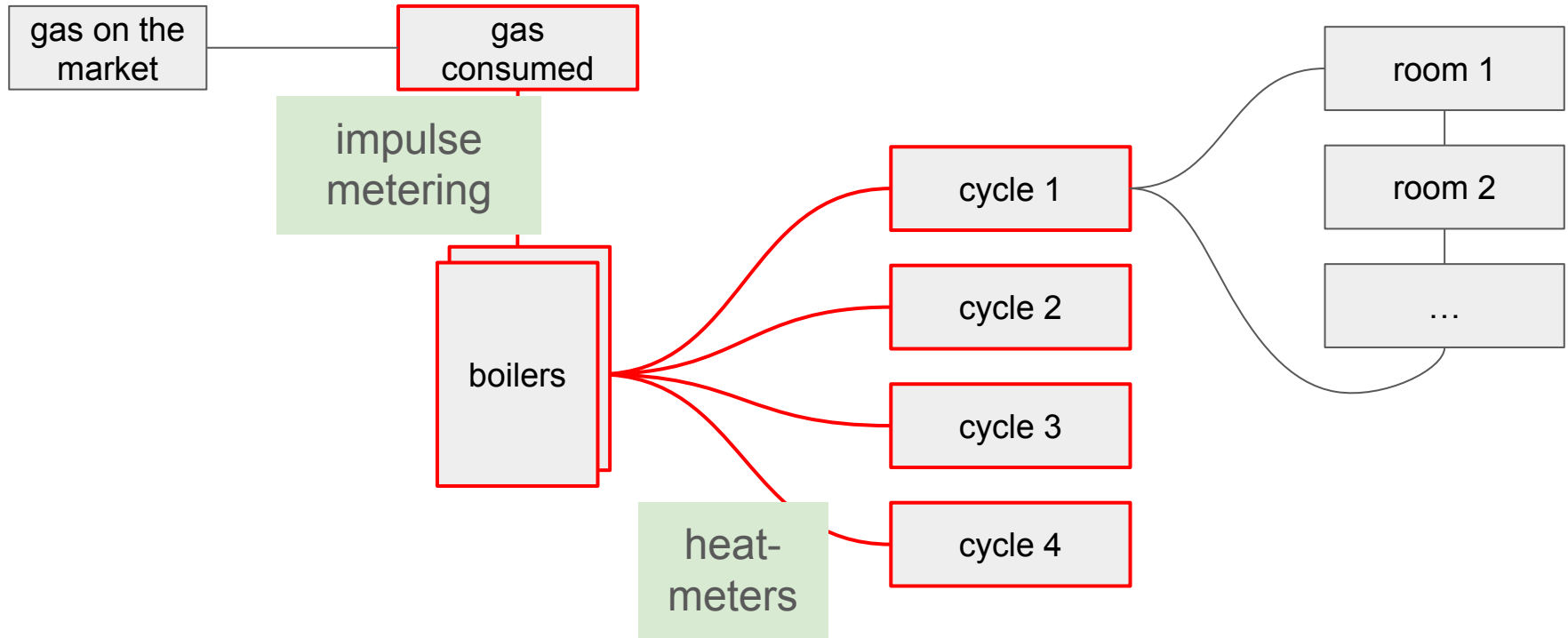
from <u>HUF</u> to <u>burnt gas</u>

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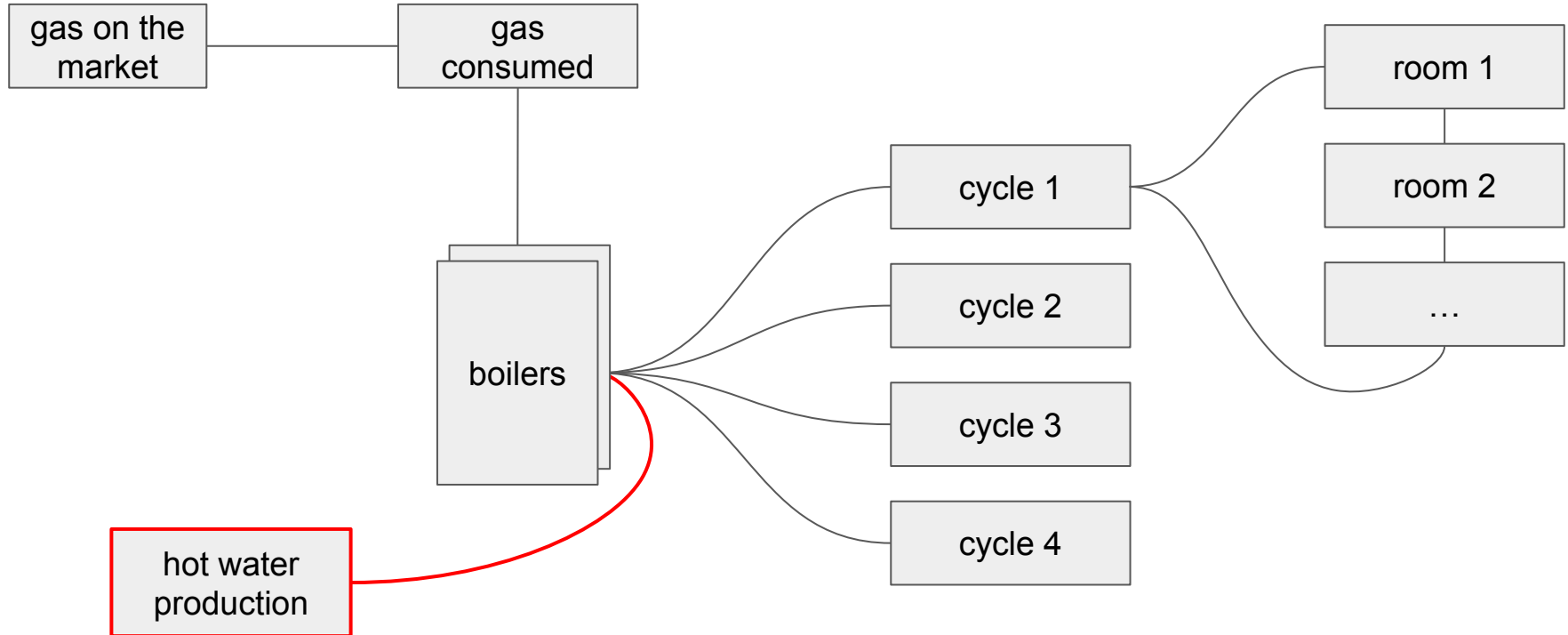

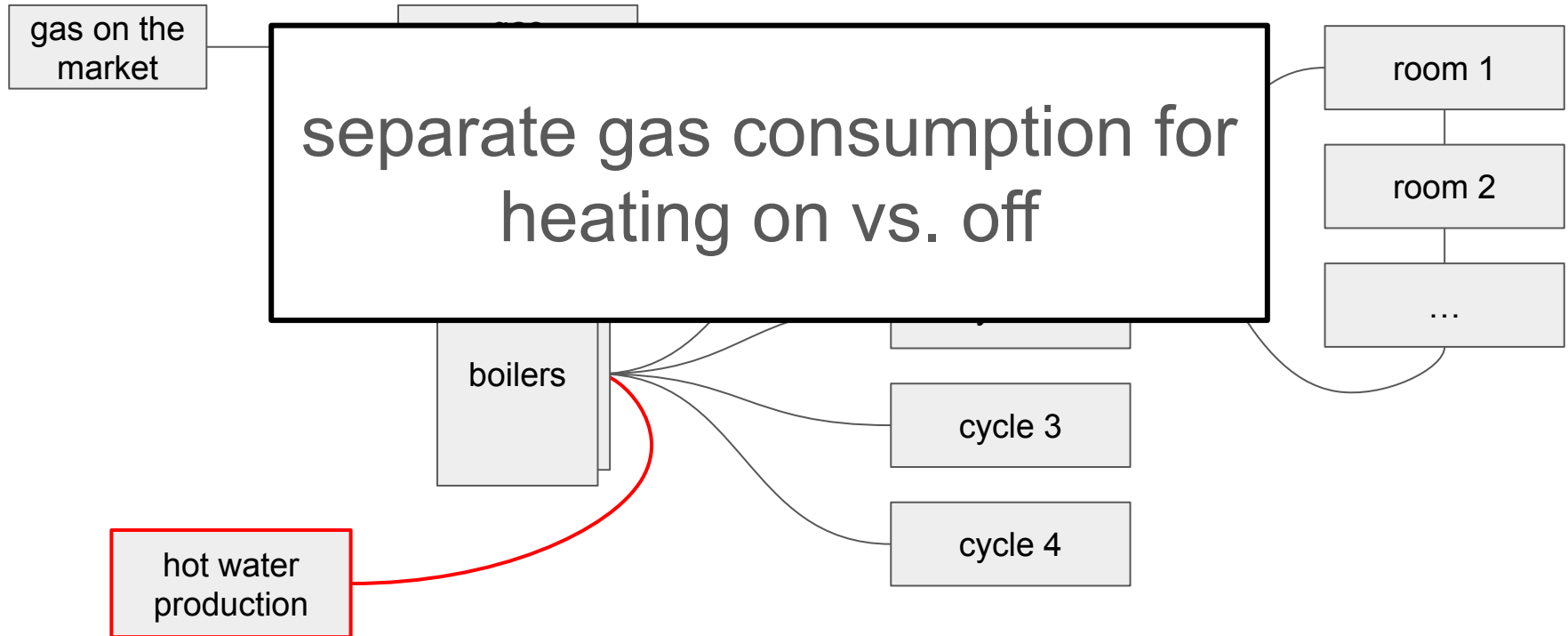gas consumption during heating season

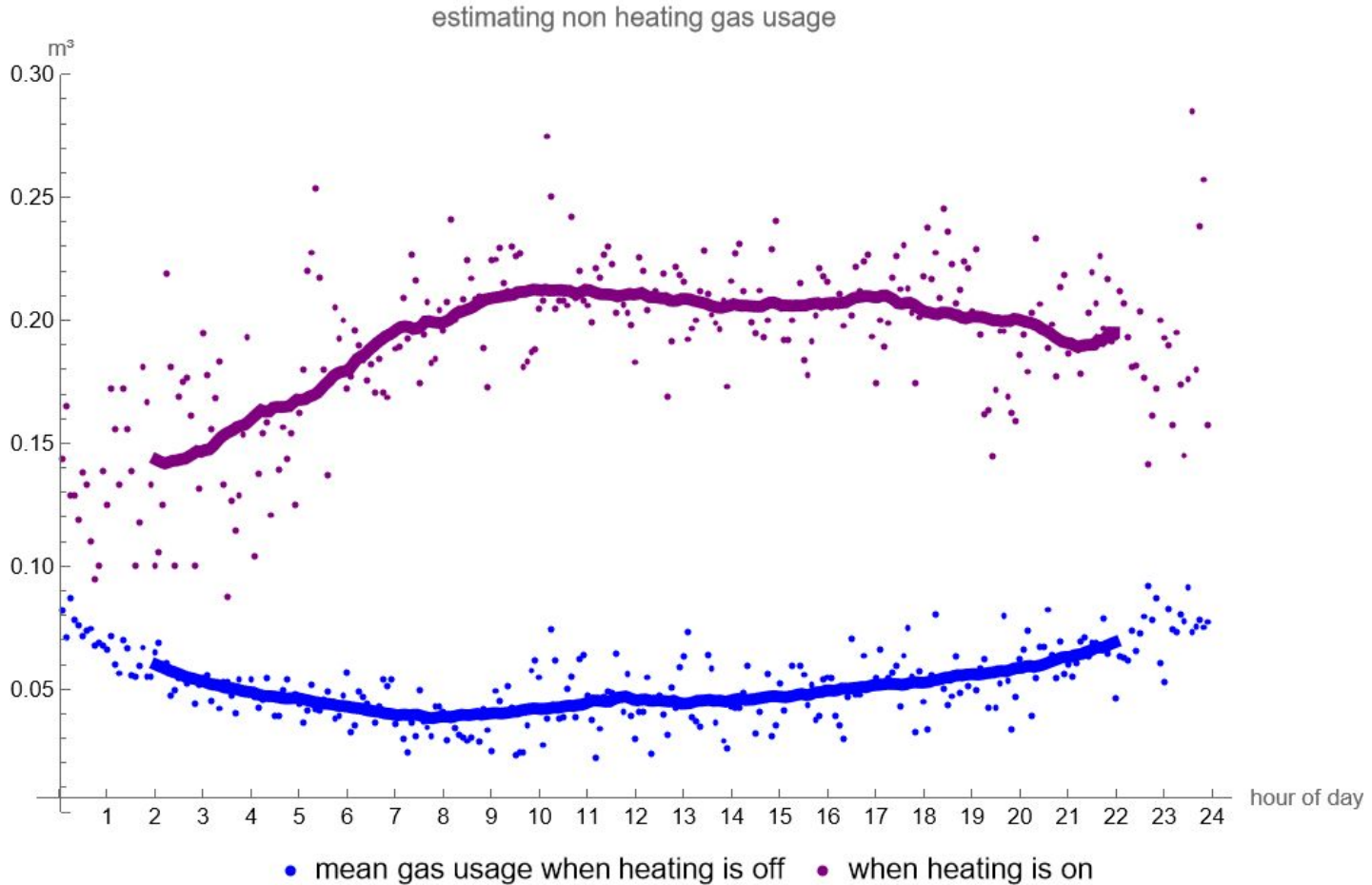# from <u>burnt gas</u> to <u>heat delivered on cycles</u>

but: hot water production

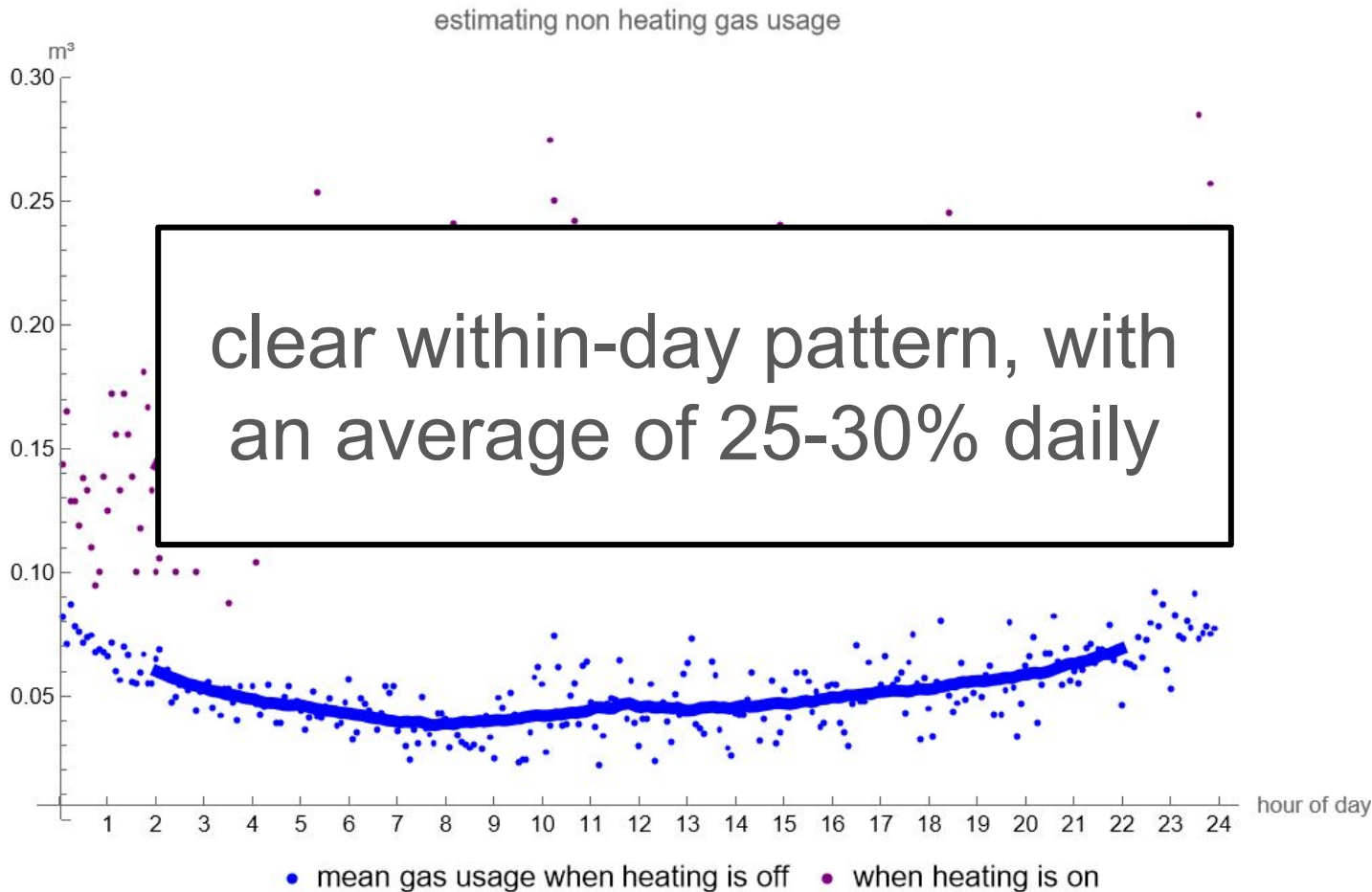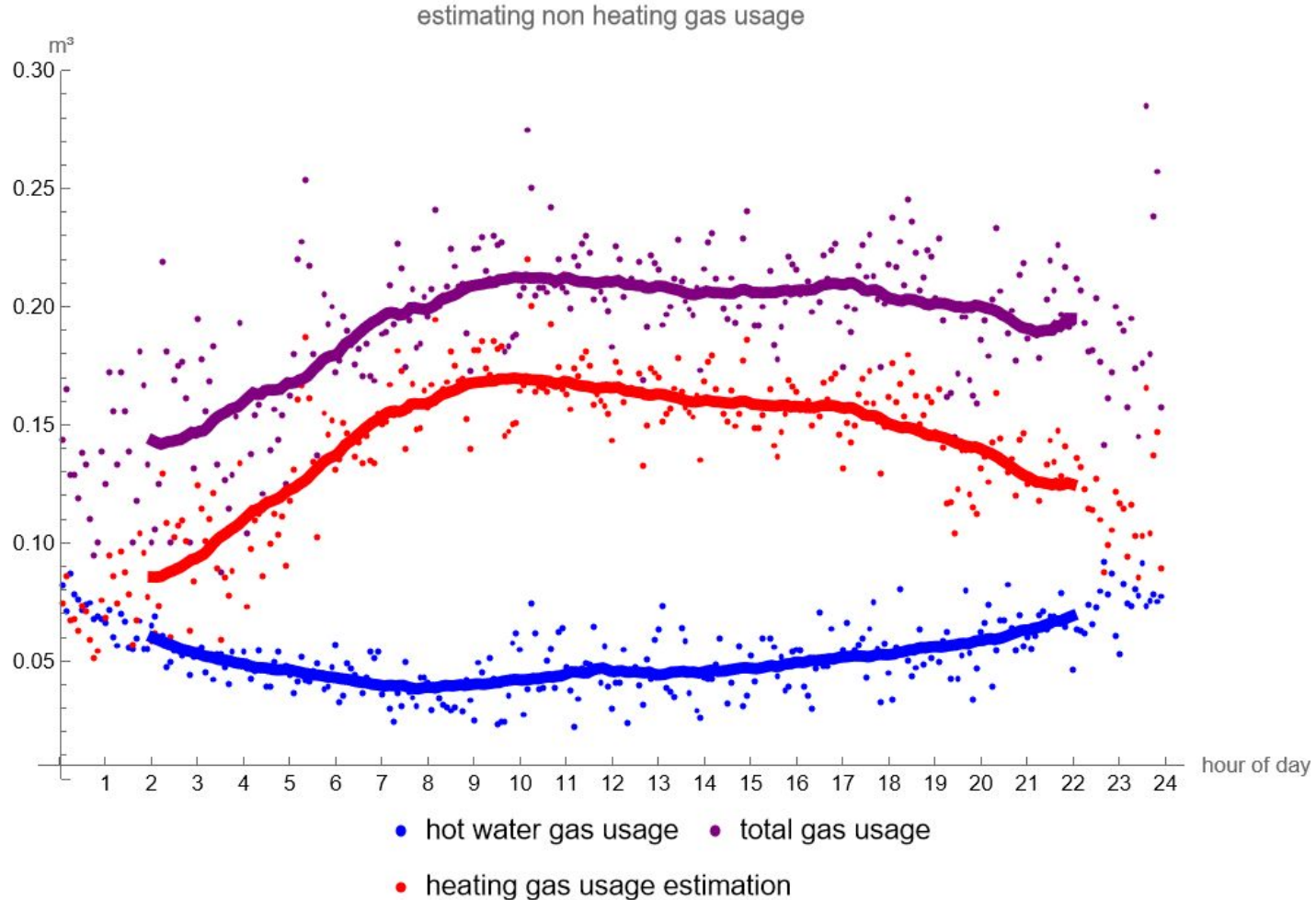# 1) estimation of non-heating gas consumption

1) estimation of non-heating gas consumption

estimating non heating gas usage

- mean gas usage when heating is off
- when heating is on

1) estimation of non-heating gas consumption

estimating non heating gas usage

clear within-day pattern, with an average of 25-30% daily

- mean gas usage when heating is off
- when heating is on

1) estimation of non-heating gas consumption

estimating non heating gas usage

- hot water gas usage
- total gas usage
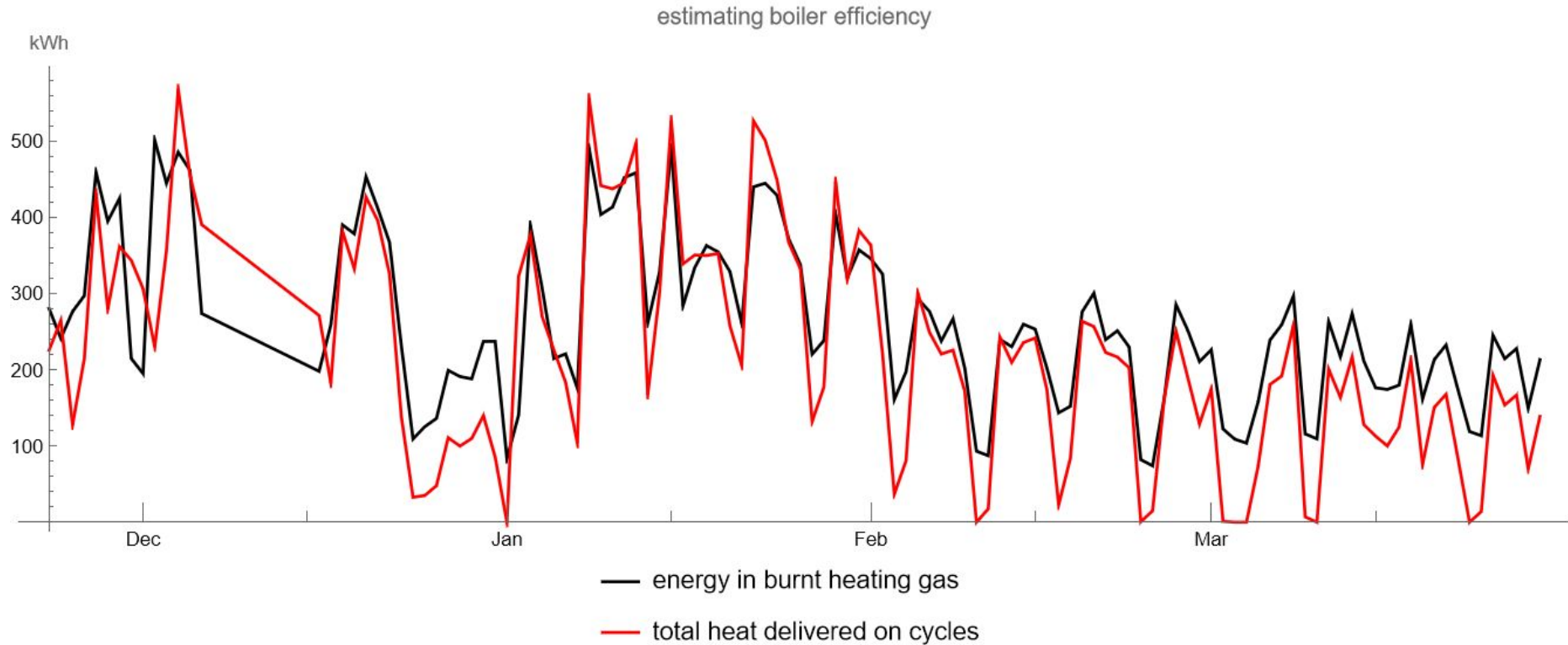- heating gas usage estimation

if we are there: estimation of boiler efficiency
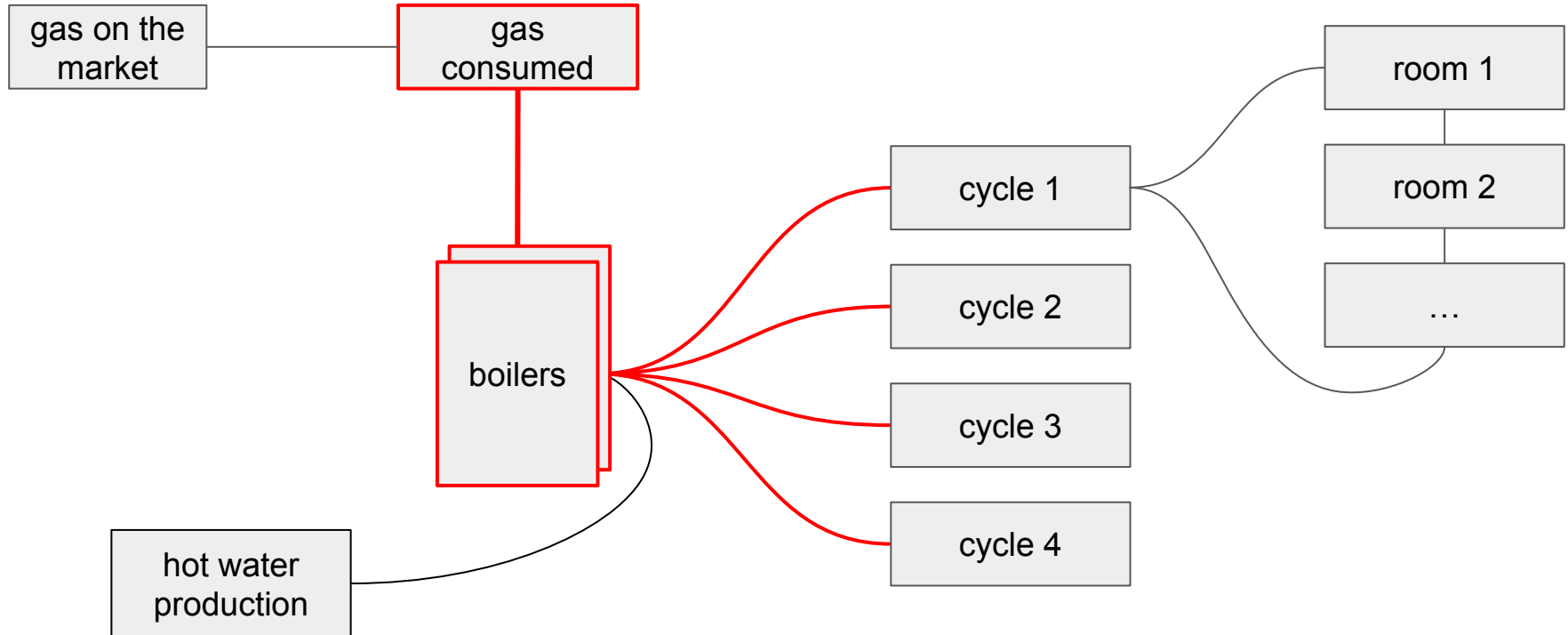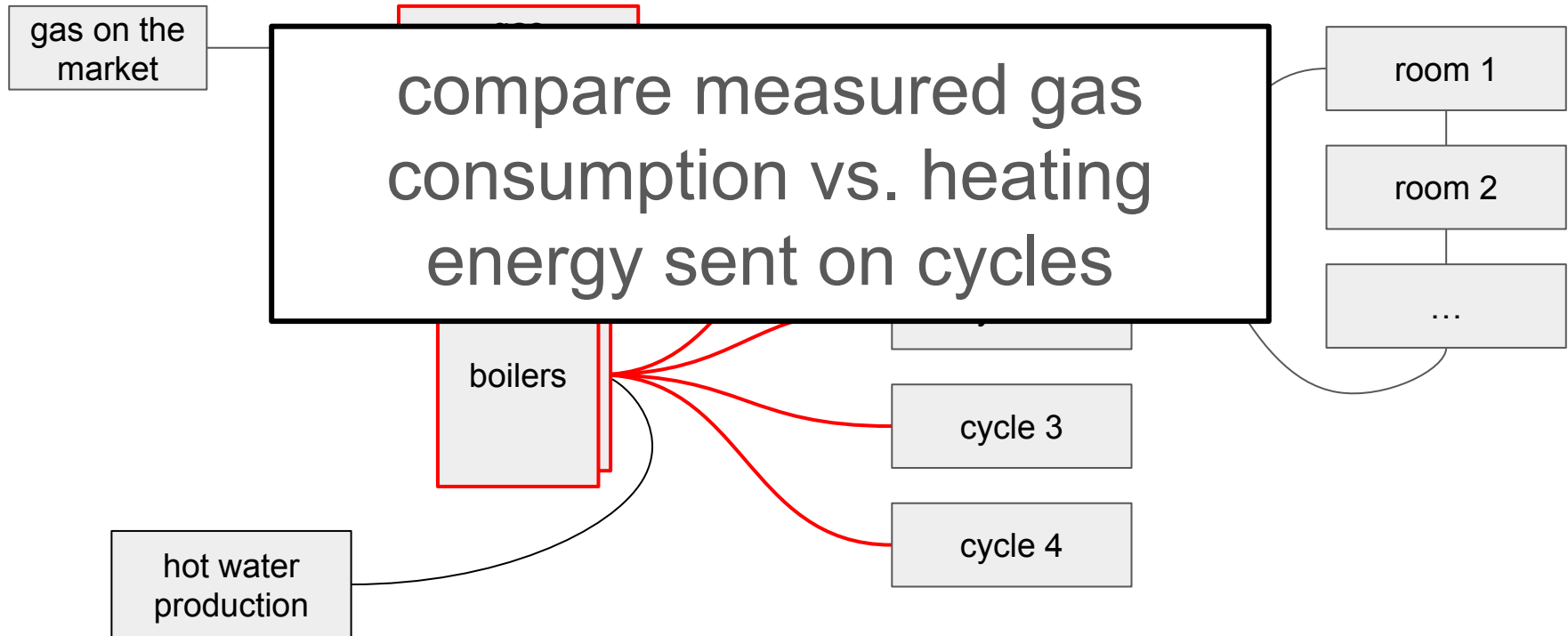
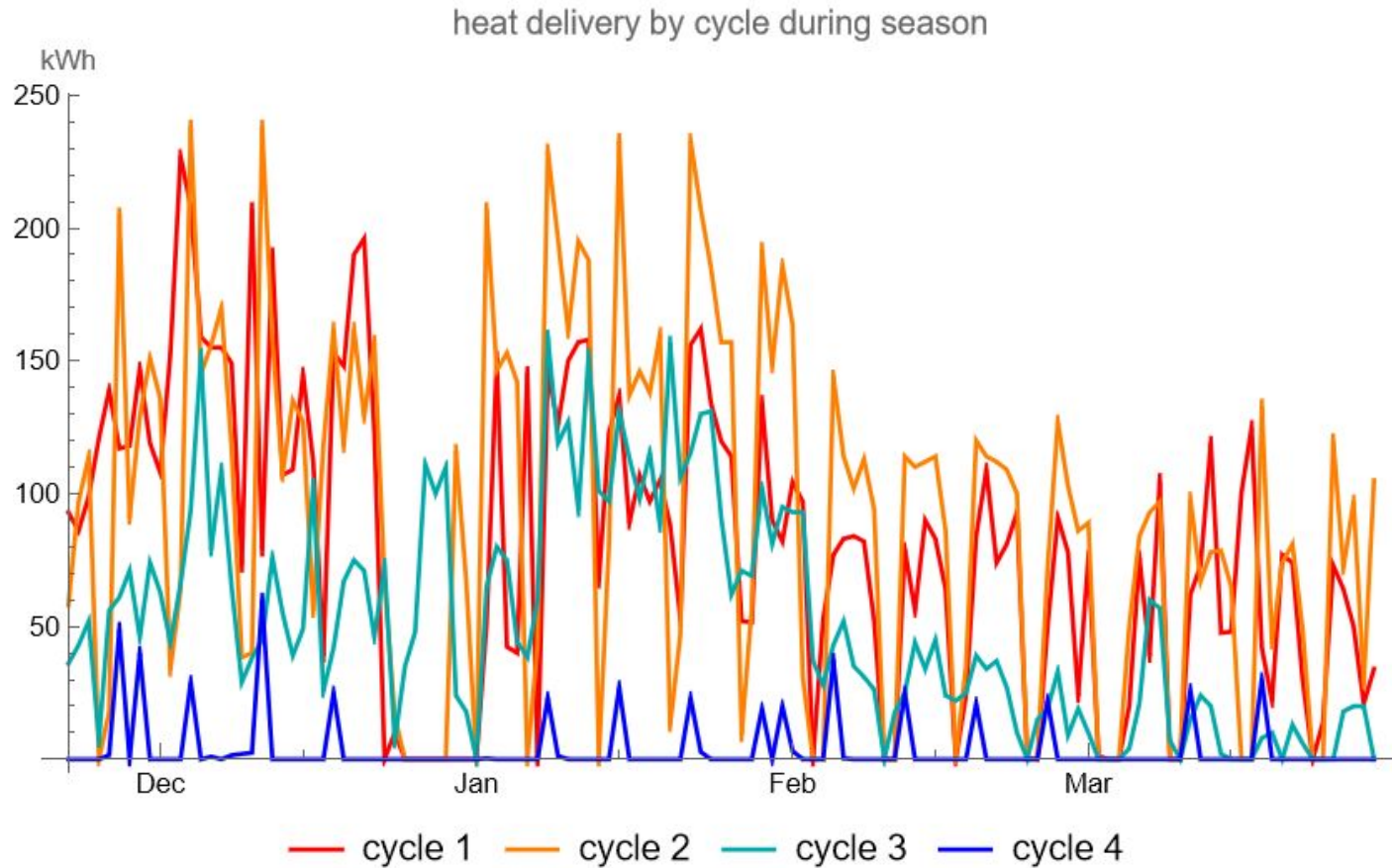# 2) estimation of boiler efficiency

2) estimation of boiler efficiency

estimating boiler efficiency

— energy in burnt heating gas

— total heat delivered on cycles

2) estimation of boiler efficiency

estimating boiler efficiency

boiler efficiency: ~93%

— energy in burnt heating gas
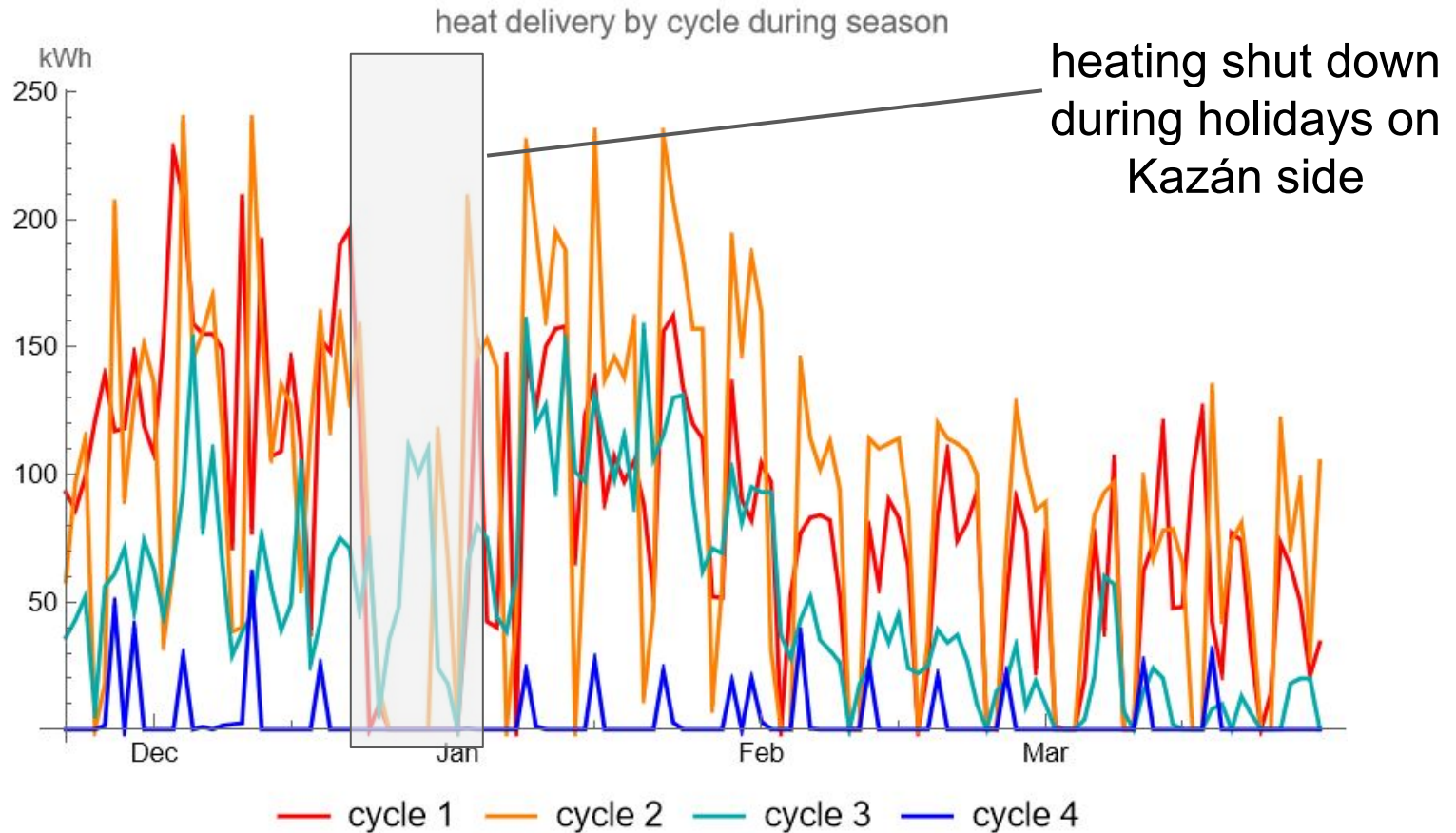
— total heat delivered on cycles
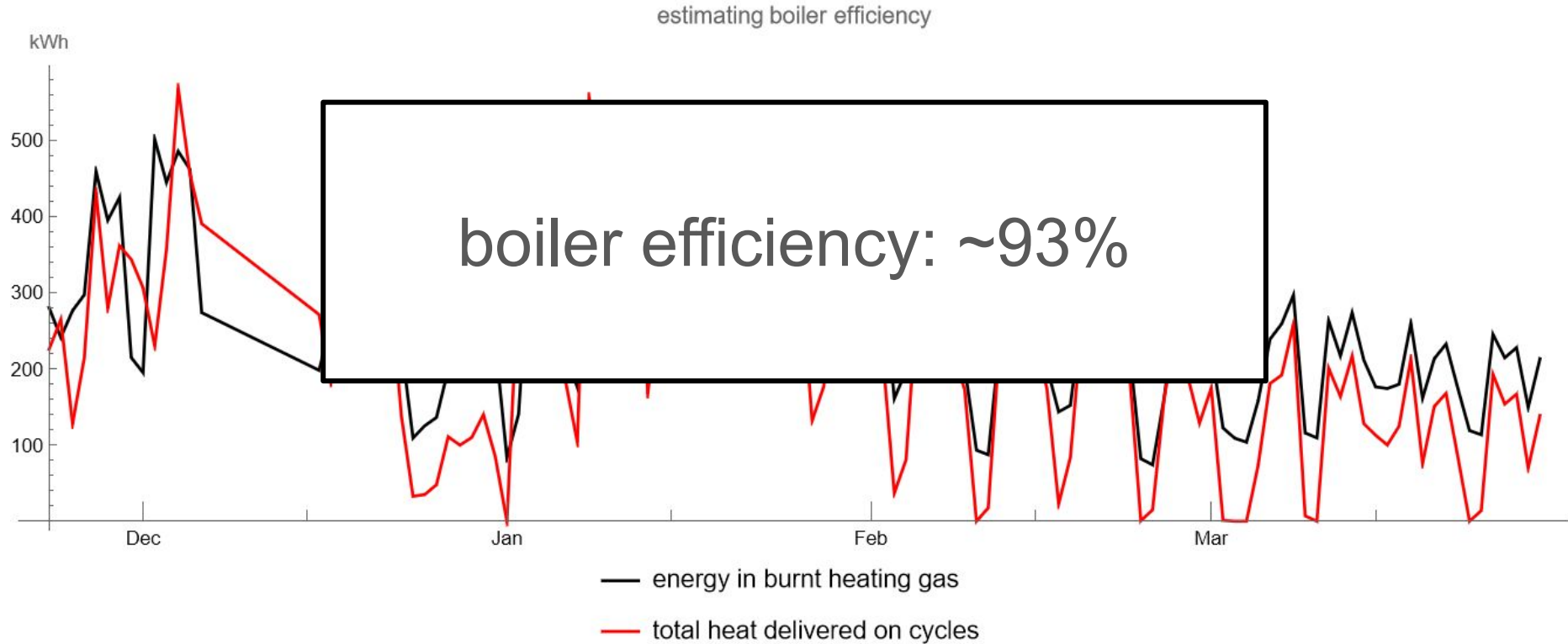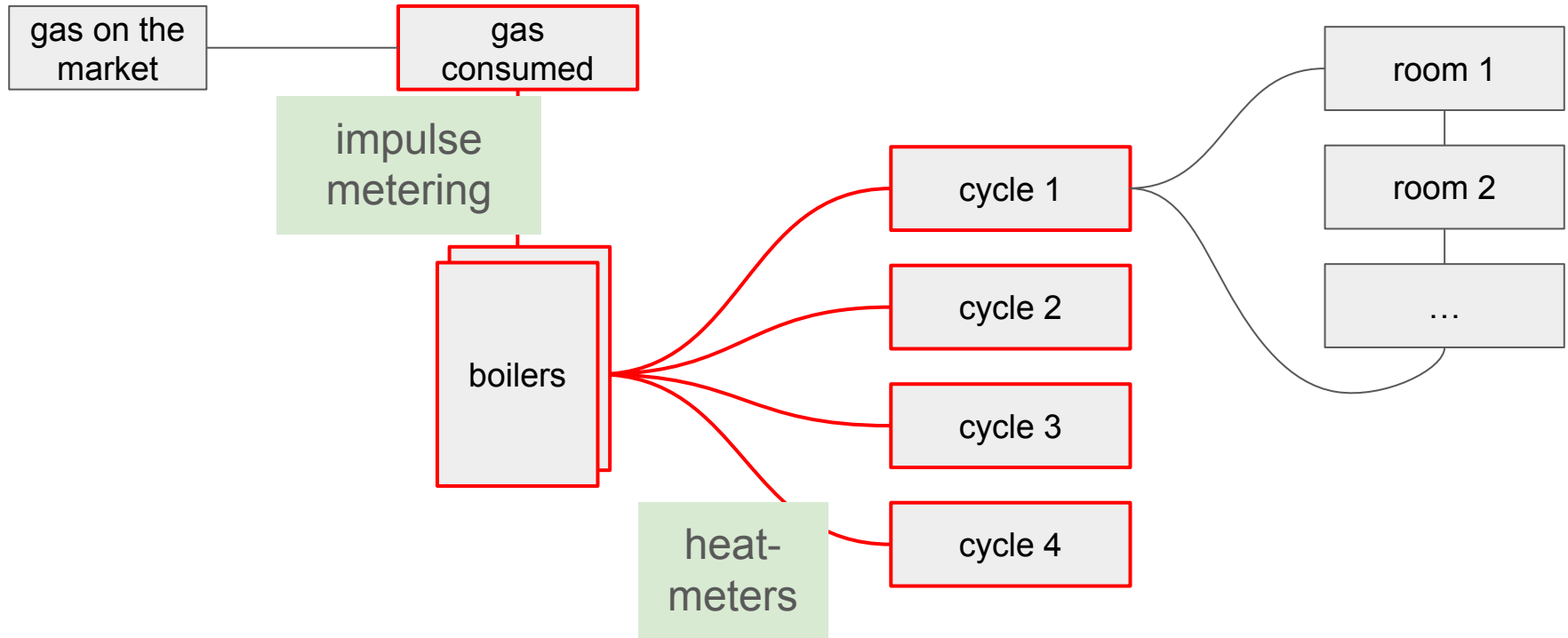
from <u>burnt gas</u> to <u>heat delivered on cycles</u>

3) relative weight of cycles

heat delivery by cycle during season

3) relative weight of cycles

heat delivery by cycle during season

heating shut down during holidays on Kazán side

— cycle 1   — cycle 2   — cycle 3   — cycle 4

3) relative weight of cycles

heat delivery by cycle during season

daily weight assigned to each cycle during whole season
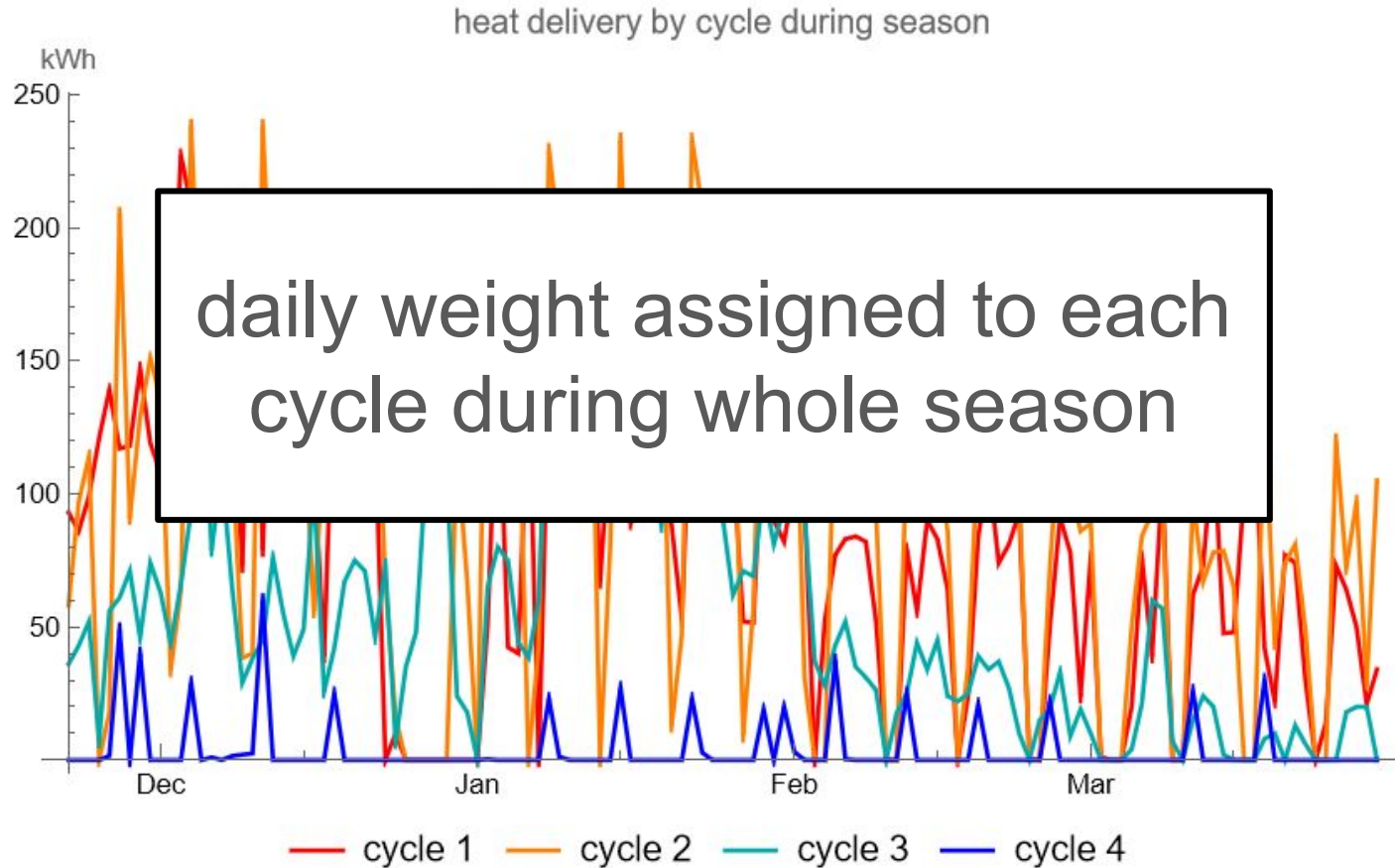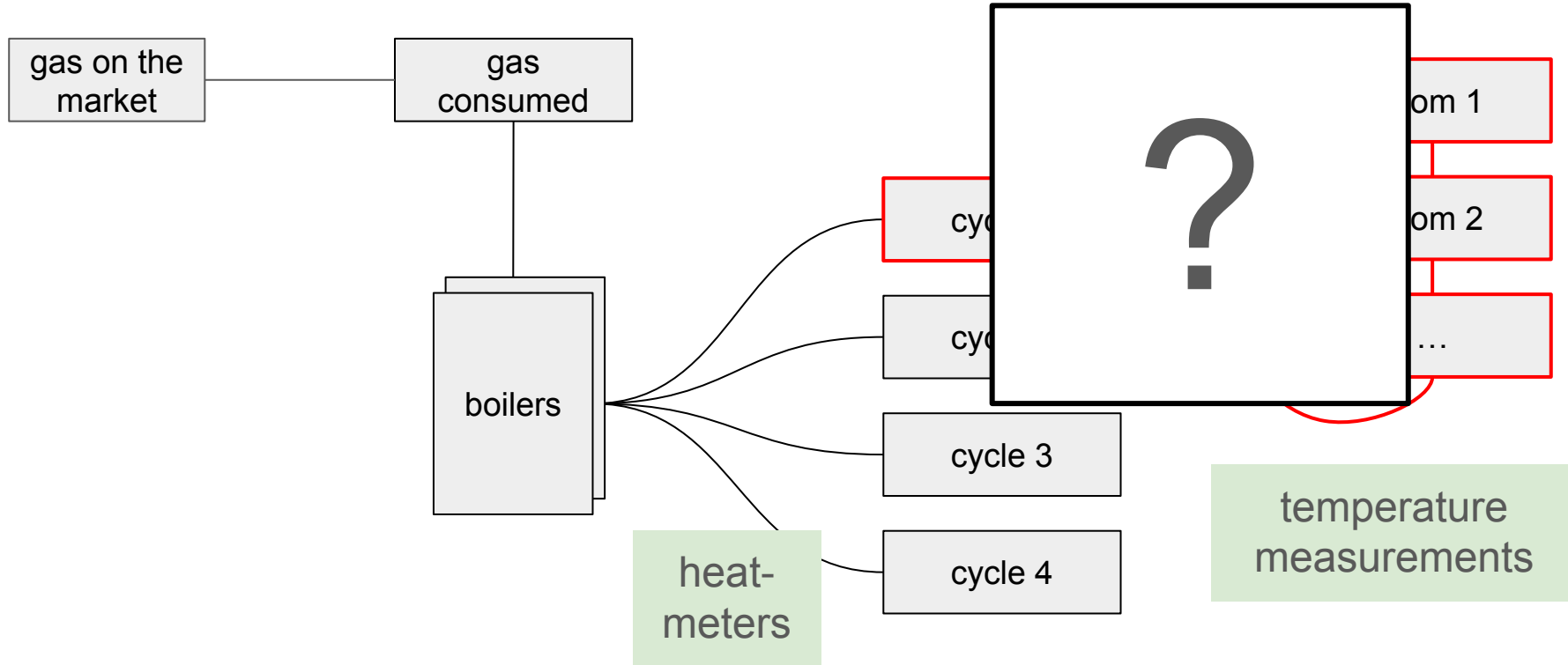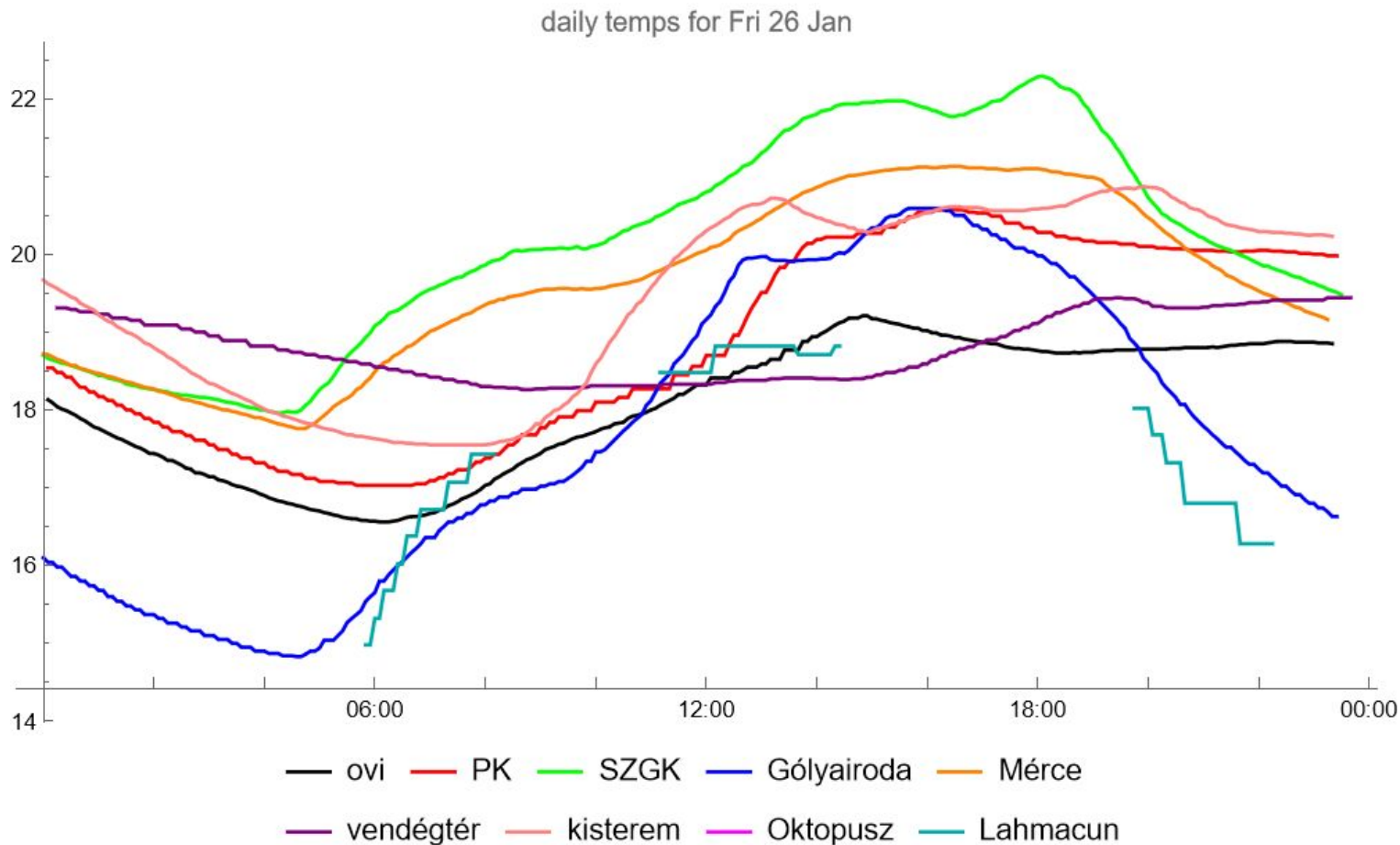
from <u>heat delivered on cycles</u> to <u>heat taken up by rooms</u>
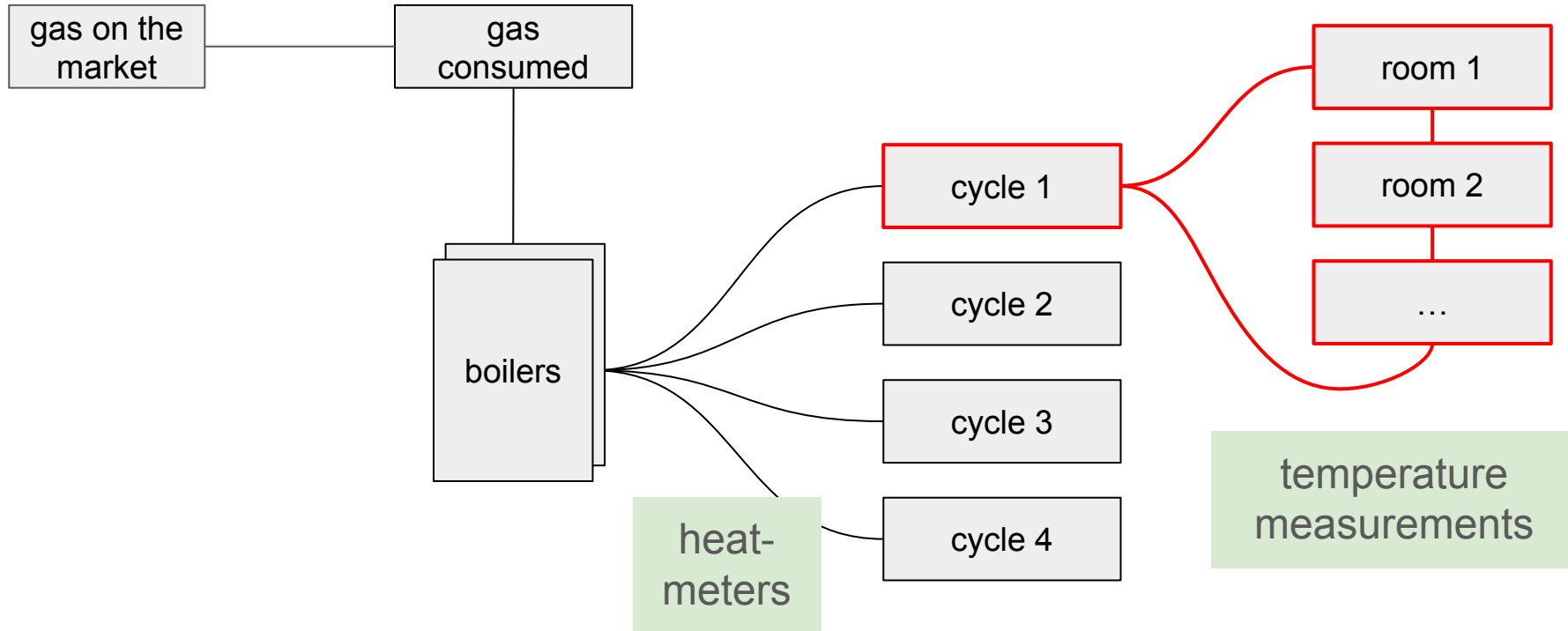
from <u>heat delivered on cycles</u> to <u>heat taken up by rooms</u>

4) evaluation of rooms based on cooling and warming data

daily temps for Fri 26 Jan

Legend: ovi, PK, SZGK, Gólyairoda, Mérce, vendégtér, kisterem, Oktopusz, Lahmacun

4) evaluation of rooms based on cooling and warming data
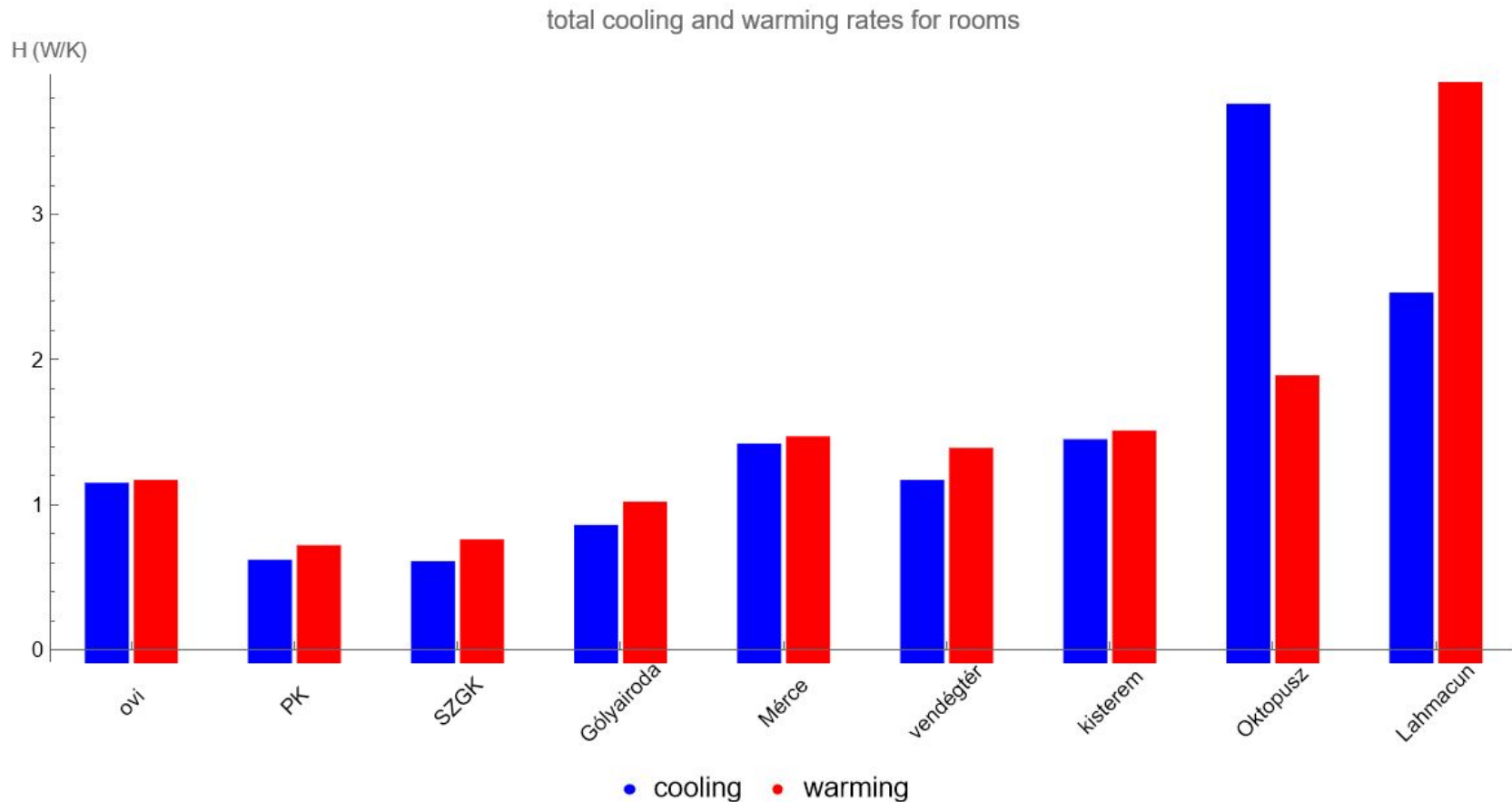
daily temps for Fri 26 Jan

take cooling periods &
model heat dynamics with:

$$(T_{\text{ext}} - T_{\text{room}}) \cdot U_{\text{env}} = \rho_{\text{air}} \cdot c_{p_{\text{air}}} \cdot V_{\text{room}} \cdot \left(\frac{\Delta T_{\text{room}}}{\Delta t} \right)$$

— vendégtér — kisterem — Oktopusz — Lahmacun

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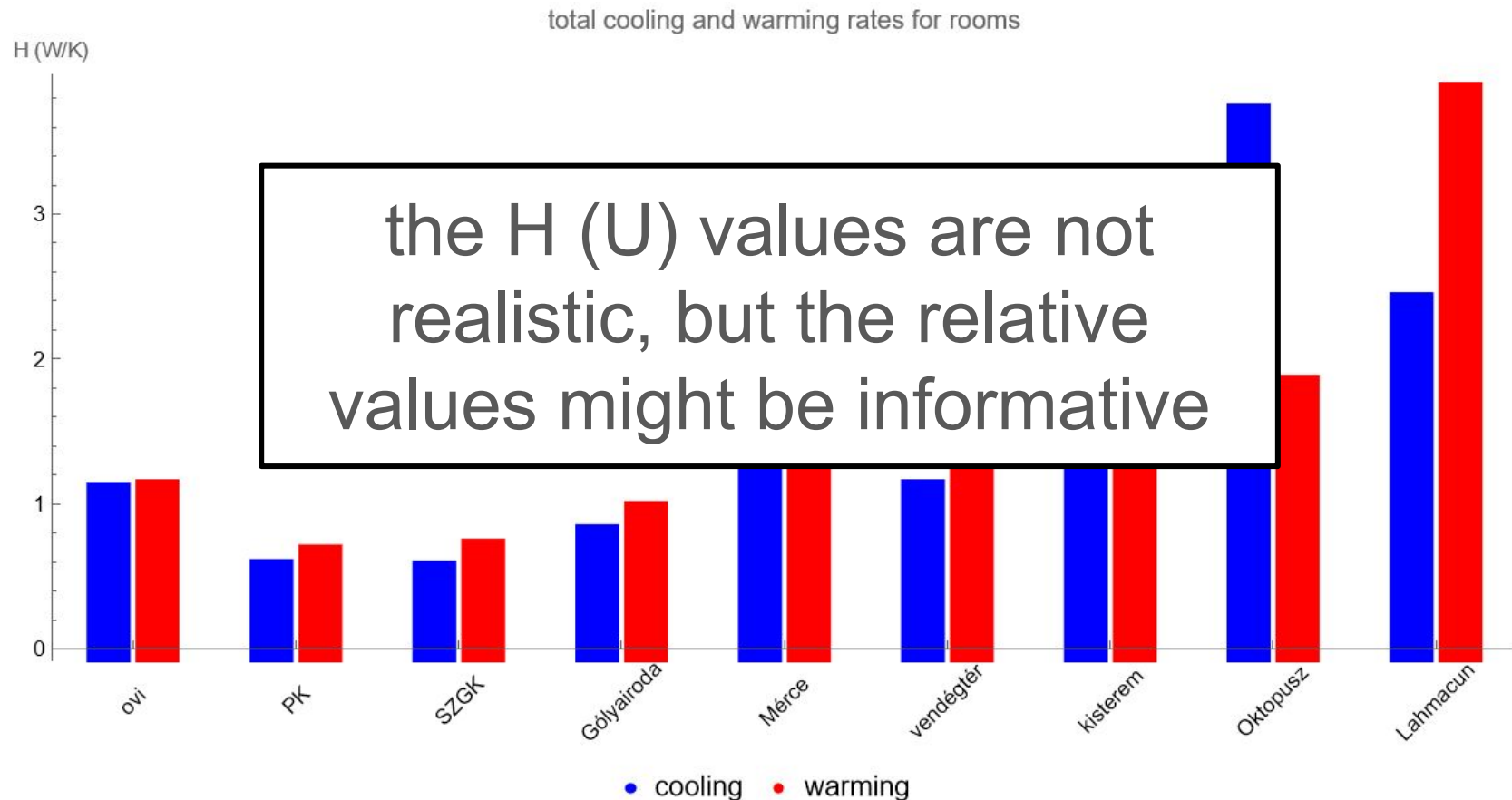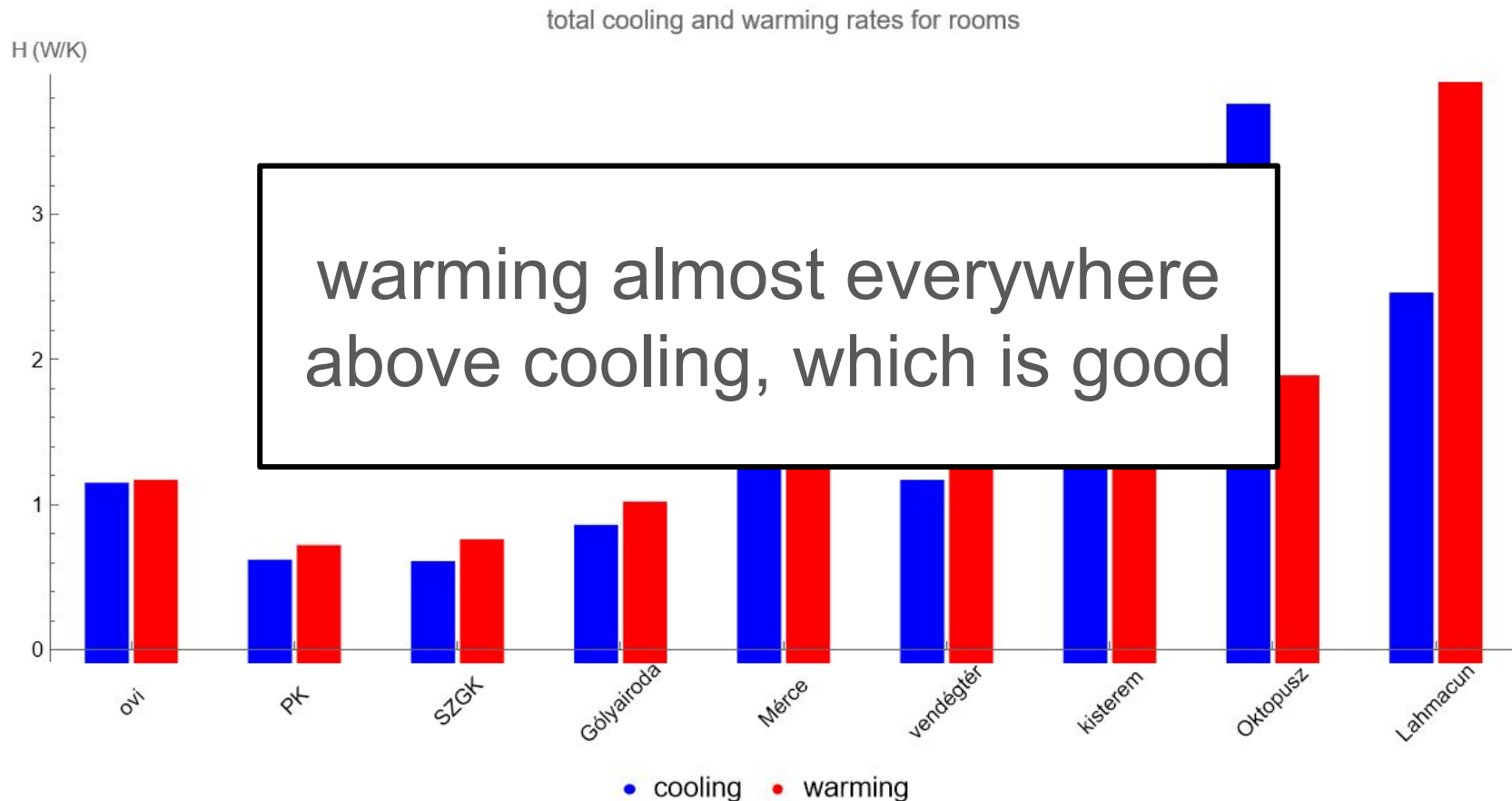
then take warming periods
and add heater:

$$(T_{\text{ext}} - T_{\text{room}}) \cdot U_{\text{env}} + (T_{\text{heater}} - T_{\text{room}}) \cdot \boxed{U_{\text{heater}}} = \rho_{\text{air}} \cdot c_{p_{\text{air}}} \cdot V_{\text{room}} \cdot \left(\frac{\Delta T_{\text{room}}}{\Delta t} \right)$$

—— vendégtér —— kisterem —— Oktopusz —— Lahmacun

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

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total cooling and warming rates for rooms

the H (U) values are not realistic, but the relative values might be informative

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

warming almost everywhere above cooling, which is good

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

but:

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

and

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

room was impossible to drive above 18 °C
→ first room we've insulated since
(and found a hole on the wall)

H (W/K)

ovi   PK   SZGK   Gólyairoda   Mérce   vendégtér   kisterem   Oktopusz   Lahmacun

• cooling   • warming

4) evaluation of rooms based on cooling and warming data

total cooling and warming rates for rooms

thermometer was placed
directly above the radiator

but also quite significant
cooling → another hole
on the wall

H (W/K)

• cooling • warming

ovi, PK, SZGK, Gólyairoda, Mérce, vendégtér, kisterem, Oktopusz, Lahmacun

4) evaluation of rooms based on cooling and warming data: thermal conductivity of envelope and insulation state

cooling of rooms per unit of external wall area

4) evaluation of rooms based on cooling and warming data: thermal conductivity of envelope and insulation state

insulatedness of rooms

4) evaluation of rooms based on cooling and warming data: warming sources

warming of rooms per unit of radiator area

4) evaluation of rooms based on cooling and warming data: warming sources

warming of rooms per unit of radiator area

"U" (W/m²K)

space heater usage

4) evaluation of rooms based on cooling and warming data: warming sources

warming of rooms per unit of radiator area

"U" (W/m²K)

misplaced thermometer

4) evaluation of rooms based on cooling and warming data: warming sources

warming of rooms per unit of radiator area

"U" (W/m²K)

people-heated

4) evaluation of rooms based on cooling and warming data: warming sources

warming of rooms per unit of radiator area

radiators

from <u>heat delivered on cycles</u> to <u>heat taken up by rooms</u>

gas on the market

gas consumed

boilers

cycle

cycle

cycle 3

cycle 4

heat-meters

?

om 1

om 2

...

temperature measurements

from <u>heat delivered on cycles</u> to <u>heat taken up by rooms</u>
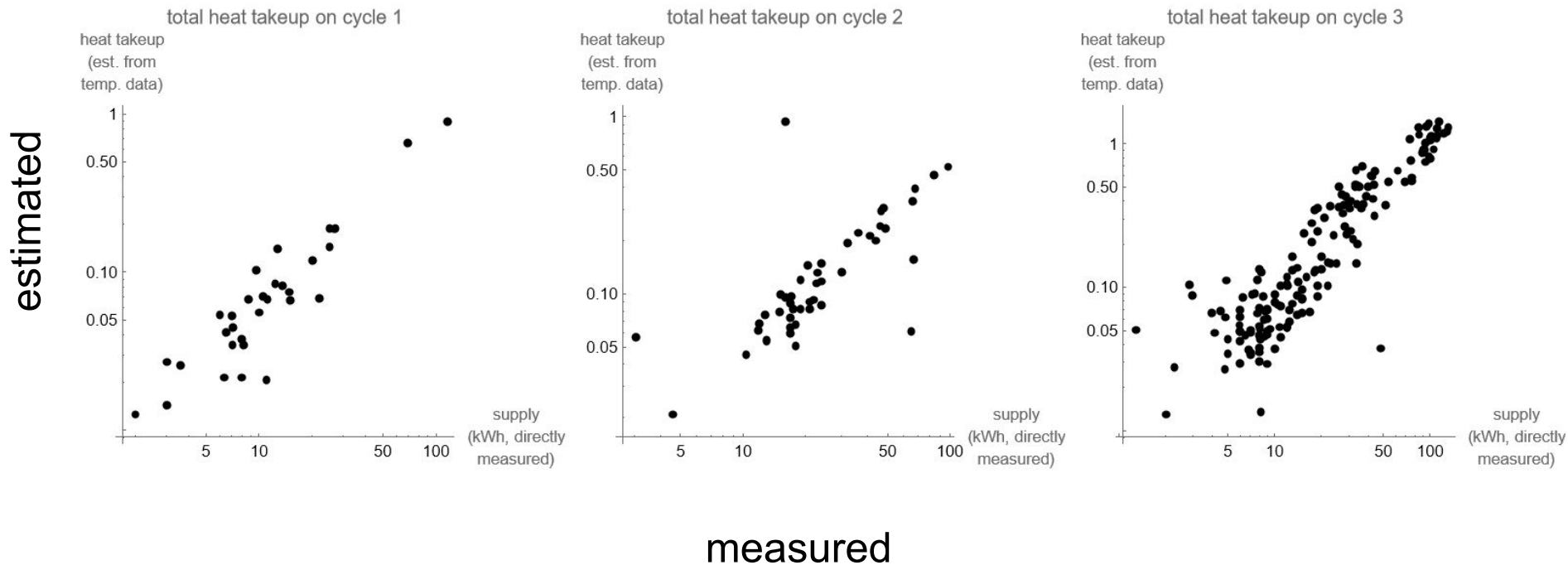
5) bridging the gap between heat per cycle to heat per room

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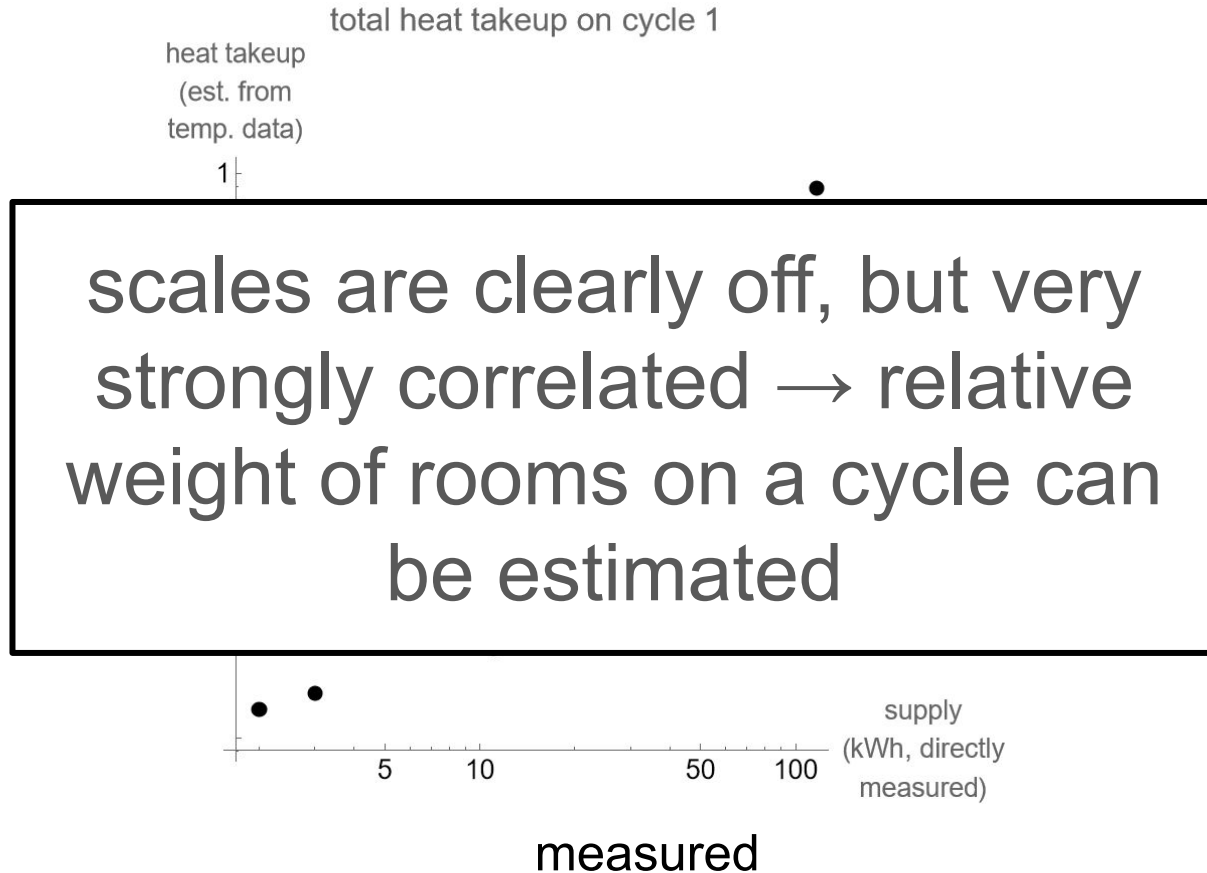
total heat takeup on cycle 1

heat takeup
(est. from
temp. data)

estimated

supply
(kWh, directly
measured)

measured

5) bridging the gap between heat per cycle to heat per room

total heat takeup on cycle 1

heat takeup
(est. from
temp. data)

1

•

scales are clearly off, but very strongly correlated → relative weight of rooms on a cycle can be estimated

•   •

| 5 | 10 | | 50 | 100 |

supply
(kWh, directly
measured)

measured
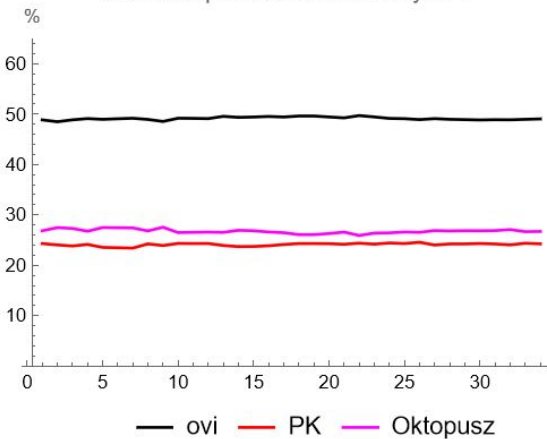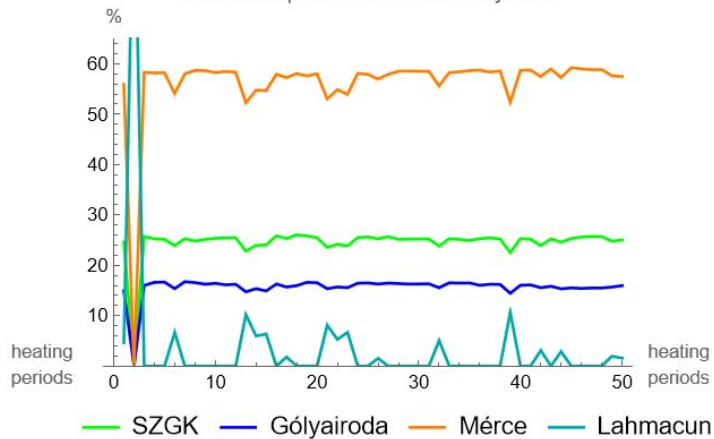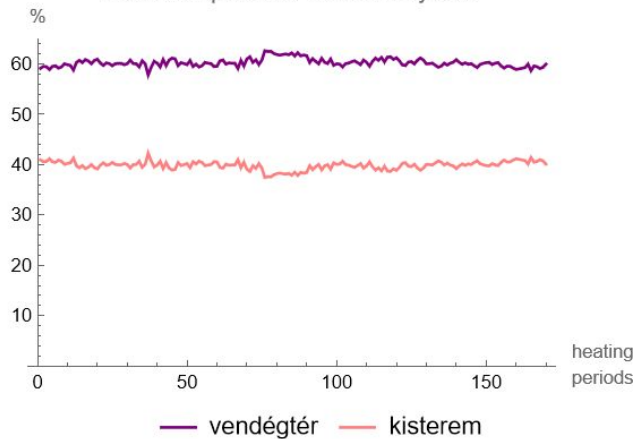
5) bridging the gap between heat per cycle to heat per room

estimated heat takeup of each room on a cycle
for selected heating periods based on temp. change

5) bridging the gap between heat per cycle to heat per room

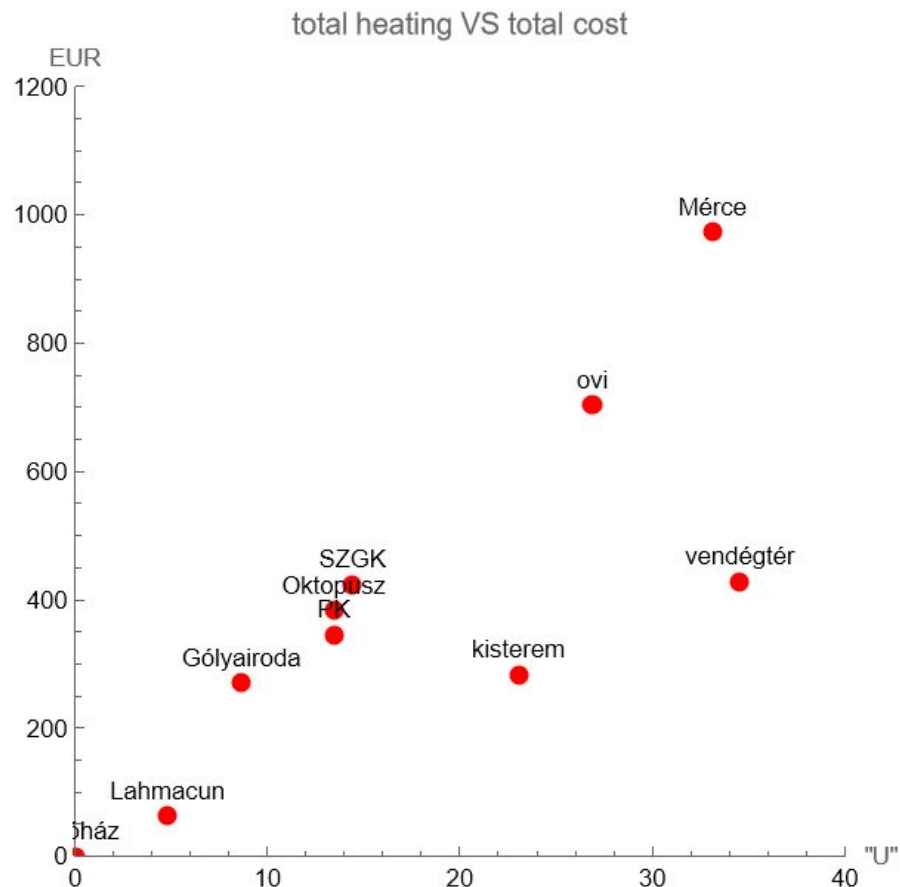estimated heat takeup of each room on a cycle
for selected heating periods based on temp. change

combine with relative weight of
cycles → relative room weights
can be estimated

5) bridging the gap between heat per cycle to heat per room

heating ratio of rooms
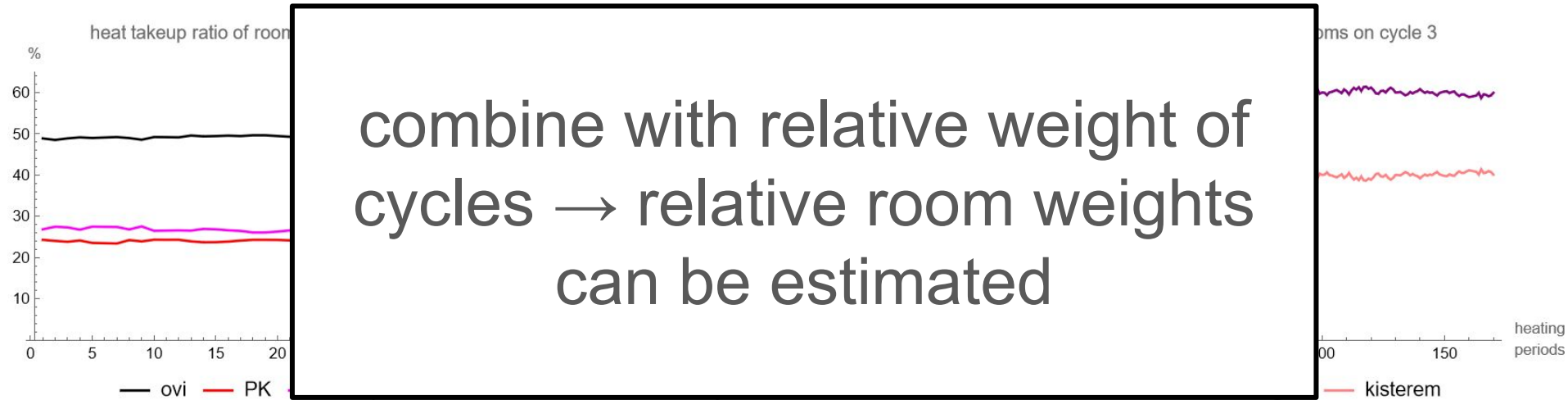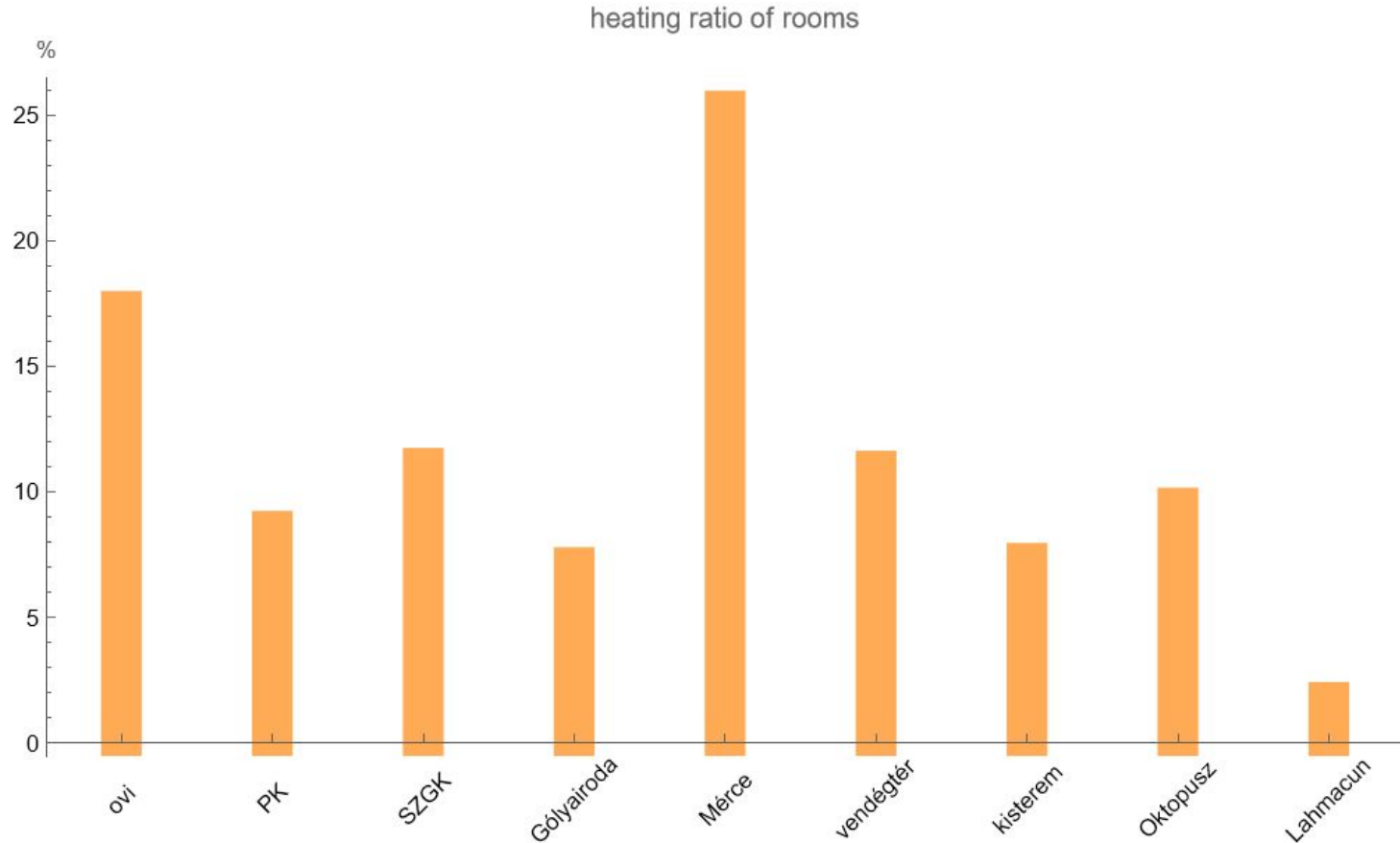
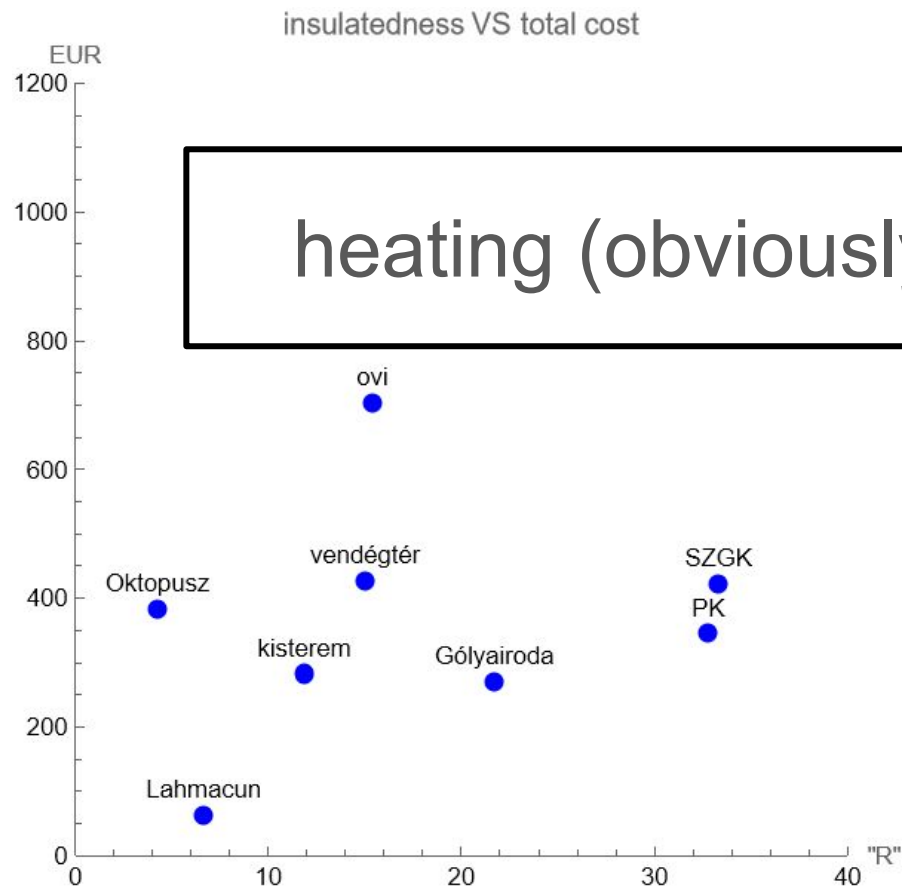# finally: cost per room
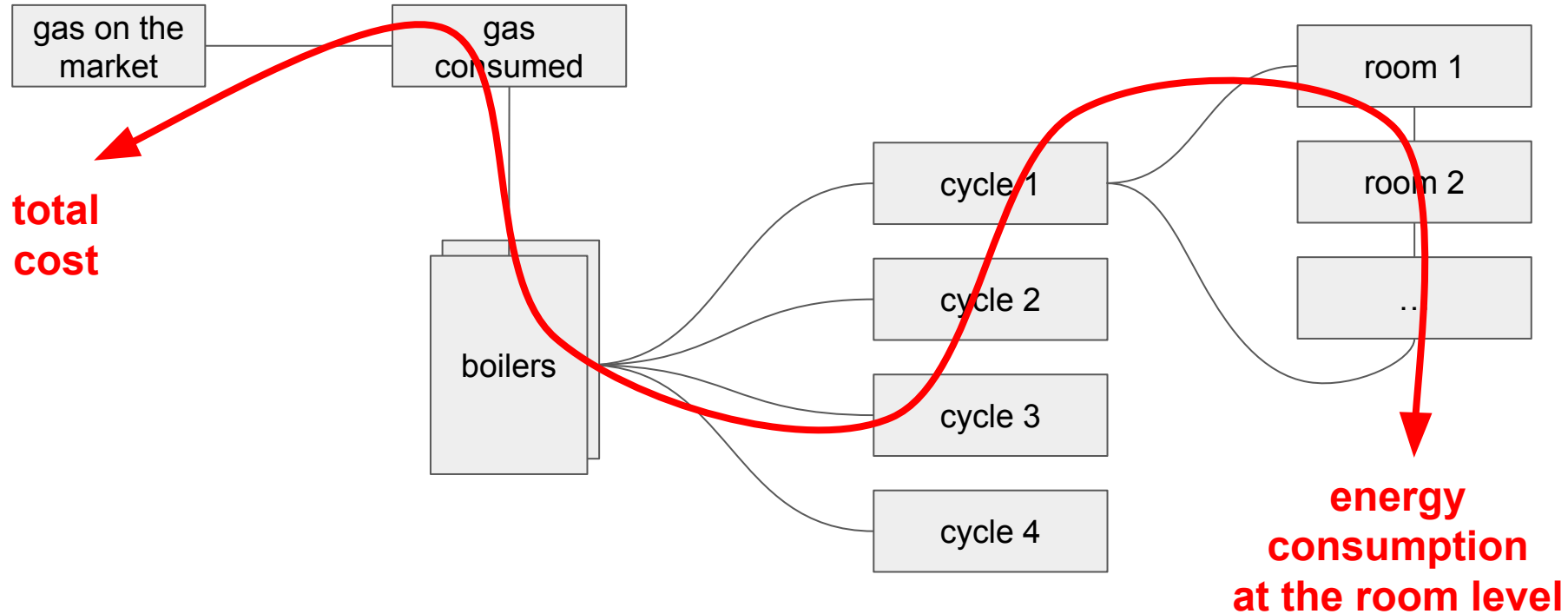
6) how much did it cost to heat each room?
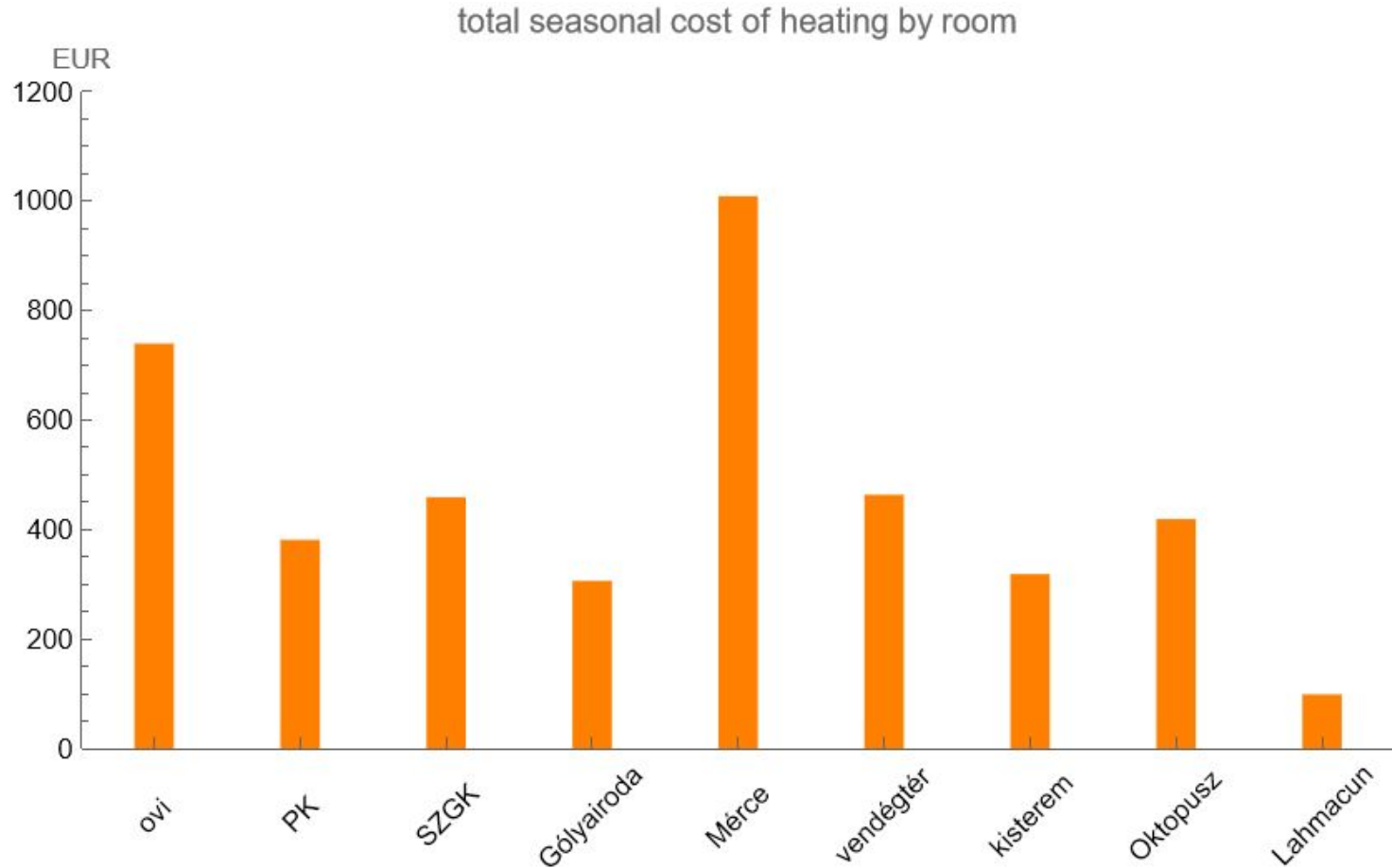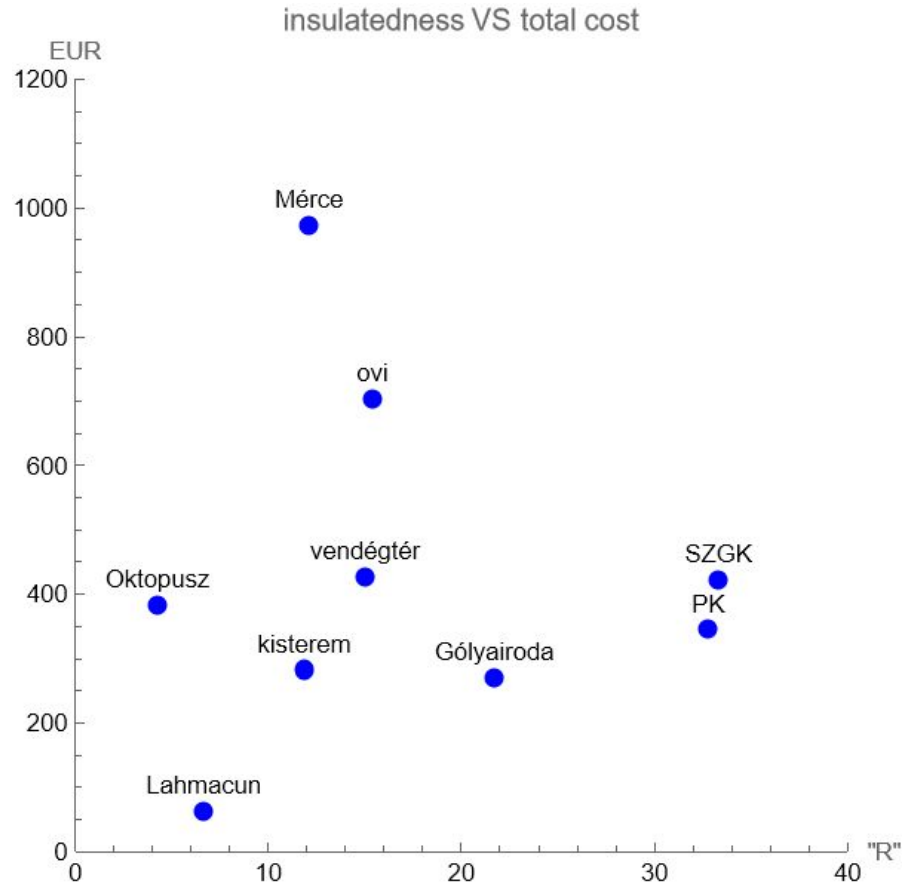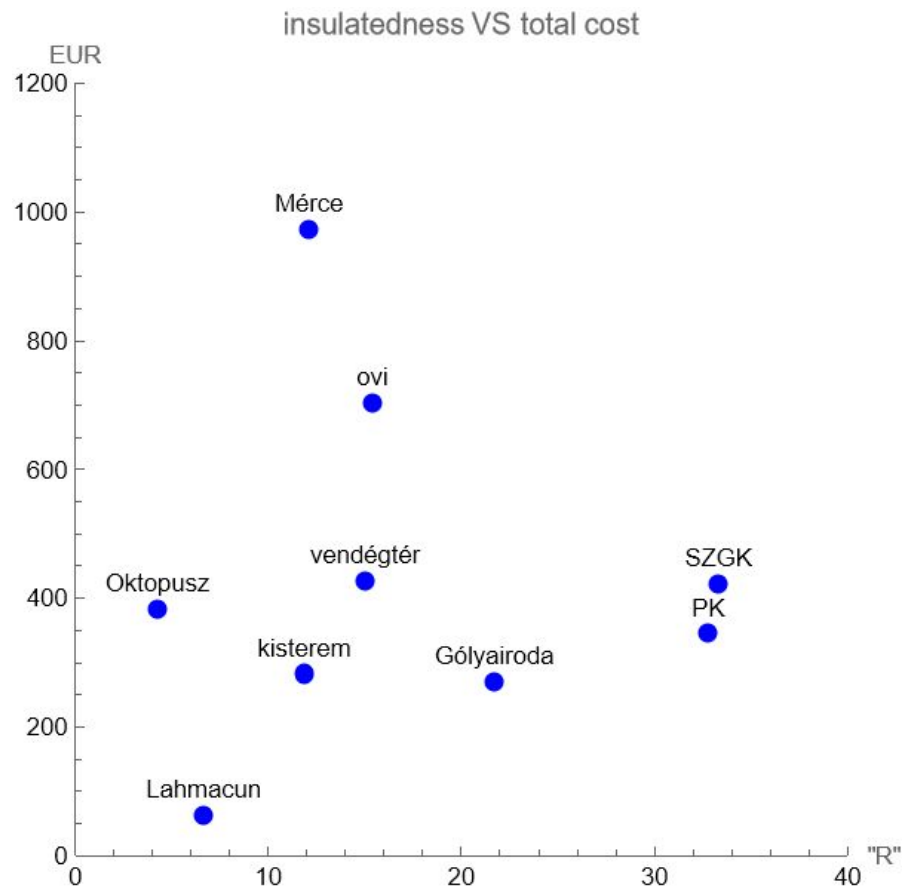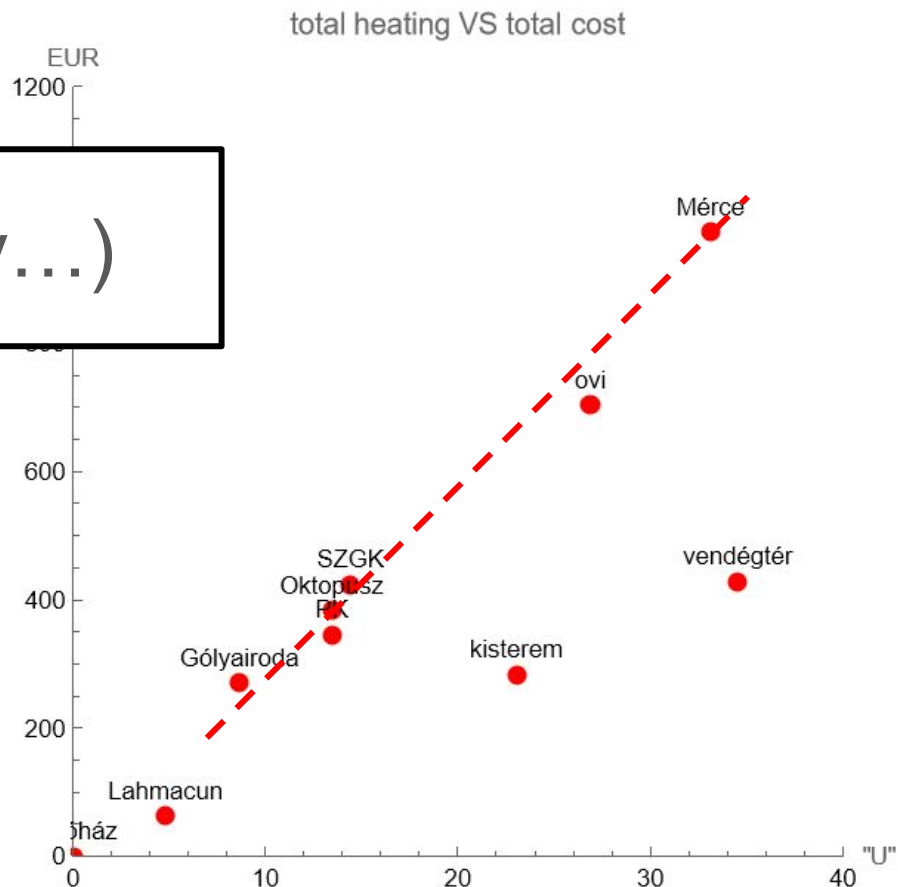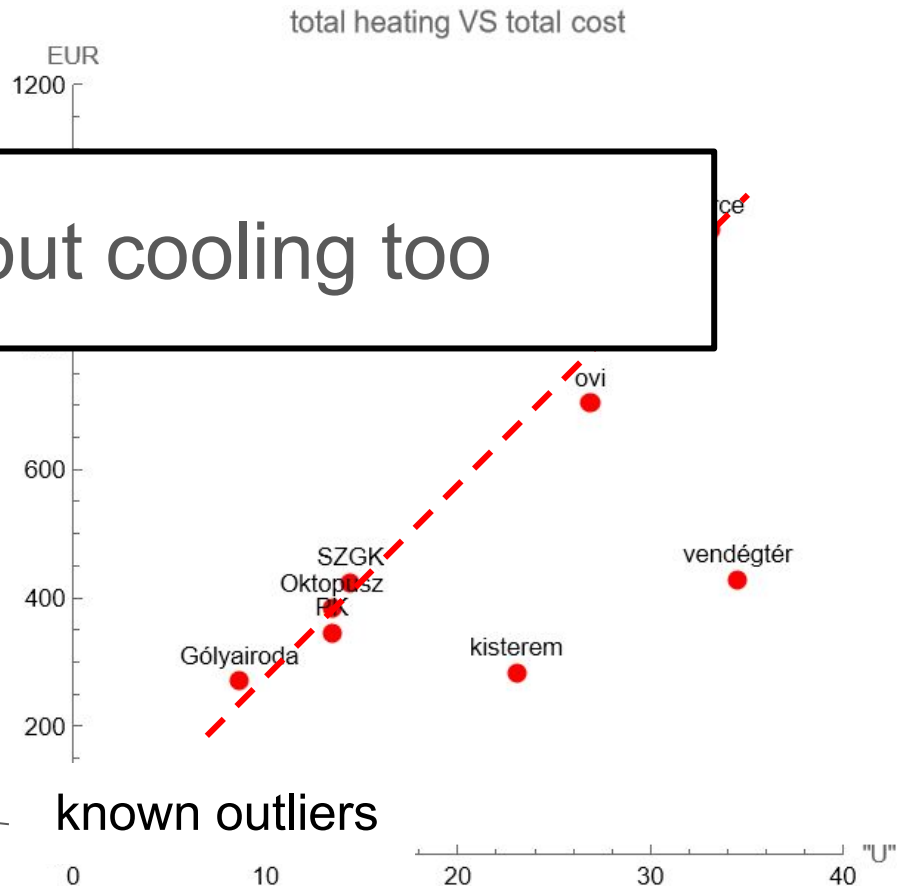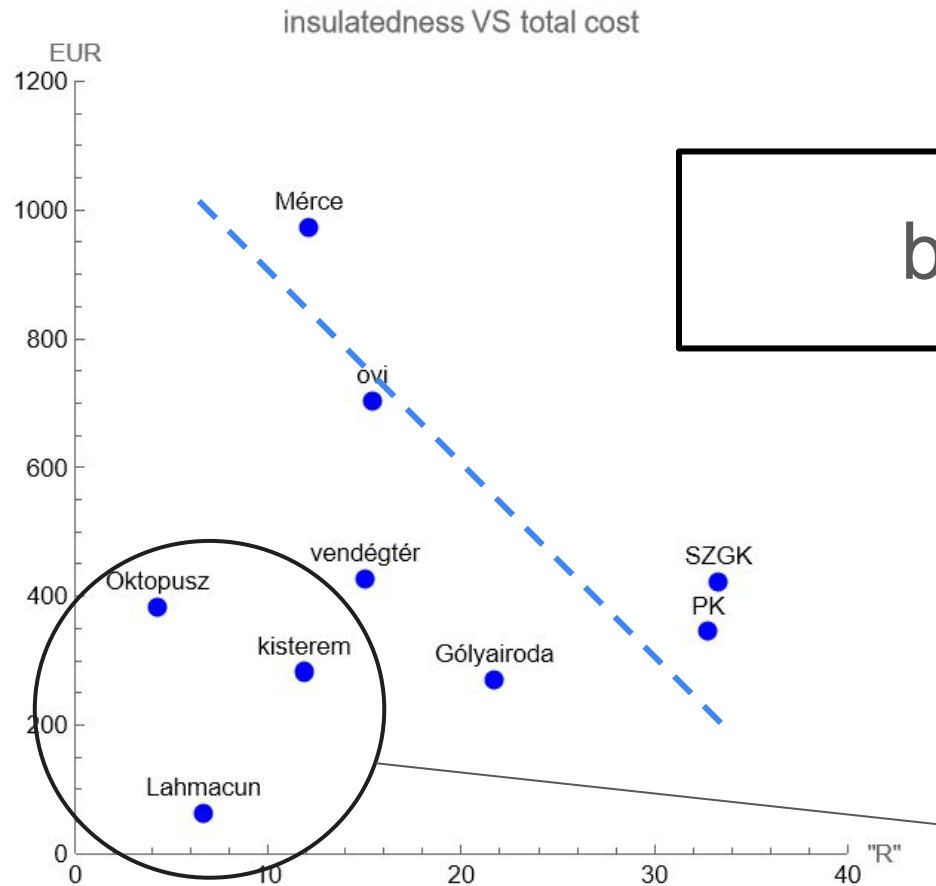

total seasonal cost of heating by room

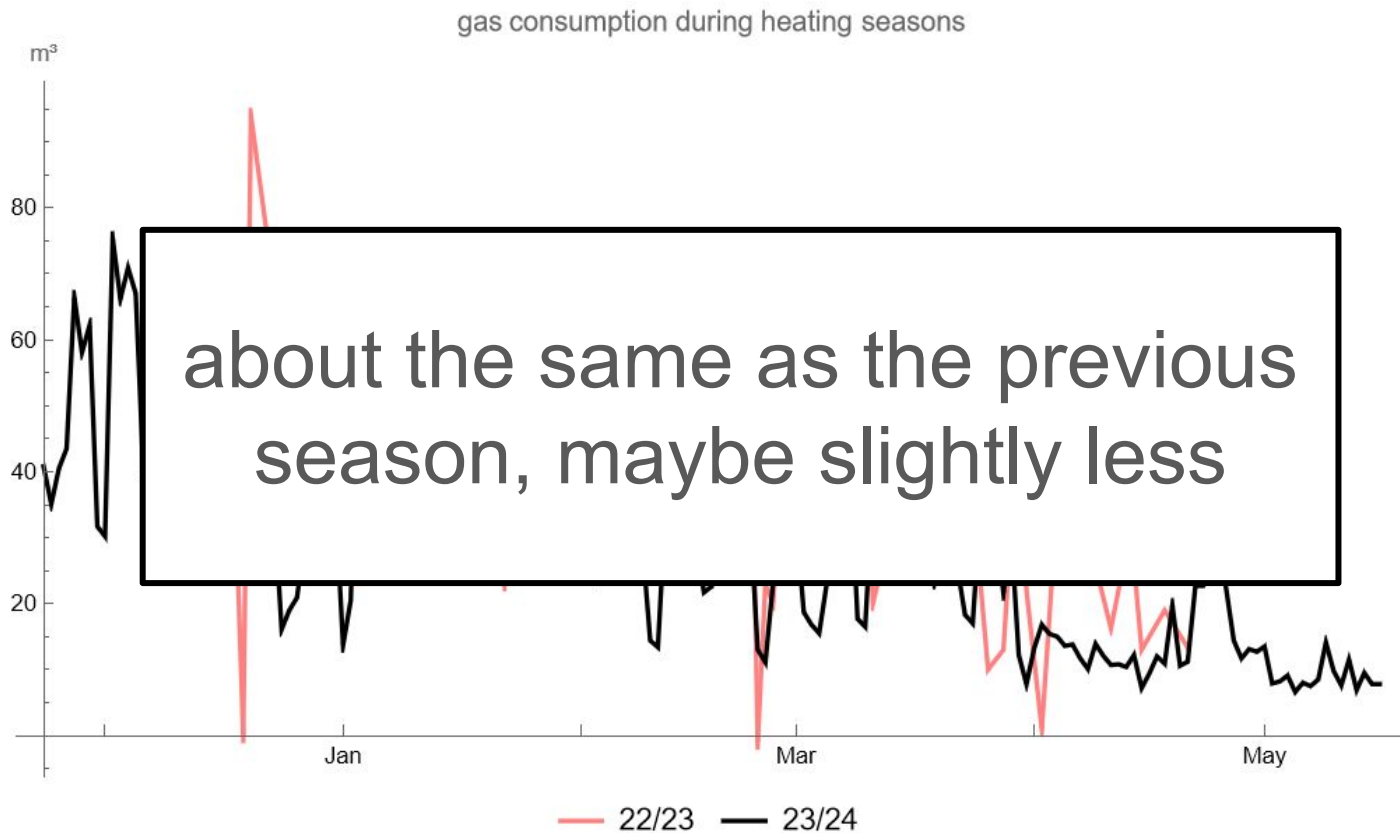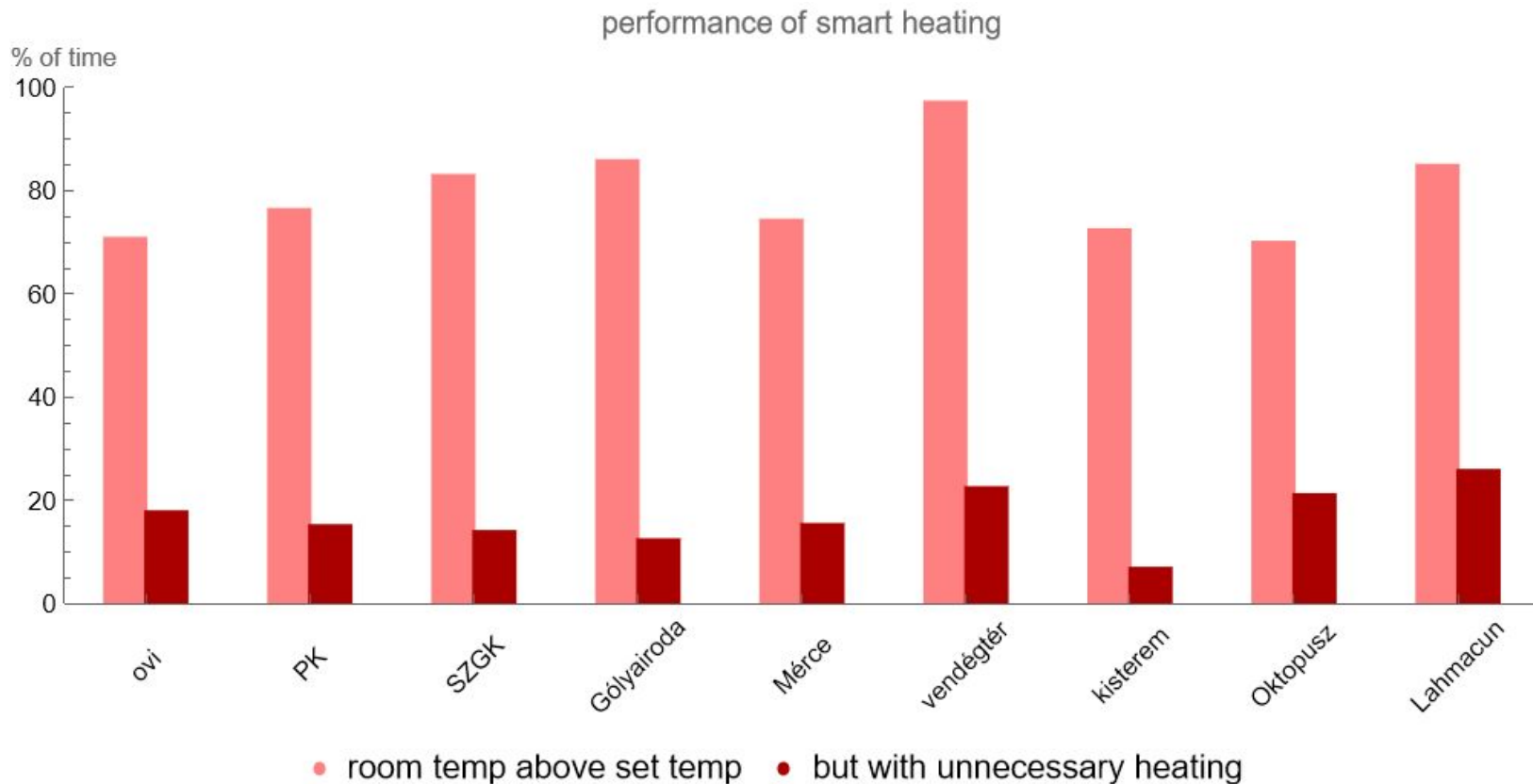# 7) what drives cost?

7) what drives cost?

7) what drives cost?

insulatedness VS total cost

total heating VS total cost

heating (obviously…)

7) what drives cost?

insulatedness VS total cost

EUR

total heating VS total cost

EUR

but cooling too

known outliers

how did the smart heating perform? -- gas consumption

gas consumption during heating seasons

how did the smart heating perform? -- gas consumption

gas consumption during heating seasons

about the same as the previous season, maybe slightly less

— 22/23 — 23/24

how did the smart heating perform? -- comfort

performance of smart heating

how did the smart heating perform? -- comfort

performance of smart heating

usually good comfort level

but quite a bit of overheating

- room temp above set temp
- but with unnecessary heating

how did the smart heating perform? -- cost of cycle based switching

cost of unnecessary heating over whole season: ~480 EUR

how did the smart heating perform? -- cost of cycle based switching

cost of unnecessary heating over whole season: ~480 EUR

~ 500 EUR, about 4-5 smart radiator valves worth -- planned in the near future
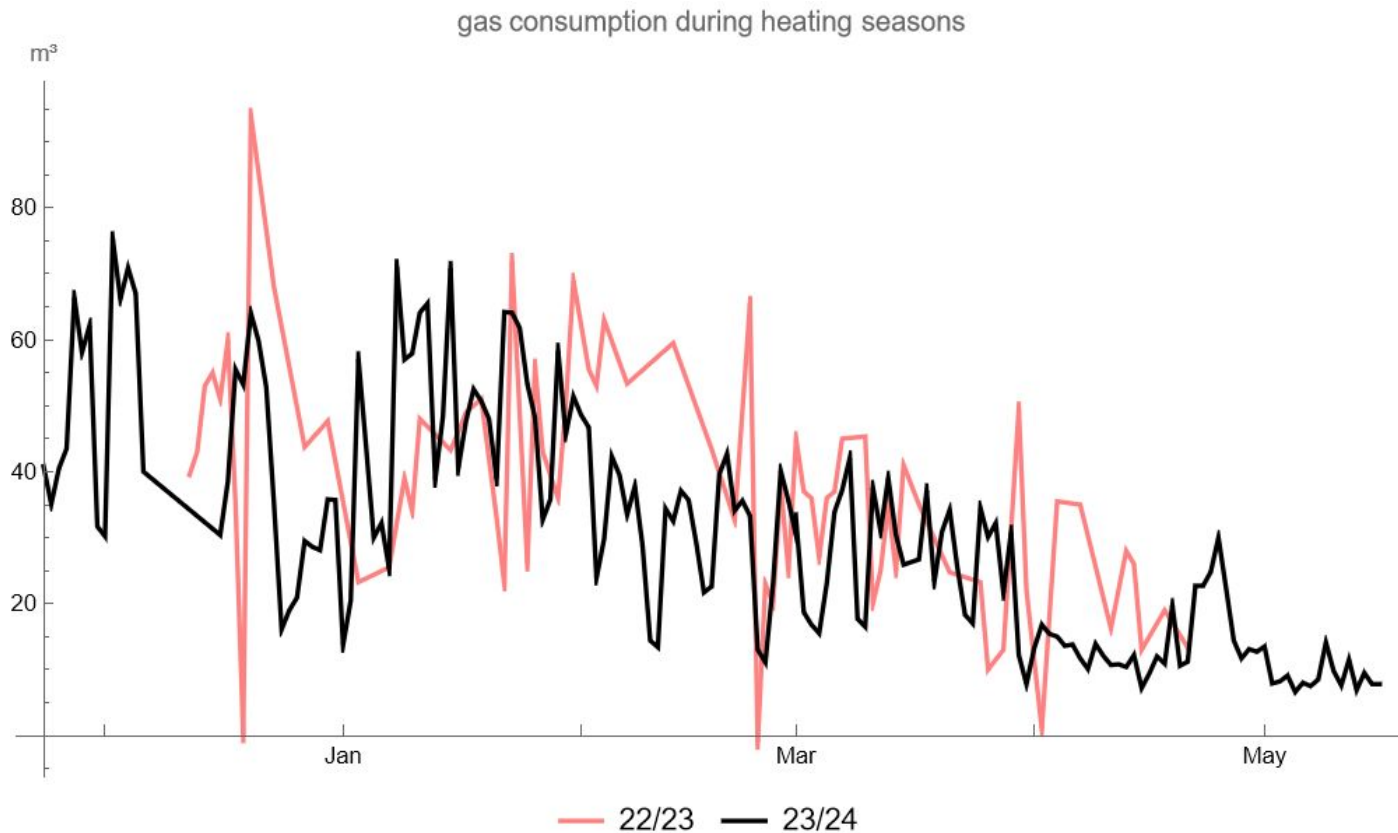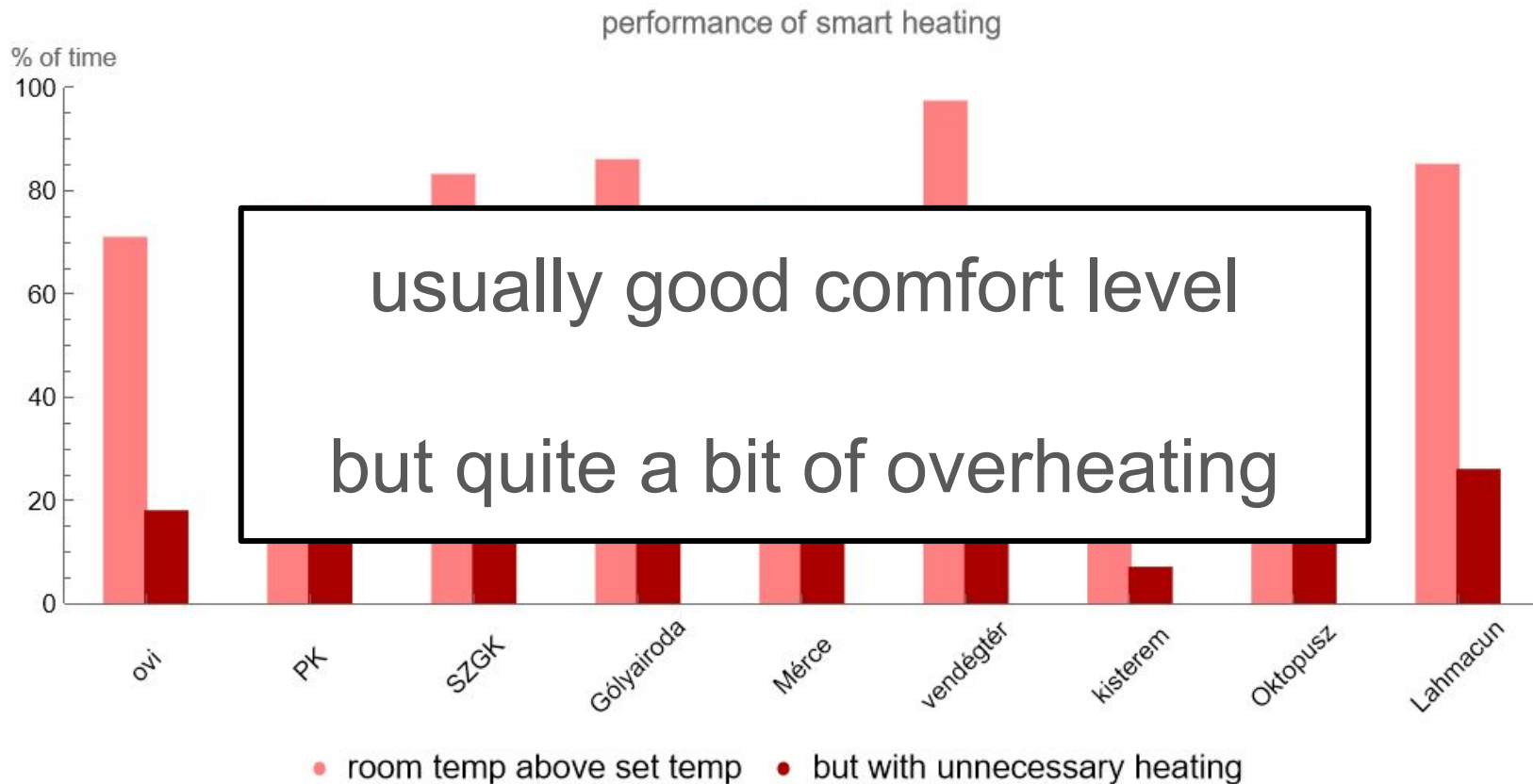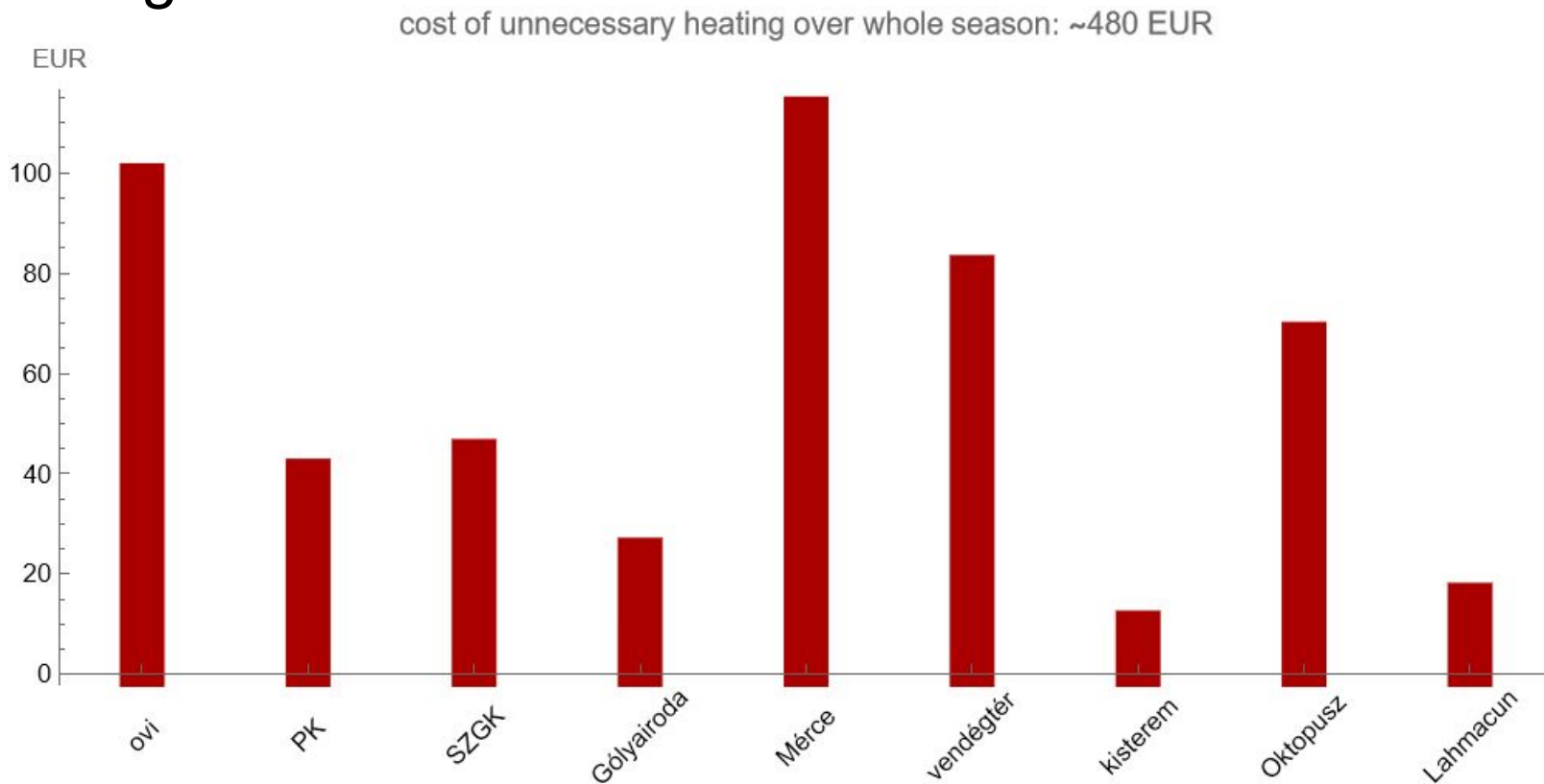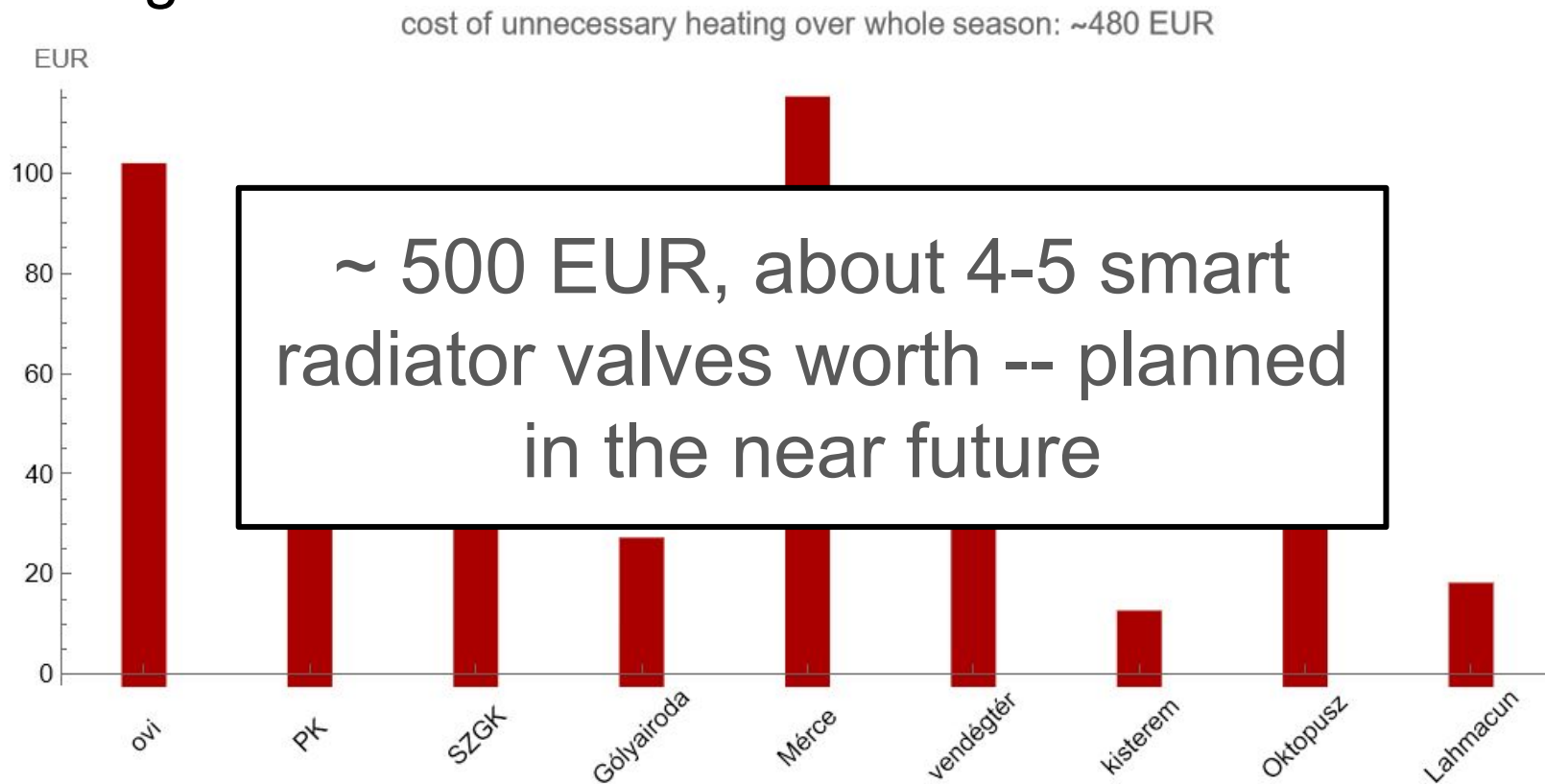
how did the smart heating perform? -- lack of comfort
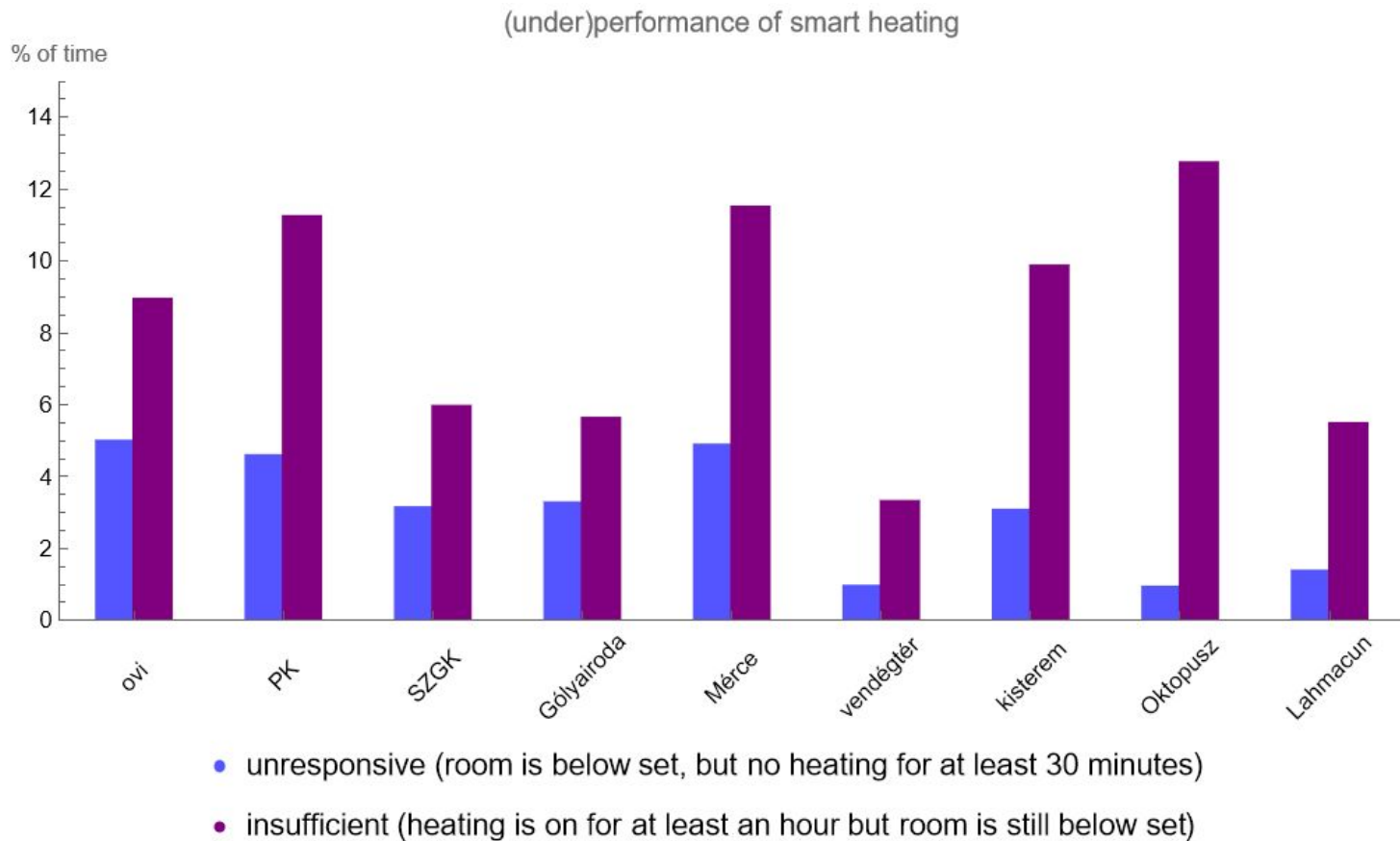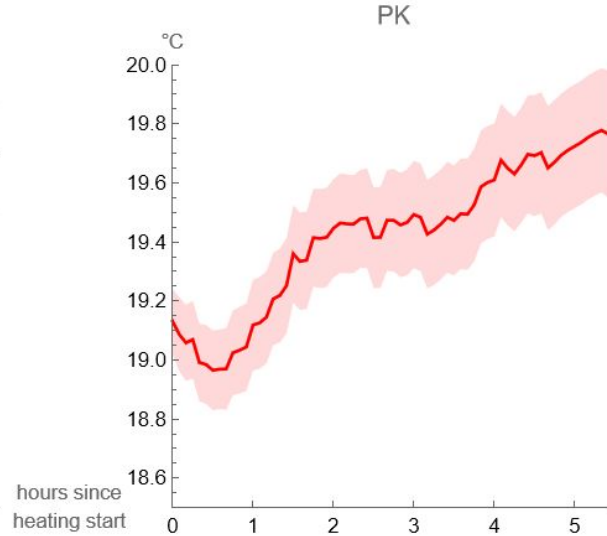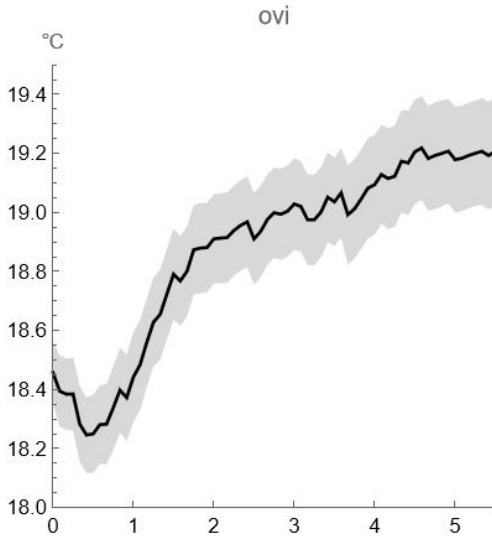
(under)performance of smart heating

% of time

- unresponsive (room is below set, but no heating for at least 30 minutes)
- insufficient (heating is on for at least an hour but room is still below set)

how did the smart heating perform? -- room response curves
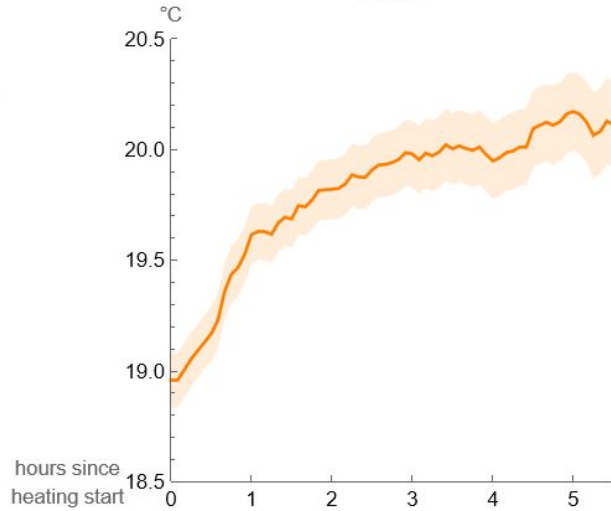
how did the smart heating perform? -- room response curves
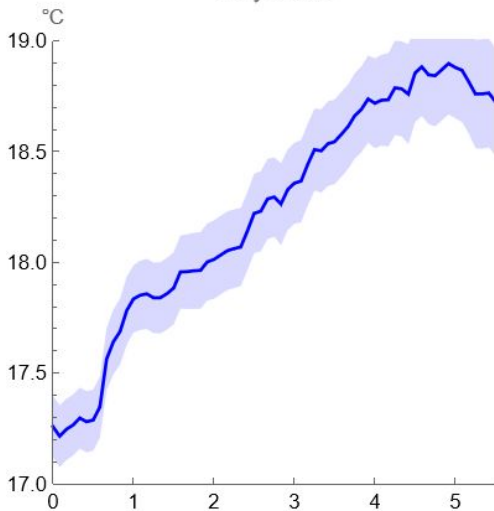
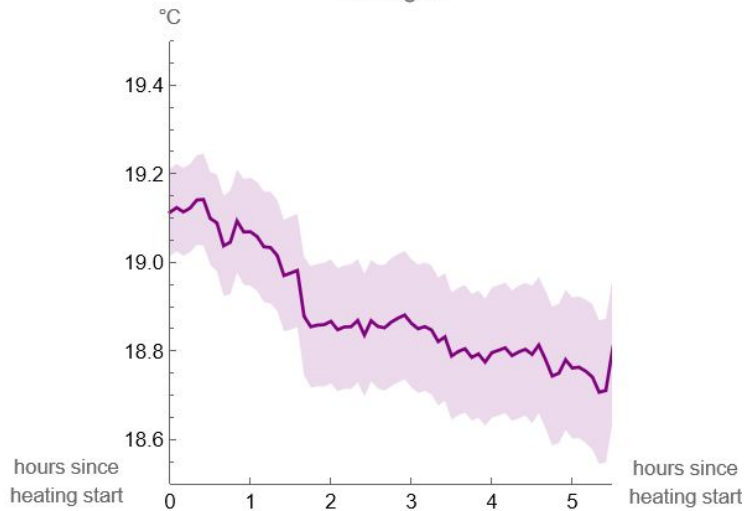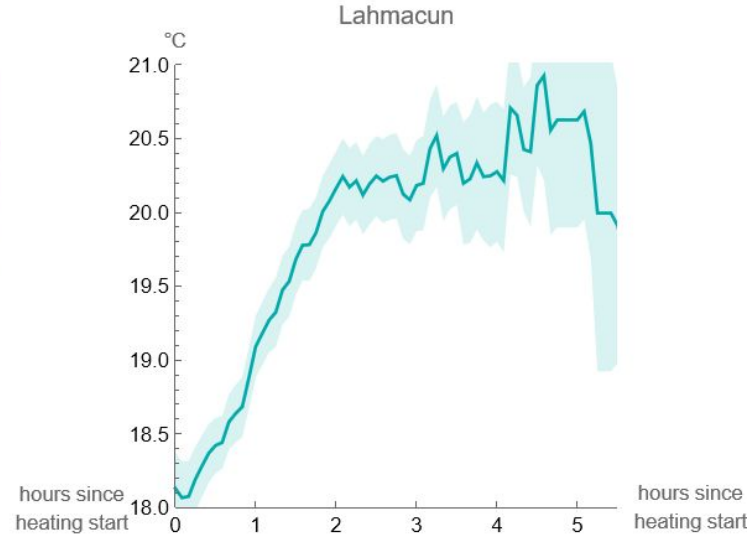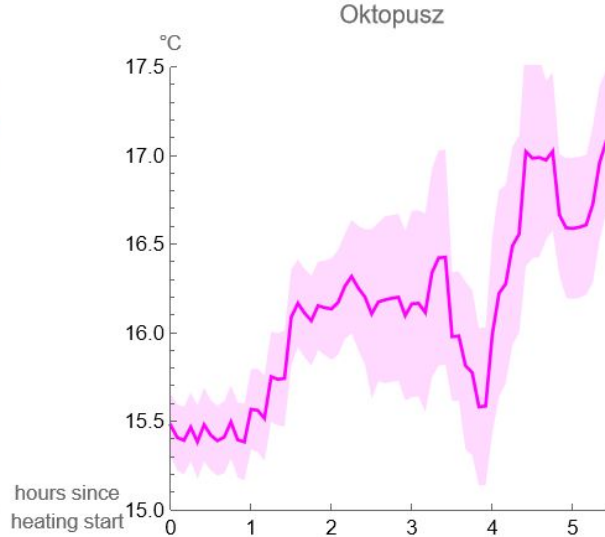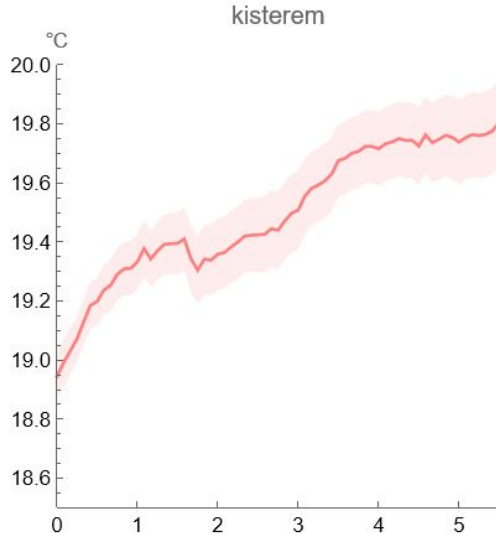# how did the smart heating perform? -- room response curves

comments & suggestions?