energy management at the Kazán Community House

Benjamin Márkus, energy coordinator of the facilities team, ACRED

overview

- community-oriented:
    1) broad-based decision making
    2) long term stability instead of profit maximization
- 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)

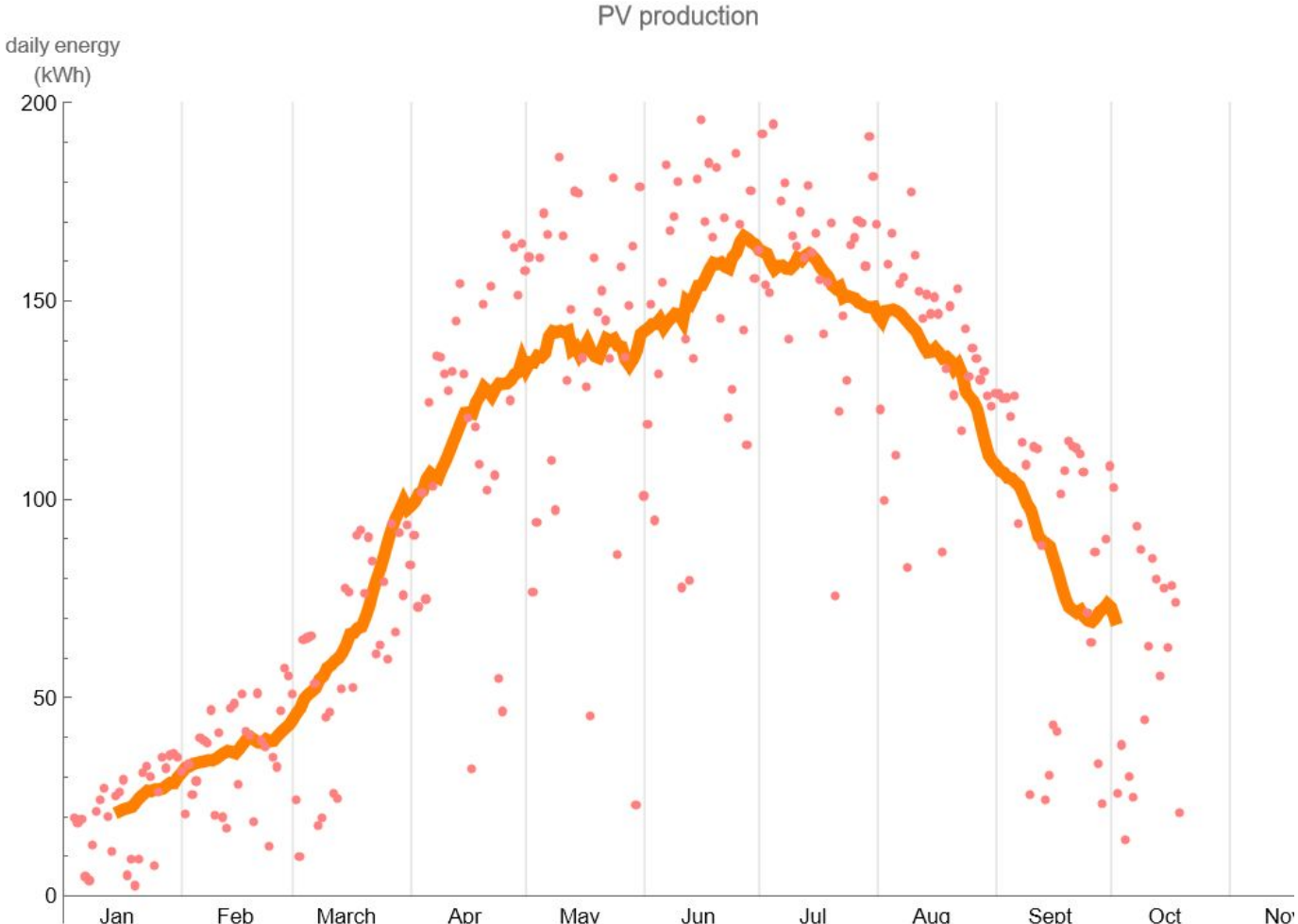
since then:
1) stalled PV installation pushed to finish line, in operation since Jan with a dedicated energy improvement fund founded on the savings
2) smart heating system developed in house with comprehensive data gathering and evaluation
3) localized improvements of insulation at points deemed the 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



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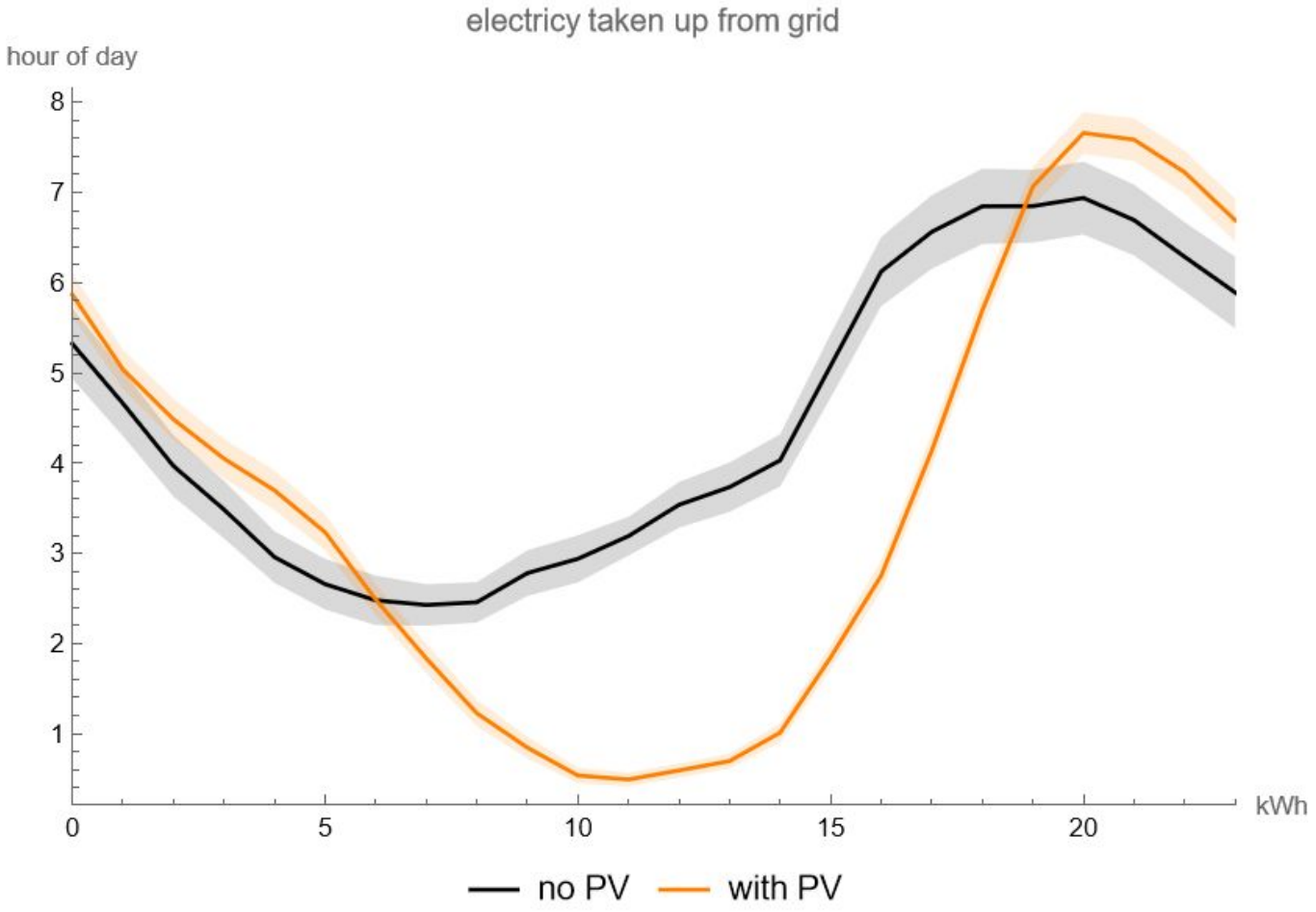


PV system: the first 10 months of operation

- 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)

  (already spent on insulation)

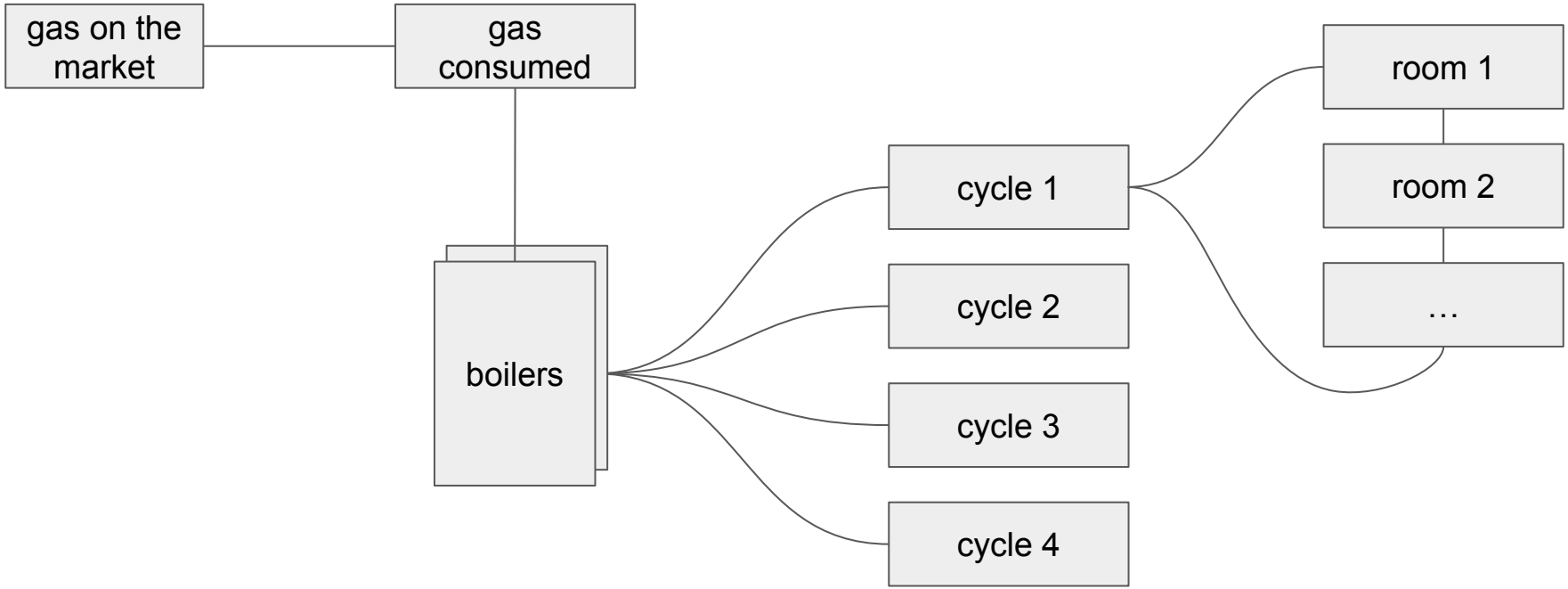
heating: smartified gas-fired central heating

- 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 (snapshot from last year)
  - intensive data gathering at each stage: gas, heating energy, heating state, temperatures
- but only the cycles can be switched → overheating of rooms

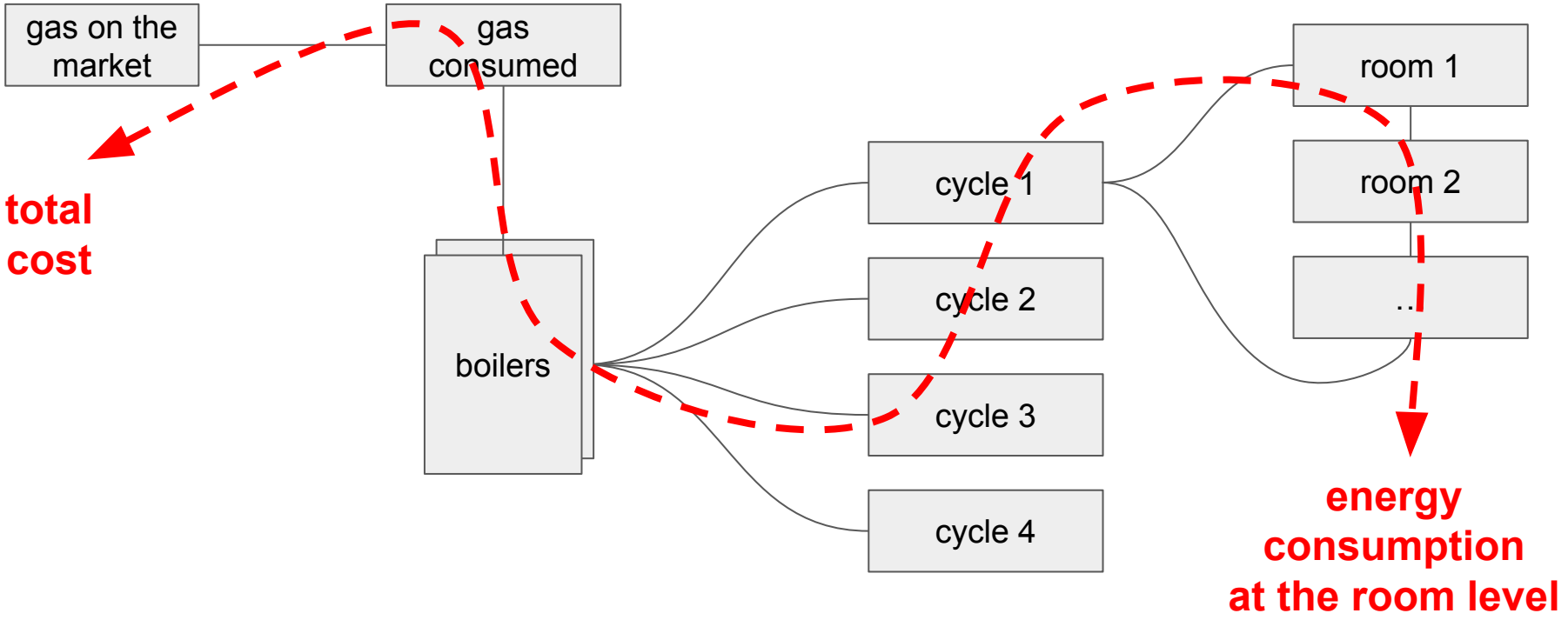
heating: analysis of first season’s dataset

- 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

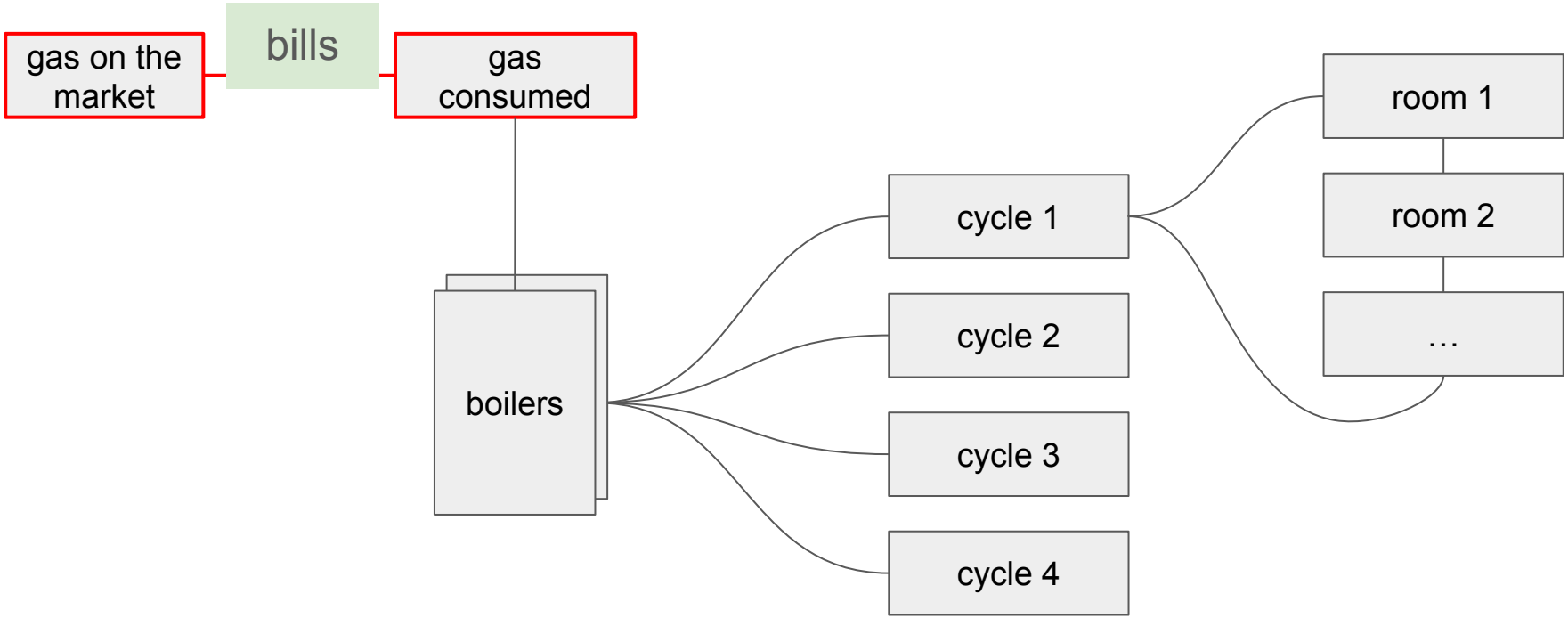
heating: analysis of first season’s dataset - cost assignment



heating: analysis of first season's dataset - cost assignment



from HUF to burnt gas



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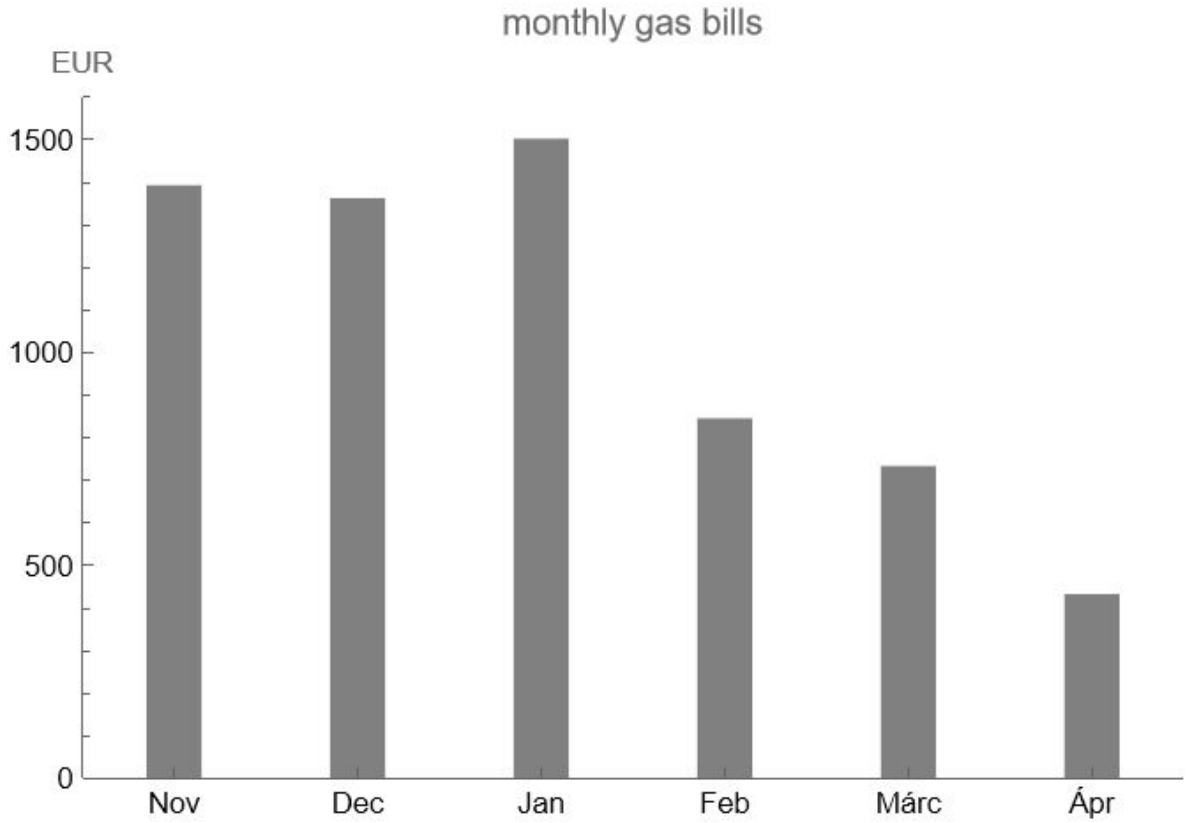

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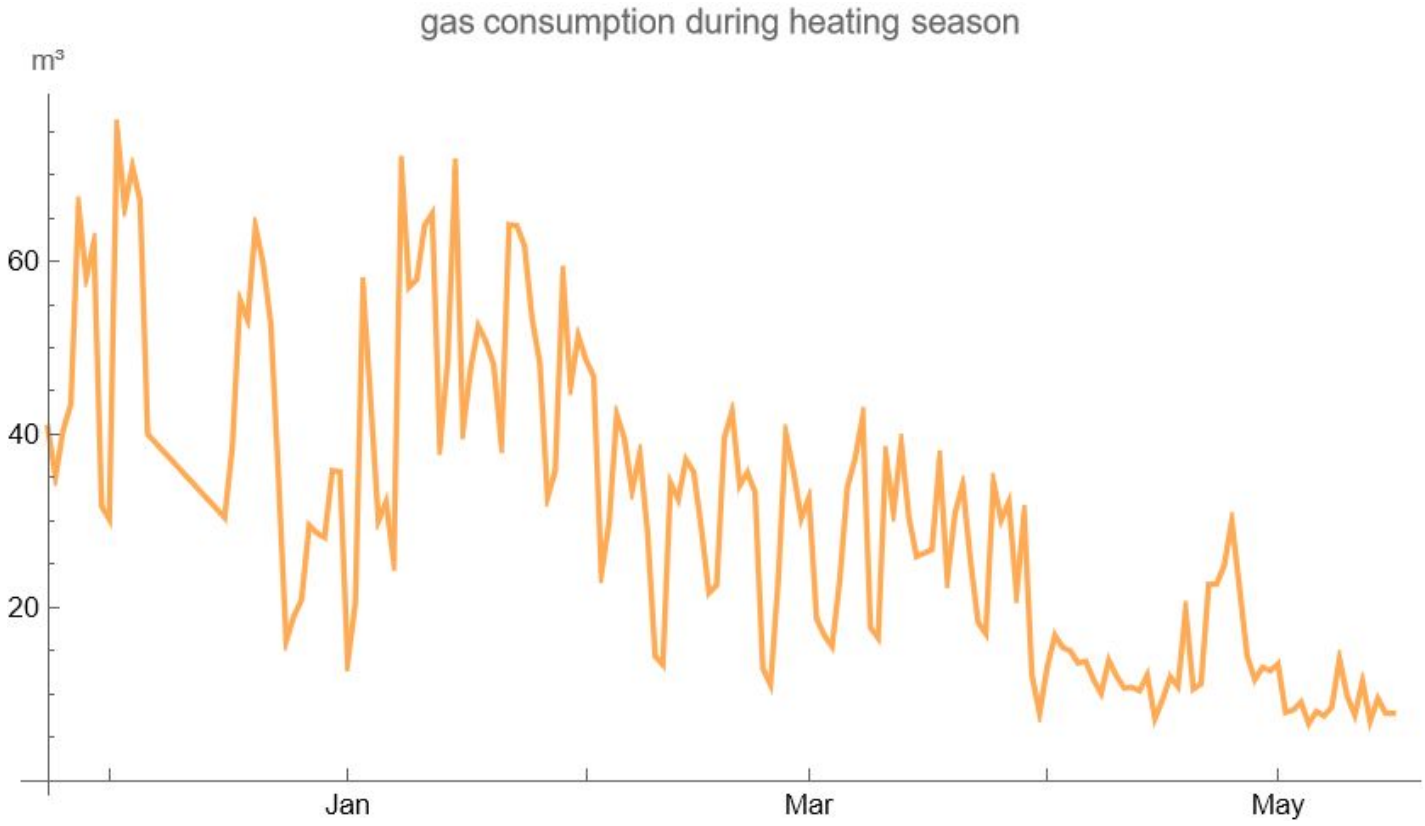
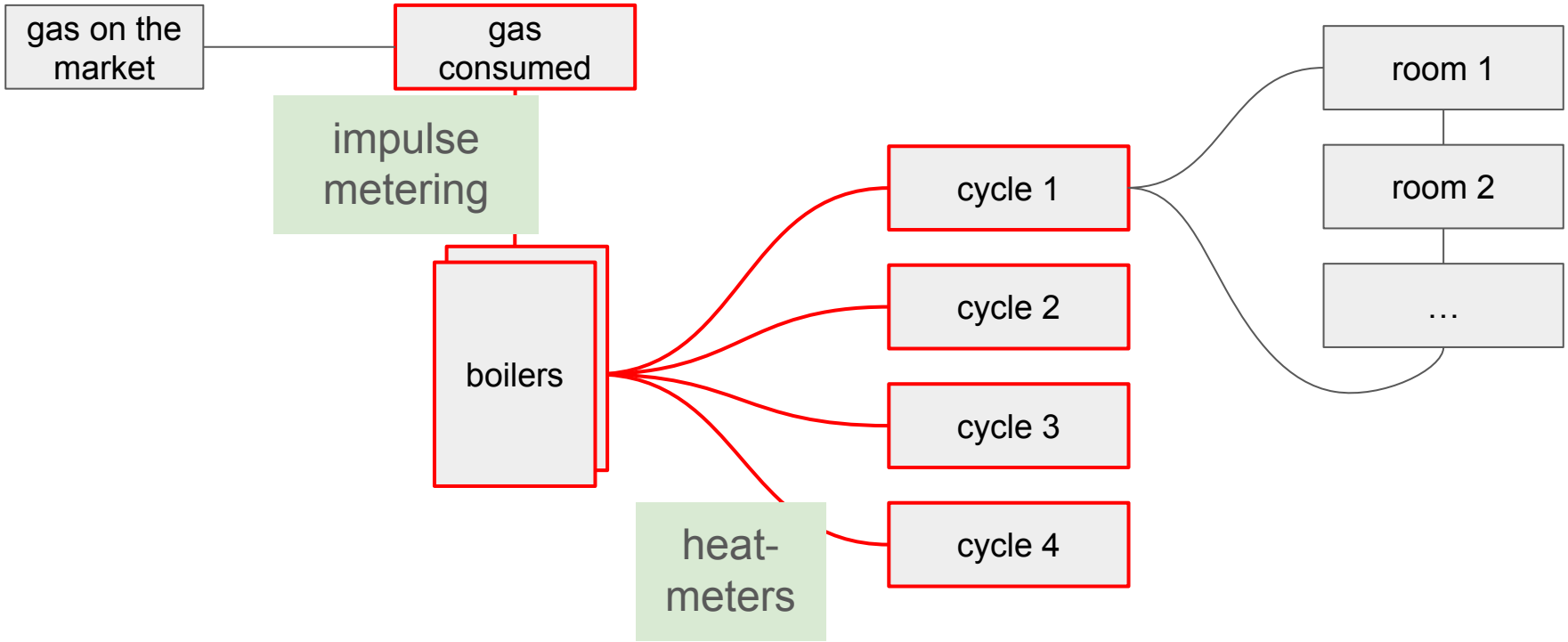
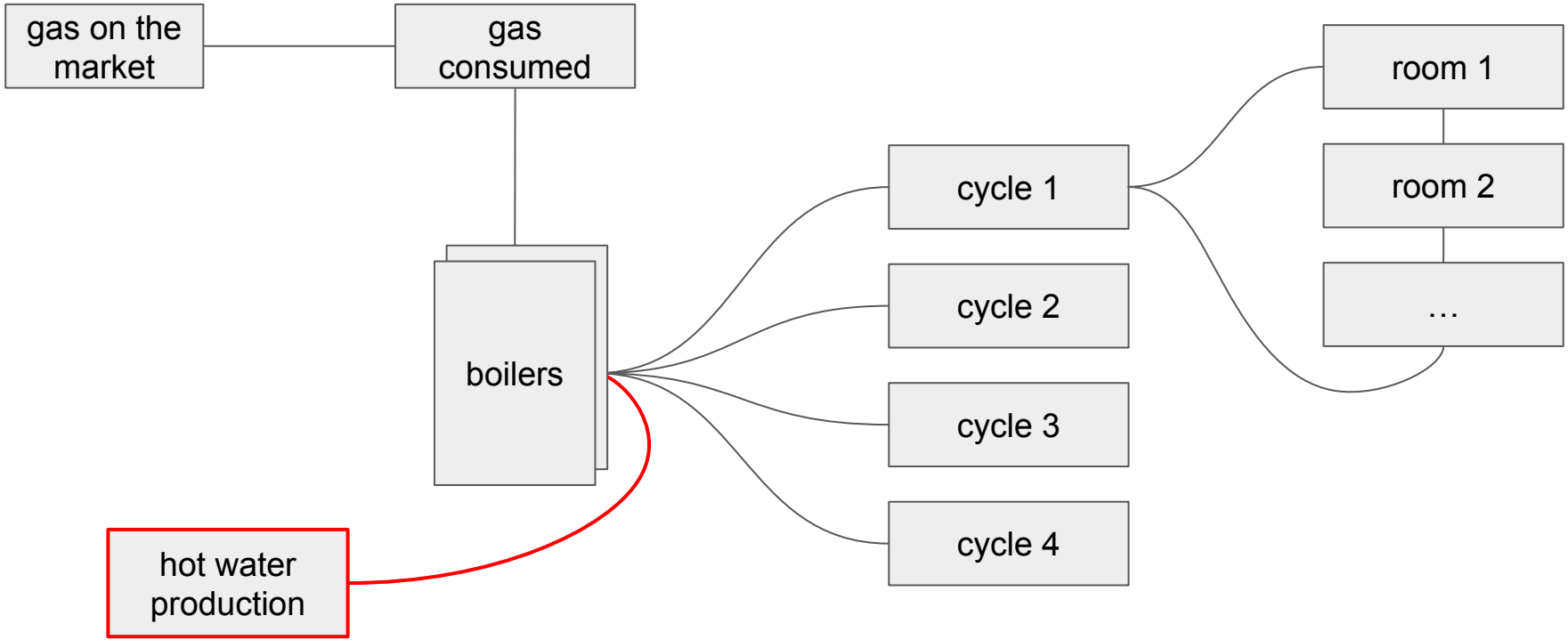


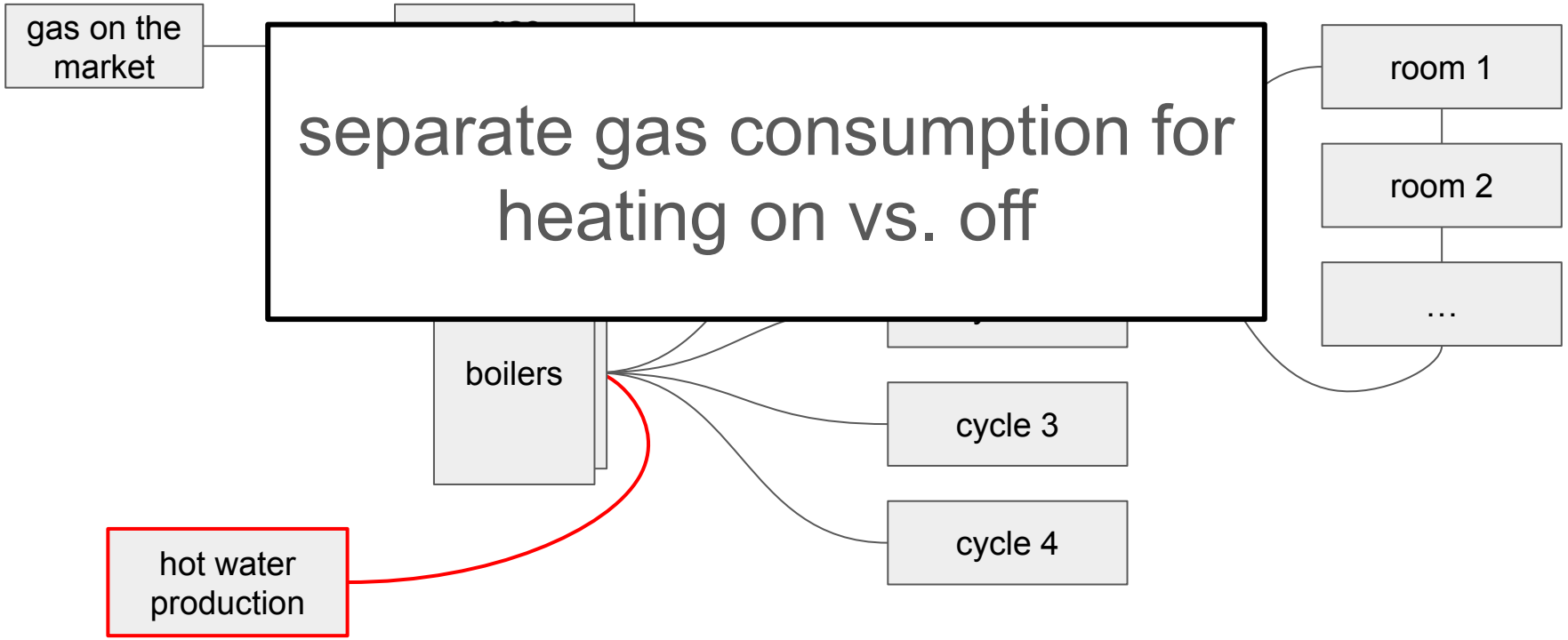
from burnt gas to heat delivered on cycles



but: hot water production



1) estimation of non-heating gas consumption



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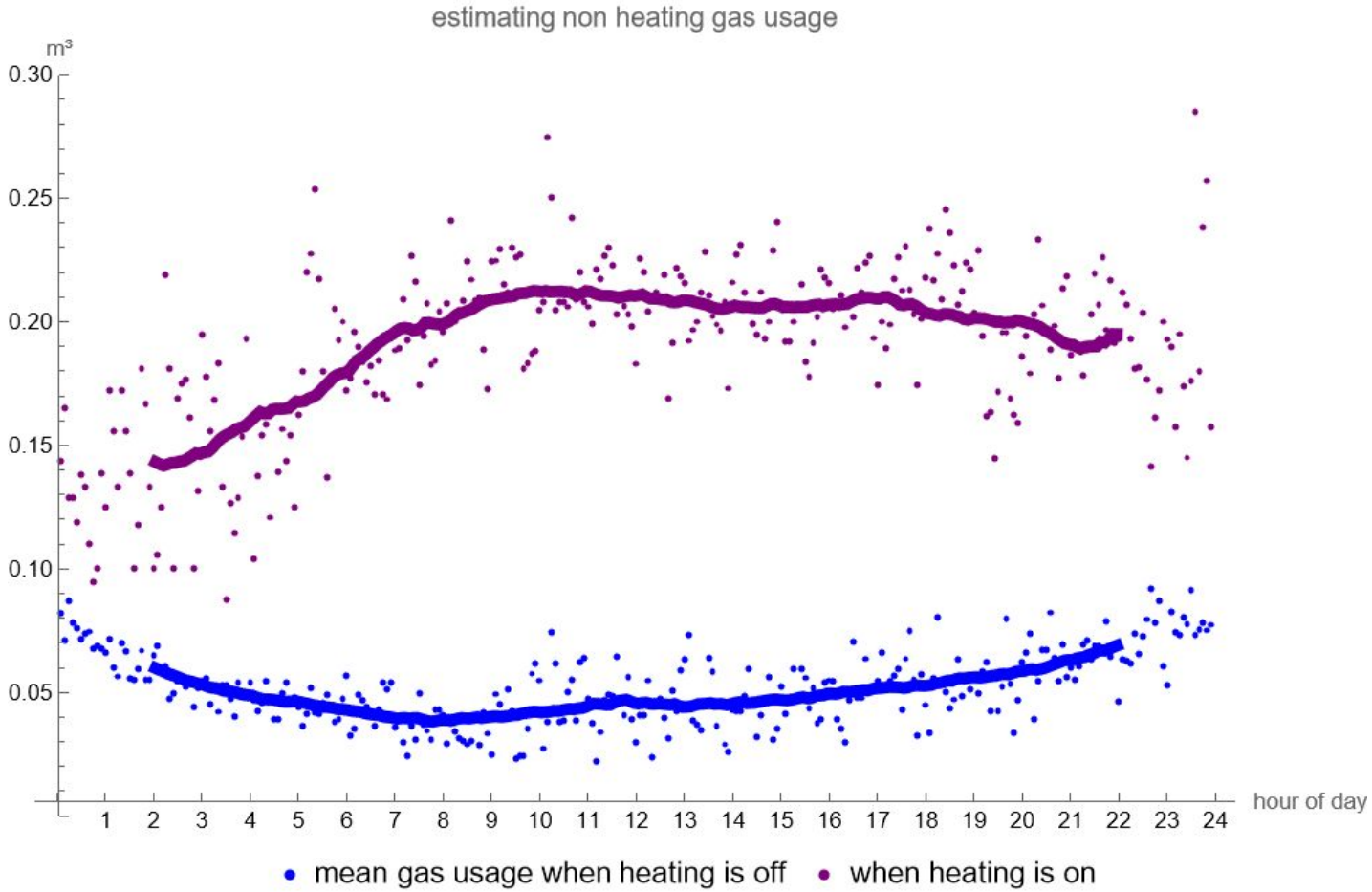

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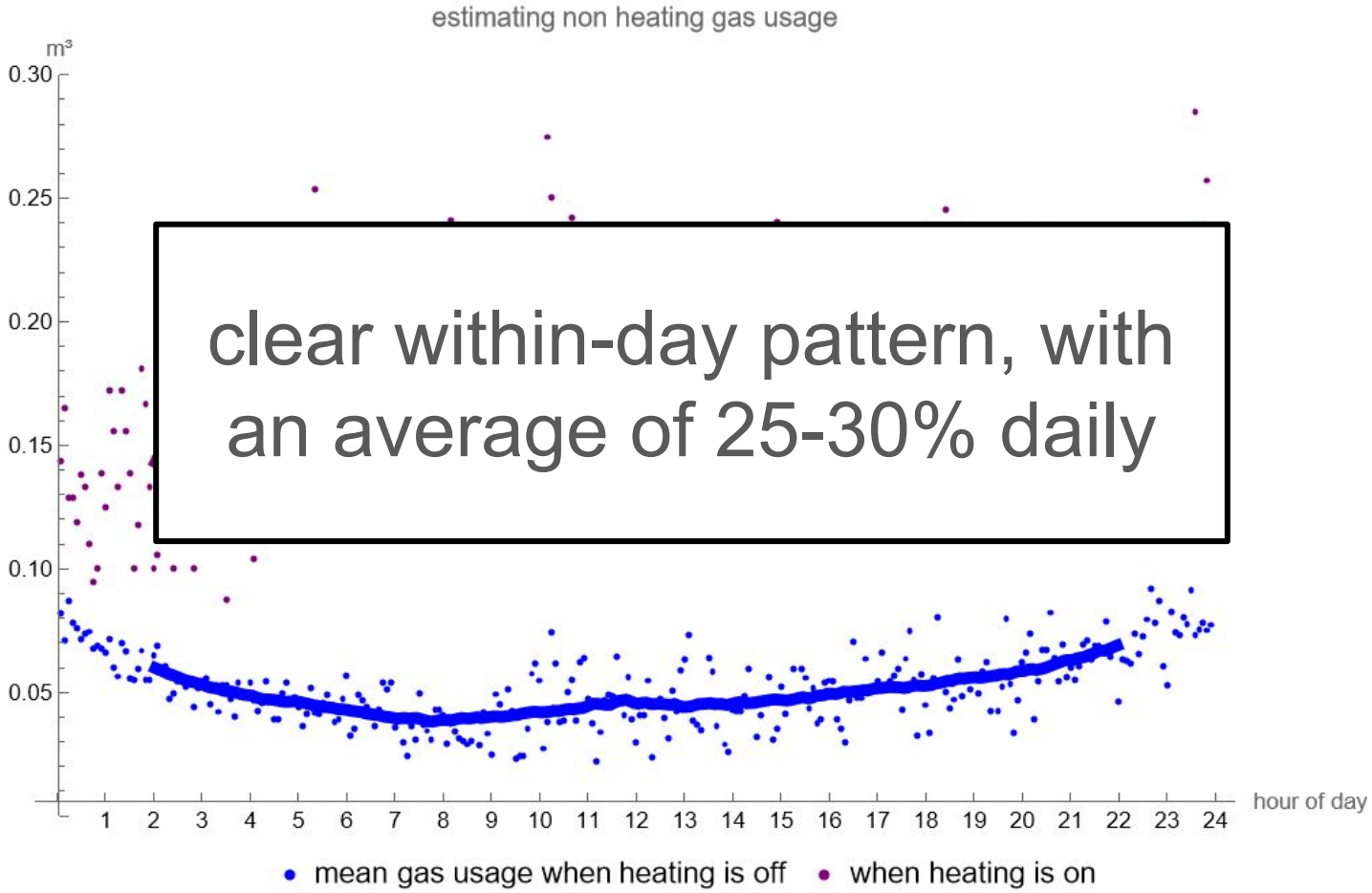

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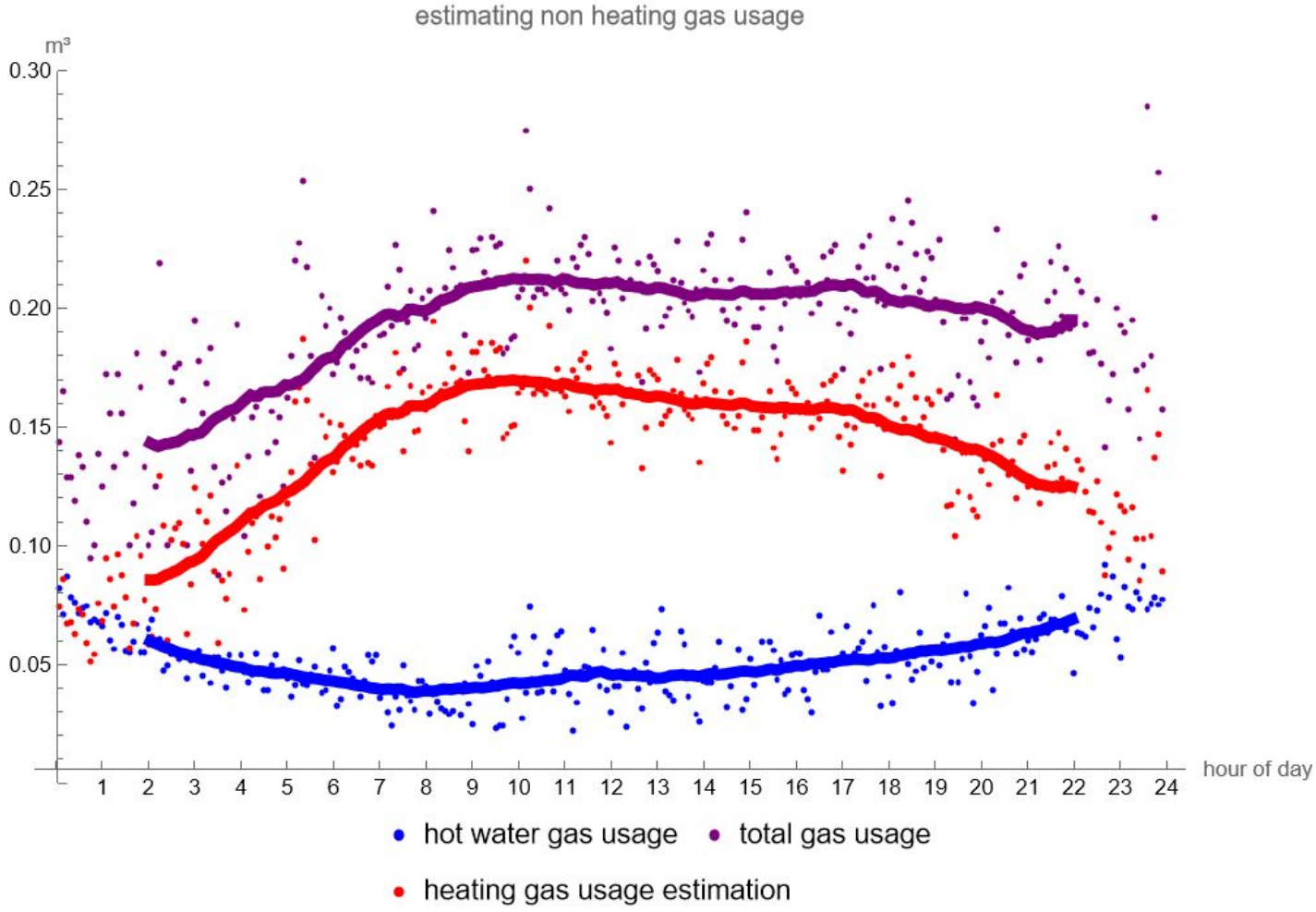
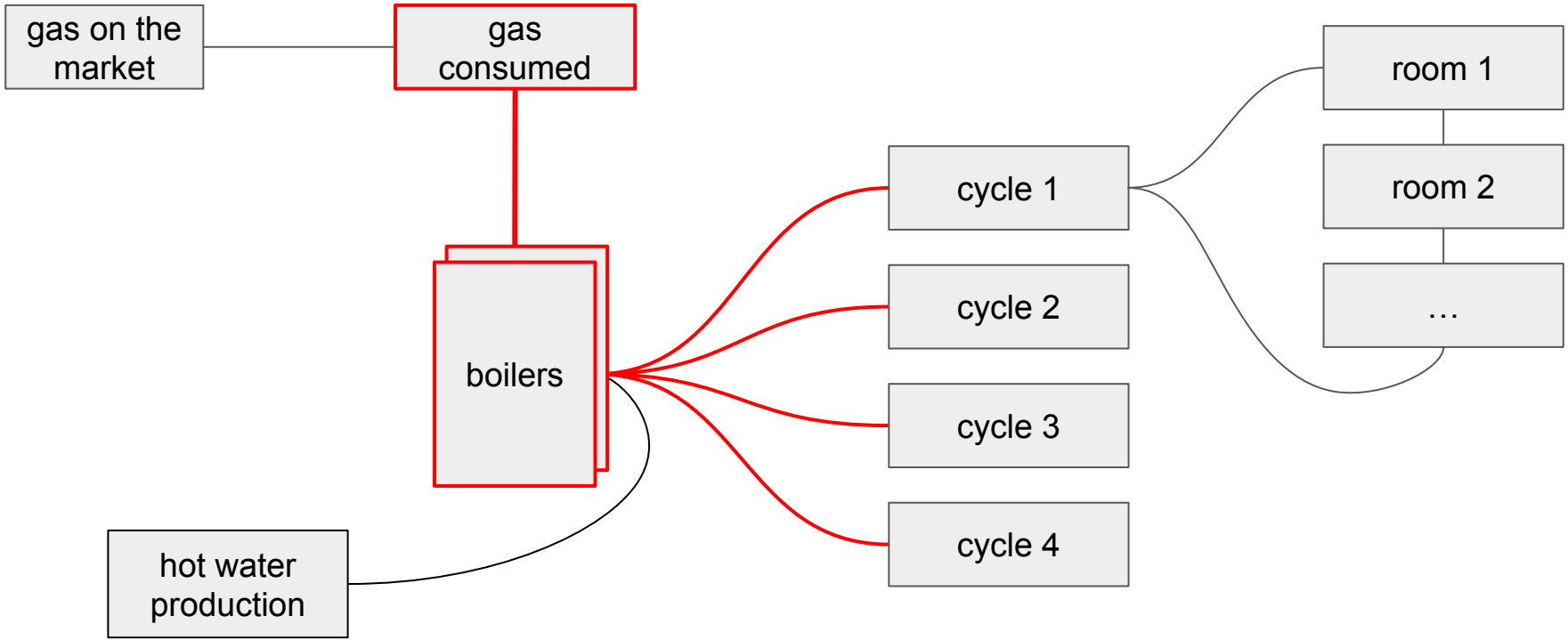
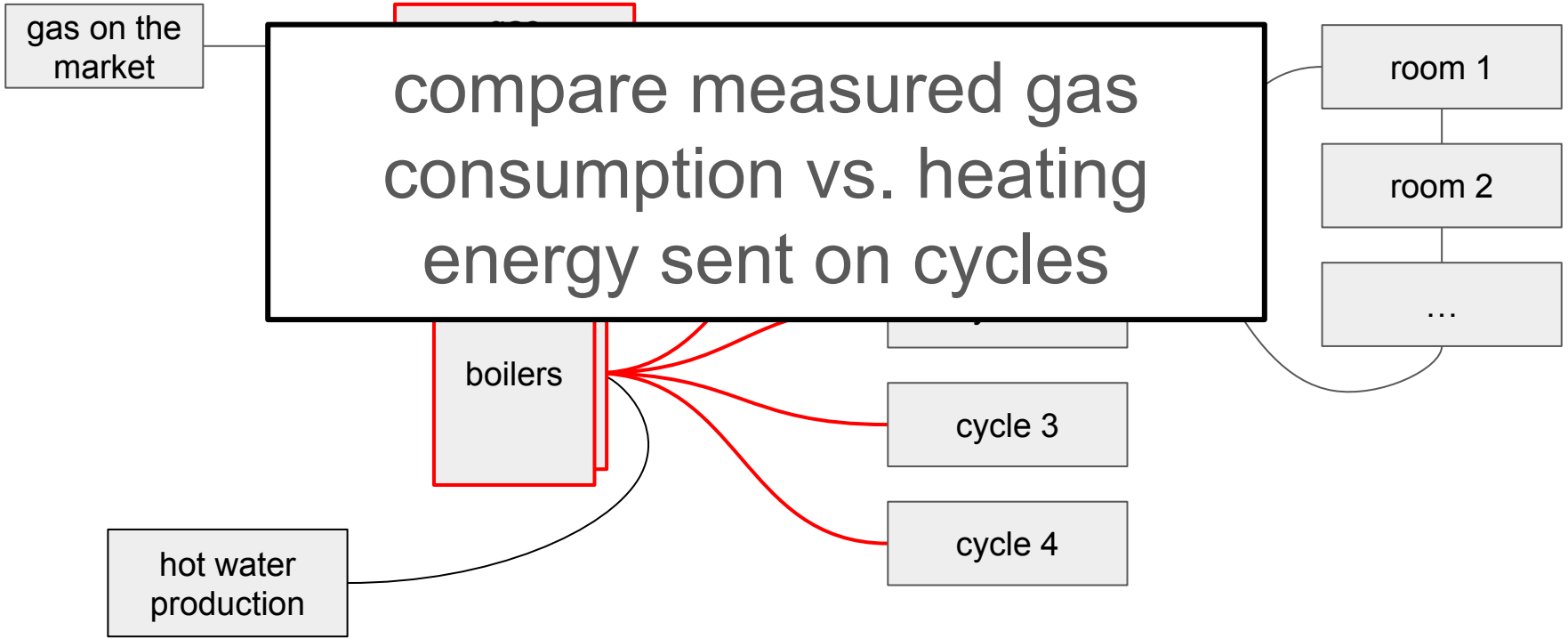


if we are there: estimation of boiler efficiency



2) estimation of boiler efficiency



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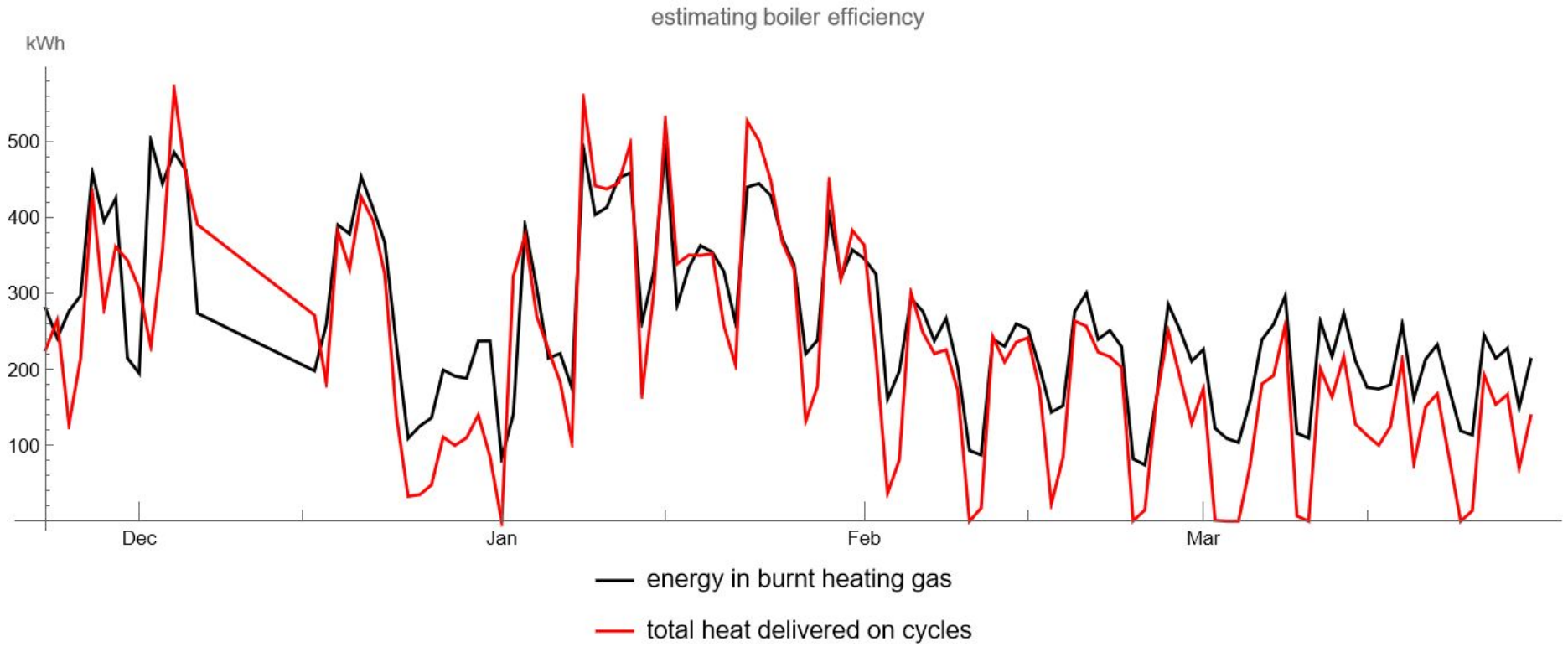

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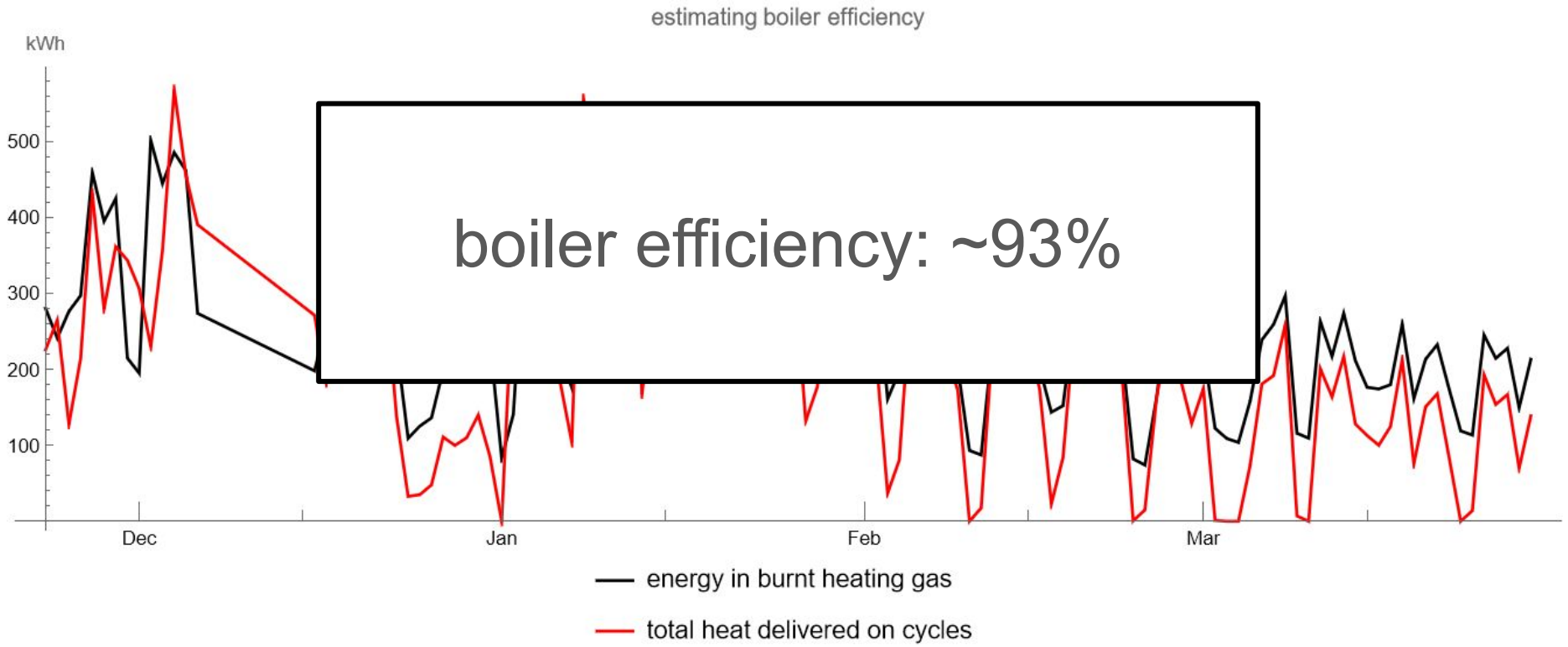
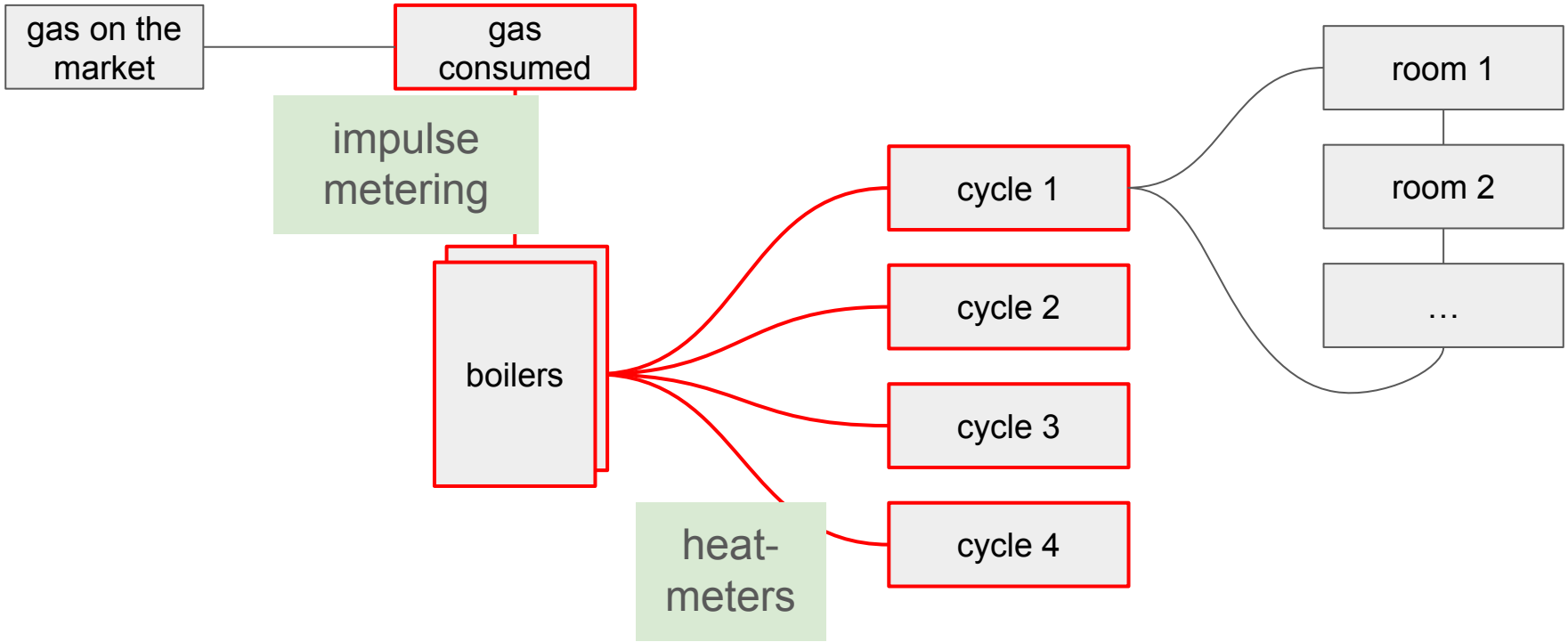
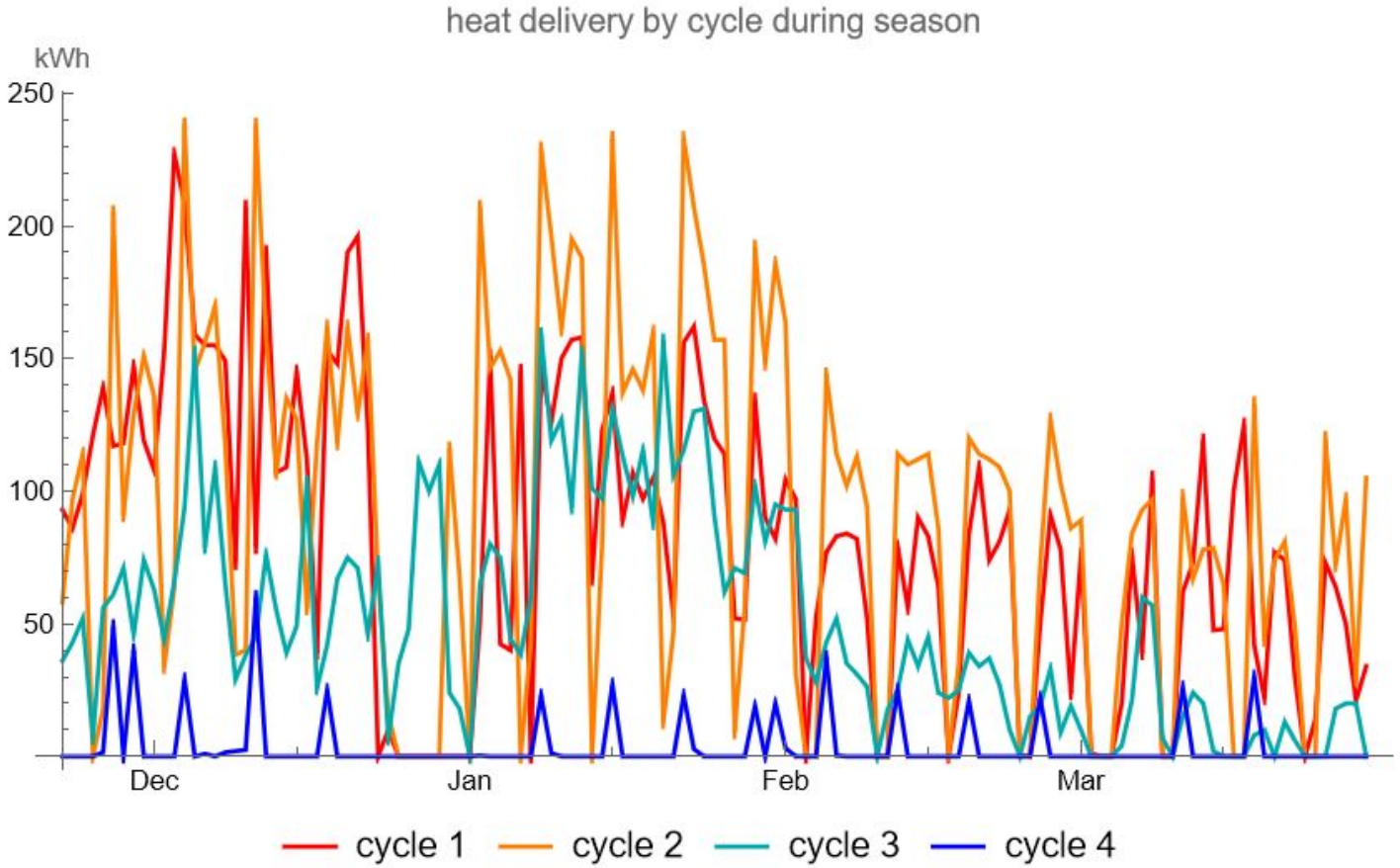


from burnt gas to heat delivered on cycles



3) relative weight of cycles



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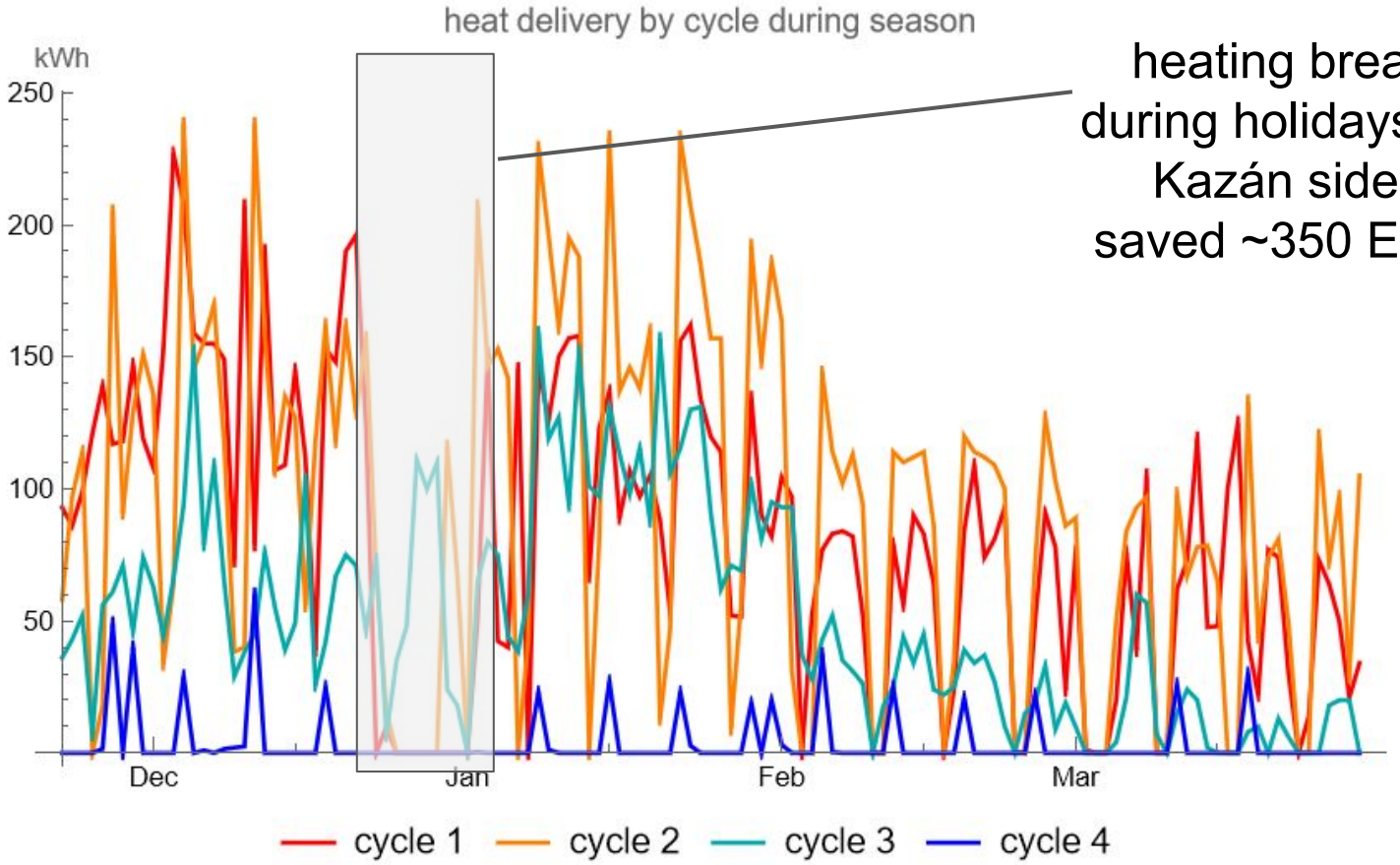
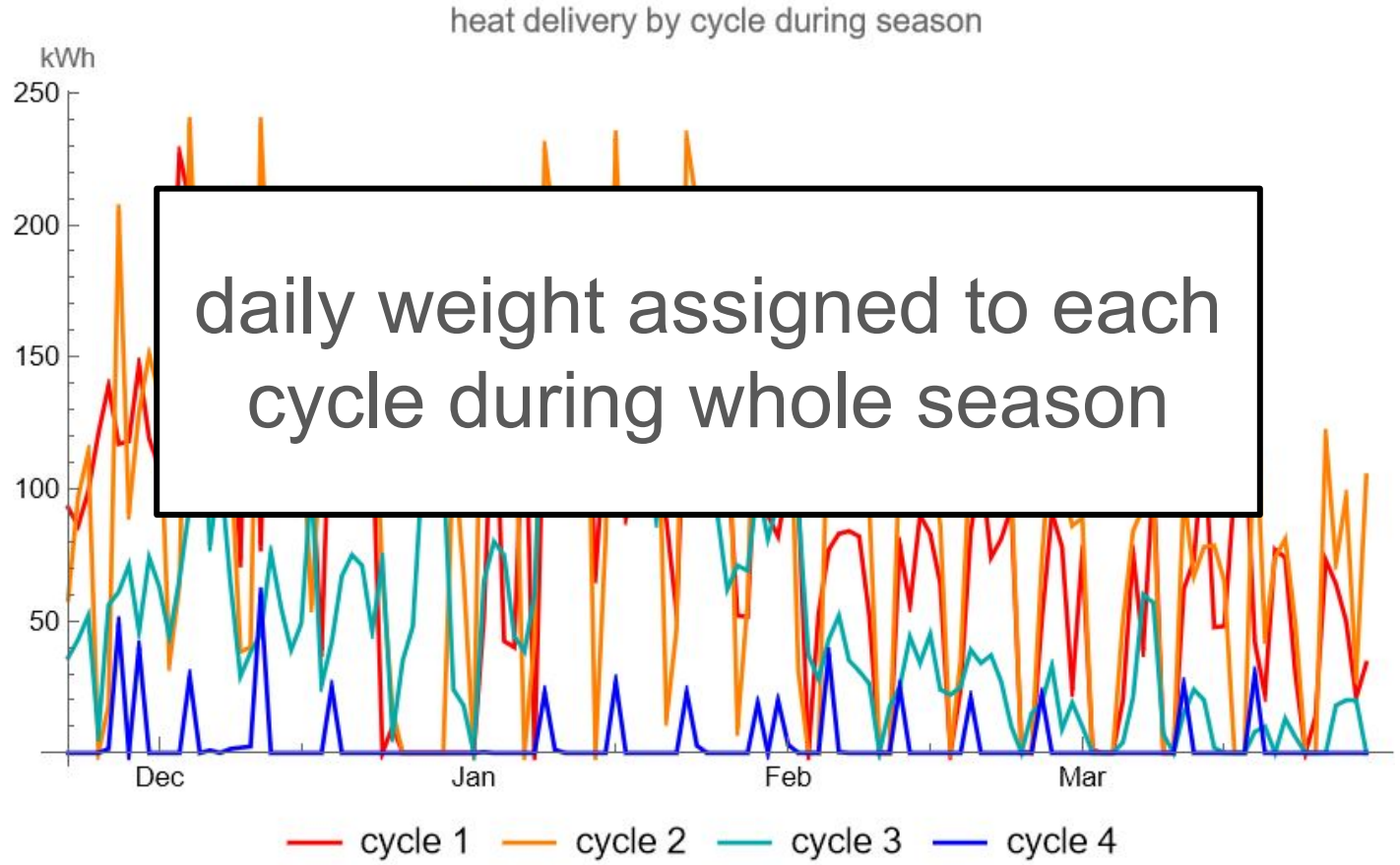


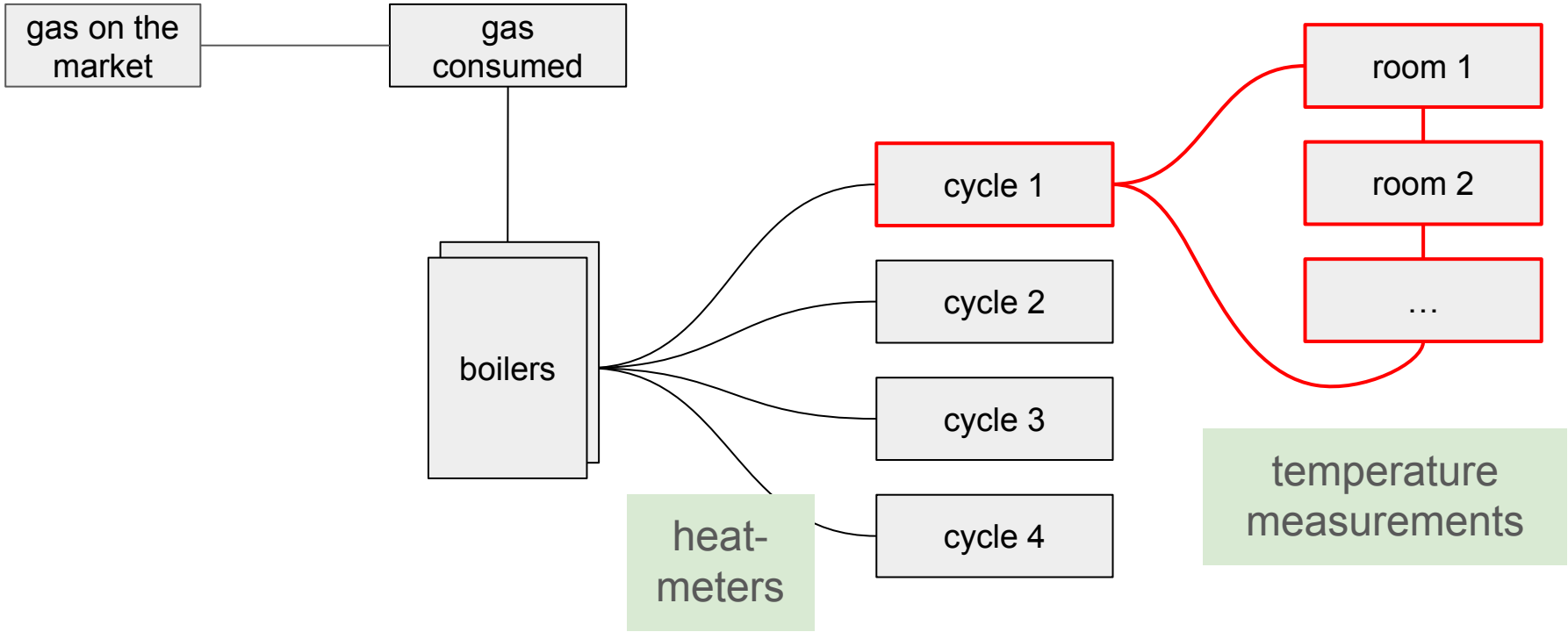
heating break during holidays on Kazán side, saved ~350 EUR

3) relative weight of cycles



daily weight assigned to each cycle during whole season

from heat delivered on cycles to heat taken up by rooms



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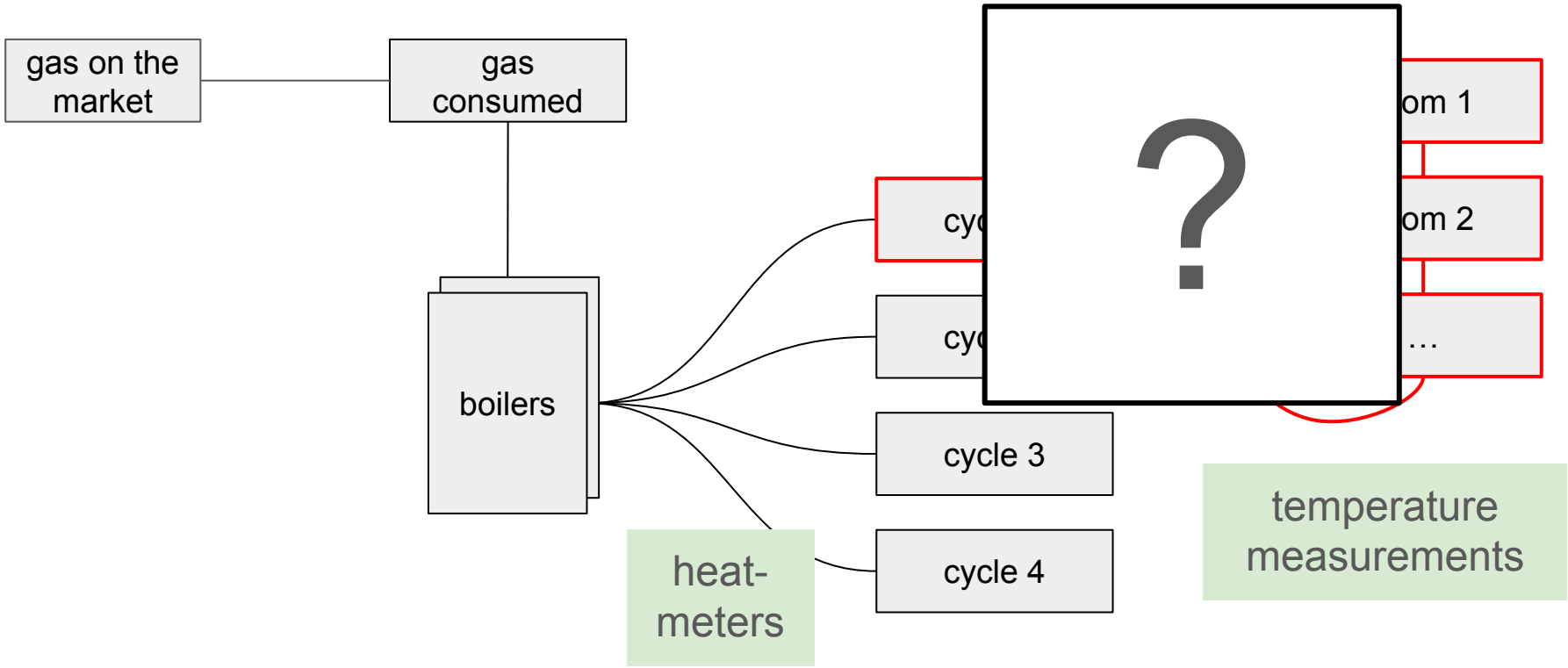
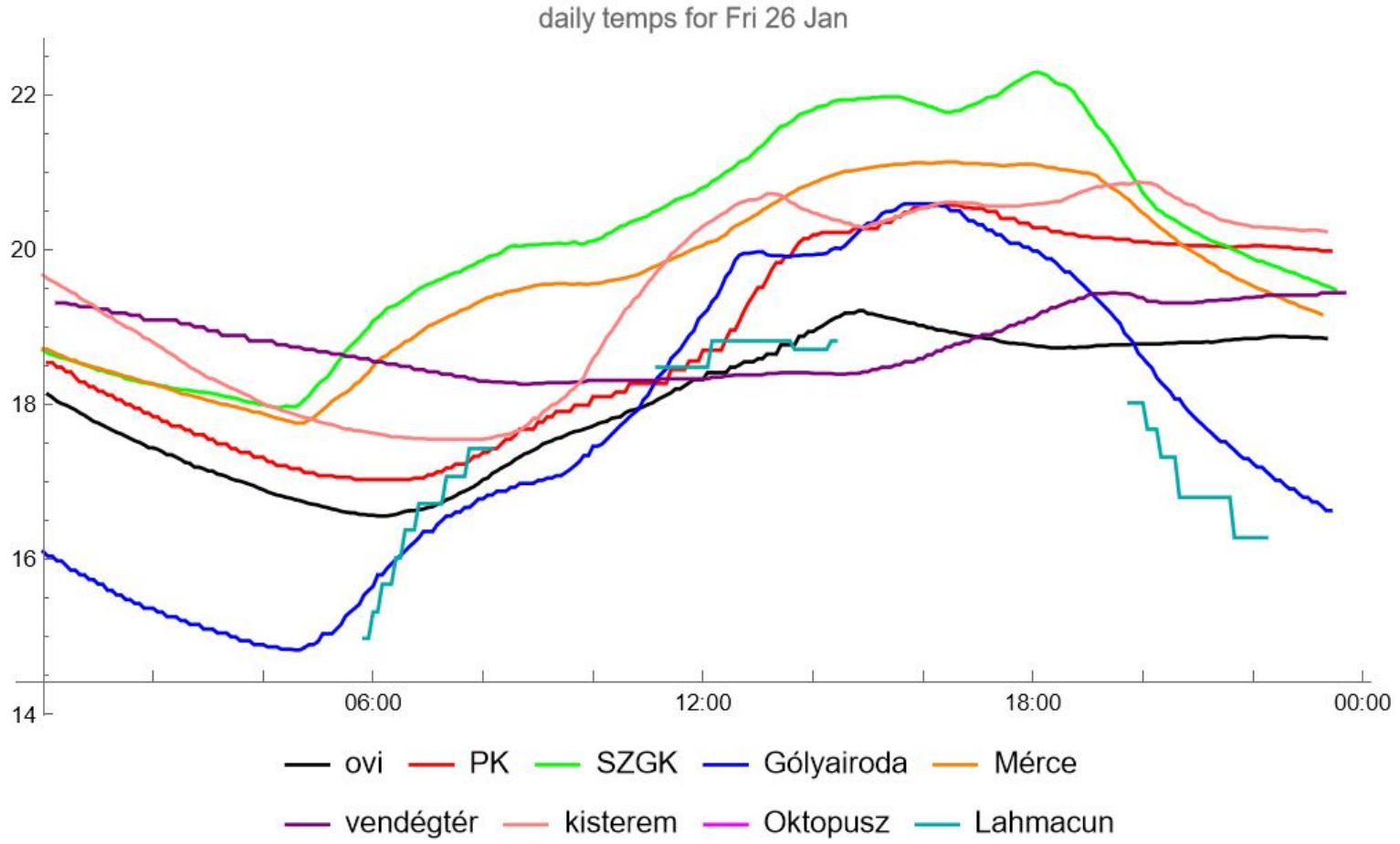


4) evaluation of rooms based on cooling and warming data



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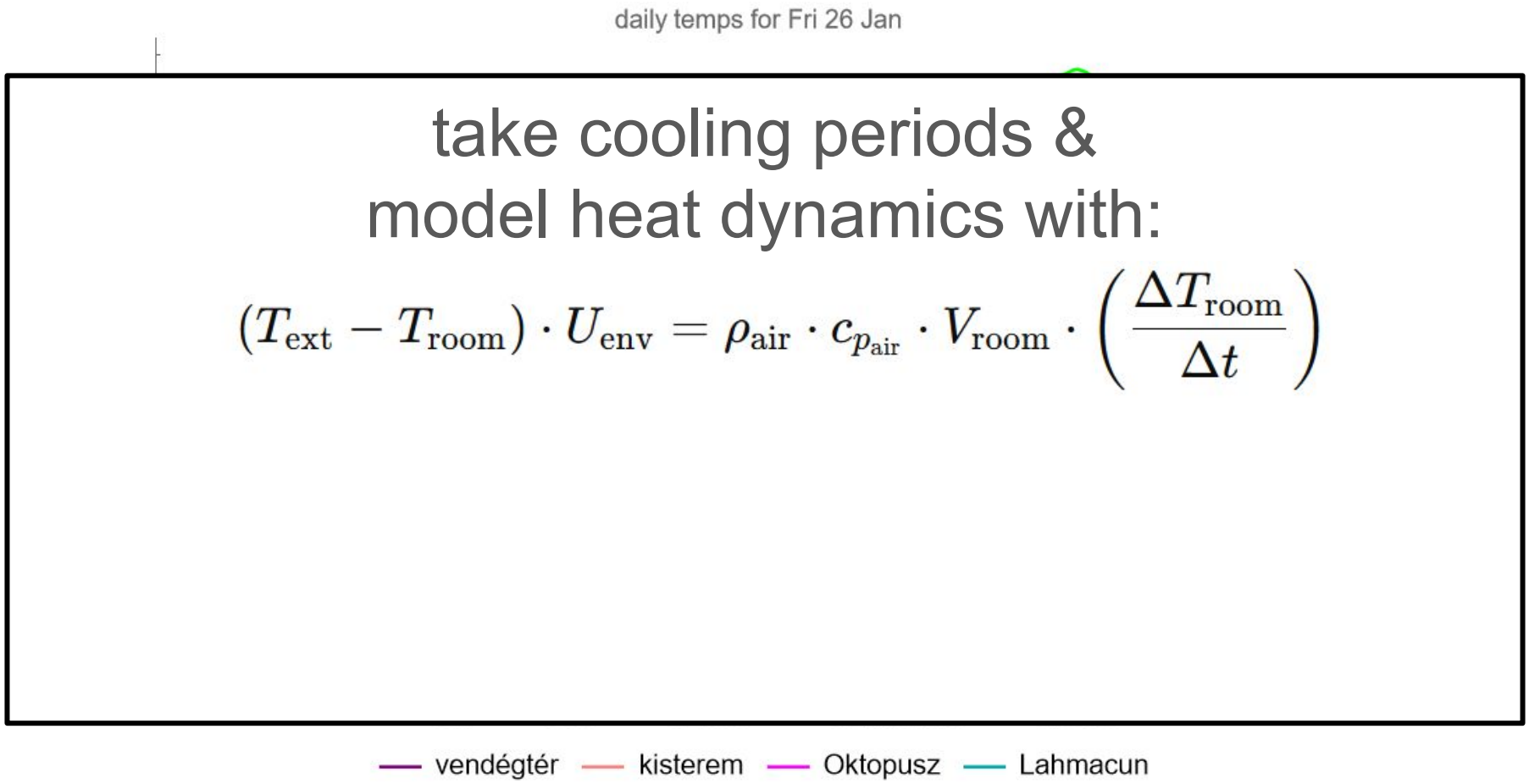

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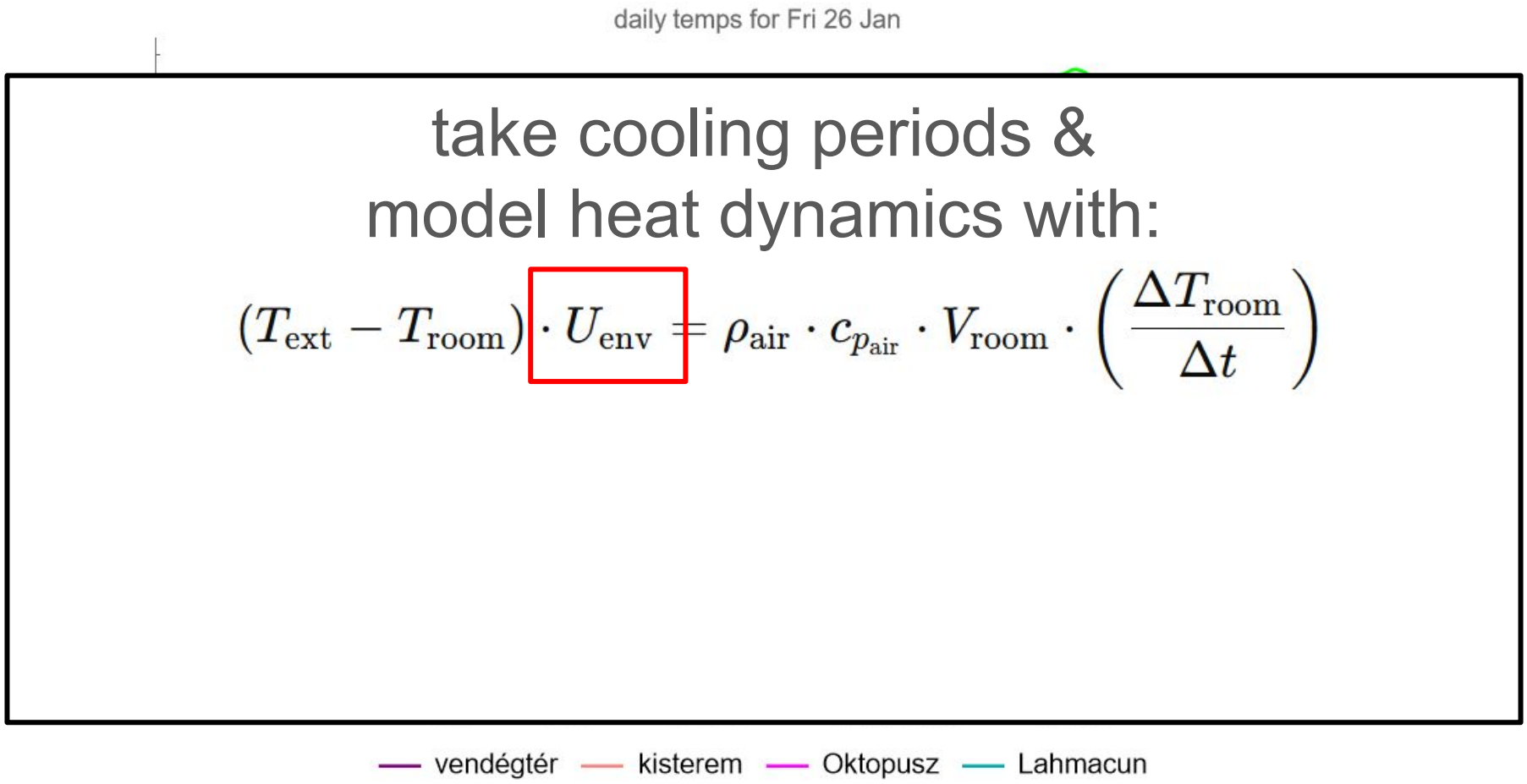

4) evaluation of rooms based on cooling and warming data

take cooling periods &
model heat dynamics with:

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

then take warming periods
and add heater:

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

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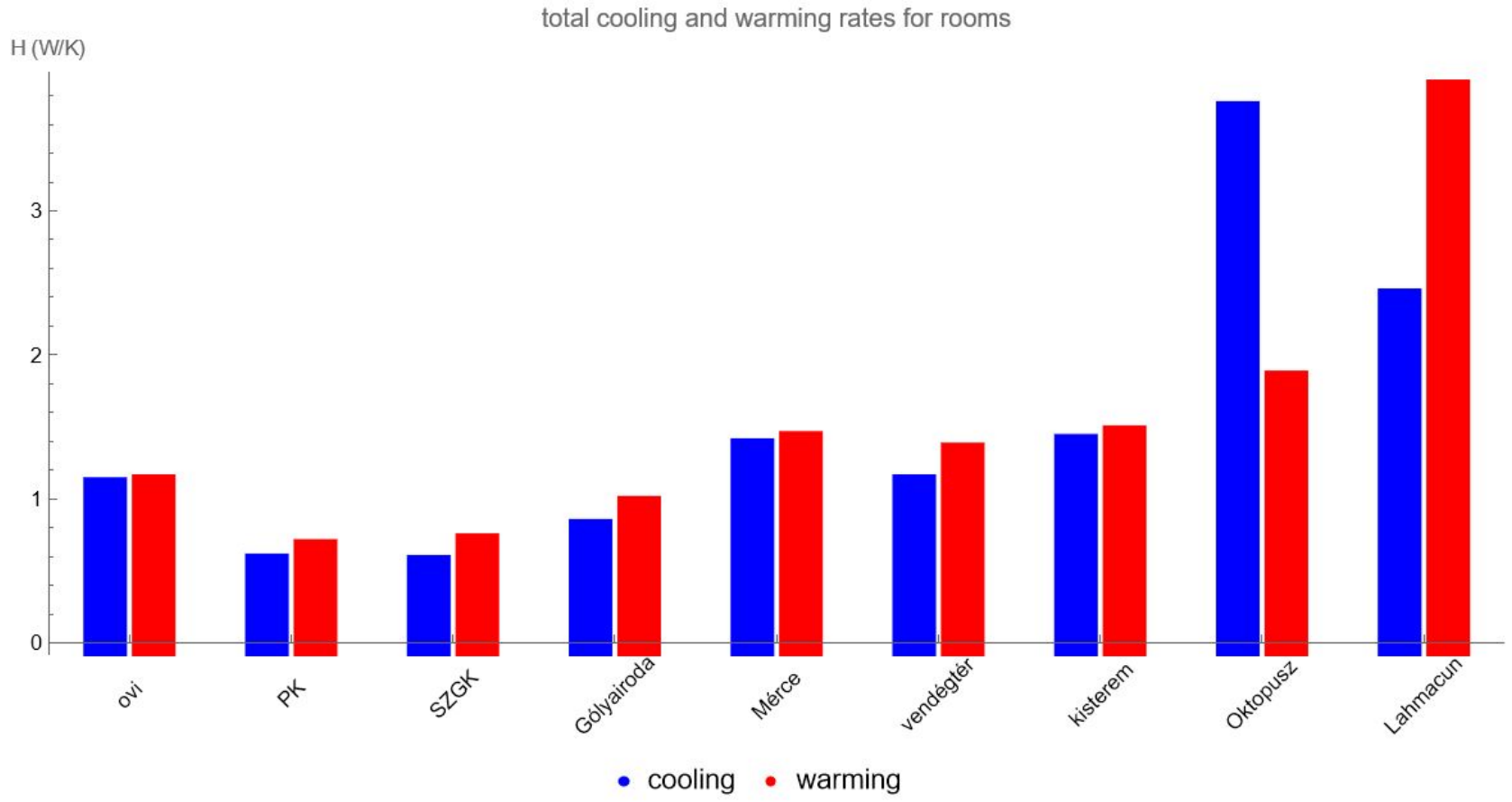

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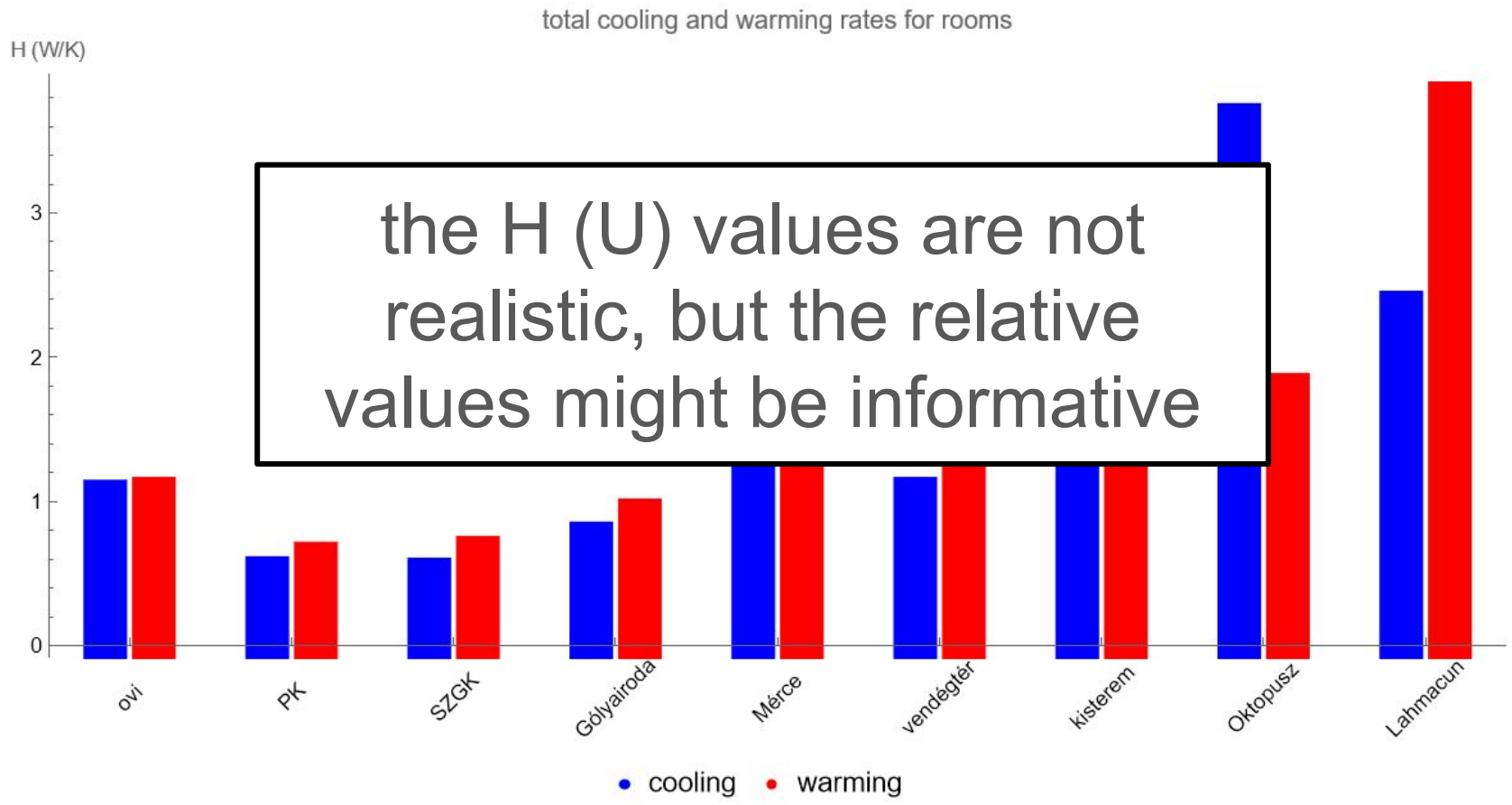

the H (U) values are not realistic, but the relative values might be informative

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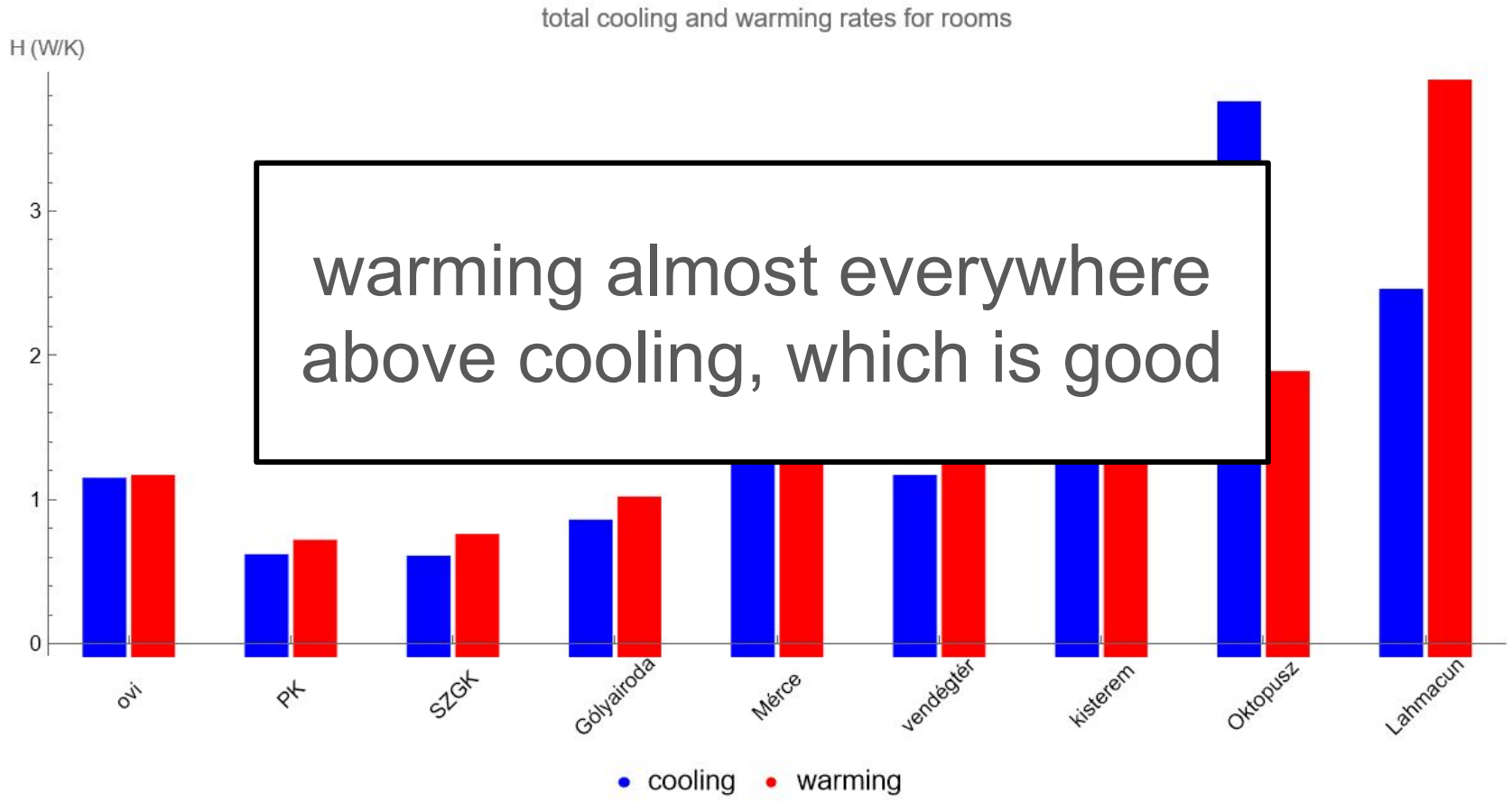

warming almost everywhere above cooling, which is good

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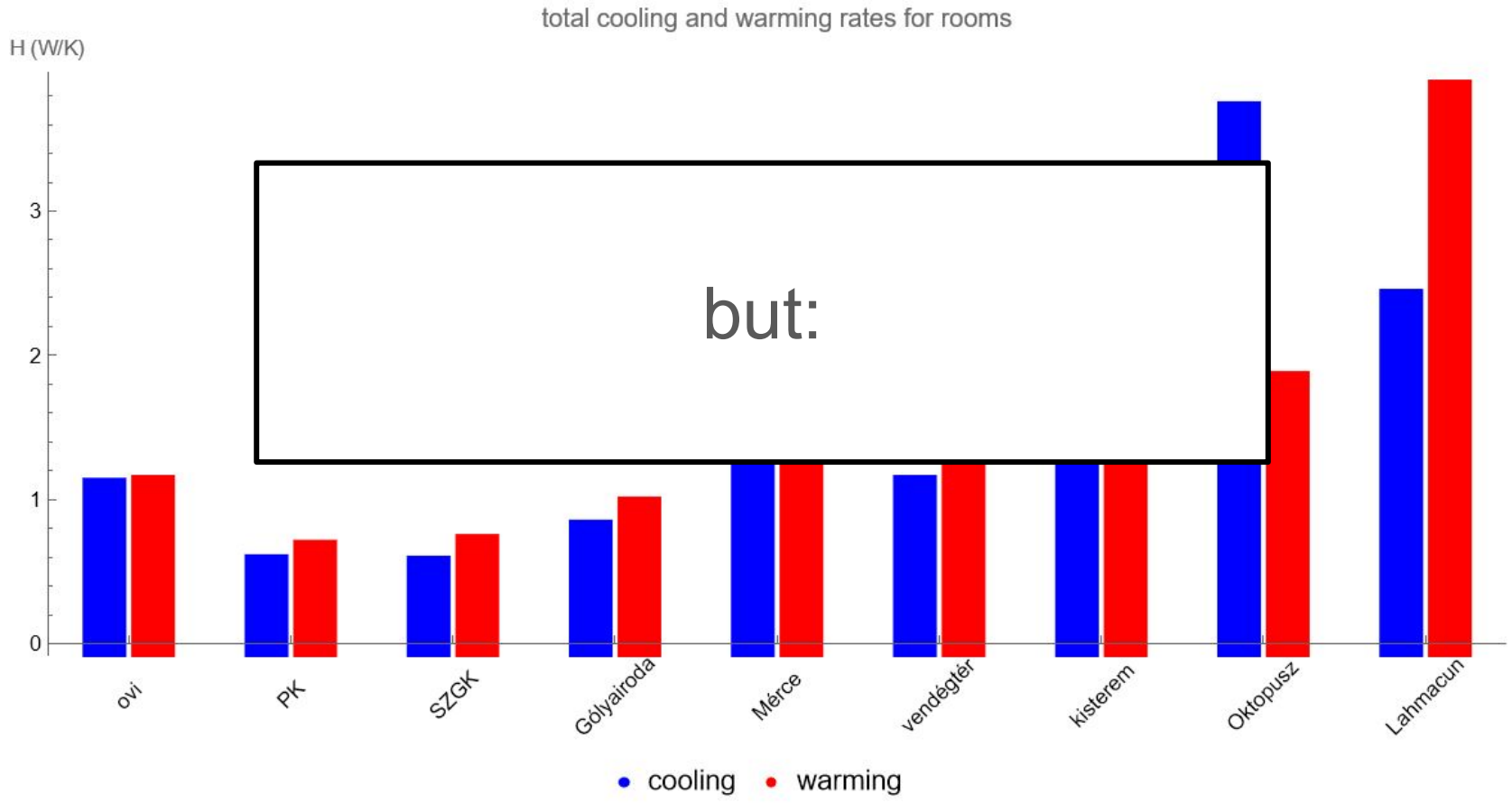

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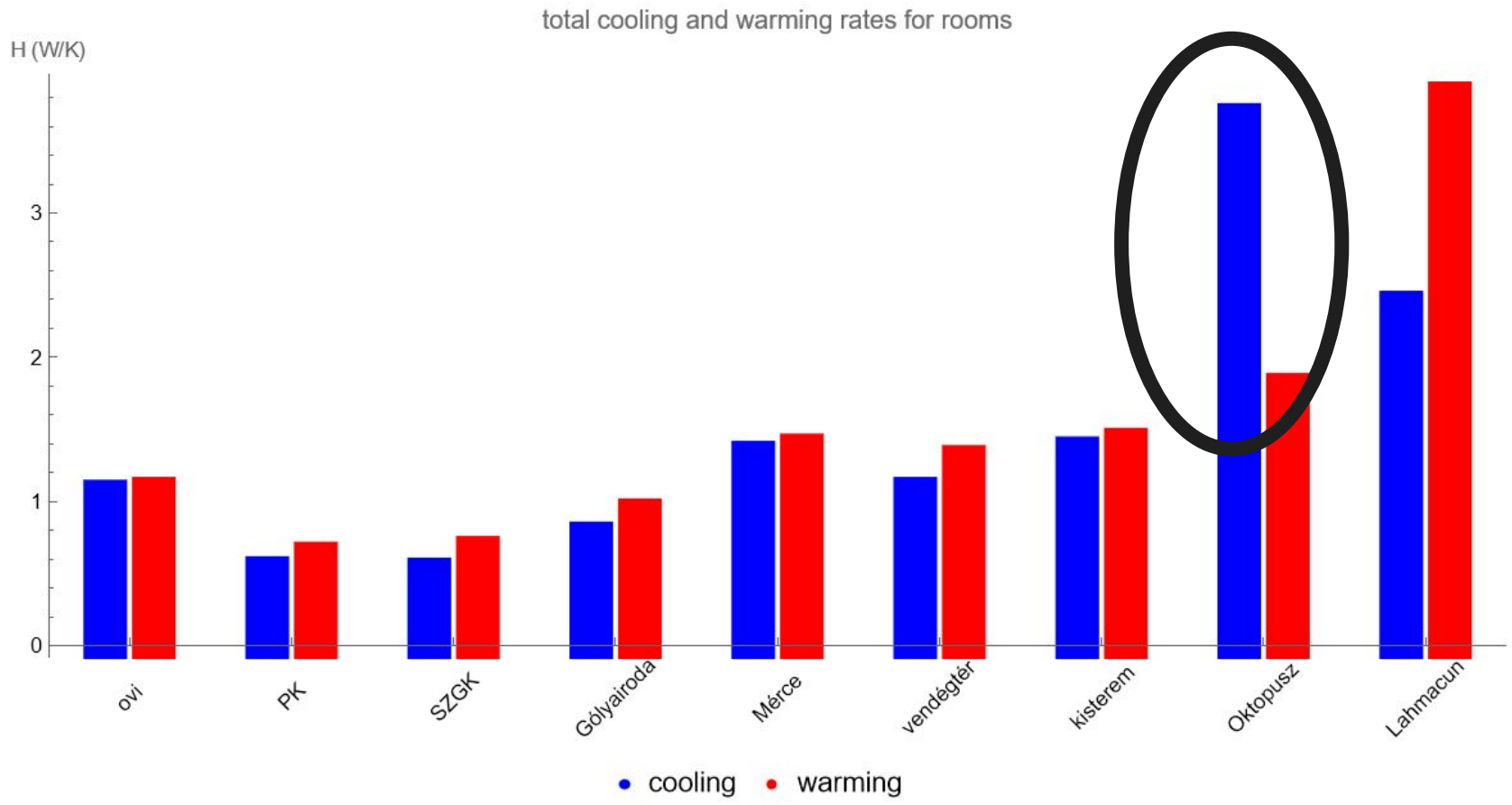

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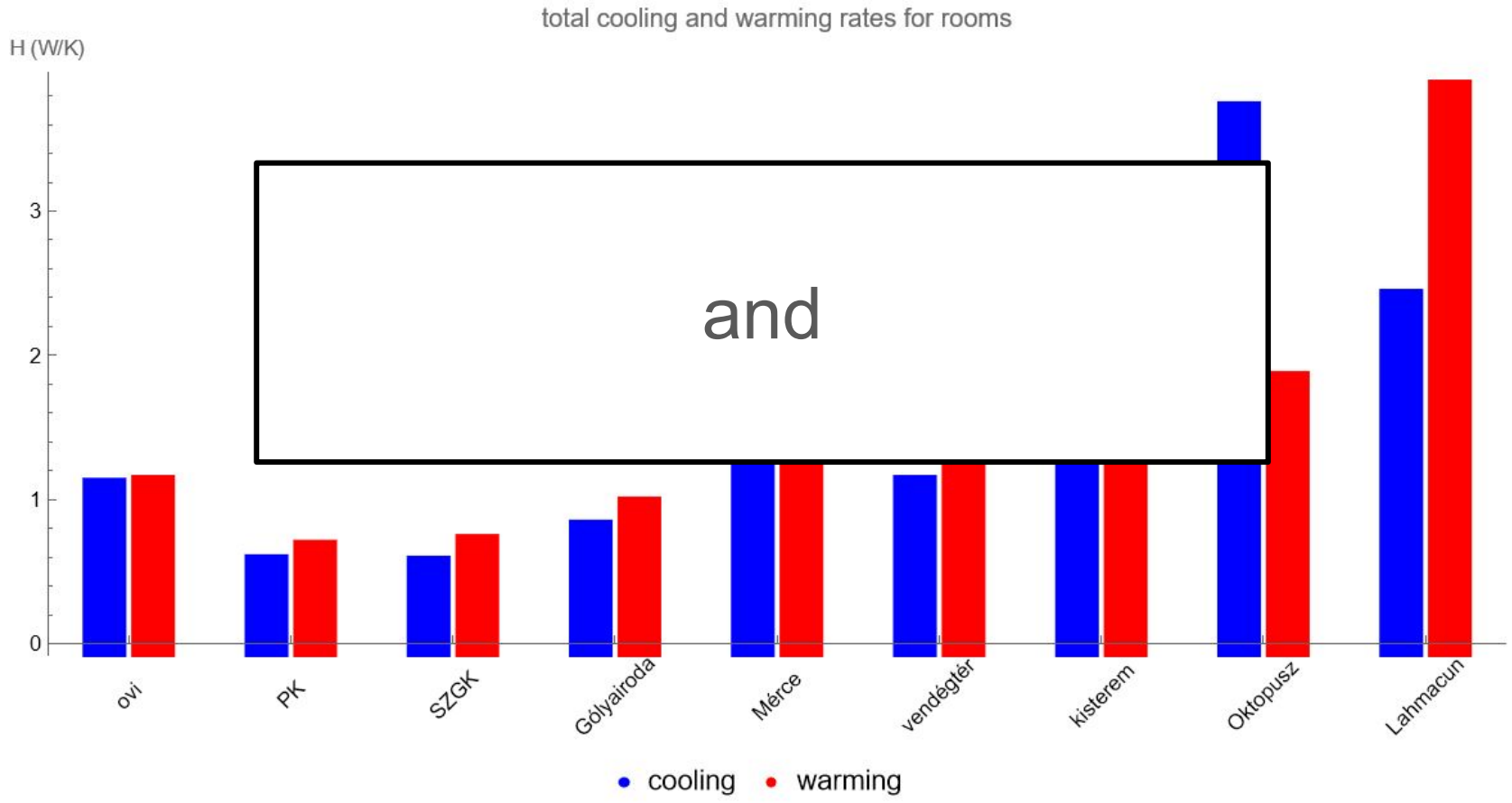

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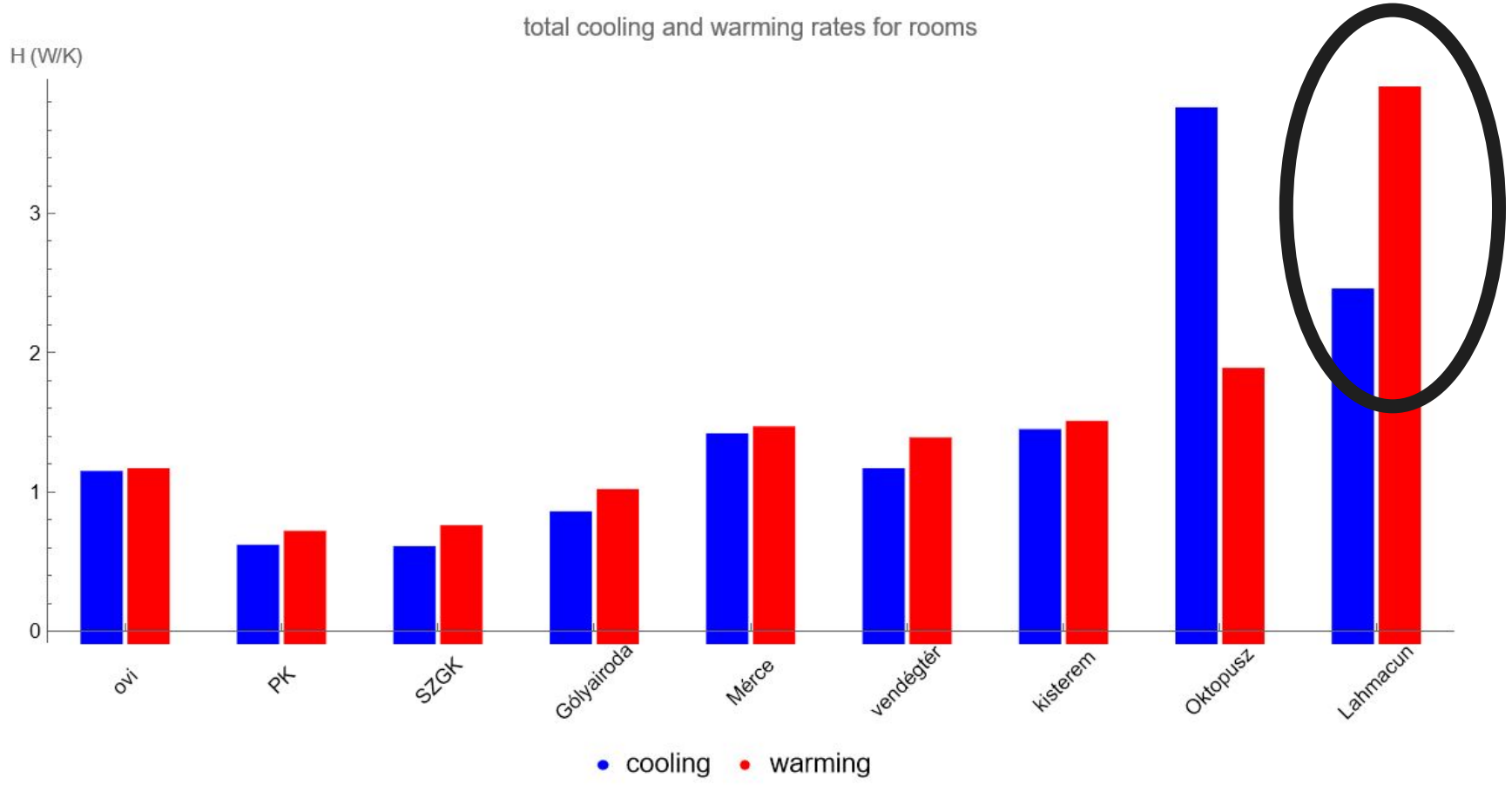

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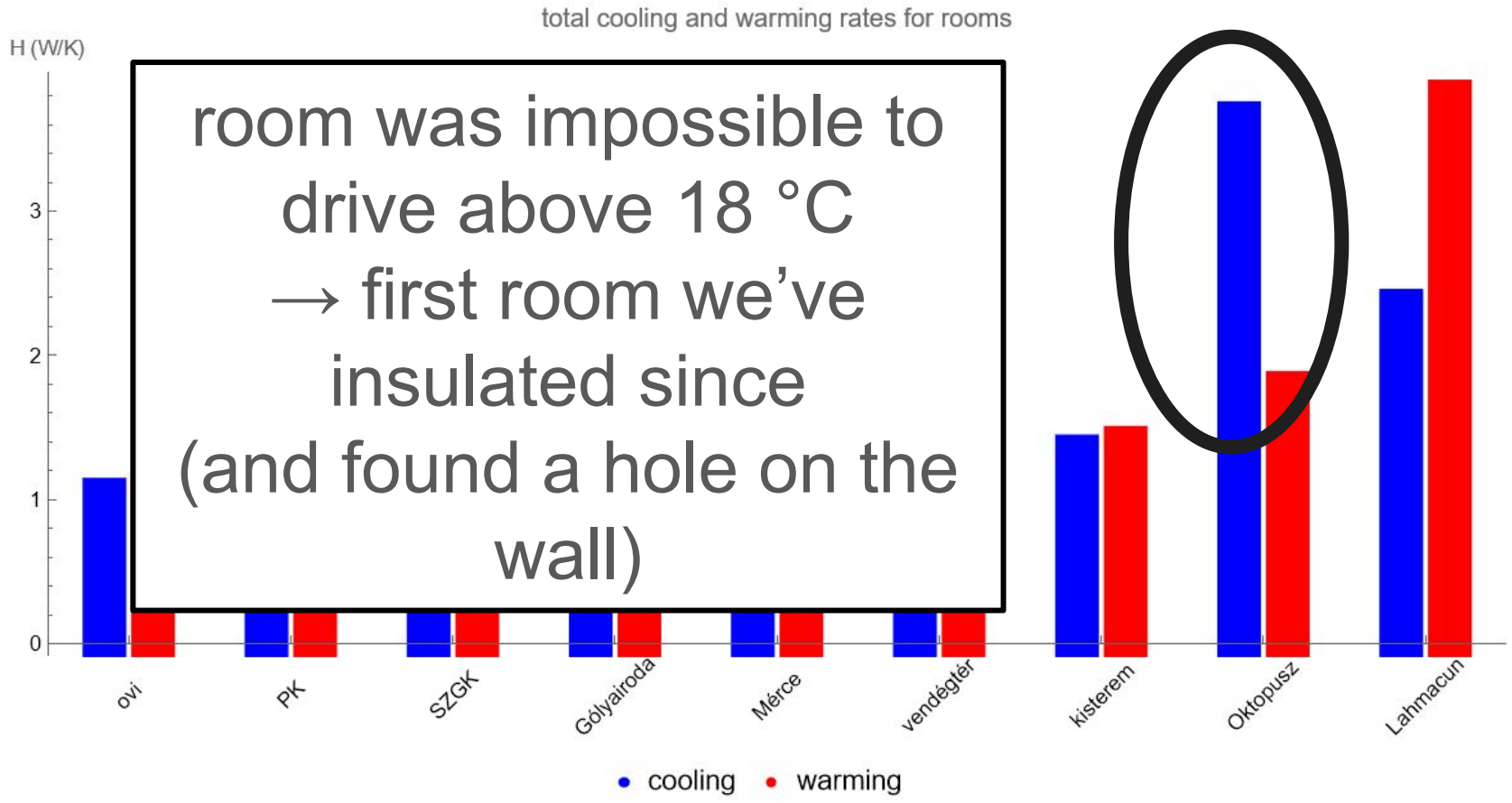
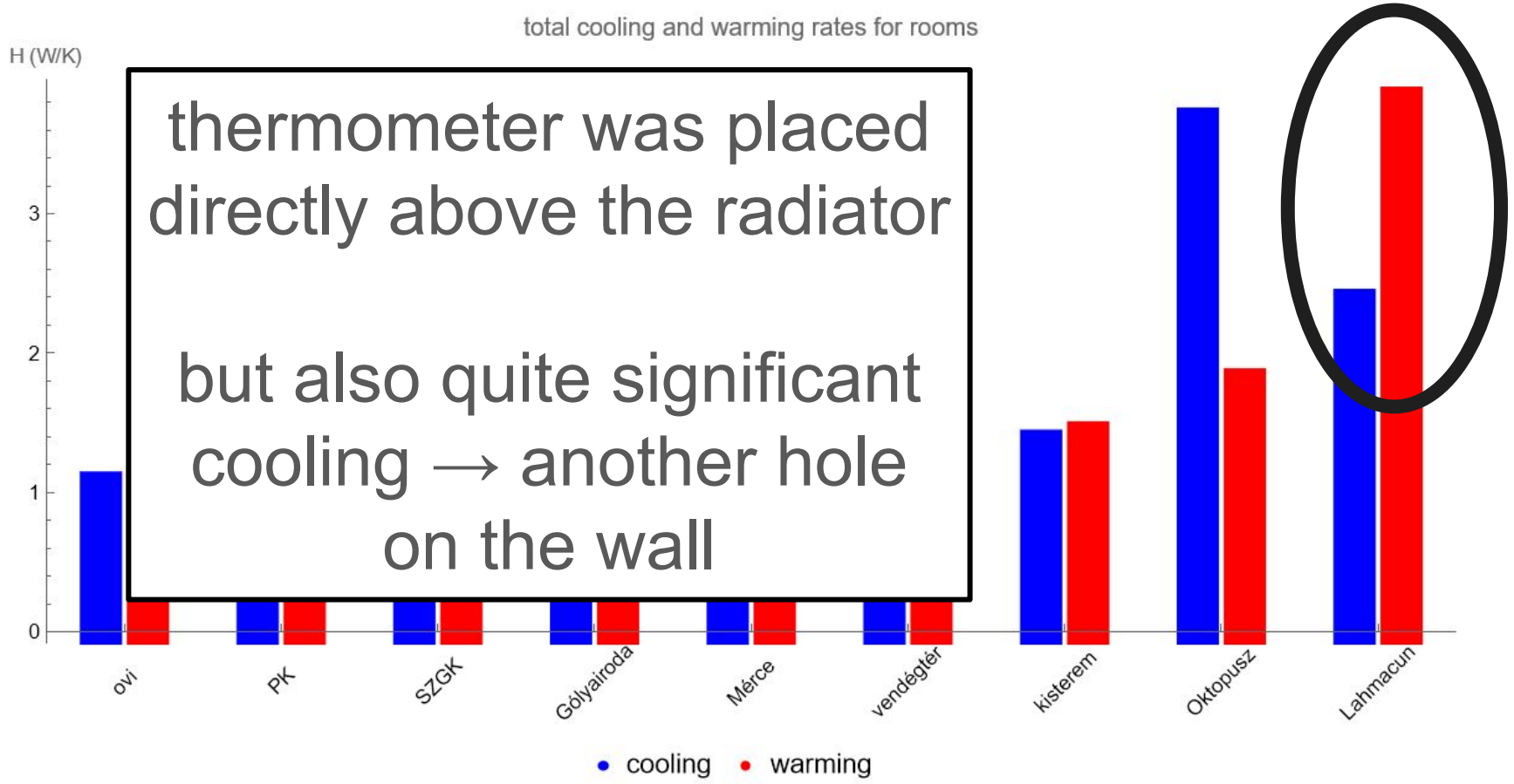
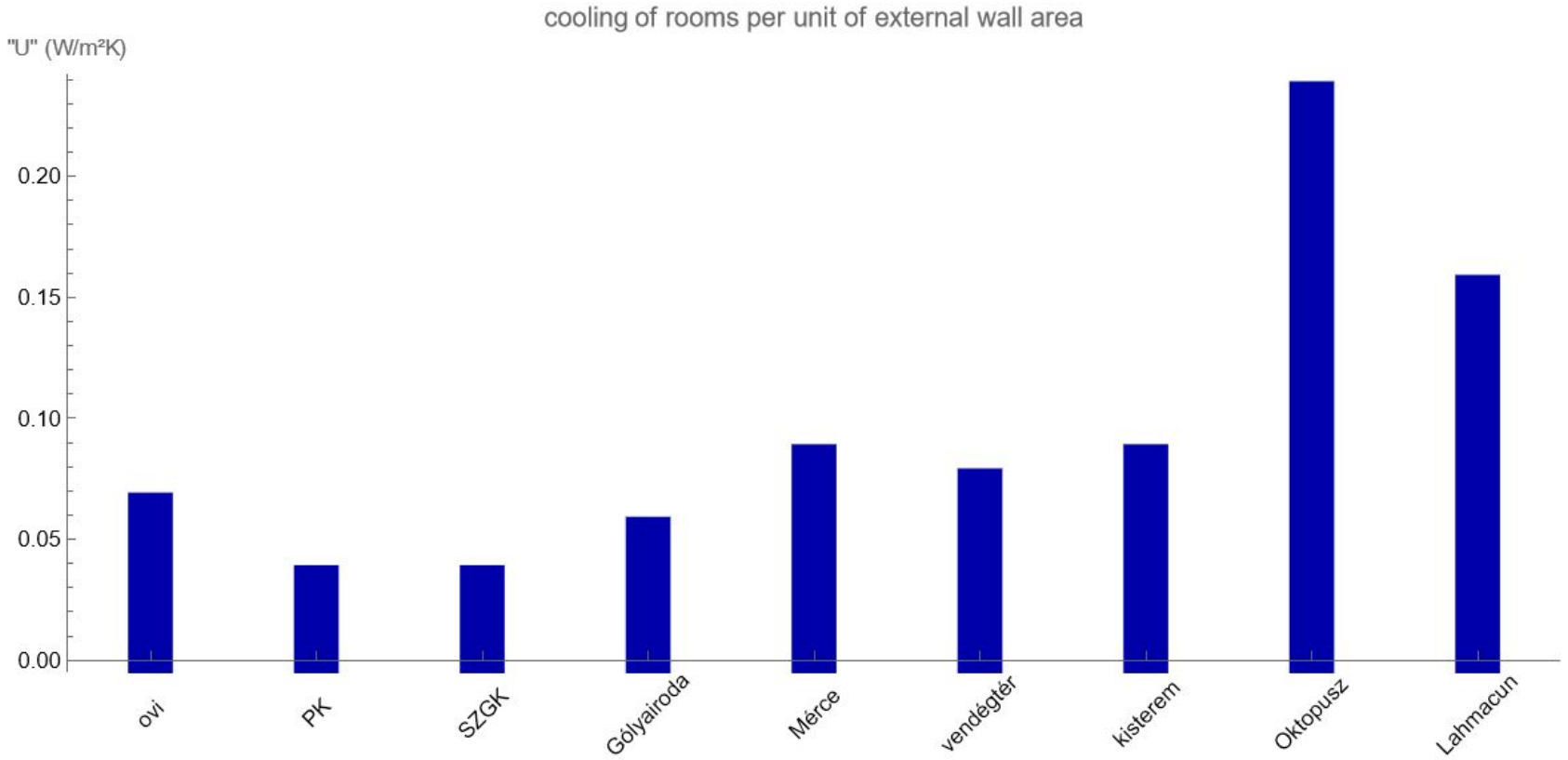


room was impossible to drive above 18 °C
→ first room we've insulated since
(and found a hole on the wall)

4) evaluation of rooms based on cooling and warming data



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



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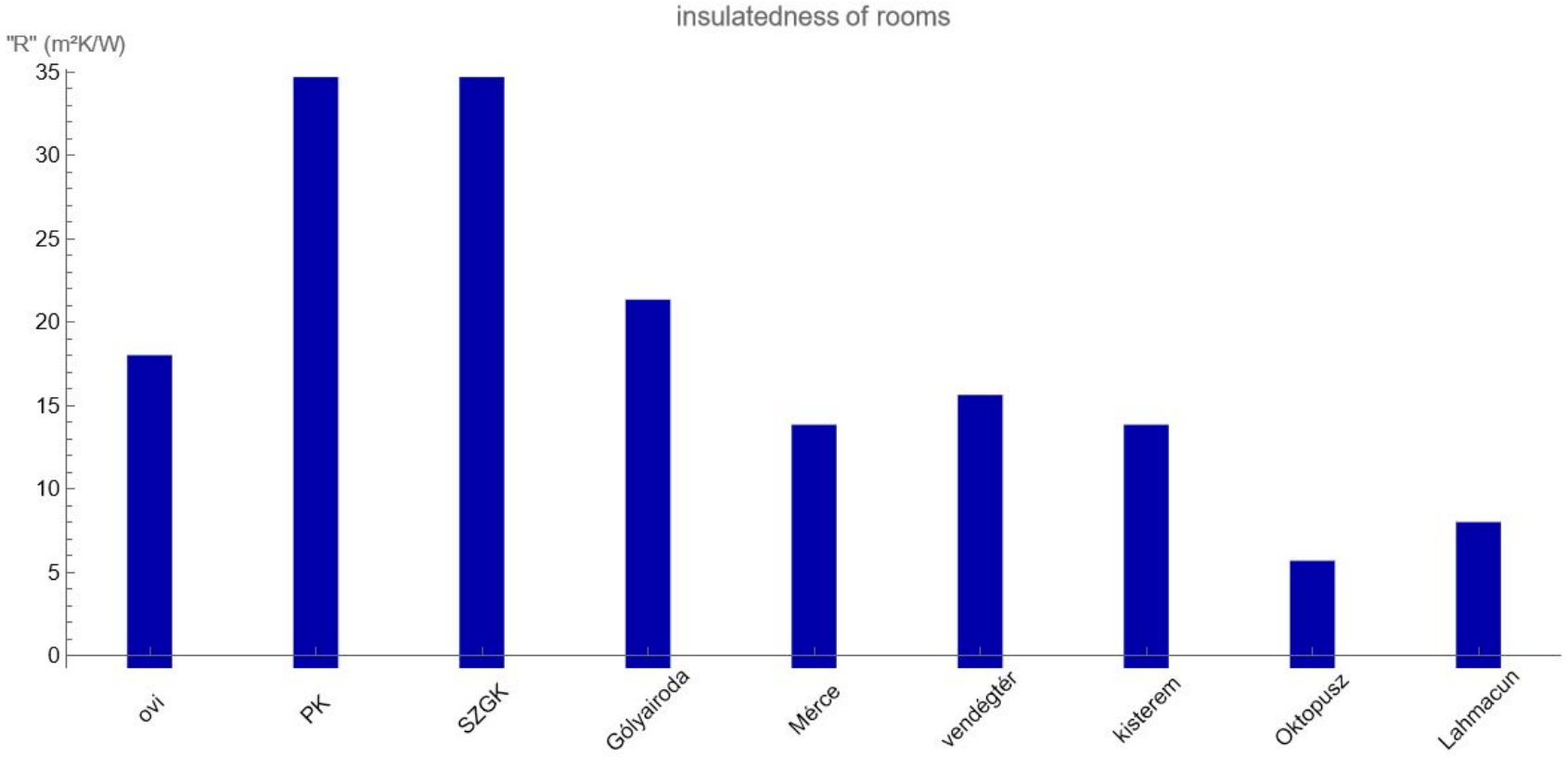
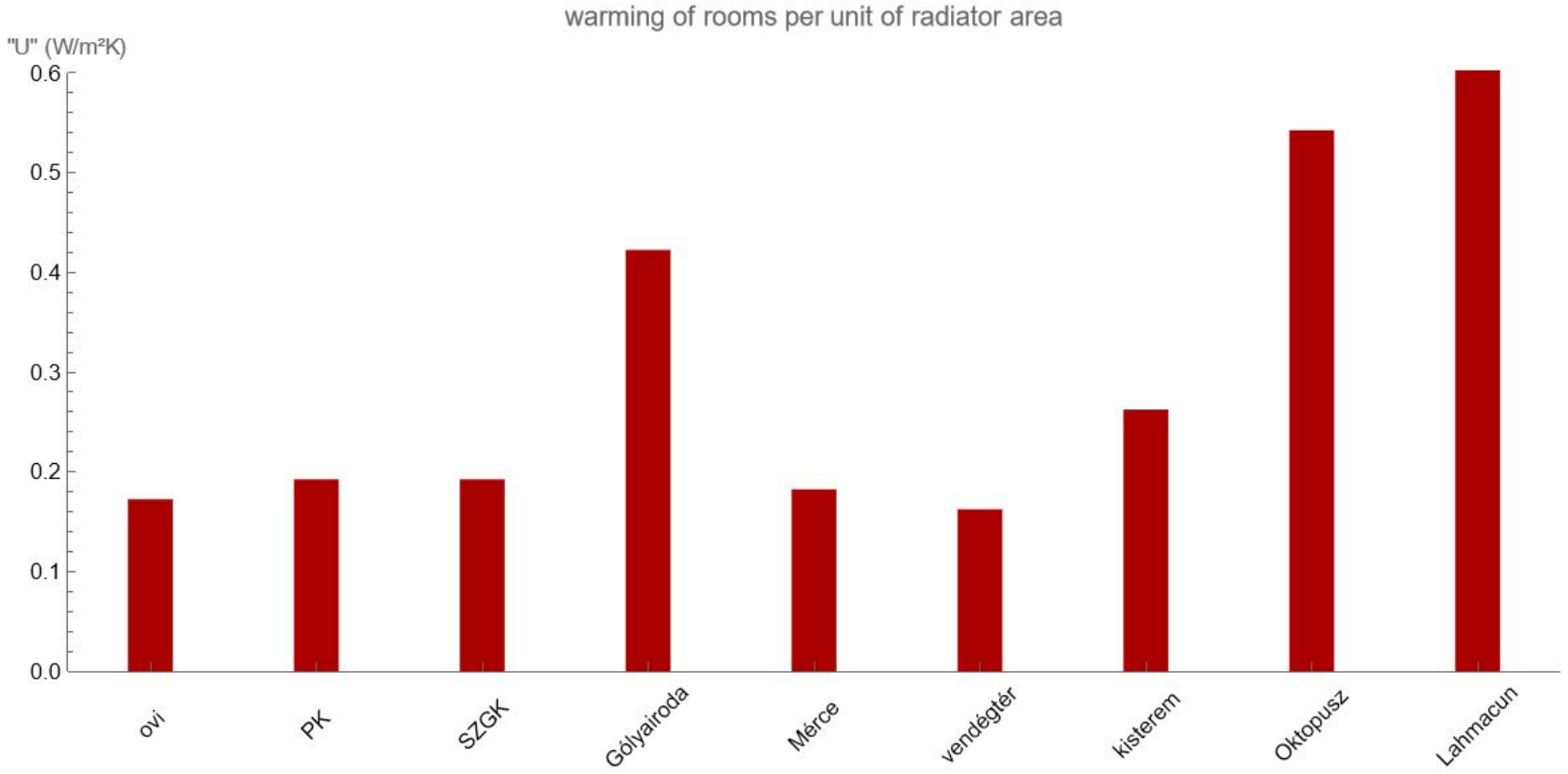


4) evaluation of rooms based on cooling and warming data: warming sources



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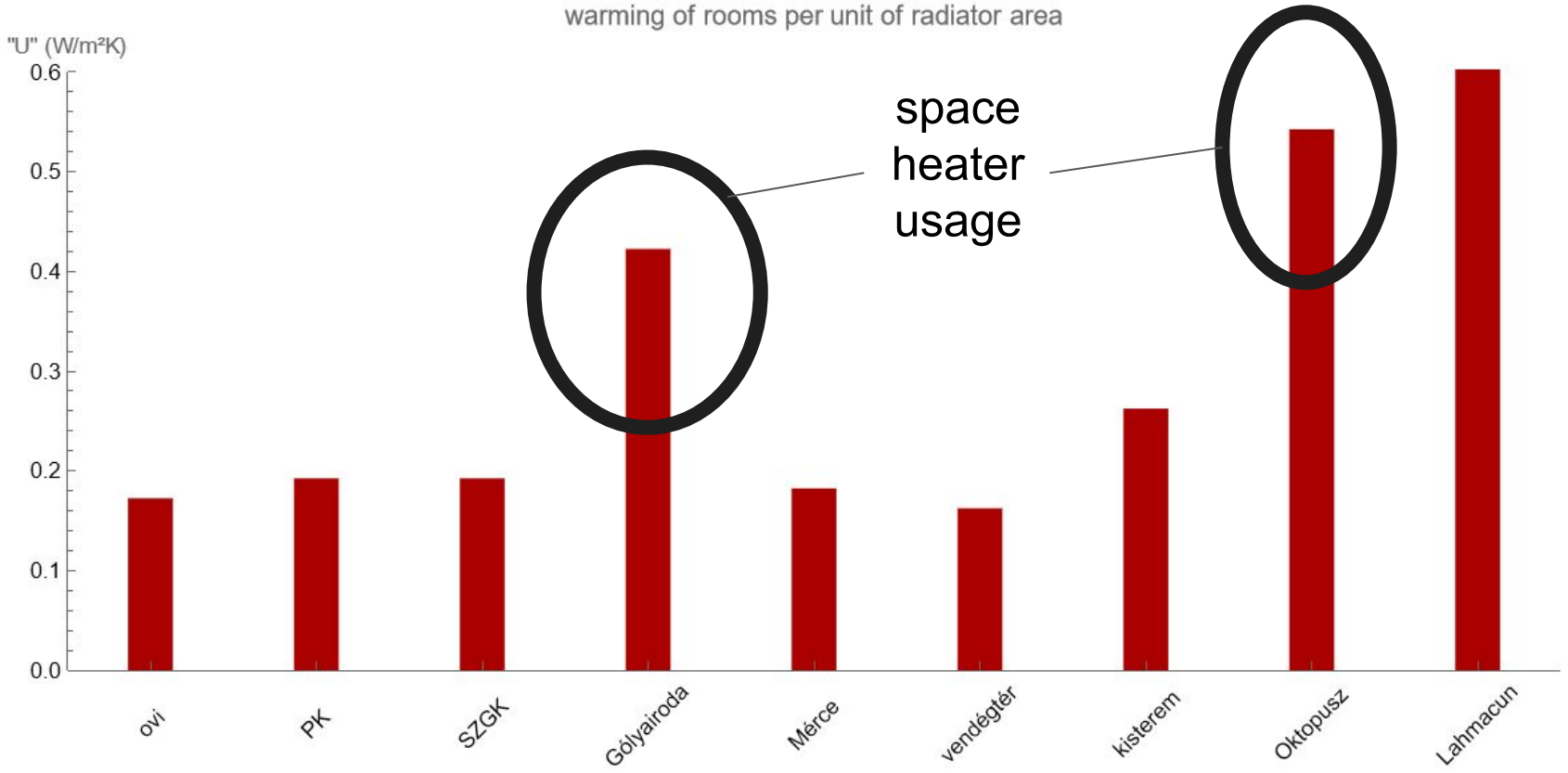

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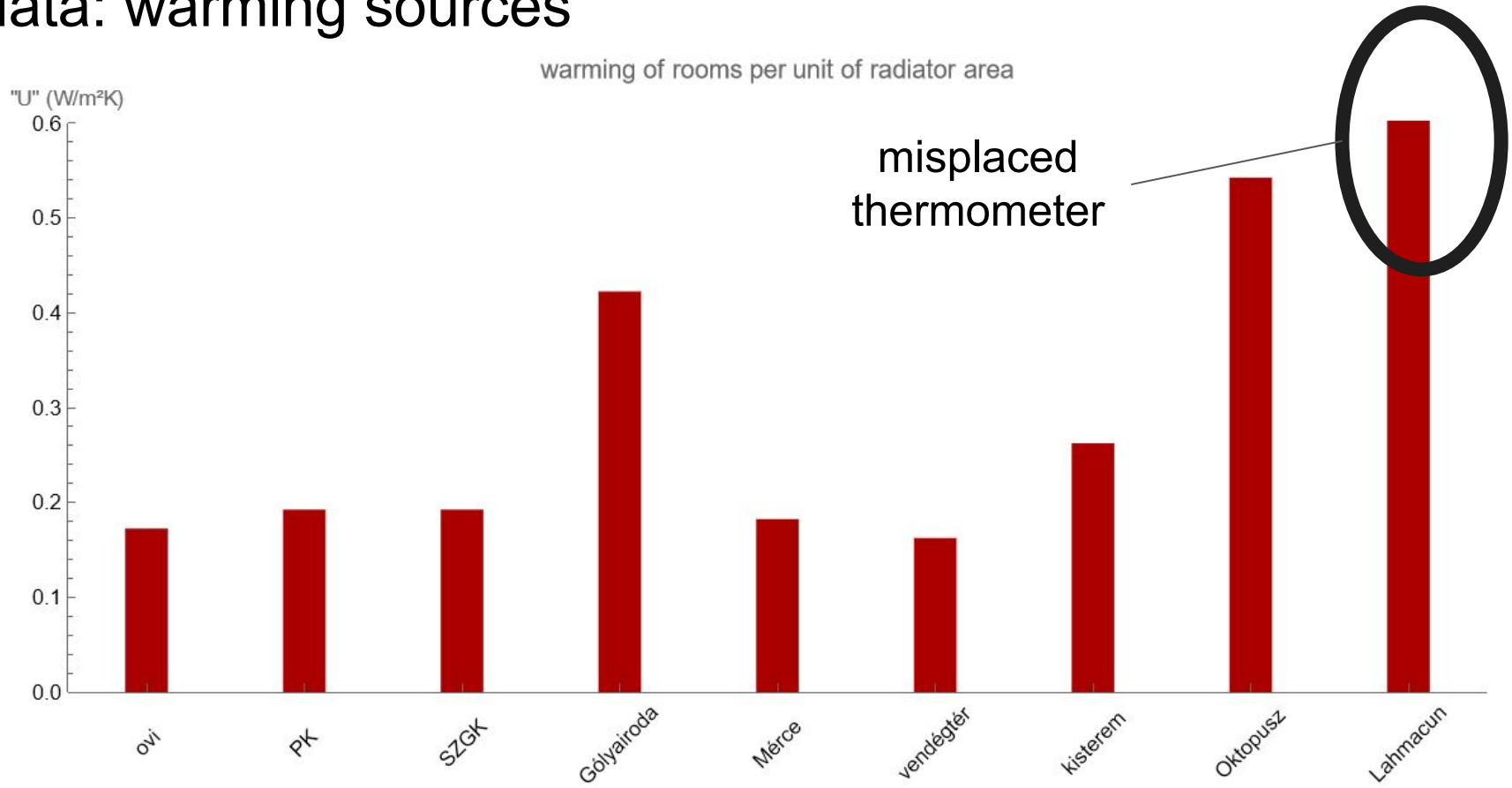

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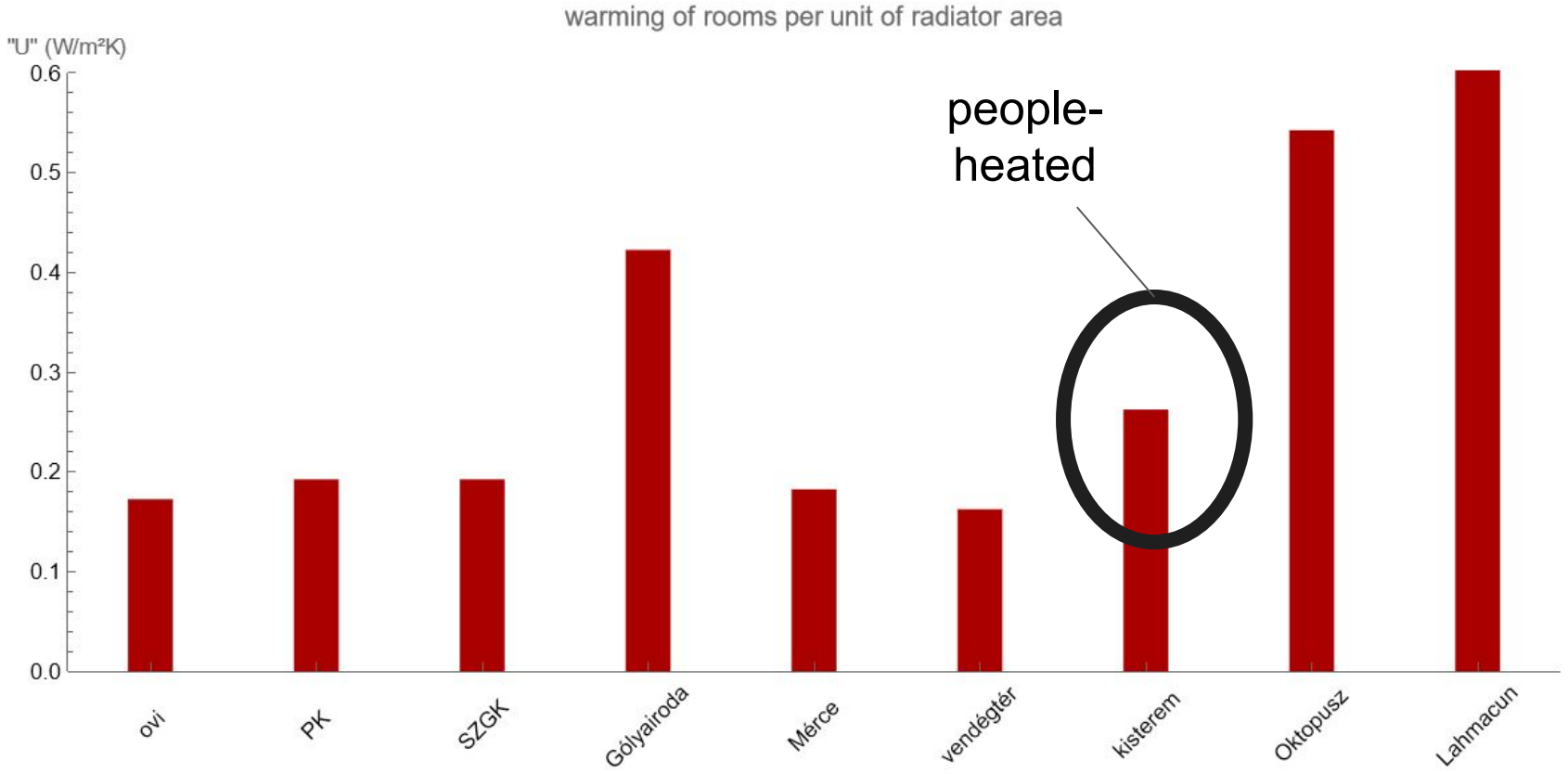

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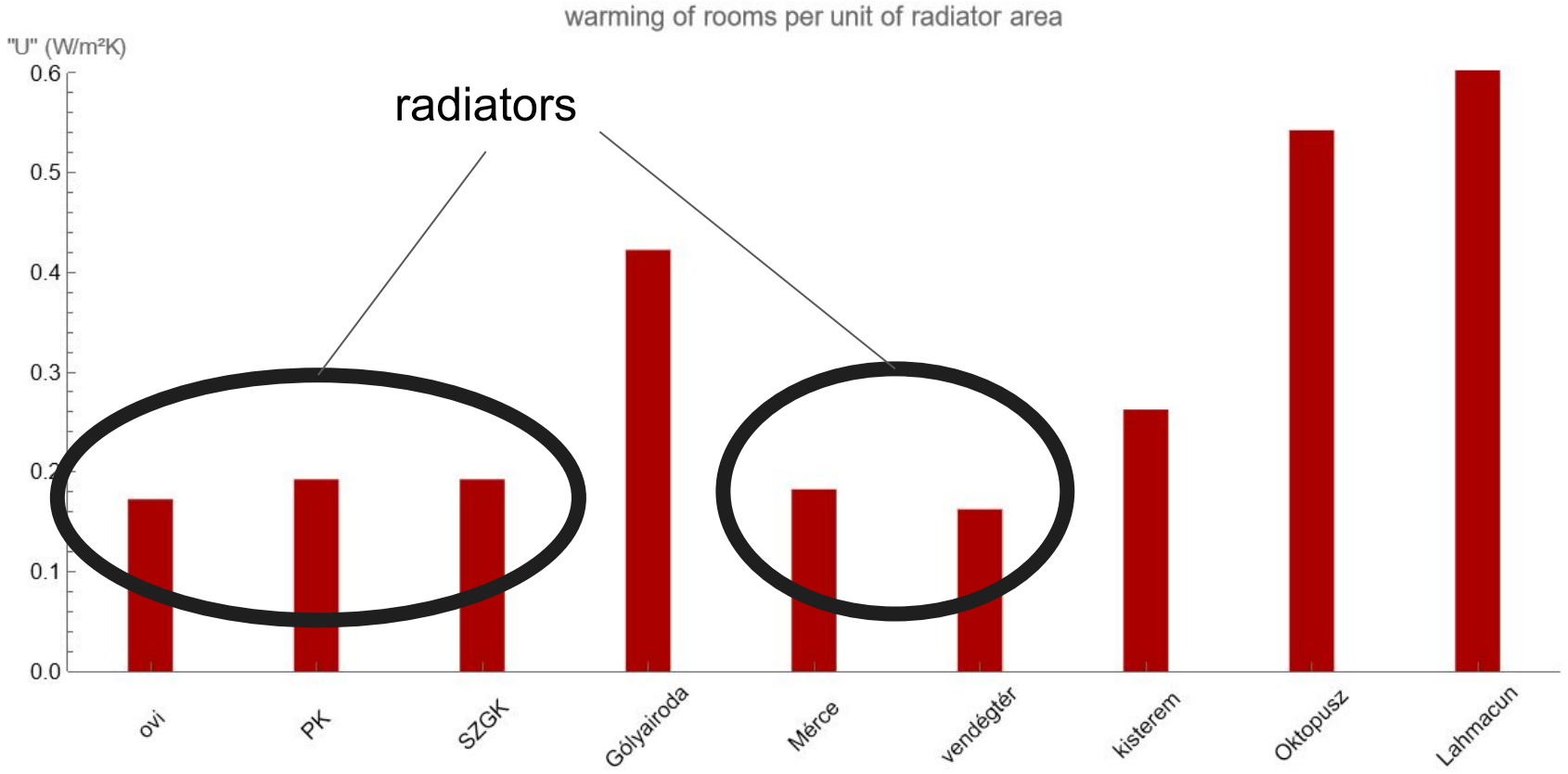
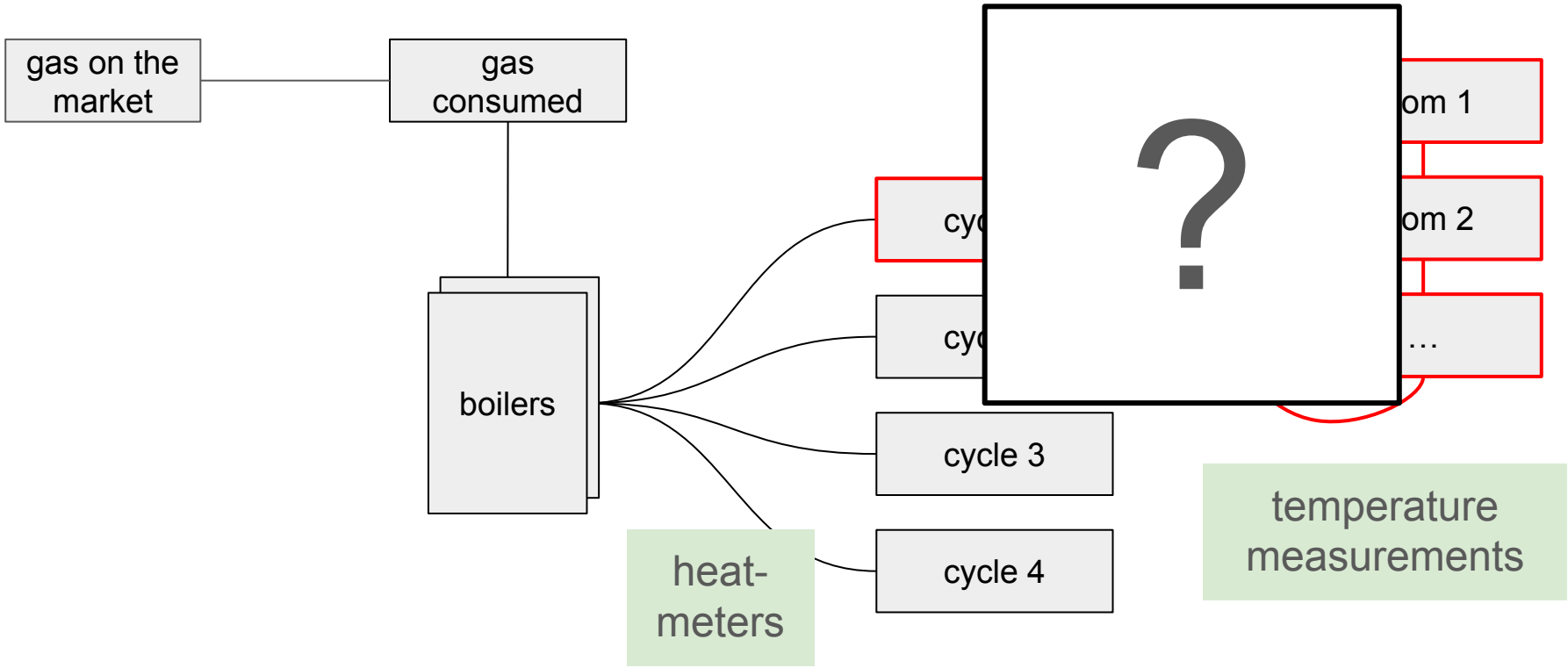


from heat delivered on cycles to heat taken up by rooms



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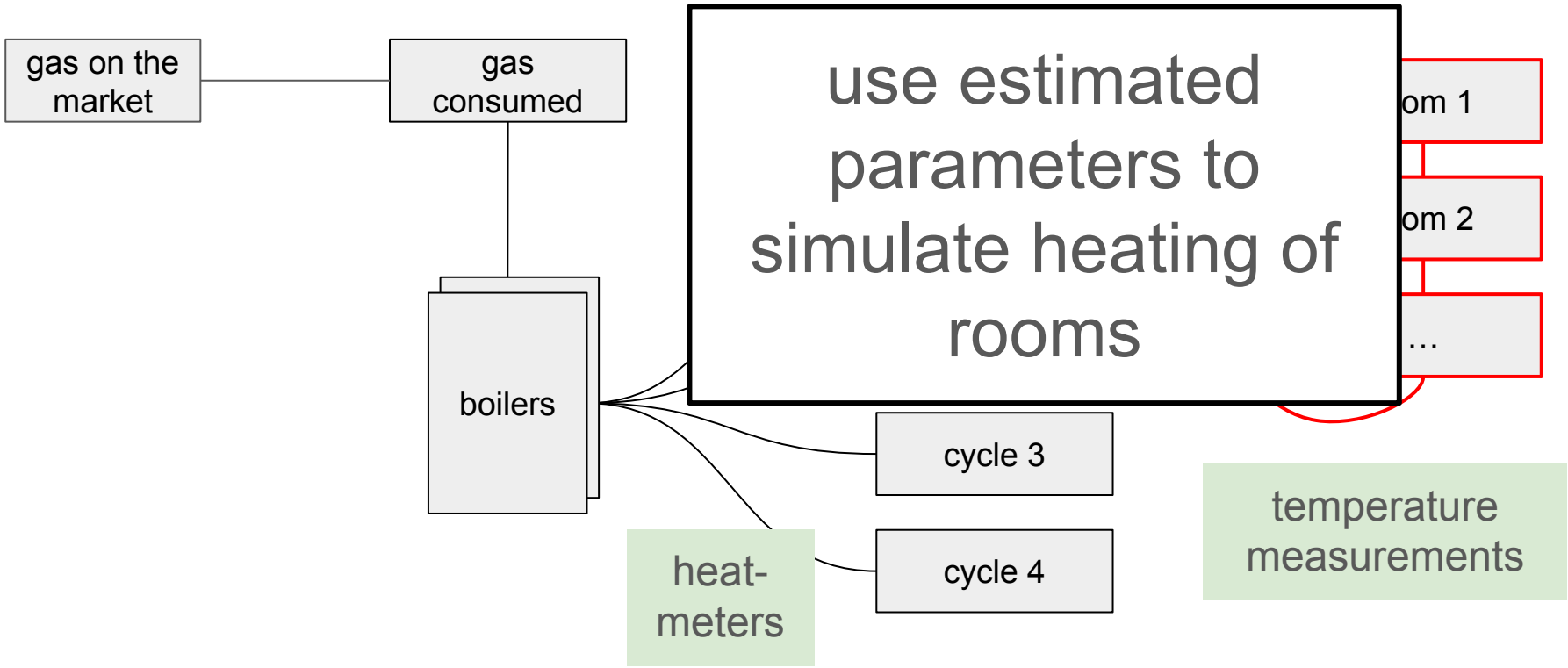
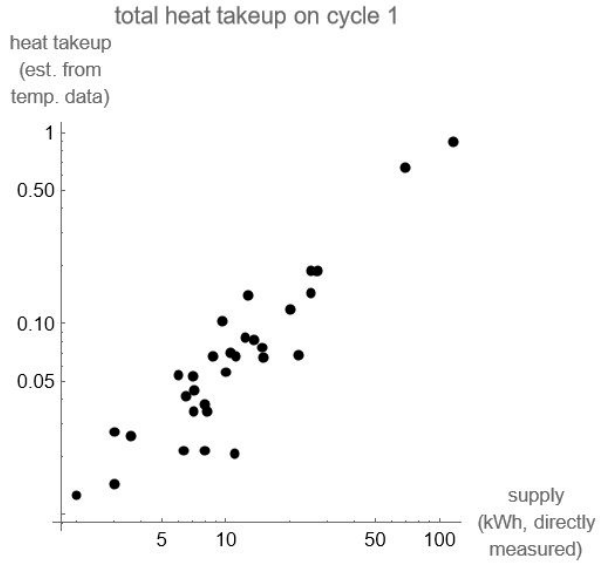
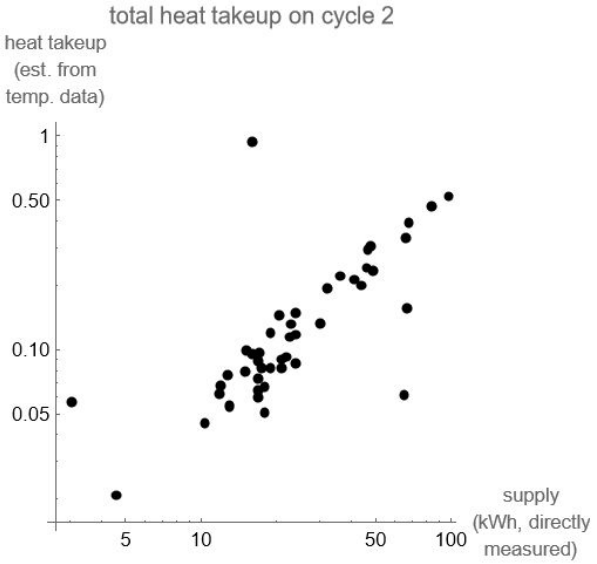
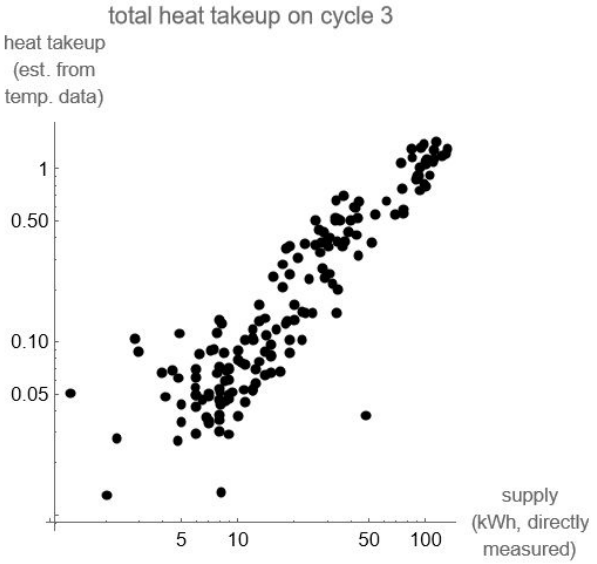


5) bridging the gap between heat per cycle to heat per room



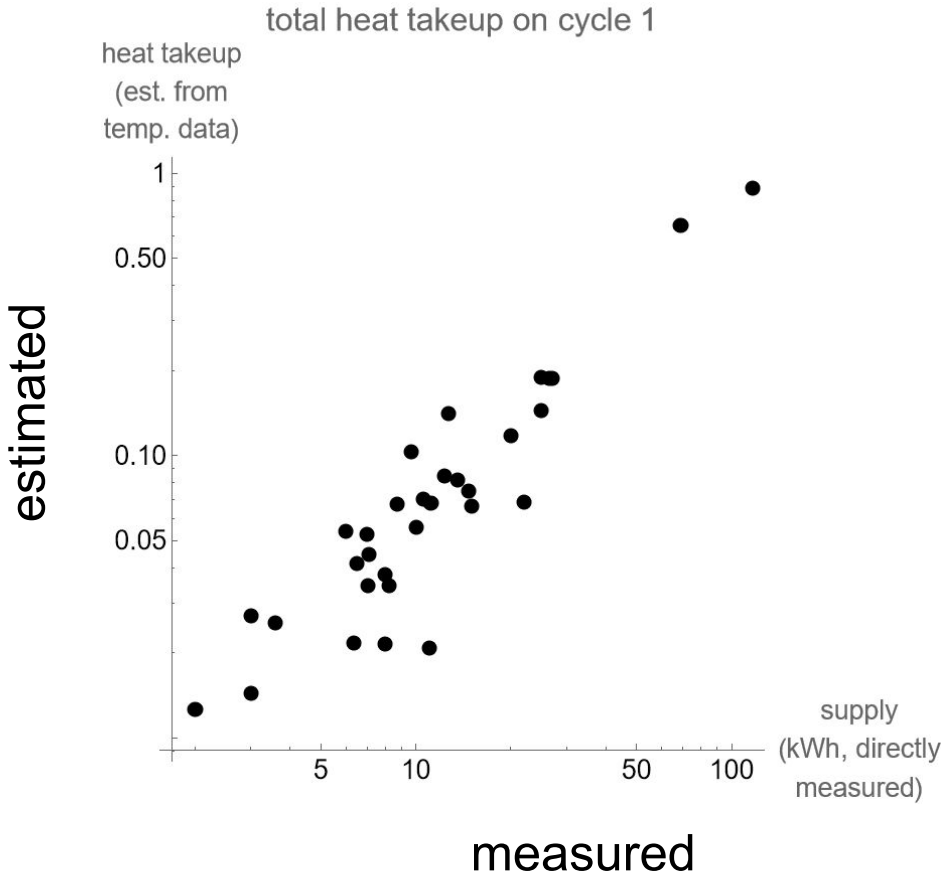




estimated

measured

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



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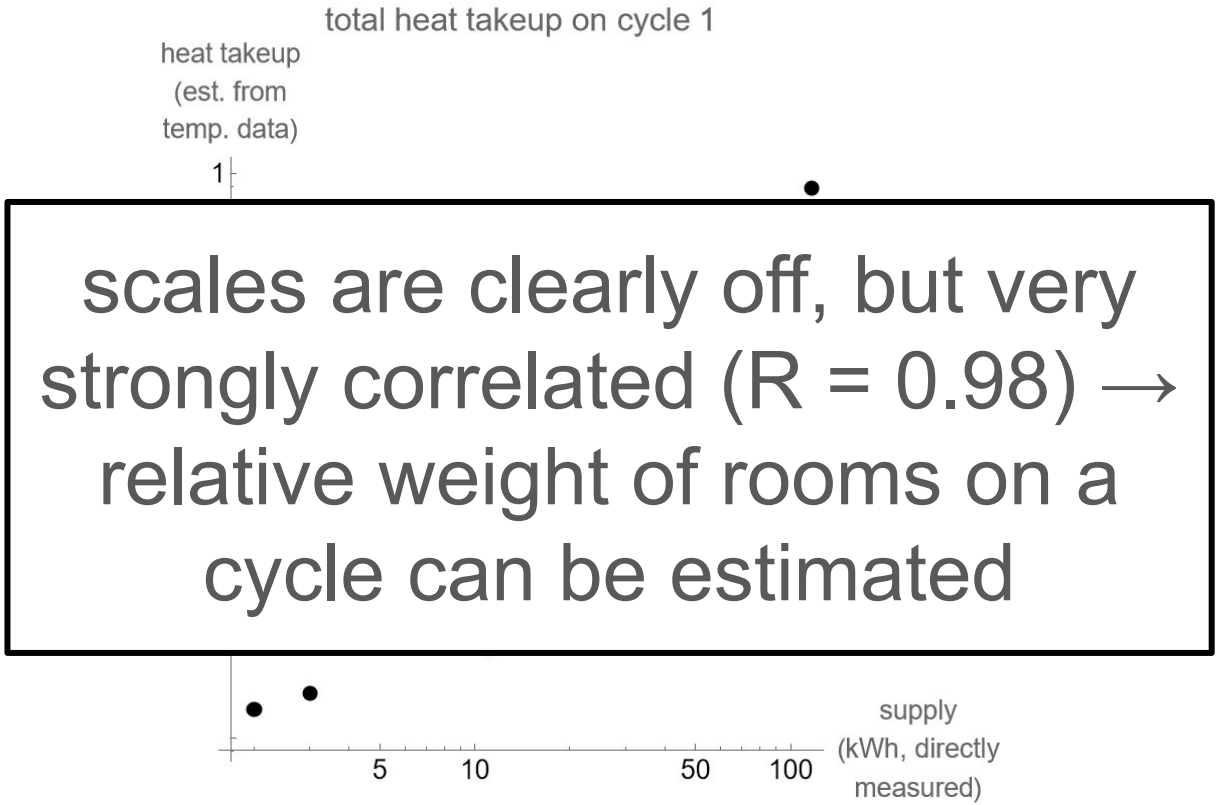
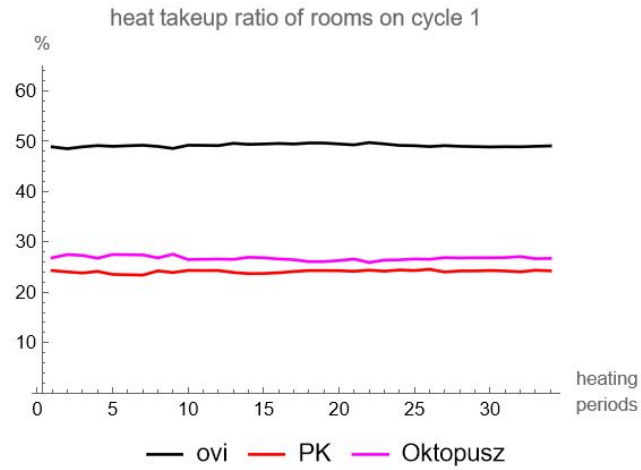
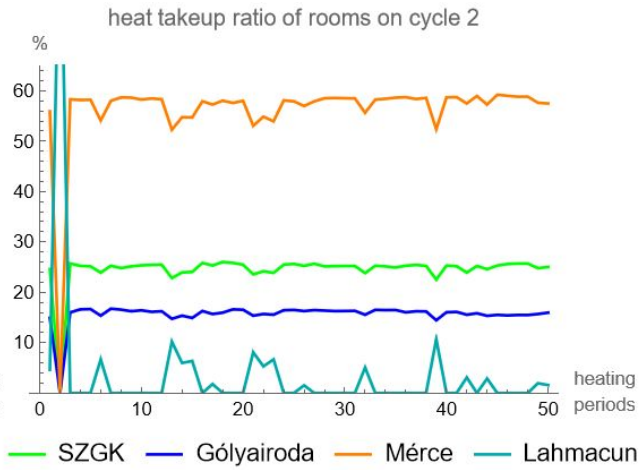


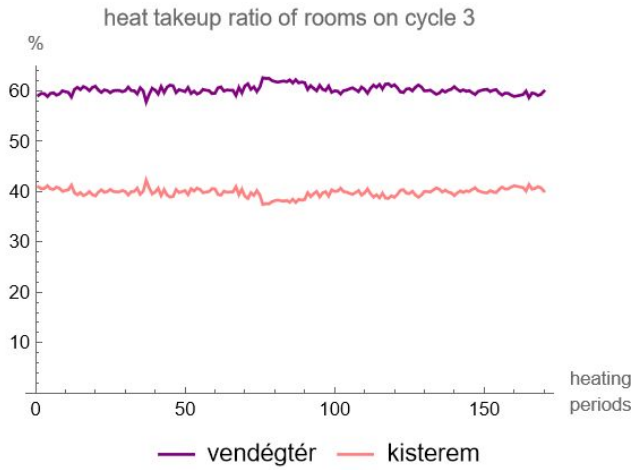
scales are clearly off, but very strongly correlated (R = 0.98) → relative weight of rooms on a cycle can be estimated

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

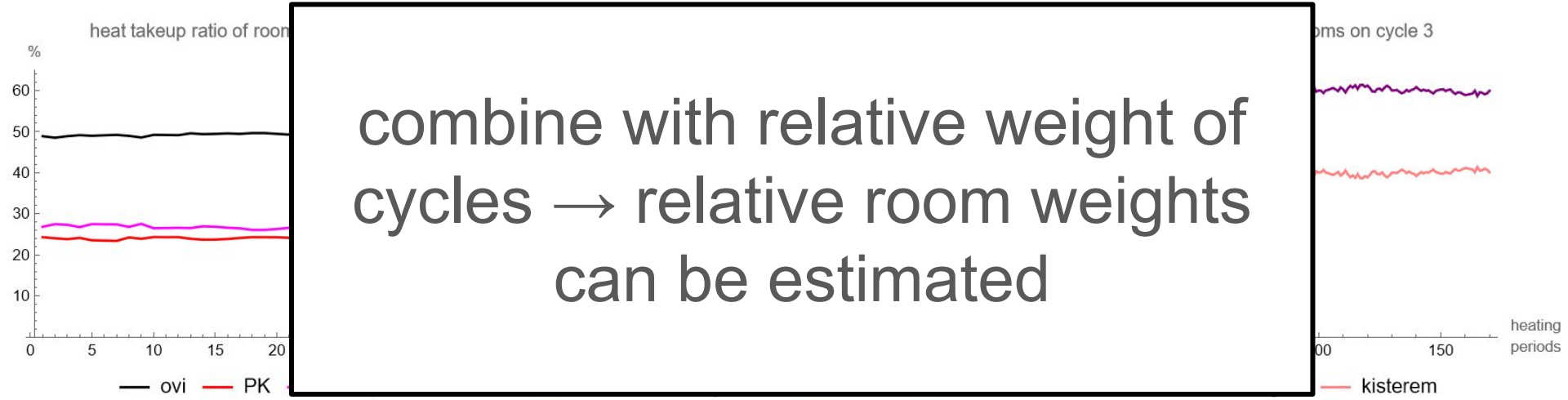






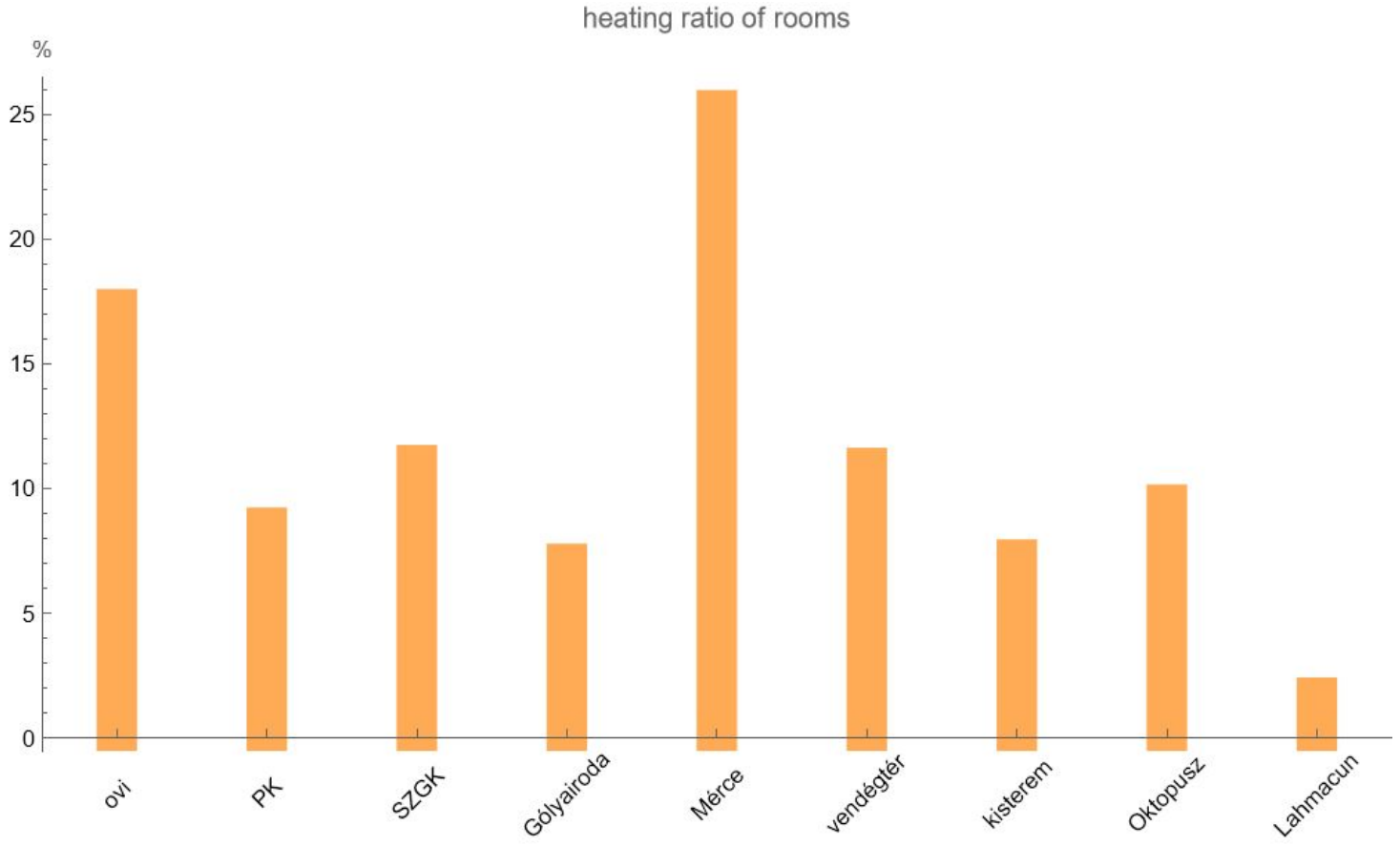
5) bridging the gap between heat per cycle to heat per room

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

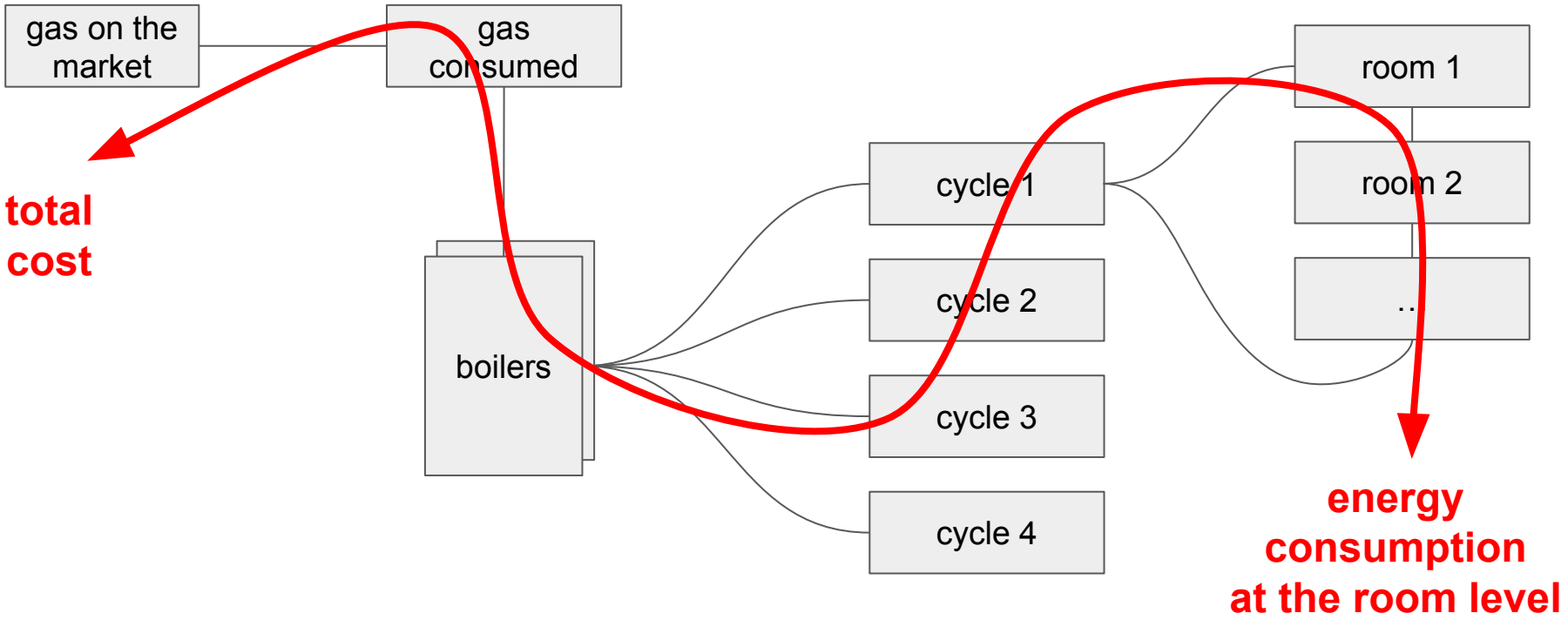


combine with relative weight of cycles → relative room weights can be estimated

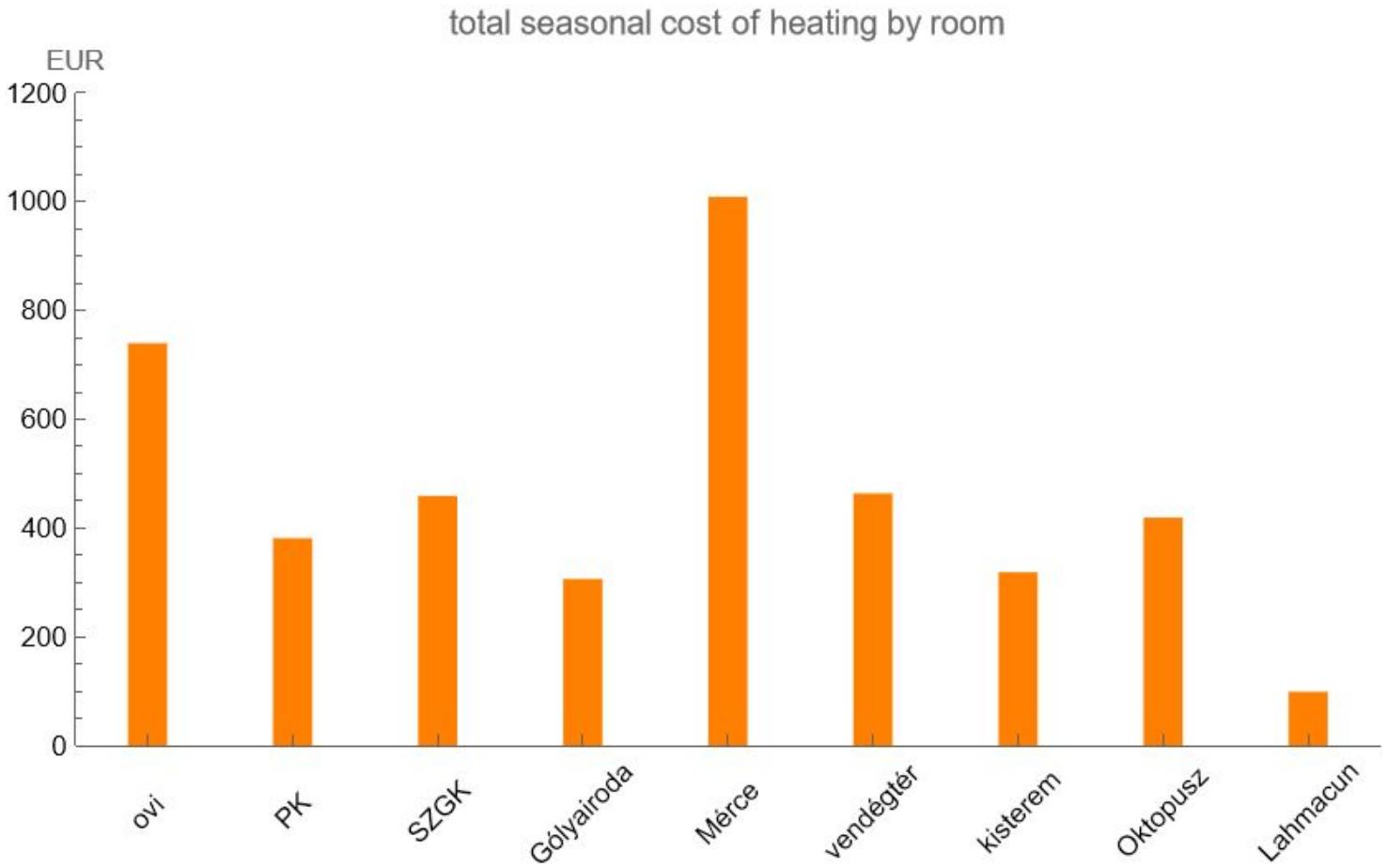
5) bridging the gap between heat per cycle to heat per room



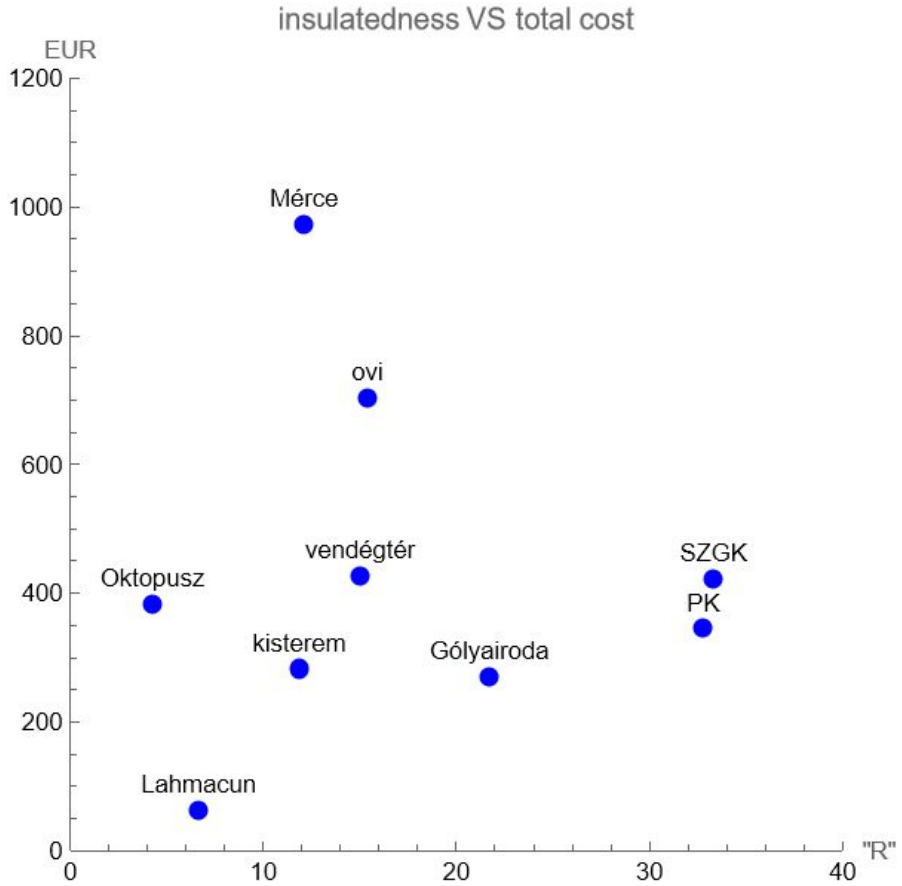
finally: cost per room



6) how much did it cost to heat each room?



7) what drives cost?



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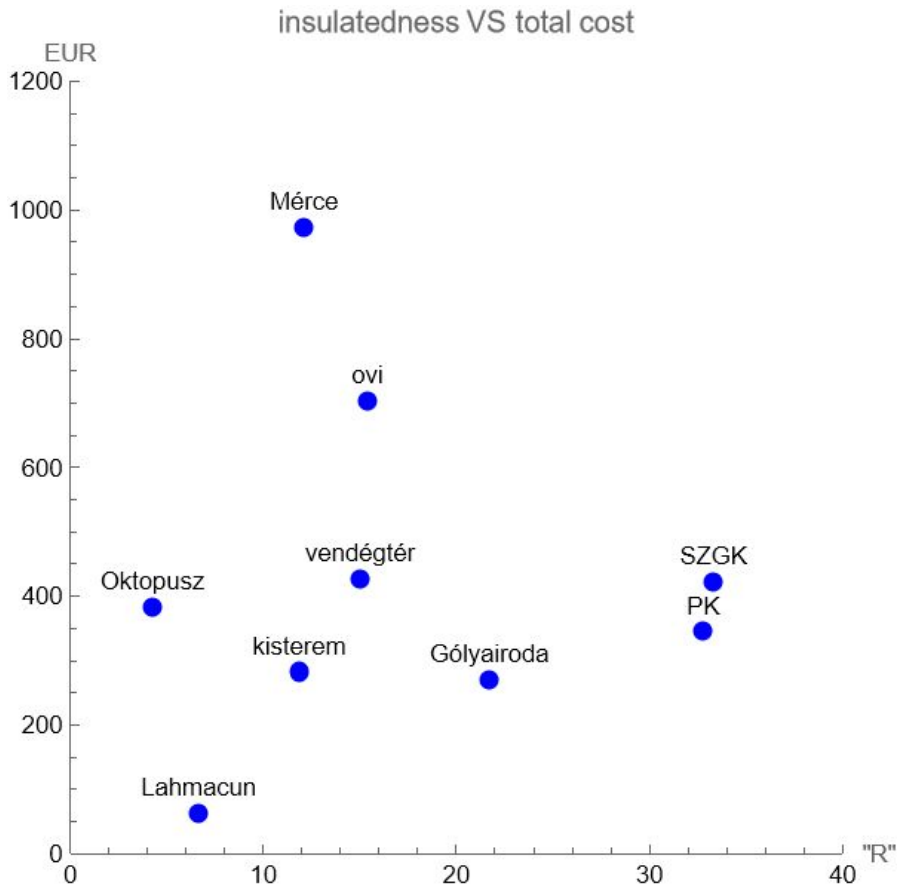
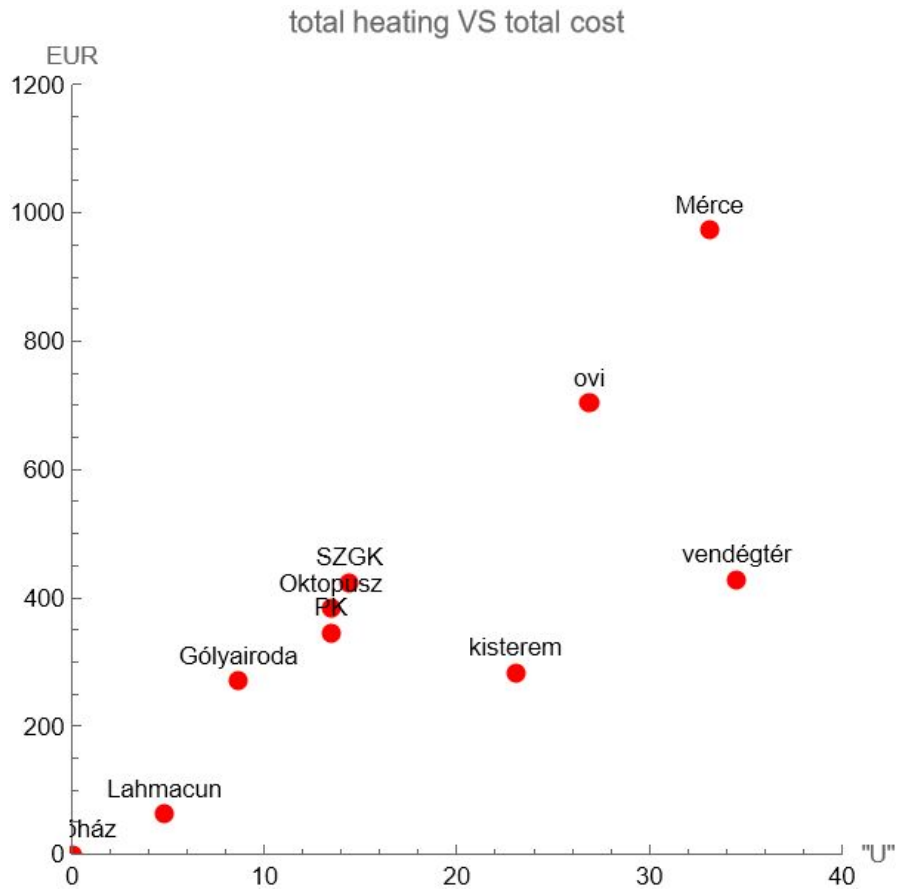
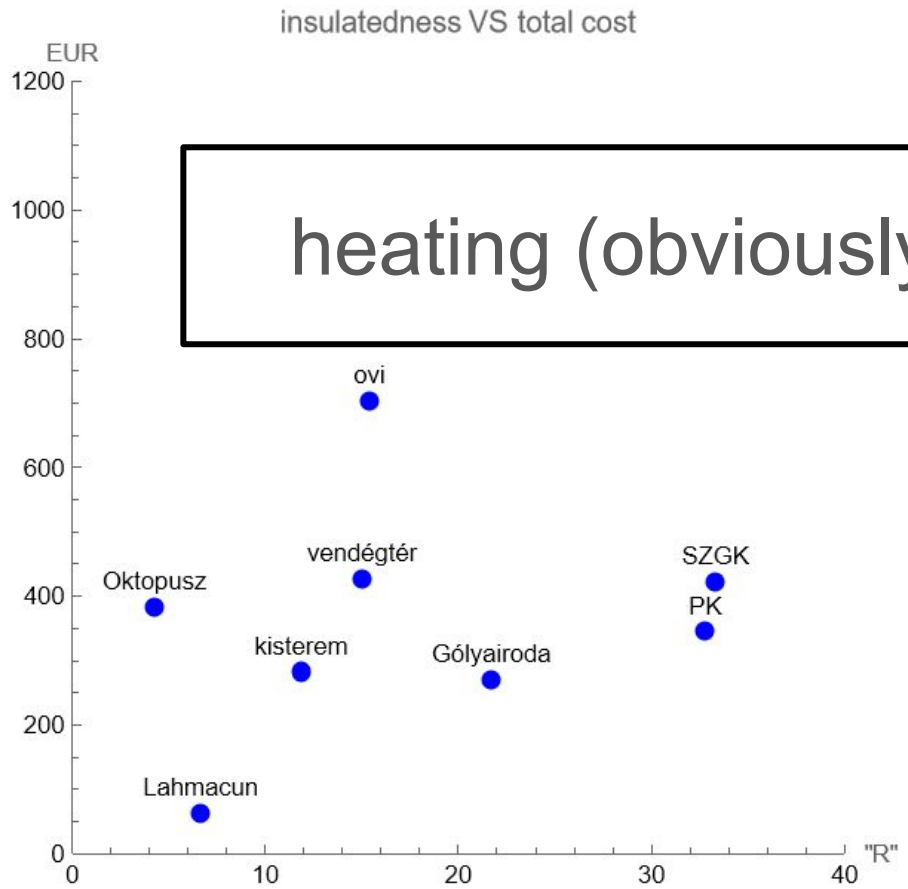
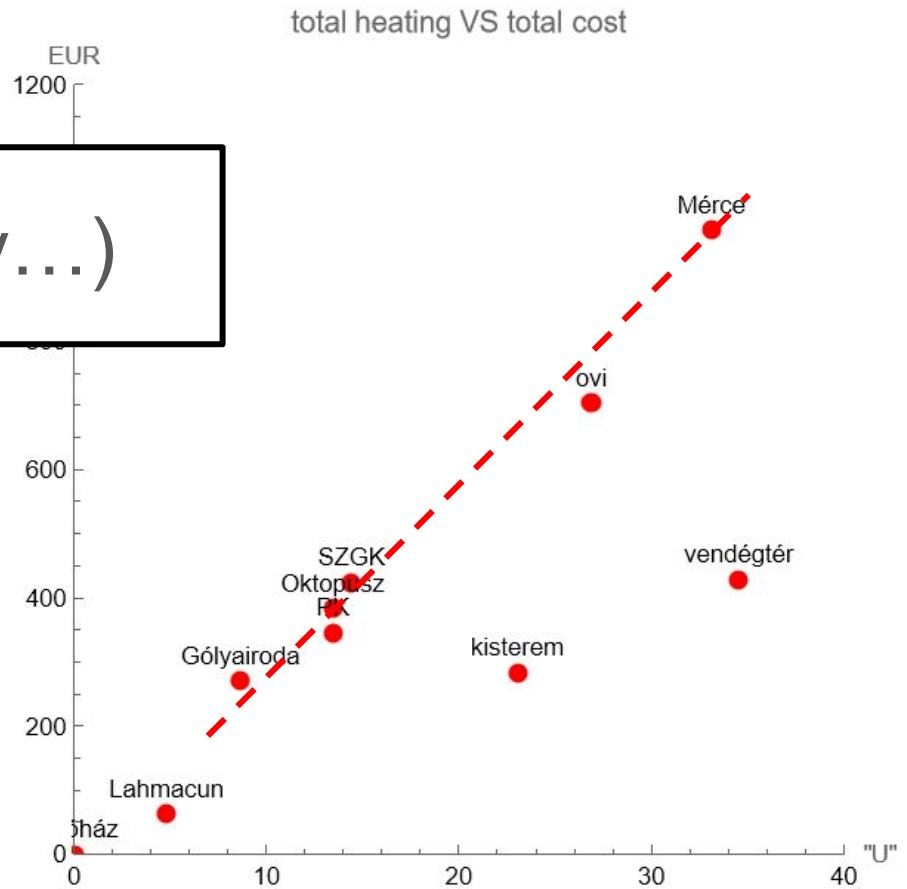




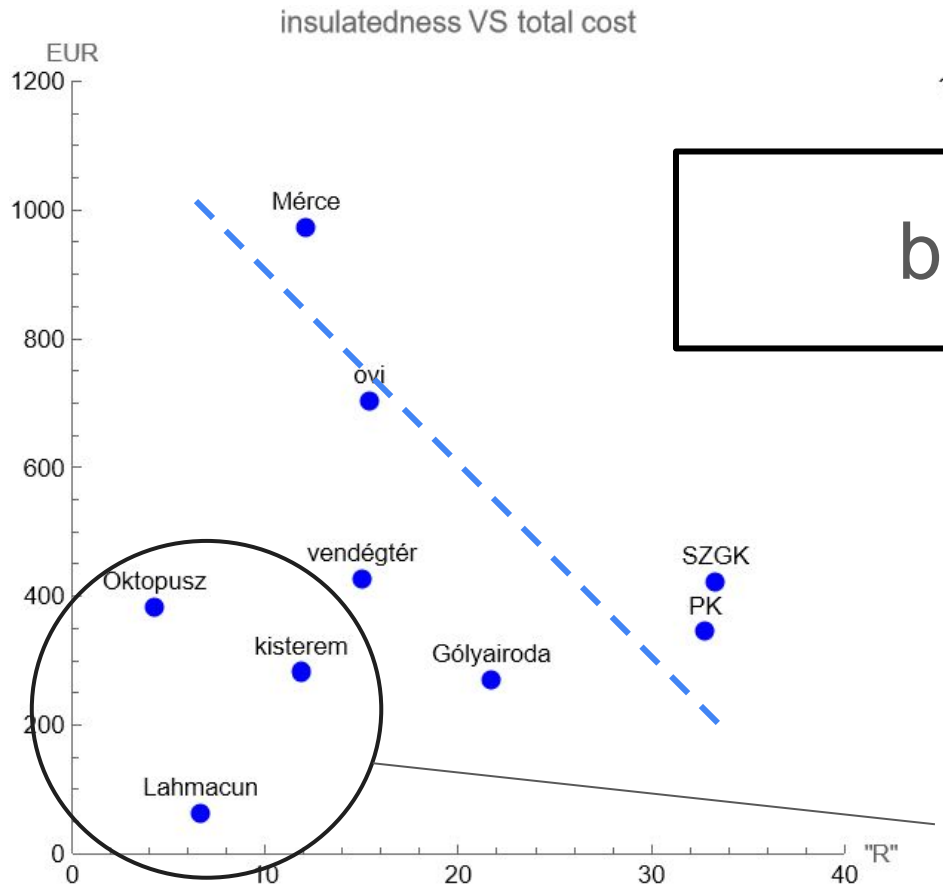
7) what drives cost?

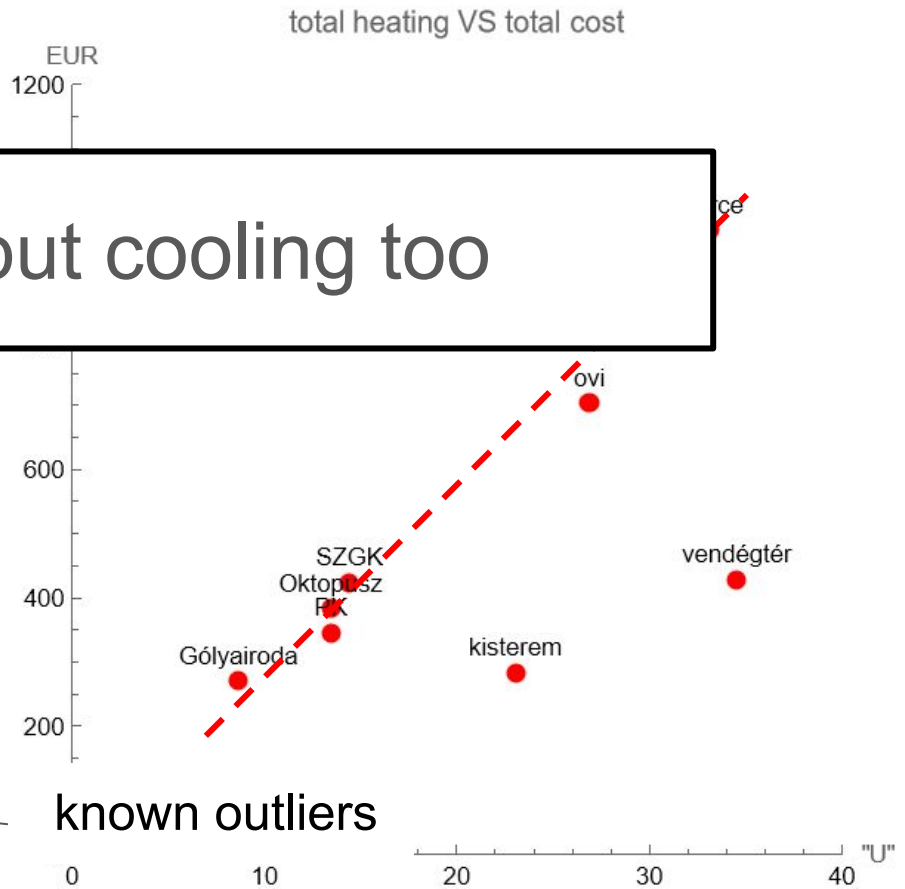


heating (obviously…)



7) what drives cost?

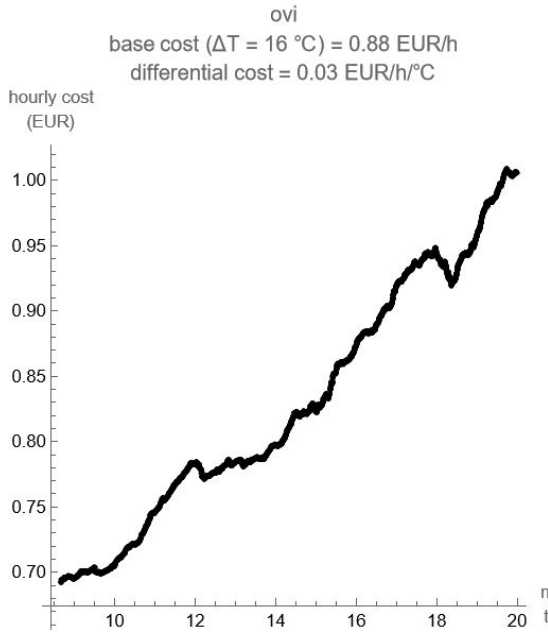


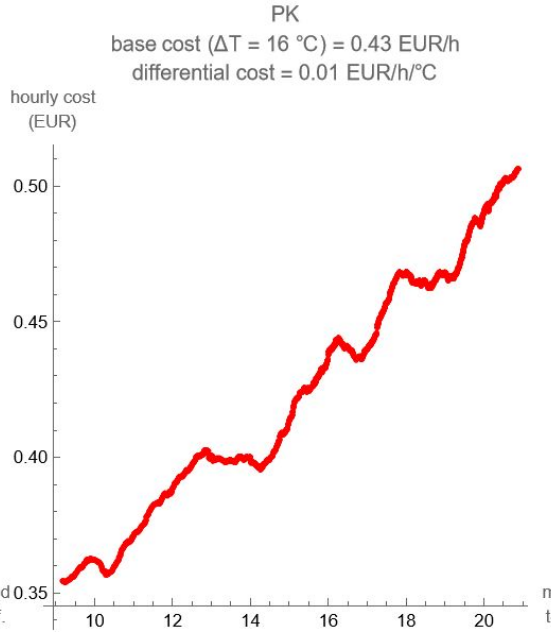


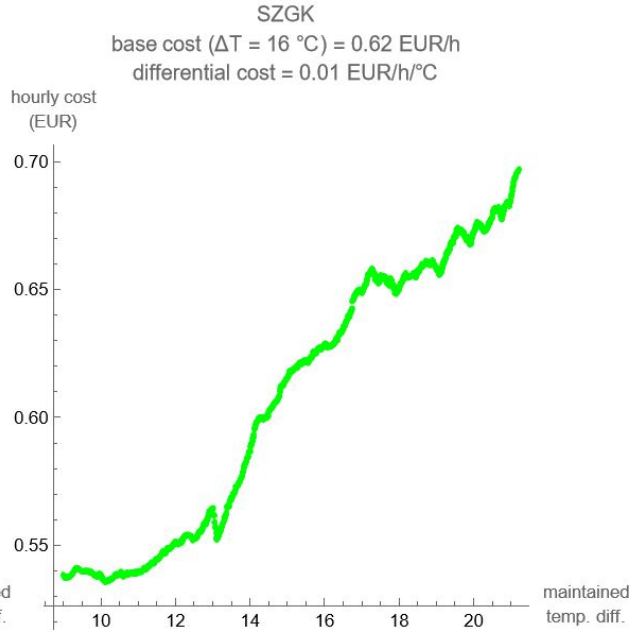
but cooling too

known outliers

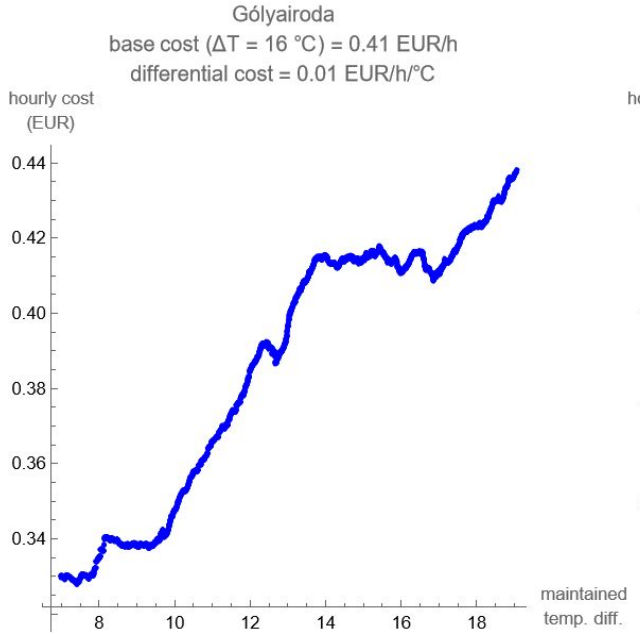
8) how much does one degree of heating for one hour cost?

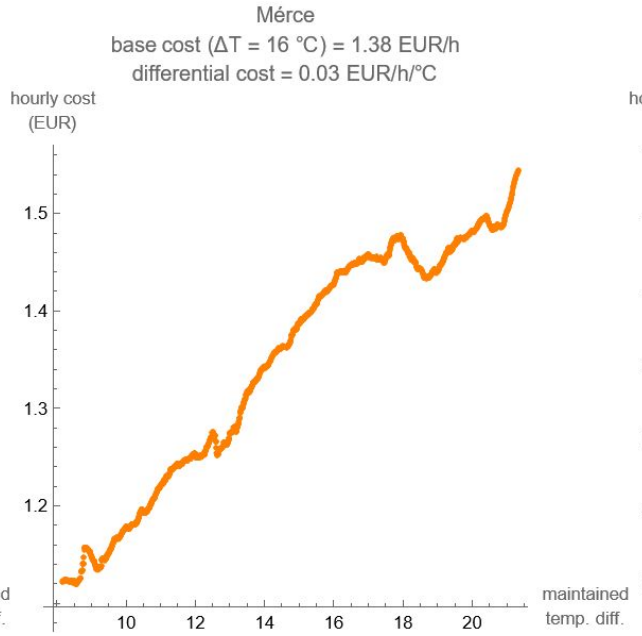


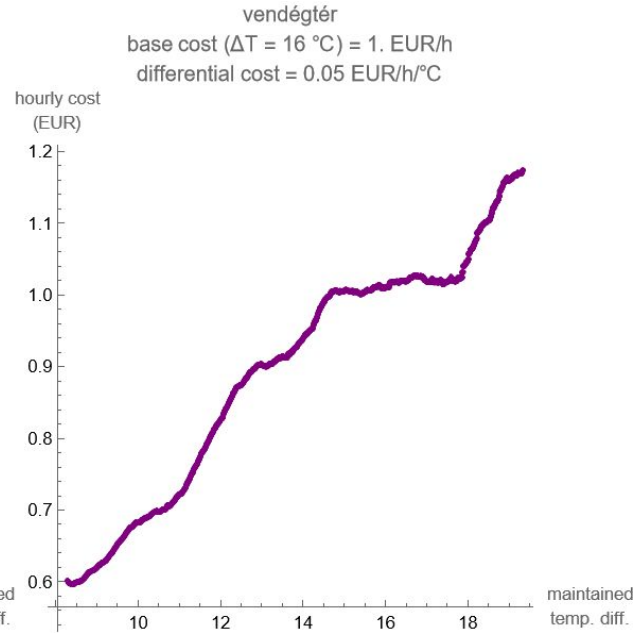




8) how much does one degree of heating for one hour cost?







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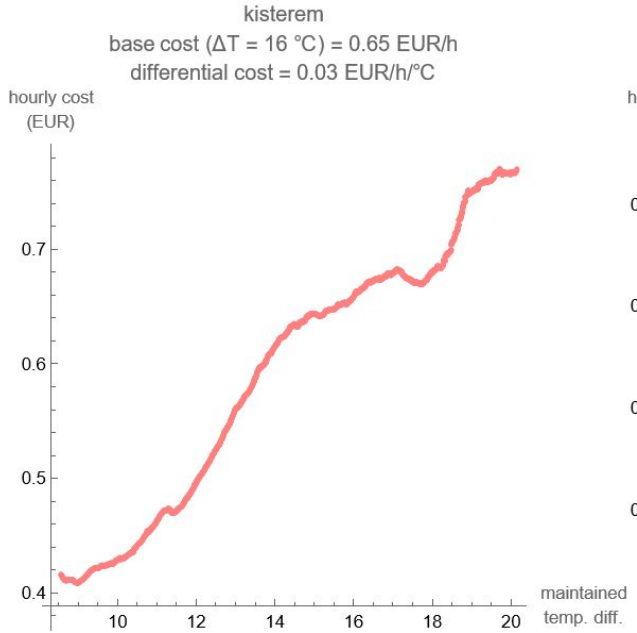

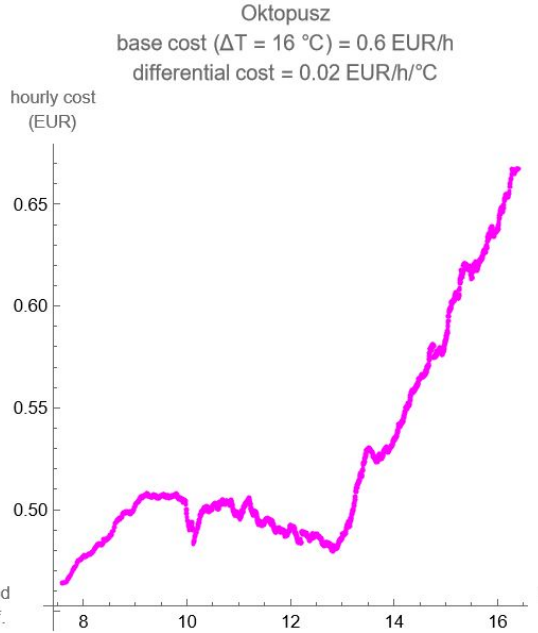

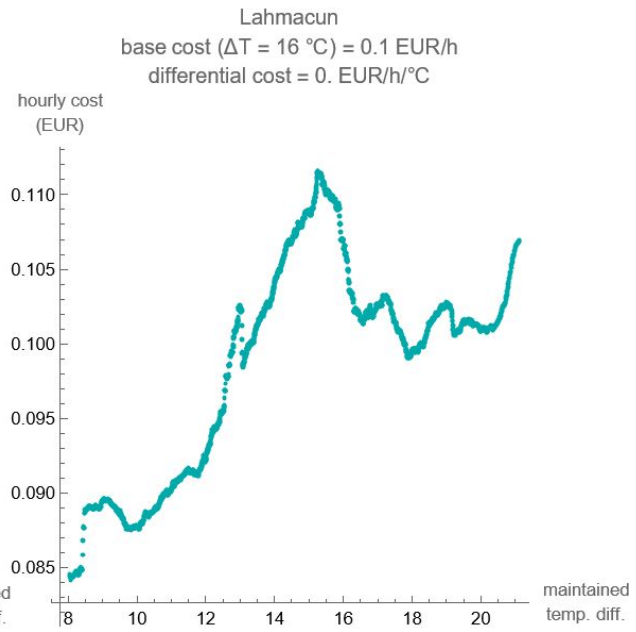

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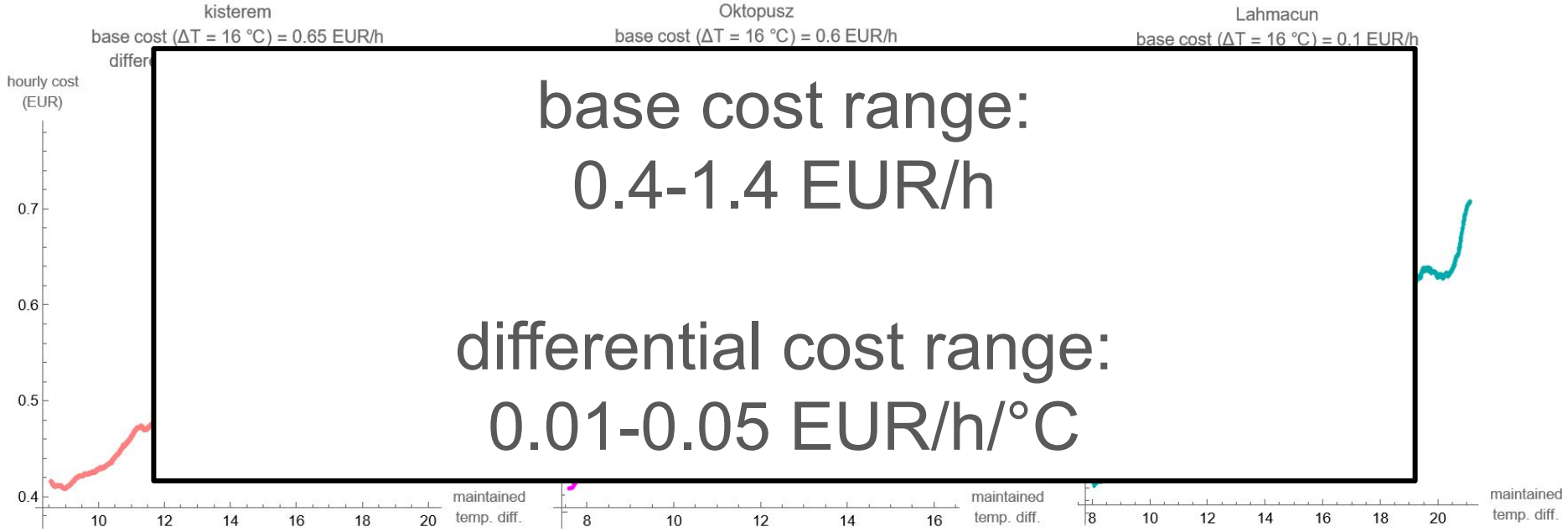
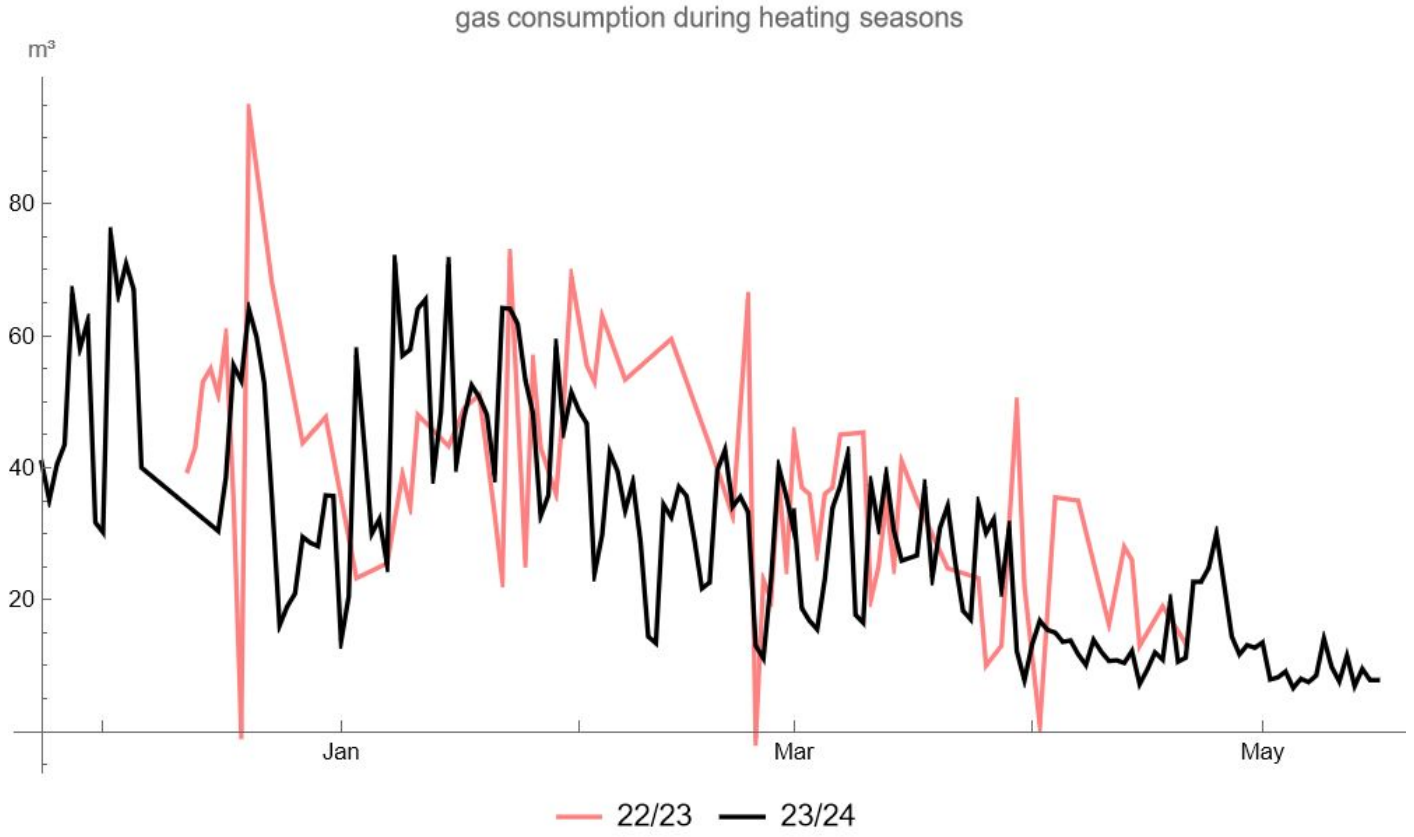


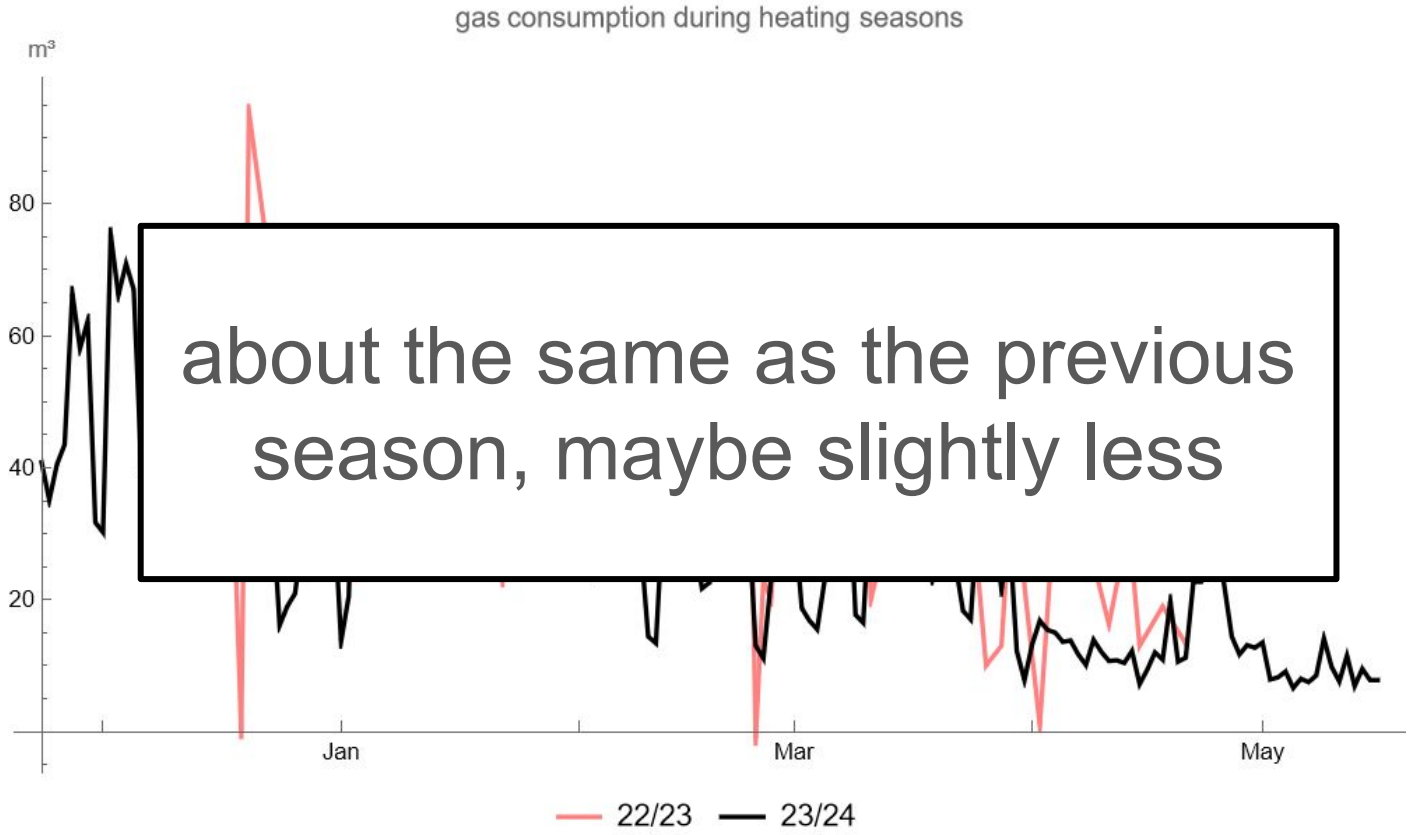
base cost range:
0.4-1.4 EUR/h

differential cost range:
0.01-0.05 EUR/h/°C

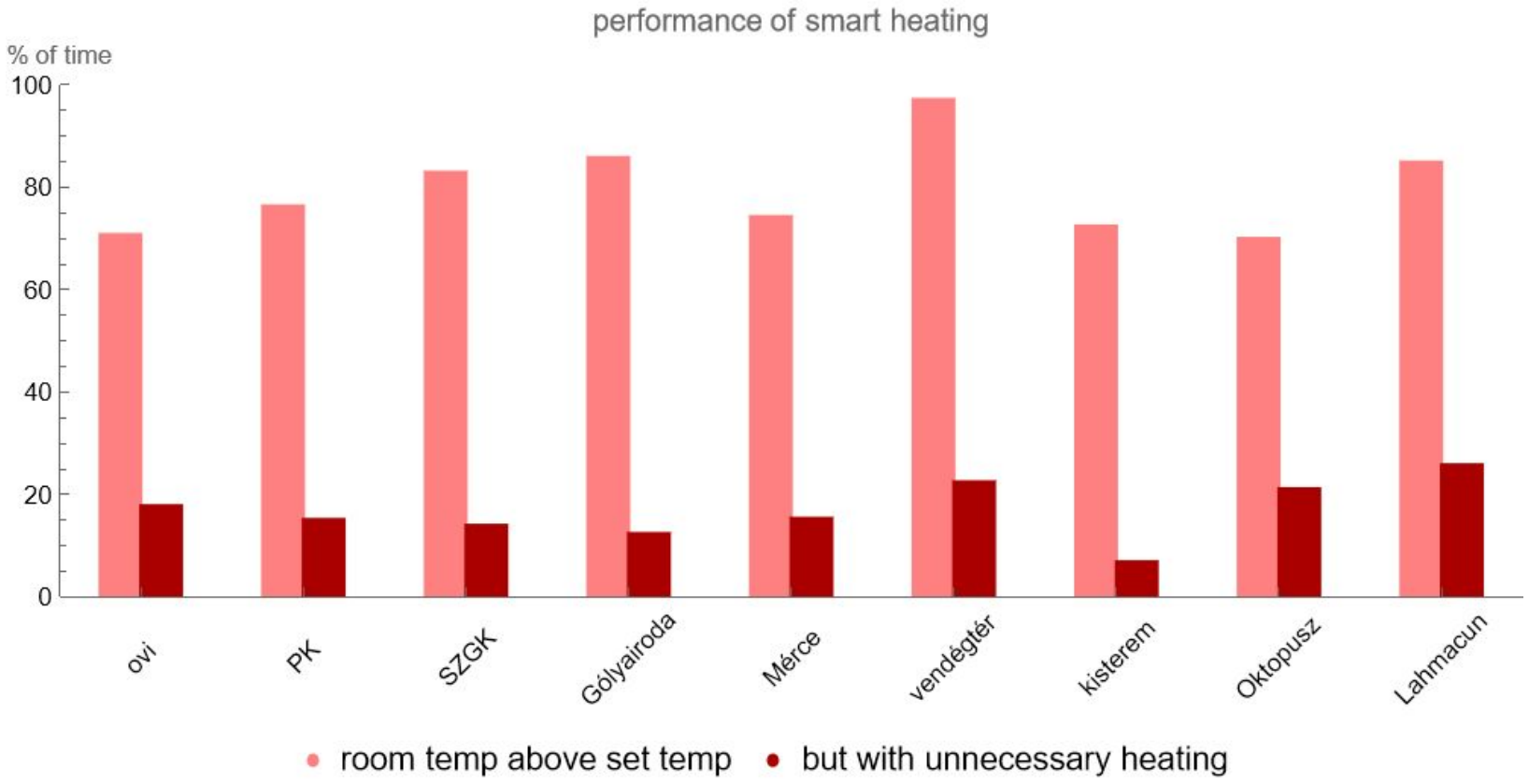
how did the smart heating perform? -- gas consumption



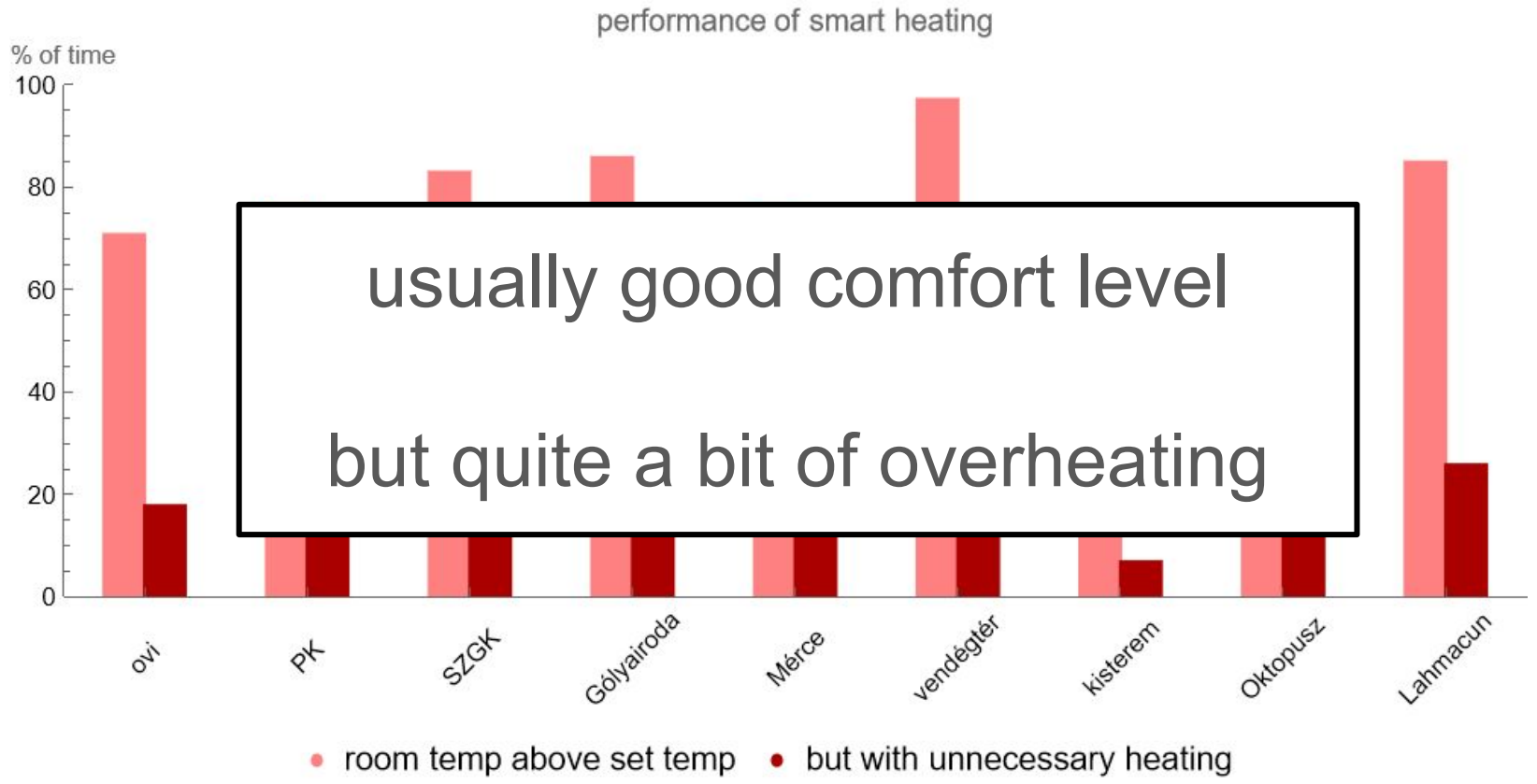
how did the smart heating perform? -- gas consumption



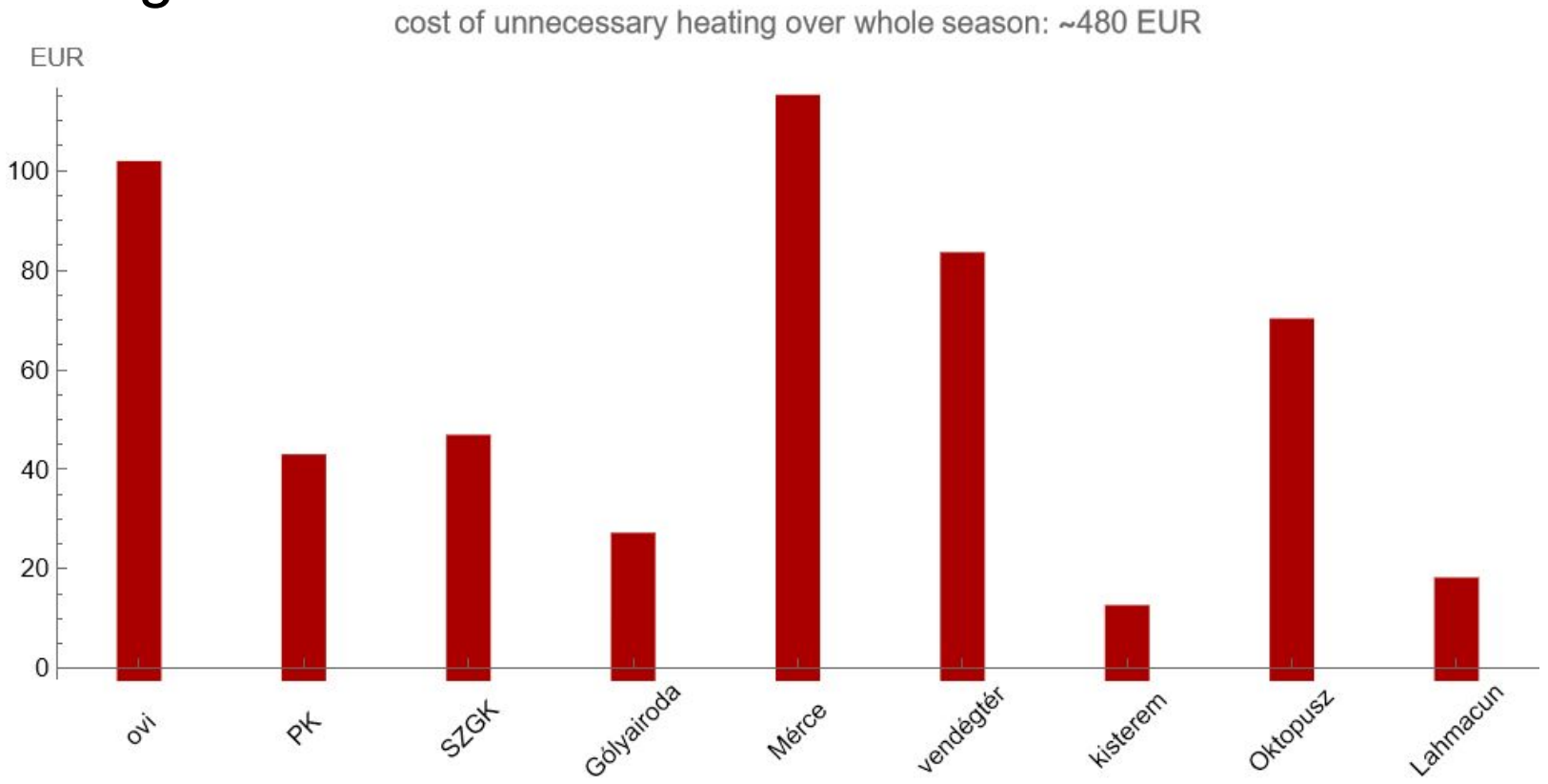
how did the smart heating perform? -- comfort



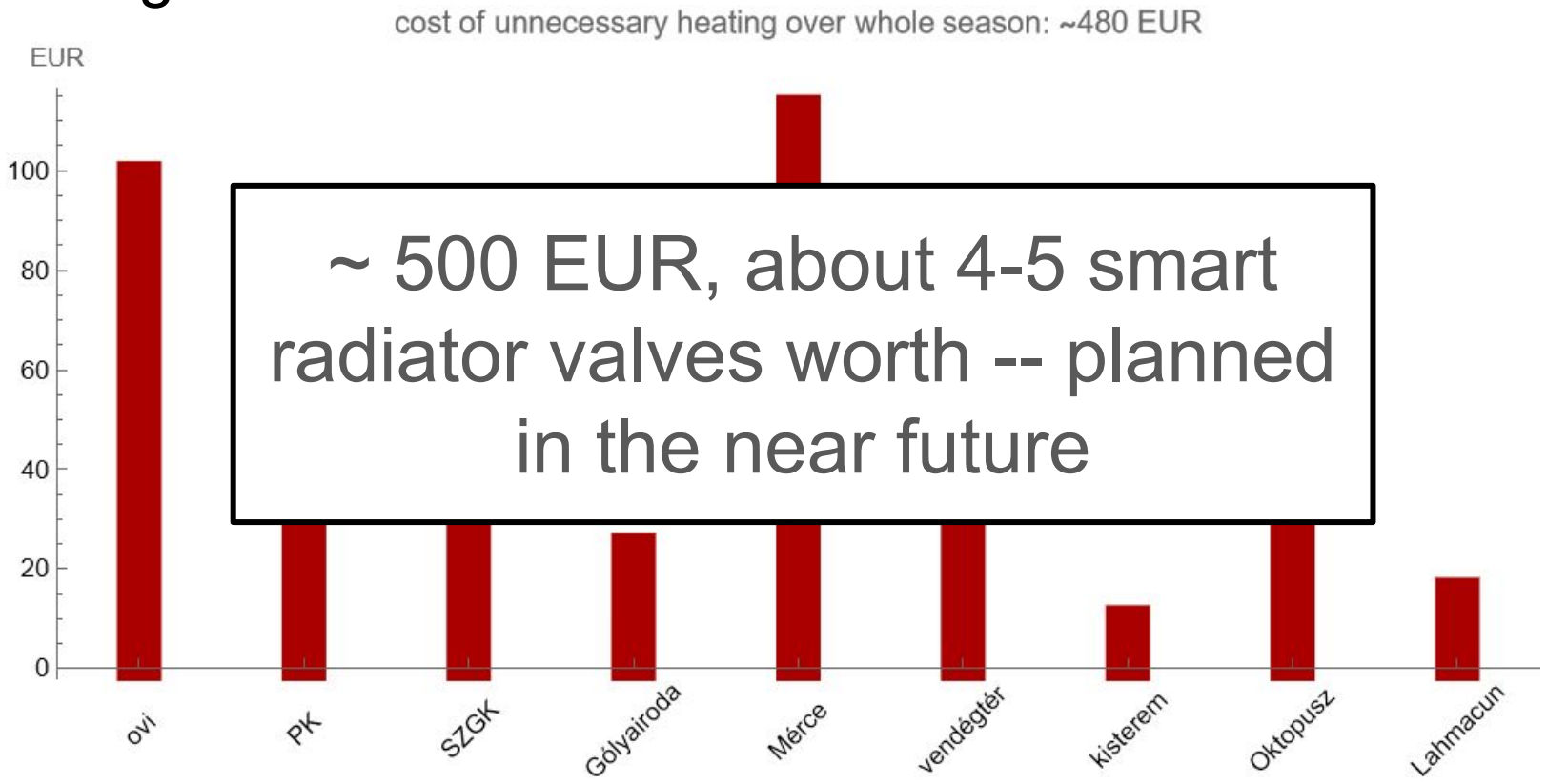
how did the smart heating perform? -- comfort



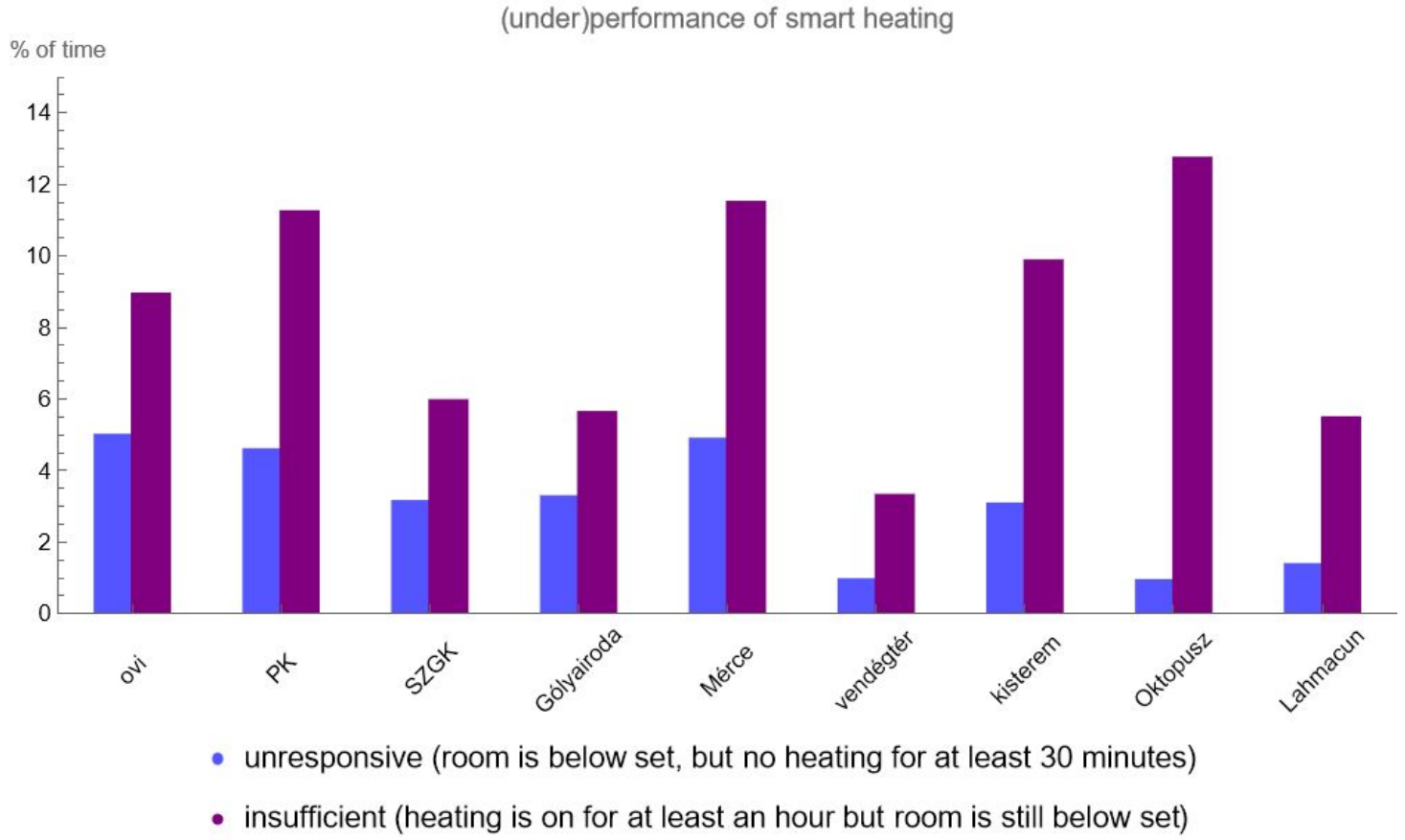
how did the smart heating perform? -- cost of cycle based switching



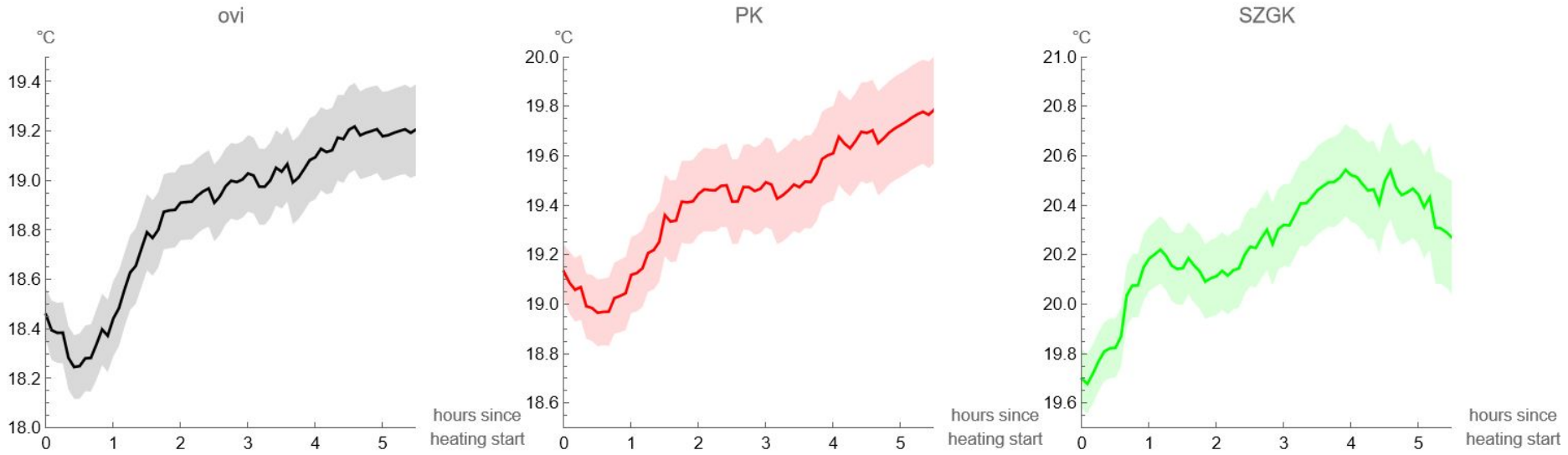
how did the smart heating perform? -- cost of cycle based switching



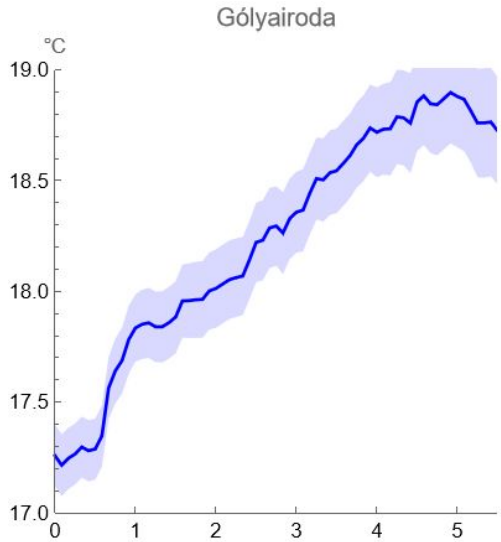
how did the smart heating perform? -- lack of comfort

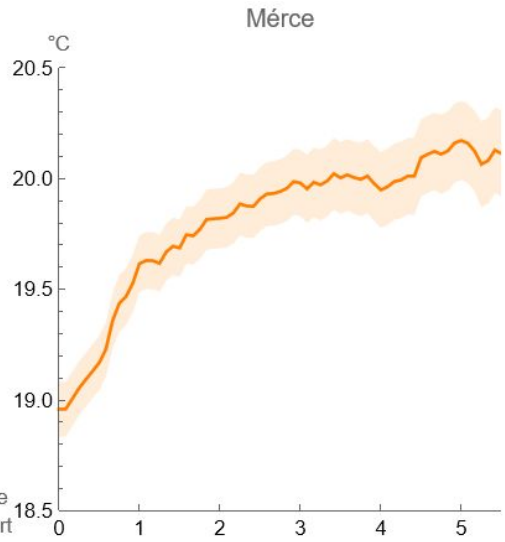


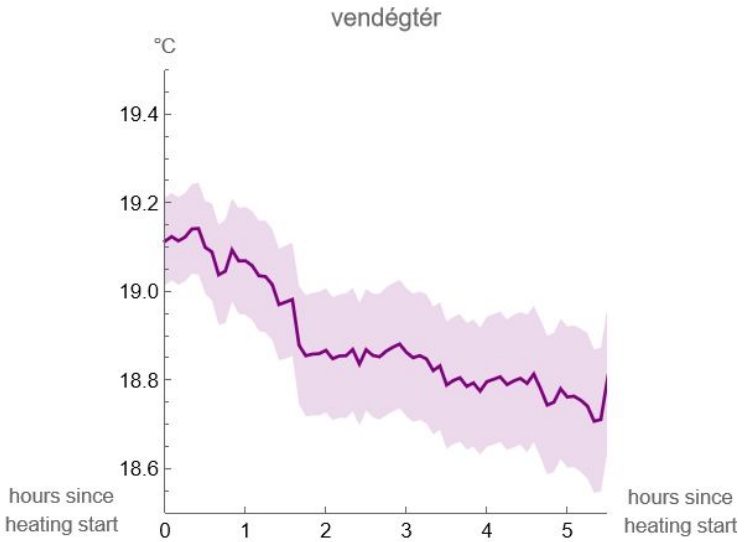
misc -- room response curves



misc -- room response curves







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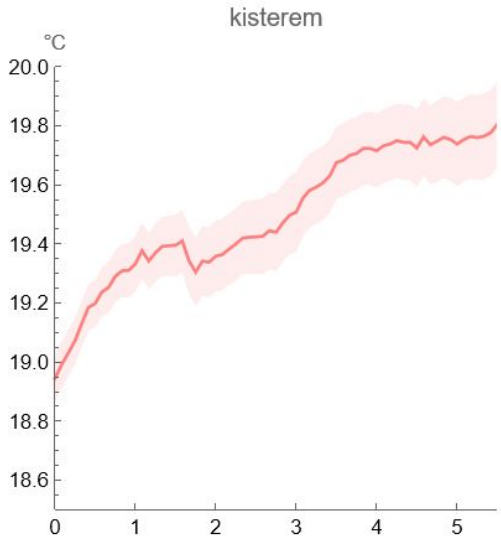

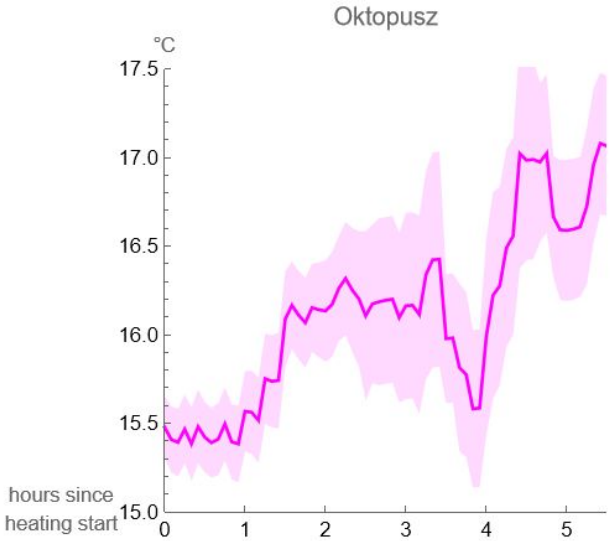

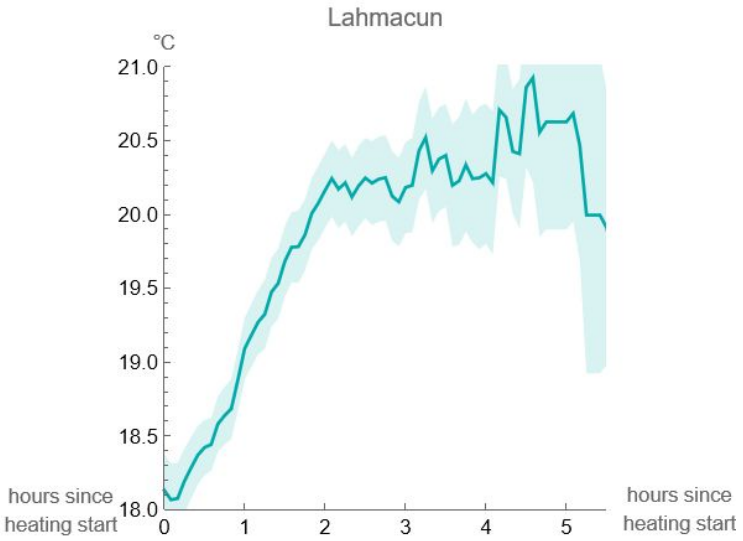

comments & suggestions?