OPTIMISING THE BUILDING MANAGEMENT SYSTEM IN SMART PASSIVE BUILDINGS

Tessa Rouwenhorst 4275292
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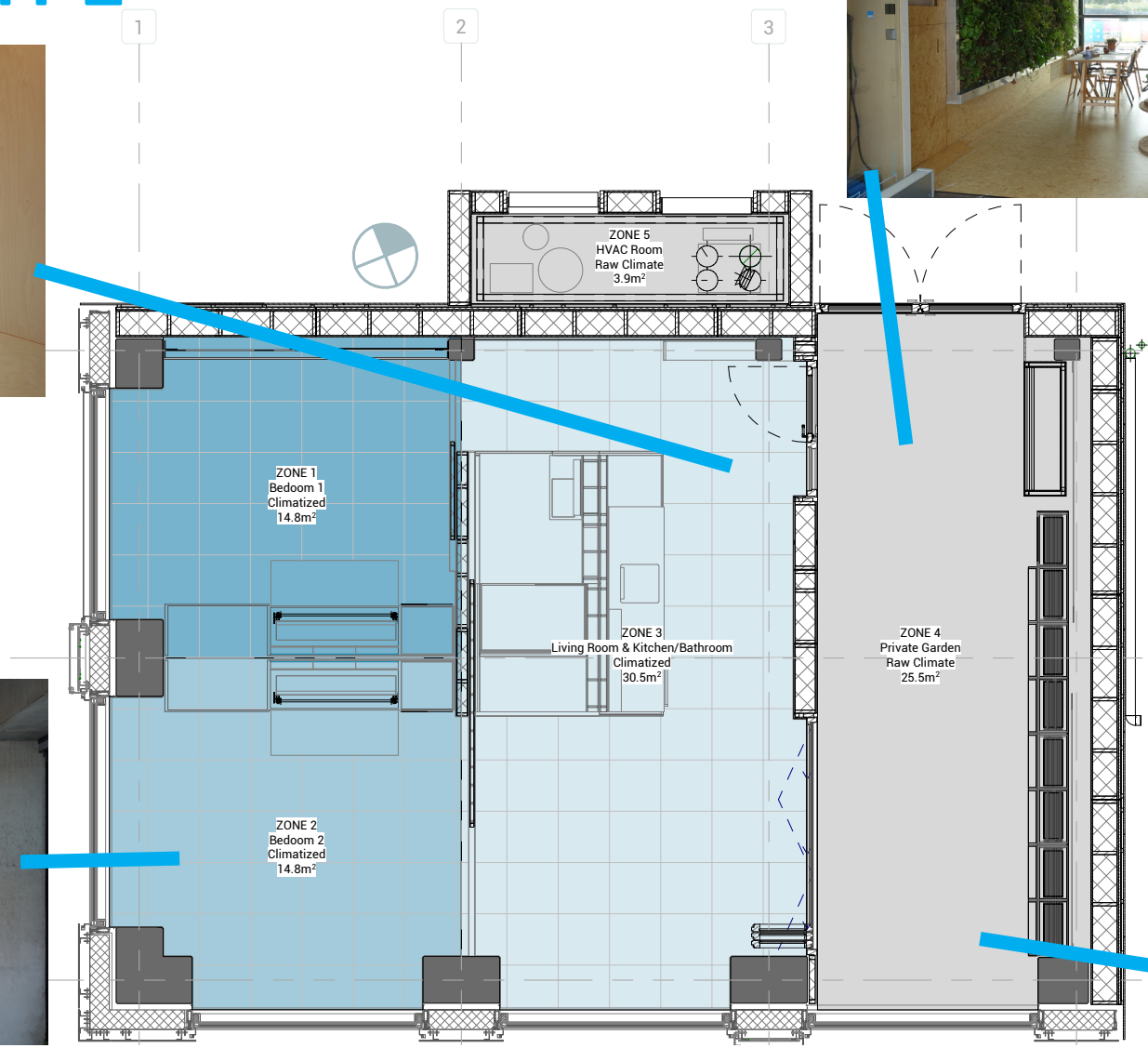
MOR


CAUTION
CONSTRUCTION AREA
WATCH FOR MOVING EQUIPMENT
TU Delft

MOR Team, 2019b

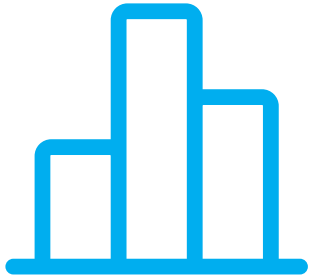
MOR PROTOTYPE




3rd
2nd
2nd
2nd
2nd
2nd
1st
1st
1st

PROBLEM STATEMENT

40% of energy use



Performance gap

Energy performance of buildings directive (EPBD)

MAIN RESEARCH QUESTION

How can the building management system be optimised to extend the passive period of having a positive impact on the energy efficiency for MOR and more?

QUANTITATIVE RESULTS

No active cooling necessary

Heating setpoint in summer 20,8 °C

Mechanical ventilation rate 1,0 ach

Little influence found for:

- mechanical ventilation setpoint
- mechanical ventilation maximum temperature difference

QUALITATIVE RESULTS

Comfort conditions

- Thermal comfort
- CO_2 levels
- Relative humidity

Lighting controls

Safety/security

Predictive maintenance

LITERATURE REVIEW

What is a building management system?

Which parameters have the biggest influence?

What are the comfort conditions that the building management system has to reach?

BUILDING MANAGEMENT SYSTEM

Main functions

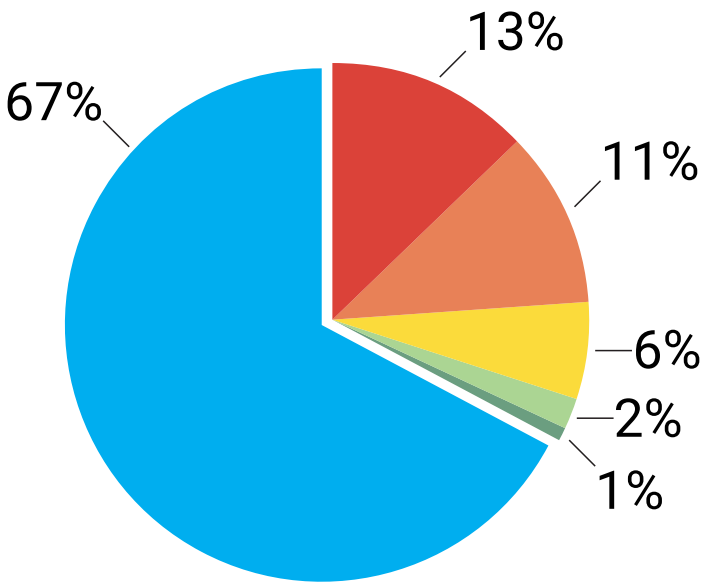
- Energy efficiency
- Comfort conditions
- Heat and cold generation

Secondary functions

- Safety and security
- Predictive maintenance

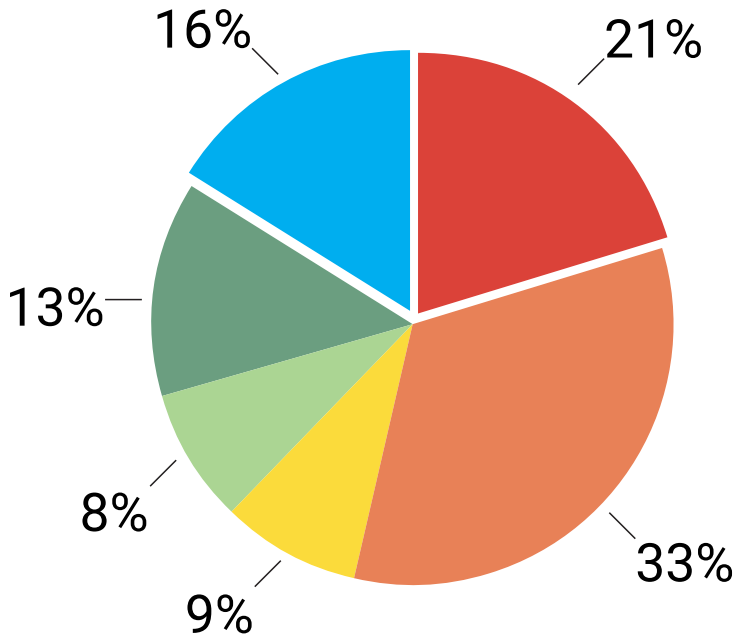
ENERGY USAGE

Average all residential buildings in the EU



Csiba, 2016

Average nZEBs in the Netherlands

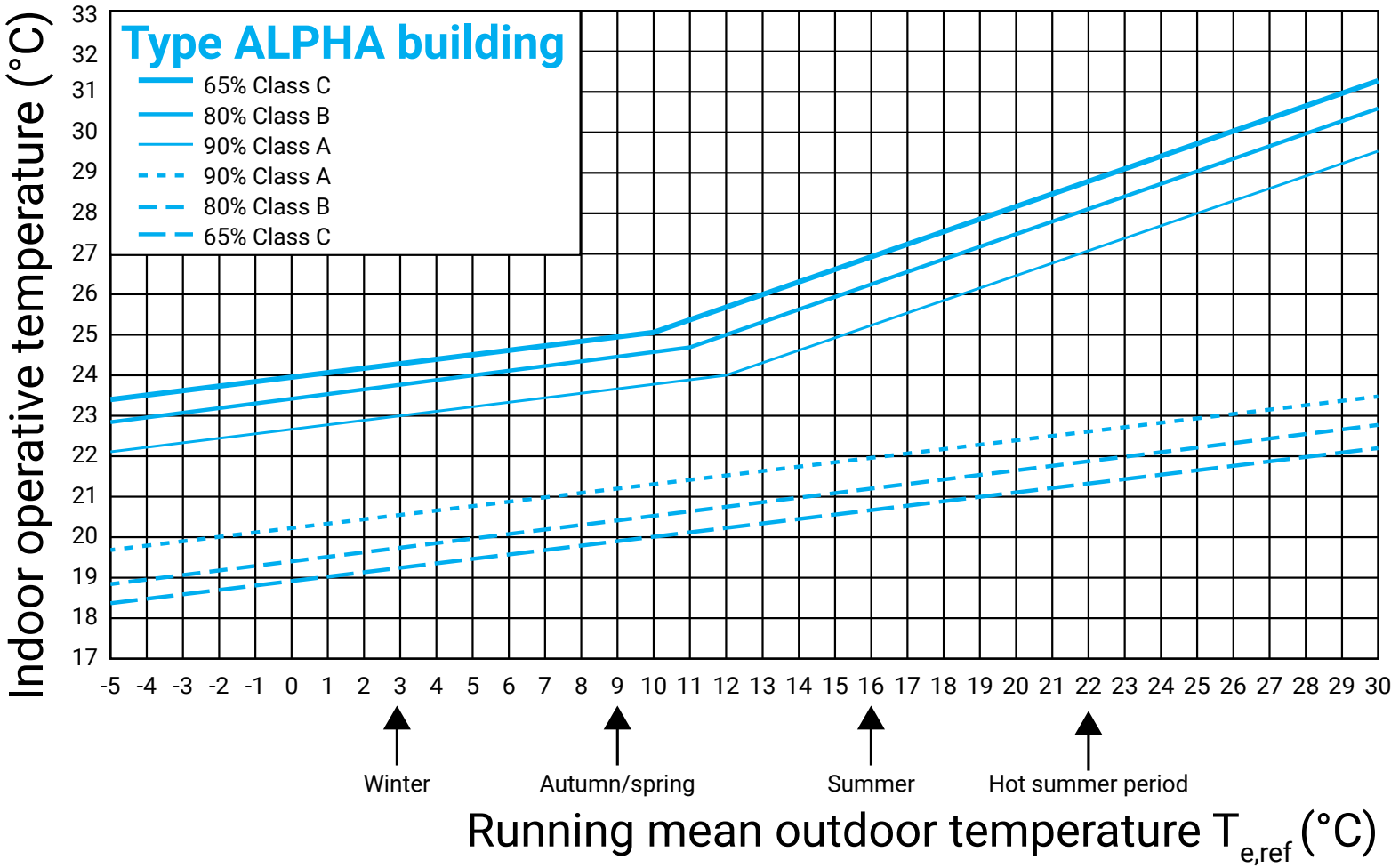


Nuiten, et al., 2019

- Space heating
- Water heating
- Electrical appliances
- Cooking
- Lighting
- Cooling

COMFORT CONDITIONS

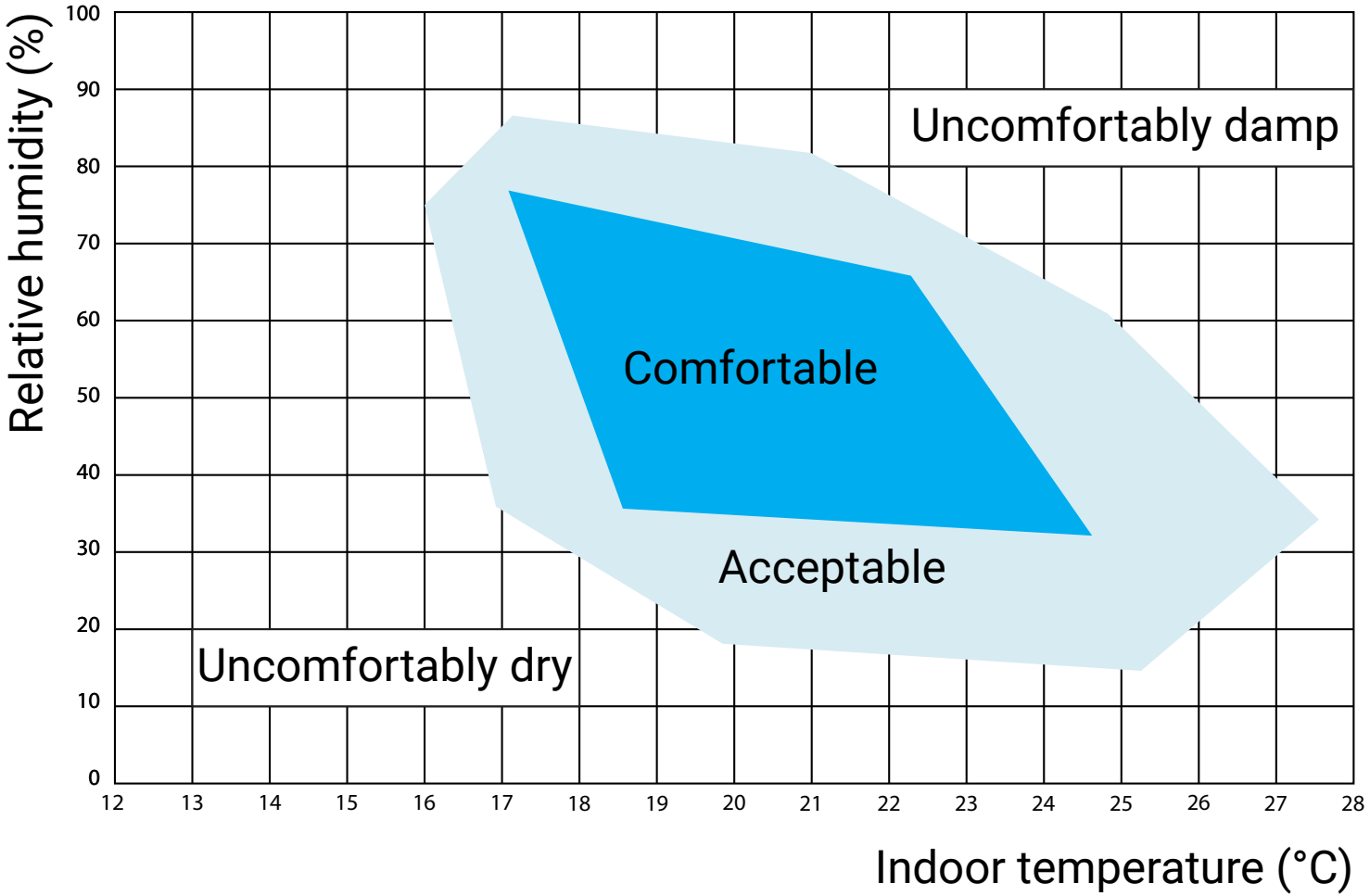
Thermal comfort



van der Linden, Boerstra, Raue, Kurvers, & de Dear, 2006

COMFORT CONDITIONS

Indoor air quality
- CO_2 levels
- Relative humidity



BOOM-SI, Milieukundig Onderzoek-& OntwerpBuro, 2019

COMFORT CONDITIONS

Visual comfort

- Illuminance levels
- Glare
- Controllability
- View outside

Room	Specific area	Lux
Bathroom	Sink and mirror Ambient lighting Toilet	300 - 500
Living room	Resting area Reading area	50 - 200 300
Bedroom	Ambient lighting Reading area	100 - 200 300
Workstation		500
Kitchen	Ambient lighting Kitchen counter	200 - 300 300 - 500
Hallway		50 - 100

Bodart, et al., 2011

CASE STUDY

How is the building management system currently programmed?

PASSIVE SYSTEMS

- Solar heat gain
- Heat recovery
- Solar shading
- Natural ventilation
- Thermal mass

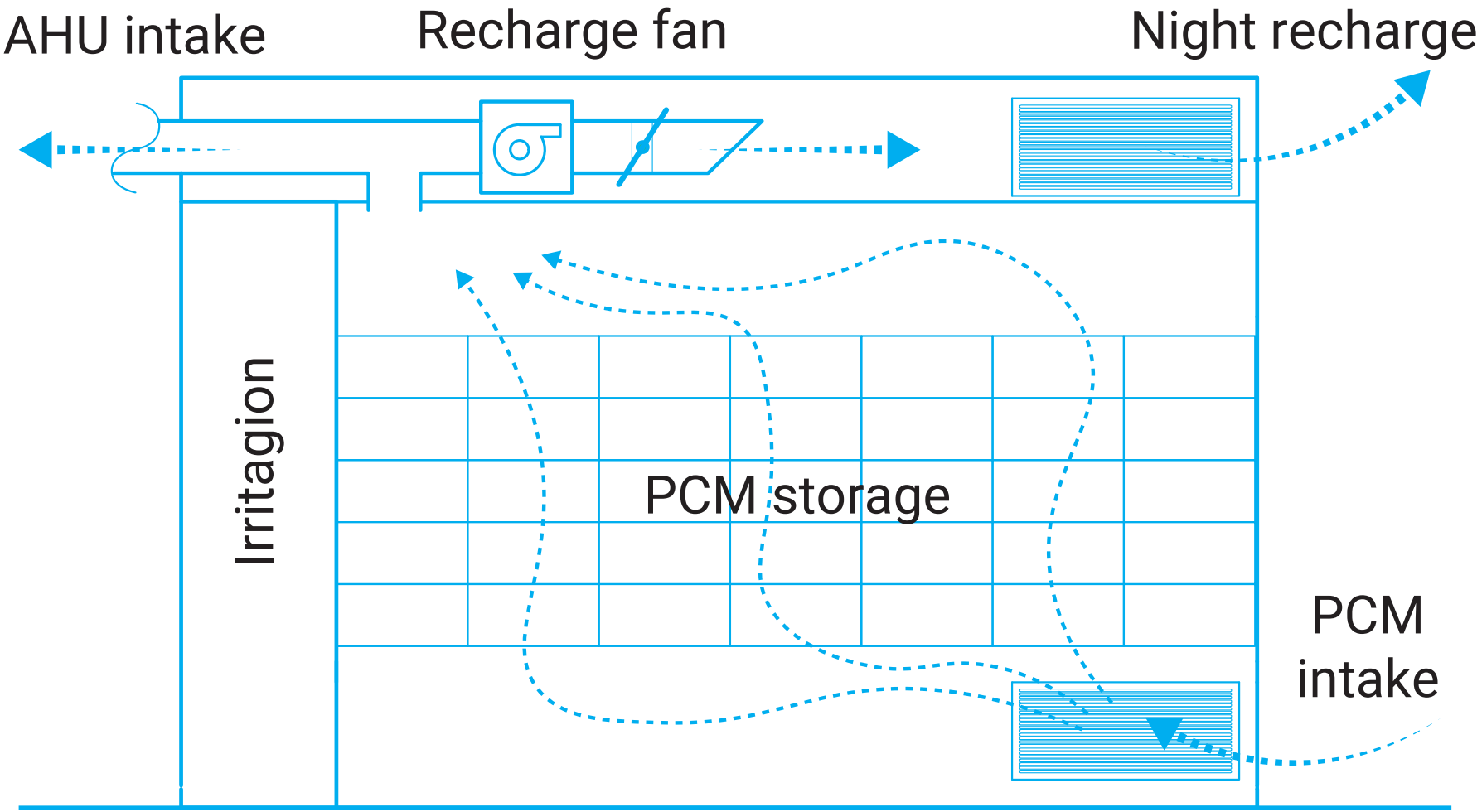
SEMI-PASSIVE SYSTEMS

Phase changing materials (PCMs)

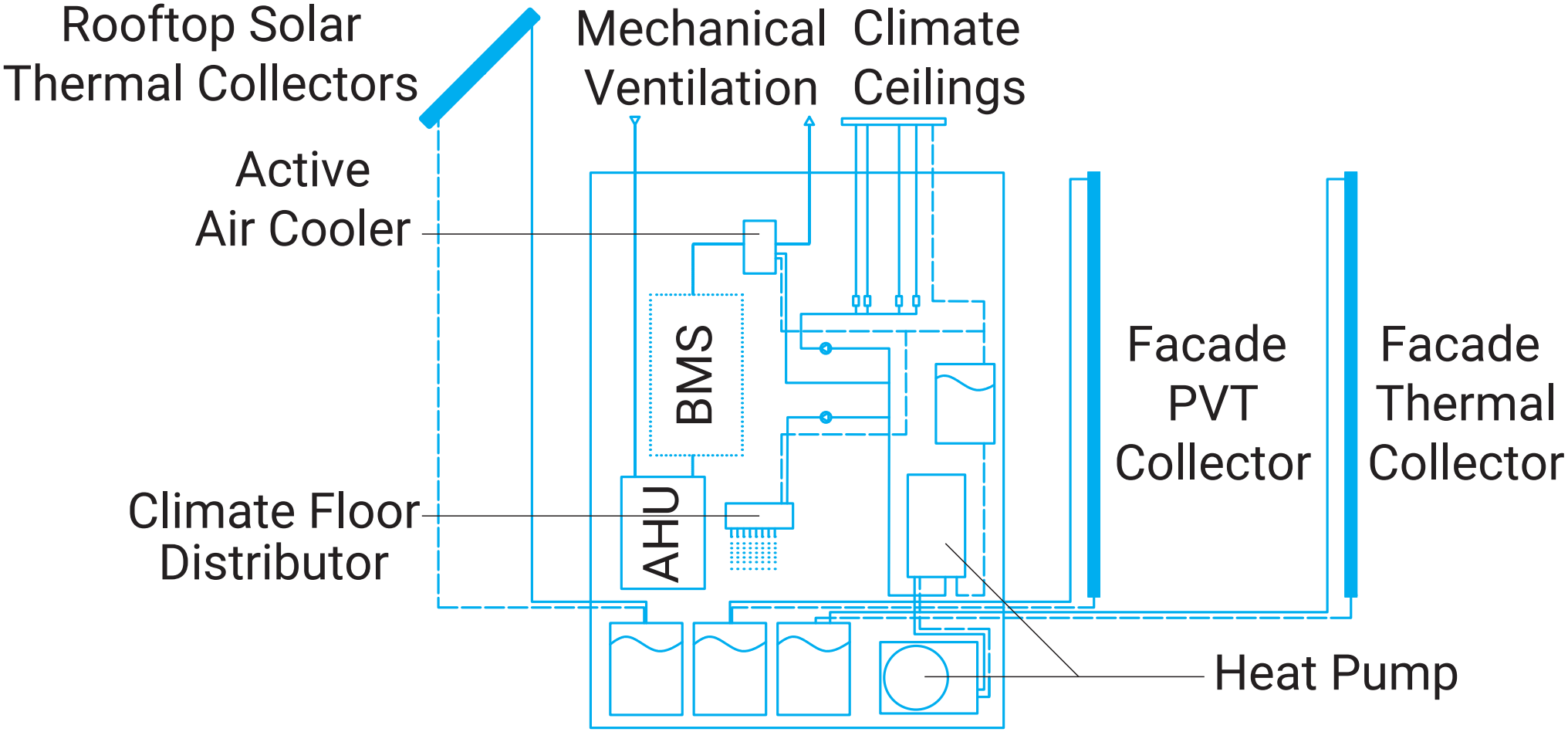
Solid - > liquid
store heat

Liquid -> solid
release heat

SEMI-PASSIVE SYSTEMS



ACTIVE SYSTEMS

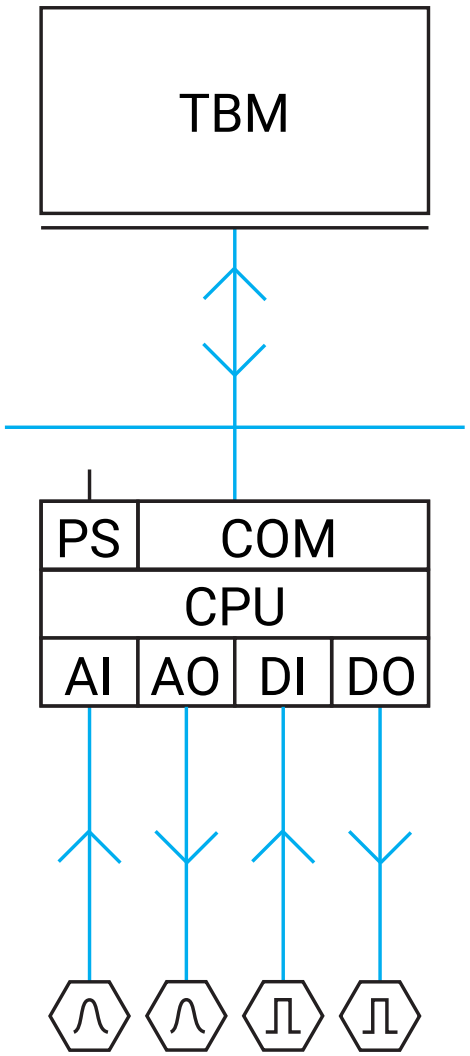


MOR team, 2020

BUILDING MANAGEMENT SYSTEM

Management level

Technical Building Management (TBM)



Automation level

Power supply (PS)
Communication interface (COM)
Central processing unit (CPU)
Analog input (AI) Analog output (AO)
Digital input (DI) Digital output (DO)

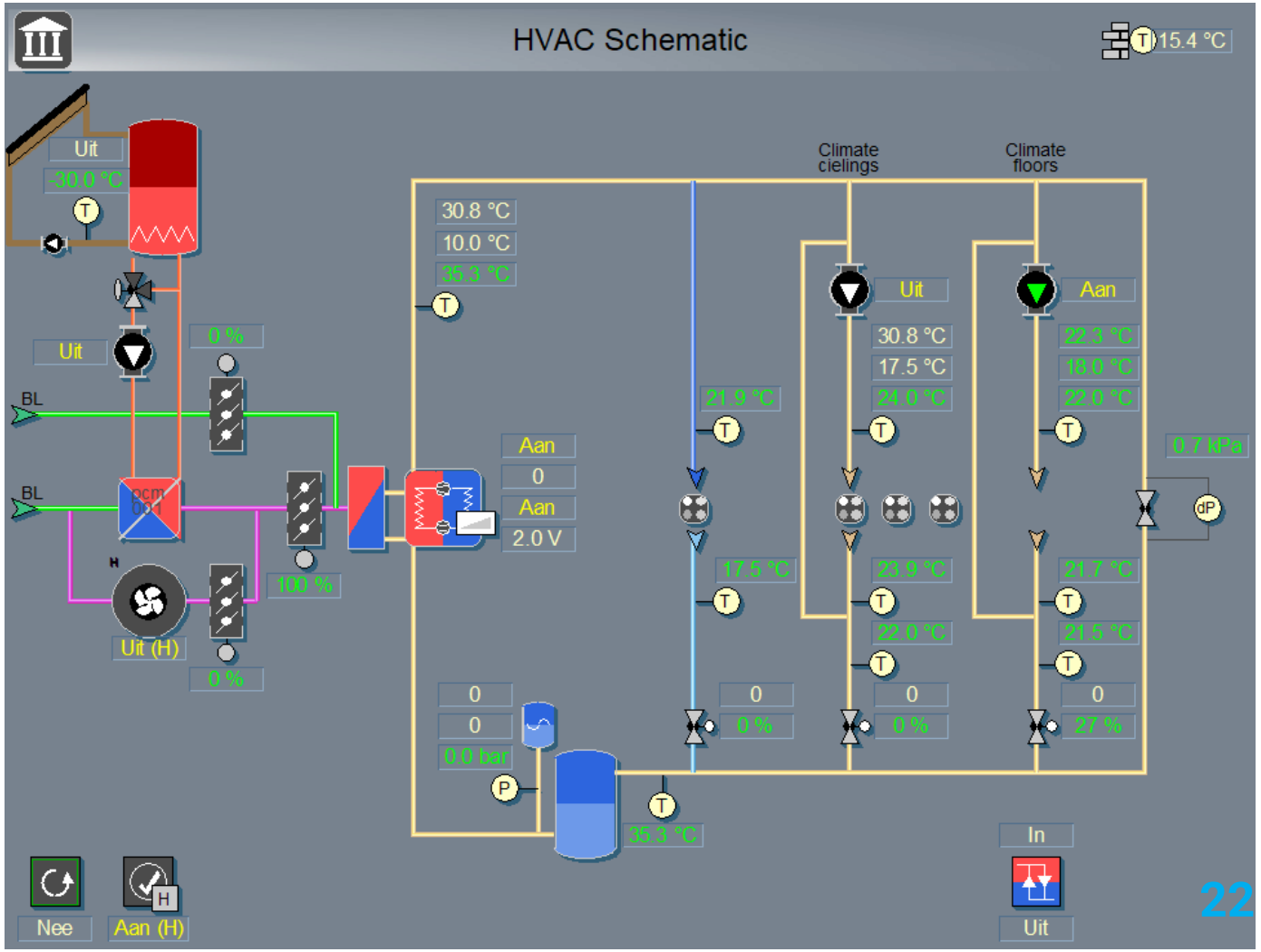
Field level

Sensor
Actuators

MANAGEMENT LEVEL

Priva Top Control 8

- TC Operator
- TC History
- (TC Energy)



AUTOMATION LEVEL

- Priva Blue ID C-Line

FIELD LEVEL

Indoor sensors

- Combined temperature and CO_2 sensor
- Duct temperature
- Water temperature

Weather station

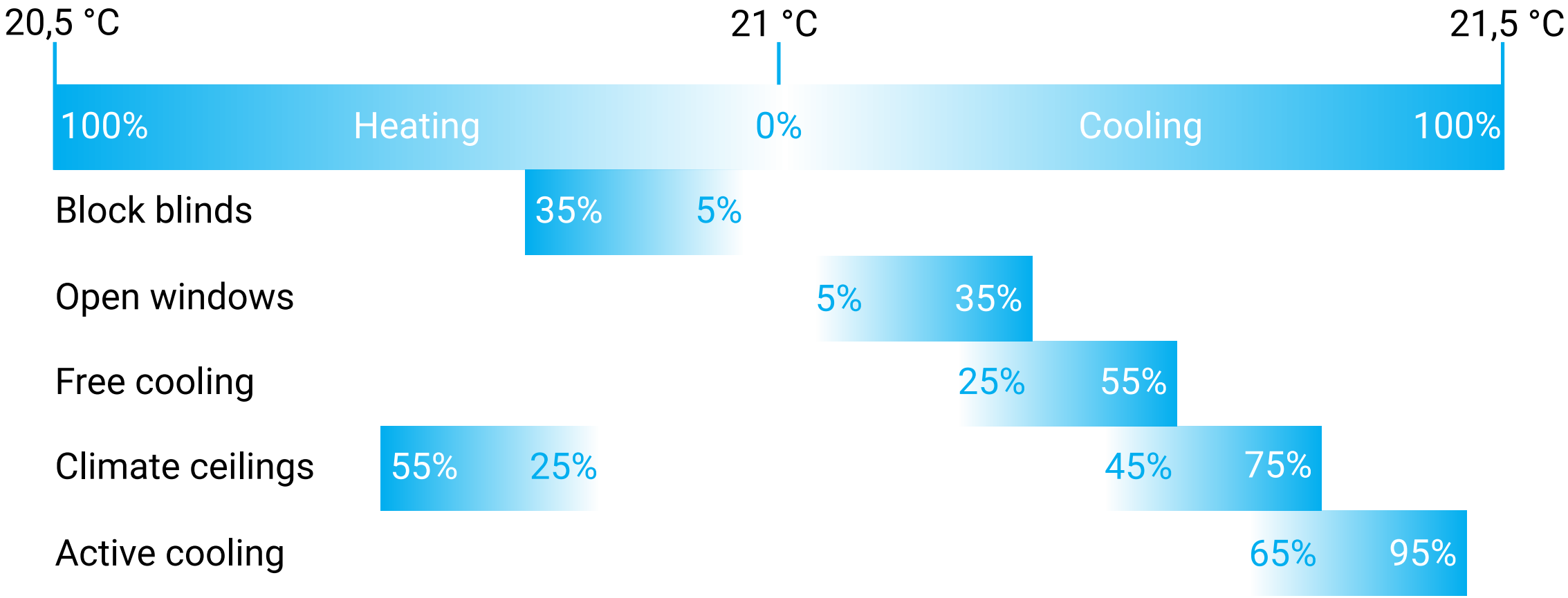
- Wind speed
- Wind direction
- Temperature
- Relative humidity
- Rainfall
- Solar radiation

FIELD LEVEL

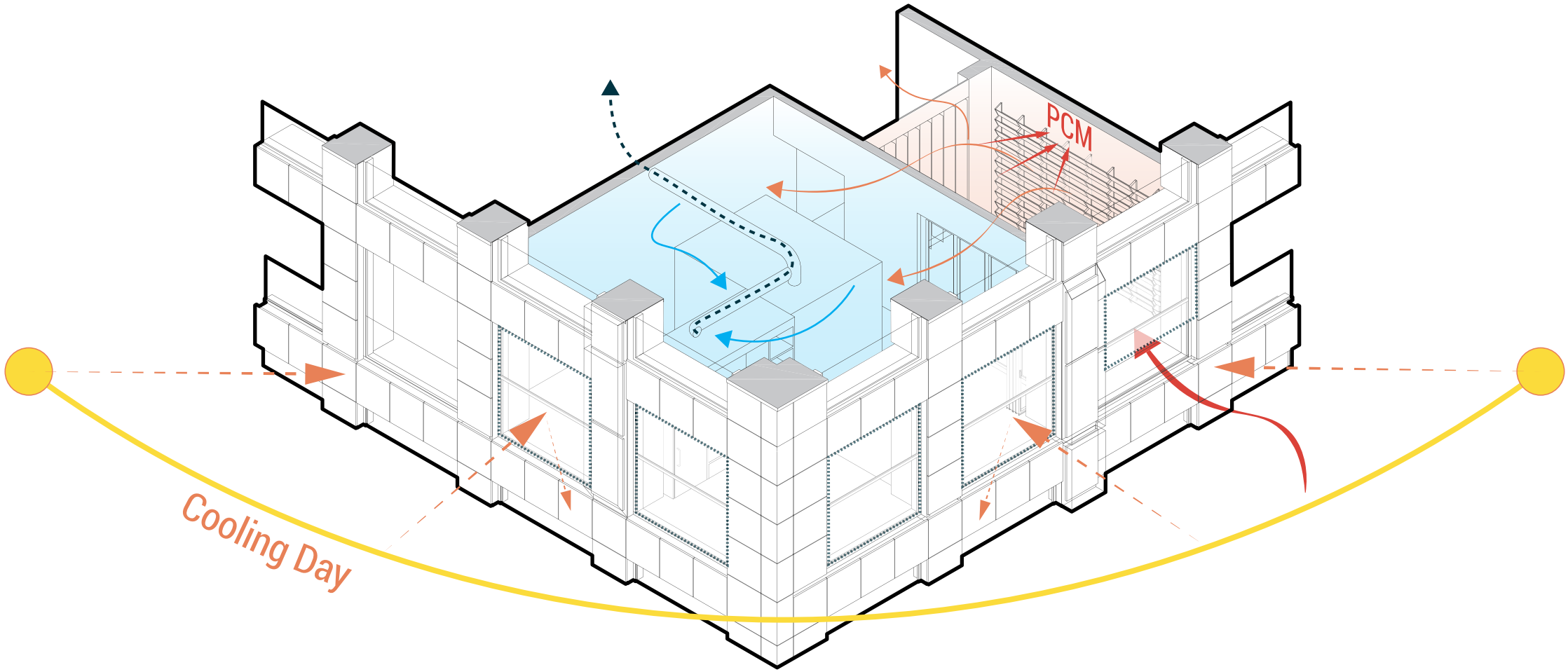
Actuators

- Window motors
- Shading motors
- Vents
- Pumps
- Control valves

COMFORT CONDITIONS



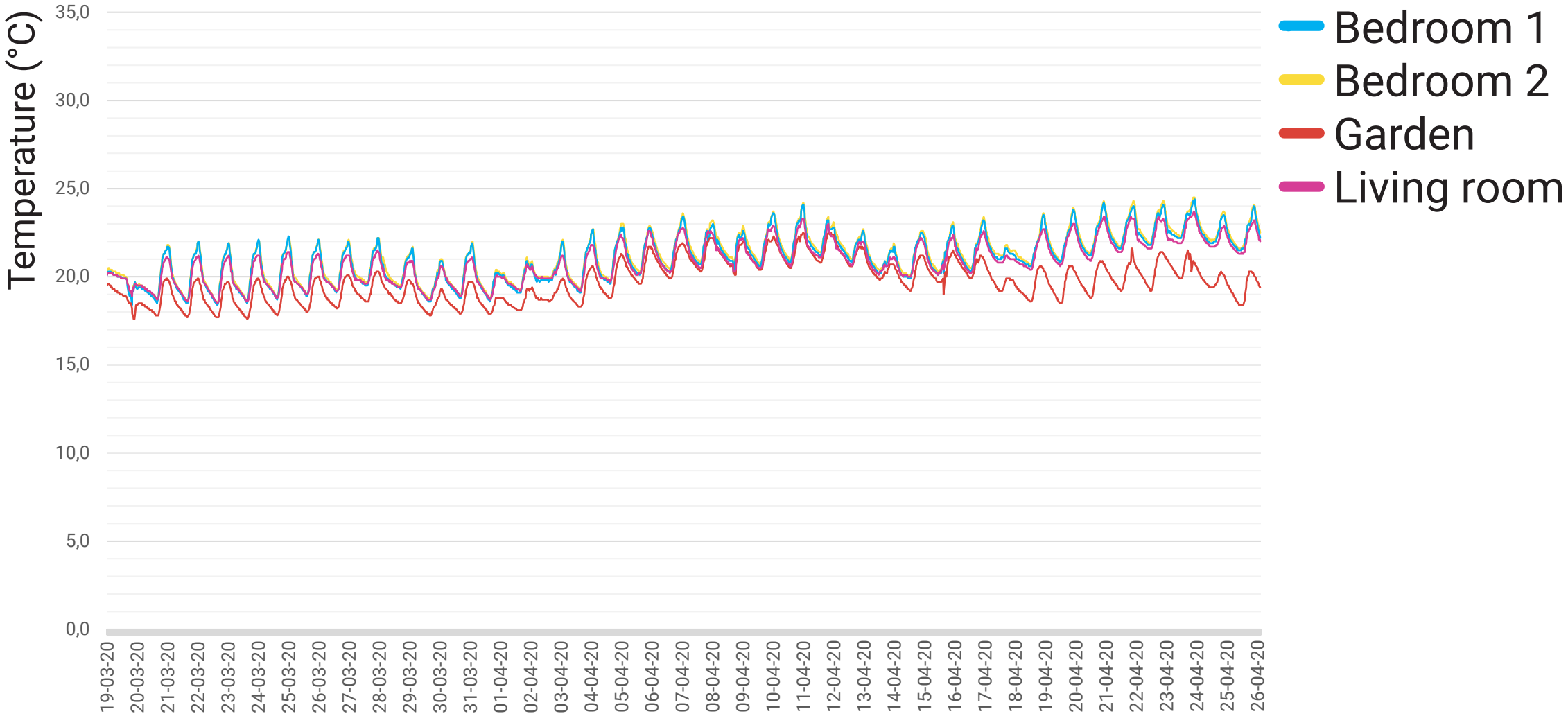
HEAT AND COLD GENERATION



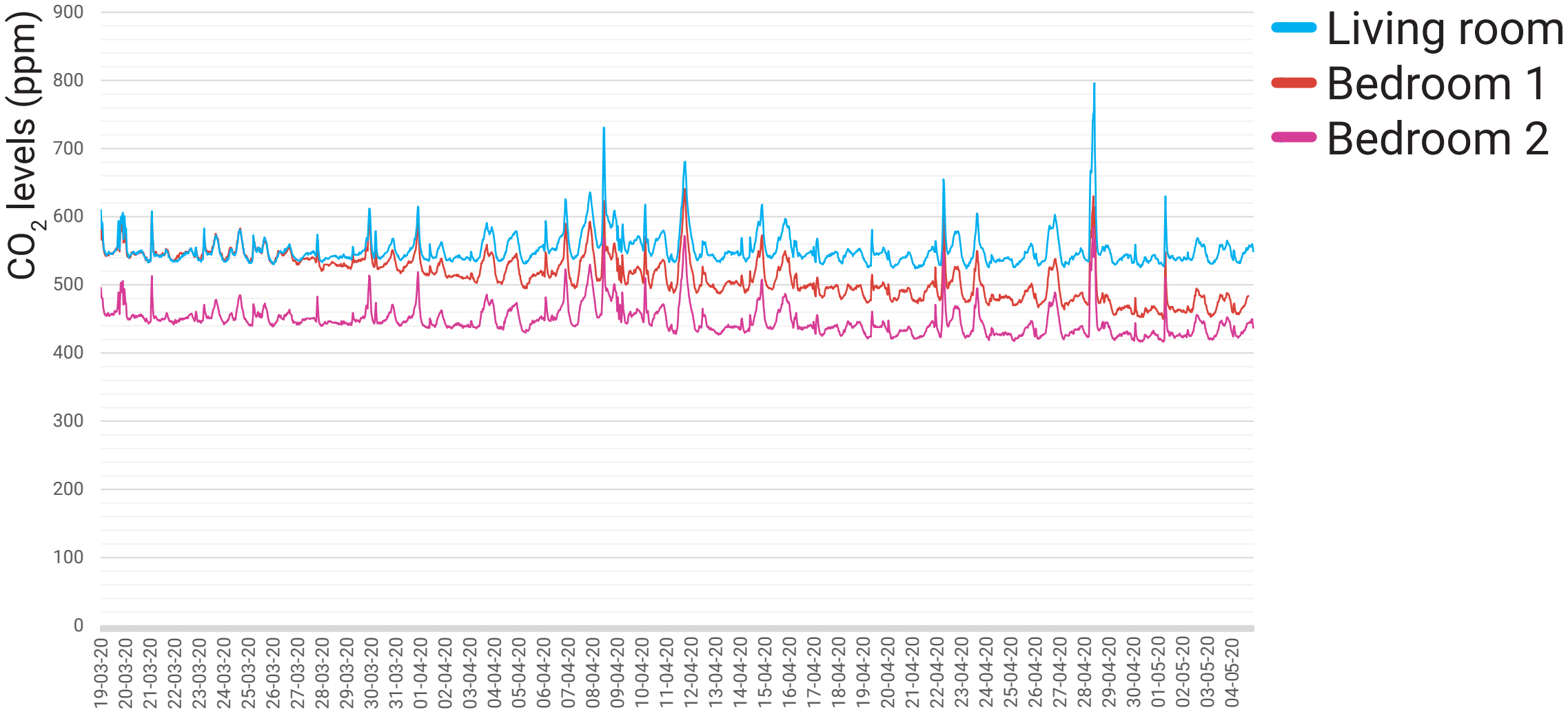
METHOD

Can simulations optimise these setpoints?

MEASUREMENTS



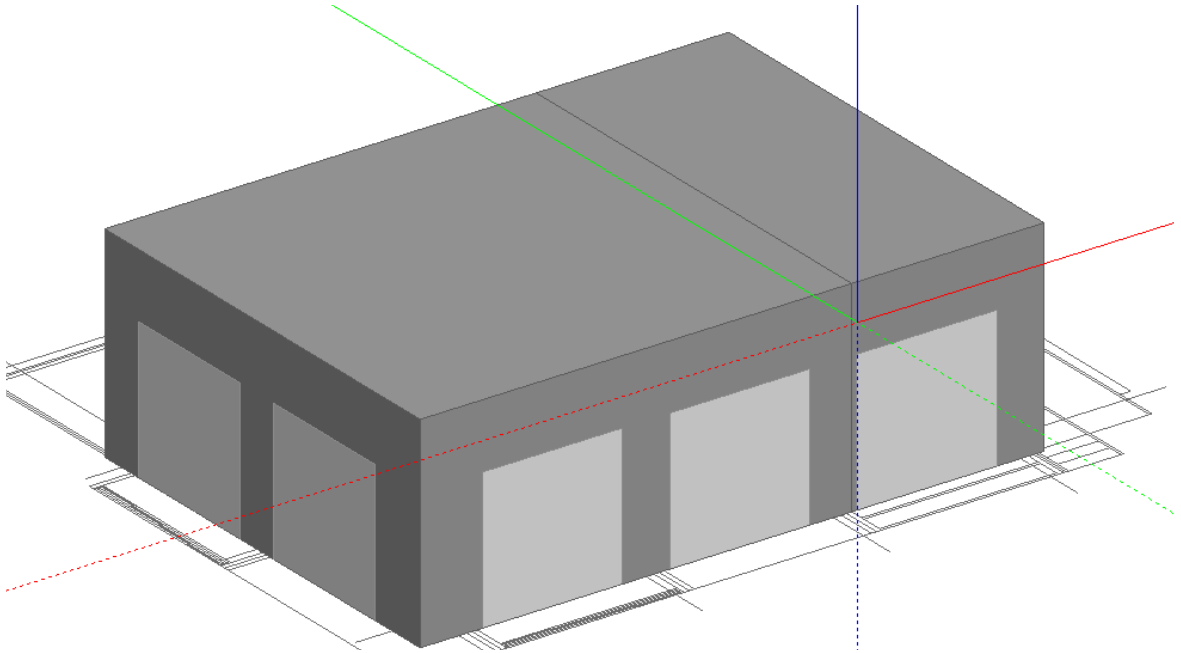
MEASUREMENTS



MODELS

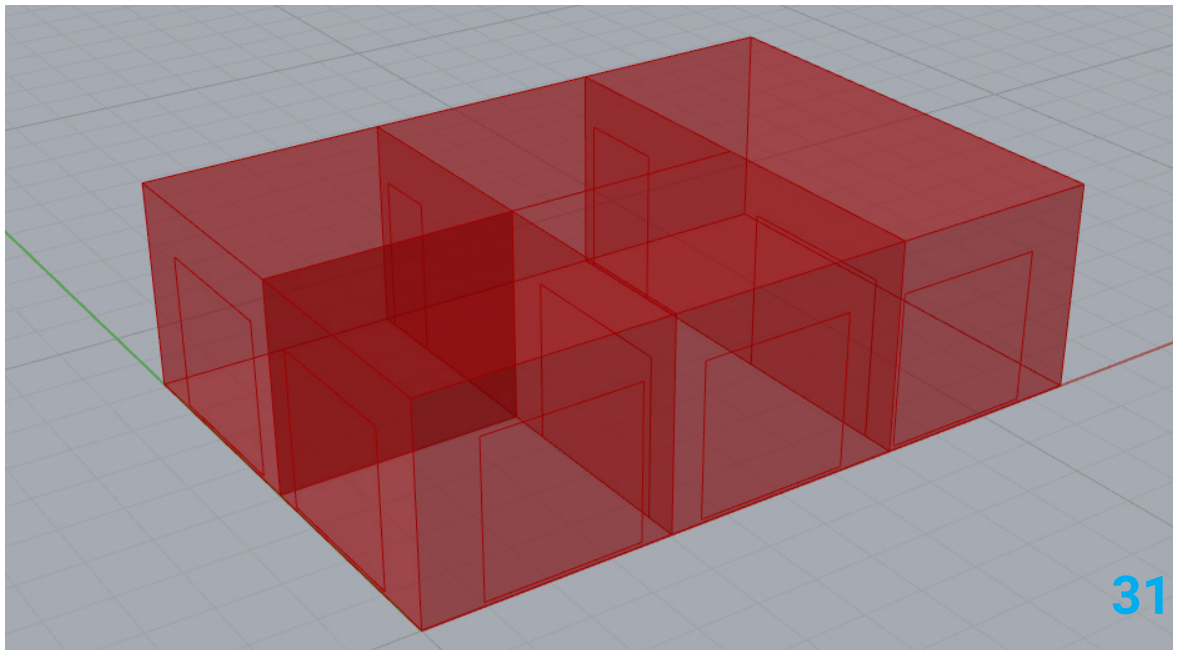
DesignBuilder model

- Existing model
- Simple HVAC template
- Built-in optimisation engine

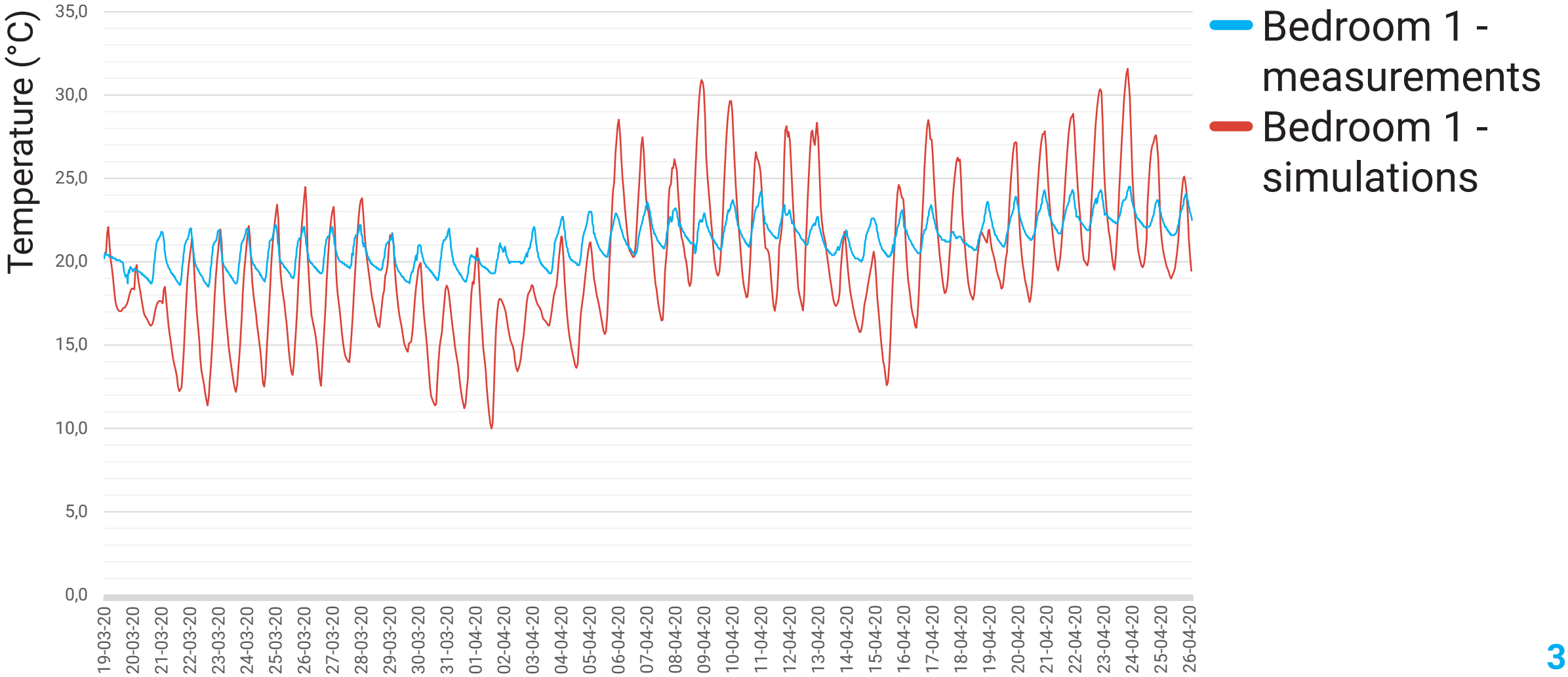


Grasshopper model

- Newly built model
- Detailed HVAC
- Integration with modeFRONTIER



SIMULATIONS GRASSHOPPER MODEL



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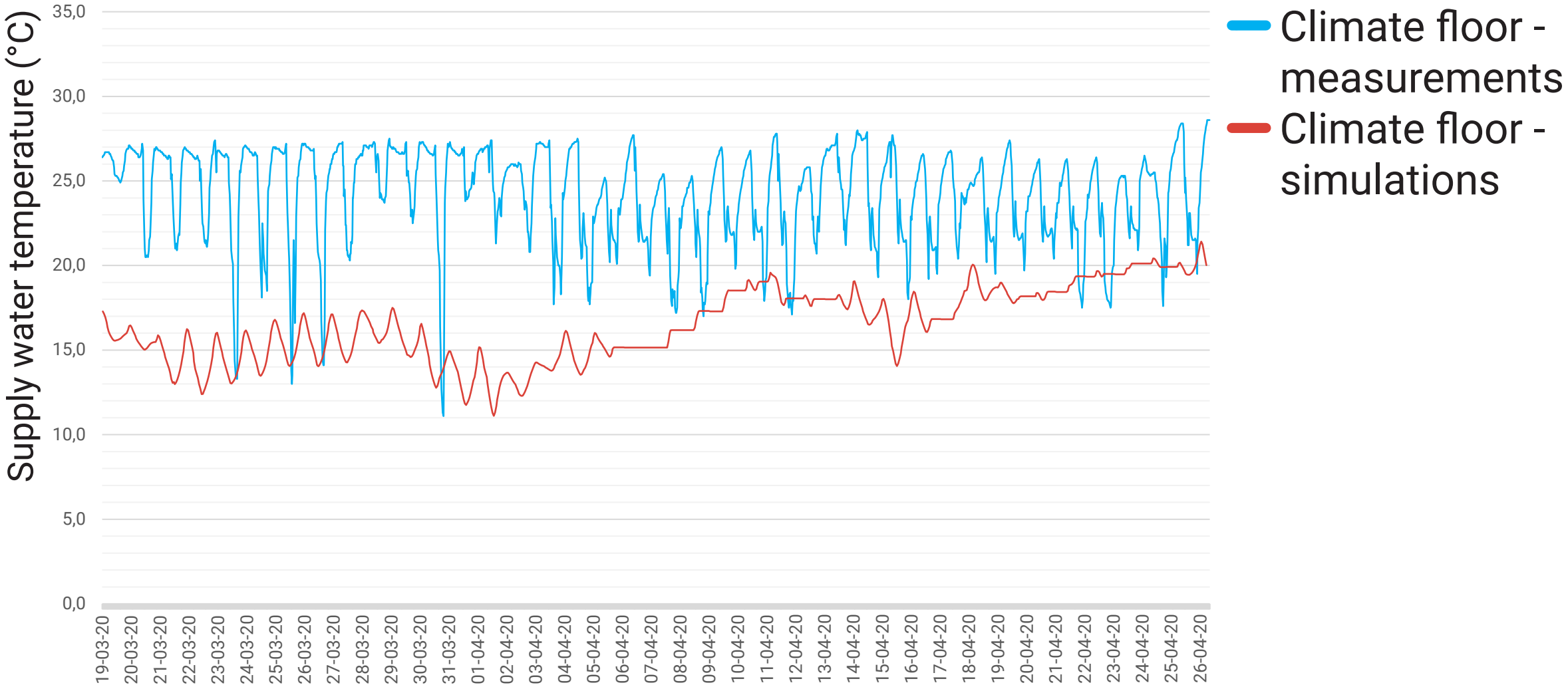
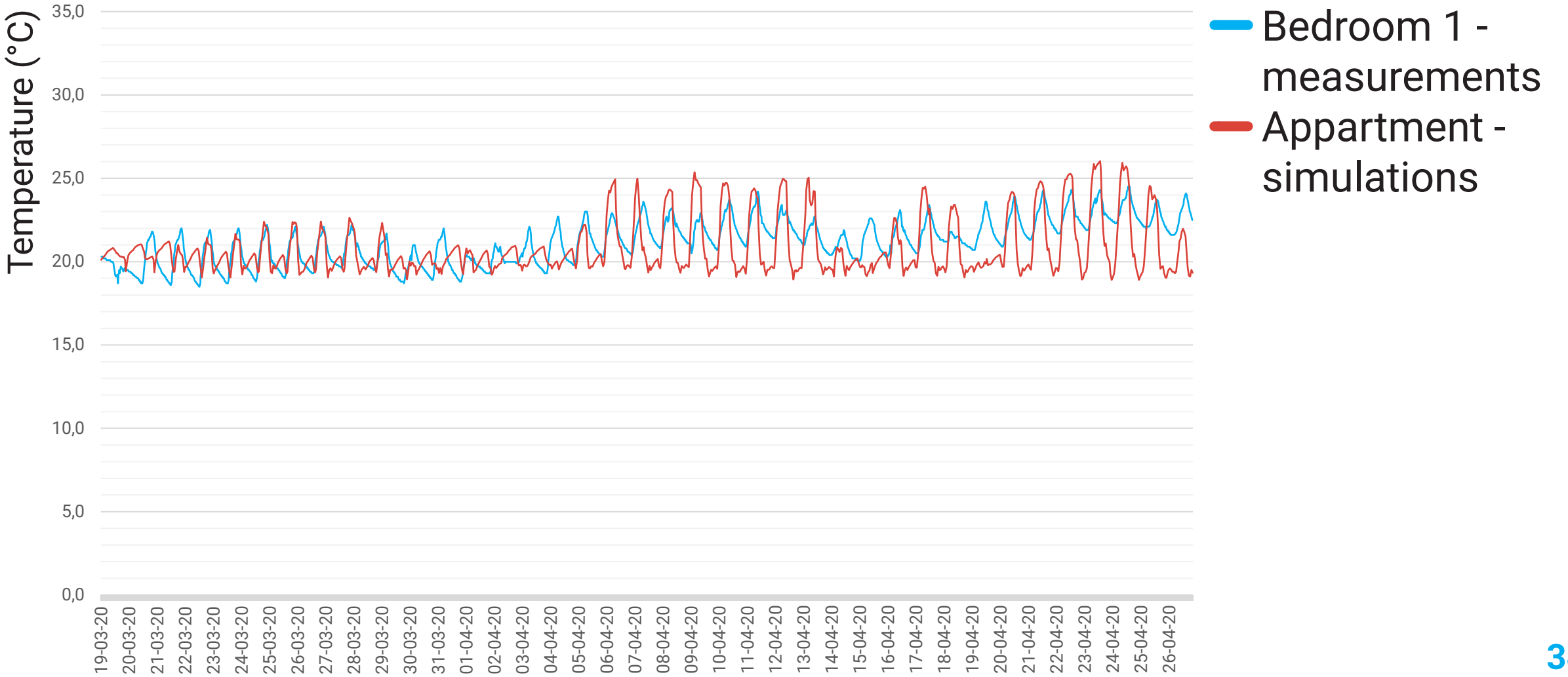


SIMULATIONS DESIGNBUILDER MODEL



STATISTICAL ANALYSIS

- CV(RMSE) < 30 %
- MBE < ± 10 %

Model	MBE	RMSE	CV(RMSE)	Pearson's correlation coefficient (r)
Grasshopper model	-7,4 %	3,510 °C	58,5 %	0,84
DesignBuilder model	-2,0 %	1,526 °C	25,4 %	0,49

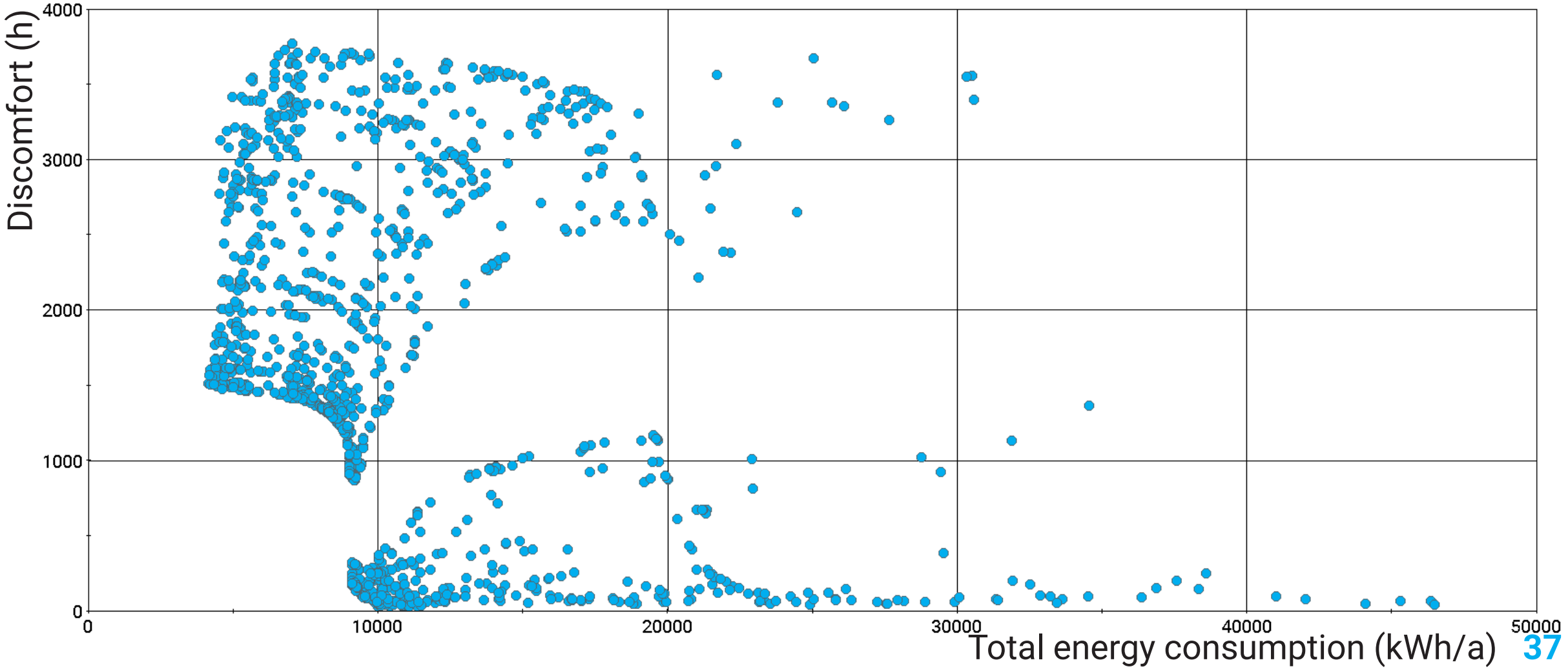
PROBLEM FORMULATION

Objectives:

- Minimising total energy consumption
- Minimising thermal discomfort.

Design variable	Lower bound	Upper bound
Cooling setpoint temperature	15,0 °C	35,0 °C
Heating setpoint temperature	10,0 °C	25,0 °C
Natural ventilation setpoint temperature	15,0 °C	35,0 °C
Natural ventilation maximum temperature difference	-30,0 °C	2,0 °C
Mechanical ventilation setpoint temperature	15,0 °C	35,0 °C
Mechanical ventilation maximum temperature difference	-30,0 °C	2,0 °C
Mechanical ventilation rate	1,0 ach	10,0 ach

OPTIMISATIONS



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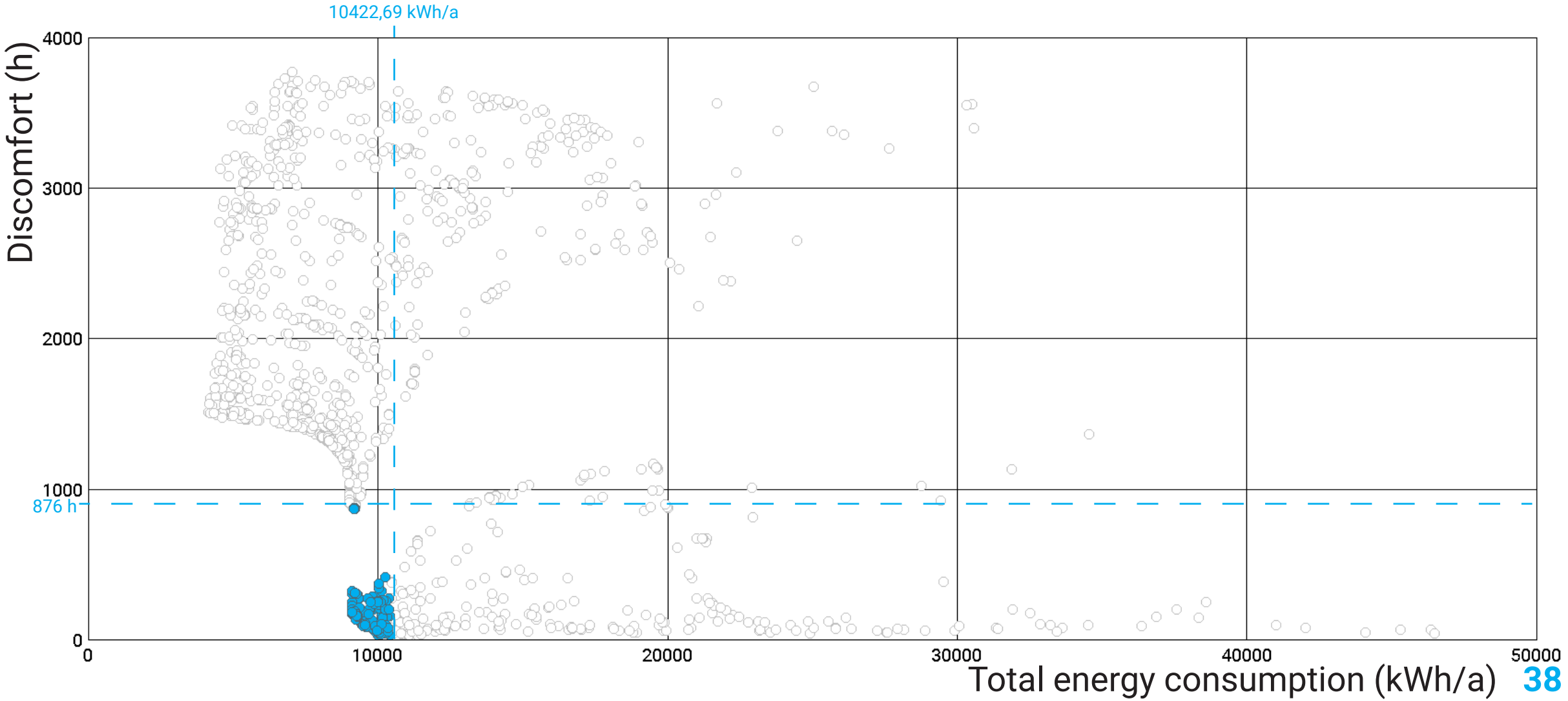

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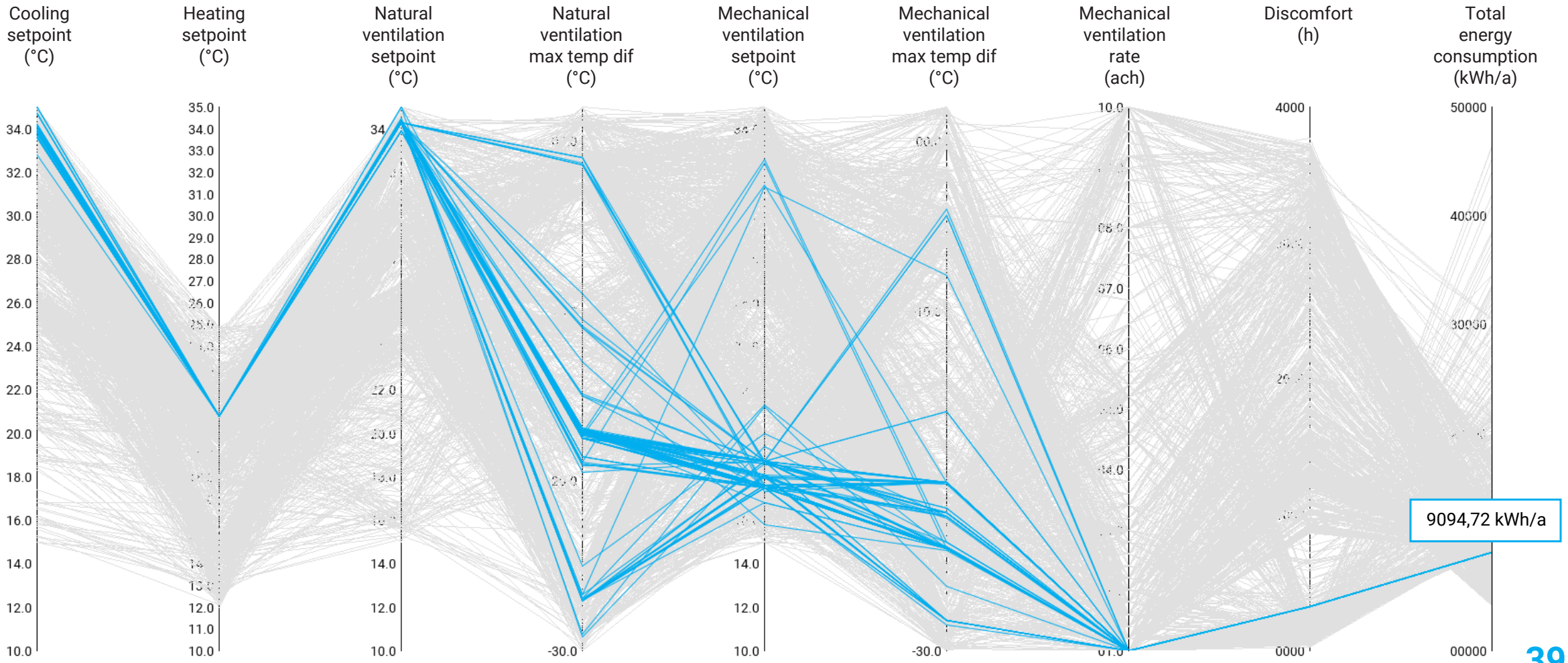
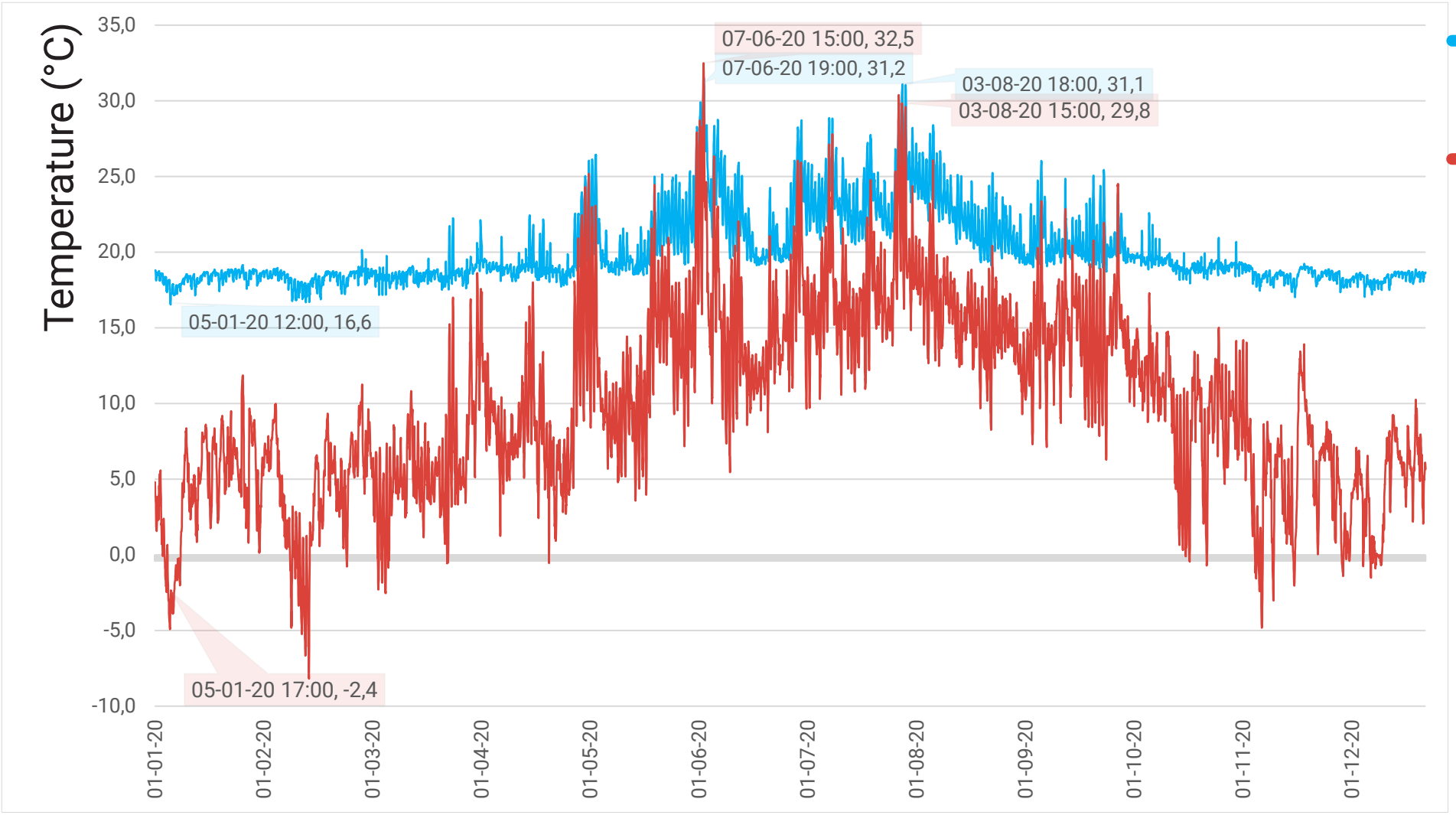


OPTIMISATIONS



CONCLUSIONS

Quantitative results

No active cooling necessary

Heating setpoint in summer 20,8 °C

Mechanical ventilation rate 1,0 ach

Little influence found for:

- mechanical ventilation setpoint
- mechanical ventilation maximum temperature difference

Qualitative results

Comfort conditions

- Thermal comfort
- CO_2 levels
- Relative humidity

Lighting controls

Safety/security

Predictive maintenance

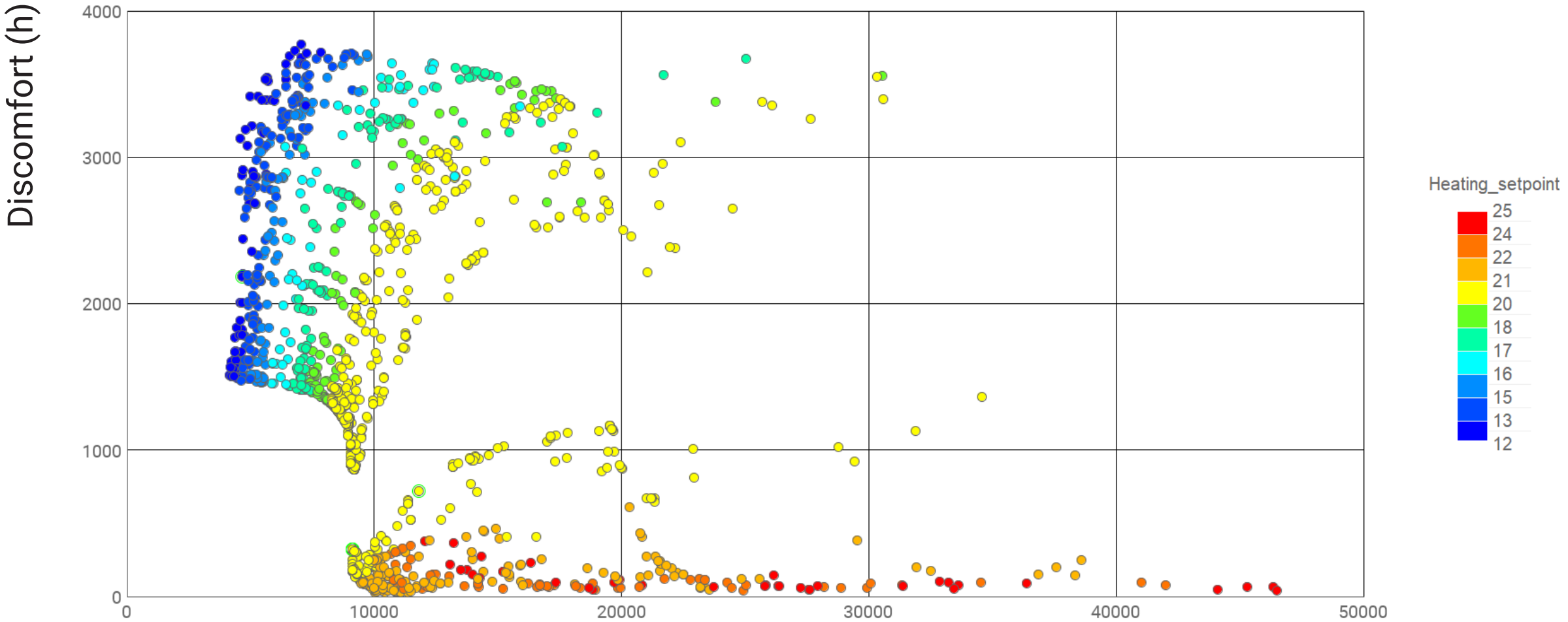
RECOMMENDATIONS

Further research:

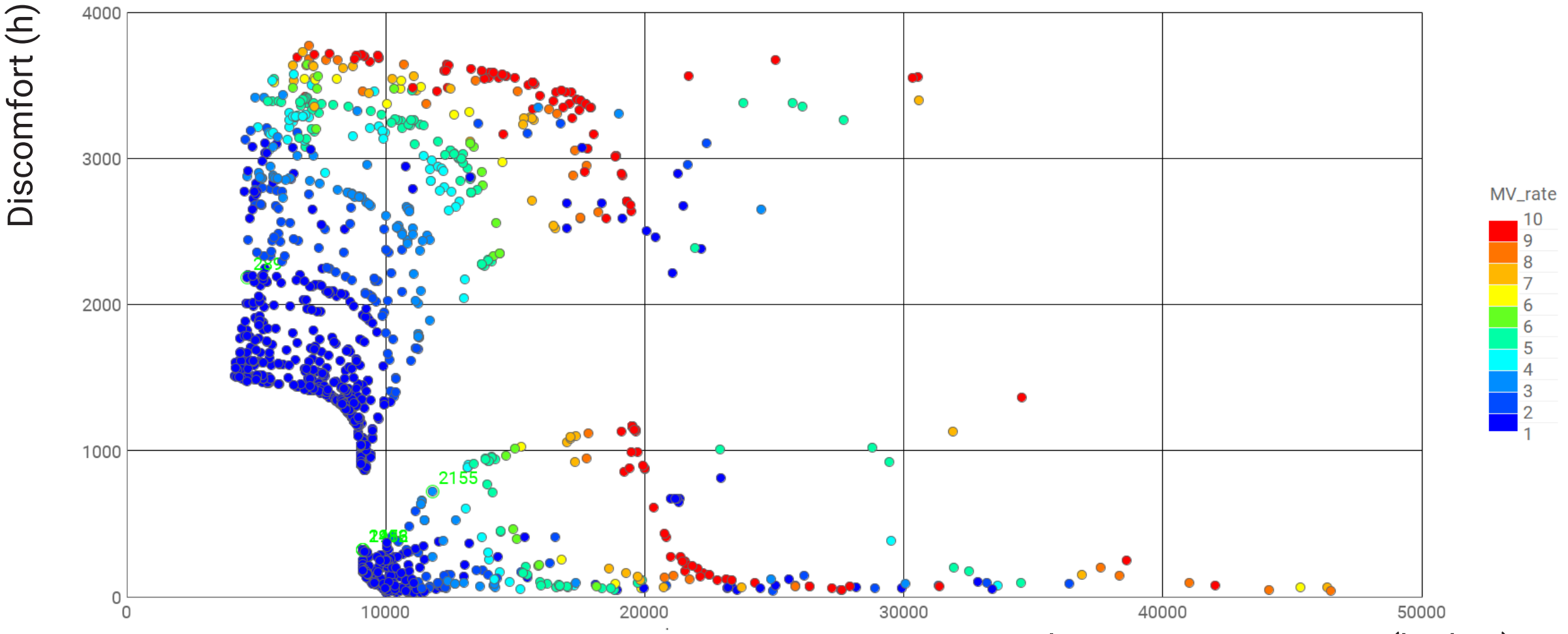
- Implementation of interventions
- Climate weather file
- Energy efficiency


sdelq

HEATING


Discomfort (h)
4000
3000
2000
1000
0
0
10000
20000
30000
40000
50000
Total energy consumption (kWh/a)
Heating_setpoint
25
24
22
21
20
18
17
16
15
13
12

MECHANICAL VENTILATION RATE




Cooling_setpoint
Heating_setpoint
MV_deltaT
MV_rate
MV_setpoint
NV_DeltaT
NV_setpoint
Adaptive_comfort
Total_energy_consumption
0.277
-0.175
-0.090
-0.187
-0.137
0.087
-0.268
-0.087
0.210
0.084
-0.088
0.015
0.057
-0.020
0.097
0.134
0.087
-0.115
-0.049
-0.135
-0.149
-0.249
-0.682
0.104
0.498
0.094
0.005
-0.120
-0.024
0.474
0.045
0.580
0.030
-0.005
-0.208
-0.096

STATISTICAL ANALYSIS

$$MBE = \frac{\frac{1}{N}\sum_{t=1}^{N}(\hat{y}_t - y_t)}{\overline{y}}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(y_t - \hat{y}_t)^2}$$

DISCUSSION

Adaptive comfort

- Heating setpoint
- Extreme temperatures

High number of excluded itterations

- Set different bounds

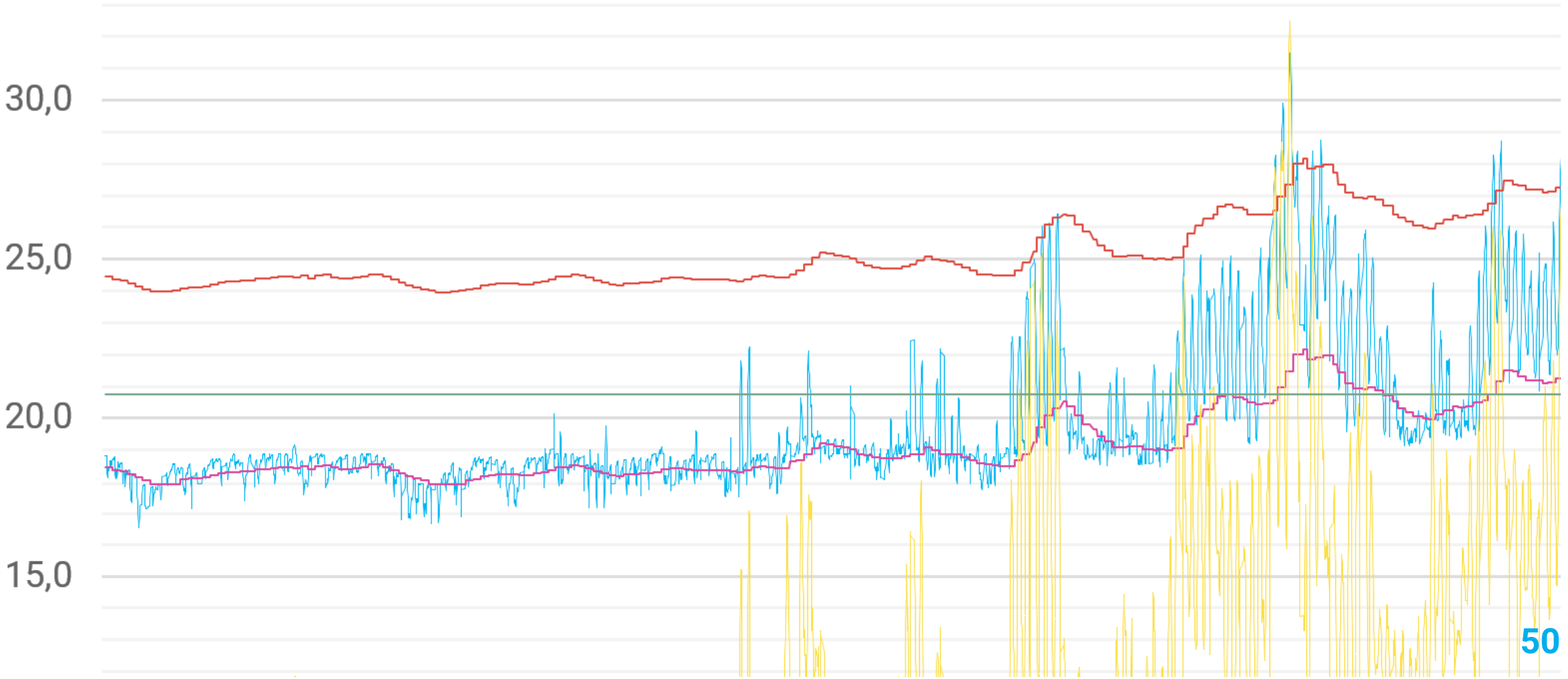
LIMITATIONS

Prototype not completely finished

Limitations in software

- Grasshopper
- DesignBuilder

HEATING SETPOINT



TECHNOLOGY IN SUSTAINABLE DEVELOPMENT (TISD)

The influence of demountable building on the building management system