

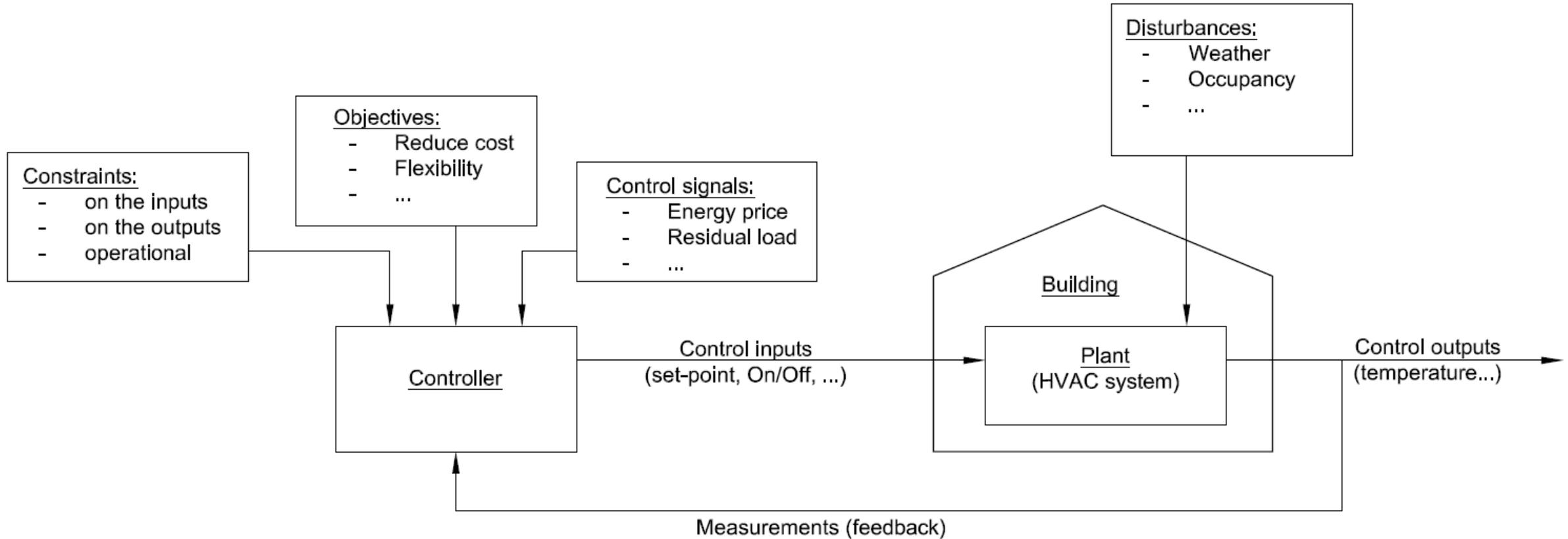
8th IEA EBC Annex 67

Control strategies for energy flexible buildings

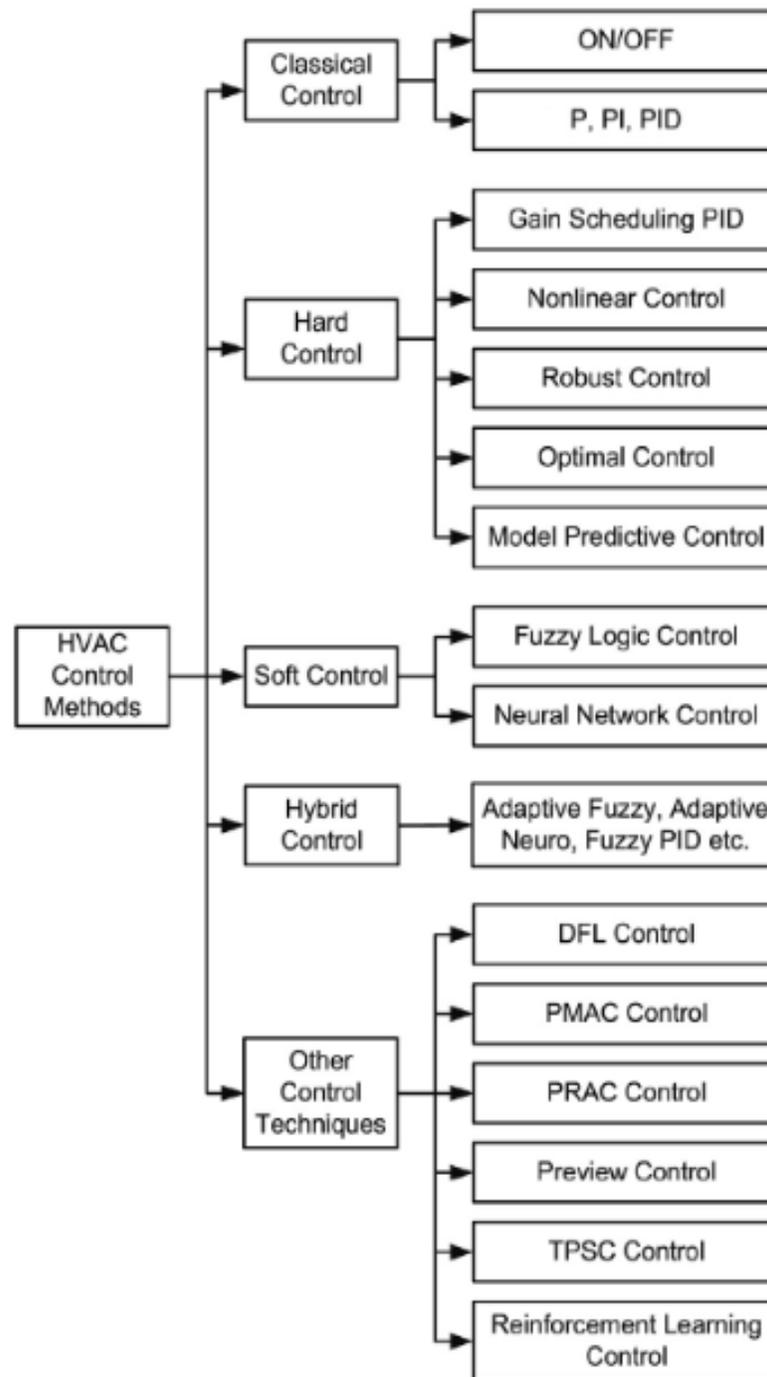
April 4th Aalborg

Athila Quaresma Santos

General Scheme of a single-level control

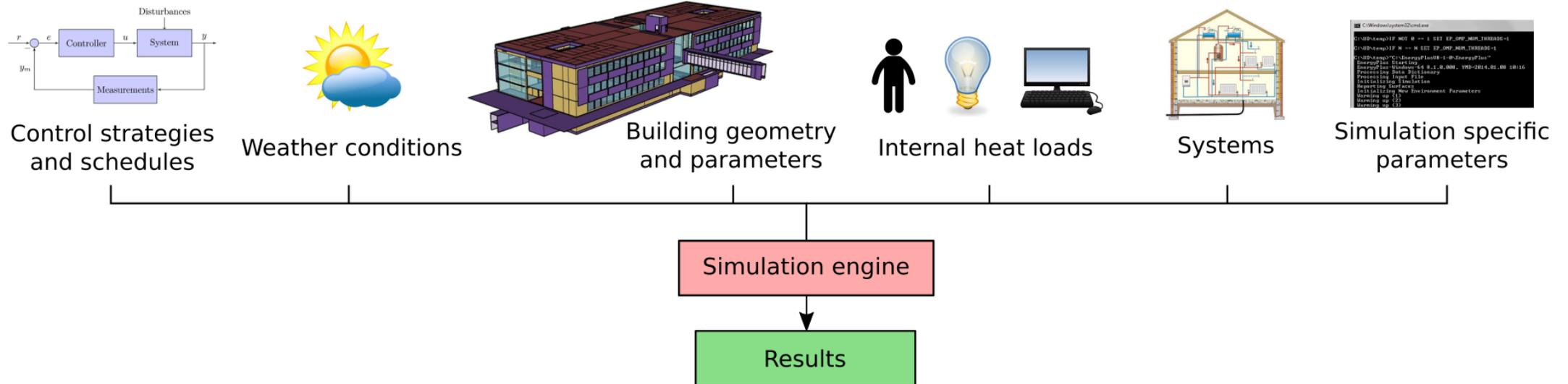


Control methods for HVAC systems



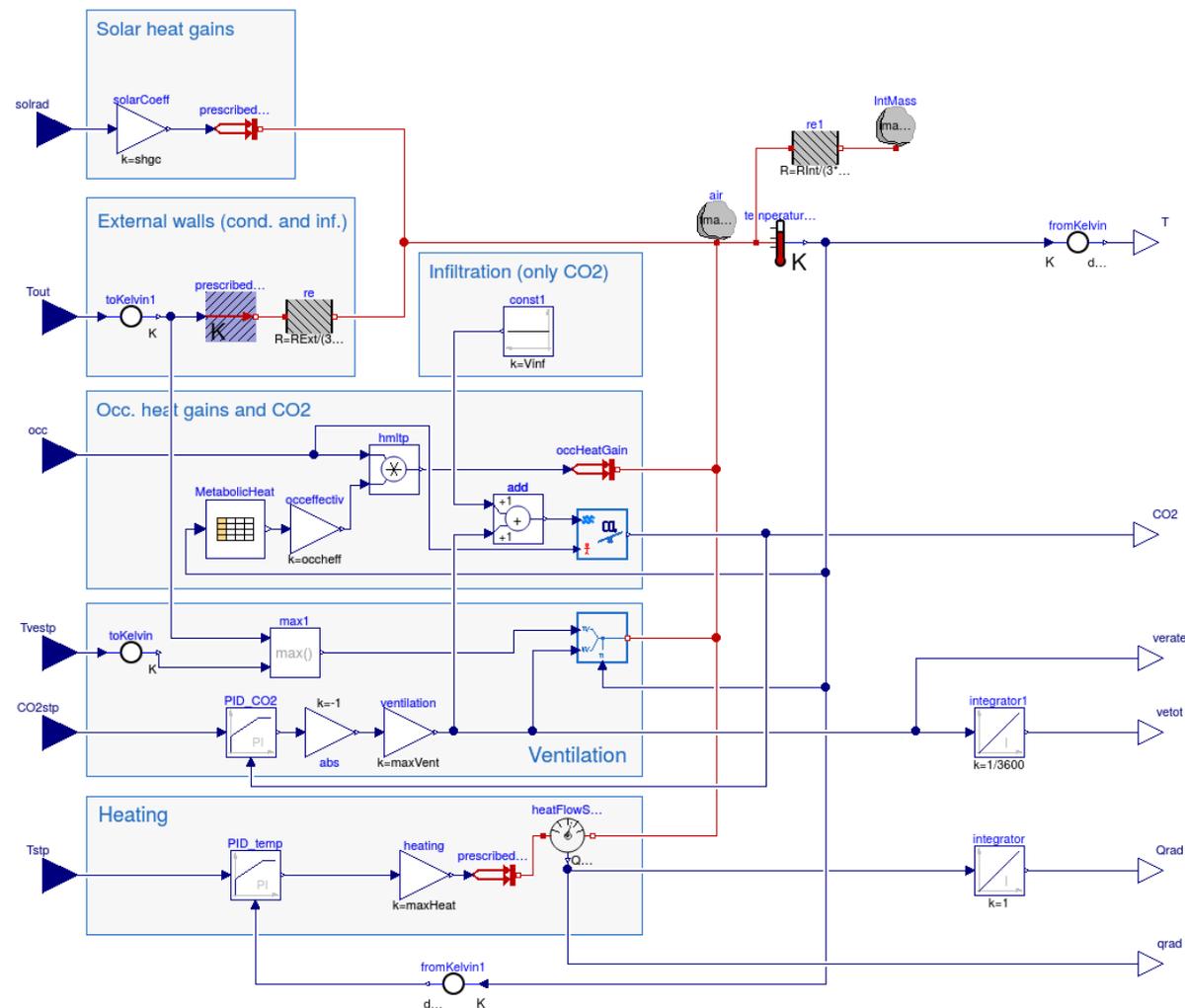
(Afram & Janabi-Sharifi 2014)

White-box Modeling



All data must be provided an expert.
Modeling requires both knowledge and time.

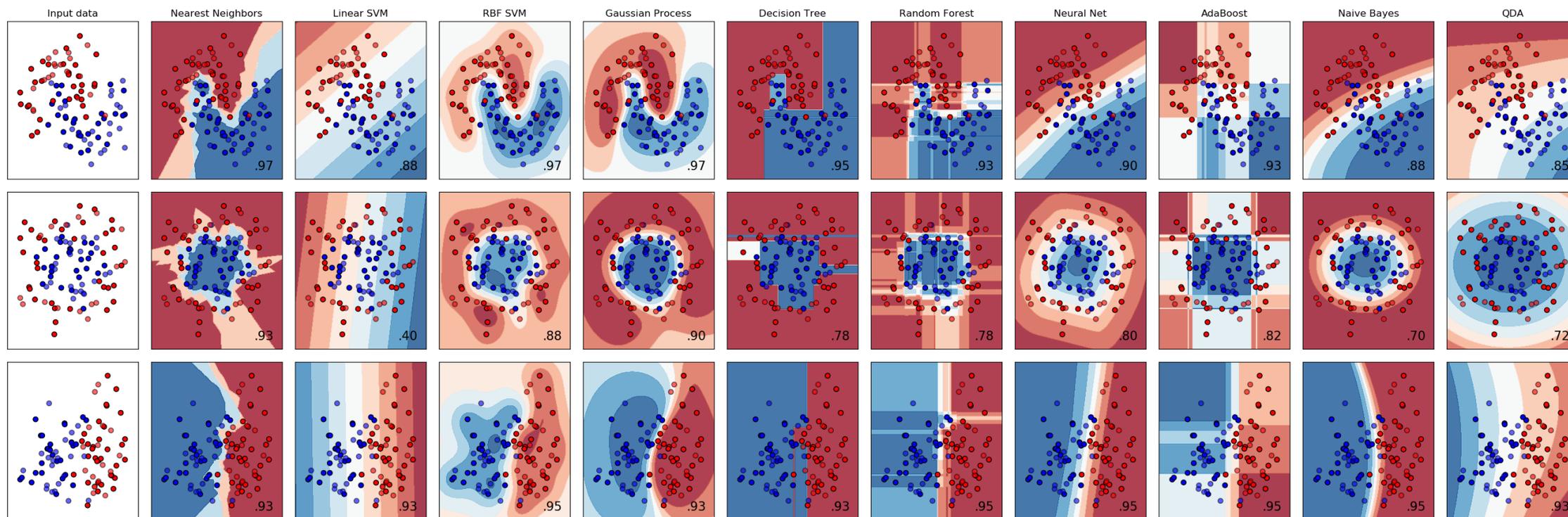
Gray-box Modeling



Include fundamentals physics, but need some sensor data for calibration.

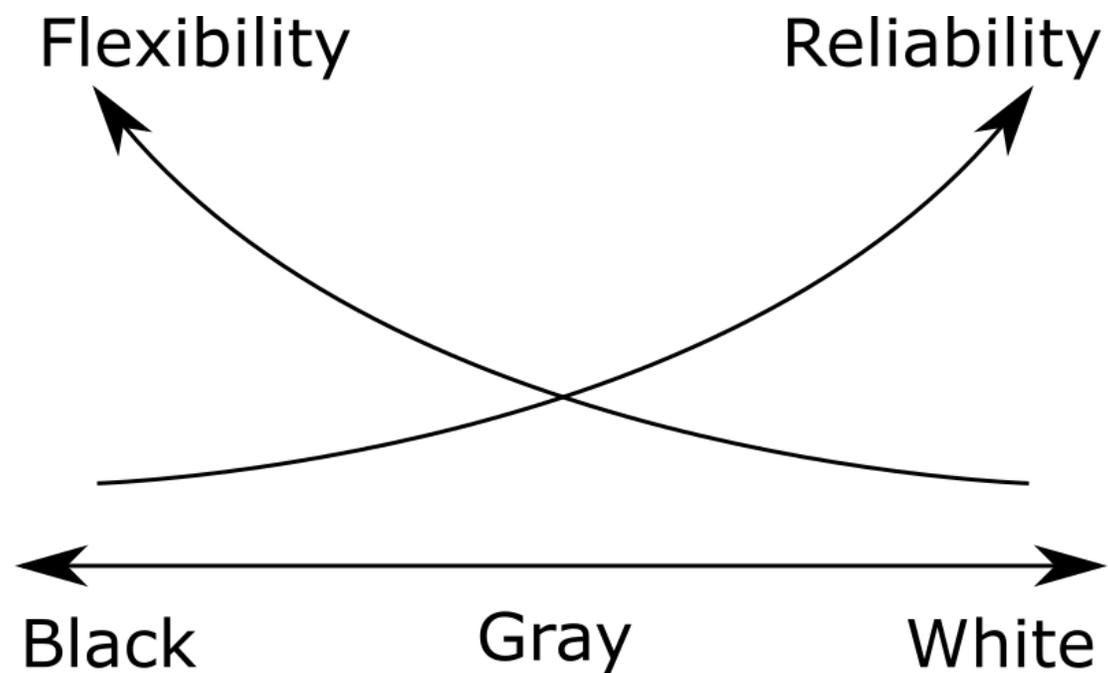
Models can be transferable, between buildings.

Black-box Modeling



Learn complex patterns from (a lot of) data and try to repeat them.
 No physical understanding of the underlying system.
 “Catastrophic forgetting”.

Short Summary



Decentralized ruled-based system
applied to a building zone

Sensors



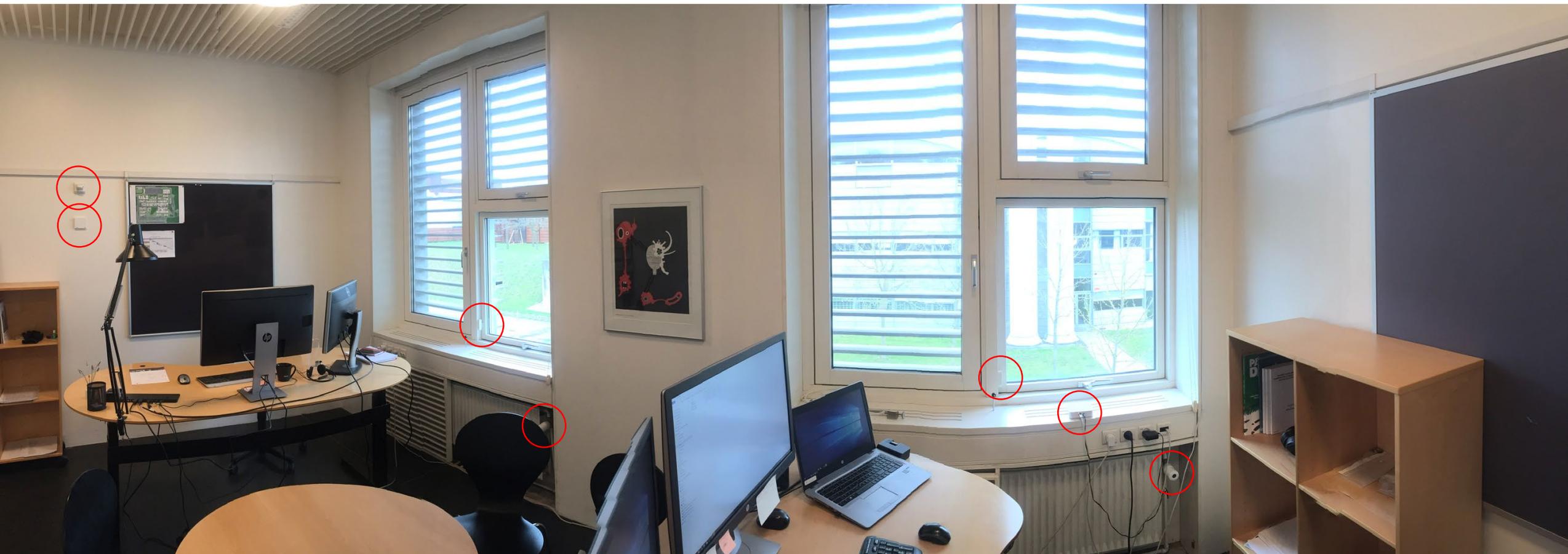
Office Ø15-610-2



Office Profile

- Building: **Mærsk Mc Kinney Møller Institut**
- Total office area: 15m²
- Location: Odense, Denmark

Office Ø15-610-2



OPC-UA: Milo Eclipse

OPC UA

- Connectivity, Security and IoT Integration
- Industry 4.0 interoperability standard

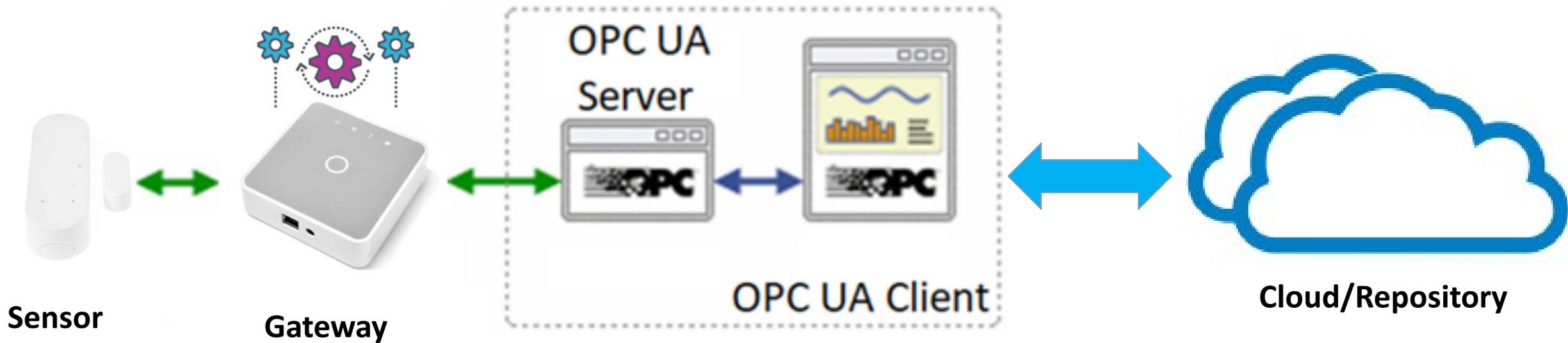


Milo Eclipse

- Java Implementation



Architecture Integration



Live Dashboard

Living Lab Office Dashboard

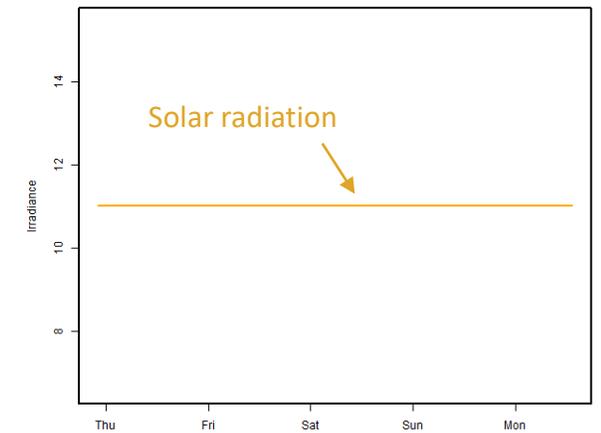
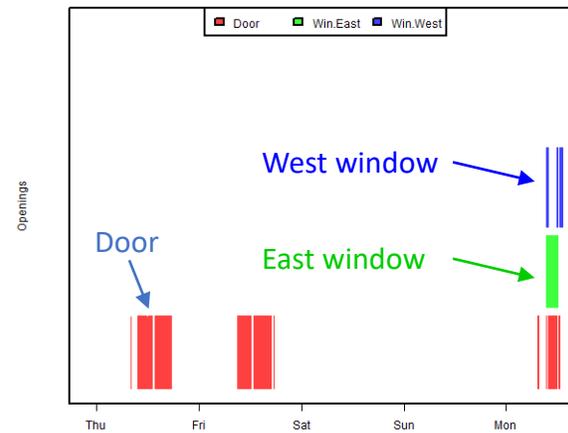
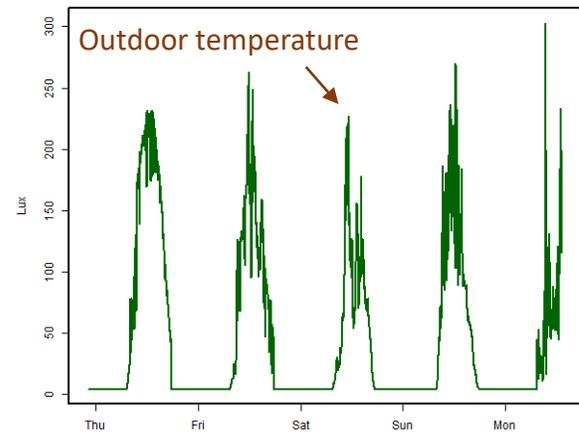
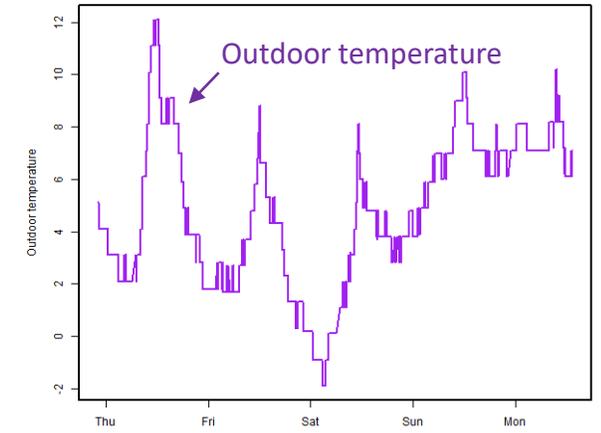
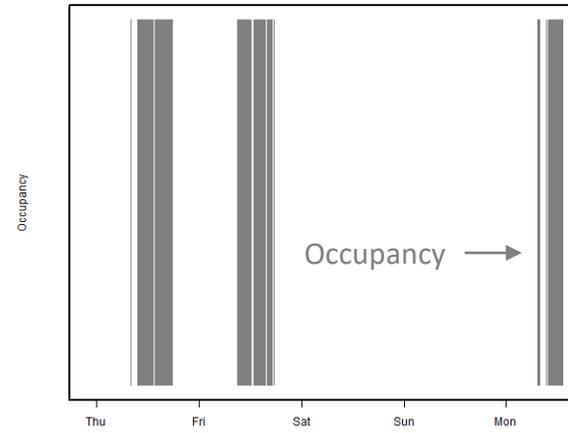
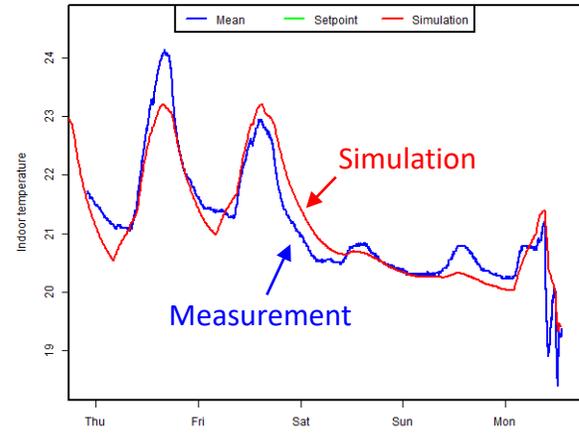
Refresh rate (seconds)

Time period (hours)

Options

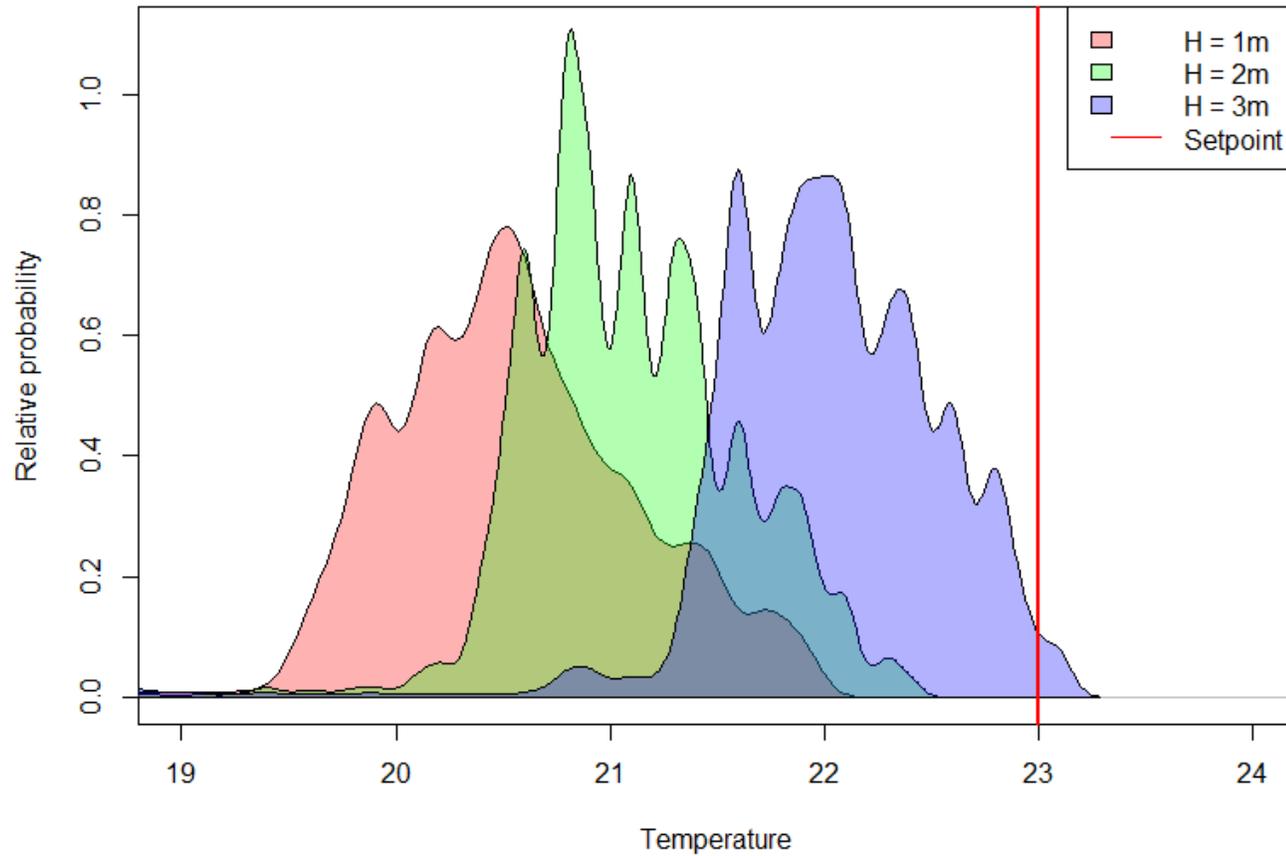
- Temperature setpoint
- Temperature simulation

Monitoring Prediction Last state
2019-03-04 13:17:06

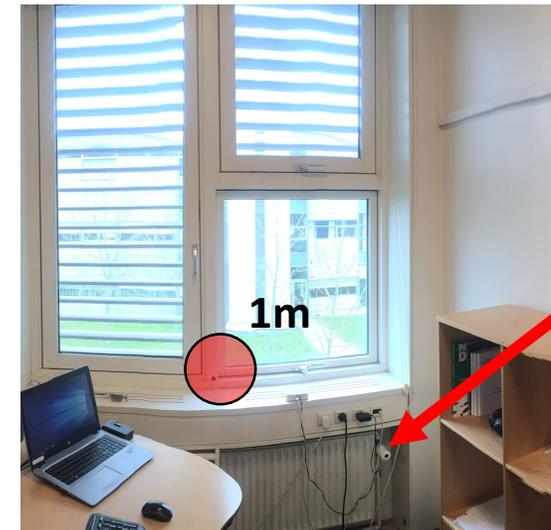
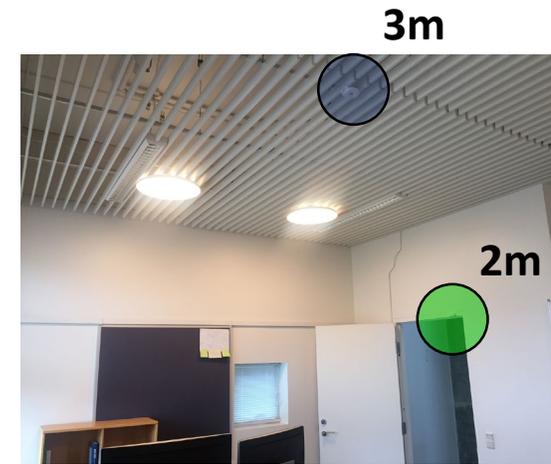


Indoor Environment Analytics

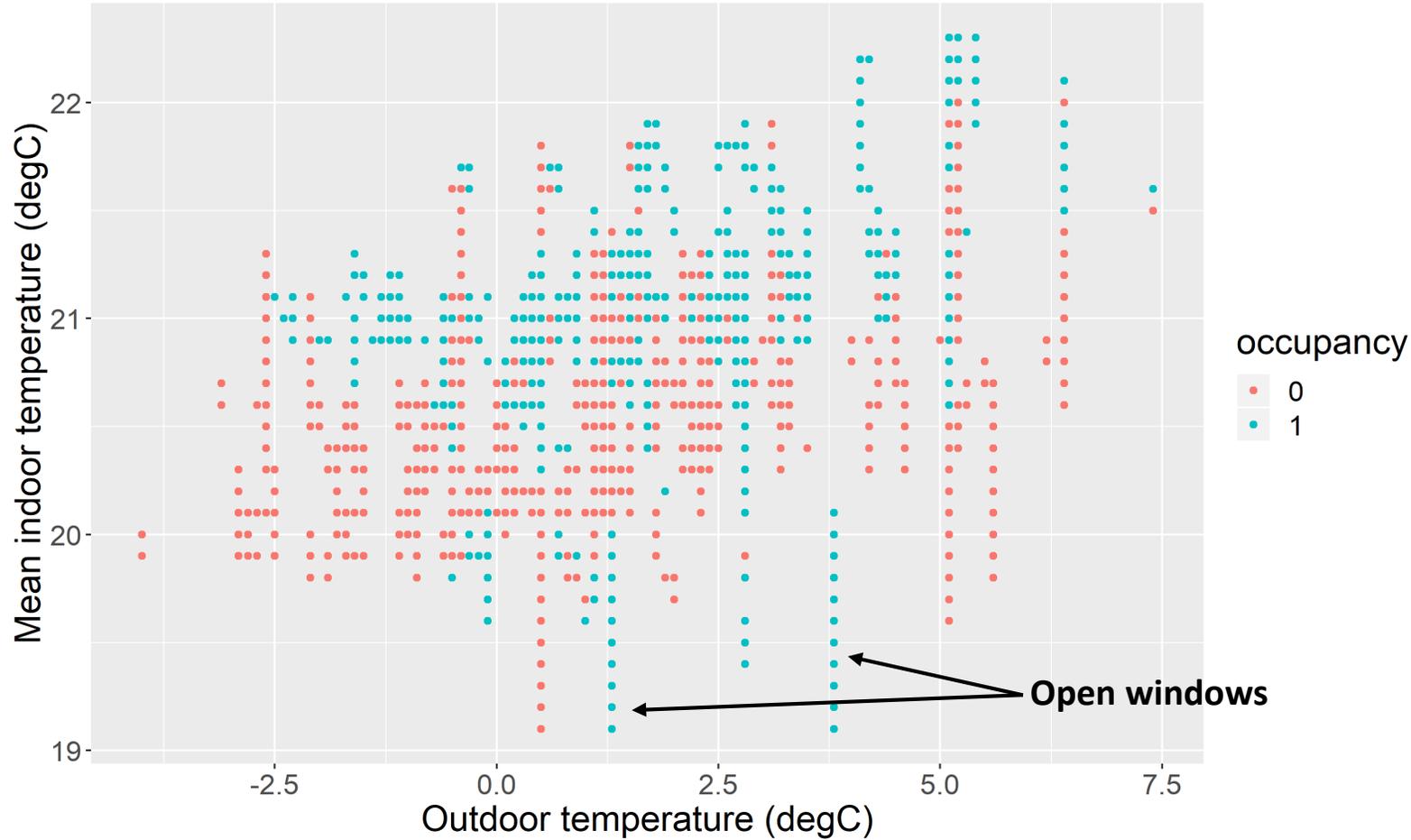
Distribution of indoor temperatures (setpoint: 23 degC)



Based on data from the period with constant heating setpoint



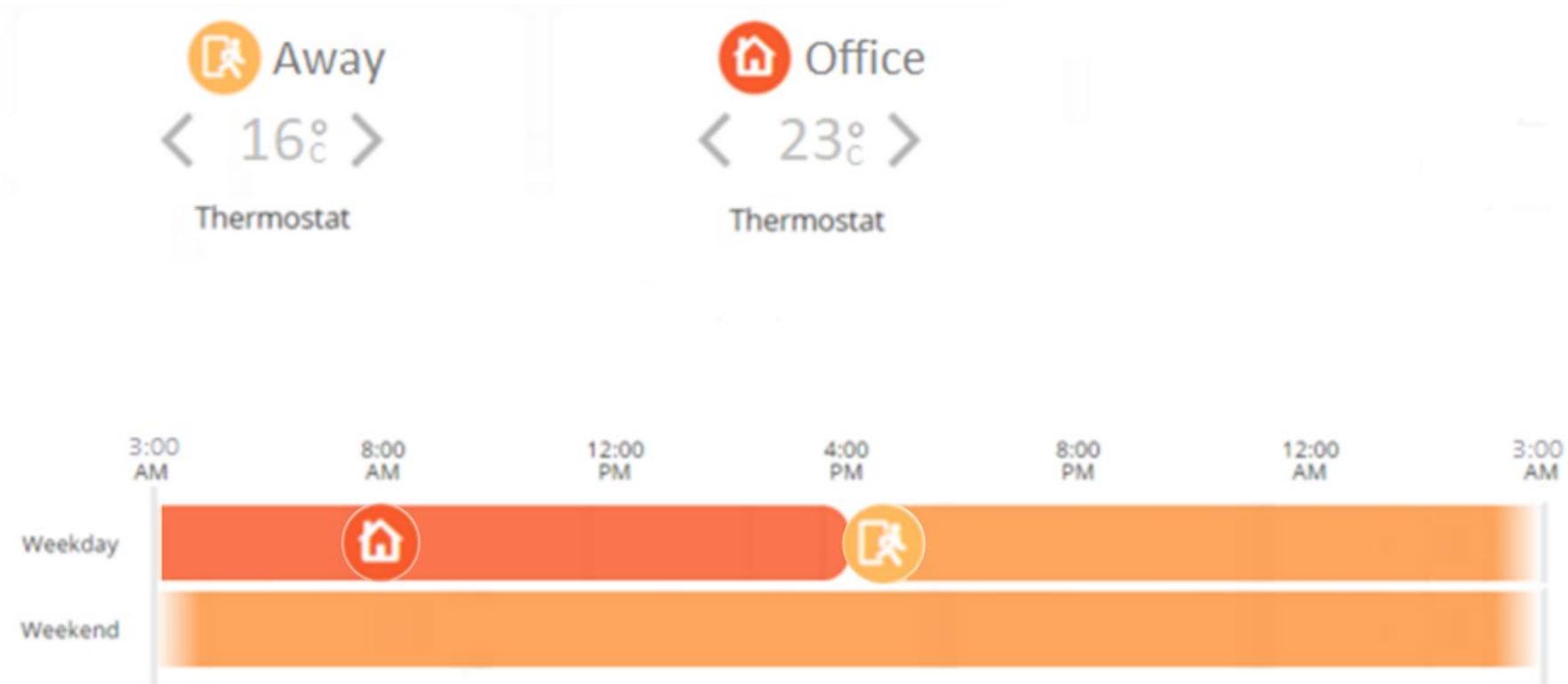
Indoor Environment Analytics



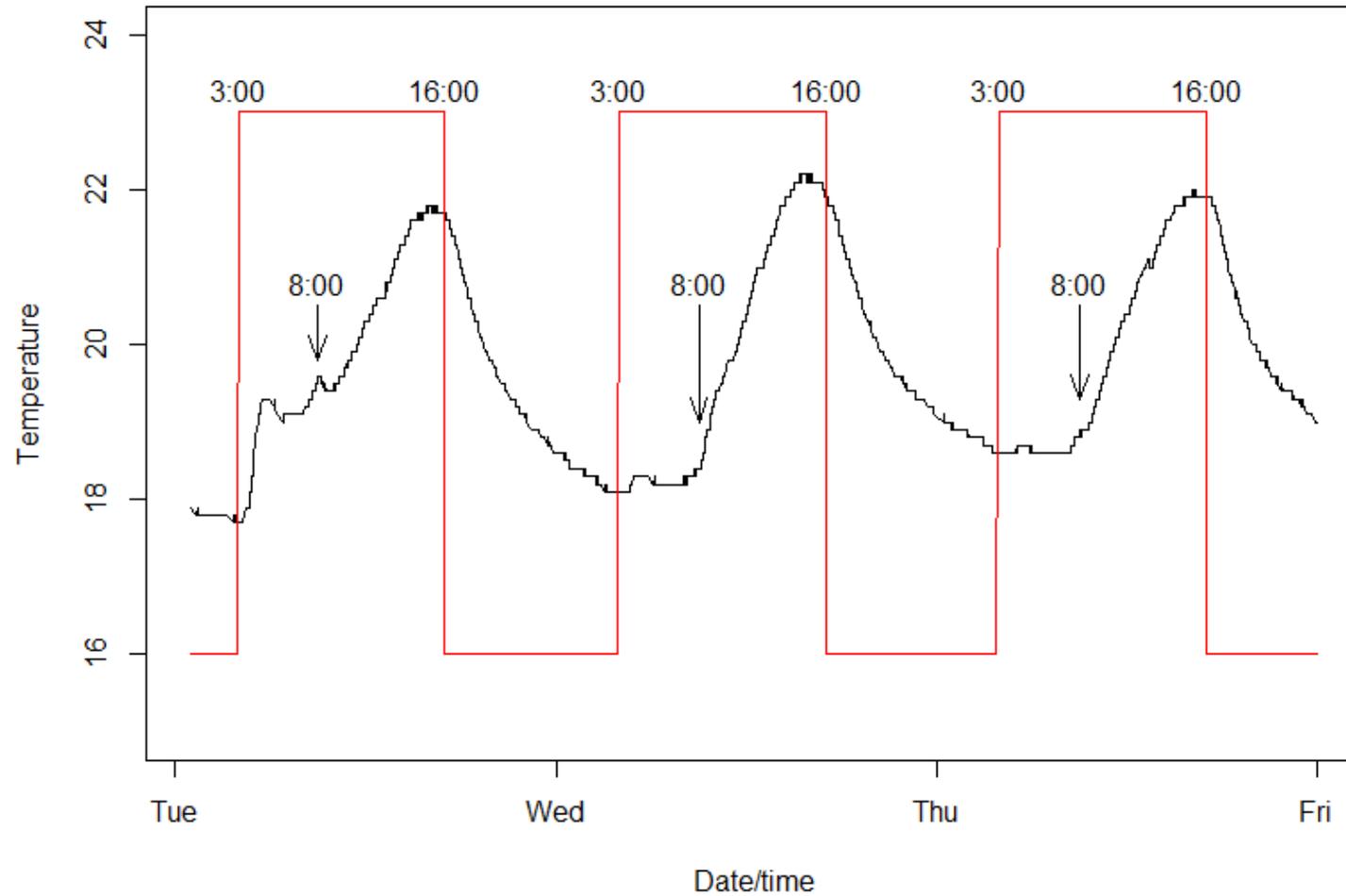
- Occupancy has higher impact on indoor temperature than solar radiation
- Outdoor temperature has a moderate impact

Based on data from the period with constant heating setpoint

Thermostat Schedule

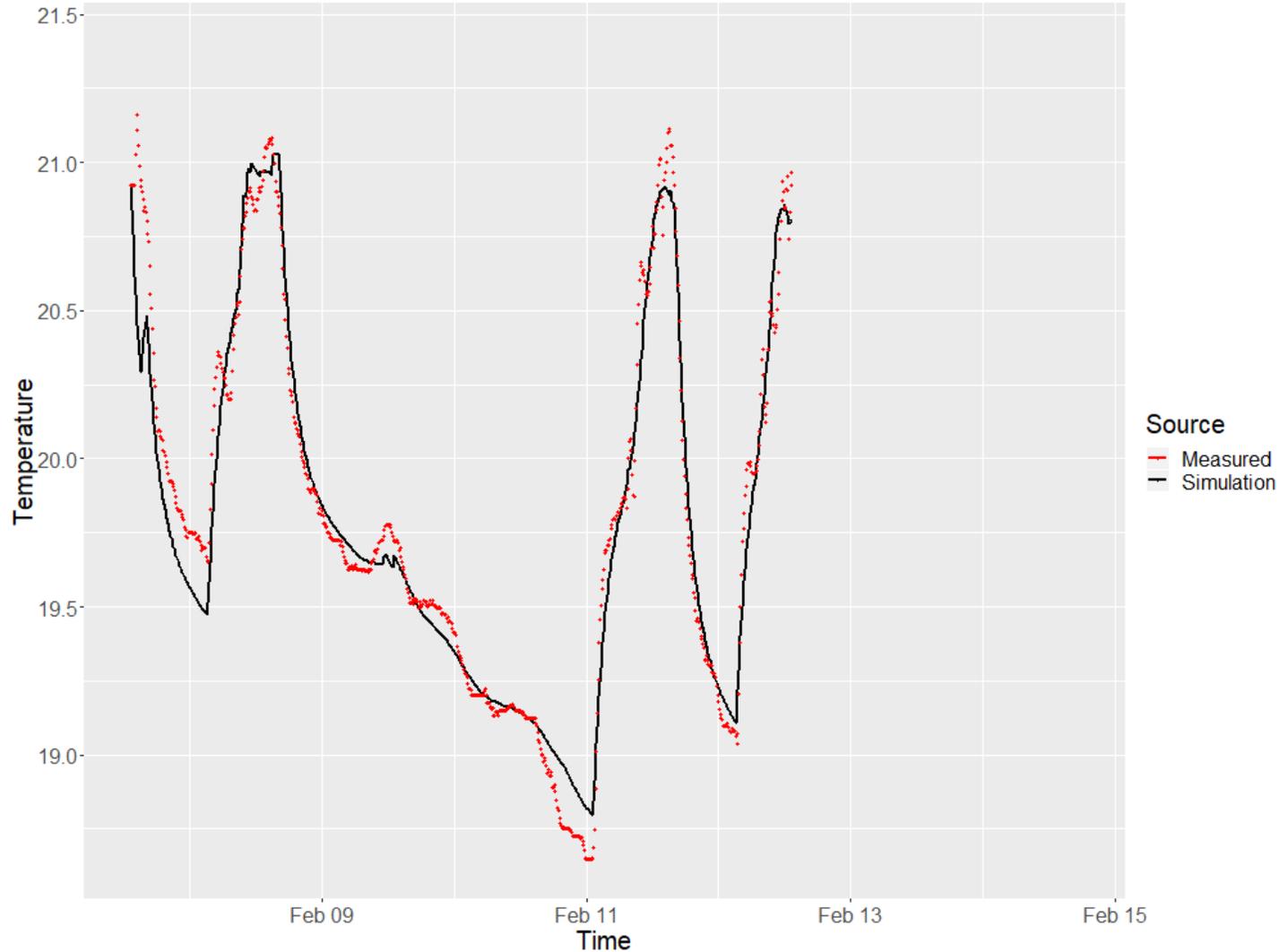


Setpoint vs. Measurements



Next Step: Towards Model-Based Control

Measured temperature vs. simulation
Time window no. 1

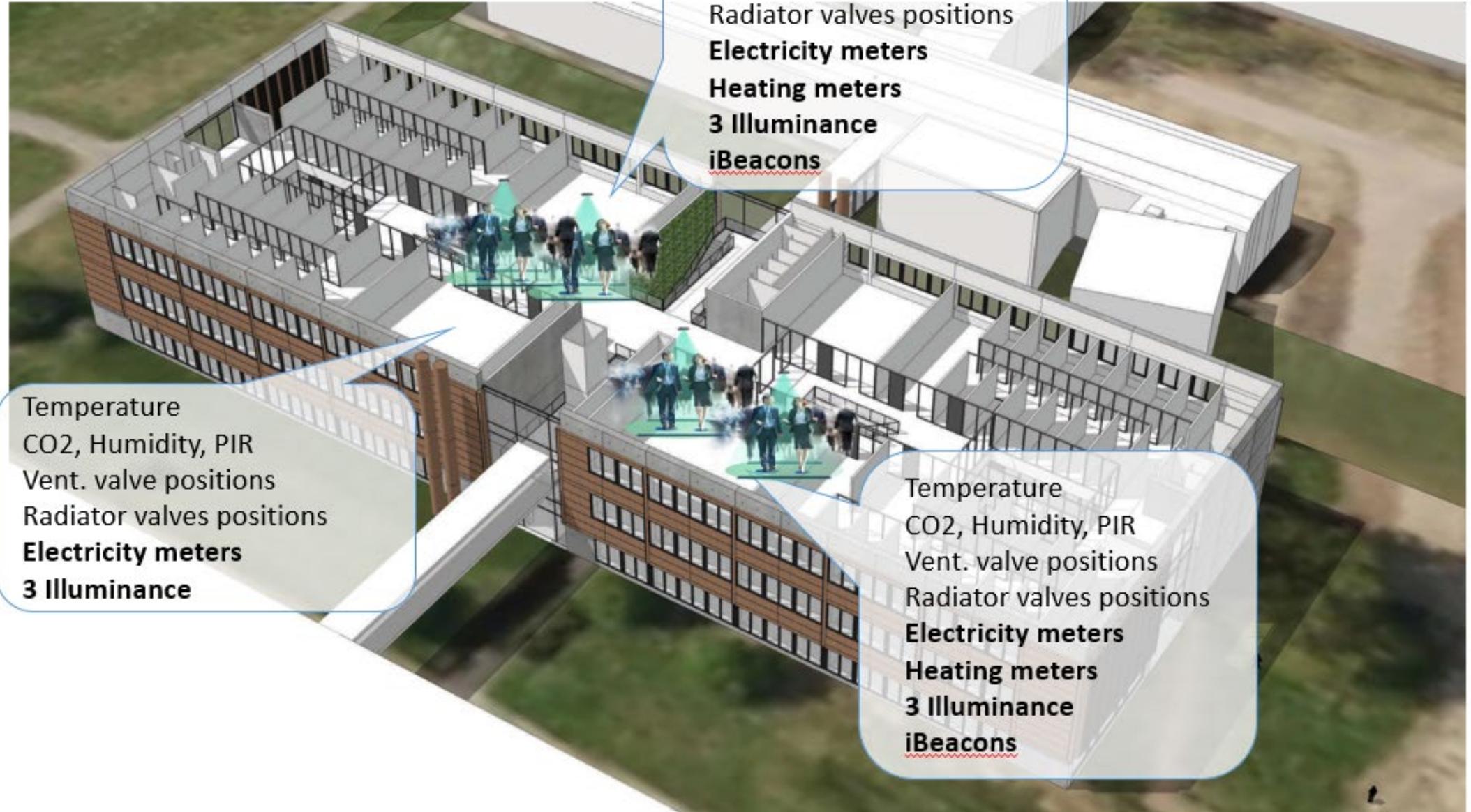


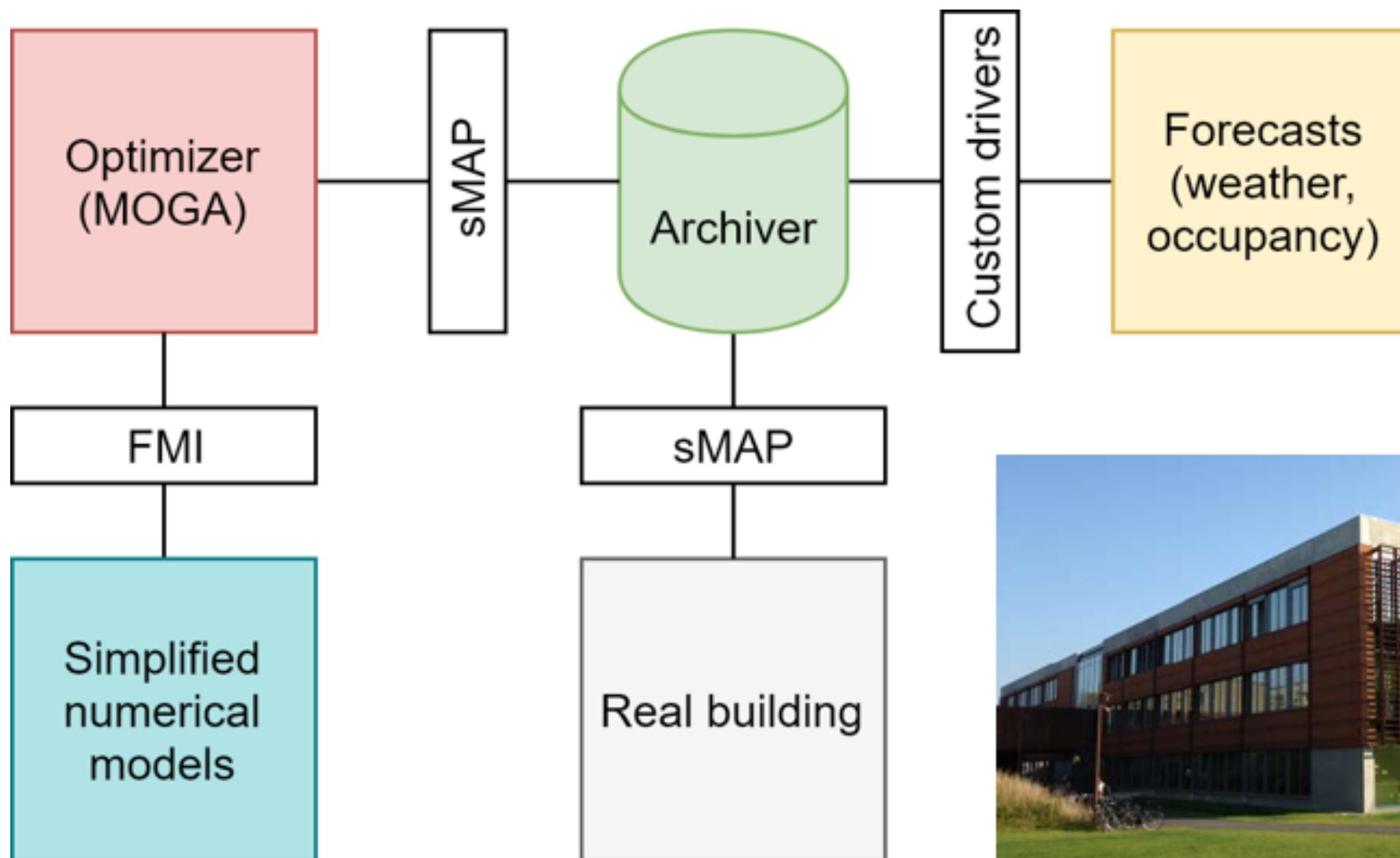
- Zone model recalibrated periodically (every 10 minutes)
- Simulation every few minutes
- Window and door opening included in training
- **Model-based optimization**

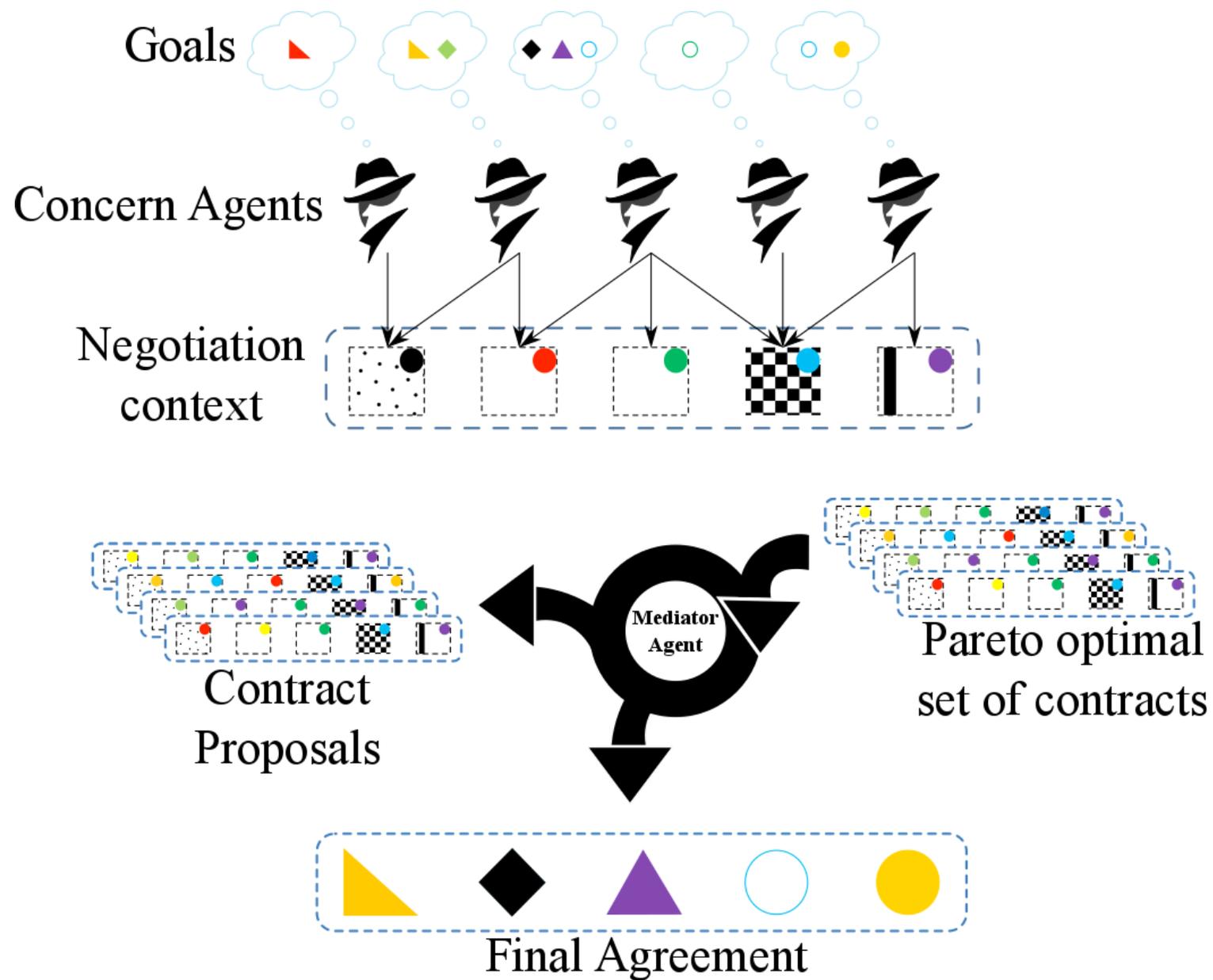
Model Predictive Control and Multi-Objective Genetic Algorithm



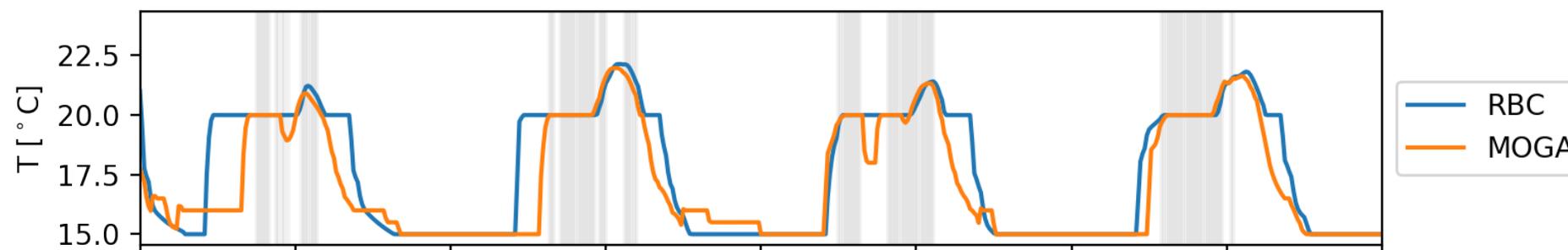
	Dwellings	Other Buildings
BR15	30 + 1000/A	41 + 1000/A
Buildings class 2020	20	25



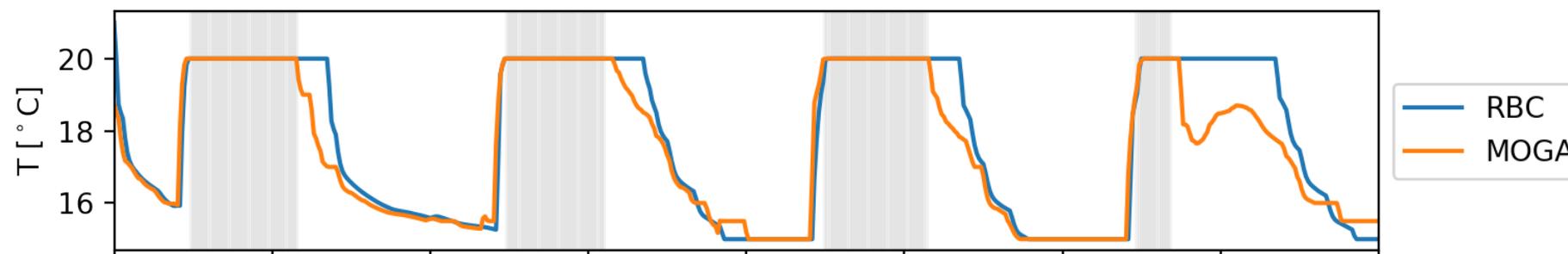




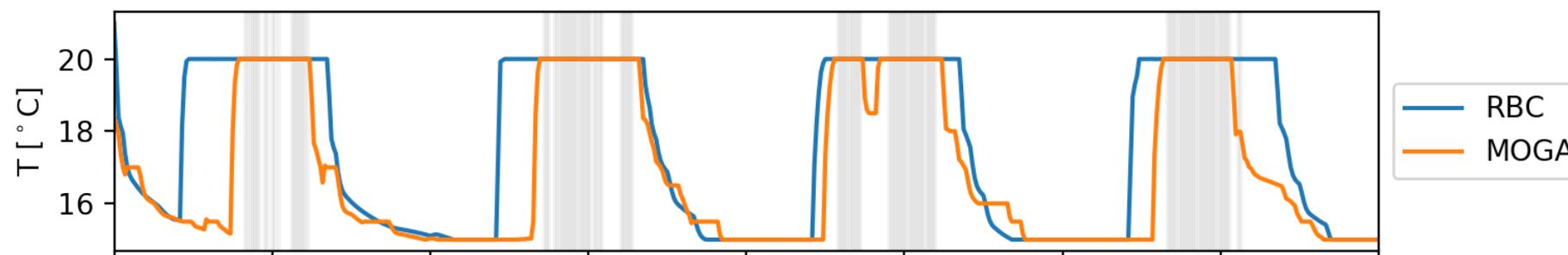
Zone 1



Zone 2



Zone 3



01-01 00 01-01 12 01-02 00 01-02 12 01-03 00 01-03 12 01-04 00 01-04 12 01-05 00

Scenario	Total heating energy [kWh]	Relative [% of RBC]
MOGA	4050.43	75.4
RBC	5368.66	100.0

Deliverable D5

International Energy Agency

Control strategies and algorithms for obtaining energy flexibility in buildings

Energy in Buildings and Communities Programme
Annex 67 Energy Flexible Buildings

April 2019



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Case Studies

ANNEX 67

	Building typology				Energy system				Storage system			Control system		Results based on	
	Single family building(s)	Multifamily building	Non-residential building	Cluster of buildings	Heat pump	District heating	Other HVAC systems	PV	Constructions	Water – tanks or pools	Batteries	Rule based	Model predictive	Simulations	Measurements
Athila			X				X		X				X	X	X
Hussain	X				X				X			?		X	
Ala	X				X	X	X	X		X	X	X	X	X	
Thibault	X	X			X				X	X			X	X	
Sunliang Cao	X							X			X				X
Young-Jae Yu	X				X					X		X		X	
John Clauss	X							X							X
Rune	X			X	X					X			X		X
Anjukan			X					X	X	X		X		X	
Christian Finck	X							X		X			X		X
Donal Finn			X					X		X		X		X	
Kun Zhang	X							X	X	X					
Ali	X							X		X		X			X

8th IEA EBC Annex 67



Thank you!

April 4rd Aalborg

Athila Quaresma Santos