

# MPC EN DIGITAL TWINS

## MPC ET JUMEAUX NUMÉRIQUES

**De universele sleutel tot HVAC-sturing en anomaliedetectie**  
**La clé universelle pour le contrôle HVAC et la détection d'anomalies**

5/3/2025

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*CEO - Builtwins*



# Context

**Today:** HVAC = 15% of the world energy use

**2050:** building = CO<sub>2</sub>-neutral

While... we spend 90% of our time indoor

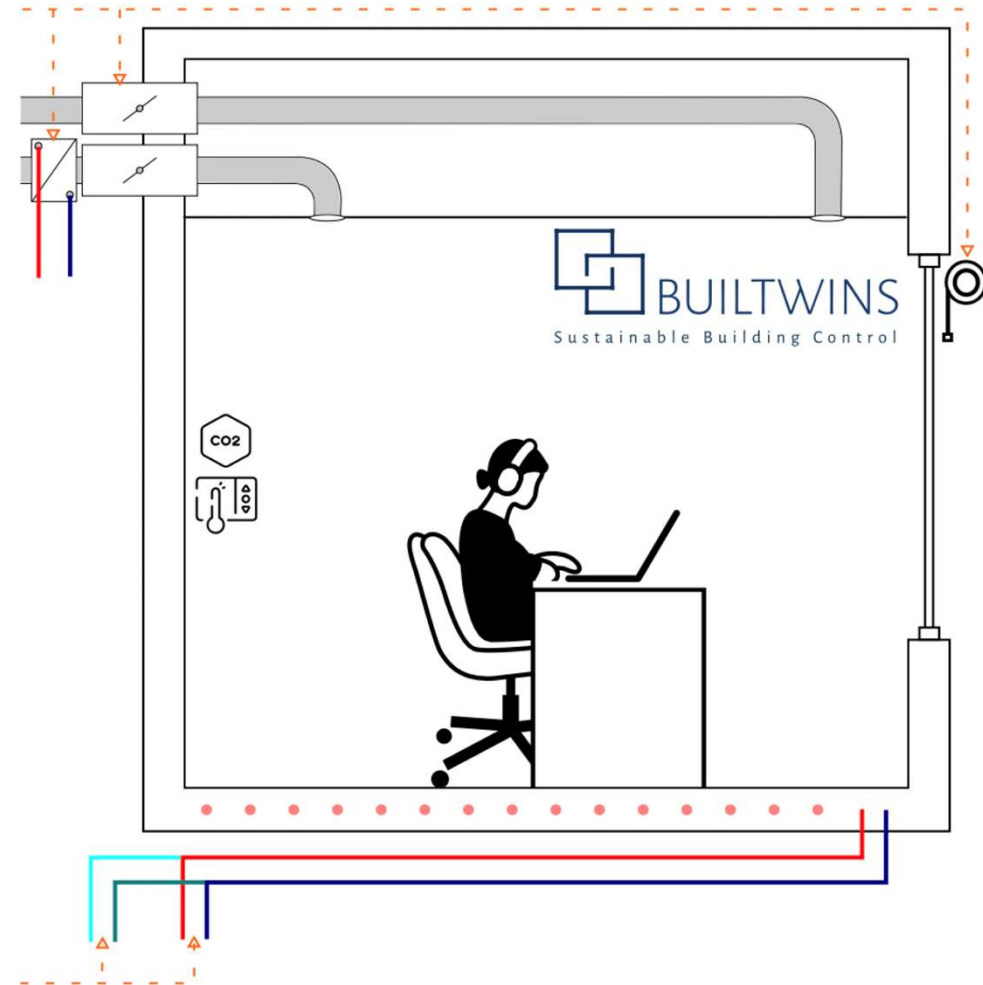
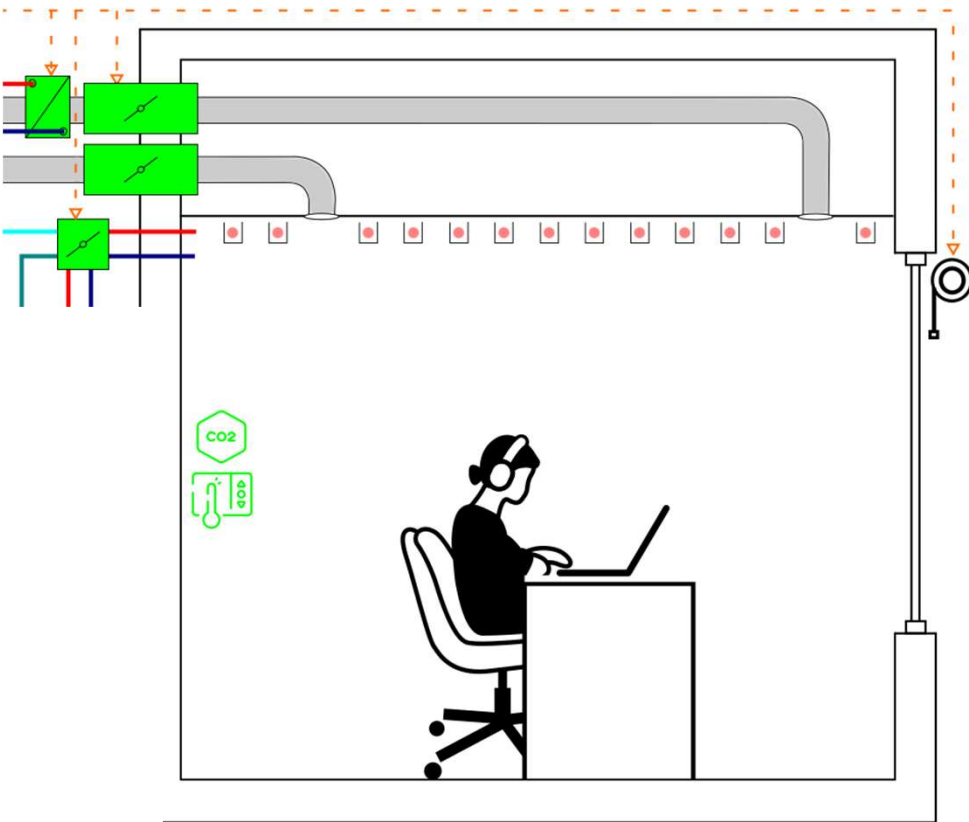
# Challenges Herman Teirlinckgebouw

Example: Herman Teirlinckgebouw





# Challenges

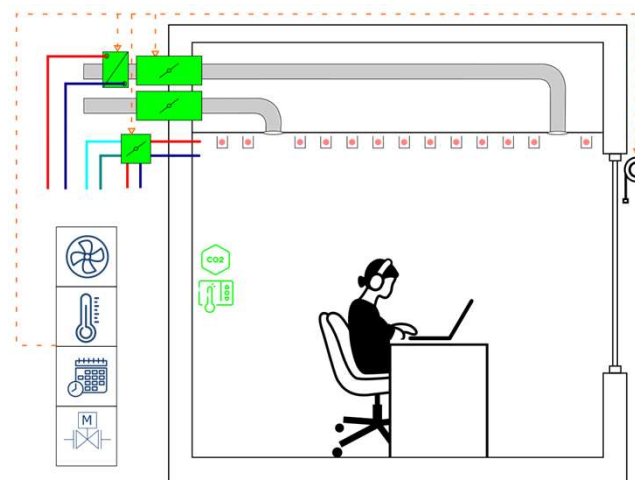






# Challenges

- 55.000 m<sup>2</sup> floor surface
- ~700 zones
- HVAC complexity:
  - > 36.000 IOs related to HVAC
  - ~ 2000 zone HVAC actuators
  - ~ 1200 zone HVAC sensors
  - Hybrid heat and cold production
  - Hybrid emission
- Building complexity:
  - Sun and occupants have a larger influence than outdoor temperature

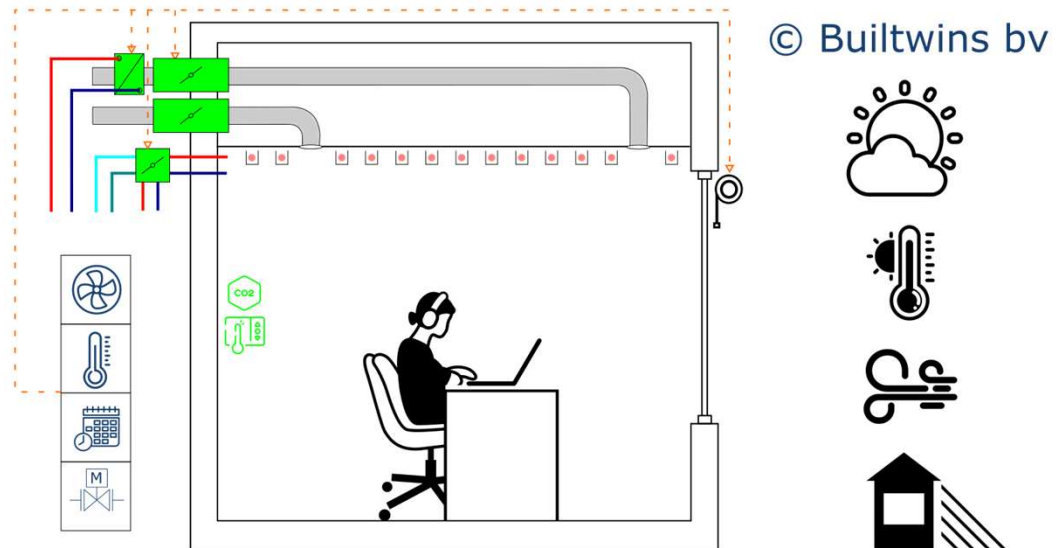
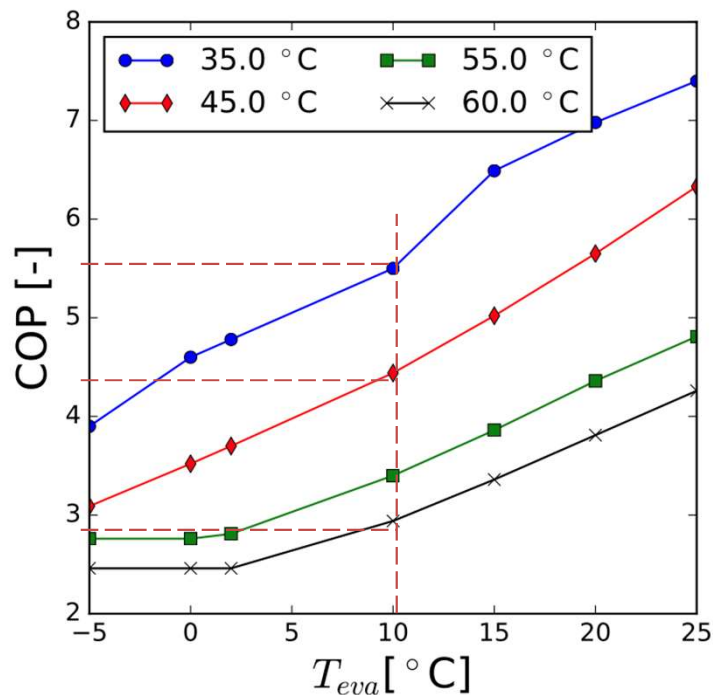


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# Challenges

Energy efficiency of projects with heat pumps are very sensitive to the quality of the control



Taking into account a primary energy factor of 2,5, a heat pump should have a (S)COP > 2,5 to use less primary energy than a gasboiler.

# Challenges

*Engineering offices, installers, facility managers,  
maintenance firms need new tools to tackle  
those new challenges*

# Technical solution: MPC

Model Predictive Control: car analogy

Hysteresis



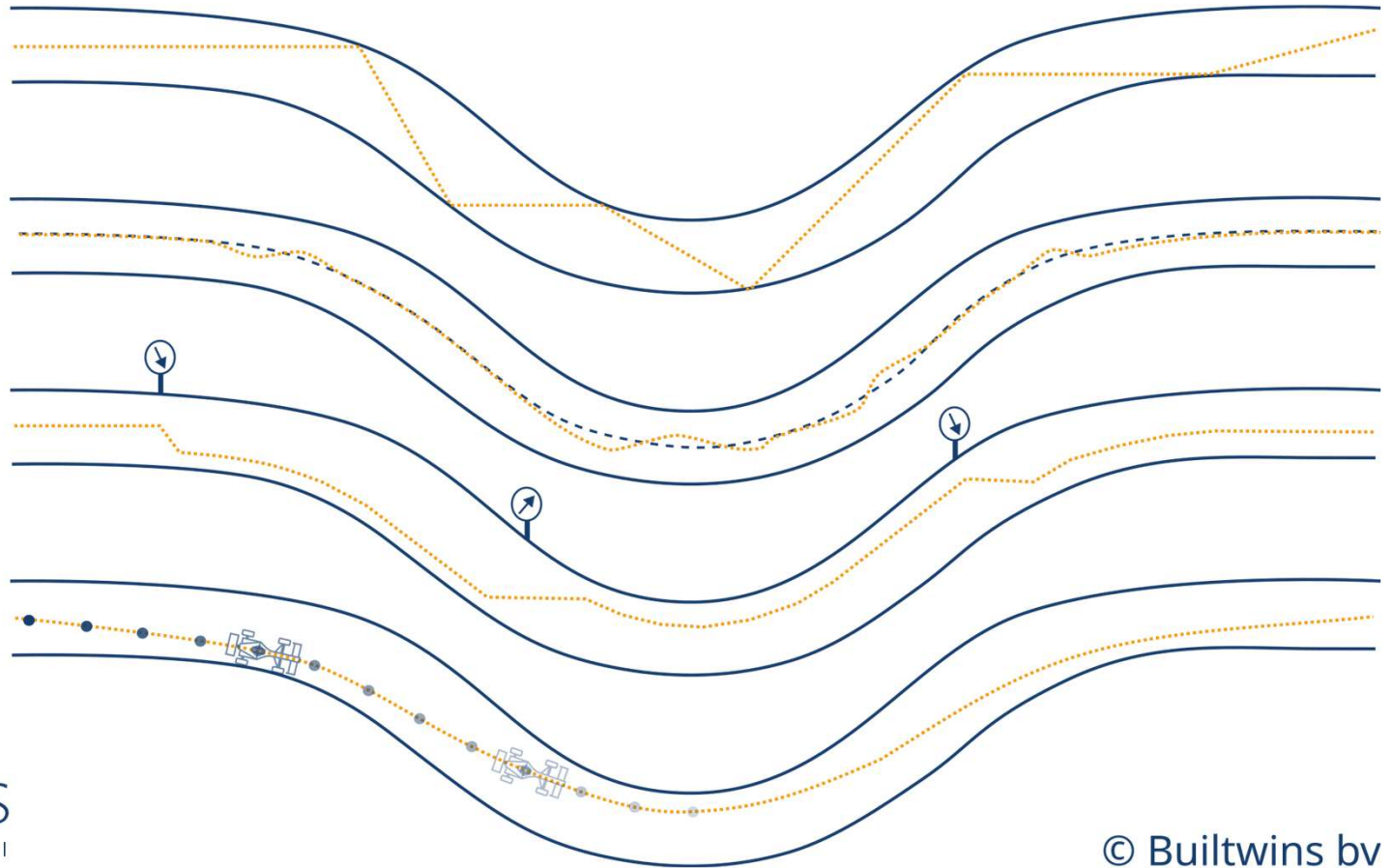
PI(D)



Rules



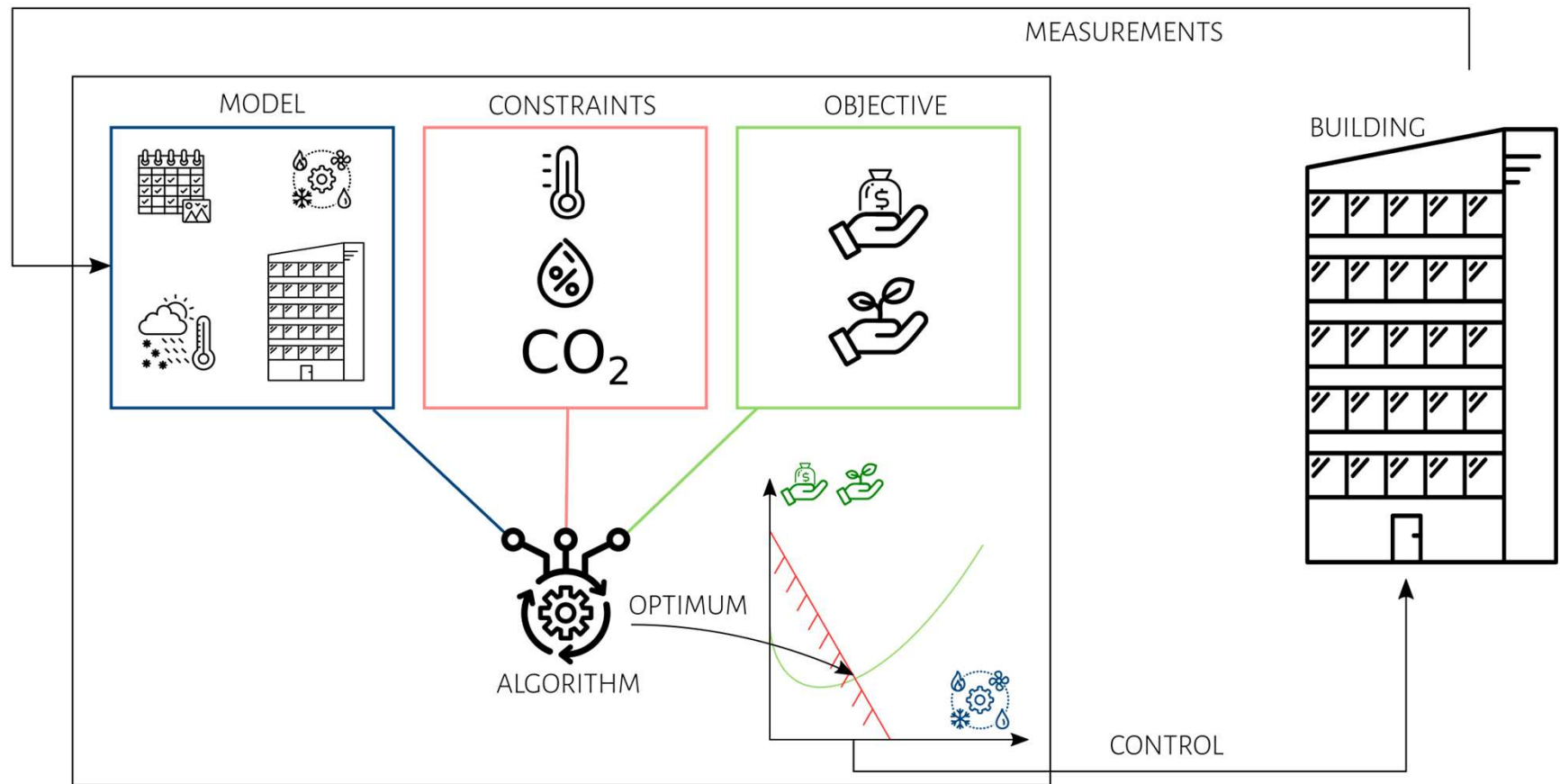
MPC





# Technical solution: MPC

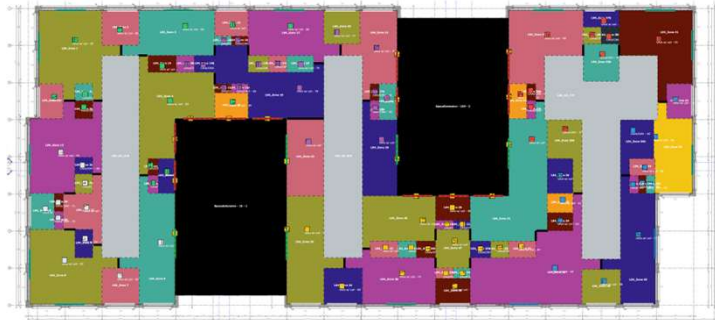
## Model Predictive Control: MPC for buildings



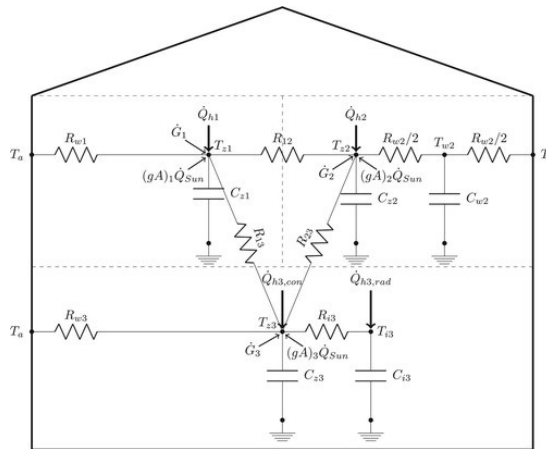
# Technical solution: MPC

Model Predictive Control: model types

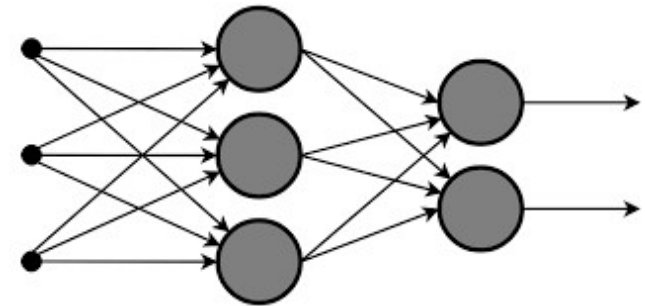
White-box



Grey-box



Black-box



# Technical solution: MPC

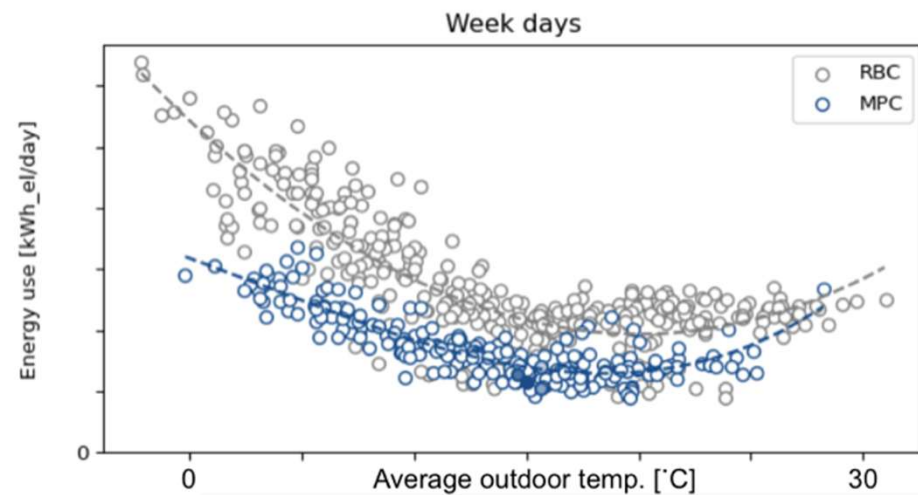
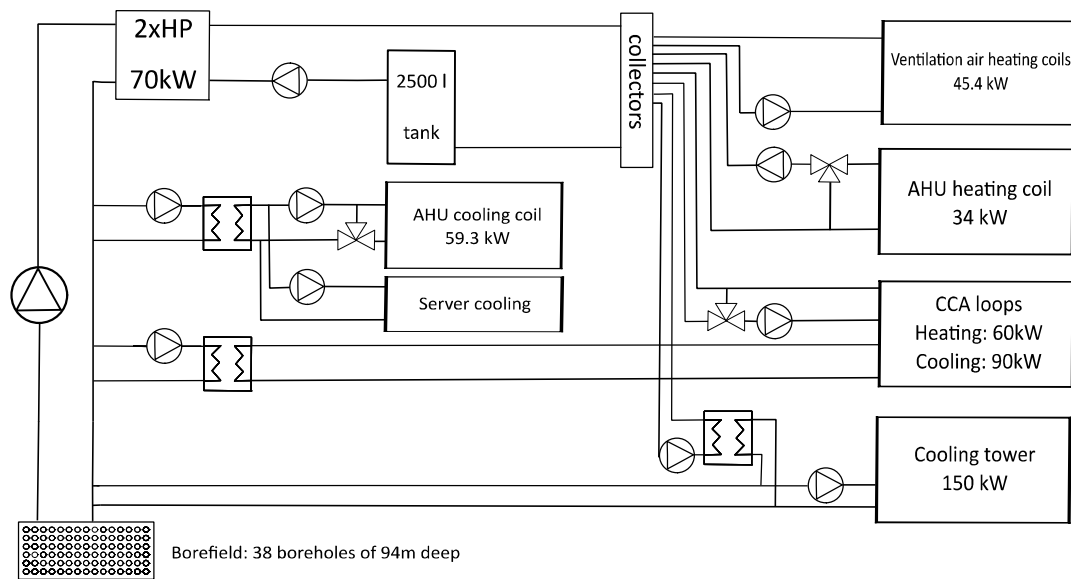
## Advantages of MPC

- Typically, 10 to > 40% energy savings due to:
  - Predictive control instead of reactive control
  - Model based control instead of scenario/rule based control
  - MPC takes influence of sun into account
  - Continuous optimization instead of tuning
- Comfort improvement
- Fault detection
- No tuning required
- Cost optimization using variable energy price

# Optimal HVAC control

# Optimal HVAC control

## Case 1: 38% savings

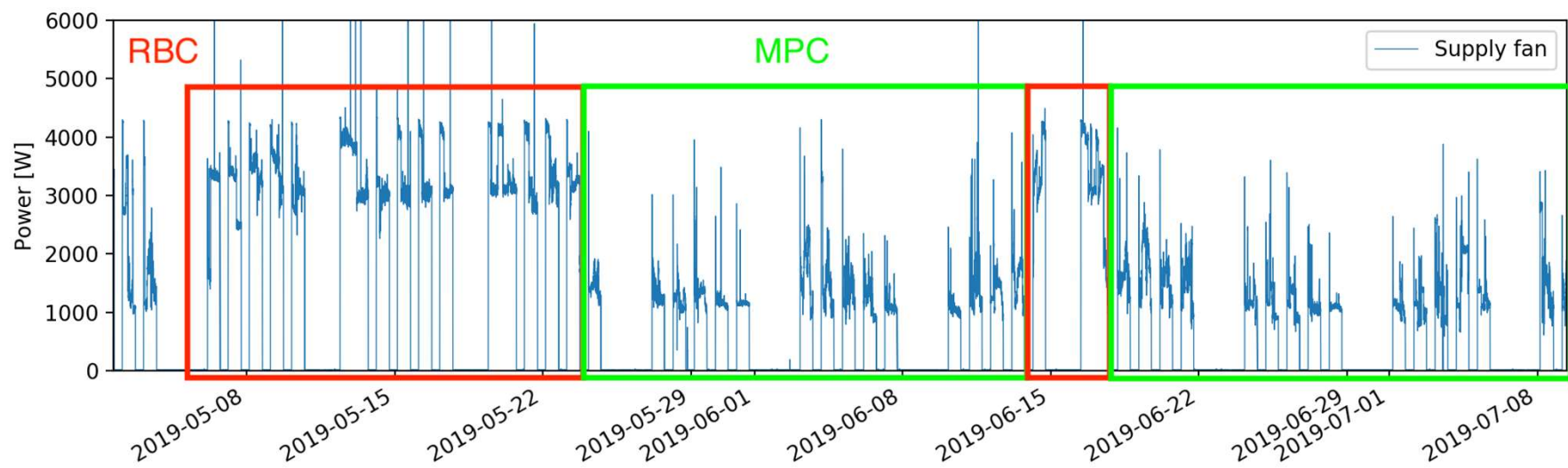




# Optimal HVAC control

## Case 1: 38% savings

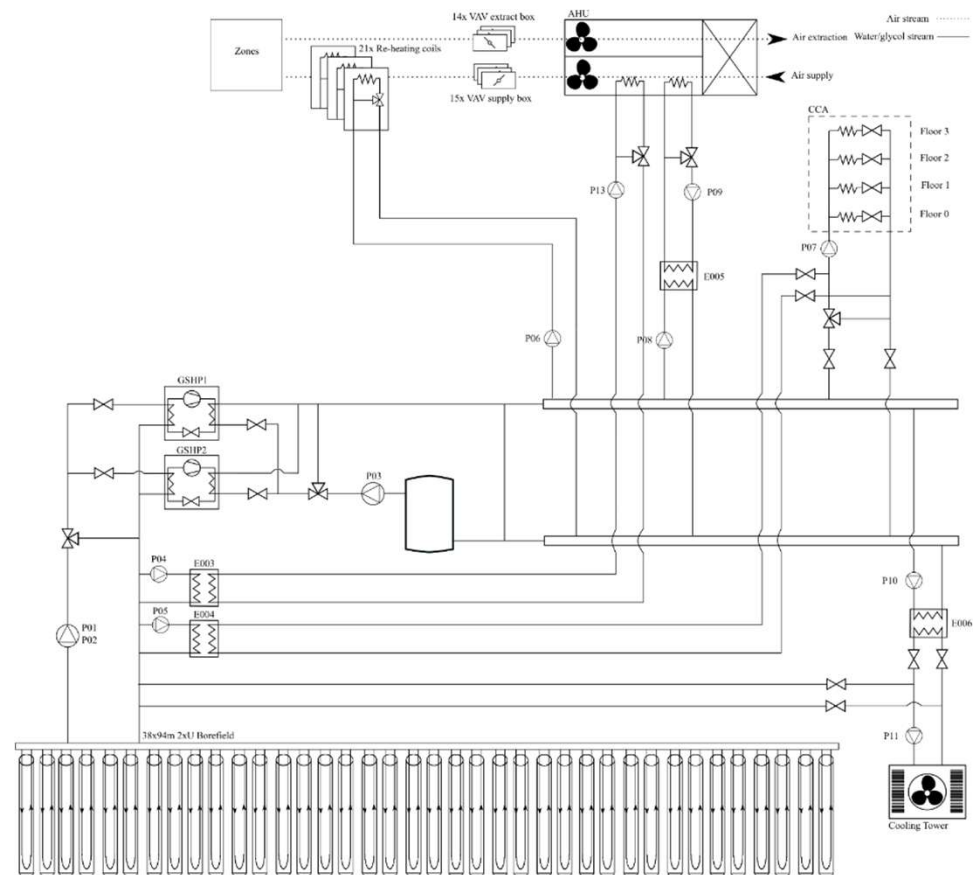
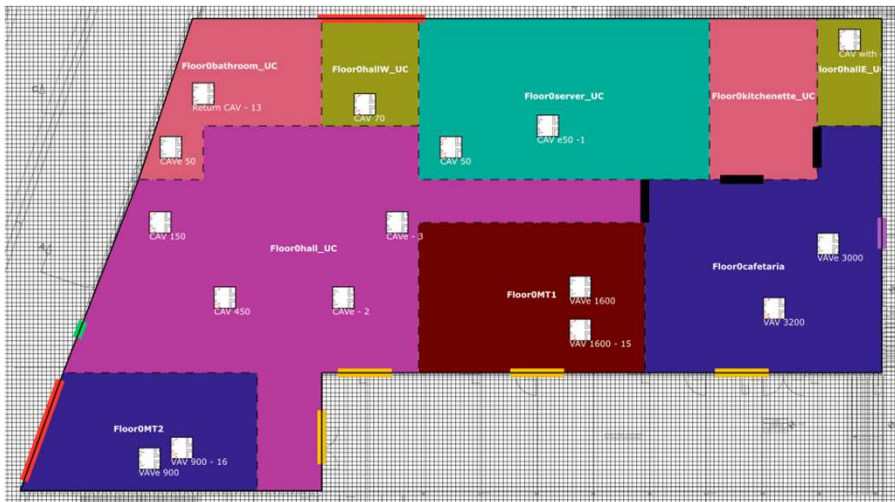
- 60% savings on the ventilation by shifting the thermal load from the ventilation to the CCA



# Optimal HVAC control

## Case 1: 38% savings

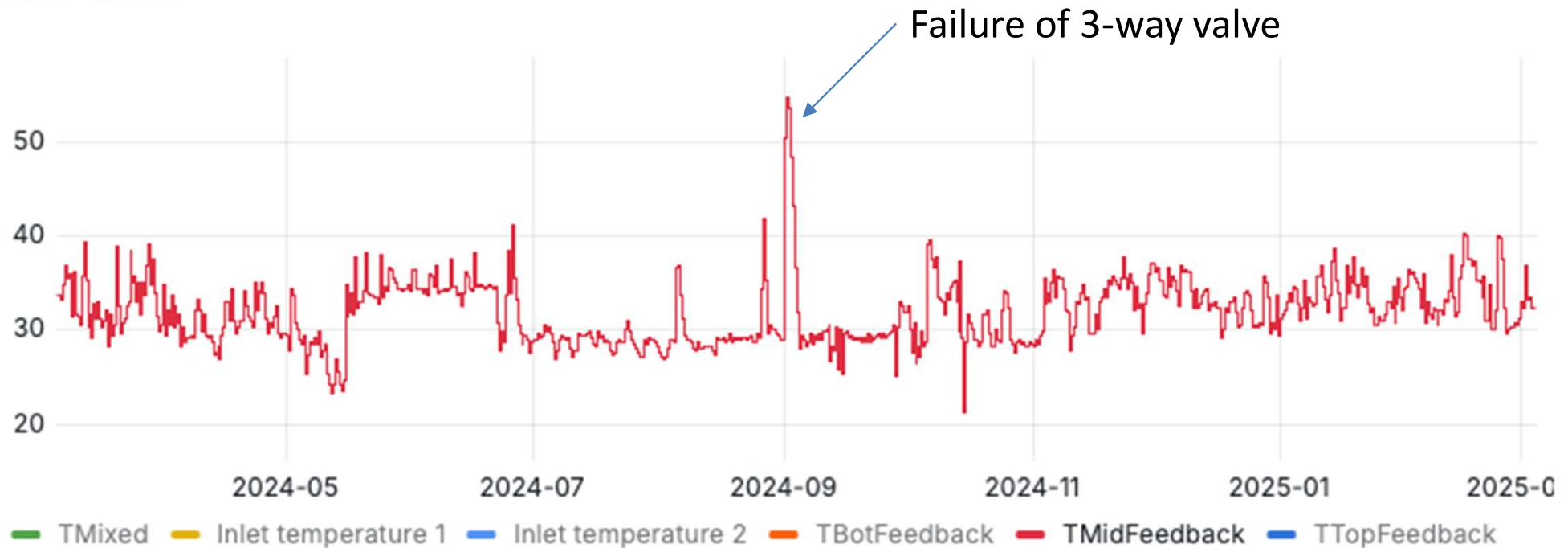
- Lowering thermal need for ventilation by heating colder spaces more through CCA



# Optimal HVAC control

Case 2: heat pump temperature  $< 40^{\circ}\text{C}$  all year

Tank TankHP



# Optimal HVAC control

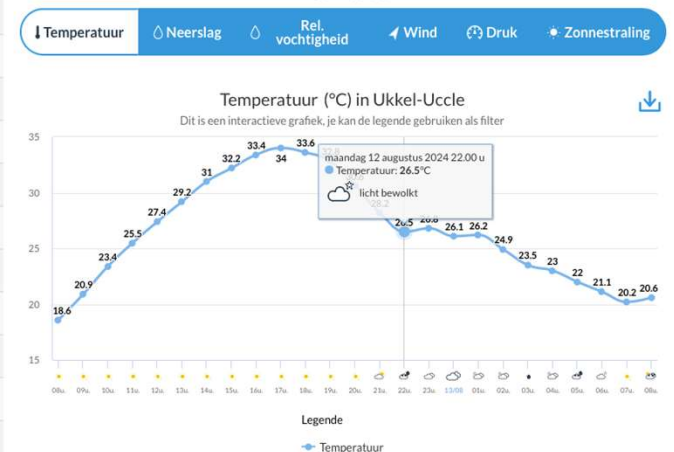
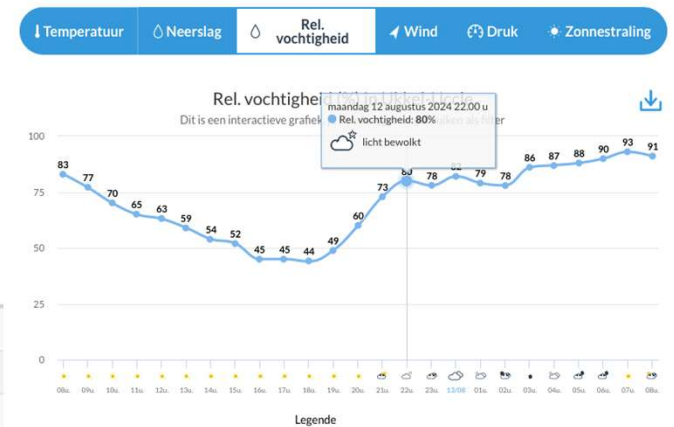
## Case 3: anticipation for cooling

12th of August 2024: dewpoint temperature = 23°C



**Atic**  
for HVAC professionals

Quantity	Value	Units
P.Ambient	101325	Pa
T.Dry.Bulb	26.500	°C
Humid.Ratio	17.560	g/kg(d.a)
Rel.Humid	80.000	%
T.Wet.Bulb	23.788	°C
T.Dew	22.769	°C
T.Saturation	23.760	°C
Enthalpy	71.412	kJ/kg(d.a)
P.Vapour	2782.064	Pa
P.Sat.Vapour	3463.911	Pa
Spec.Heat	1.028	kJ/(kg.K)
Spec.Volume	0.873	m^3/kg(d.a)
Density	1.166	kg/m^3

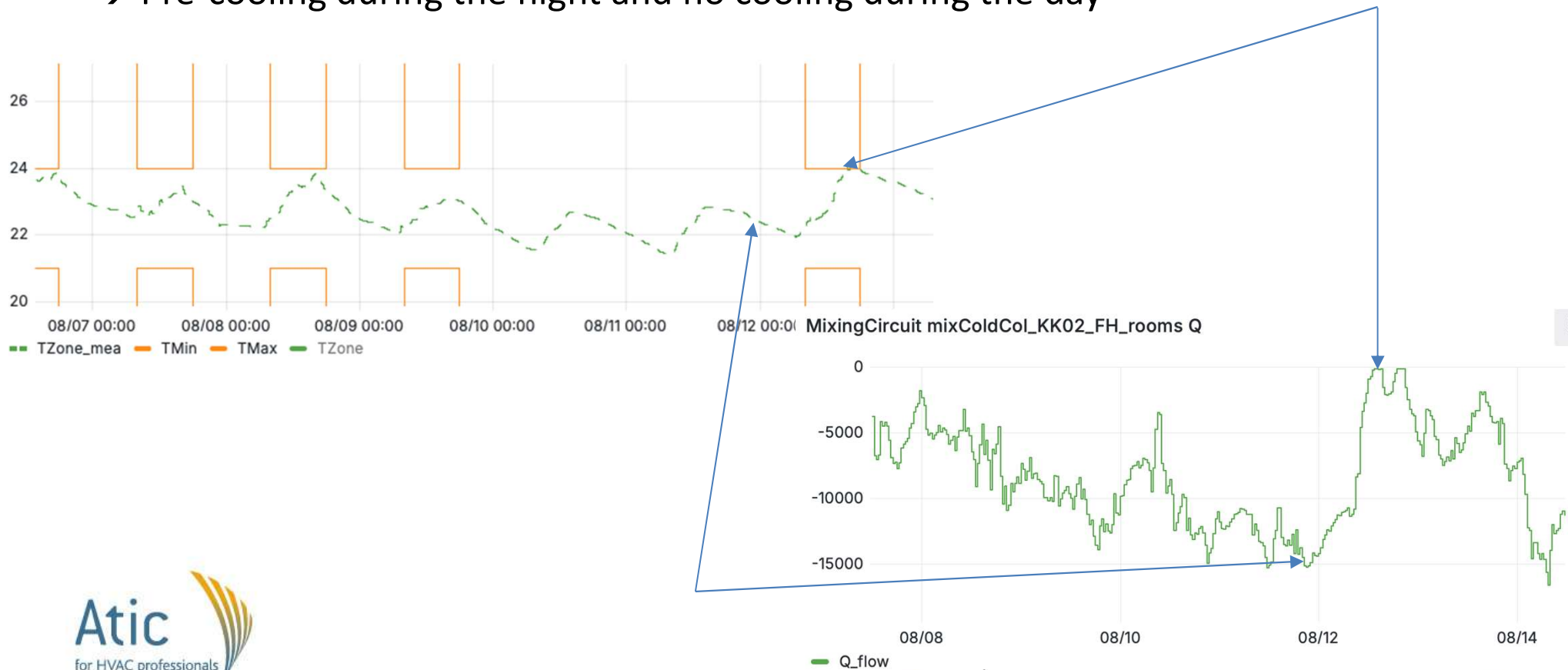


# Optimal HVAC control

## Case 3: anticipation for cooling

12th of August 2024: dewpoint temperature = 23°C

→ Pre-cooling during the night and no cooling during the day



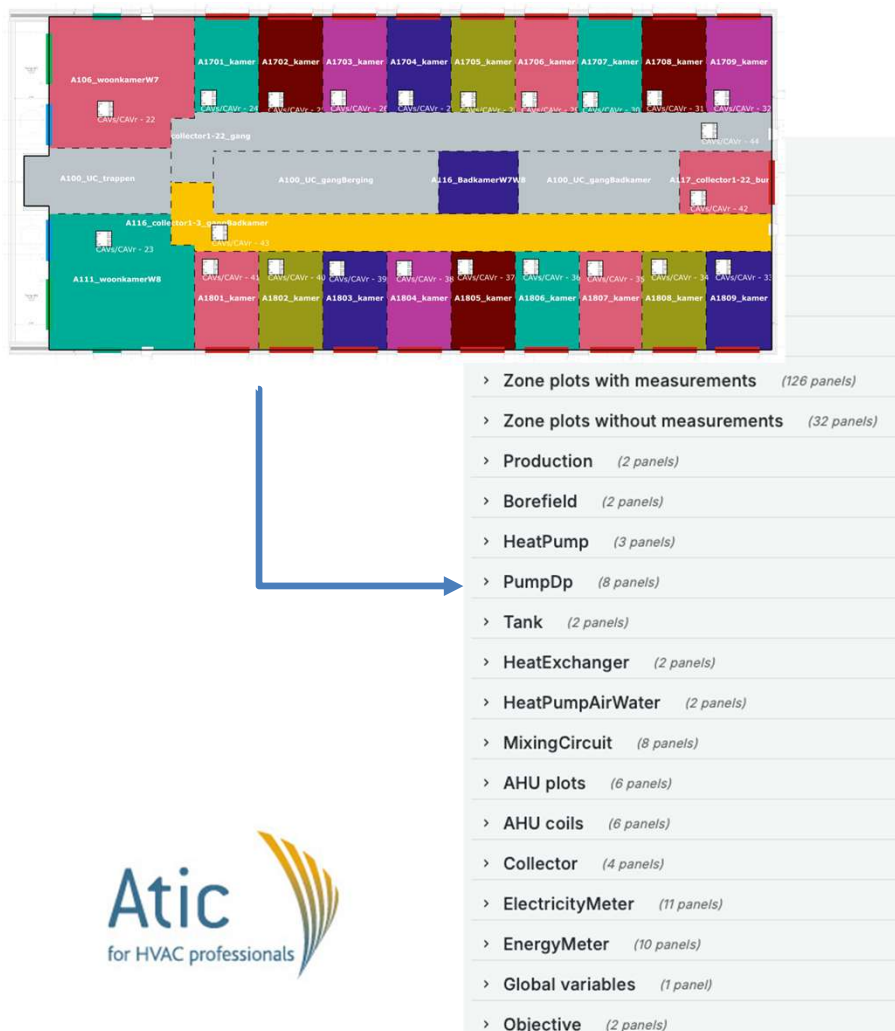


# Fault detection

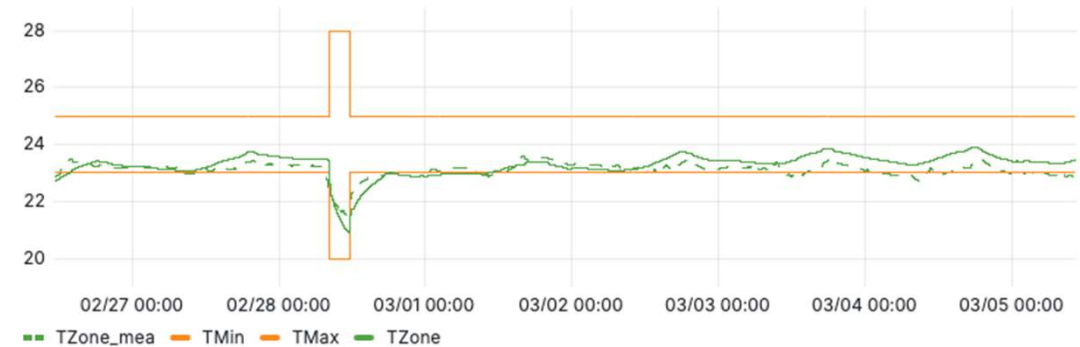
# Fault detection: using digital twin

## Basic fault detection:

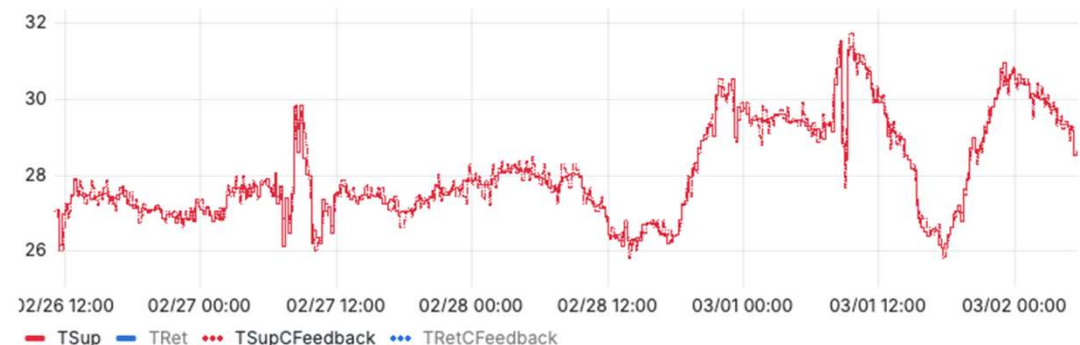
Digital twin > automatic dashboard > fault detection through comparison model with measurements



zone\_\_A1702\_kamer



MixingCircuit mixHotCol\_KW02\_FH\_rooms



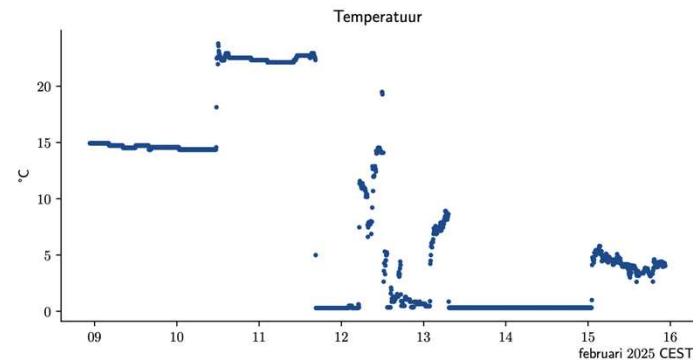
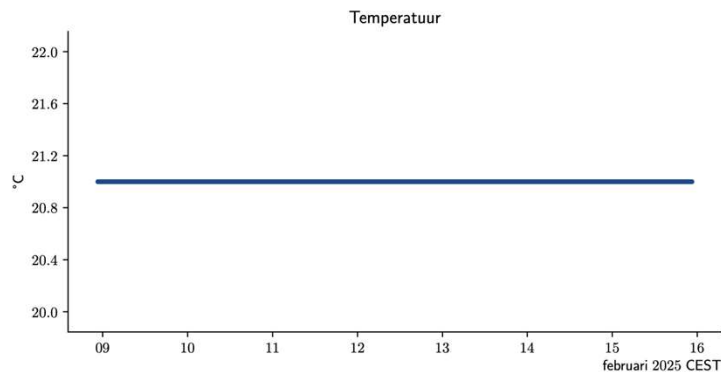
# Fault detection: using digital twin

## Intermediate fault detection:

Sanity check of all room sensors

### Room temperature

ID	Zone	Samples	Min	Max	Gem.	Defect	Waarschuwing
192.168.101.47@AI:3503	L00_inkomsas_00B127	2049	3.2	18.2	12.0	low	/
192.168.101.45@AI:3005	L00_koudekeuken_00B129	2016	15.2	20.2	18.0	low	/
192.168.101.47@AI:3009	L00_loket_00B169	2021	14.7	21.2	18.1	low	/

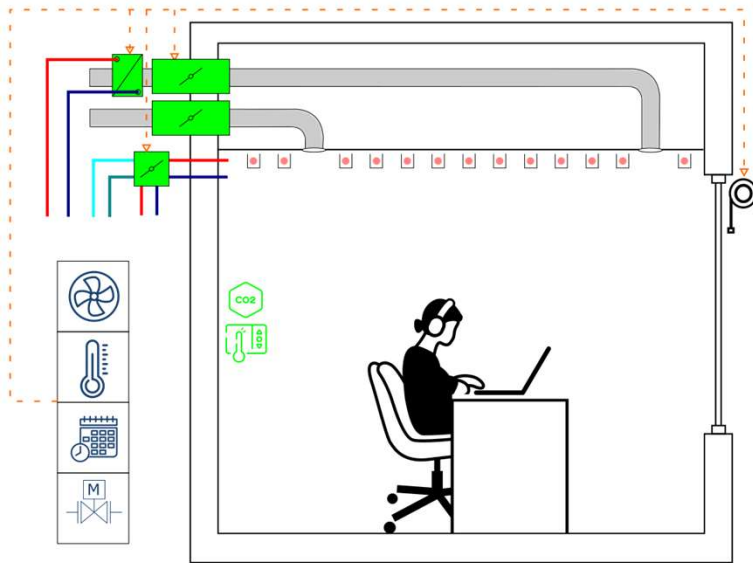


### CO<sub>2</sub> concentration

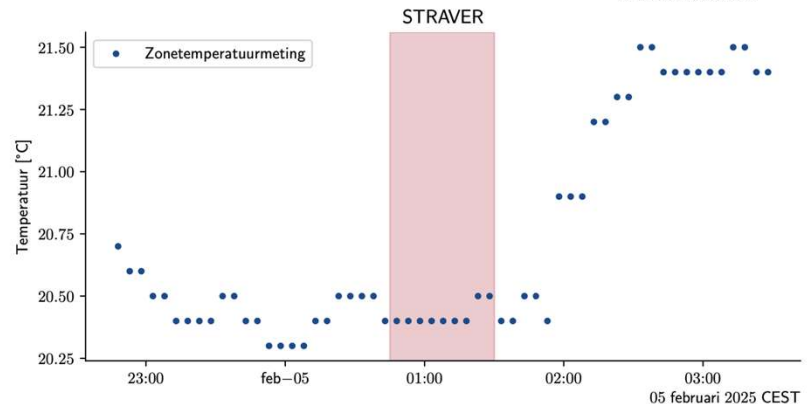
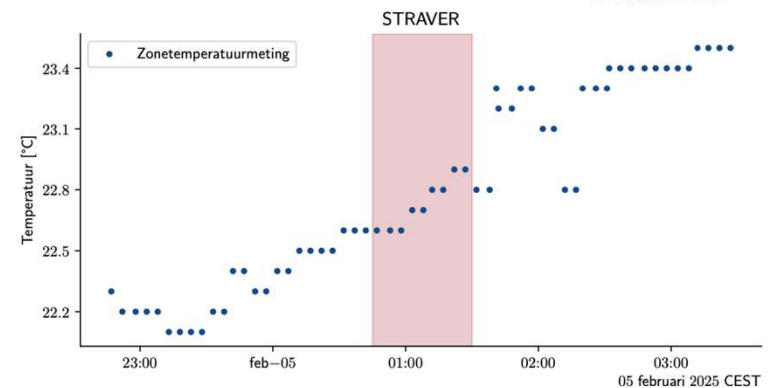
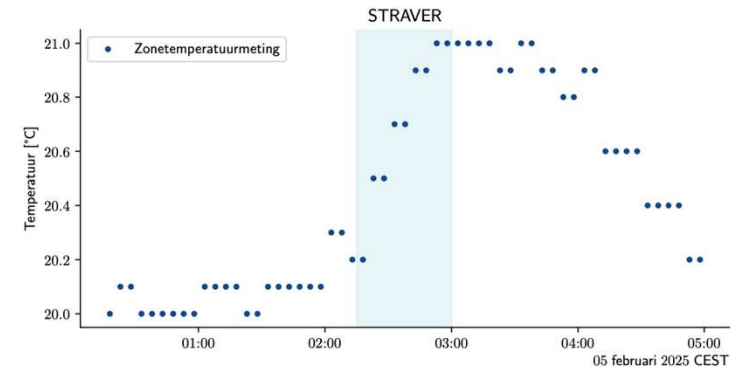
ID	Zone	Samples	Min	Max	Gem.	Defect	Waarschuwing
192.168.101.31@AI:3107	L01_vergaderlokaal_01A304	2016	457.0	457.0	457.0	constant	/
192.168.101.11@AI:3109	L04_samenwerkplekken_04B171	2009	0.0	0.0	0.0	constant,low	/
192.168.101.45@AI:3116	L00_overleg_00B143	2035	267.0	505.9	404.2	/	low
192.168.101.42@AI:3104	L00_EHBO_00A802	2028	377.9	609.9	411.8	/	/
192.168.101.43@AI:3108	L00_balie_00A300	2029	382.1	561.0	437.5	/	/

# Fault detection: using digital twin

**Advanced** fault detection: excitation of each room actuator individually



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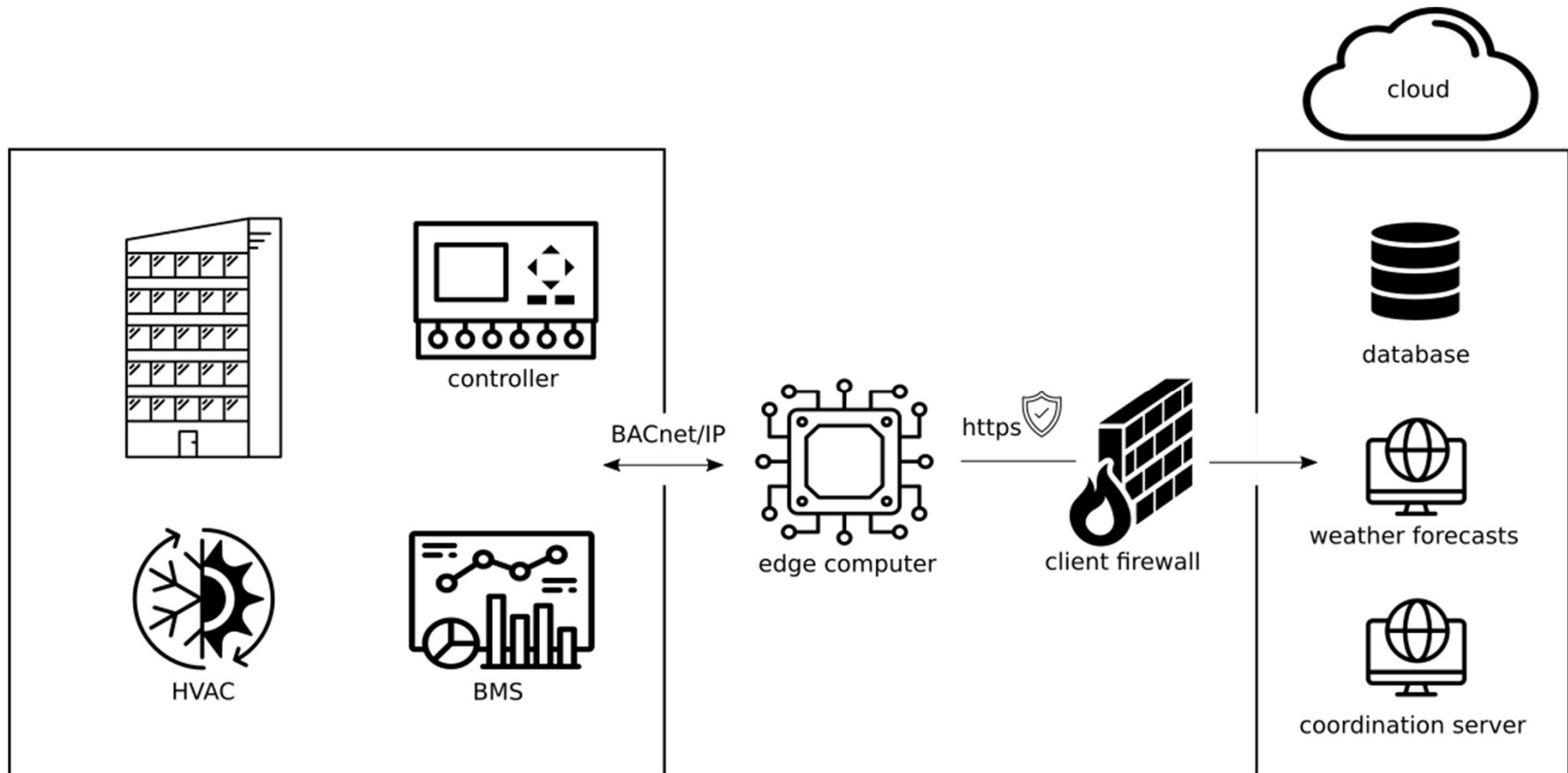


# Conclusions

- Current buildings are complex, requiring new technologies to control and diagnose their HVAC
- Model predictive control allows to:
  - Significantly improve the control of building
  - Avoid the need of tuning
  - Automatically detect anomalies



# How to connect MPC to the BMS?



# Questions?

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