KU LEUVEN

Energy Ville

vito

IBPSA Project 1

Sharing BOPTEST experience

IBPSA Expert Meeting
7-May-2021

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Co-supervisor: Fred Spiessens
Assessor: Geert Deconinck
Assessor: Dirk Saelens

Outline

- Building description
- System identification
- MPC formulation
- Results

Building description

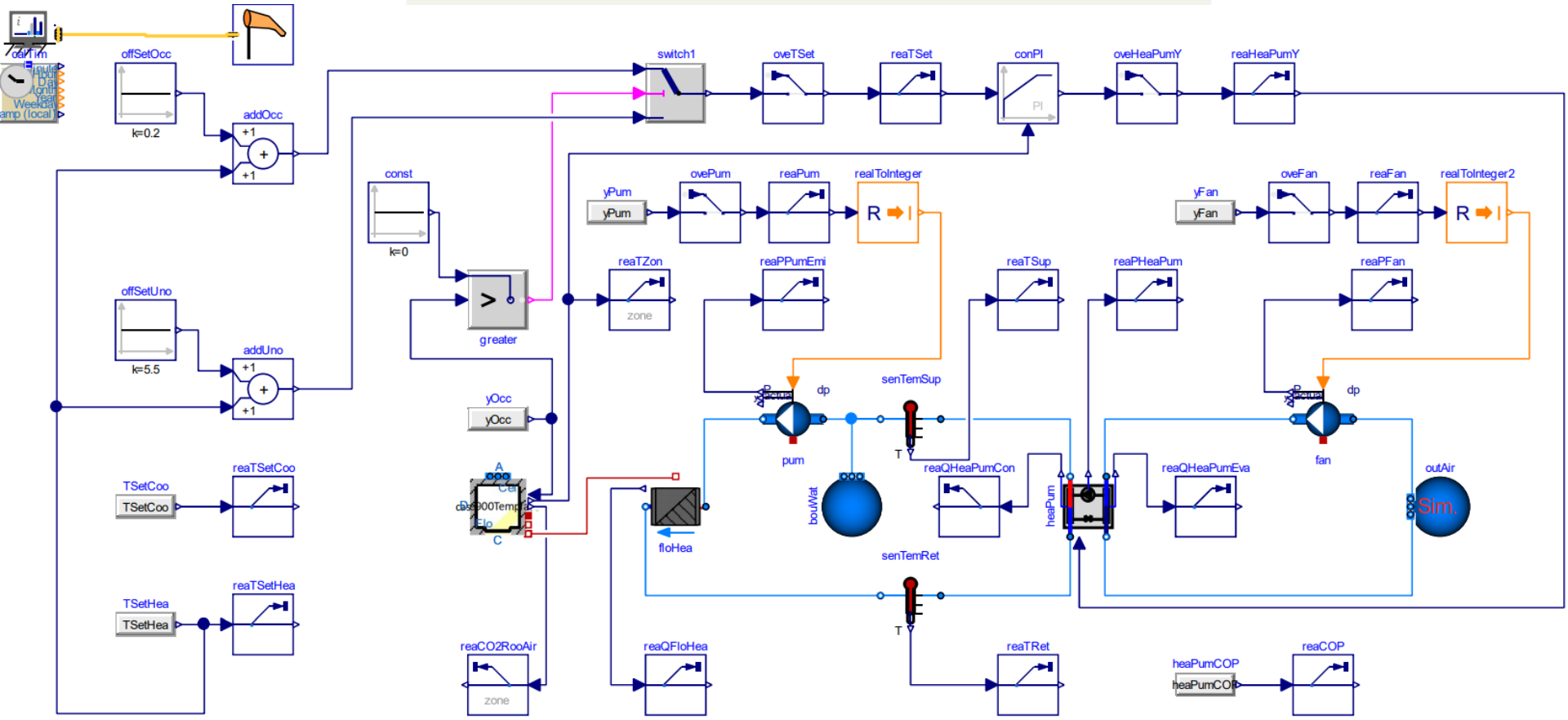
- *bestest_hydronic_heat_pump*
- Residential single-zone hydronic
- Air-to-water heat pump
- Floor heating
- Located in Brussels
- PI baseline controller
- Good trade-off

Wall type	Description
Outer wall	Wood siding (d=9, λ=0.14), insulation (d=61.5, λ=0.04) and concrete block (d=100, λ=0.51)
Floor	Concrete (d=150, λ=1.4), insulation (d=200, λ=0.02 W/mK), screed (d=50, λ=0.6) and tile (d=10, λ=1.4)
Ceiling	Roof deck (d=19, λ=0.14), fiber glass (d=111.8, λ=0.04) and plaster board (d=10, λ=0.16)
Fenestration	Glass (d=3.175, λ=1.06), air (d=13, λ=0.0241) and glass (d=3.175, λ=1.06)

Table 2.: Material layers (outside to inside) of the emulator building envelope. d is the layer thickness in mm, λ is the thermal conductivity of the material with units of W/mK.

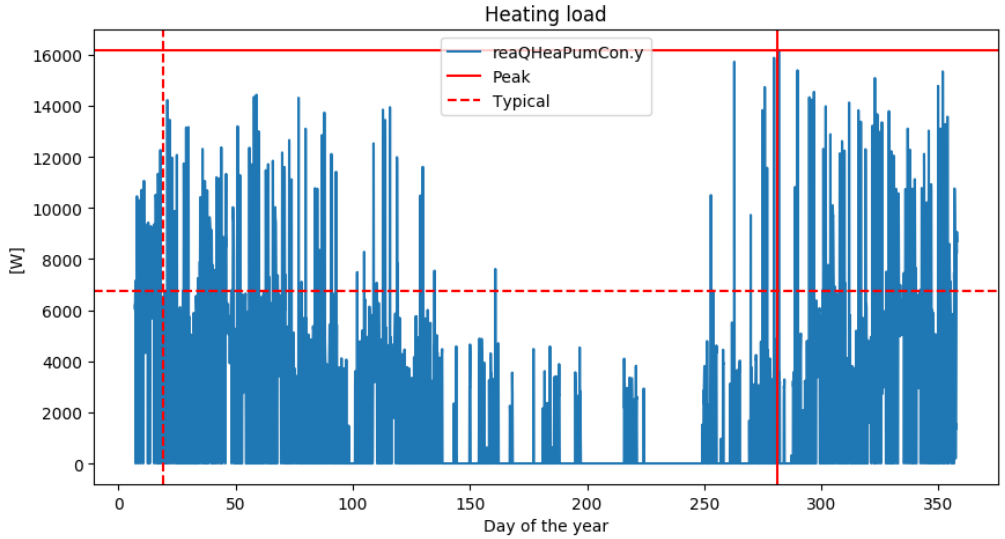
Building description

```python
import requests

url = "http://127.0.0.1:5000"

# Find all measurements and inputs of this emulator
inputs       = requests.get("{0}/inputs".format(url)).json()
measurements = requests.get("{0}/measurements".format(url)).json()
all_points   = measurements.keys() + inputs.keys()

```

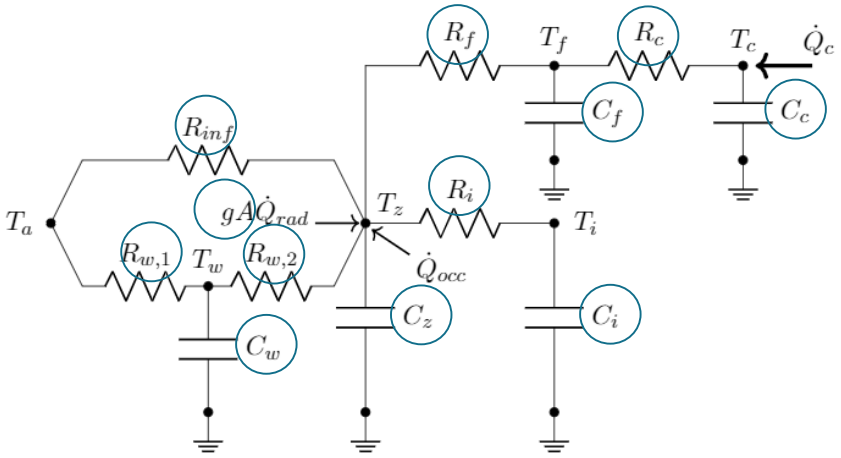


Building description

- Pricing scenarios
  - Constant
  - Dynamic
  - Highly-dynamic
- Scenario periods
  - Heat peak day
  - Typical heat day
- Uncertainty
  - Deterministic

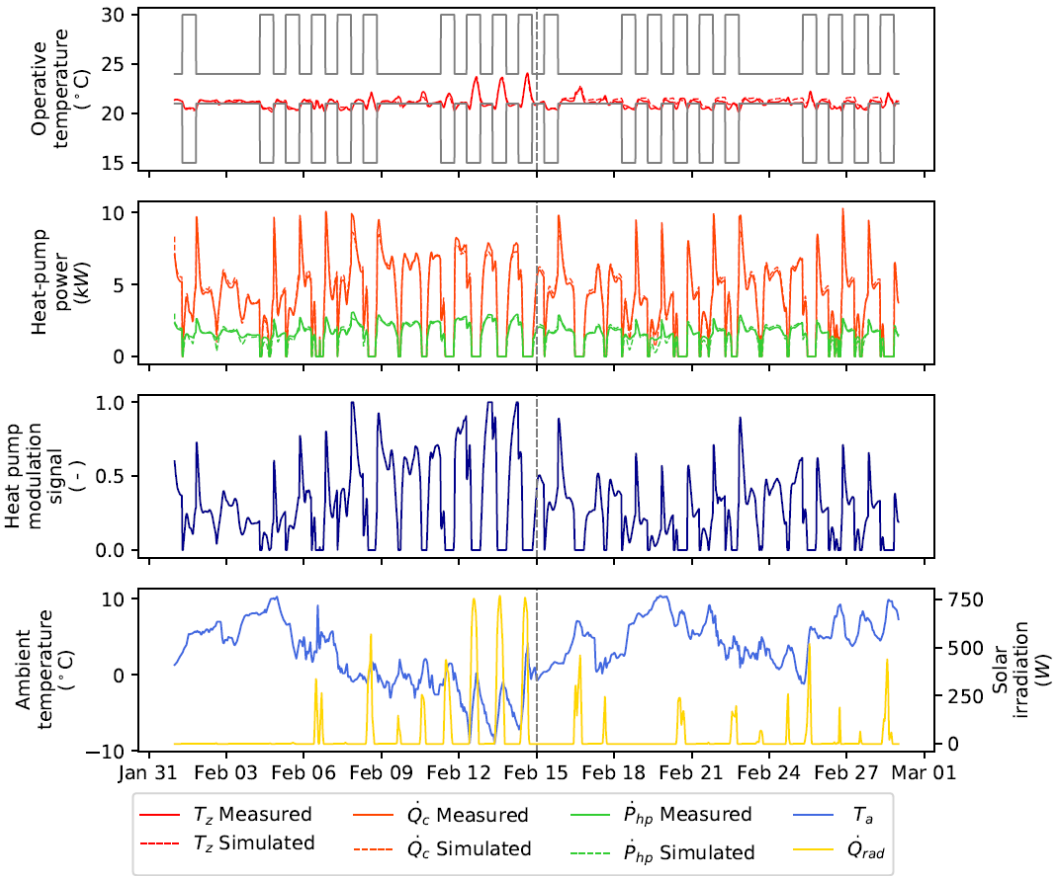


System identification



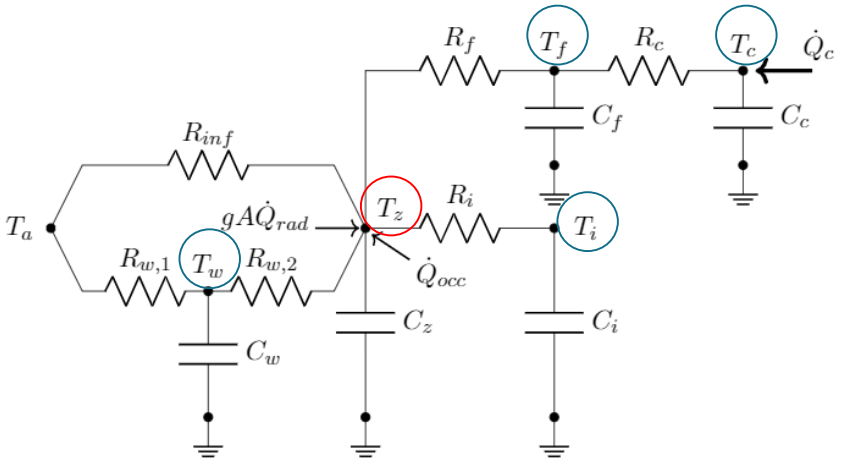
$$\dot{Q}_c = (a_c + b_c(T_c - T_{c,n}) + c_c(T_a - T_{a,n}))k_c \cdot u_{hp}$$
$$\dot{Q}_e = (a_e + b_e(T_c - T_{c,n}) + c_e(T_a - T_{a,n}))k_e \cdot u_{hp}$$
$$\dot{P}_{hp} = \dot{Q}_c - \dot{Q}_e$$
$$COP = \frac{\dot{Q}_c}{\dot{P}_{hp}}$$

```
# Set the emulator in the desired simulation period and initialize
requests.put("{0}/initialize".format(url),
             data={"start_time":31*24*3600,
             "warmup_period":7*24*3600}).json()

# Simulate with baseline control for one month
for _ in range(28*24)
    y = requests.post("{0}/advance".format(url), data={}).json()

# Gather data
data = {}
for point in all_points:
    res = requests.put("{0}/results".format(url),
                       data={"point_name":point,
                             "start_time":0,
                             "final_time":3.1536e7}).json()
    data[point] = res
```



(*) Watch out with the testing periods!

MPC formulation



$$\dot{Q}_c = (a_c + b_c(T_c - T_{c,n}) + c_c(T_a - T_{a,n}))k_c \cdot u_{hp}$$
$$\dot{Q}_e = (a_e + b_e(T_c - T_{c,n}) + c_e(T_a - T_{a,n}))k_e \cdot u_{hp}$$
$$\dot{P}_{hp} = \dot{Q}_c - \dot{Q}_e$$
$$COP = \frac{\dot{Q}_c}{\dot{P}_{hp}}$$

```
# -- Implement your MPC magic --
```

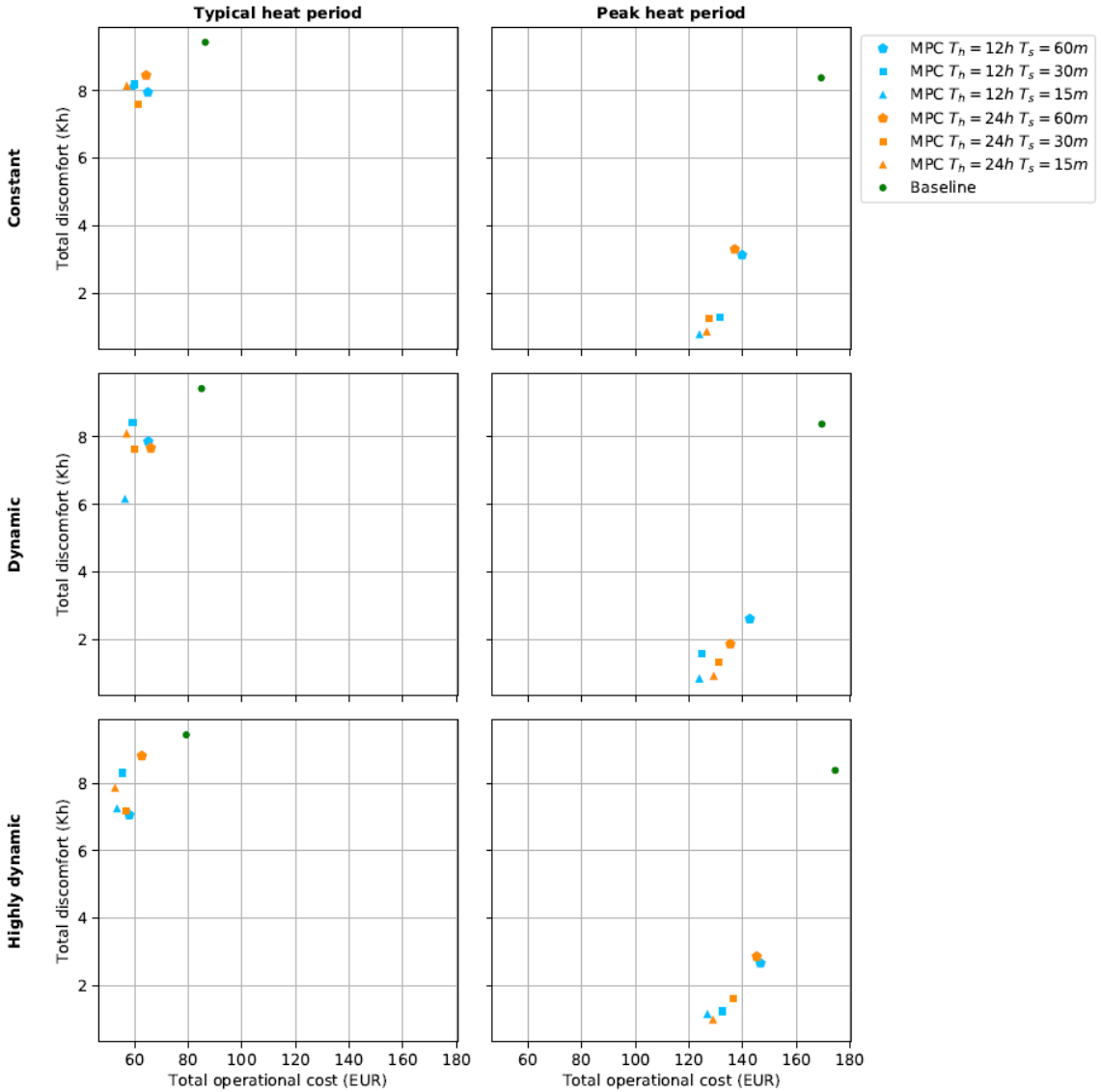
```
# Move the emulator to the peak heat testing period
y = requests.put("{0}/scenario".format(url),
                 data={"time_period":"peak_heat_day"}).json()

# Test your MPC magic
while y:
    # Get forecast
    f = requests.get("{0}/forecast".format(url)).json()

    # Compute control signal
    u = mpc.compute_control(y, f)

    # Advance simulation with control signal
    y = requests.post("{0}/advance".format(url),
                      data=u).json()
```

$$\min_{u_{HP}} \int_{t=t_i}^{t_h} (p^{e,\tau}(\dot{P}_{hp} + \dot{P}_{fan} + \dot{P}_{pum}) + ws^{T_z})dt$$
$$\dot{T}_z = f(u_{hp}, \dot{Q}_{rad}, \dot{Q}_{occ}, T_a, T_z, T_c, T_f, T_i, T_w)$$
$$\underline{T}_z - s^{T_z} \leq T_z \leq \overline{T}_z + s^{T_z}$$
$$0 \leq u_{hp} \leq 1$$
$$s^{T_z} \geq 0$$

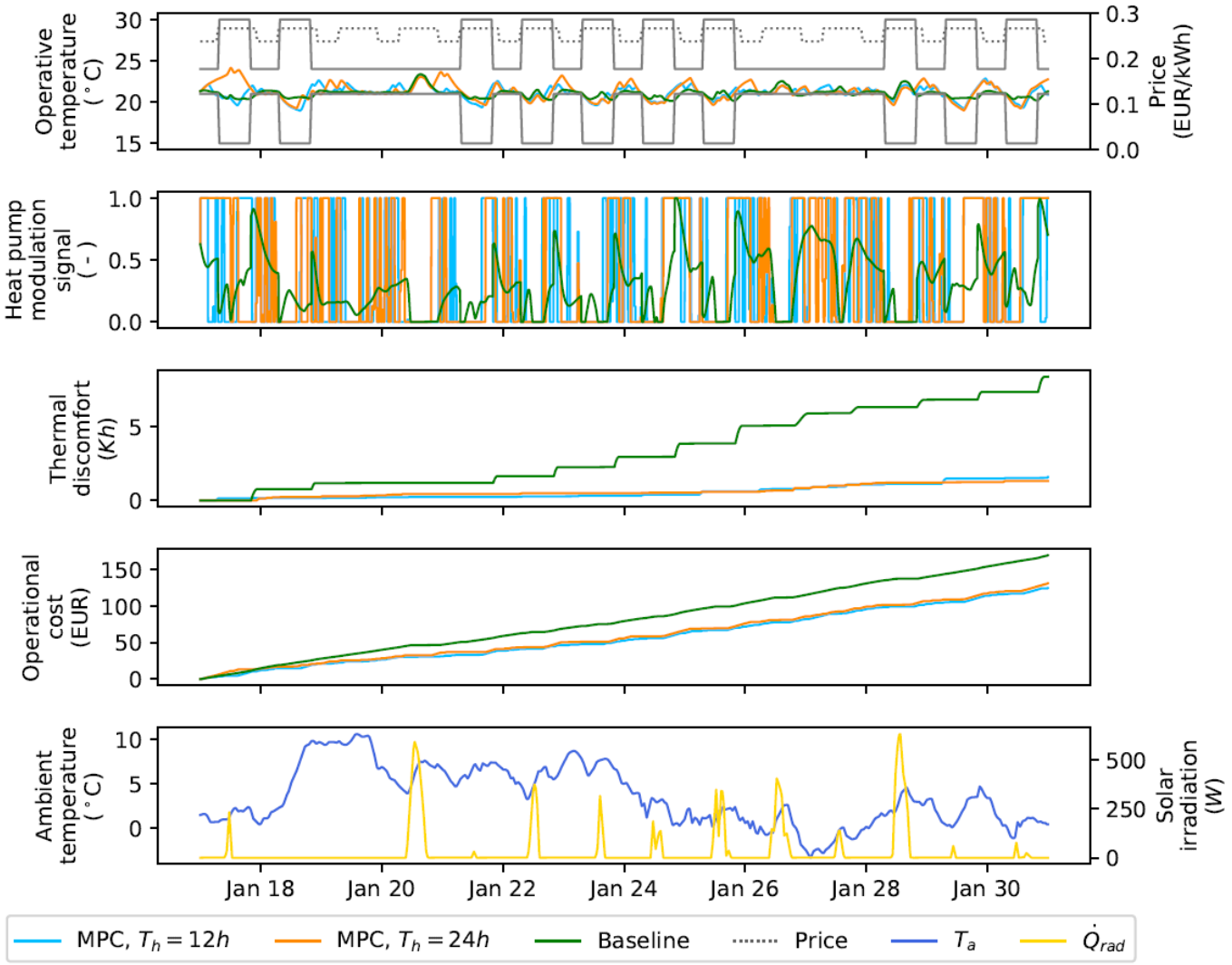
- JModelica
  - Direct collocation
  - UKF

Results

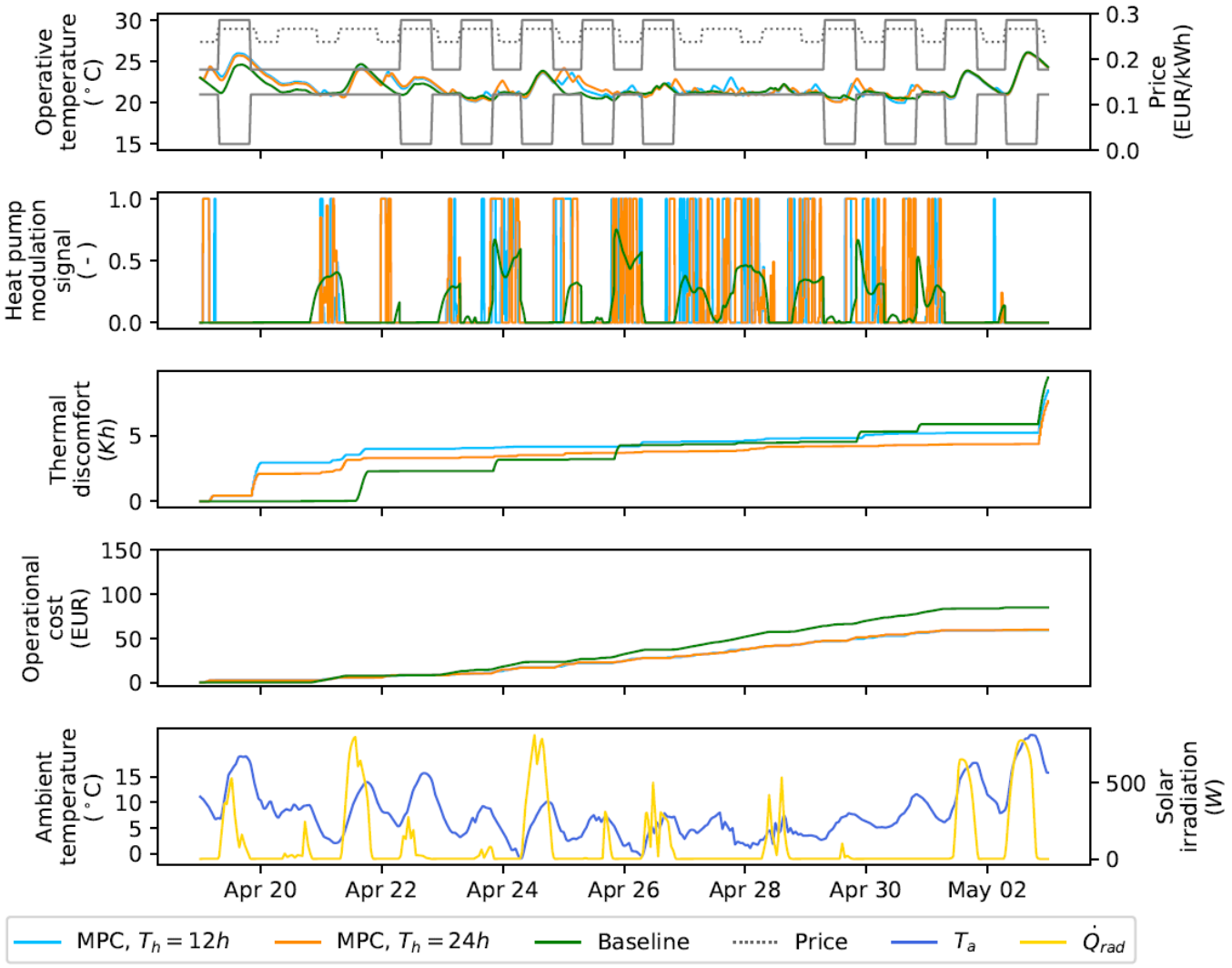
```
46 # Get KPIs
47 kpi = requests.get("{0}/kpi".format(url)).json()
```



Results


Operative temperature (°C)
30
25
20
15
0.3
0.2
0.1
0.0
Price (EUR/kWh)
Heat pump modulation signal (-)
1.0
0.5
0.0
Thermal discomfort (Kh)
5
0
Operational cost (EUR)
150
100
50
0
Ambient temperature (°C)
10
5
0
500
250
0
Solar irradiation (W)
Jan 18
Jan 20
Jan 22
Jan 24
Jan 26
Jan 28
Jan 30
MPC, $T_h = 12h$
MPC, $T_h = 24h$
Baseline
Price
T_a
$\dot{Q}_{rad}$

Results


Operative temperature (°C)
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25
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0.3
0.2
0.1
0.0
Price (EUR/kWh)
Heat pump modulation signal (-)
1.0
0.5
0.0
Thermal discomfort (Kh)
5
0
Operational cost (EUR)
150
100
50
0
Ambient temperature (°C)
15
10
5
0
500
0
Solar irradiation (W)
Apr 20
Apr 22
Apr 24
Apr 26
Apr 28
Apr 30
May 02
MPC, $T_h = 12h$
MPC, $T_h = 24h$
Baseline
Price
T_a
$\dot{Q}_{rad}$

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Thank you!

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