Output Factsheet

Output title: T4.1 Transnational training activities

Summary of the output

The output contains documented learning interactions performed during pilot study visits to the 3Smart locations for piloting of the developed modular tool for integrated grid-building energy management including demand response. Pilot study visits were attended by the members of the 3Smart consortium and for each pilot they were organized in two rounds. In the first round the pilot leaders/hosts explained the interventions performed while modules developers explained the needed steps for installation of the modules. In the second round the pilot leaders/hosts explained the progress with modules installations on the pilot of the study visit while the developers presented the results of modules operation on data from the building.

The documented learning interactions are organized as short explanation of how the learning interaction took place (minutes) which refer to presentation materials as annexes. For each round of pilot study visits a separate document is provided which contains the interactions from all five pilots of the 3Smart project –pilots in Croatia, Slovenia, Austria, Bosnia and Herzegovina and Hungary. The reader can by passing through this documentation get a basic insight into the pilots organization and 3Smart platform operation on them.

As the 3Smart pilots were very versatile in configuration, interested users can also estimate the effort and investment needed for some new planned sites. Of course, there are other outputs that detail the topics of platform organization in modules (T2.1), costs and benefits (T4.2) and 3Smart system performance on pilots (T5.1), but this output can be used to roughly get to know the platform and its possible very versatile usages.

Contribution to EUSDR actions and/or targets

The project in general contributes to Priority Area 2 "To encourage more sustainable energy" of the EUSDR within which the following actions are required: „To explore the possibility to have an increased energy production originating from local renewable energy sources to increase the energy autonomy", „To promote energy efficiency and use of renewable energy in buildings and heating systems", „To facilitate networking and cooperation between national authorities in order to promote awareness and increase the use of renewable energies".

As the developed output spreads the experiences in setting up and operation of energy management systems with demand response, which are of key importance to enable demand side flexibility and energy security, it also contributes to EUSDR implementation.

Performed testing, if applicable

The output has for now been used as a resource only among the 3Smart consortium members.

Integration and use of the output by the target group
The identified target groups for this output are: local public authorities, sectoral agencies, enterprise, excluding SME. It will support local public authorities and their counselling sectoral agencies in decisions on investments in smart energy communities on their territories. Software development enterprises can learn on business opportunities existing in energy management systems from the provided materials, while grids operators may also opt to consider in their future operations to use demand response based on procedures exposed. Of course, more detailed exposition for interested stakeholders should be found in other textual 3Smart outputs.
Geographical coverage and transferability
There are no geographical constraints in usage of the modular 3Smart platform for energy management. It can be used throughout the Danube region and beyond. The same also holds for this material which gives an overview how the 3Smart platform was applied in pilots of various countries and of various configurations.
Durability
The question of durability of this material is foremost the question of durability of the 3Smart platform. The 3Smart platform is a cutting-edge energy management platform since it uses a sequence of convex optimization procedures to exhibit an intelligent behaviour of the buildings and grids. Predictive control turns out to be the only viable option for inducing flexibility in buildings while maintaining comfort and safe supply.
Synergies with other projects/ initiatives and / or alignment with current EU policies/ directives/ regulations, if applicable
This output provides a case-based introduction to the usage of 3Smart platform in various environments of buildings and grids which were incurred in the 3Smart pilots. The 3Smart platform in general is in line with the major intention to make Europe an energy-neutral continent by 2050 (and numerous directives and national energy plans stemming out of it) as it unlocks the flexibility of energy demand. Synergy with some projects that are about to start can be mentioned – e.g. Horizon 2020 REWAISE project (Resilient water innovation for smart economy) where integration of energy management strategies with water management is envisioned and will be verified in several water cycles in different parts of Europe.
Output integration in the current political/ economic/ social/ technological/ environmental/ legal/ regulatory framework
The output can be foremost considered as a picturesque introduction into the 3Smart platform usage and energy management for savings and demand response in general, but more in-depth learning through other textual outputs of the 3Smart project is necessary for making an influence to different committees in charge for various formal frameworks like technical or regulatory frameworks.

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.3.1

Transnational training materials – Pilot study visits to Croatia – Pilot study visit No. 2

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
Project Start Date	1 January 2017
Project Duration	30 months
Work Package	6
Task	6.3
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 23 December 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, HEP, UNIDEBTTK, EON, UNIBGFME, SVEMOFSR
Authors (Partners)	Mario Vašak, Tomislav Capuder, Vinko Lešić, Anita Martinčević, Hrvoje Novak, Danko Marušić, Nikola Hure, Paula Perović (UNIZGFER), Leon Lepoša, Tomislav Stašić, Martin Bolfek (HEP), Arpad Racz (UNIDEBTTK), Gabor Peter (EON), Vladimir Jovanović, Nebojša Manić (UNIBGFME), Ivan Bevanda, Petar Marić (SVEMOFSR)
Contact person	Mario Vašak (UNIZGFER)
Abstract (for dissemination)	This document contains the minutes of the second study visit to the Croatian pilot in 3Smart. The pilot consists of two pilot buildings and the pilot electricity distribution grid around the buildings. On the pilot study visits the pilot leaders and hosts together with developers for different modules on the pilot site have performed demonstration to the consortium of functioning of different installations performed on the pilot and of the installed 3Smart modules.
Keyword List	building-side energy management system, grid-side management, pilot installations, 3Smart IT environment, 3Smart database

Revision history

Revision	Date	Description	Author (Organization)
v1.0	23 December 2019	Prepared materials from the second pilot study visit in the presentation form	Mario Vašak (UNIZGFER)

Table of Contents

Executive summary

The 3Smart project deals with transnational development of integrated energy management of buildings and energy distribution grids in real time. To substantiate knowledge transfer between partners, to synchronize developments and demonstrate the installation procedure to developers, pilots leaders and pilots hosts, a series of transnational trainings is organized, first for getting acquainted with the software modules for energy management, and then for getting acquainted with performed pilot installations and modules operation on the pilot site.

This deliverable provides minutes and materials from the pilot study visits to the 3Smart pilot in Croatia that consists of UNIZGFER and HEP buildings and of the electricity distribution grid around these two buildings. The visits were split in two parts for each pilot site – this second part of the deliverable for the Croatian pilot site concerns the second pilot study visit.

1. Minutes from the second pilot study visit to the 3Smart pilot in Croatia

Time: 2 July 2019

Venue: HEP headquarters building, Ulica grada Vukovara 37, HR-10000 Zagreb

2 July 2019 (Tuesday)

Time	Place	Event
09:00-11:00	7th floor, Big Meeting Room	Session No. 1 – Analysis of pilot status and analysis of 3Smart system performance on pilot
11:00-11:15	7th floor	Coffee break
11:15-13:00	7th floor, Big Meeting Room	Session No. 2 – Analysis of 3Smart system performance on pilot
13:00-14:00	7th floor	Lunch
14:00-16:00	7th floor, Big Meeting Room	Session No. 3 – Analysis of 3Smart system performance on pilot
16:00-16:15	7th floor	Coffee break
16:15-18:00	7th floor, Big Meeting Room	Session No. 4 – Discussion and preparation for the public presentation of pilots results
20:00-22:00	Restaurant Kaptolska klet	Working dinner

Session No. 1

Current status of the pilot buildings and grid was quickly assessed and then focus was given to analysis of optimized UNIZGFER pilot building response and respective flexibility bids for demand response. The responses were commented in detail on zone and central HVAC level and explained different emerging behaviours in responses. The presentation is given in Annex 1.

Session No. 2

In session 2 the analysis of optimized pilot building response continued. Microgrid level responses were analyzed and the overall gain in building operation in 3Smart way, which is quite significant and amounts almost 50%. Then the developers continued the presentation of the individual modules operation, on zone level. The presentation is given in Annex 1.

Session No. 3

The developers continued the presentation of individual modules on central HVAC and microgrid level, such that all three levels were encompassed. The materials are also in Annex 1.

Session No. 4

Session 4 was used for dicsussion on the results obtained with the 3Smart tool on the Croatian pilot. Along with that the public presentation for the next day was discussed and prepared among the consortium.

Annexes:

Annex 1: 3Smart system performance on pilot.

2nd Croatian pilot study visit: 3Smart system performance on pilot

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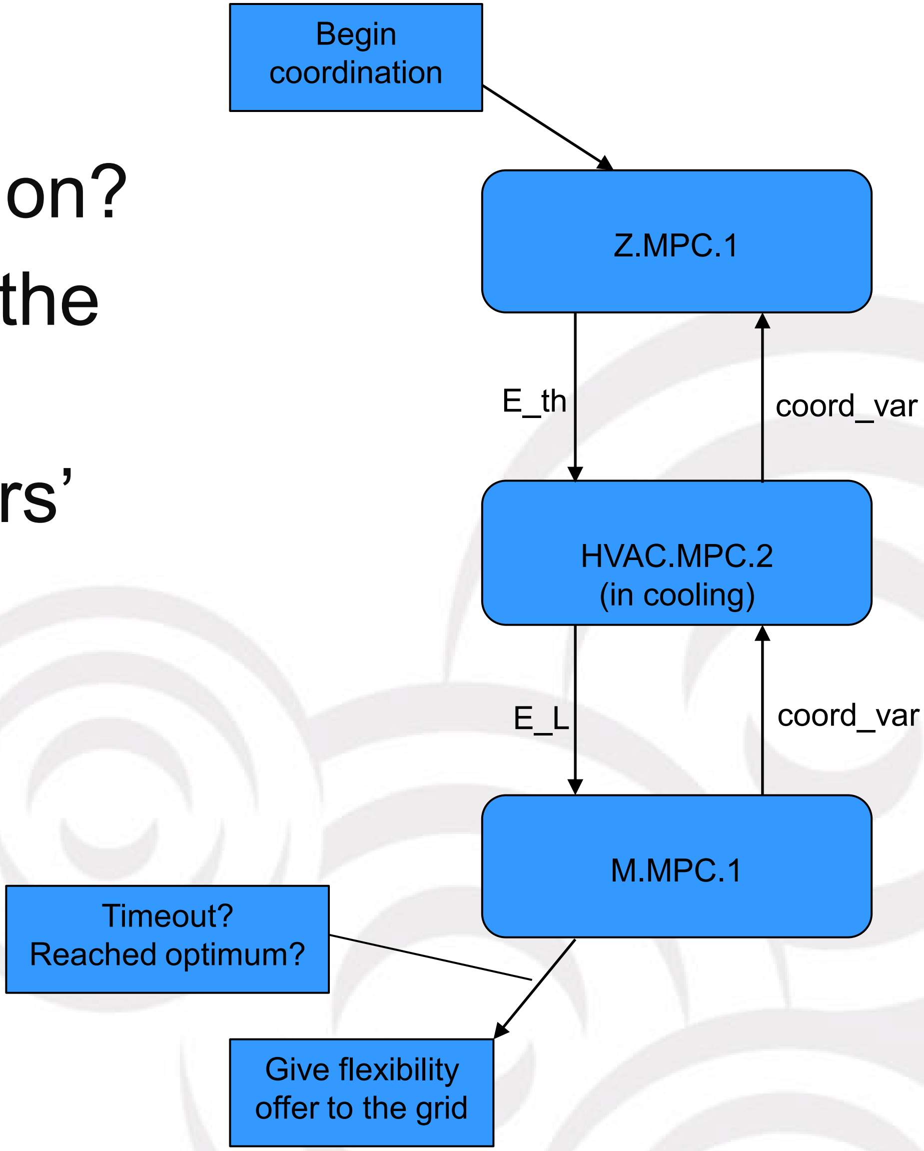
HR pilot study visit No. 2

Zagreb, 2 July 2019

Project co-funded by the European Union

MPC coordination

- Can we obtain flexibility by adjusting HVAC consumption?
- Is that cheaper than using the battery?
- Is it possible to assure users' comfort while providing flexibility?
- Iterative process

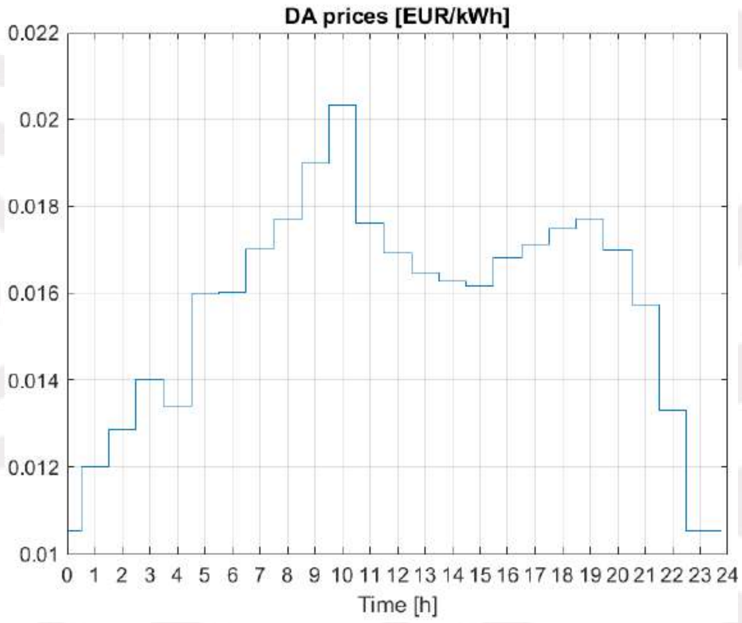


Long-term contracting – simulation environment

- LT calculation performed for typical days in a month
- Typical weather conditions; non-controllable consumption deduced or extracted from historical data
- Accounted flexibility request from the grid
- Must be repeatable: building should be planned to be in the same state at the beginning and at the end of the day
- Computations given next are for UNIZGFER building for cooling season (July, sunny workday)

3Smart system operation -- FER building (1)

- Conditions: sunny workday in July
- Questions:
  - Which is the optimal way of daily building operation?
    - When and how much to cool a specific zone, when and how much to cool the medium, when and how much to charge/discharge the battery?
  - By which offered flexibility is the building expenditure minimal?
  - How much is the optimal way of operation better than usual?
- Flexibility intervals (LT grid):
  - 11:30-11:45
  - 13:00-13:30
  - 14:30-15:00
- Flexibility prices (LT grid):
  - reservation: 0.027 EUR/kW/15 min
  - activation: 0.109 EUR/kWh
  - penalty: 0.219 EUR/kWh

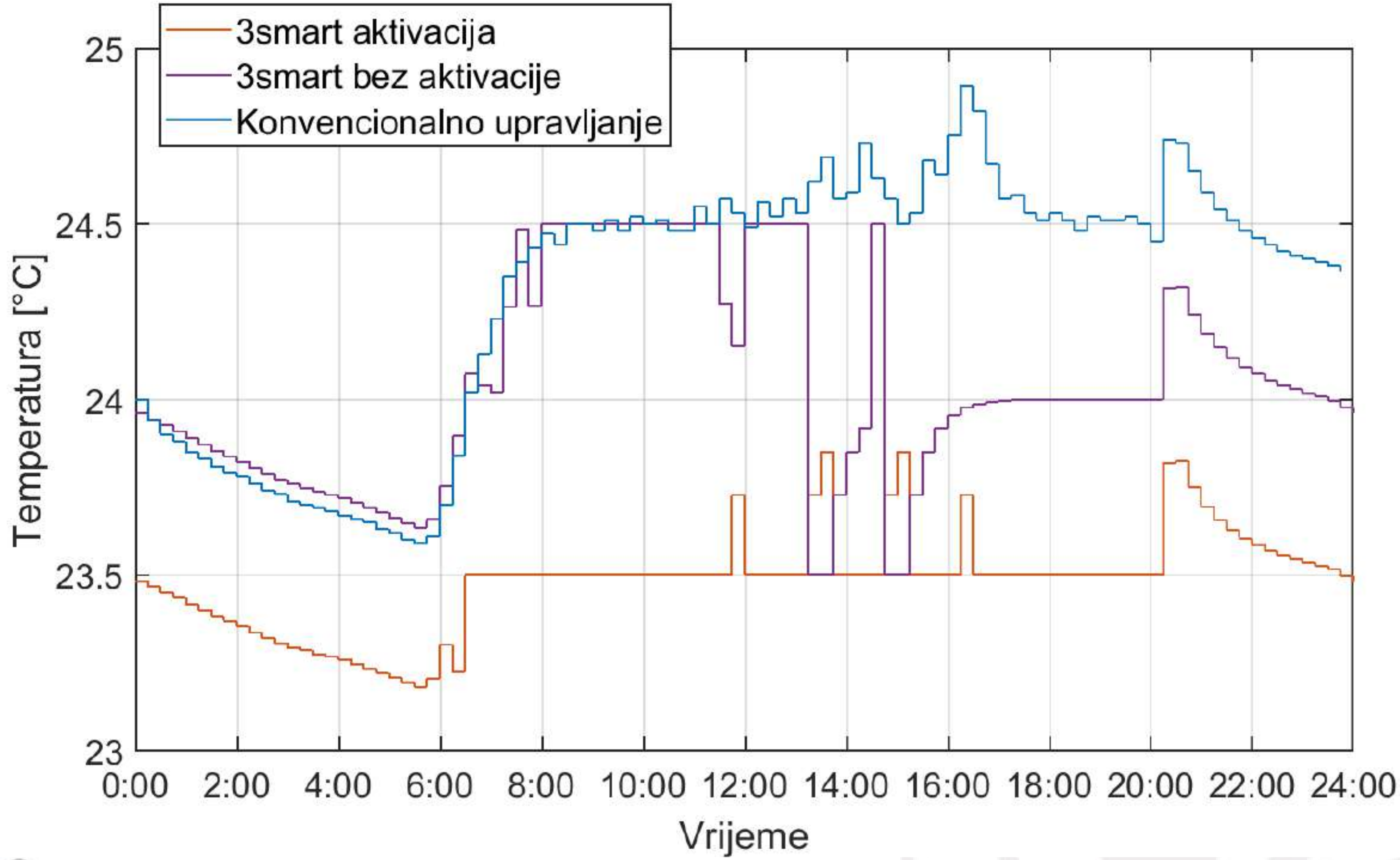


3Smart system operation -- FER building (2)

- Zone level operation analysis:
  - conventional control
  - 3Smart system operation when flexibility is not called (or, without activation)
  - 3Smart system operation when flexibility is called

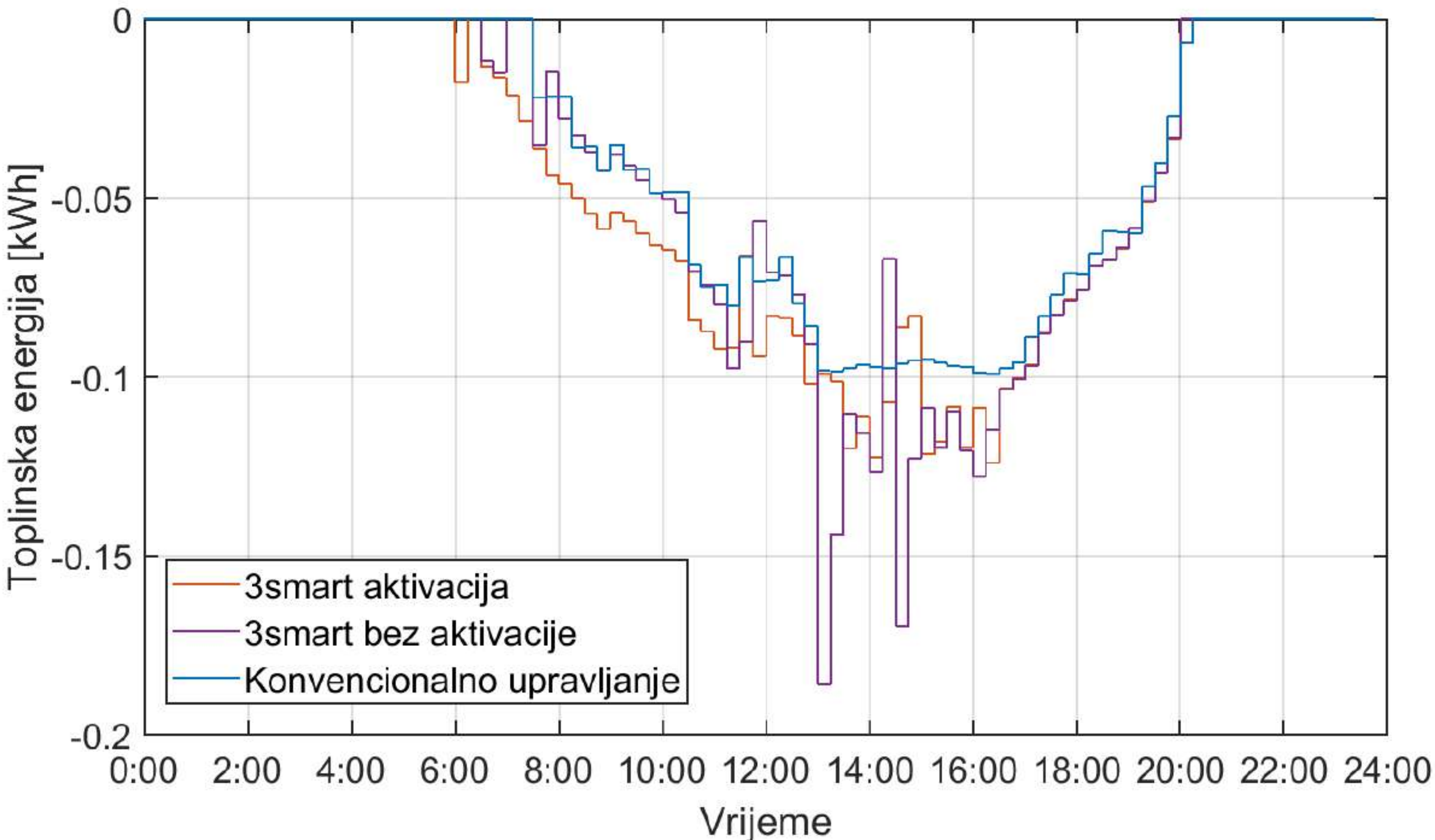
3Smart system operation -- FER building (3)

- Typical response for one building zone



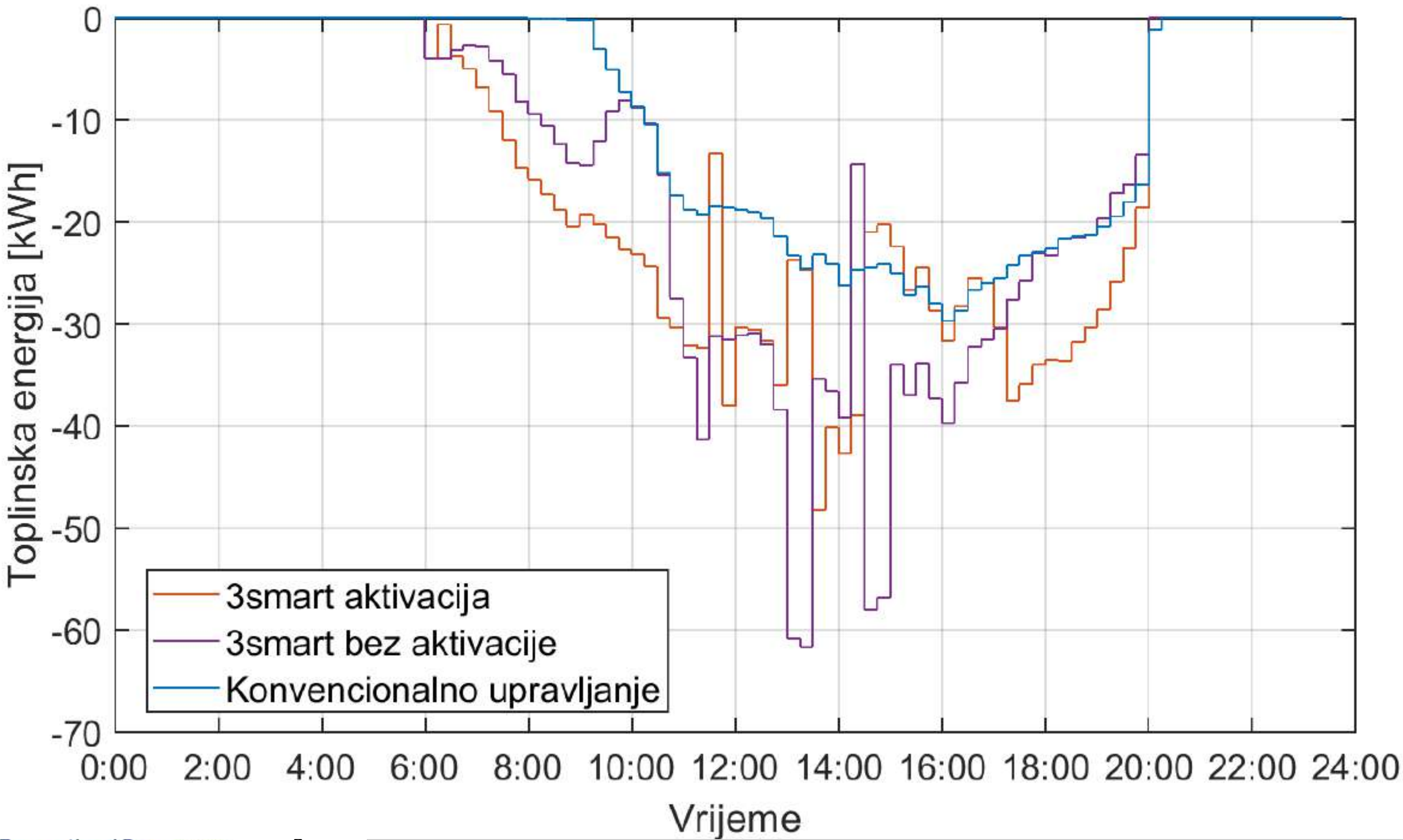
3Smart system operation -- FER building (4)

- Typical cooling needs for one zone



3Smart system operation -- FER building (5)

- Overall cooling energy needs (higher with 3Smart since comfort improved)

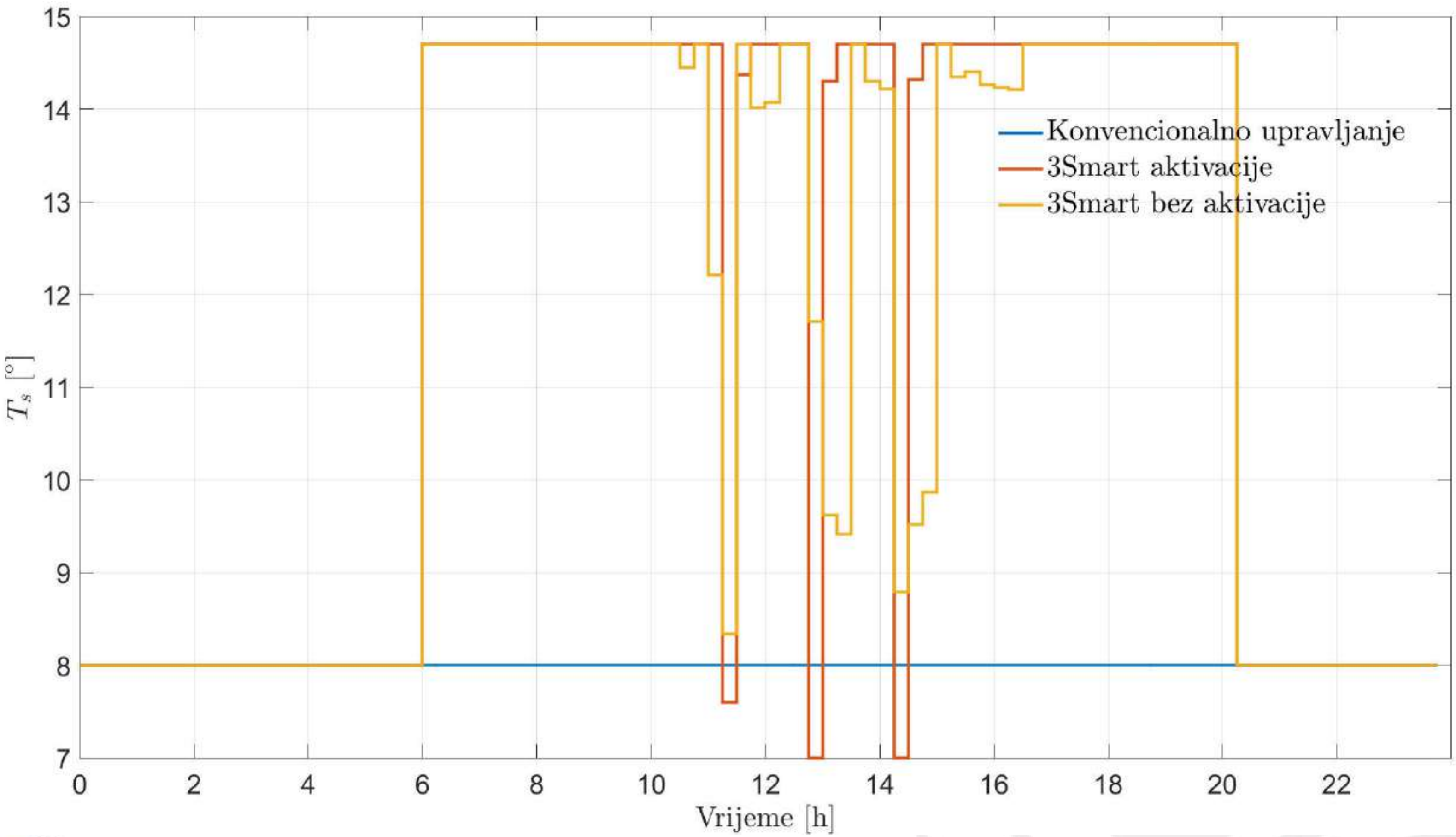


3Smart system operation -- FER building (6)

- Central HVAC: Profile of medium temperature towards the building
  - conventional (without 3Smart)
  - 3Smart without activation of flexibility
  - 3Smart with activation of flexibility

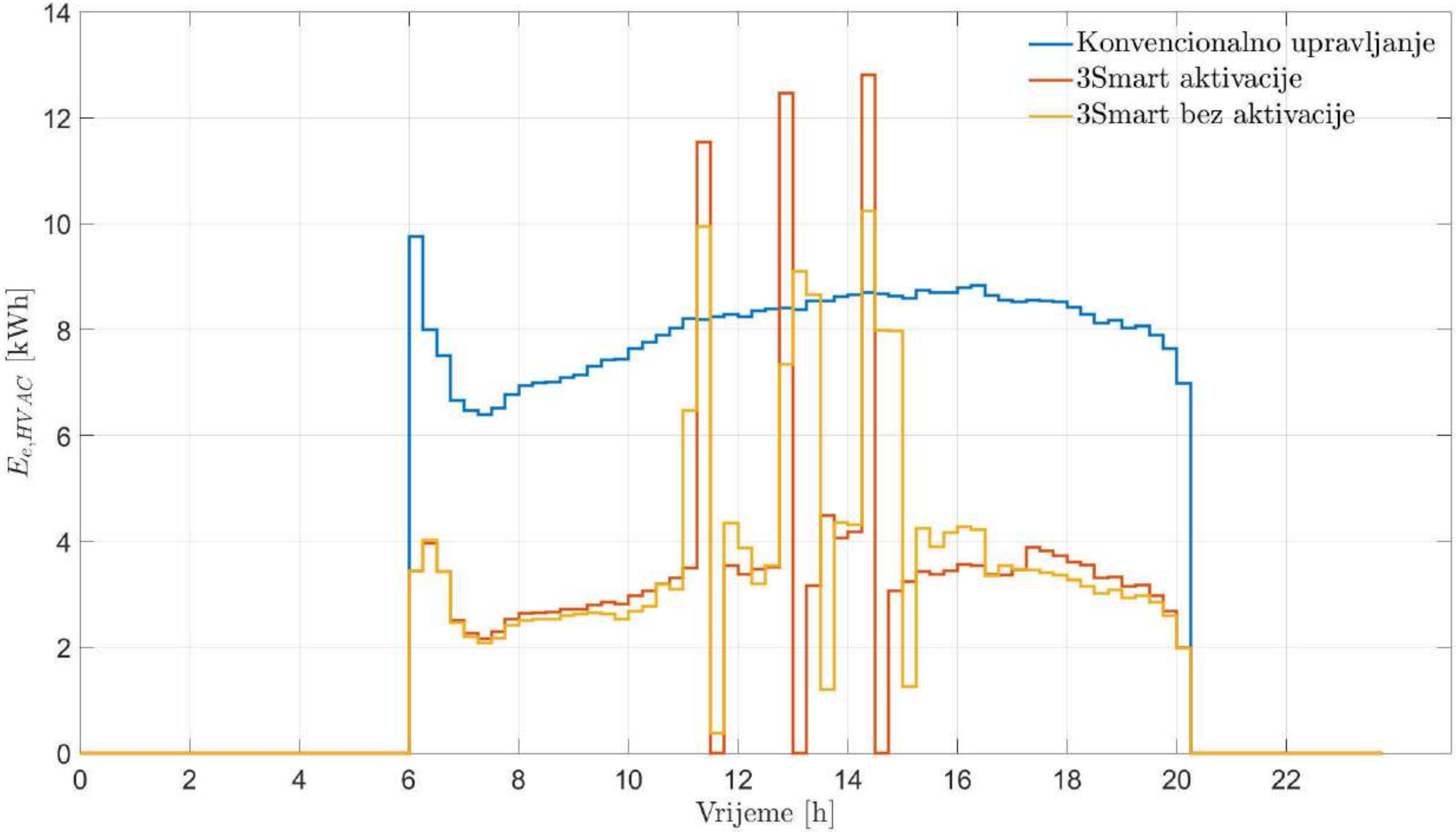
3Smart system operation -- FER building (7)

- Profile of medium temperature towards zones



3Smart system operation -- FER building (8)

- Electrical energy consumption of the cooling system (chiller + fan coils fans)

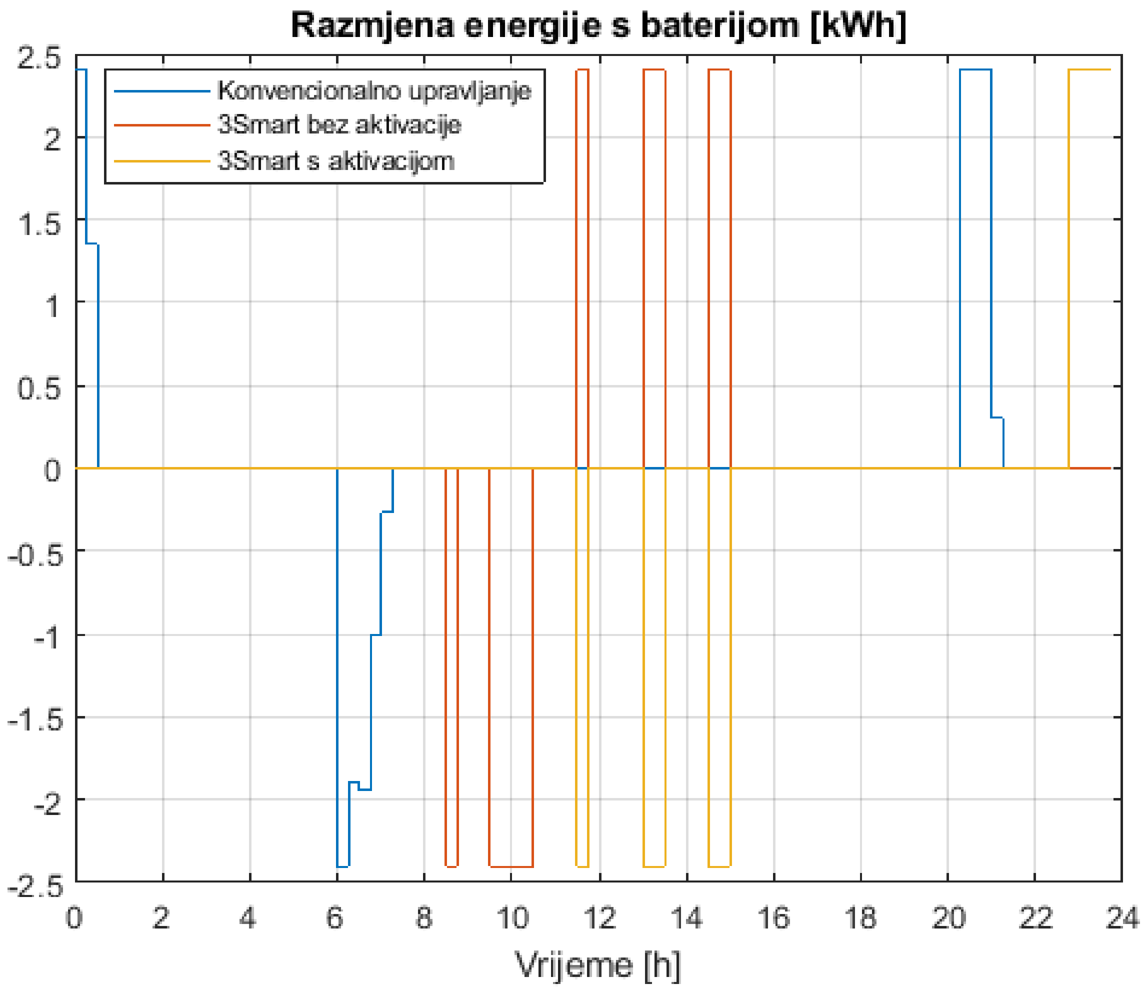


3Smart system operation -- FER building (9)

- Microgrid: Charging/discharging energy for the battery system and total electricity exchange with the grid
  - conevntional control (without 3Smart)
    - flattening the consumption curve towards the grid
  - 3Smart without activation of flexibility
  - 3Smart with activation of flexibility
- Optimal building flexibility offer
- Overall price for building operation
  - conventioanl control (without 3Smart)
  - 3Smart without activation of flexibility
  - 3Smart with activation of flexibility

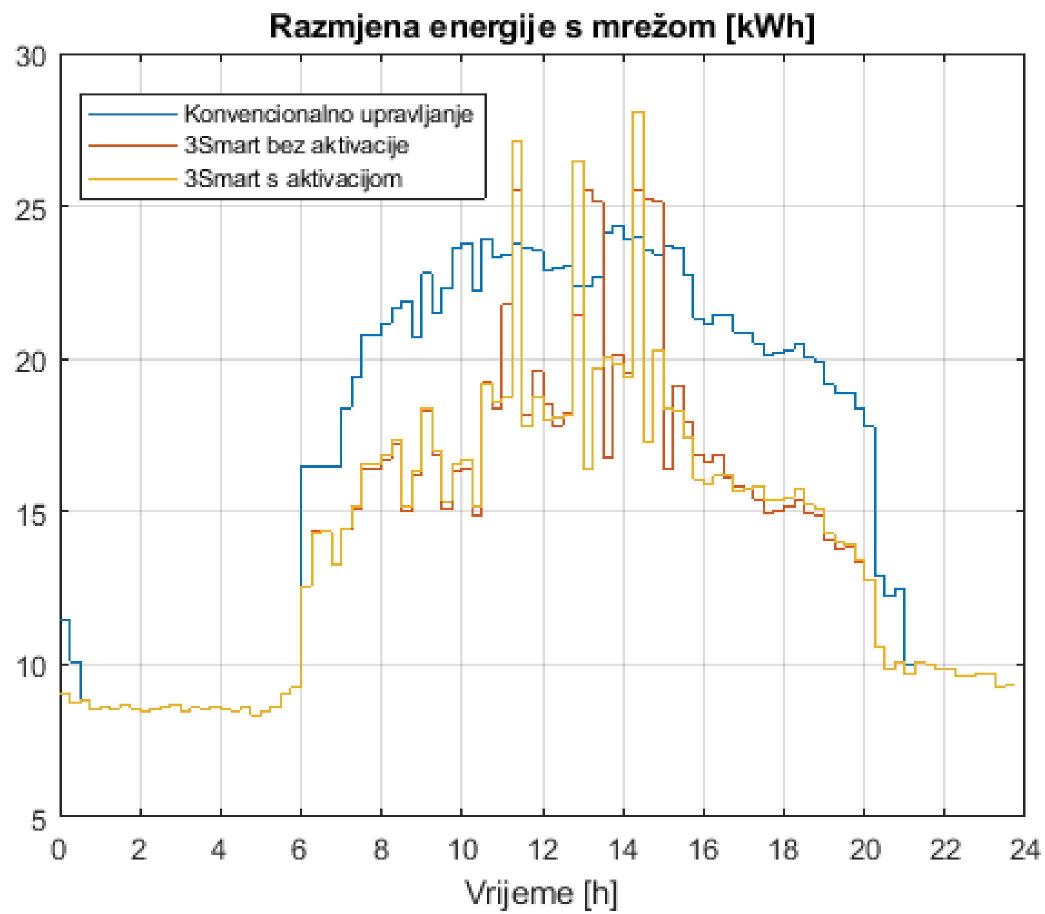
3Smart system operation -- FER building (10)

- Battery system energy exchange in kWh



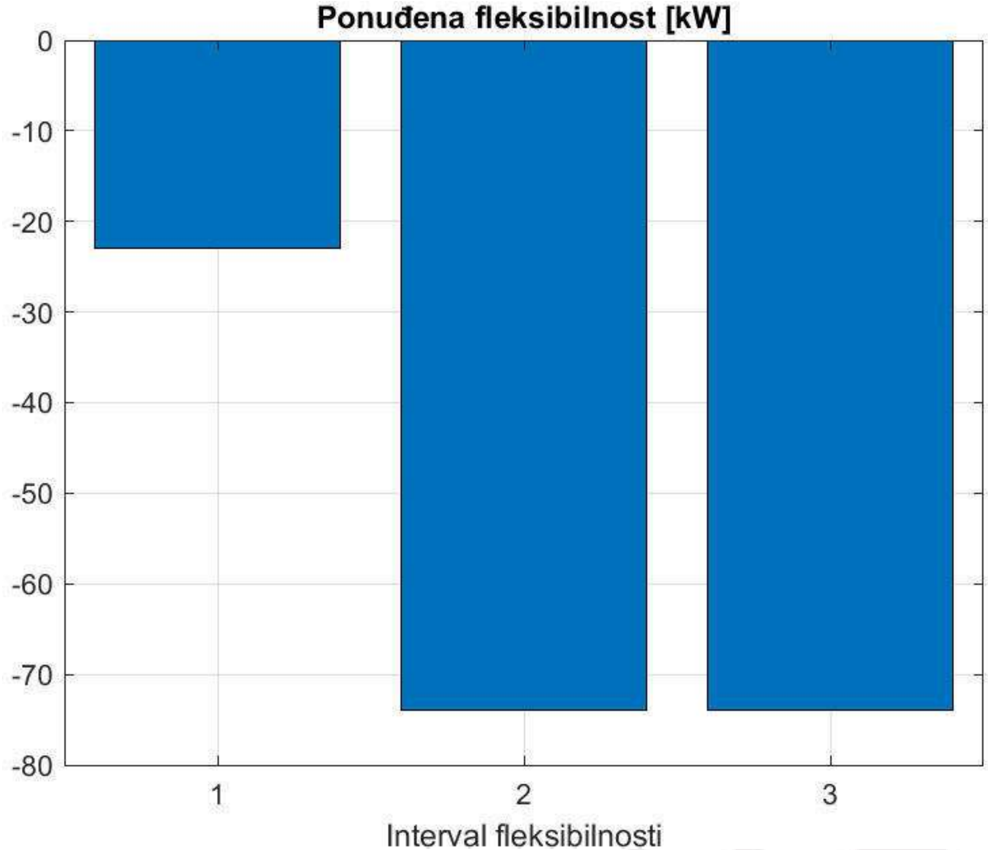
3Smart system operation -- FER building (11)

- Electricity exchange with the grid in kWh



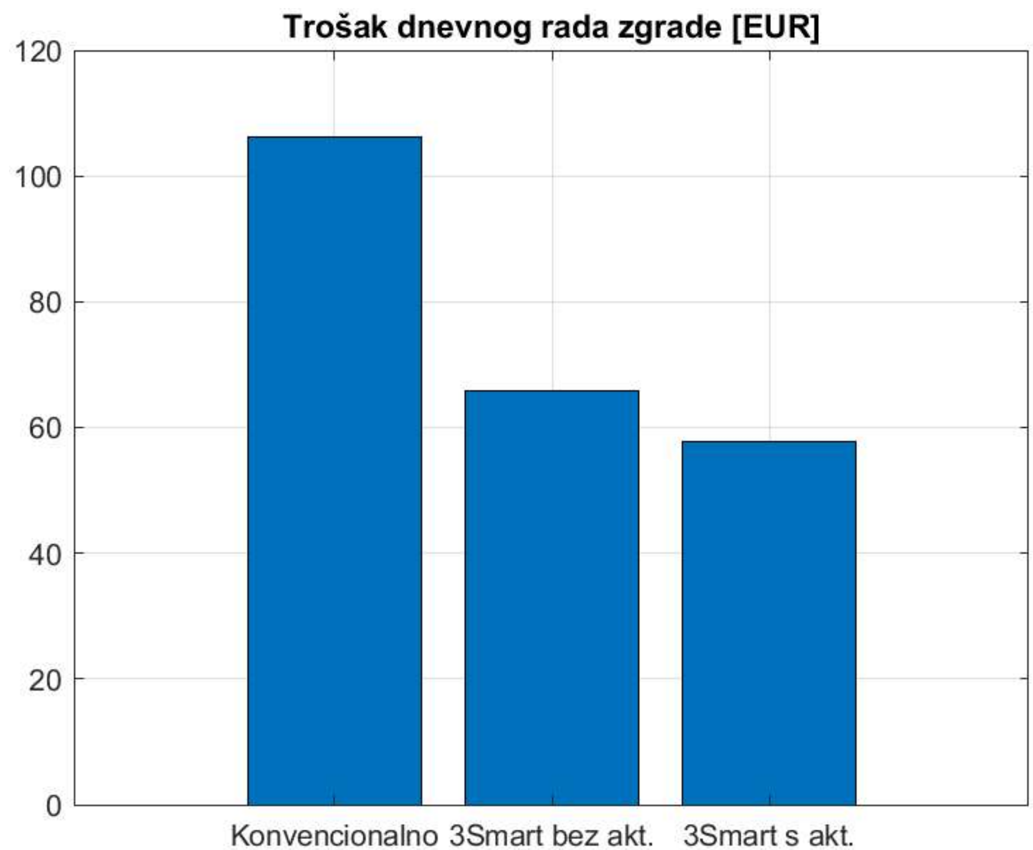
3Smart system operation -- FER building (12)

- Offered flexibility in kW for the 3 flexibility intervals: 1. 11:30-11:45, 2. 13:00-13:30, 3. 14:30-15:00

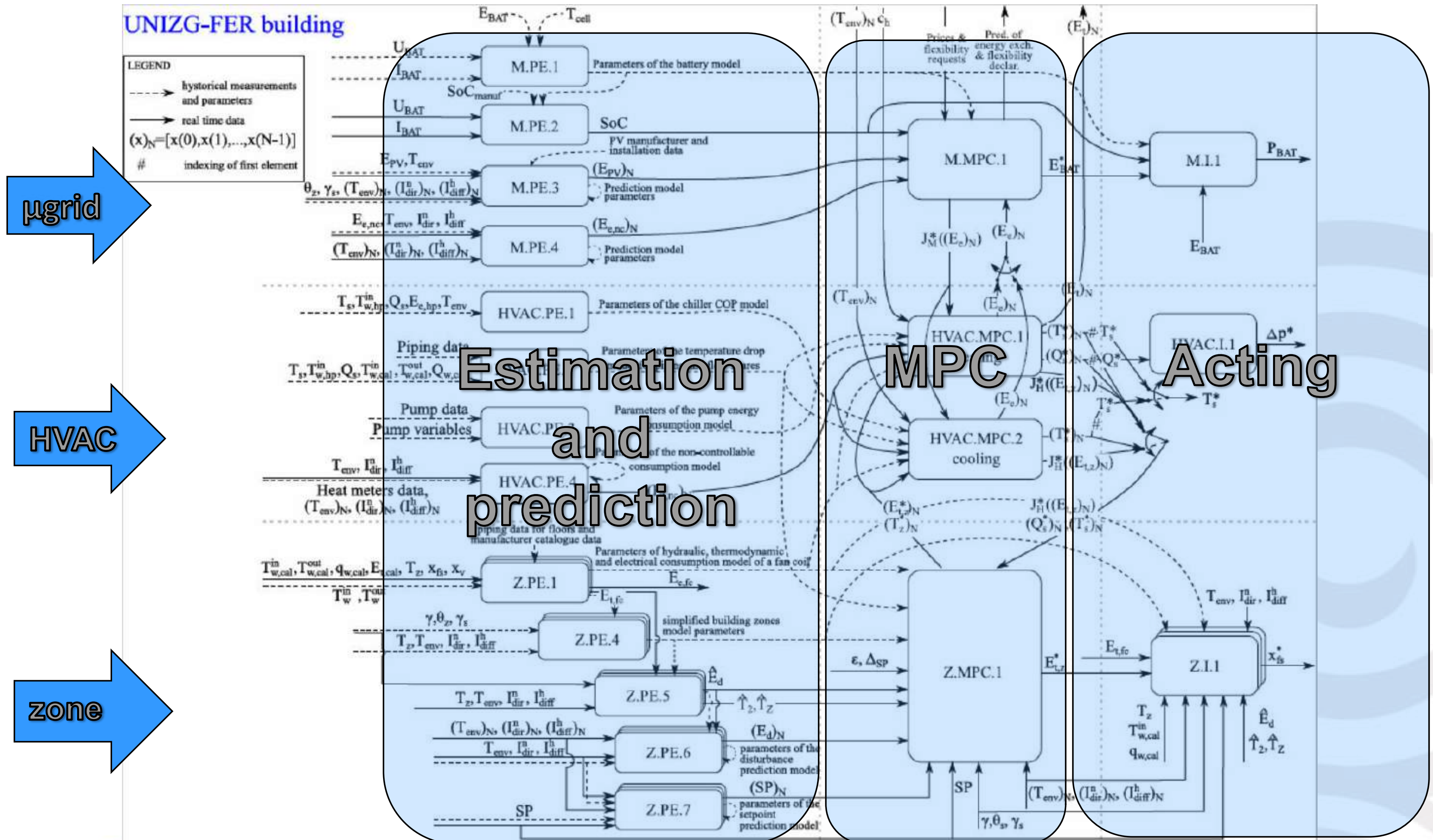


3Smart system operation -- FER building (13)

- Overall daily operational expenditure in EUR



Organisation of the 3Smart tool on HR pilot buildings



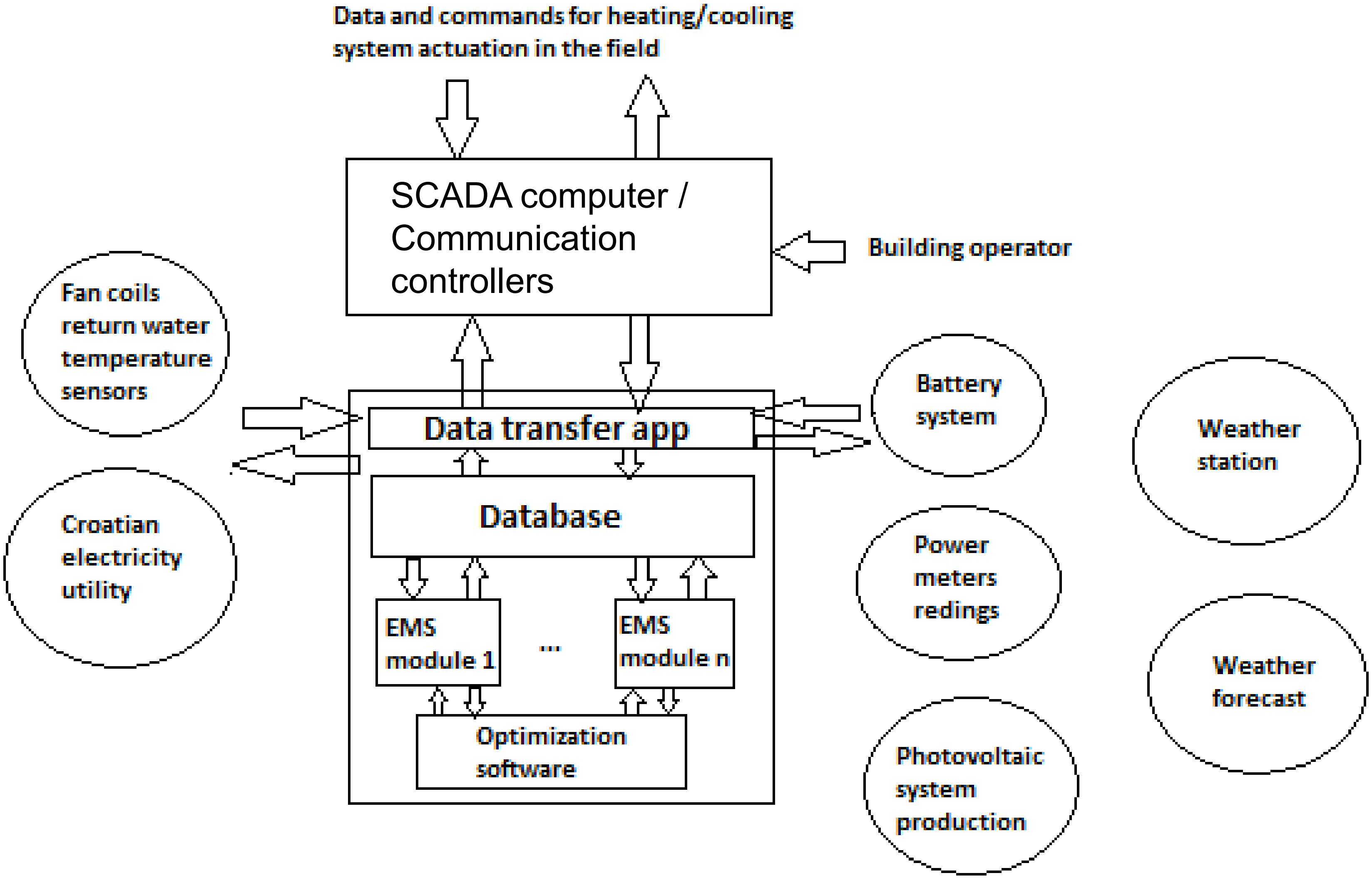
Requirements on building interventions

- Software-selectable which parts are coordinated
  - selection down to the level of individual rooms
- Simple and automated return to classical control if needed
  - time-stamped command actions
- Sampling of building data into 3Smart database on ~1 min level
- Control commands set by software modules in 3Smart database propagate to building automation end-devices
- Non-disturbing of local control loops for HVAC/μgrid

3Smart interventions of FER building

- Zone level:
  - reconfiguration of room control units with producers guarantee
  - 1-wire return medium temperature sensors for all fan coils (368)
  - built-up SCADA (3Smart on/off)
- Floors:
  - built-in calorimeters for every half-floor supply duct and integrated in SCADA
- Central HVAC level (preparation of medium for heating/cooling):
  - heating substation integrated into SCADA
- Microgrid level:
  - 32 kWh / 10 kW Li-ion battery system with a controllable power converter
  - integrated electric energy meters
- 3Smart server computer, 3Smart database, communication controllers towards the building automation system
- Communication with HEP server on grid side

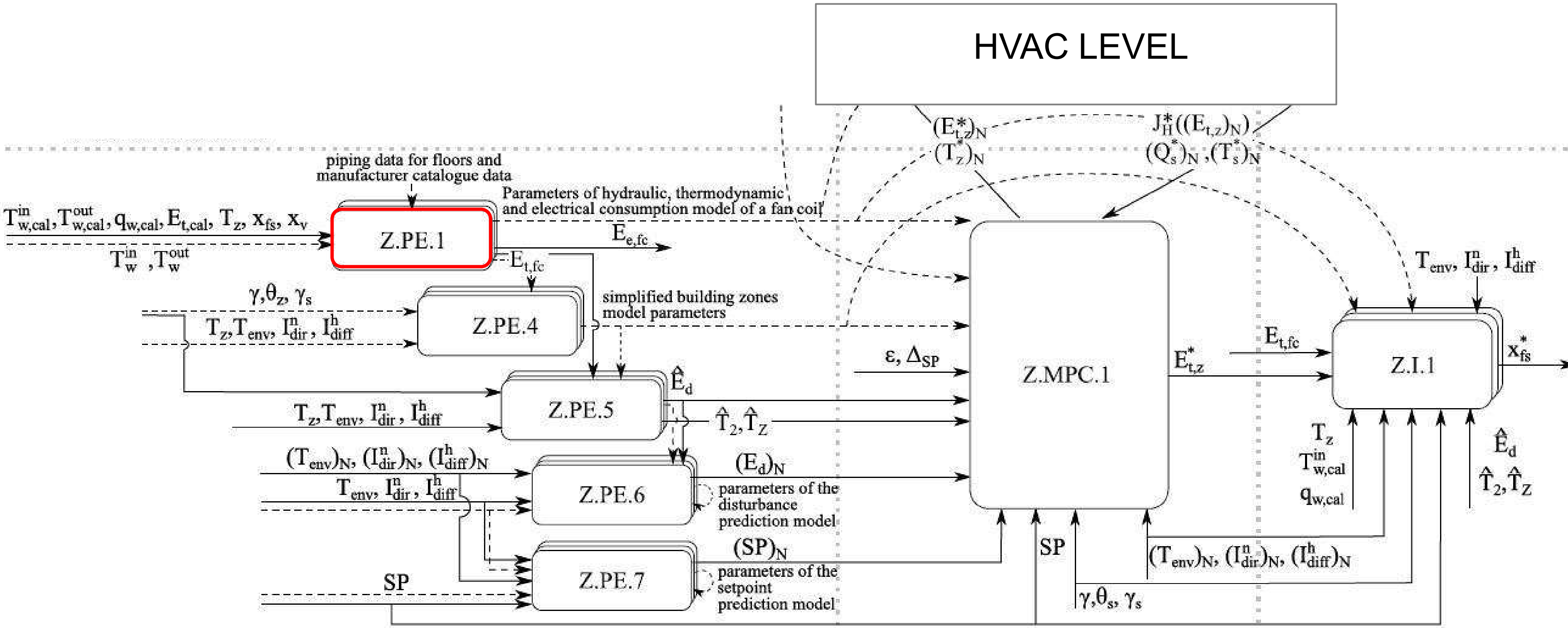
Information flow streams for both buildings



Demonstration of modules operation

Zone level

Z.PE.1 – offline
(fan coil identification submodule)



Z.PE.1 – offline
(fan coil identification submodule)

Running once

- Identification of **hydraulic installations model**

Medium flow measurement from the considered duct calorimeter → Hydraulic fan coil model
Valve position → Hydraulic fan coil model
Hydraulic fan coil model → Medium flow through the fan coil

- Identification of **thermodynamic fan coils model**

Supply water temperature (calorimeter) → Thermodynamic fan coil model
Return medium temperature → Thermodynamic fan coil model
Fan state → Thermodynamic fan coil model
Valve position → Thermodynamic fan coil model
Medium flow through the coil → Thermodynamic fan coil model
Zone temperature → Thermodynamic fan coil model
Thermodynamic fan coil model → Thermal energy exerted into zone

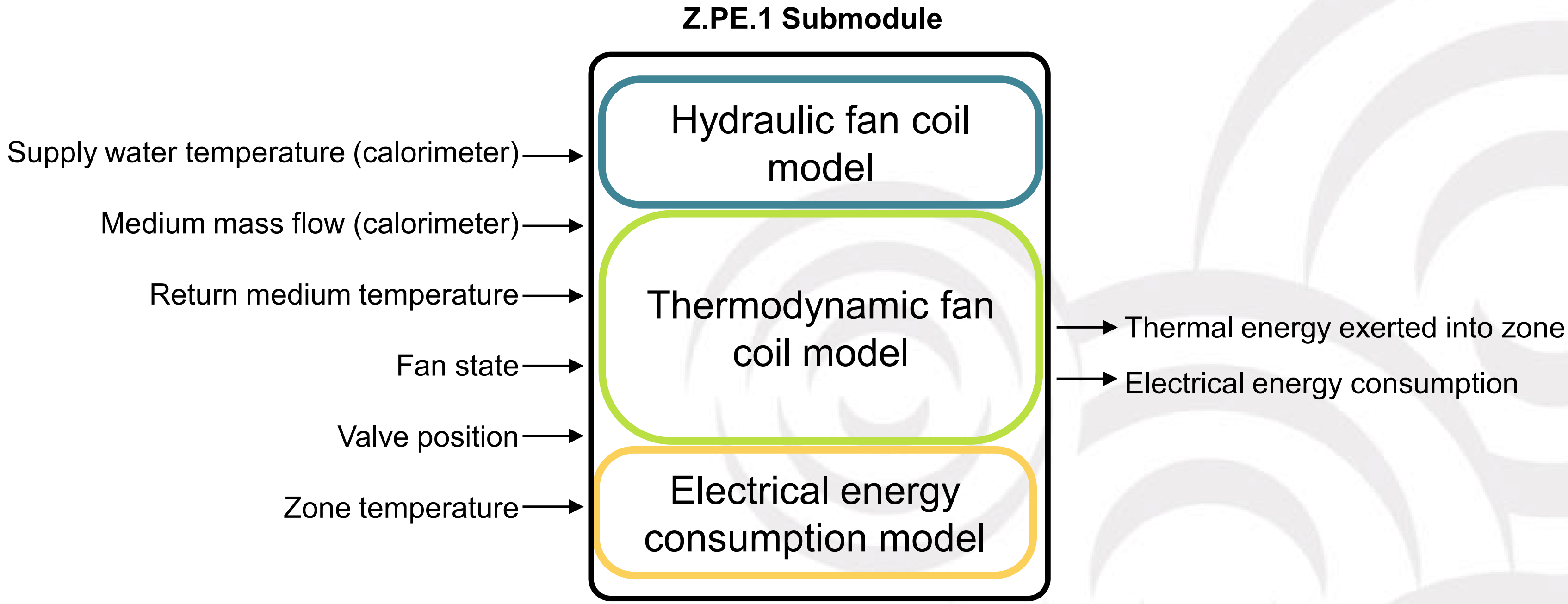
- Identifivcation of **electricity consumption model of fan coil fans**

Fan state → Electrical energy consumption model
Electrical energy consumption model → Electrical energy consumption

Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of a fan coil every minute heating energy exerted from fan coil is calculated as well as fan coil electricity consumed

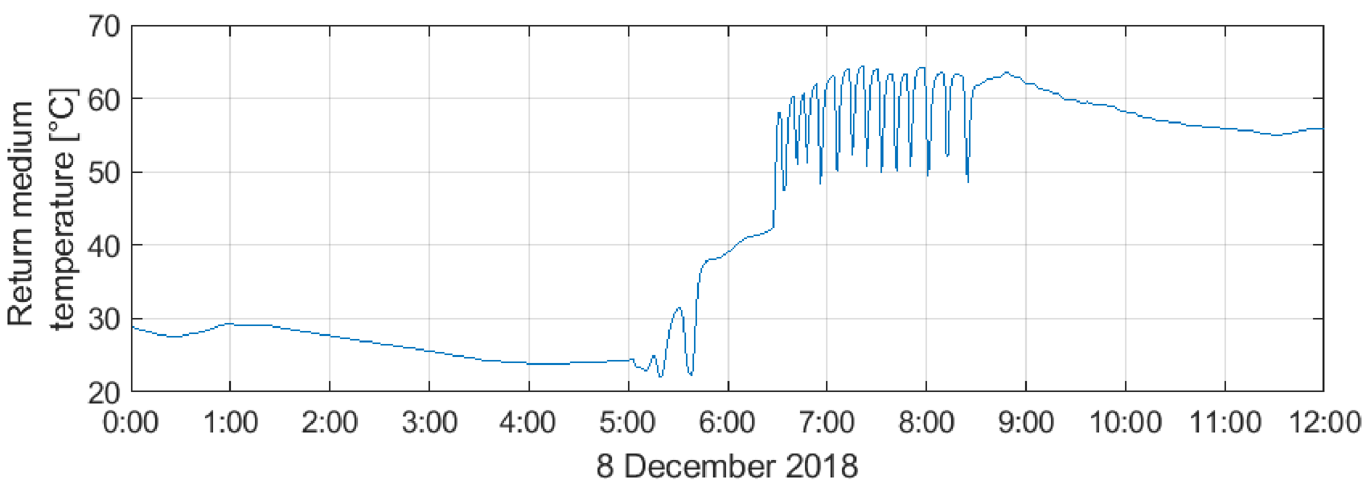
Running every 1 min



Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of a fan coil every minute heating energy exerted from fan coil is calculated as well as fan coil electricity consumed

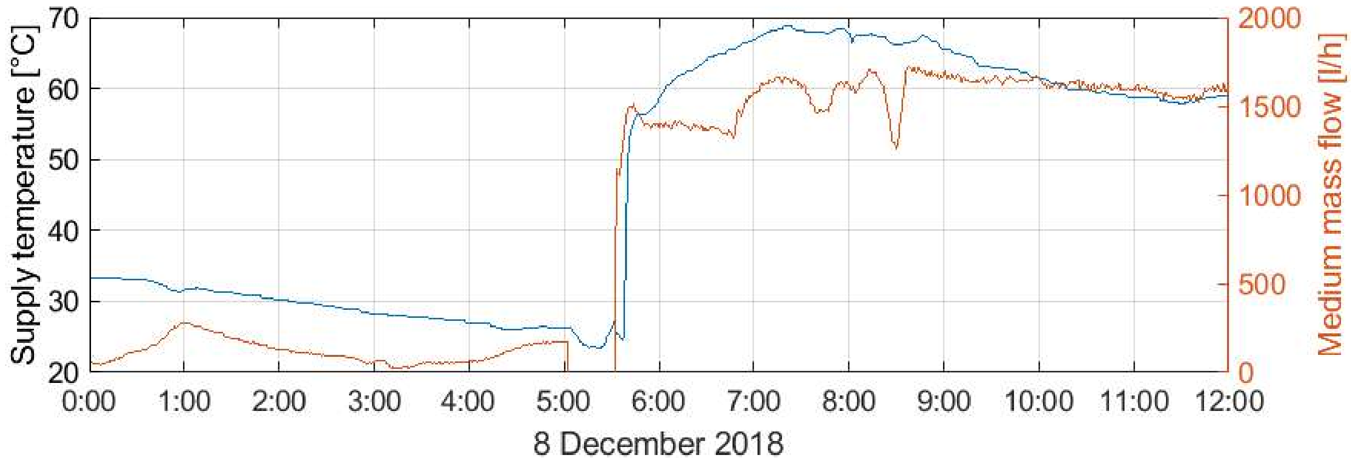
INPUT 1: current measurement of return medium temperature



Z.PE.1 – online
(fan coil identification submodule

- By using **hydraulic, thermodynamic and electricity consumption model** of a fan coil every minute heating energy exerted from fan coil is calculated as well as fan coil electricity consumed

INPUT 1: current measurement of return medium temperature
INPUT 2: current measurement of supply medium temperature
INPUT 3: current measurement of medium flow

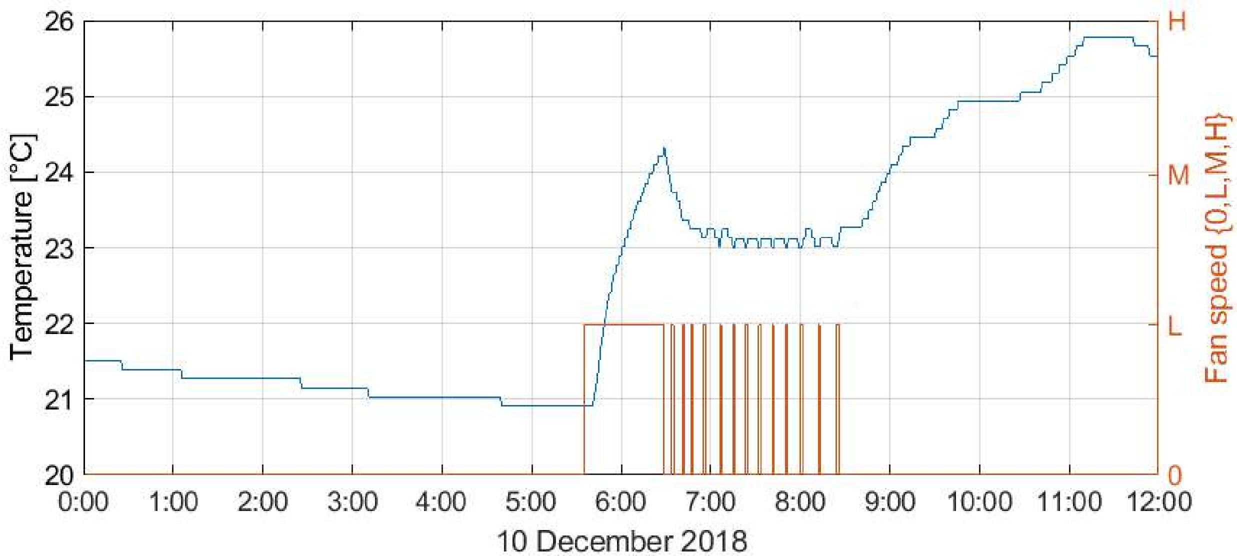


Z.PE.1 – online

(fan coil identification submodule

- By using **hydraulic, thermodynamic and electricity consumption model** of a fan coil every minute heating energy exerted from fan coil is calculated as well as fan coil electricity consumed

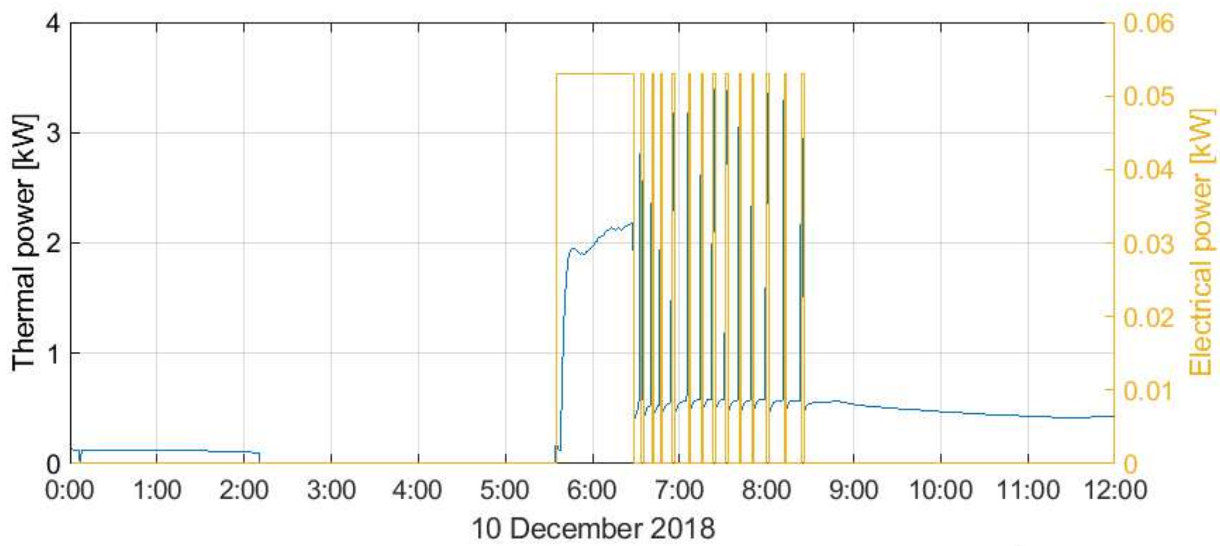
INPUT 1: current measurement of return medium temperature
INPUT 2: current measurement of supply medium temperature
INPUT 3: current measurement of medium flow
INPUT 4: current room temperature measurement
INPUT 5: current fan coil fan sped measurement



Z.PE.1 – online
(fan coil identification submodule

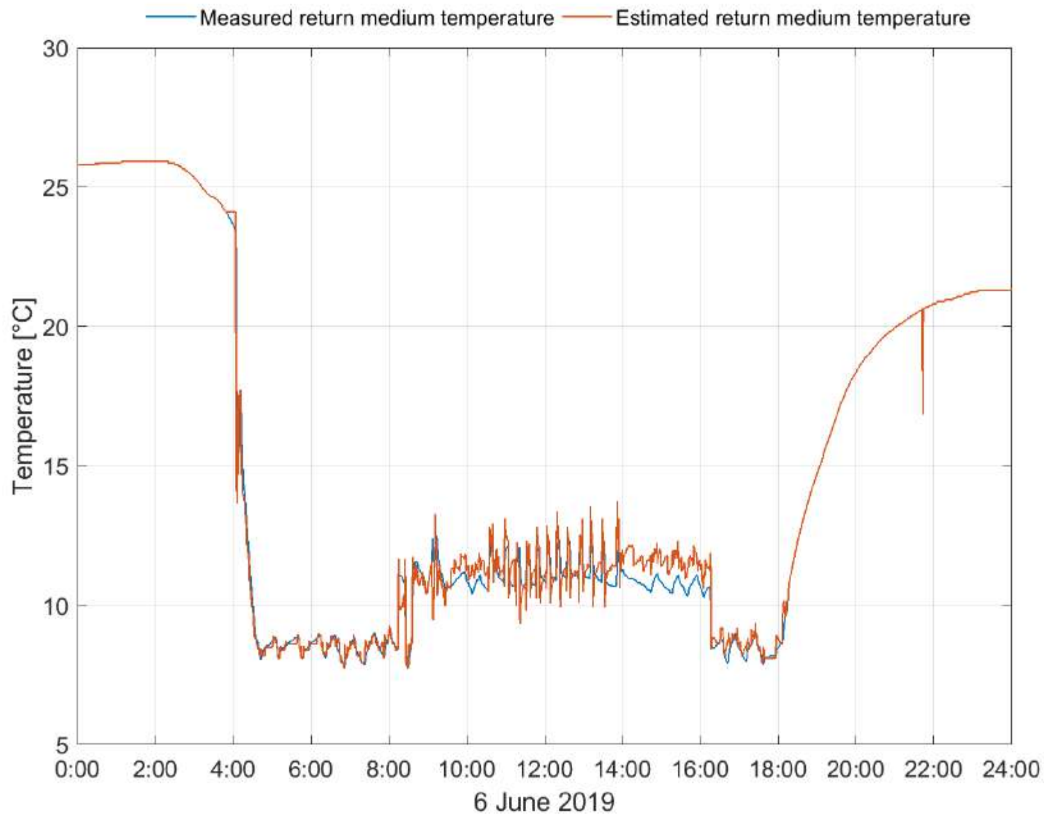
- By using **hydraulic, thermodynamic and electricity consumption model** of a fan coil every minute heating energy exerted from fan coil is calculated as well as fan coil electricity consumed

OUTPUT 1: heating energy provided to room air
OUTPUT 2: fan coil fan electricity consumption



Z.PE.1 – online
(fan coil identification submodule

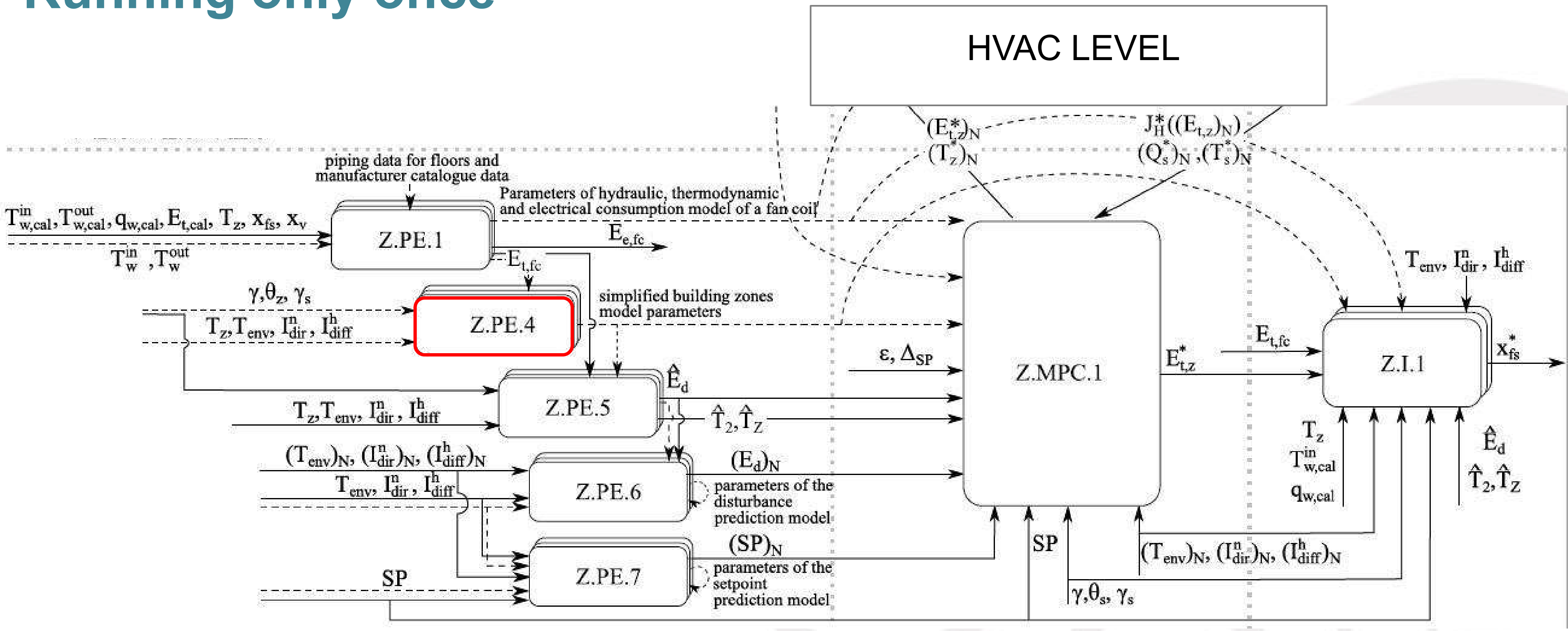
OUTPUT 3: Estimated return medium temperature of the fan coil – resistance to errors in data communication with sensors



Zone PE 4

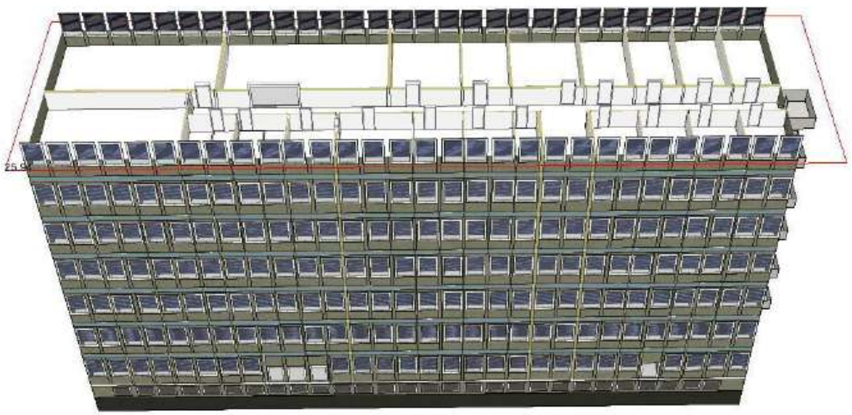
(identification of the simplified building thermodynamic model)

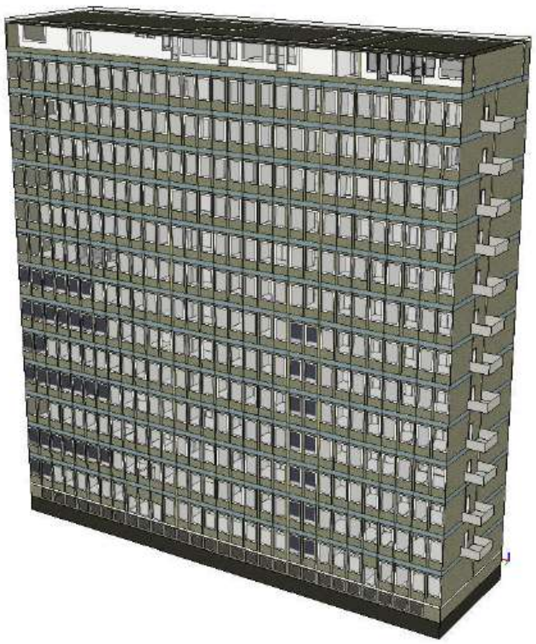
Running only once



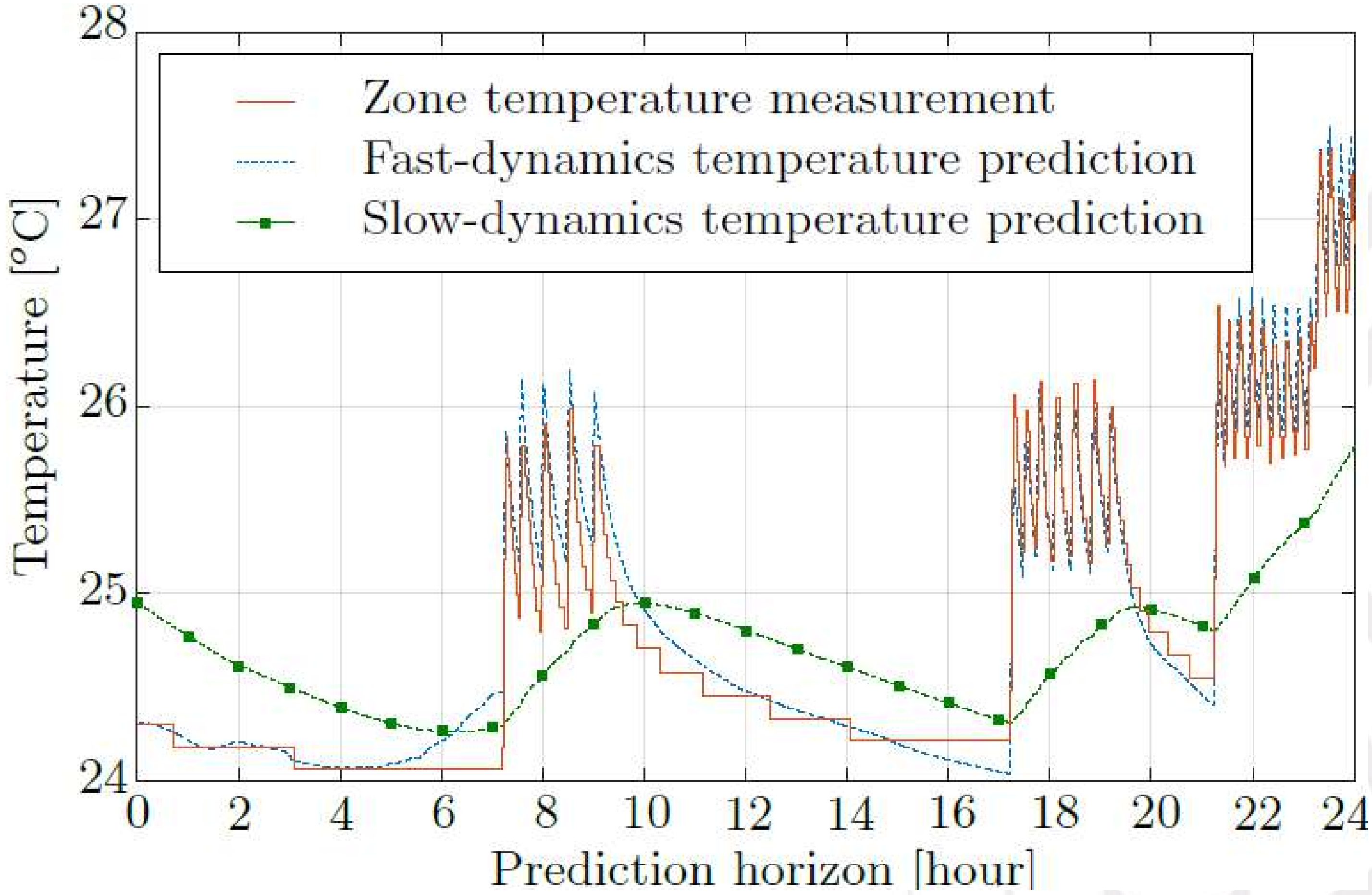
Zone PE 4
(identification of the simplified building thermodynamic model)

INPUTS: historical room temperature measurements, historical measurements of outdoor weather conditions, historical estimates of heating powers from heating elements to room air
OUTPUTS: parameters of the thermodynamic building mathematical model (from heating power to air to room air temperature)



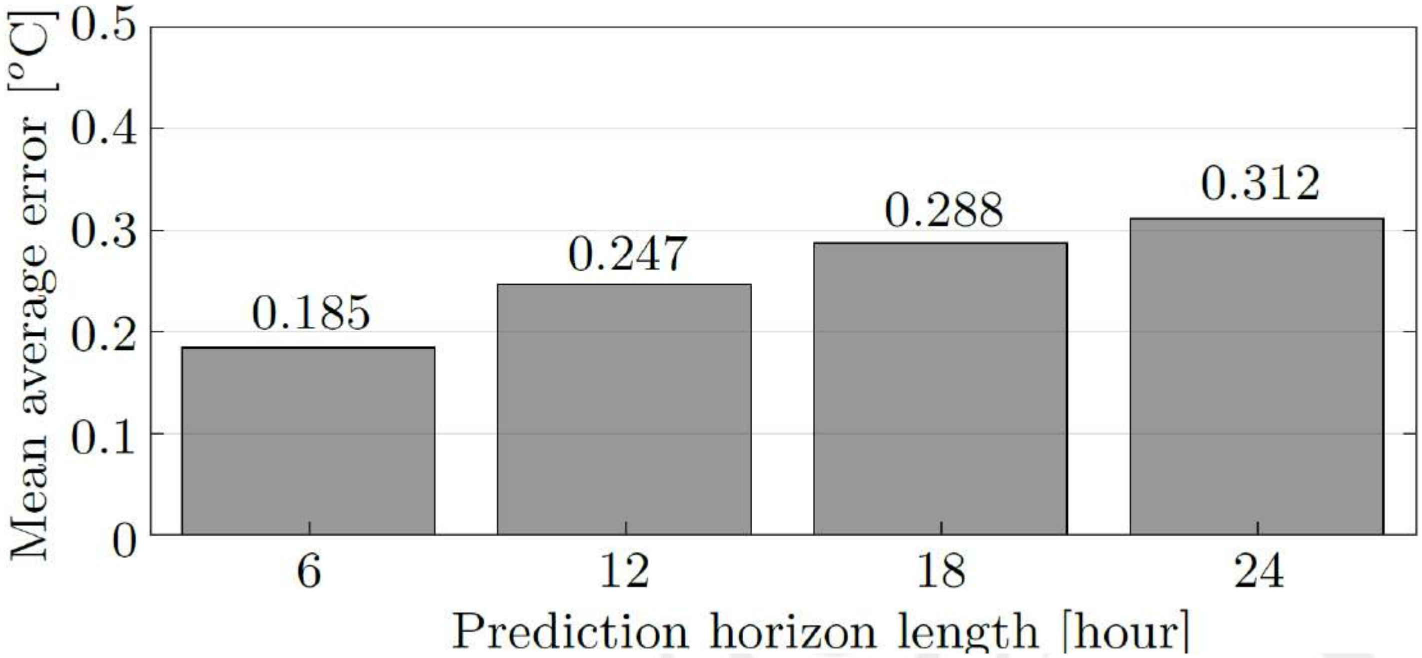


Zone PE 4
(identification of the simplified building thermodynamic model)



Zone PE 4

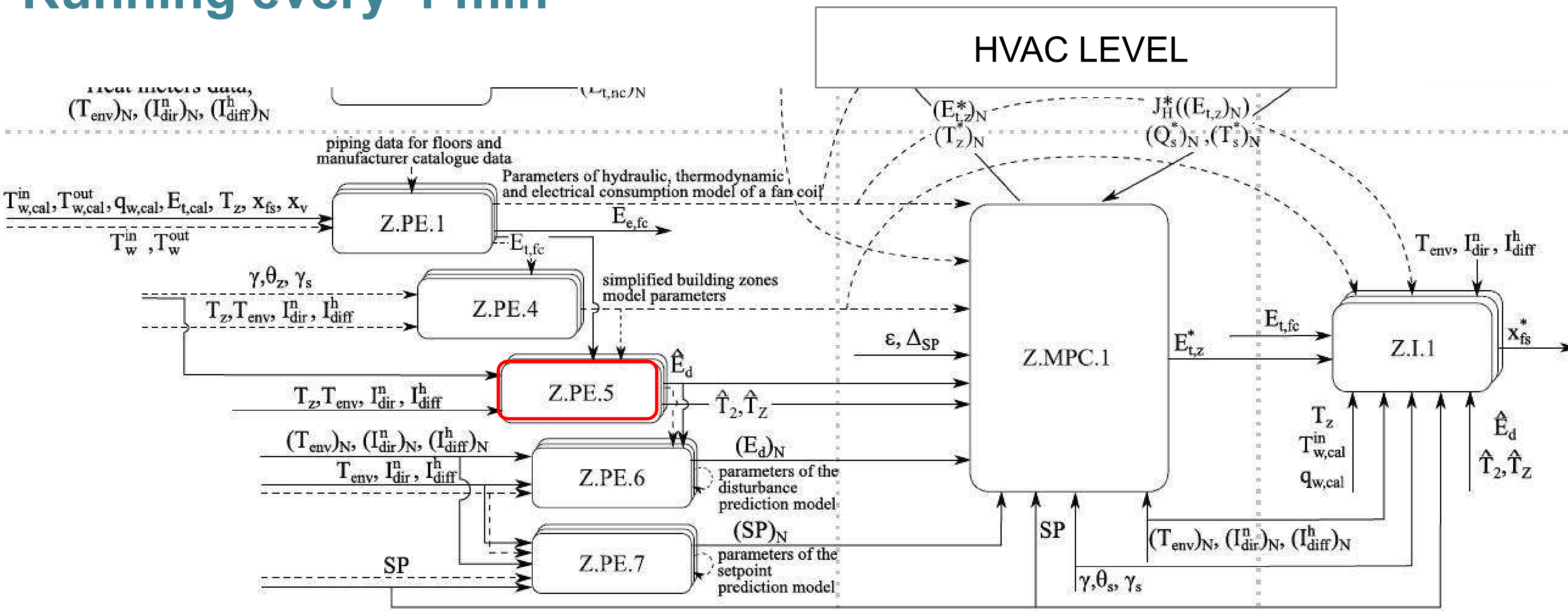
(identification of the simplified building thermodynamic model)



Zone PE 5

(module for estimation of non-measurable building model states and of heat disturbances in zones)

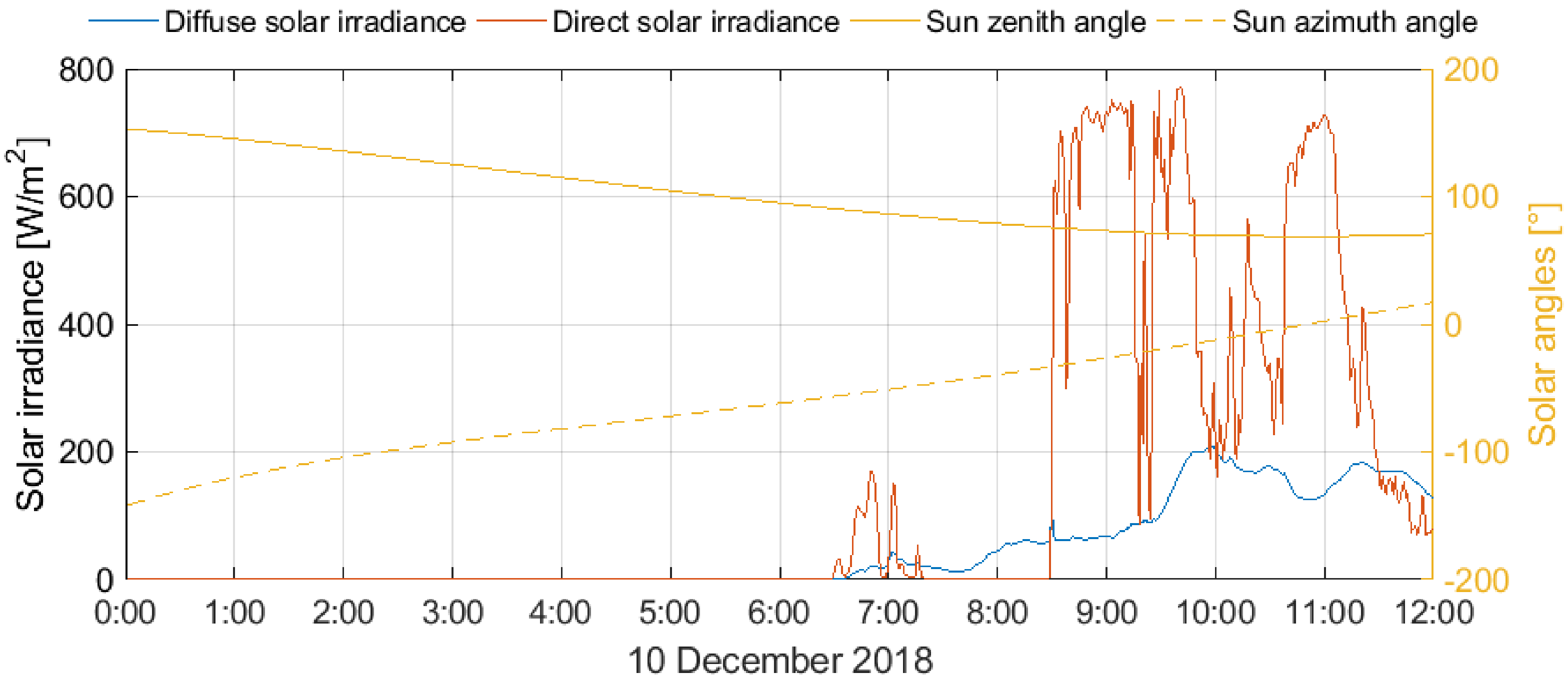
Running every 1 min



Zone PE 5

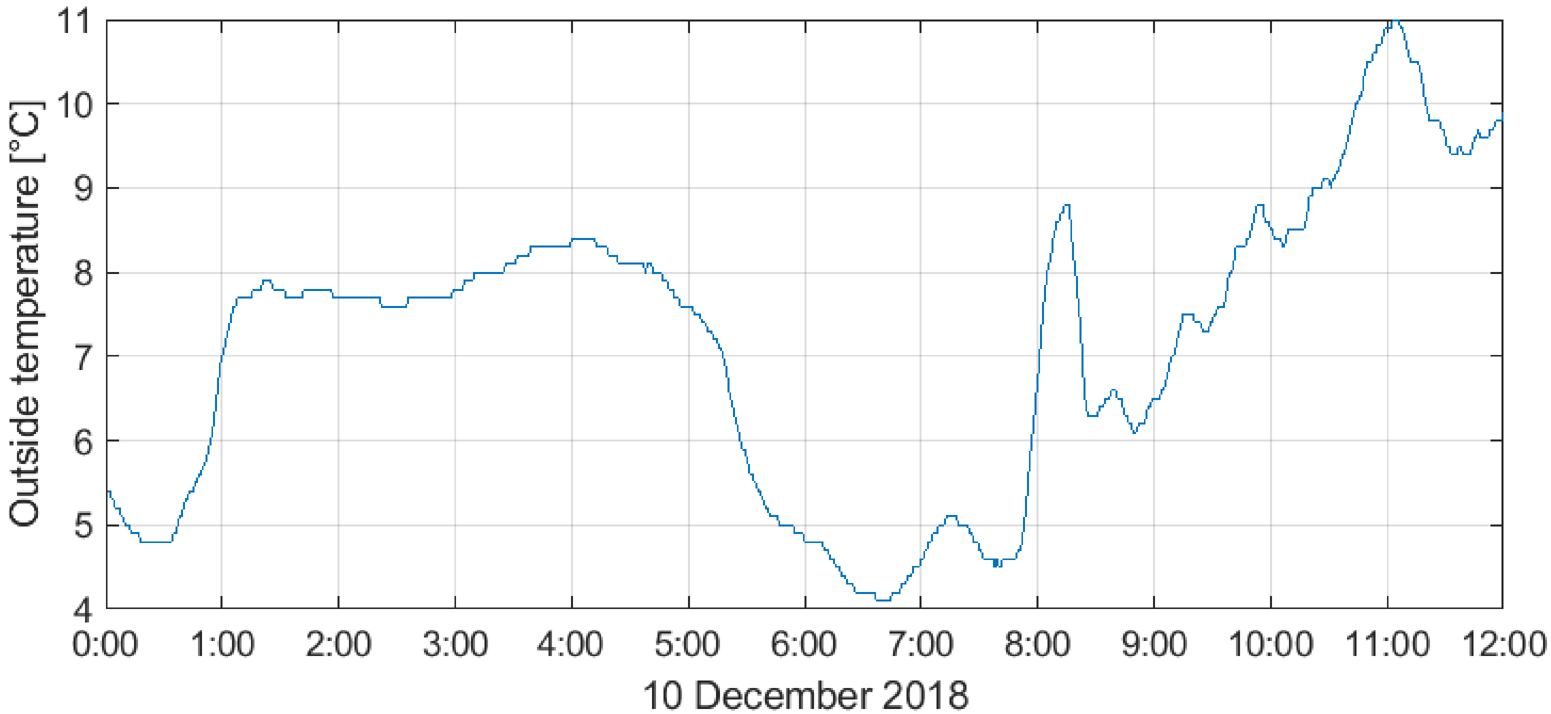
(module for estimation of non-measurable building model states and of heat disturbances in zones)

INPUT 1: current measurement of direct and diffuse solar irradiance



Zone PE 5
(module for estimation of non-measurable building model states and of heat disturbances in zones)

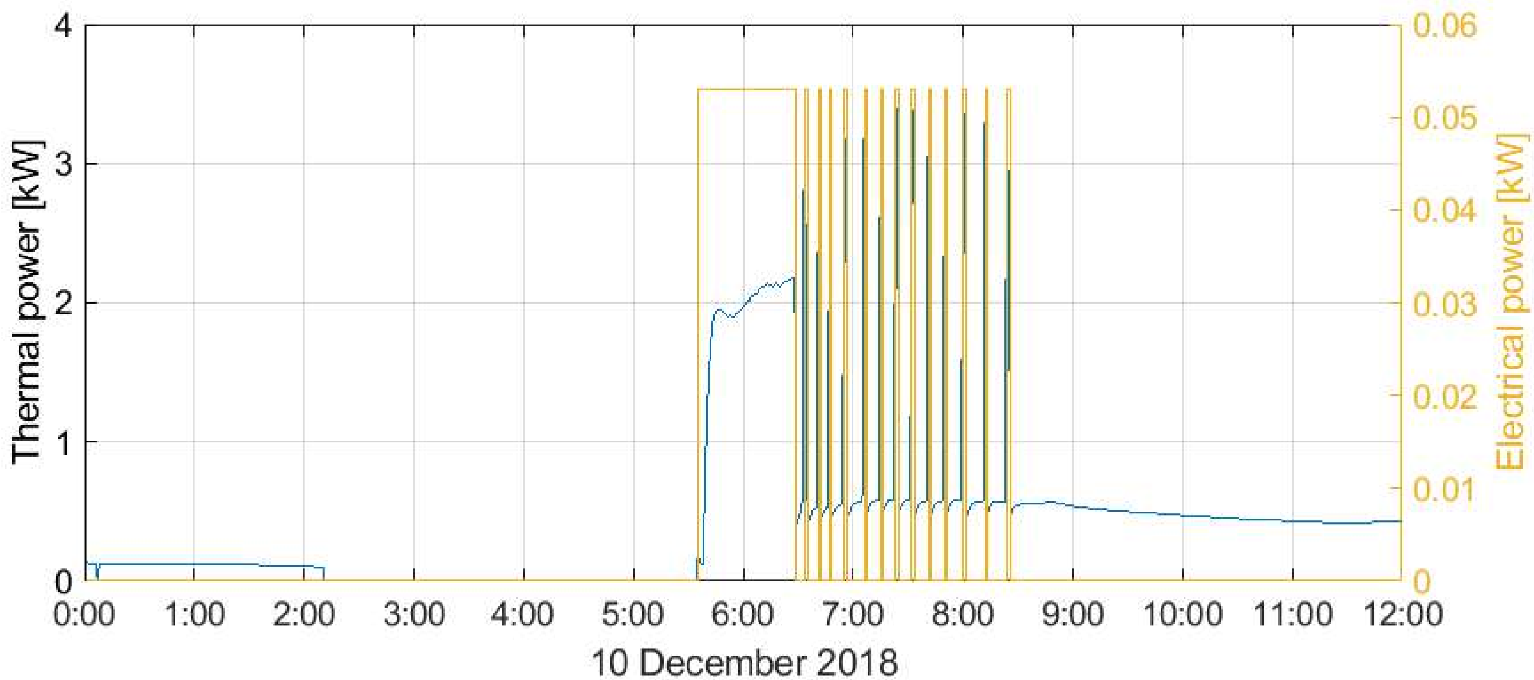
INPUT 1: current measurement of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature



Zone PE 5

(module for estimation of non-measurable building model states and of heat disturbances in zones)

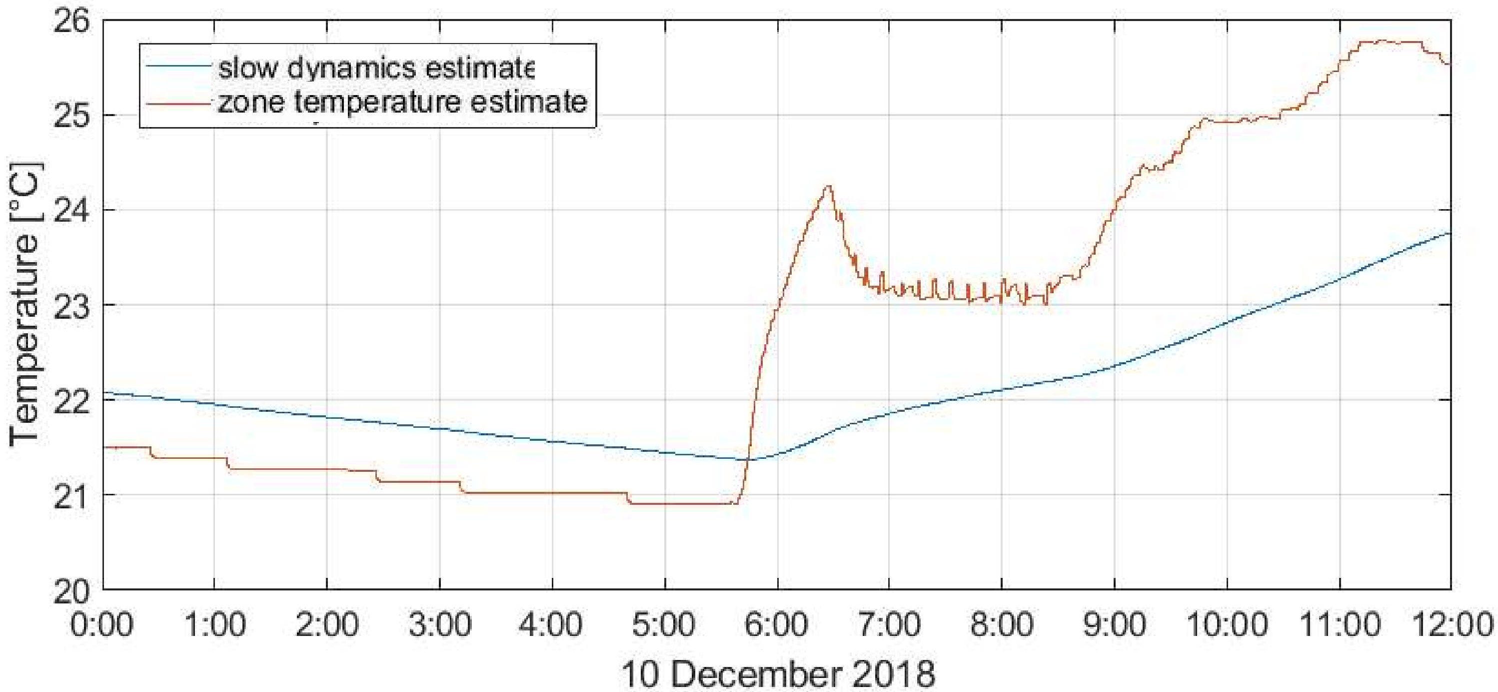
INPUT 1: current measurement of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature
INPUT 3: current values of heating energy exerted to zone air (Zone PE 1 module)
INPUT 4: current measurement of room temperature



Danube Transnational Programme
3Smart

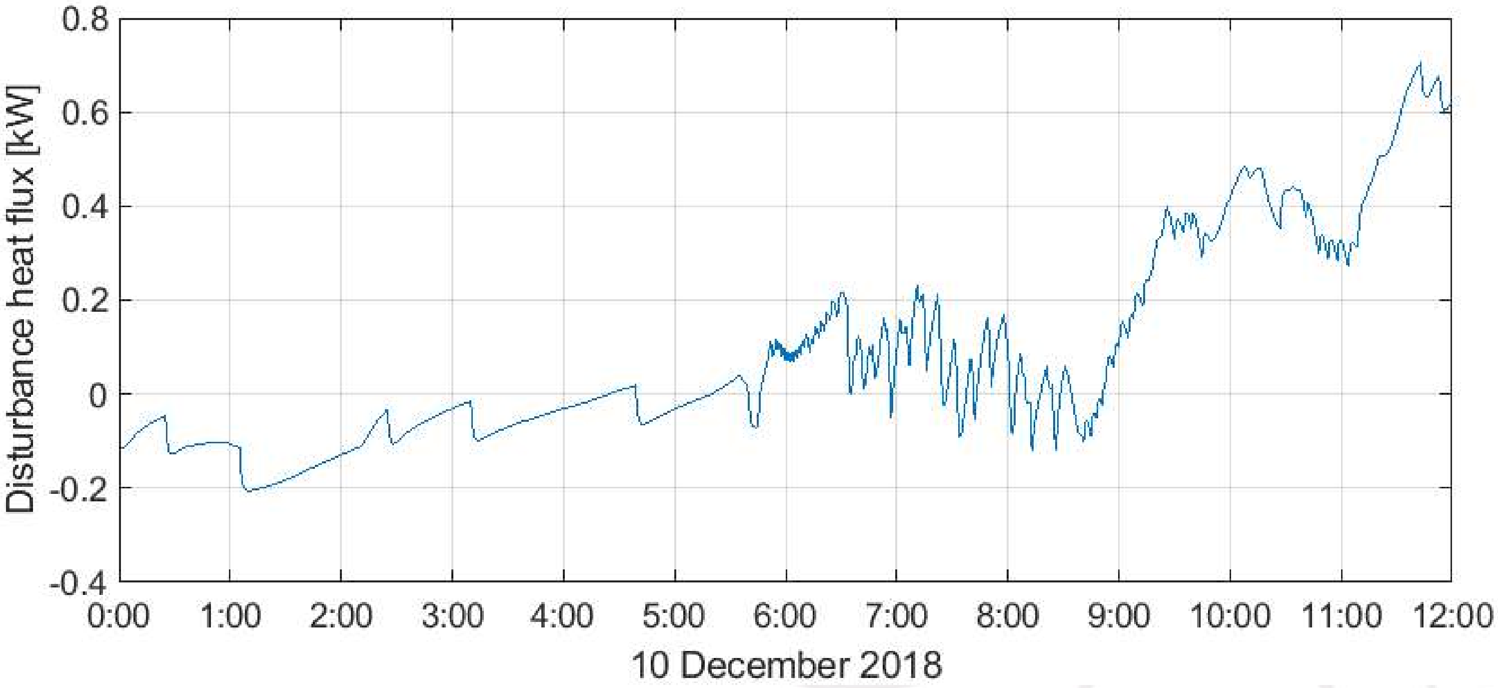
Zone PE 5
(module for estimation of non-measurable building model states and of heat disturbances in zones)

OUTPUT 1: Estimated current values of zone mode air temperature and slow dynamics state



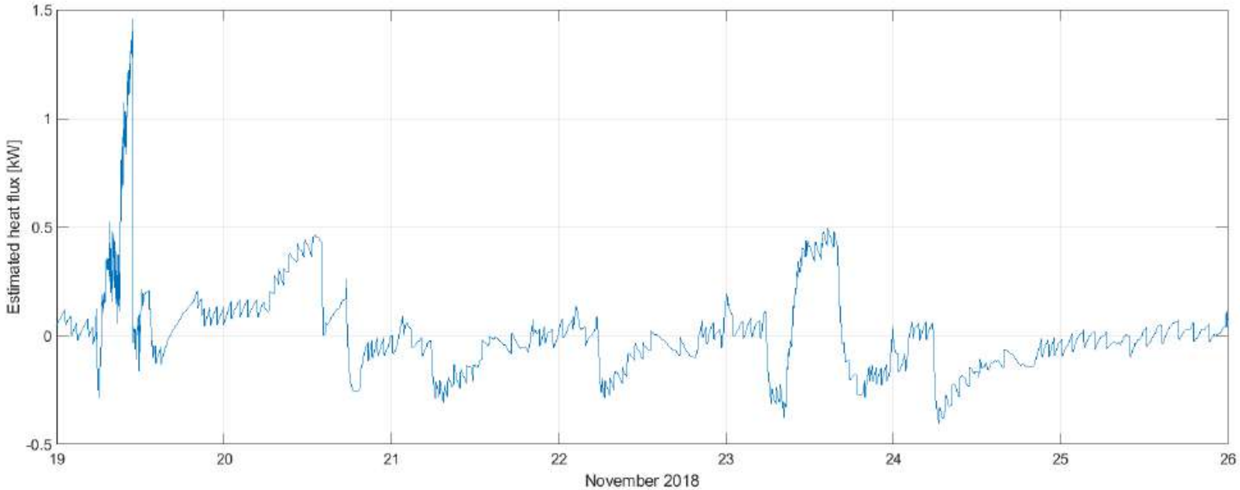
Zone PE 5
(module for estimation of non-measurable building model states and of heat disturbances in zones)

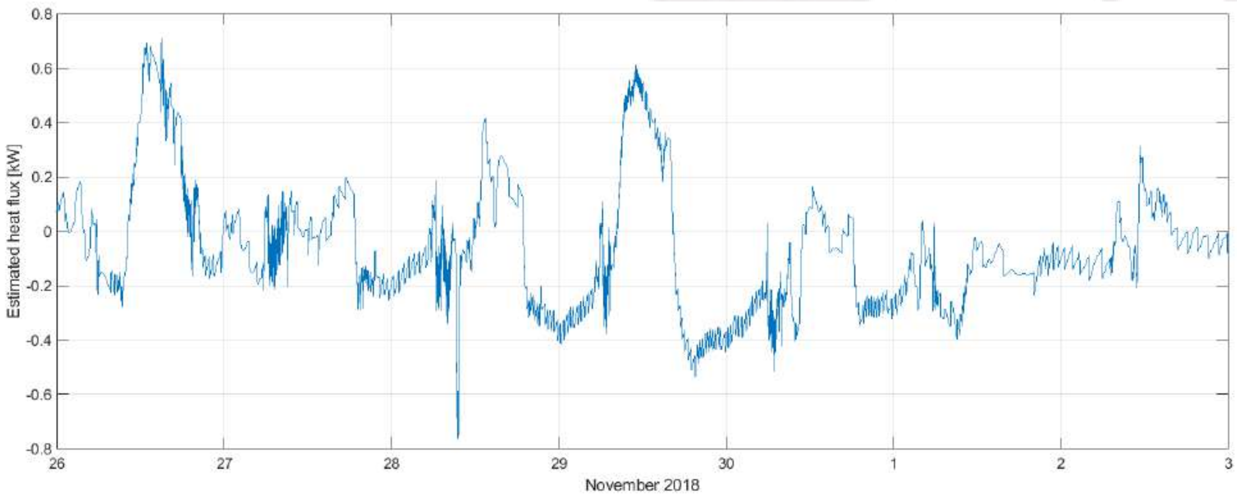
OUTPUT 1: Estimated current values of zone mode air temperature and slow dynamics state
OUTPUT 2: Estimated current value of the heat disturbance



Zone PE 5

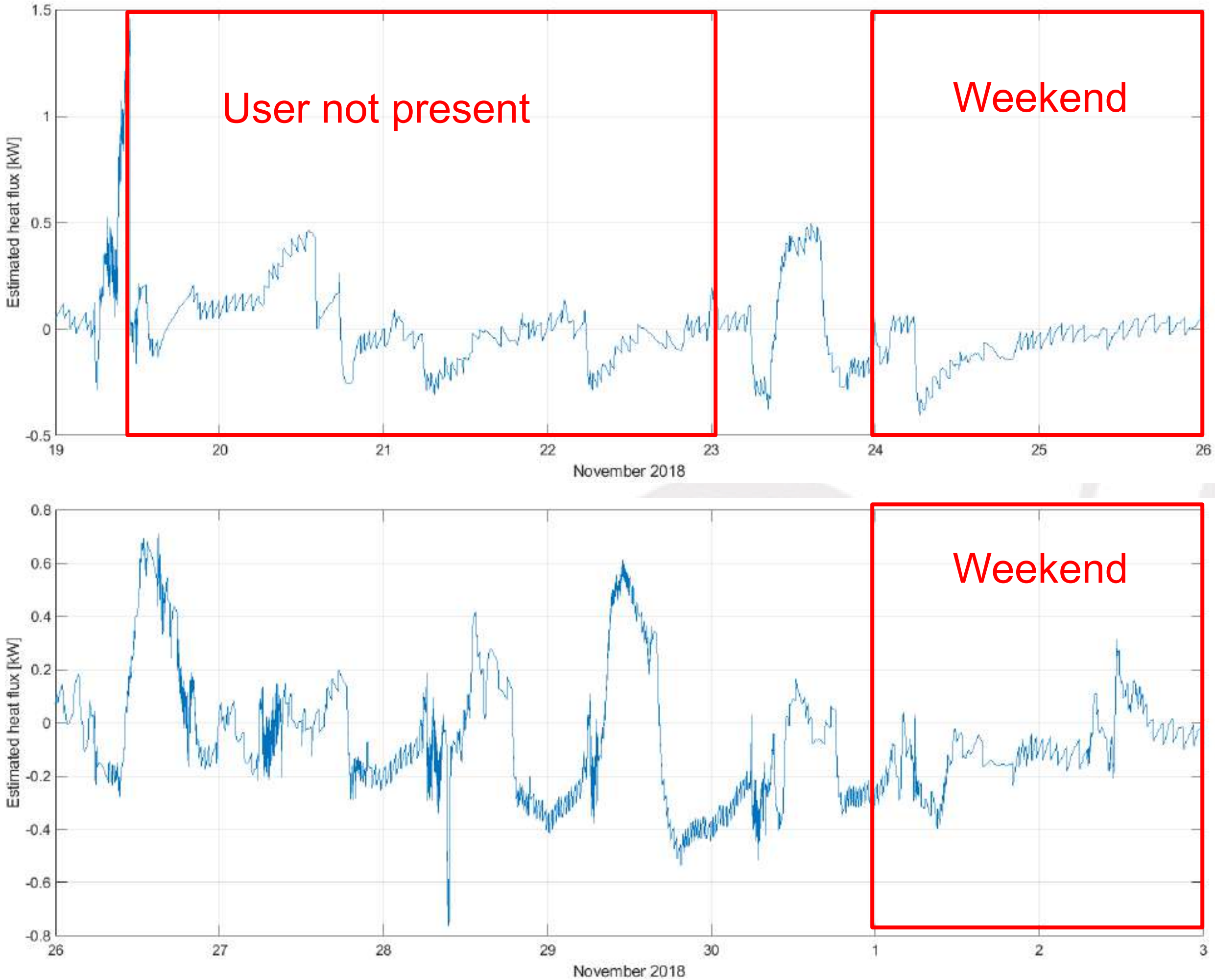
(module for estimation of non-measurable building model states and of heat disturbances in zones)





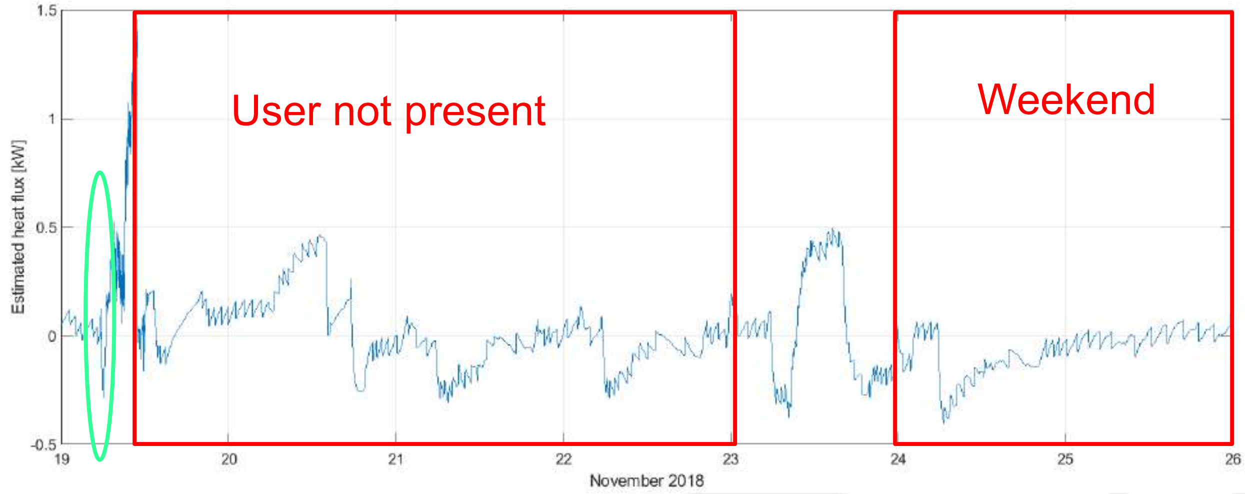
Zone PE 5

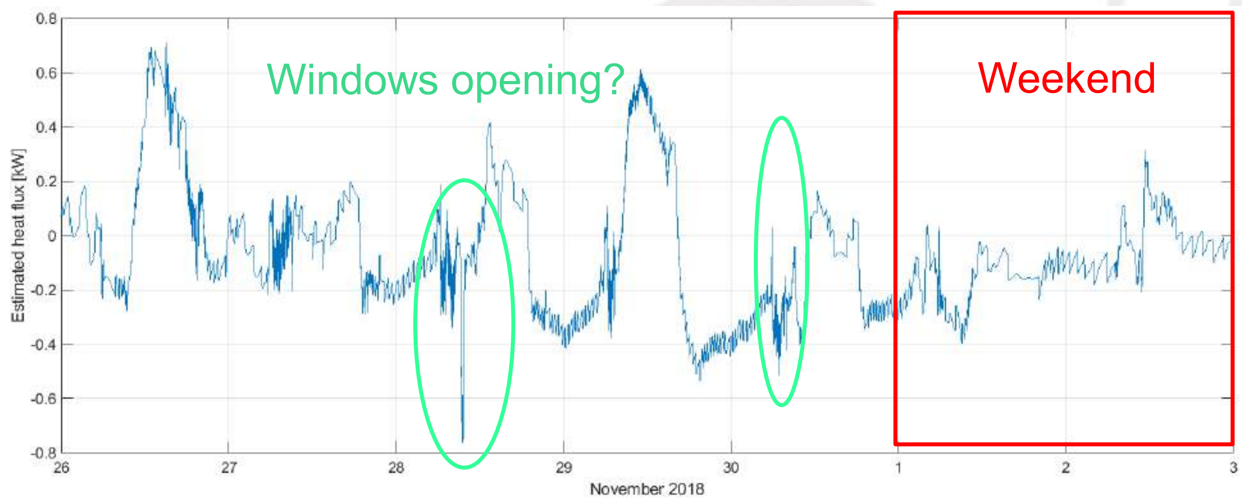
(module for estimation of non-measurable building model states and of heat disturbances in zones)



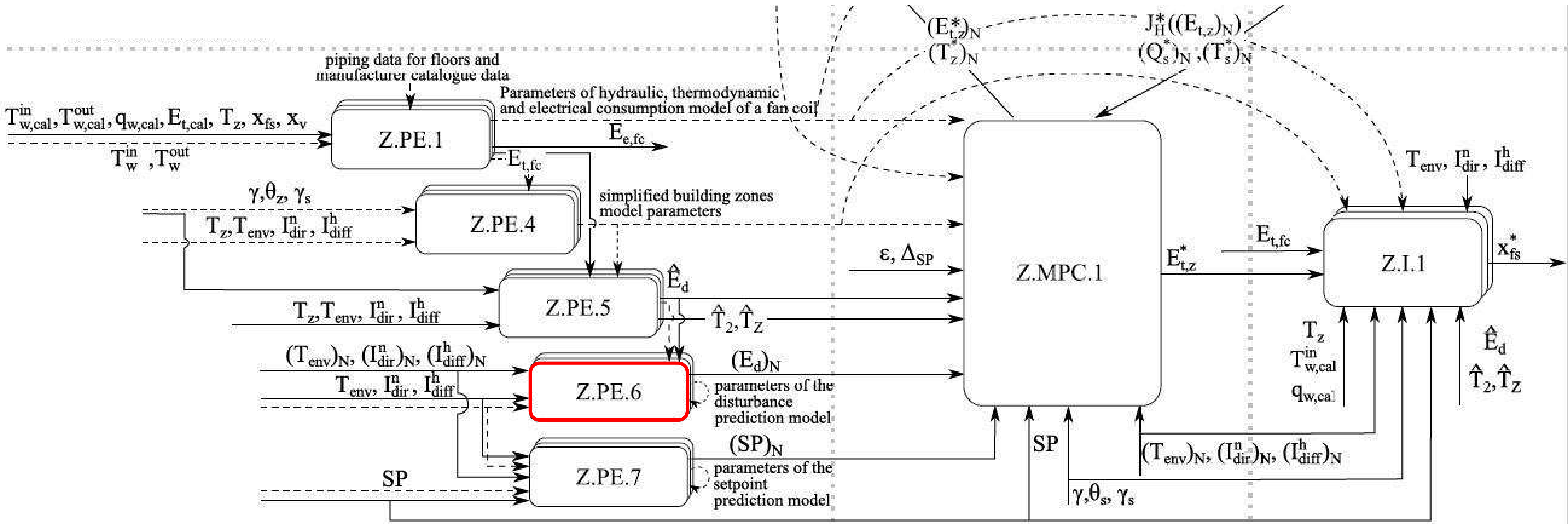
Zone PE 5

(module for estimation of non-measurable building model states and of heat disturbances in zones))

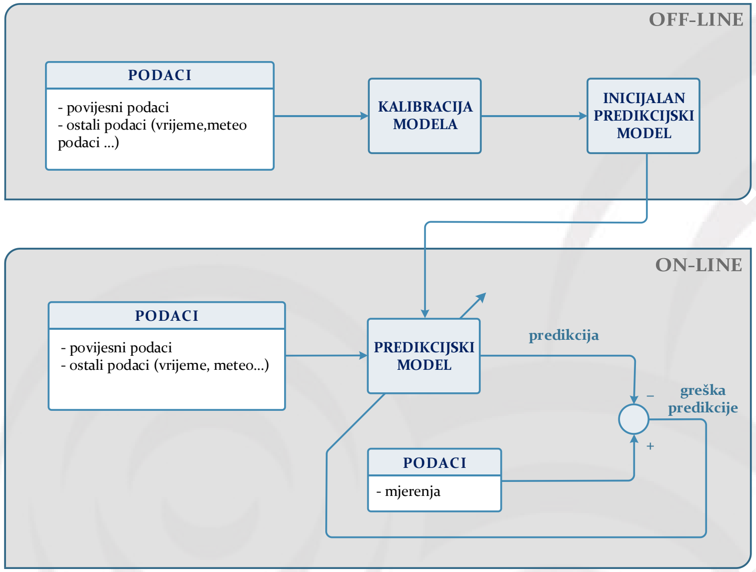




Zone PE 6
(prediction of heat disturbance in a zone)

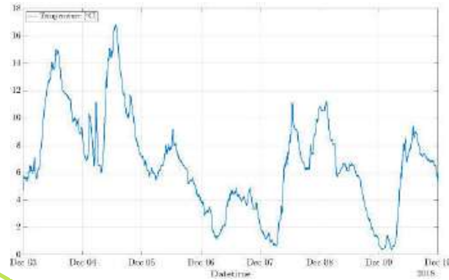


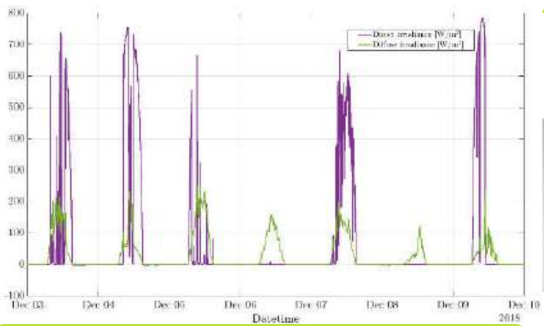
Zone PE 6 – off-line initialization



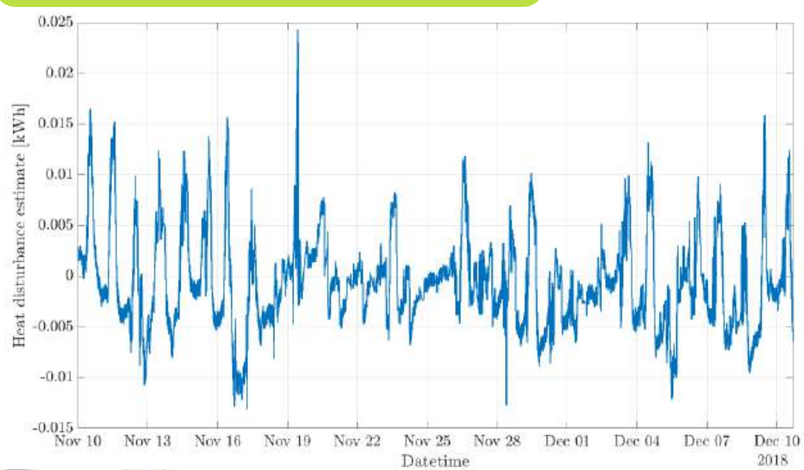
Zone PE 6 – off-line initialization

Historical meteo measurements:
- Air temperature
- Direct and diffuse solar irradiance

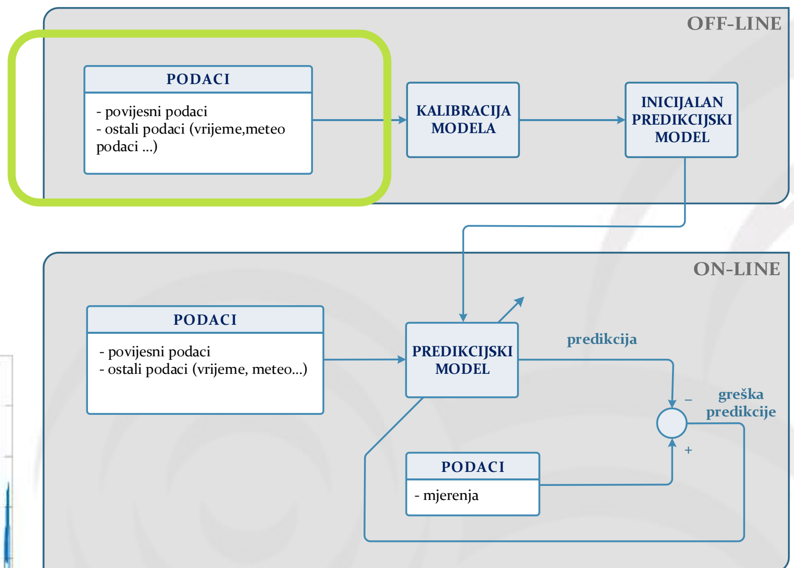




Historical values of estimated heat disturbance **(Z.PE.5)**



MODEL INPUTS



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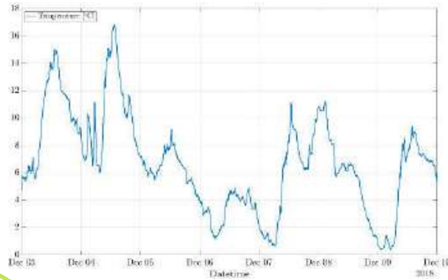
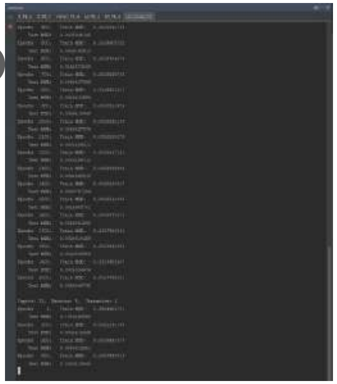
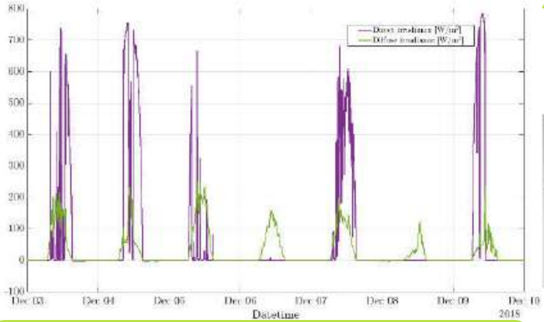
Zone PE 6 – off-line initialization

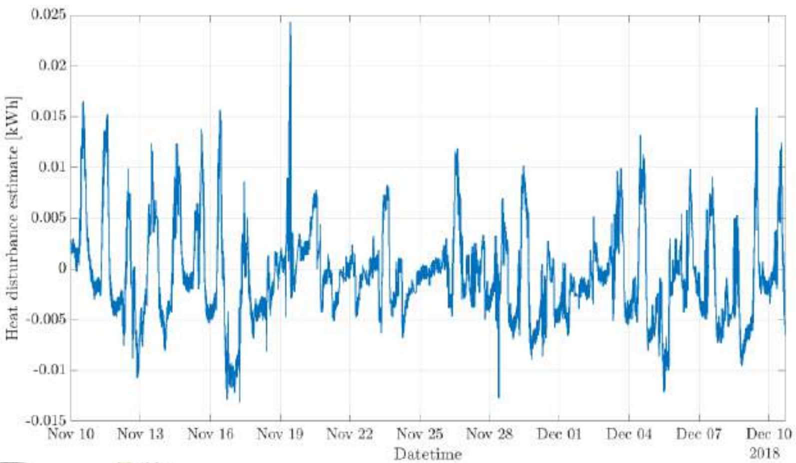
Historical meteo measurements:
- Air temperature
- Direct and diffuse solar irradiance



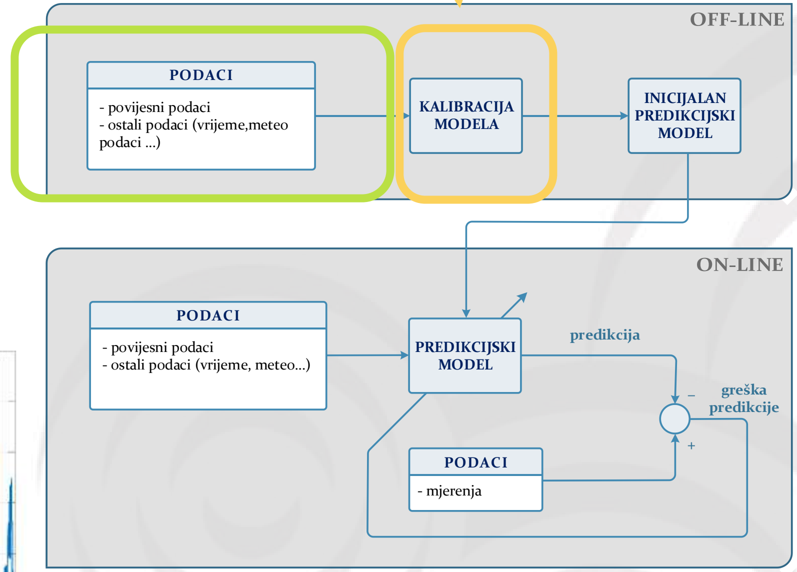


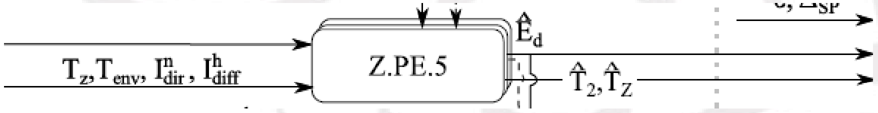


Historical values of estimated heat disturbance **(Z.PE.5)**

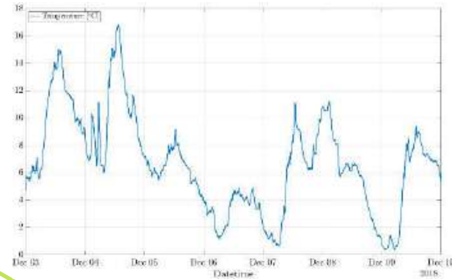


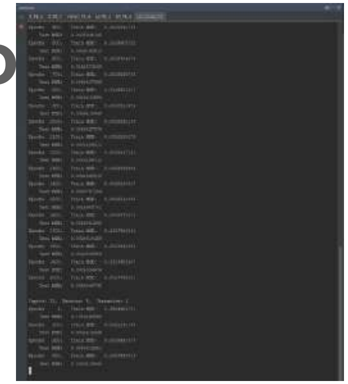
MODEL INPUTS





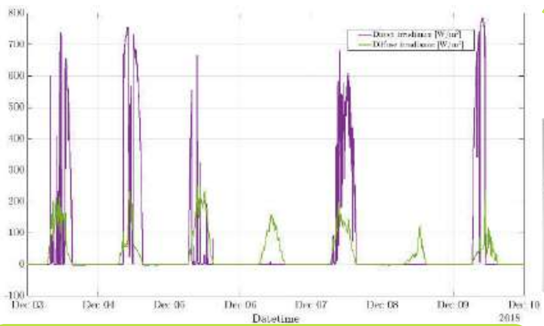
Zone PE 6 – off-line initialization





Historical meteo measurements:

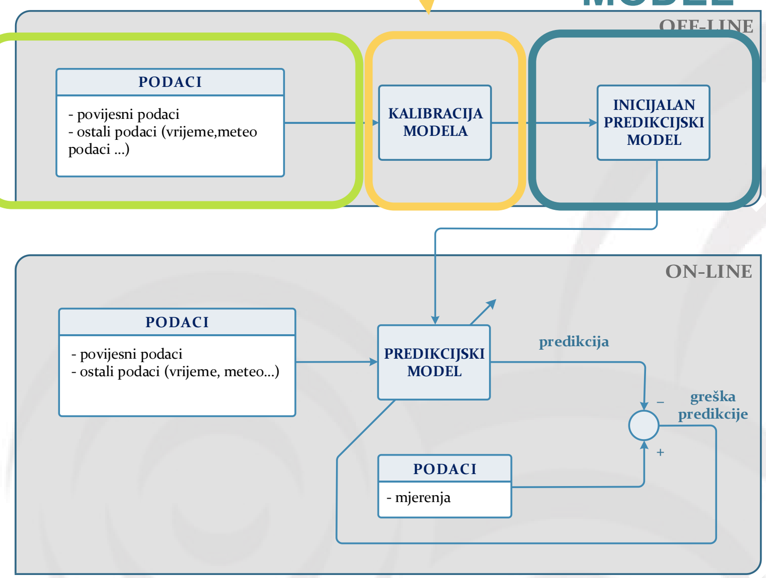
- Air temperature
- Direct and diffuse solar irradiance



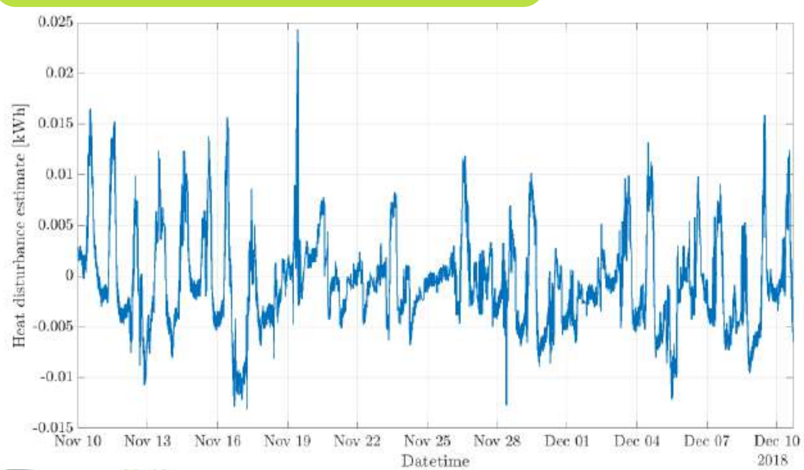
Locally stored: inputsXY_neuronsZ.net

MODEL INPUTS

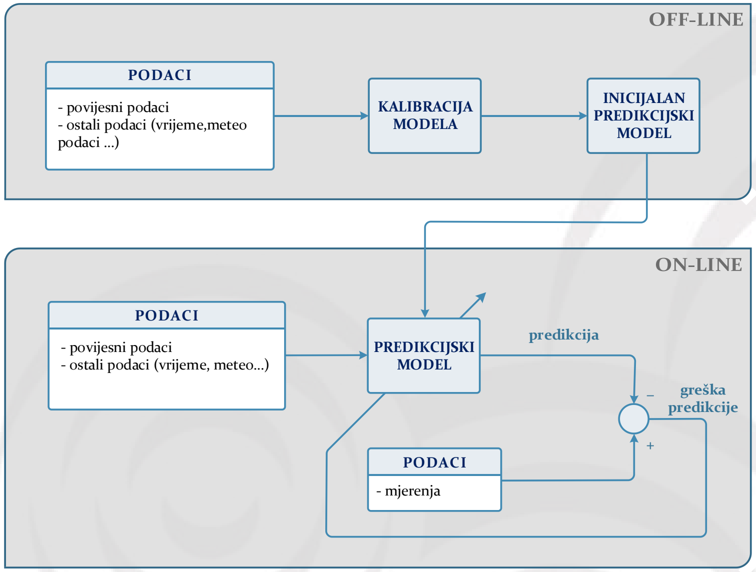
MODEL



Historical values of estimated heat disturbance **(Z.PE.5)**



Zone PE 6 – on-line operation



Zone PE 6 – on-line operation

Regressor composed of specific historical data samples:

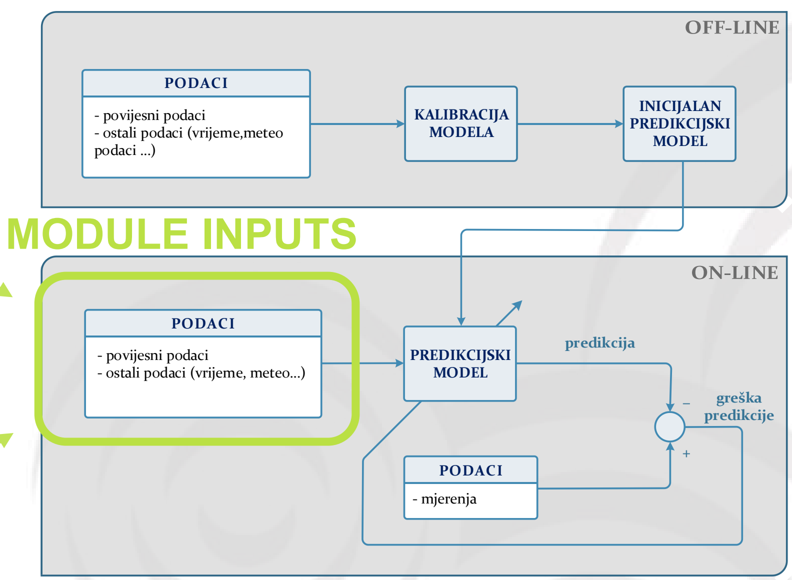
- heat disturbance(t-1,…,t-5)
- heat disturbance(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

- room temperature(t-1,…,t-3)
- room temperature(t-671,…,t-673)

- direct irradiance(t-1,…,t-3)
- direct irradiance(t-671,…,t-673)

- diffuse irradiance(t-1,…,t-3)
- diffuse irradiance (t-671,…,t-673)



Zone PE 6 – on-line operation

Locally stored:
inputsXY_neuronsZ.net

Regressor composed of specific historical data samples:

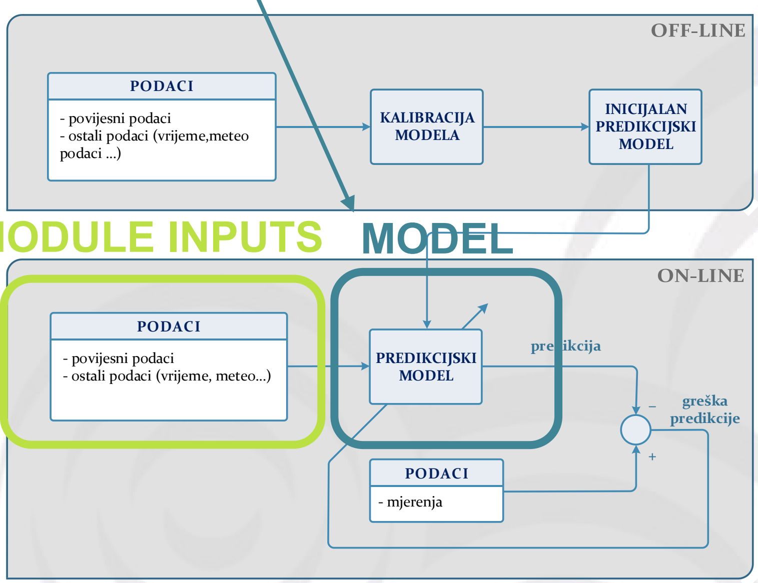
- heat disturbance(t-1,…,t-5)
- heat disturbance(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

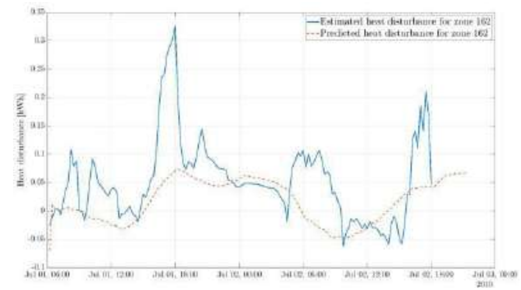
- room temperature(t-1,…,t-3)
- room temperature(t-671,…,t-673)

- direct irradiance(t-1,…,t-3)
- direct irradiance(t-671,…,t-673)

- diffuse irradiance(t-1,…,t-3)
- diffuse irradiance (t-671,…,t-673)



Zone PE 6 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor composed of specific historical data samples:

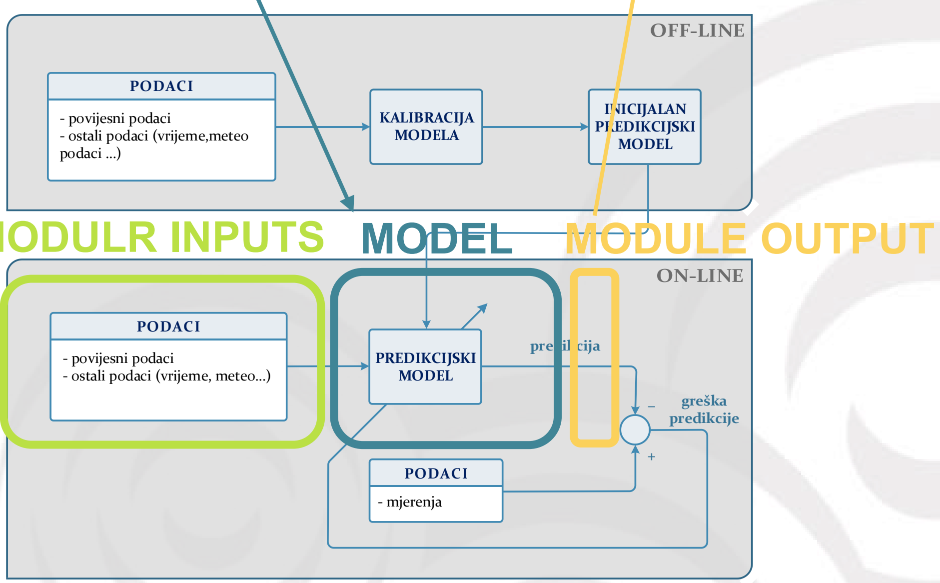
- heat disturbance(t-1,…,t-5)
- heat disturbance(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

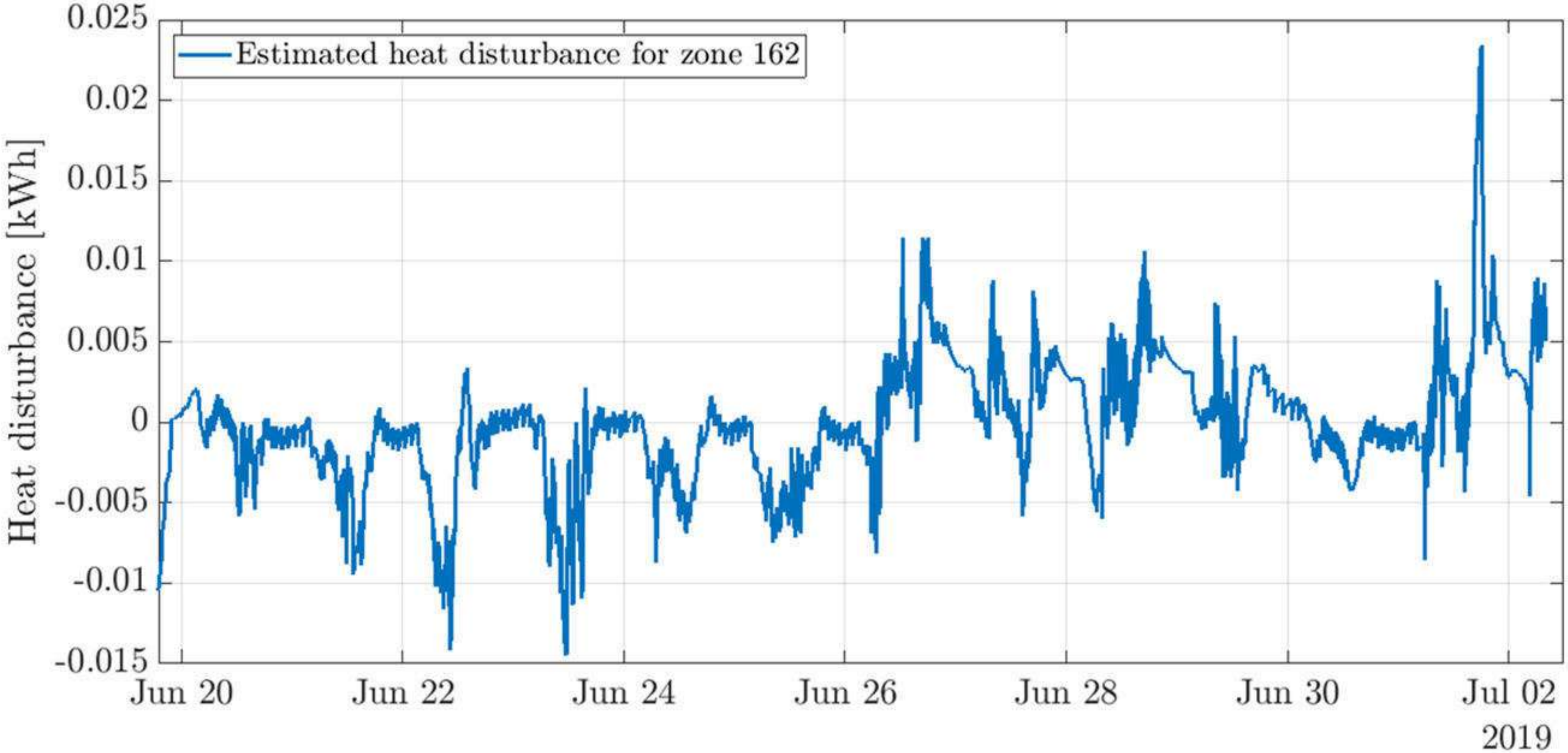
- room temperature(t-1,…,t-3)
- room temperature(t-671,…,t-673)

- direct irradiance(t-1,…,t-3)
- direct irradiance(t-671,…,t-673)

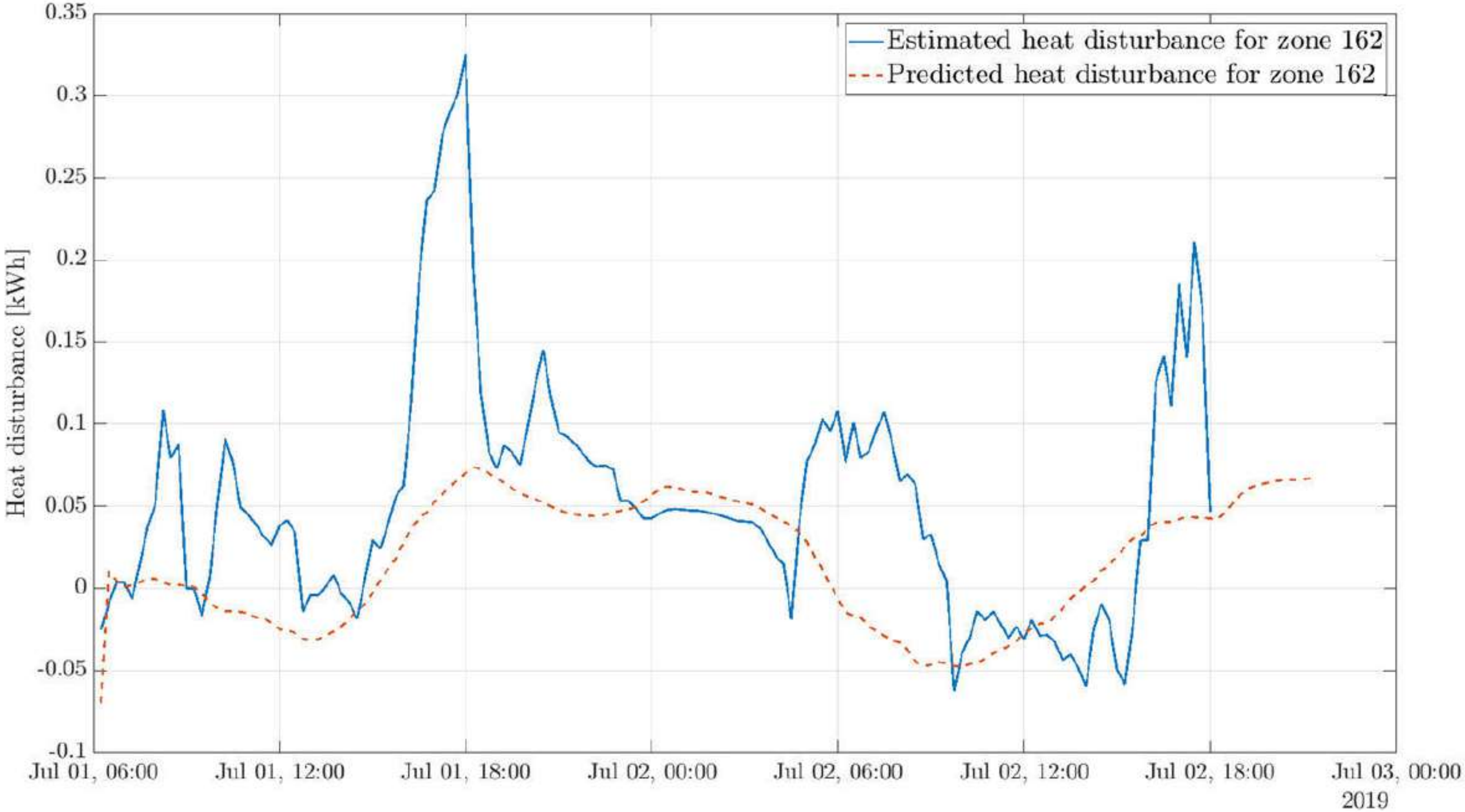
- diffuse irradiance(t-1,…,t-3)
- diffuse irradiance (t-671,…,t-673)



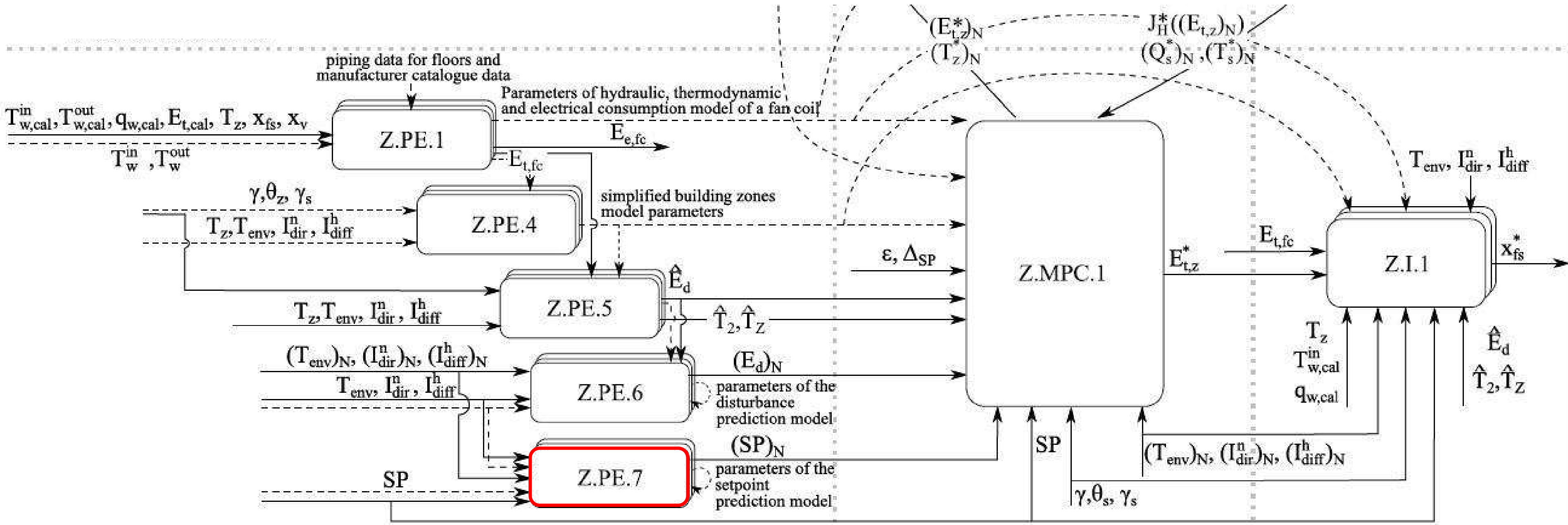
Zone PE 6 – example of historical values



Zone PE 6 – example of generated prediction (01.07. 08:00)



Zone PE 7 (prediction of reference temperature value in a zone)



Zone PE 7 – automatic room heating/cooling mode selected

MODULE INPUTS

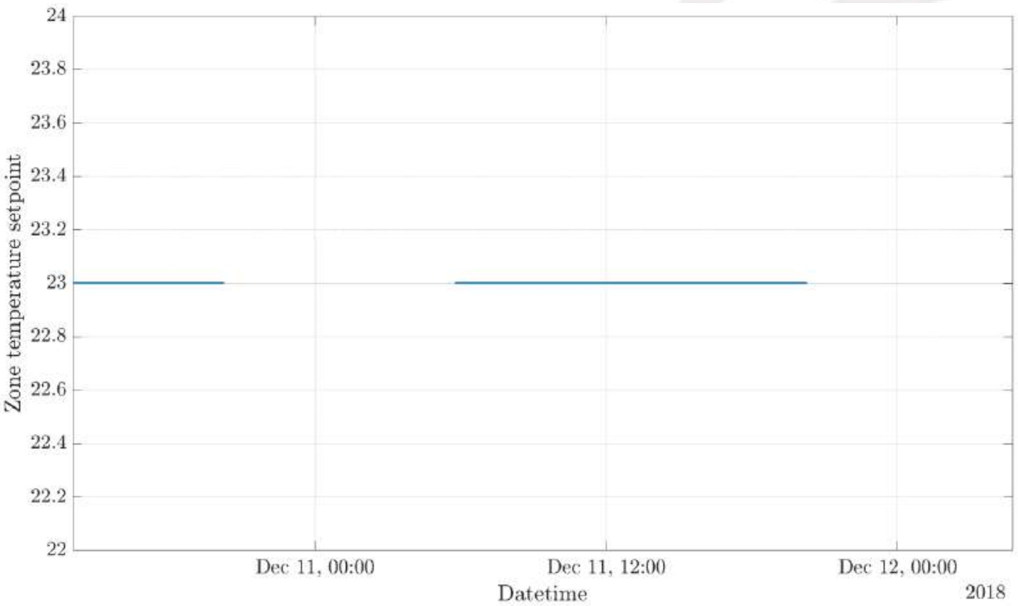
Currently set reference temperature value
Time schedule of heating/cooling system operation
Busines system data (leaves/sick leaves/travels)

MODULE

Zone PE 7

MODULE OUTPUTS

Assumed the same value along the prediction horizon with exception of night time 21:00 – 6:30 (system off)



Zone PE 7

MODULE INPUTS

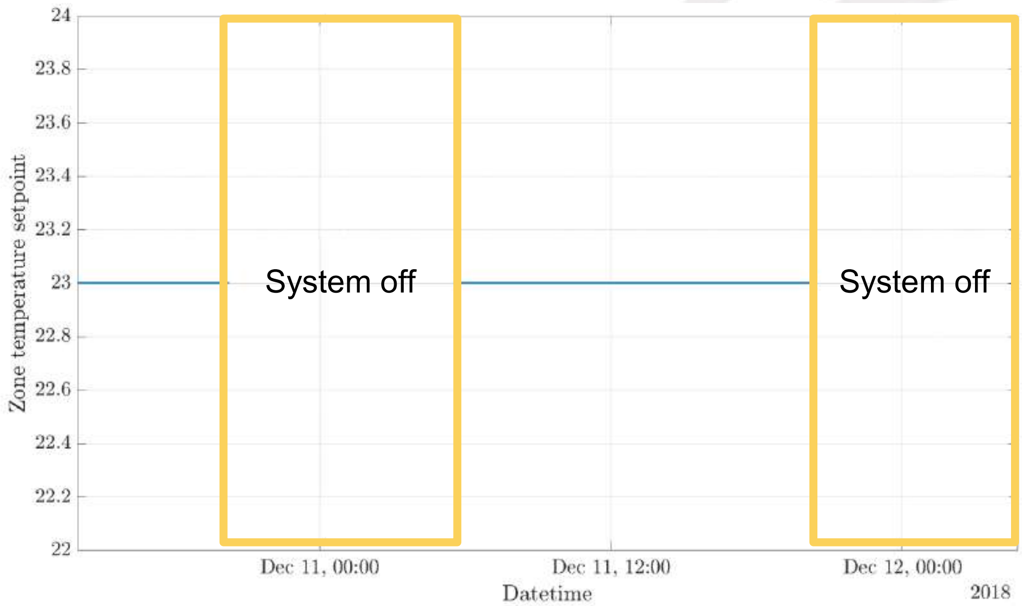
Currently set reference temperature value
Time schedule of heating/cooling system operation
Busines system data (leaves/sick leaves/travels)

MODULE

Zone PE 7

MODULE OUTPUTS

Assumed the same value along the prediction horizon with exception of night time 21:00 – 6:30 (system off)



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Zone PE 7 – stand-by/manual room heating/cooling mode selected

MODULE INPUTS

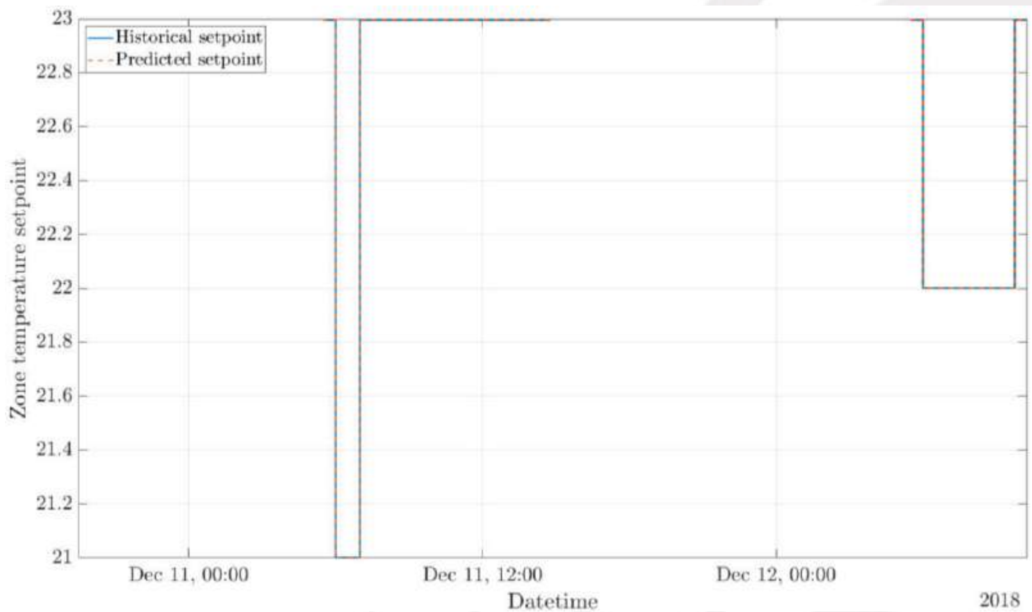
Historical reference value from the same time interval of the preceding week
Time schedule of heating/cooling system operation
Busines system data (leaves/sick leaves/travels)

MODULE

Zone PE 7

MODULE OUTPUTS

Historical reference temperature value with exception for night time 21:00 – 6:30 (system off)



Zone PE 7 – stand-by/manual room heating/cooling mode selected

MODULE INPUTS

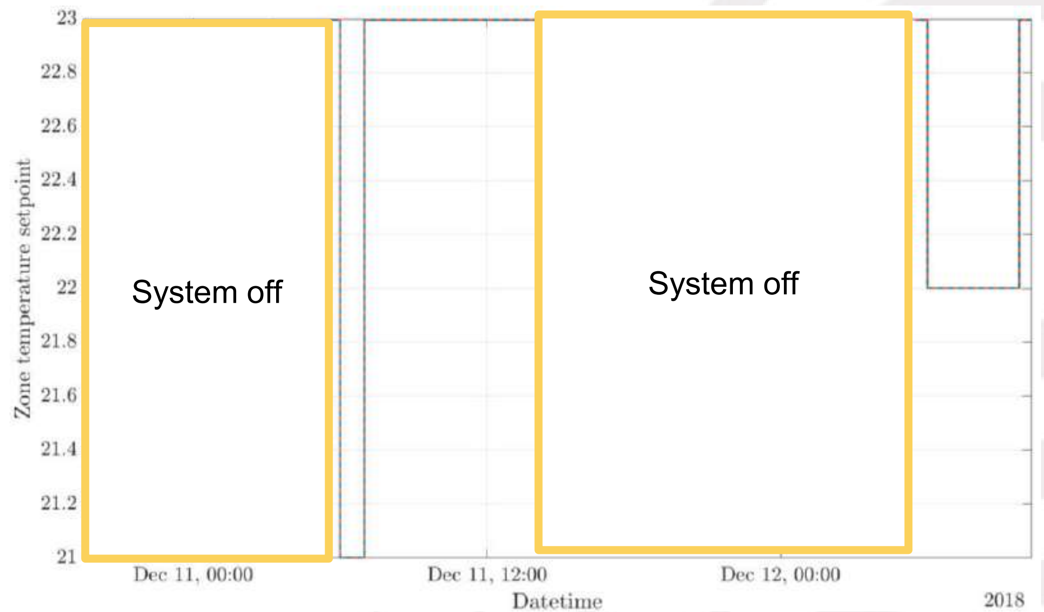
Historical reference value from the same time interval of the preceding week
Time schedule of heating/cooling system operation
Busines system data (leaves/sick leaves/travels)

MODULE

Zone PE 7

MODULE OUTPUTS

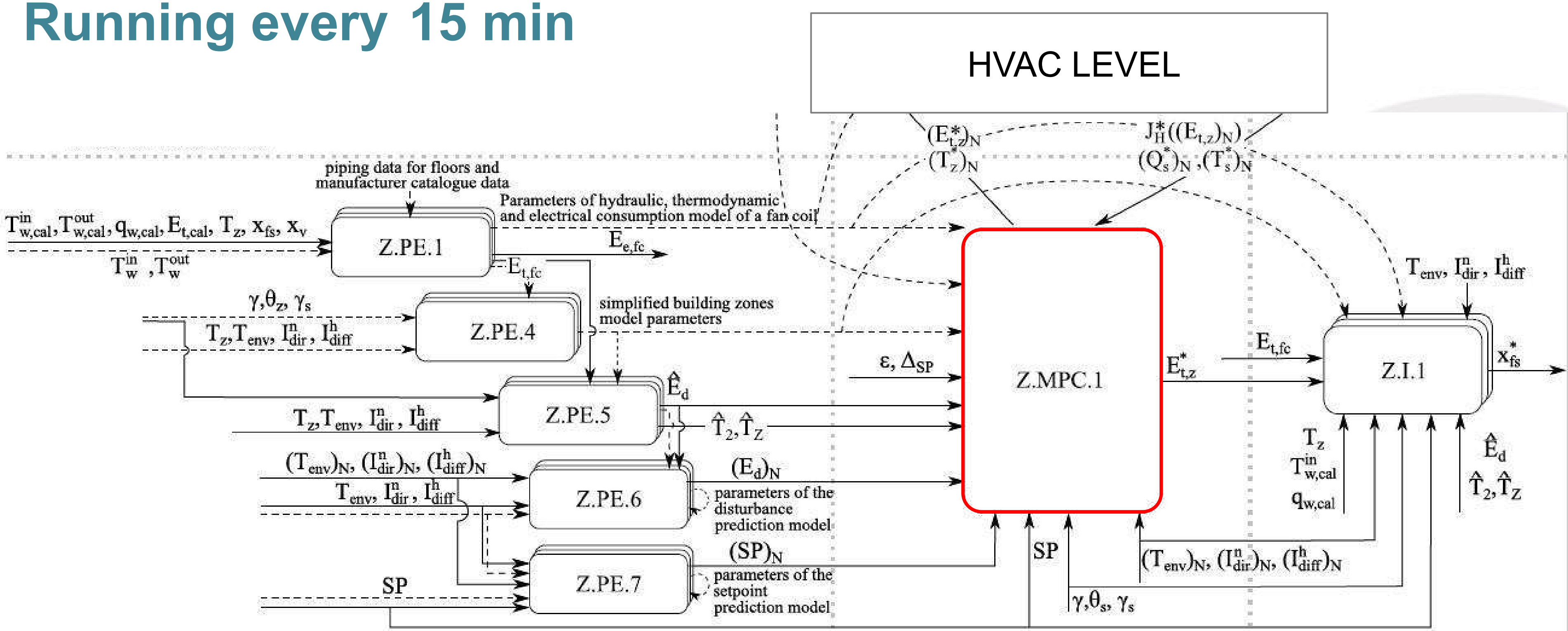
Historical reference temperature value with exception for night time 21:00 – 6:30 (system off)



Zone MPC 1

(model predictive control of comfort in building zones)

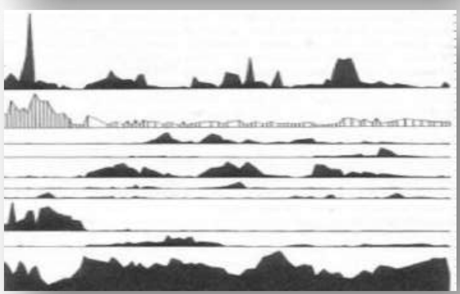
Running every 15 min



Zone MPC 1

(model predictive control of comfort in building zones)

Optimization of room temperature on time horizon of next 12 – 36 h with 15 min sampling time



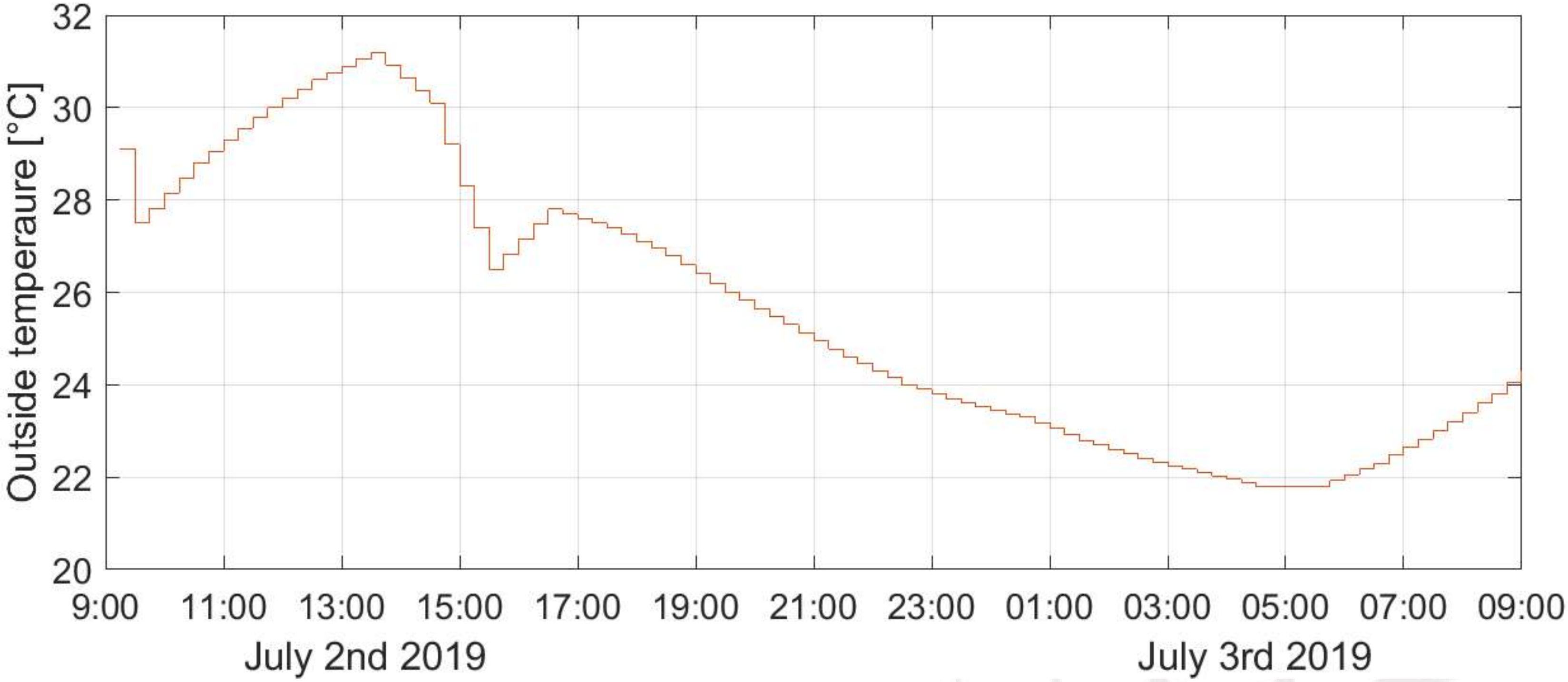
MATHEMATICAL OPTIMIZATION

Optimal profiles of energy exertion to zone sair

Optimal temperature profiles in building zones

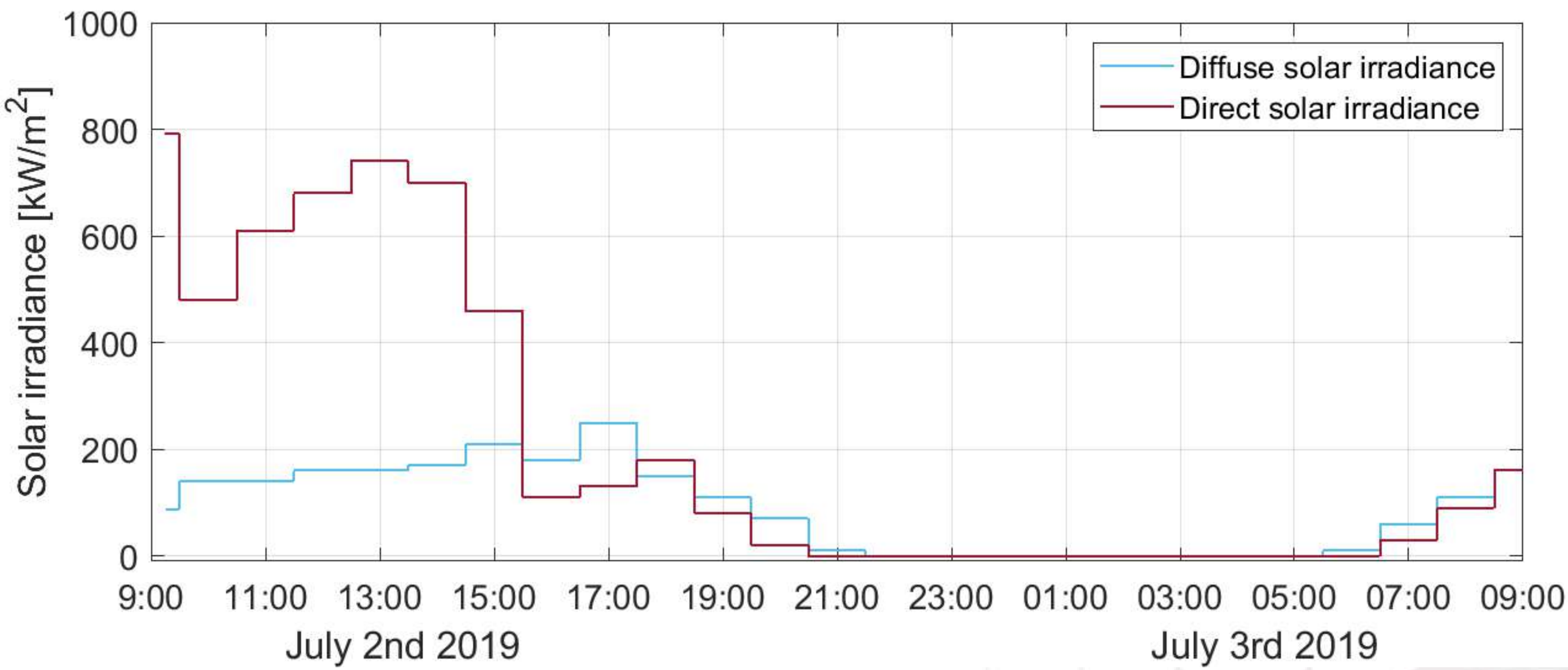
Zone MPC 1
(model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance



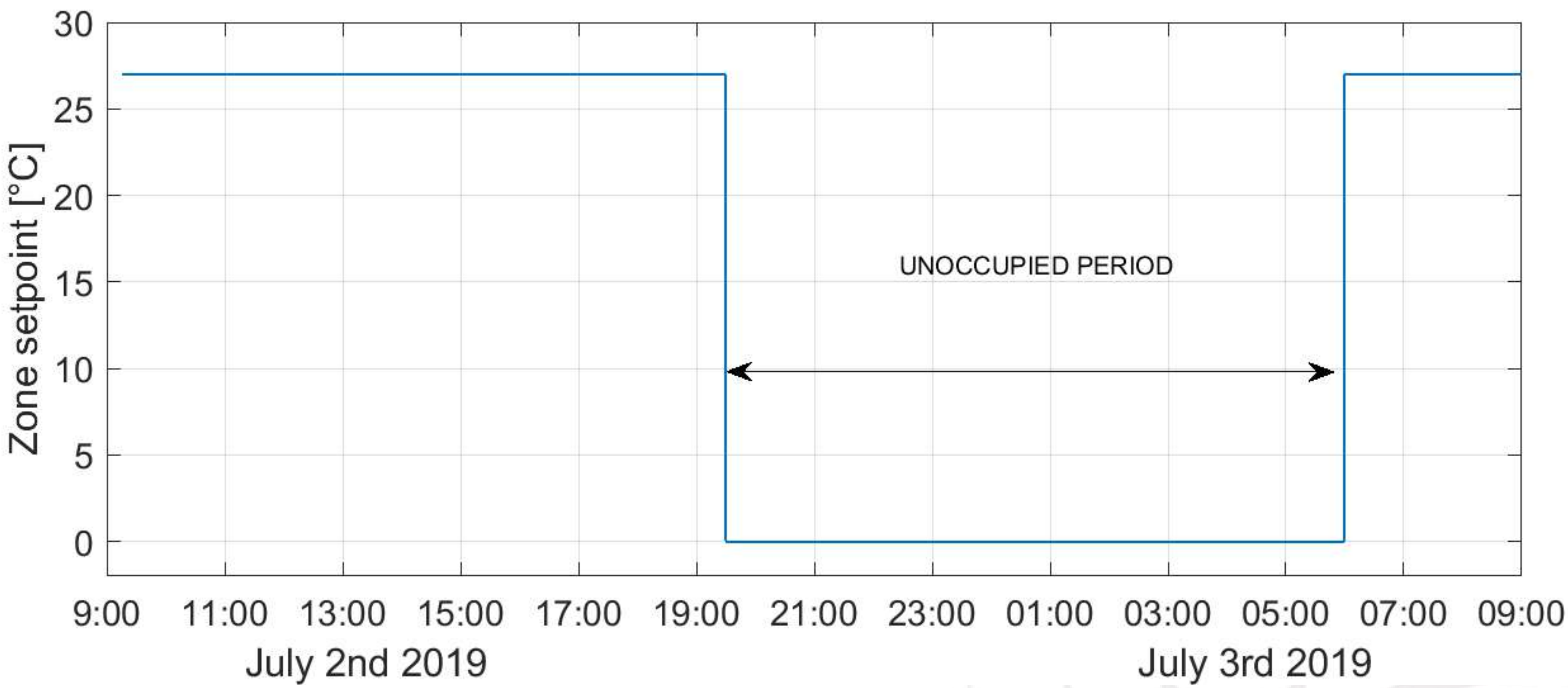
Zone MPC 1
(model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance



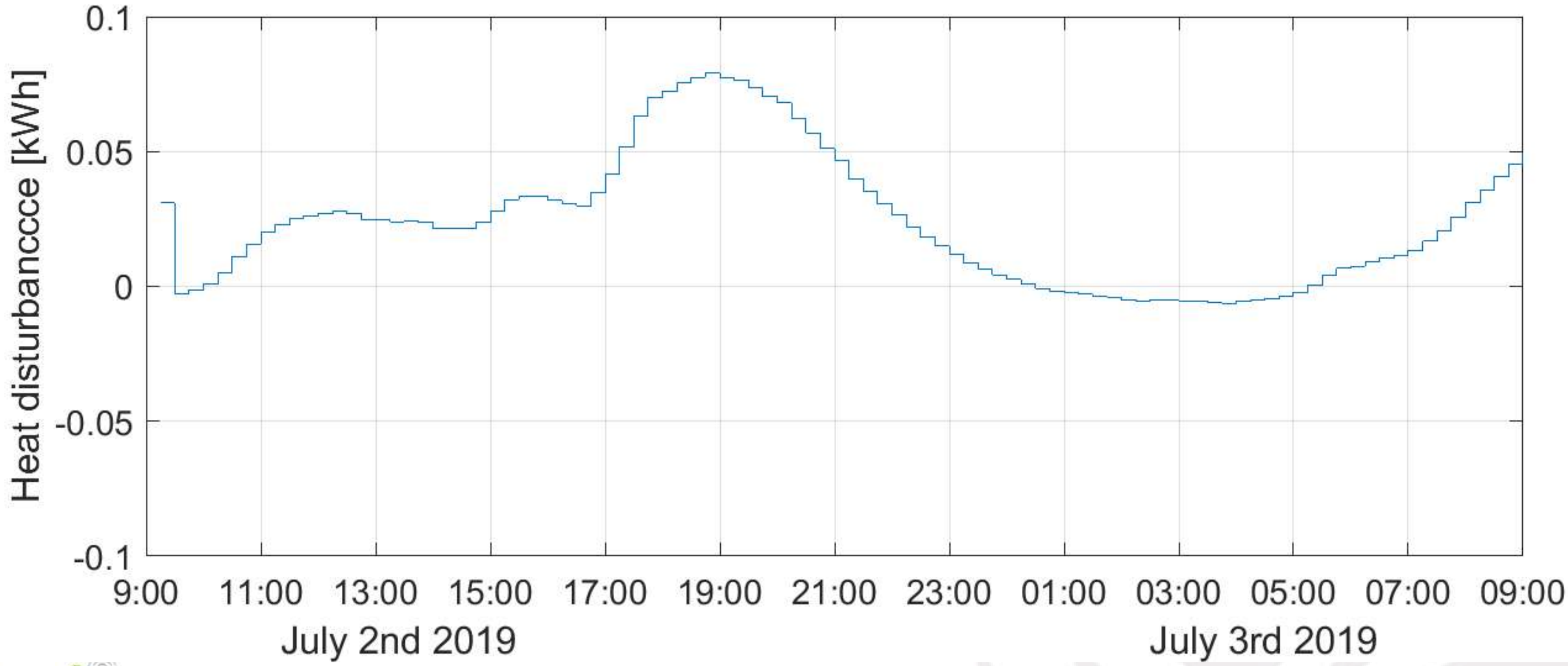
Zone MPC 1
(model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance
INPUT 3: Prediction of users behaviour 12-36 h in advance



Zone MPC 1
(model predictive control of comfort in building zones)

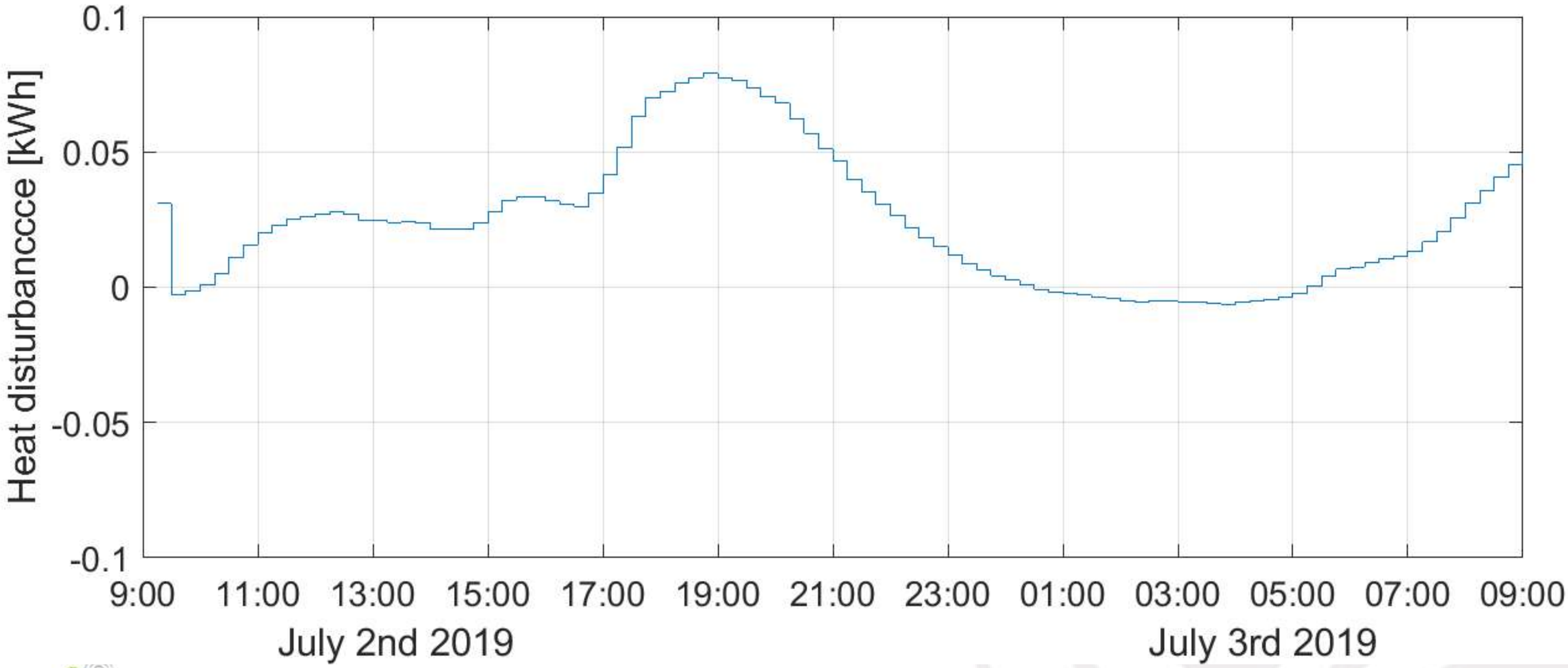
INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance
INPUT 3: Prediction of users behaviour 12-36 h in advance
INPUT 4: Prediction of heat disturbance 12-36 h in advance



Zone MPC 1

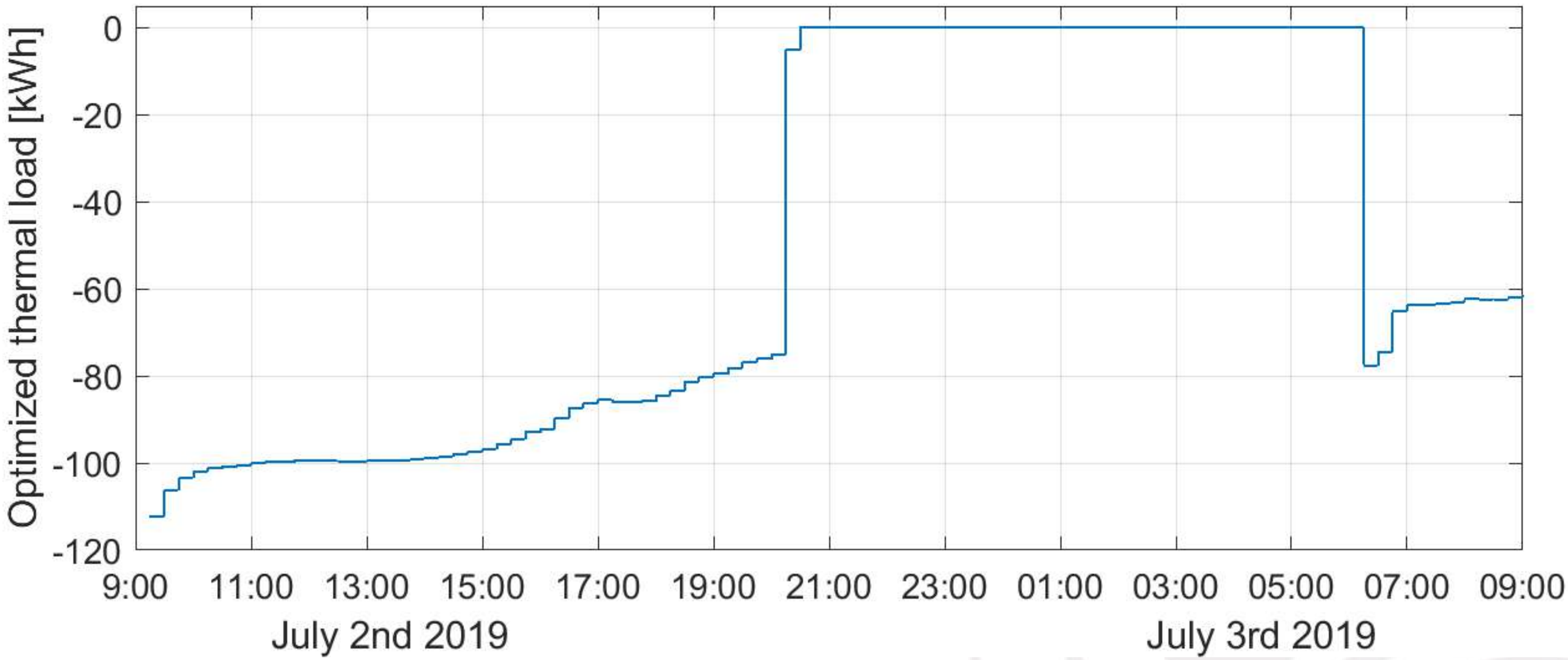
(model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance
INPUT 3: Prediction of users behaviour 12-36 h in advance
INPUT 4: Prediction of heat disturbance 12-36 h in advance
OTHER INPUTS: Electricity price, comfort requirements, mathematical models,…



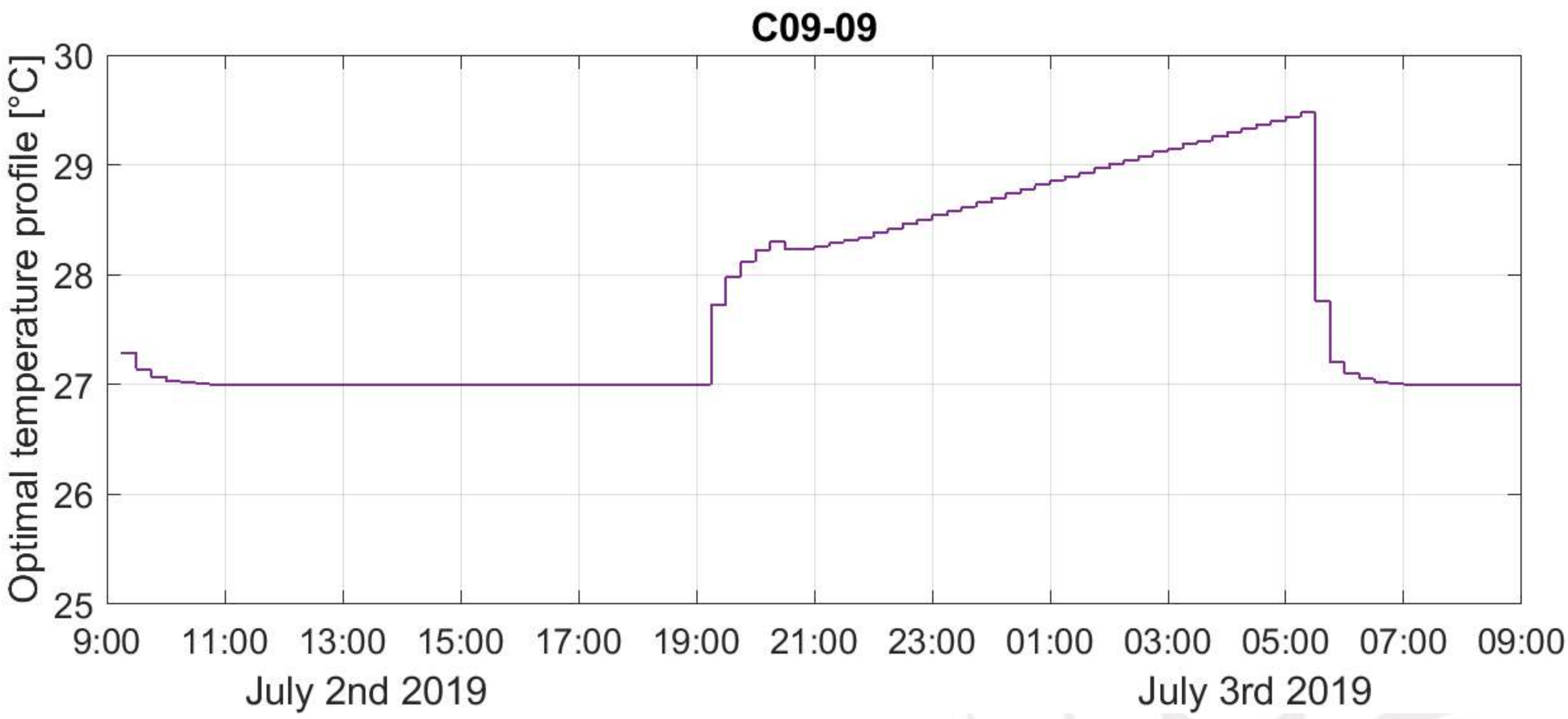
Zone MPC 1
(model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of overall heating energy needed in zones 12-36 h in advance



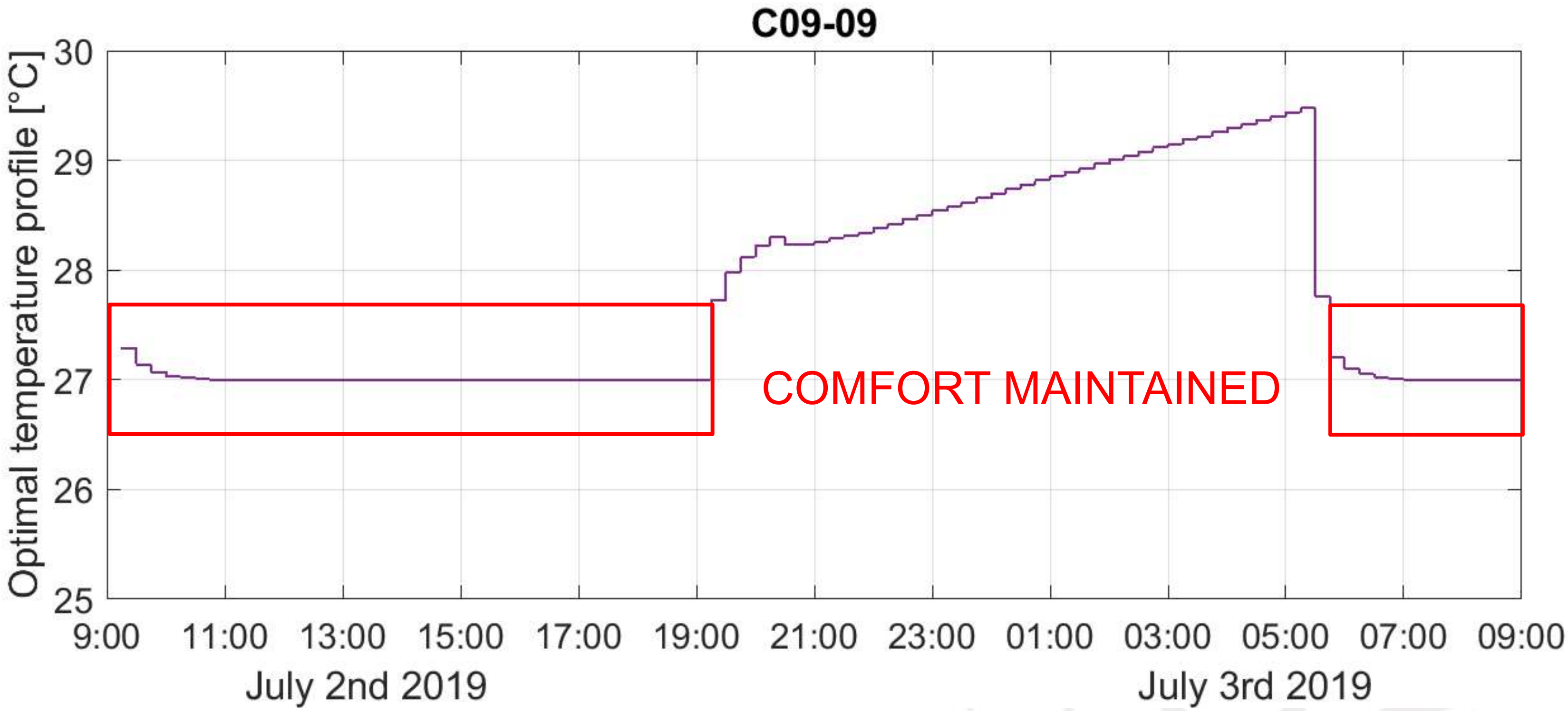
Zone MPC 1
(model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of overall heating energy needed in zones 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building zones 12-36 h in advance



Zone MPC 1
(model predictive control of comfort in building zones)

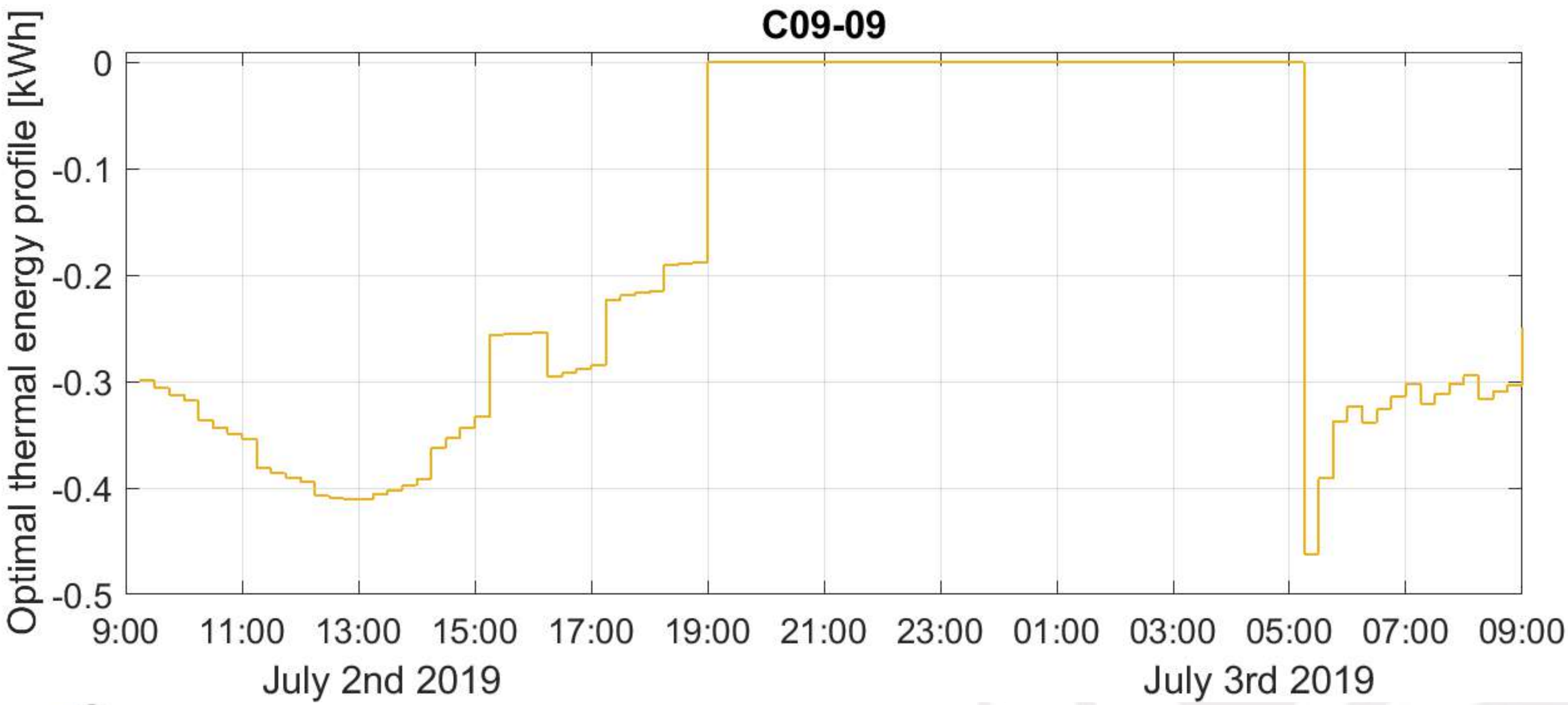
OUTPUT 1: Optimal profile of overall heating energy needed in zones 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building zones 12-36 h in advance



Zone MPC 1

(model predictive control of comfort in building zones)

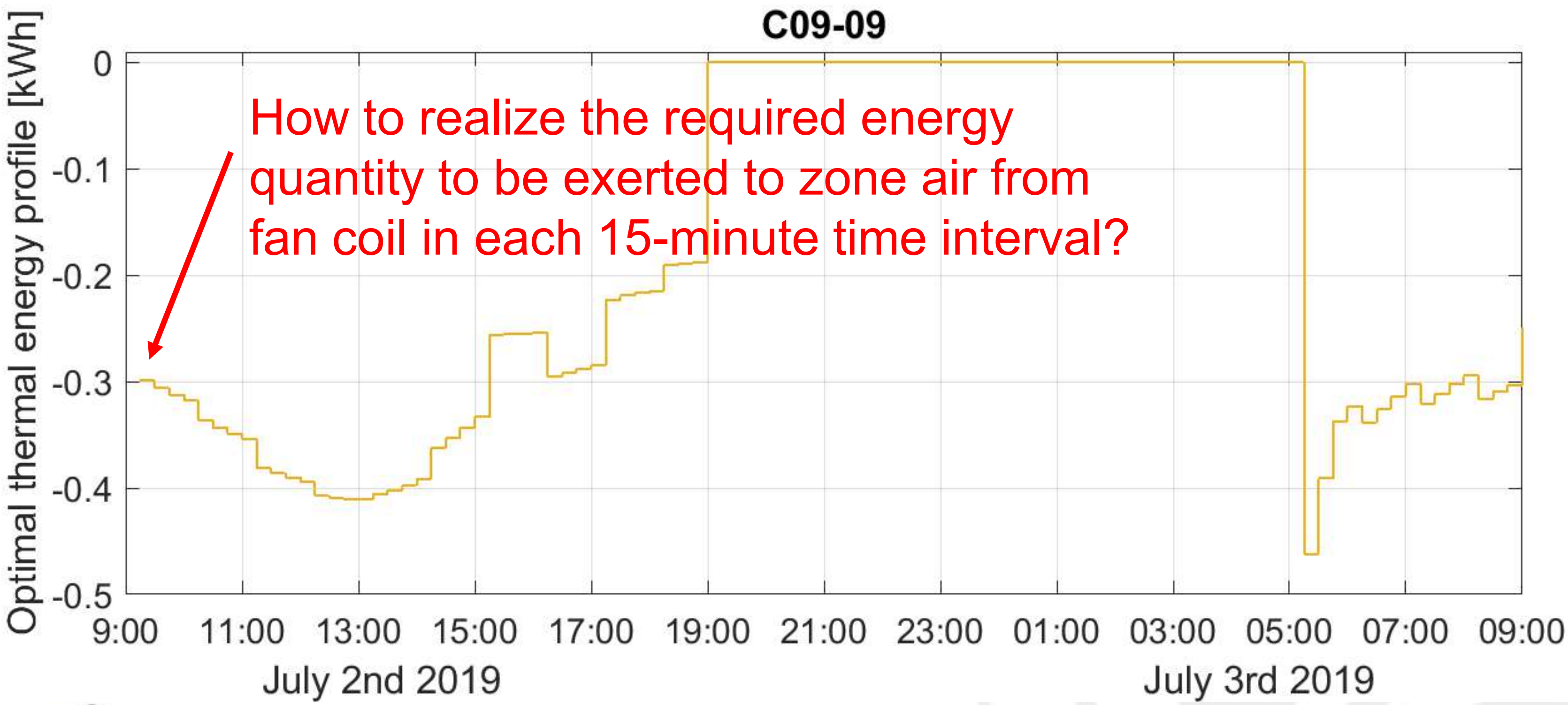
OUTPUT 1: Optimal profile of overall heating energy needed in zones 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building zones 12-36 h in advance
OUTPUT 3: Optimal profile of heating energy exertion per zone 12-36 hours in advance



Zone MPC 1

(model predictive control of comfort in building zones)

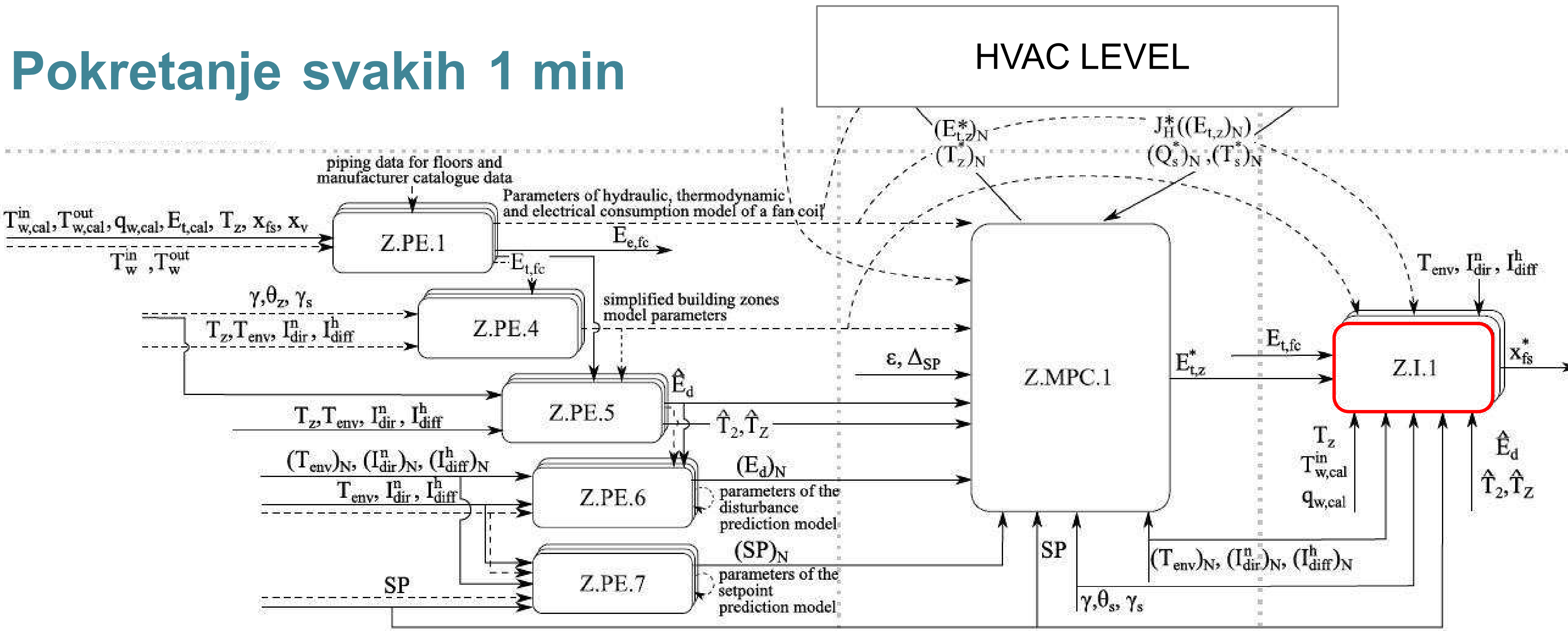
OUTPUT 1: Optimal profile of overall heating energy needed in zones 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building zones 12-36 h in advance
OUTPUT 3: Optimal profile of heating energy exertion per zone 12-36 hours in advance



Zone Interface 1

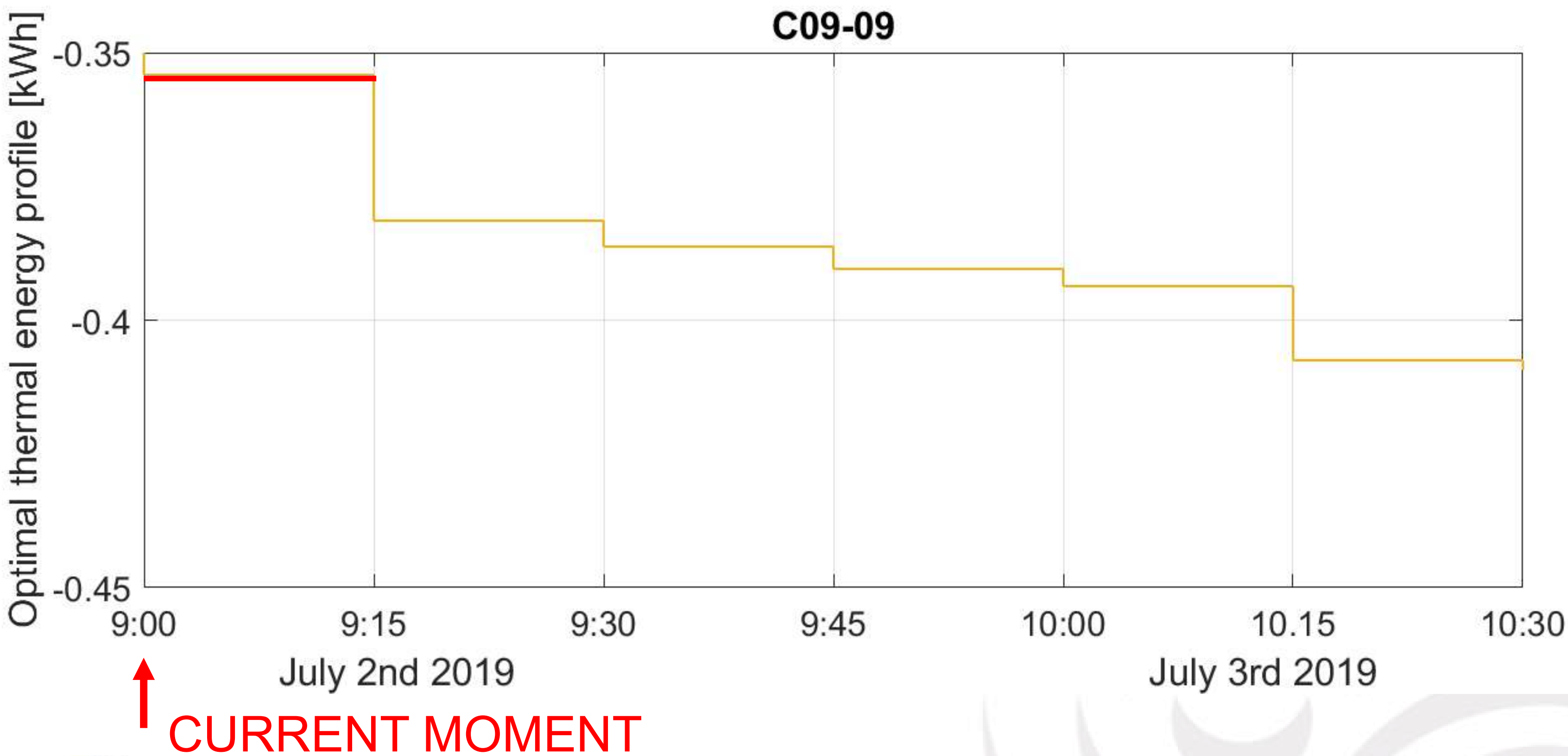
(module for control of energy exertion from fan coil to air)

Pokretanje svakih 1 min



Zone Interface 1
(module for control of energy exertion from fan coil to air)

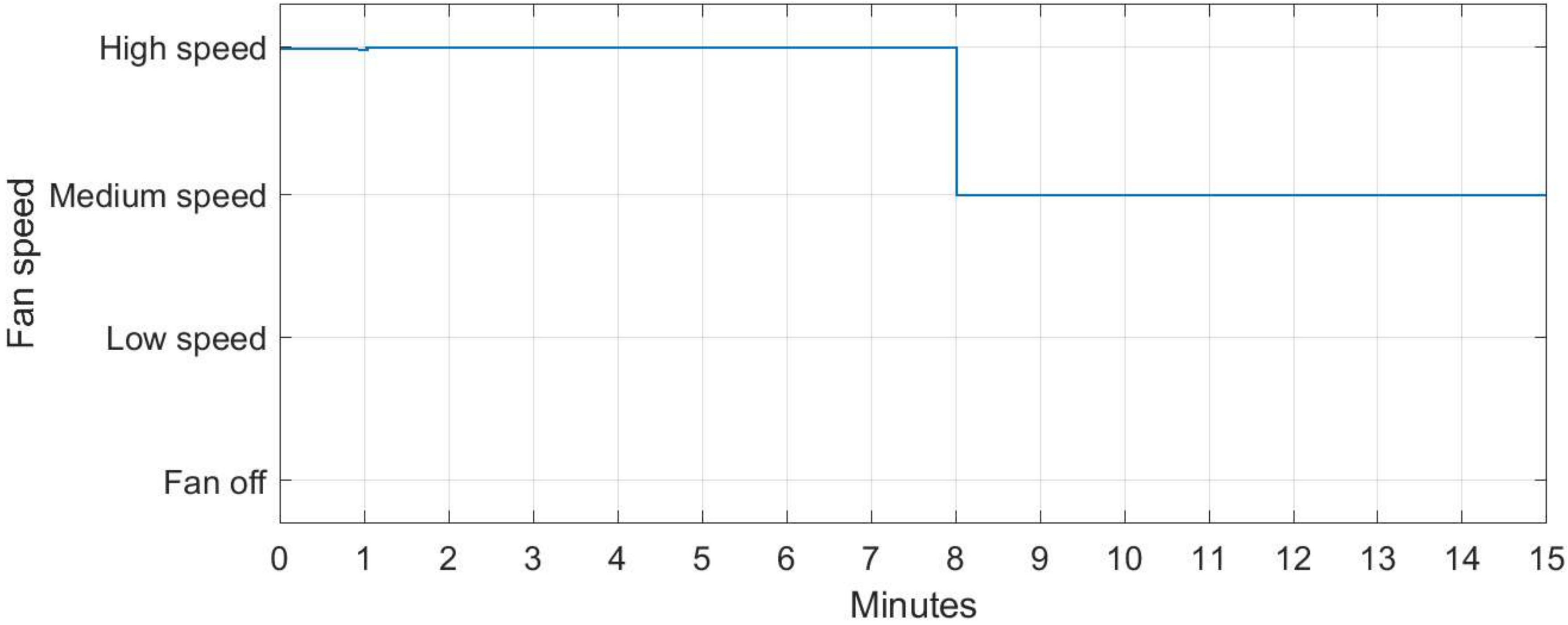
INPUTS: required heating energy to be exerted to zone air in next 15 minutes computed by zone MPC, current measurement of temperature and flow of the heating/cooling medium, current measurements from zones, currently estimated heat disturbance, …



Zone Interface 1
(module for control of energy exertion from fan coil to air)

OUTPUT

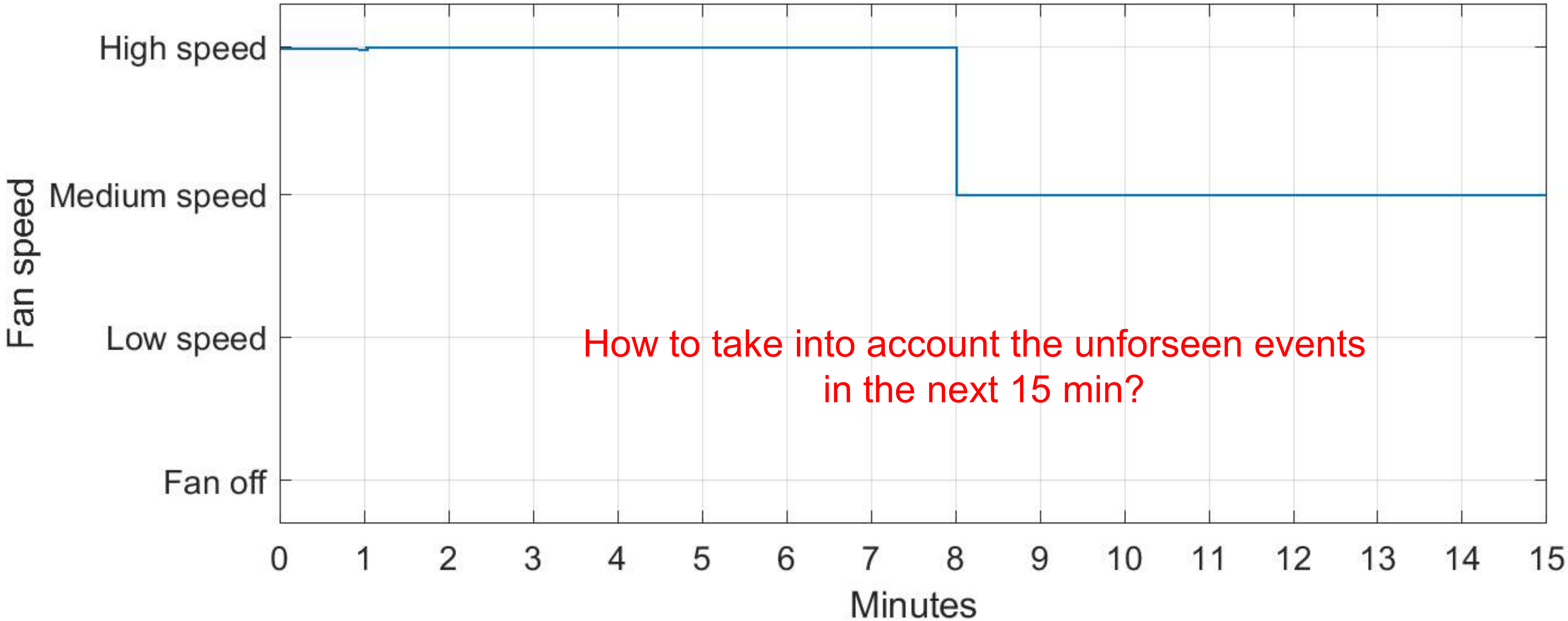
OPTIMIZED PROFILE OF FAN COIL OPERATION FOR THE NEXT 15 min



Zone Interface 1
(module for control of energy exertion from fan coil to air)

OUTPUT

OPTIMIZED PROFILE OF FAN COIL OPERATION FOR THE NEXT 15 min



Zone Interface 1
(module for control of energy exertion from fan coil to air)

RECEDING HORIZON – new computation every 1 min

9:00	[H H H H H H H M M M M M M M M]
9:01	[H H H H H H M M M M M M M M]
9:02	[H H H H H M M M M M M M M]
9:03	[H H H H M M M M M M M M]
9:04	[H H H M M M M M M M M]
9:05	[H H M M M M M M M M]
9:06	[H M M M M M M M M]
9:07	[M M M M M M M M M]

Ideal prediction of zone air energy inputs

Unforseen positive heat disturbance at 9:07

Zone Interface 1

(module for control of energy exertion from fan coil to air)

RECEDING HORIZON – new computation every 1 min

9:00	[H H H H H H H M M M M M M M M]
9:01	[H H H H H H M M M M M M M M]
9:02	[H H H H H M M M M M M M M]
9:03	[H H H H M M M M M M M M]
9:04	[H H H M M M M M M M M]
9:05	[H H M M M M M M M M]
9:06	[H M M M M M M M M]
9:07	[M M M M M M M M]
9:08	[H H H M M M M]
9:09	[H H M M M M]
9:10	[H M M M M]
9:11	[M M M M]
9:12	[M M M]
9:13	[M M]
9:14	[M]

Ideal prediction of zone air energy inputs

Unforseen positive heat disturbance at 9:07

In the cooling season fan coil instead of switching to intermediate speed (M), as initially planned, continues to operate in hthe ighest speed (H) for another 3 minutes in order to cancel out the infleuence of the heat disturbance.

Zone Interface 1
(module for control of energy exertion from fan coil to air)

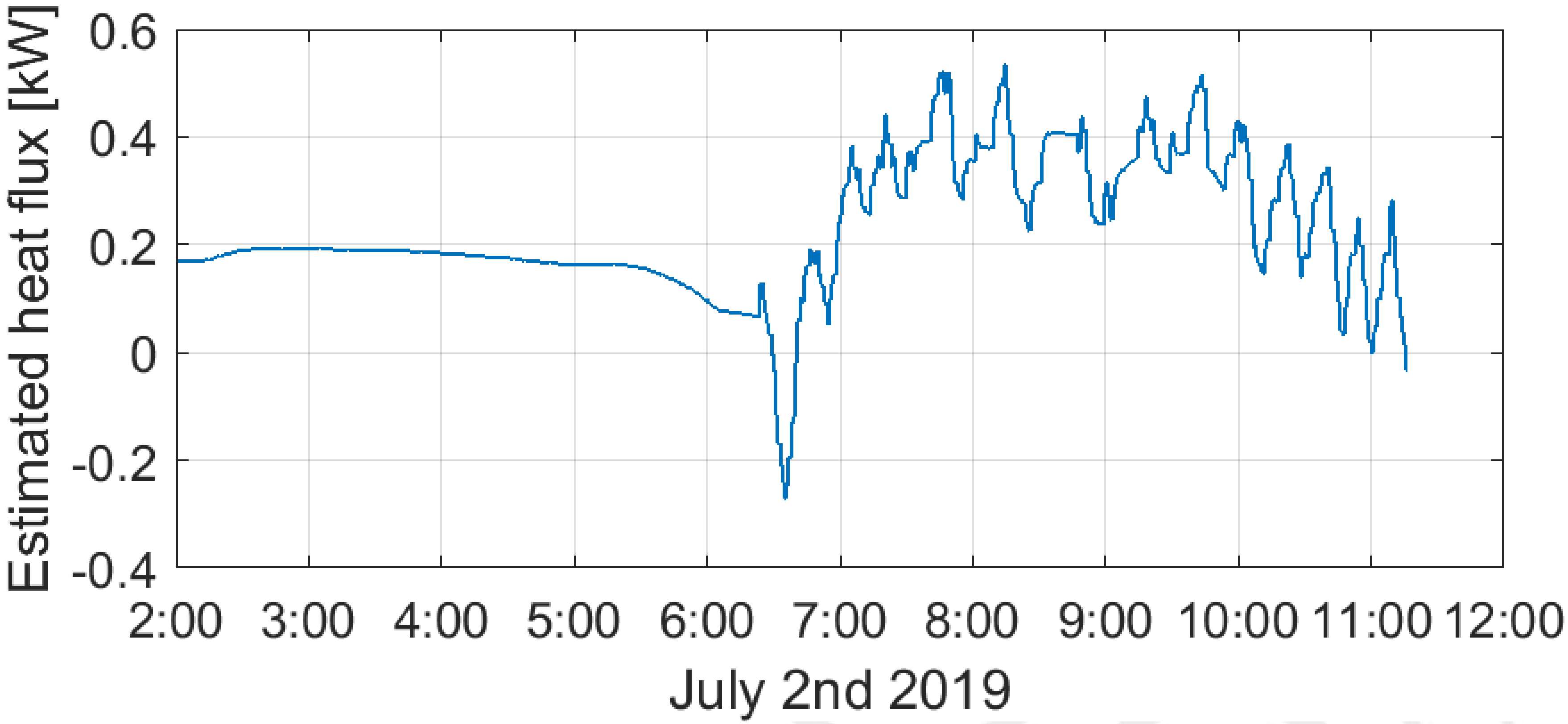
Computation time – max. 1 min before applicaton to the system

2019-07-02 08:43:20	0		[0]
2019-07-02 08:42:20	0		[0, 0]
2019-07-02 08:41:20	33		[33, 33, 33]
2019-07-02 08:40:20	33		[33, 33, 33, 33]
2019-07-02 08:39:20	66		[66, 33, 33, 33, 33]
2019-07-02 08:38:20	33		[33, 33, 33, 33, 33, 33]
2019-07-02 08:37:20	66		[66, 33, 33, 33, 33, 33, 33]
2019-07-02 08:36:20	66		[66, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:35:20	33		[33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:34:20	66		[66, 33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:33:21	66		[66, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:32:20	33		[33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:31:21	33		[33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:30:20	33		[33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33]
2019-07-02 08:29:20	33		[33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33, 33]

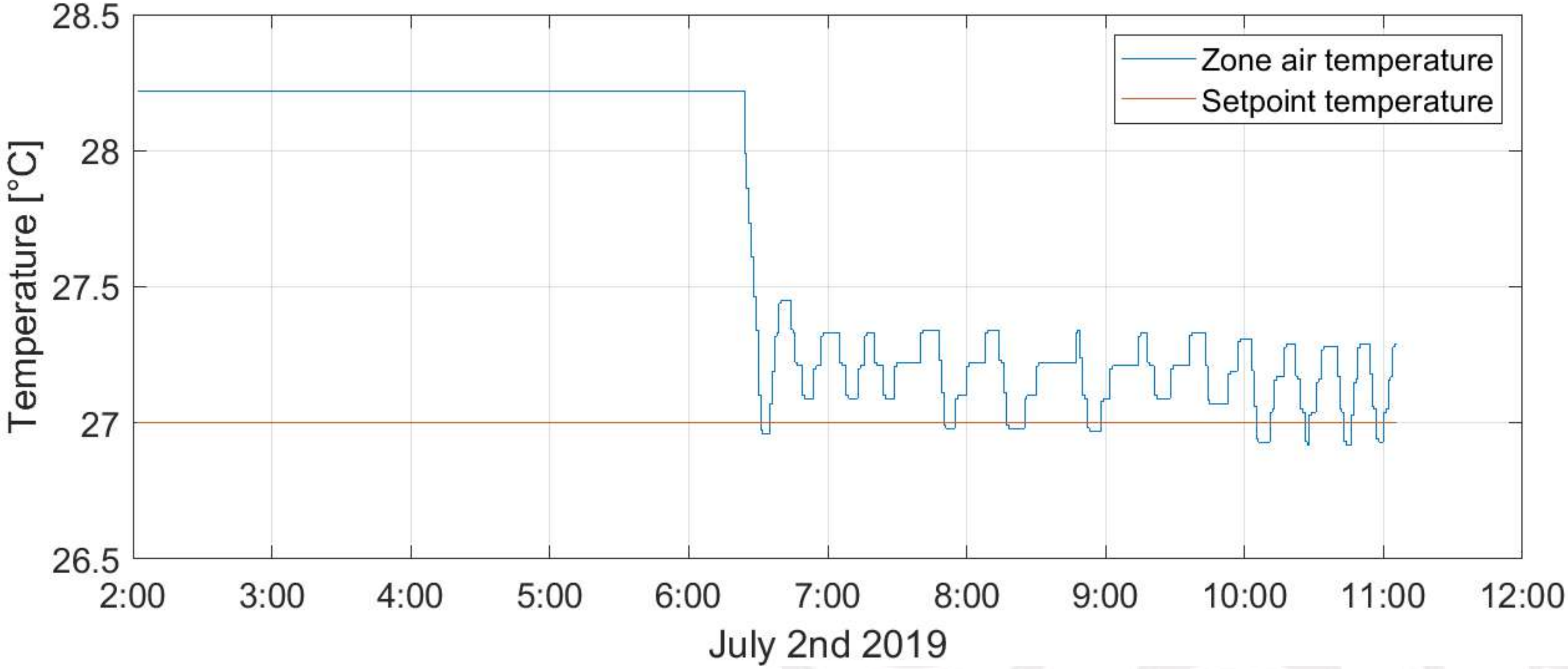
Control commands forwarded to fan coils

Zone Interface 1

(module for control of energy exertion from fan coil to air)

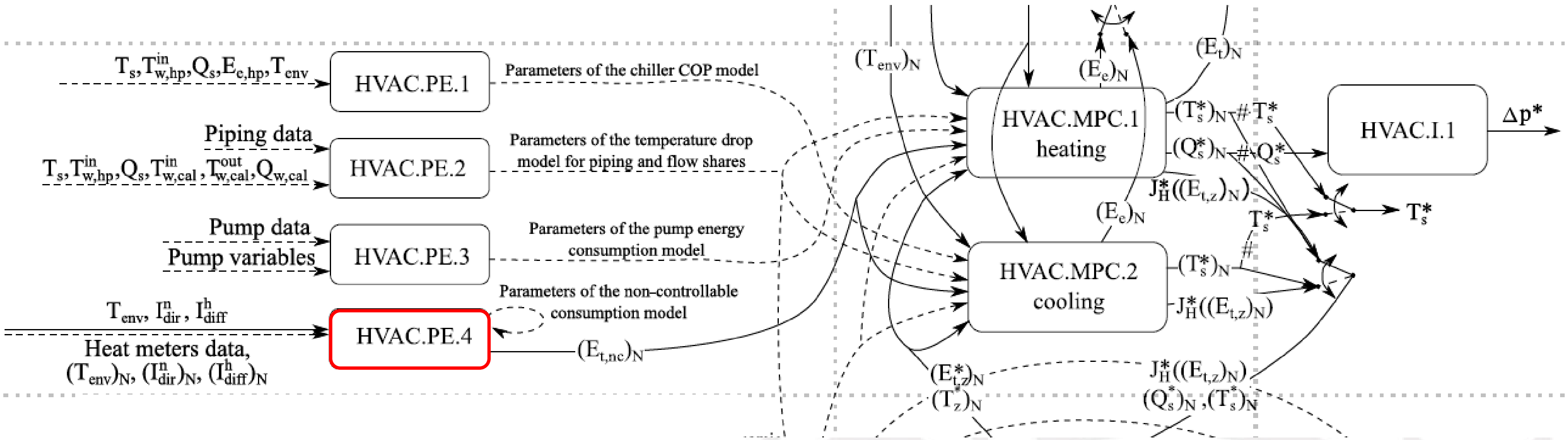


Zone Interface 1
(module for control of energy exertion from fan coil to air)

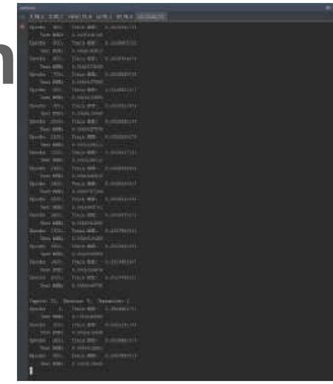


HVAC level

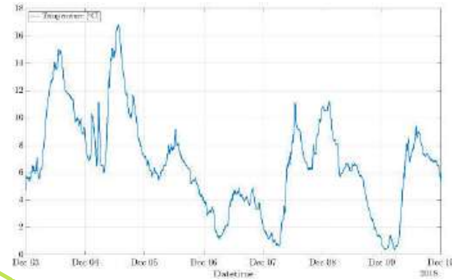
HVAC PE 4
(prediction of non-controllable heat consumption on the central HVAC level)

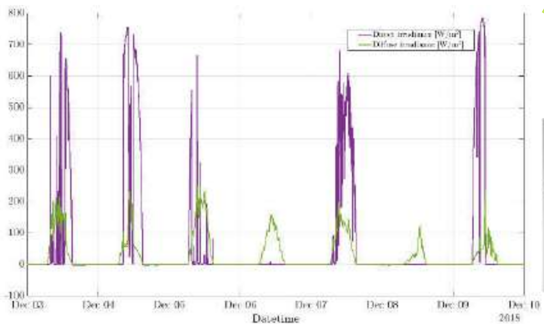


HVAC PE 4 – off-line initialization



Historical meteo measurements:
- Air temperature
- Direct and diffuse solar irradiance

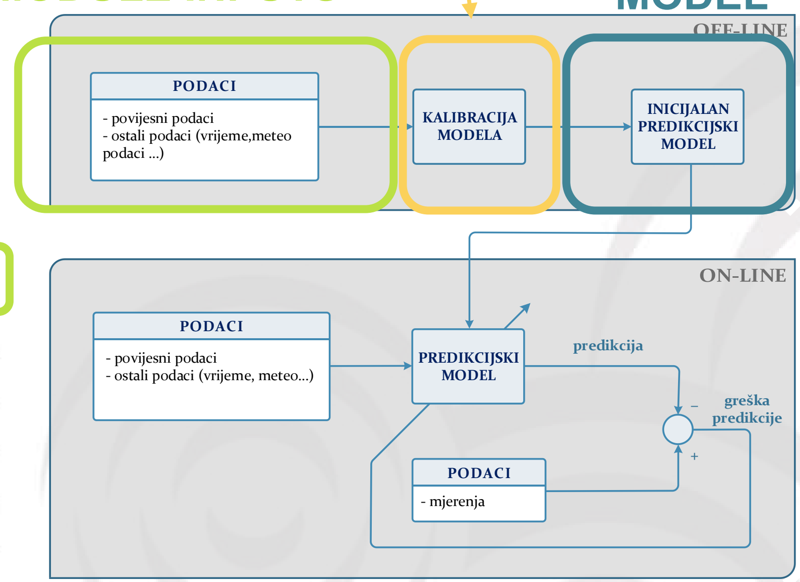




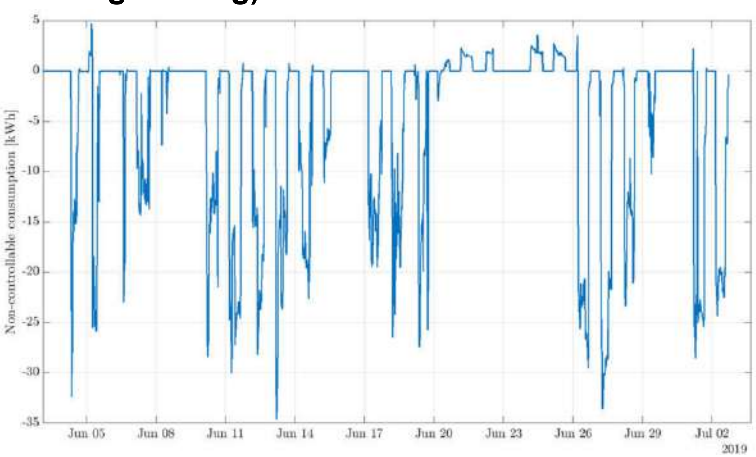
Locally stored: inputsXY_neuronsZ.net

MODULE INPUTS

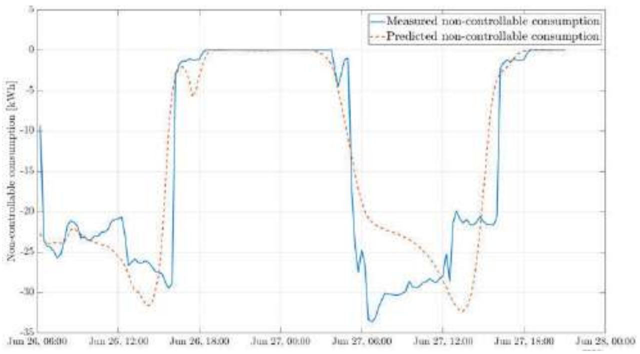
MODEL



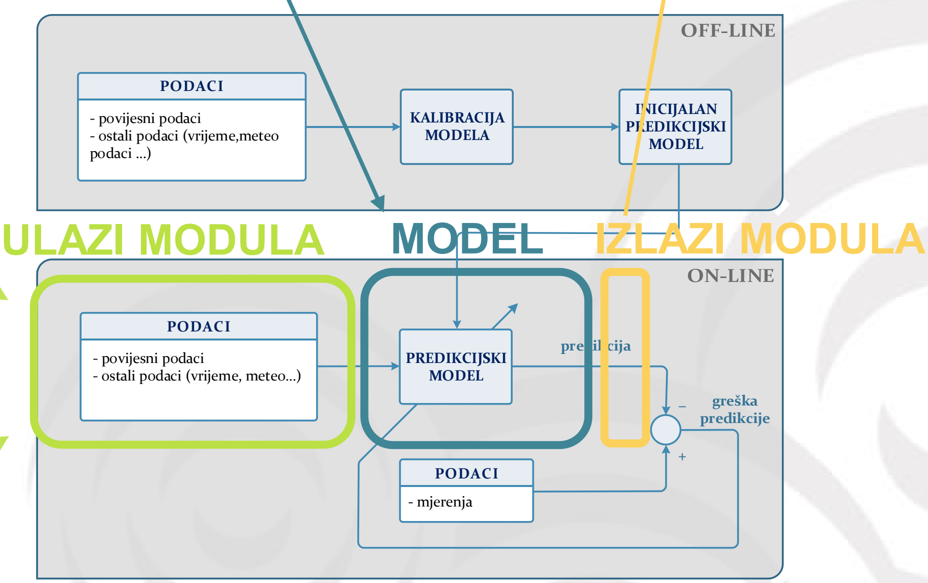
Historical **non-controllable consumption (B building cooling)**



HVAC PE 4 – on-line operation



Locally stored:
inputsXY_neuronsZ.net



Regressor composed of specific historical data samples:

- non-controllable consumption(t-1,…,t-5)
- non-controllable consumption(t-670,…,t-674)

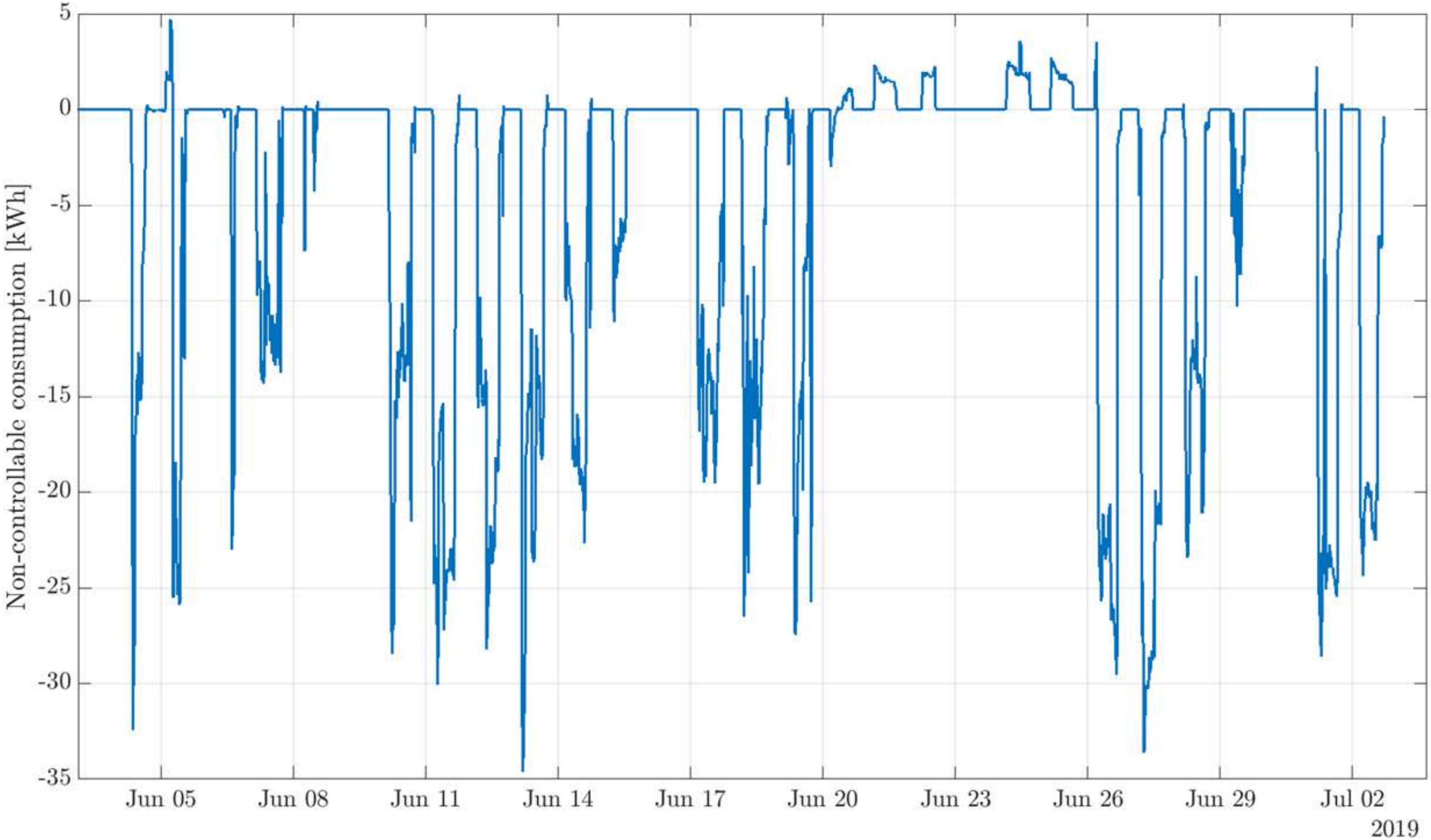
- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

- air temperature(t-1,…,t-3)
- air temperature(t-671,…,t-673)

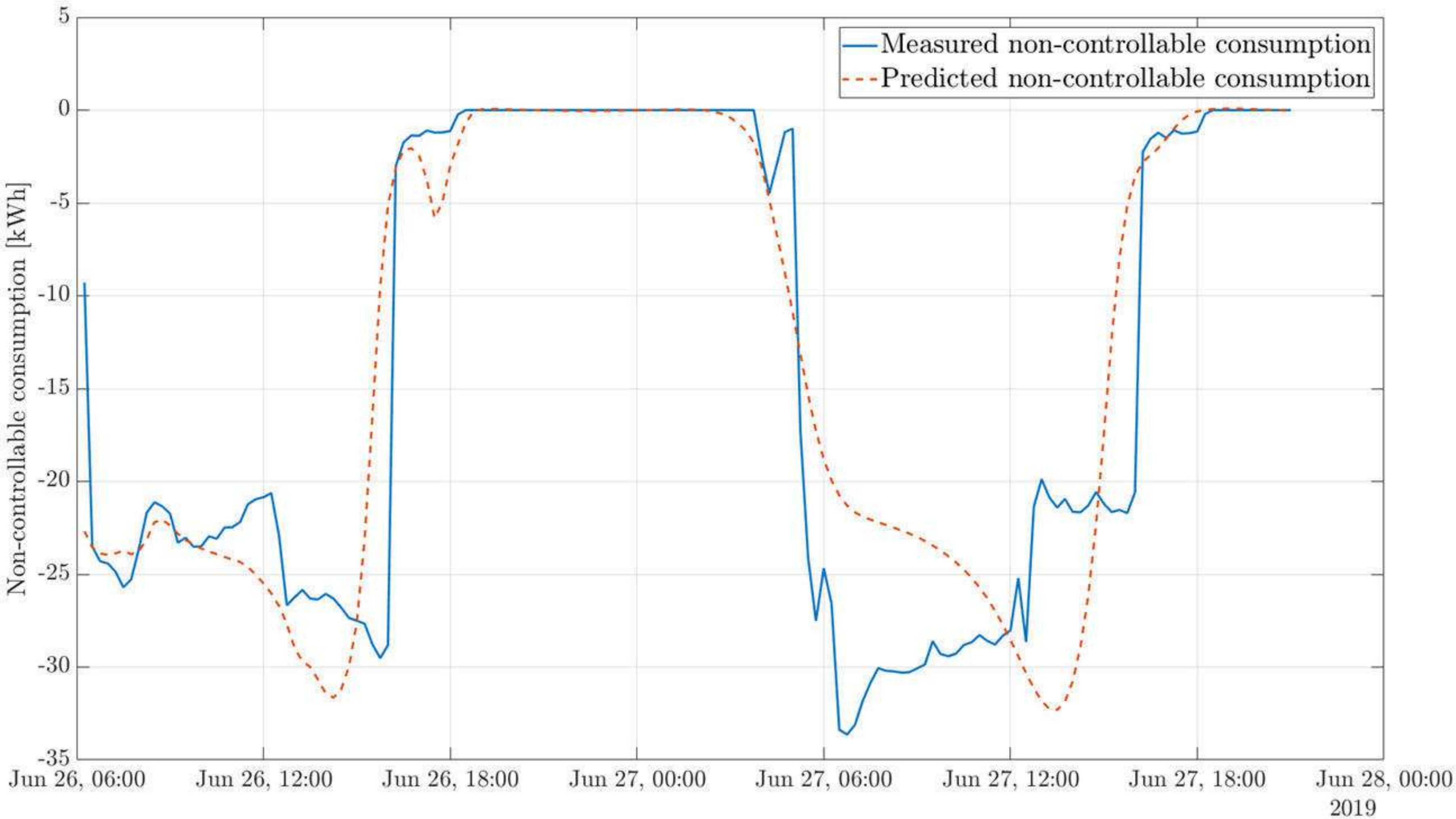
- direct irradiance(t-1,…,t-3)
- direct irradiance(t-671,…,t-673)

- diffuse irradiance(t-1,…,t-3)
- diffuse irradiance (t-671,…,t-673)

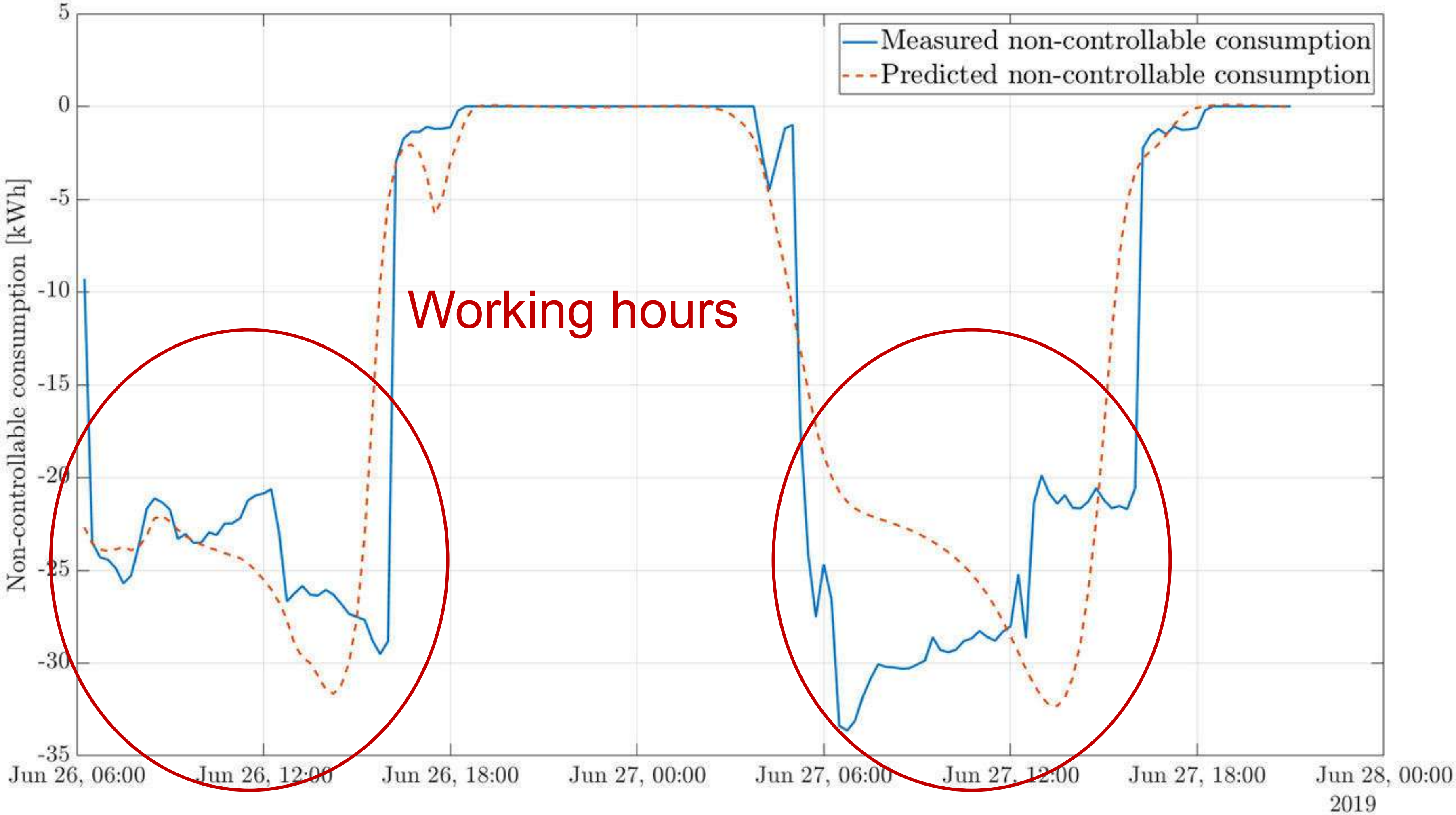
HVAC PE 4 – example of historical consumption



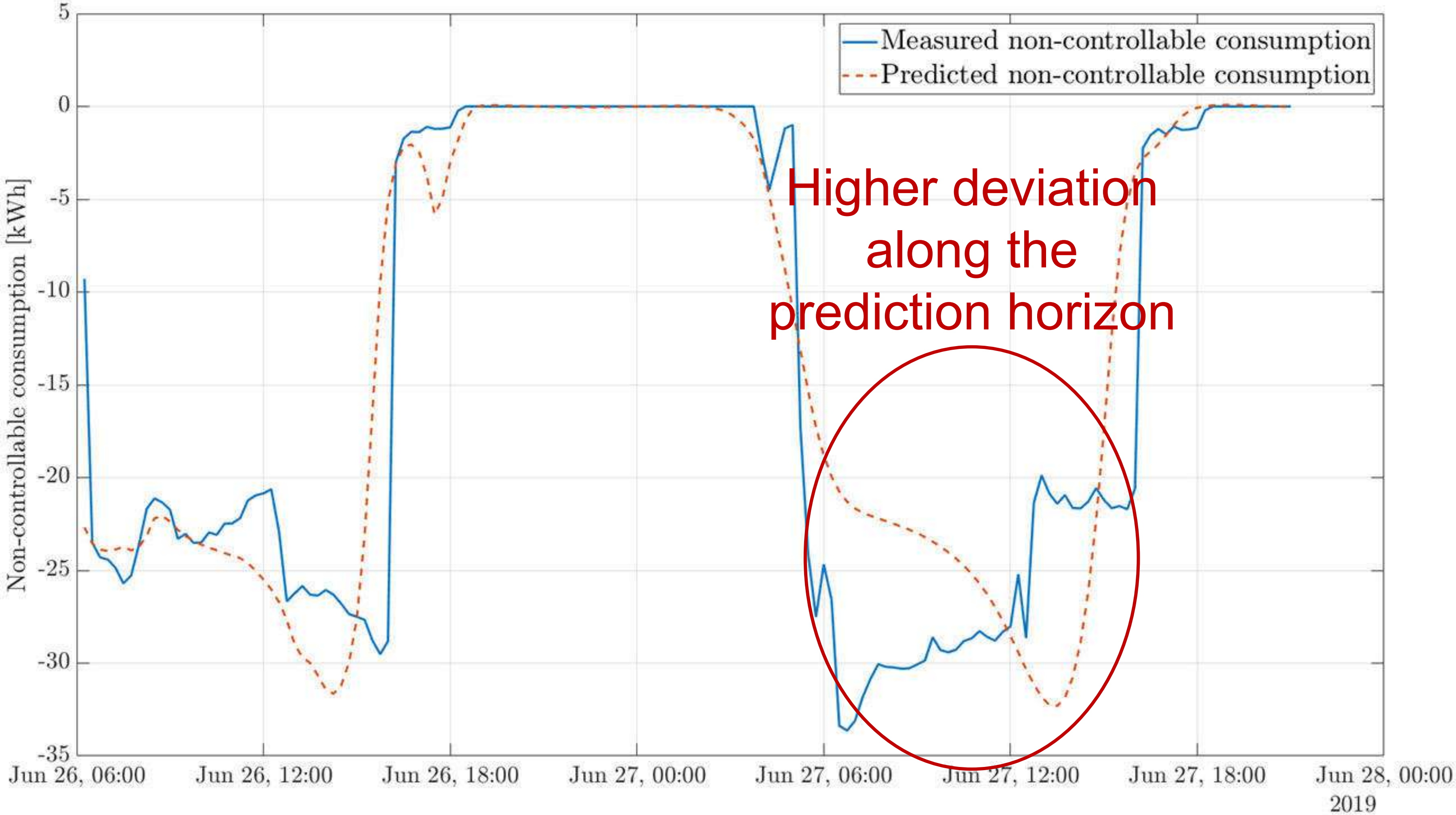
HVAC PE 4 – example of a generated prediction



HVAC PE 4 – example of a generated prediction



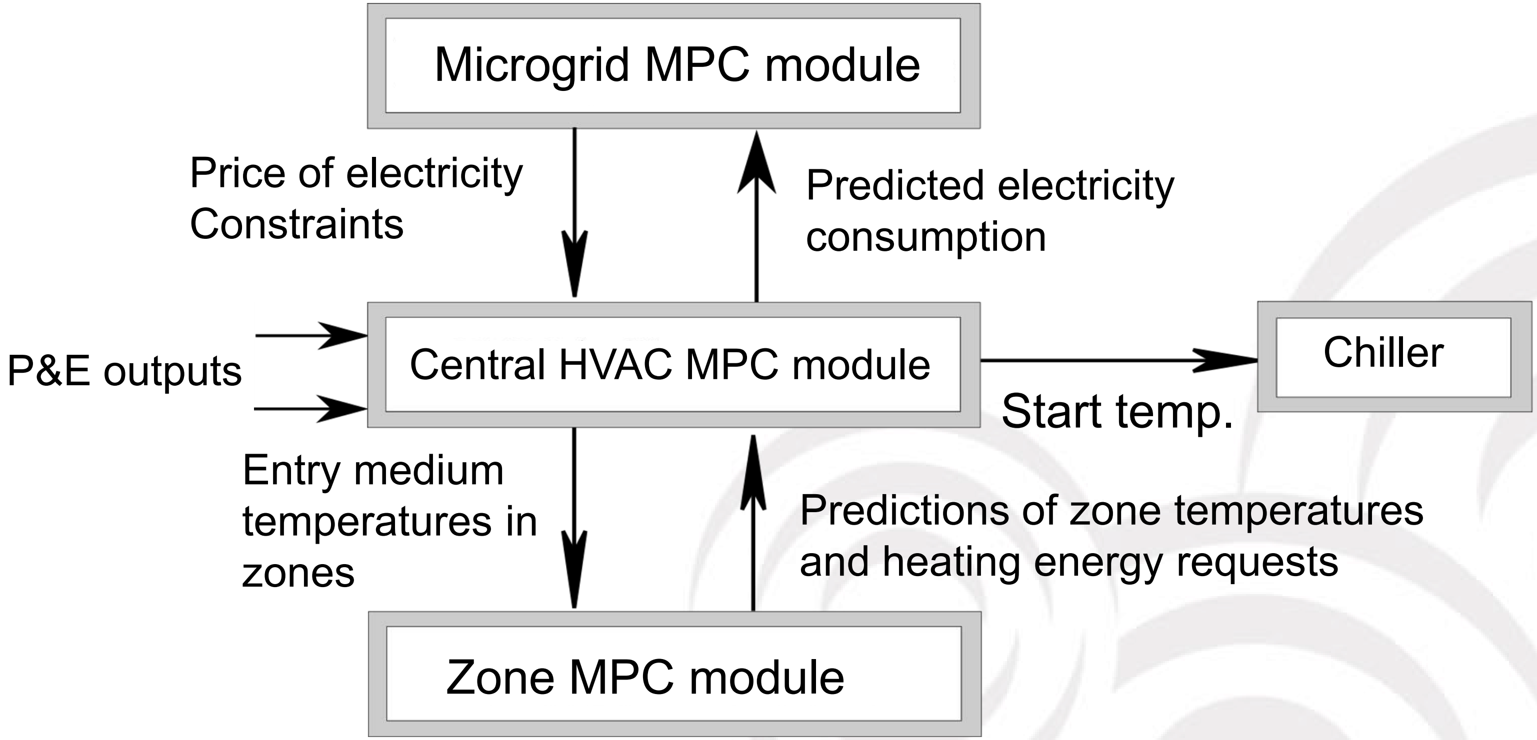
HVAC PE 4 – example of a generated prediction



Module of model predictive control for central HVAC (HVAC MPC 2 module)

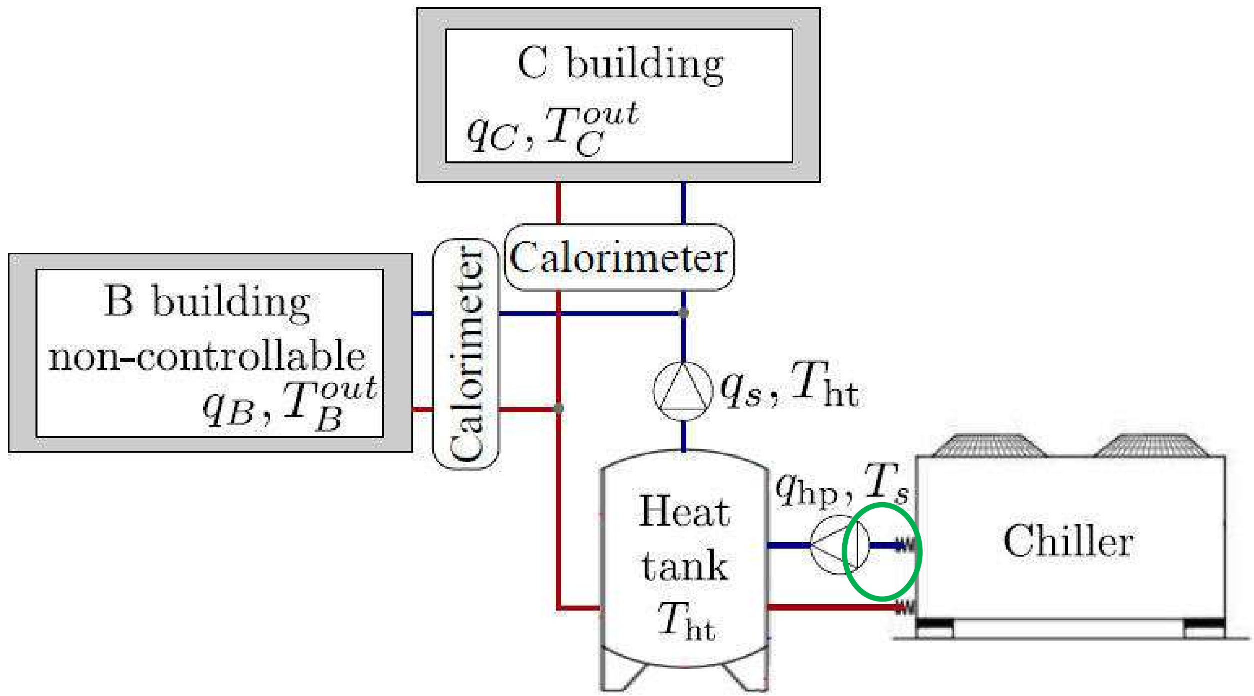
- Description: conditioning of the cooling medium → minimization of operation cost of the central HVAC system under constraints of ensuring enough cooling energy for all zones
- Interaction:
  - 4.2.1. - Microgrid MPC module
  - 4.4.1. – Zone MPC module
  - 4.3.1./4.4.1 – P&E modules
- Period of execution: 15 minutes
- Prediction at least 24 hours ahead

HVAC MPC in the modular structure



Conceptual scheme of the HVAC system at FER

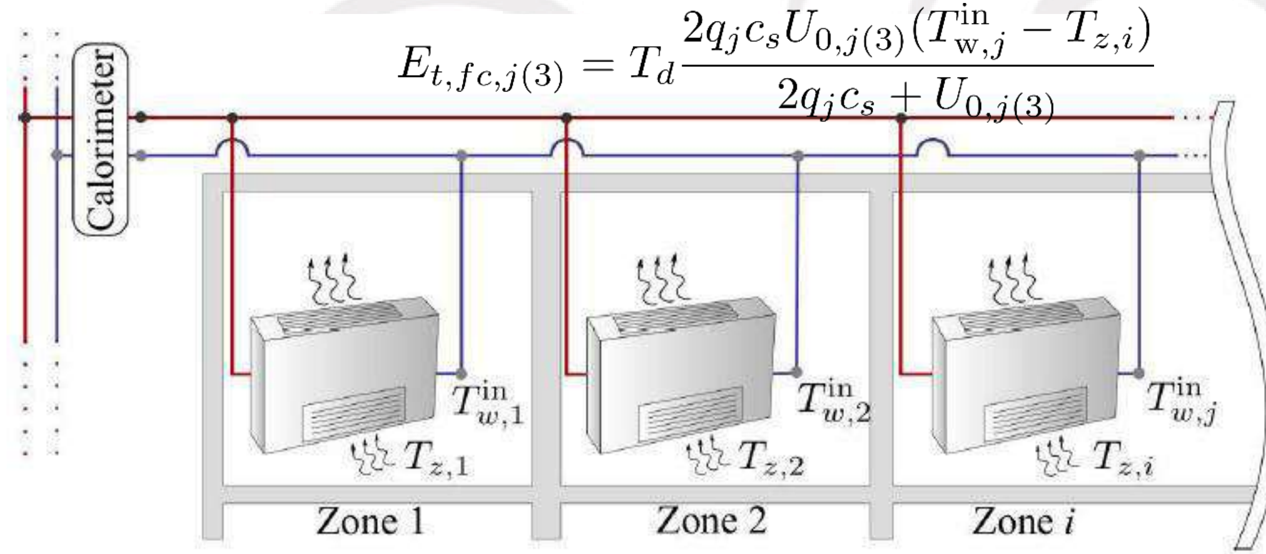
- C building – controllable load
- B building – non-controllable load
- Heat tank
- Chiller
- Ducts



Submodels of the HVAC system

- COP chiller model $COP(T_o, P_t)$
- Duct, heat losses, flows
- Zones
- Fan coils (FC)
- Flows per FC
- Model of medium temp. at FC
- Non-contr. load
- Heat tank

$$E_{t,fc,j(3)} = T_d \frac{2q_j c_s U_{0,j(3)} (T^{\text{in}}_{\text{w},j} - T_{z,i})}{2q_j c_s + U_{0,j(3)}}$$



HVAC MPC problem

INPUTS:
predicted zone conditions, outdoor temp. etc.

Minimize according to prices, constraints →

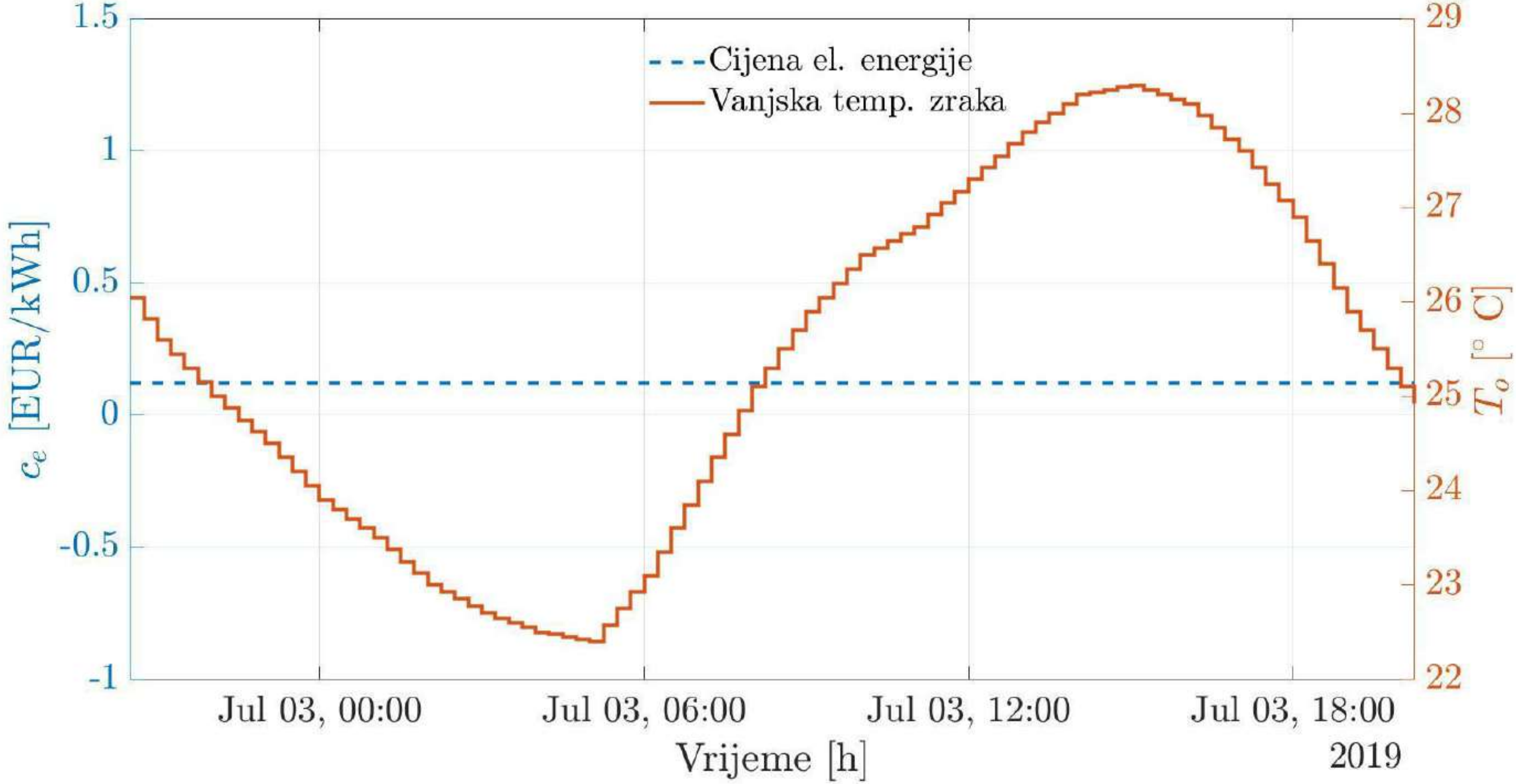
OUTPUTS:
medium starting temperature (+flow) & el. cons. 24h ahead

- HVAC operation price = price of electricity consumed
- Constraints:
  - starting temperature
  - compressor loading (122.5 kW)
  - heat requests in zones
  - electricity consumption (constrained by microgrid)

Online HVAC MPC scenario

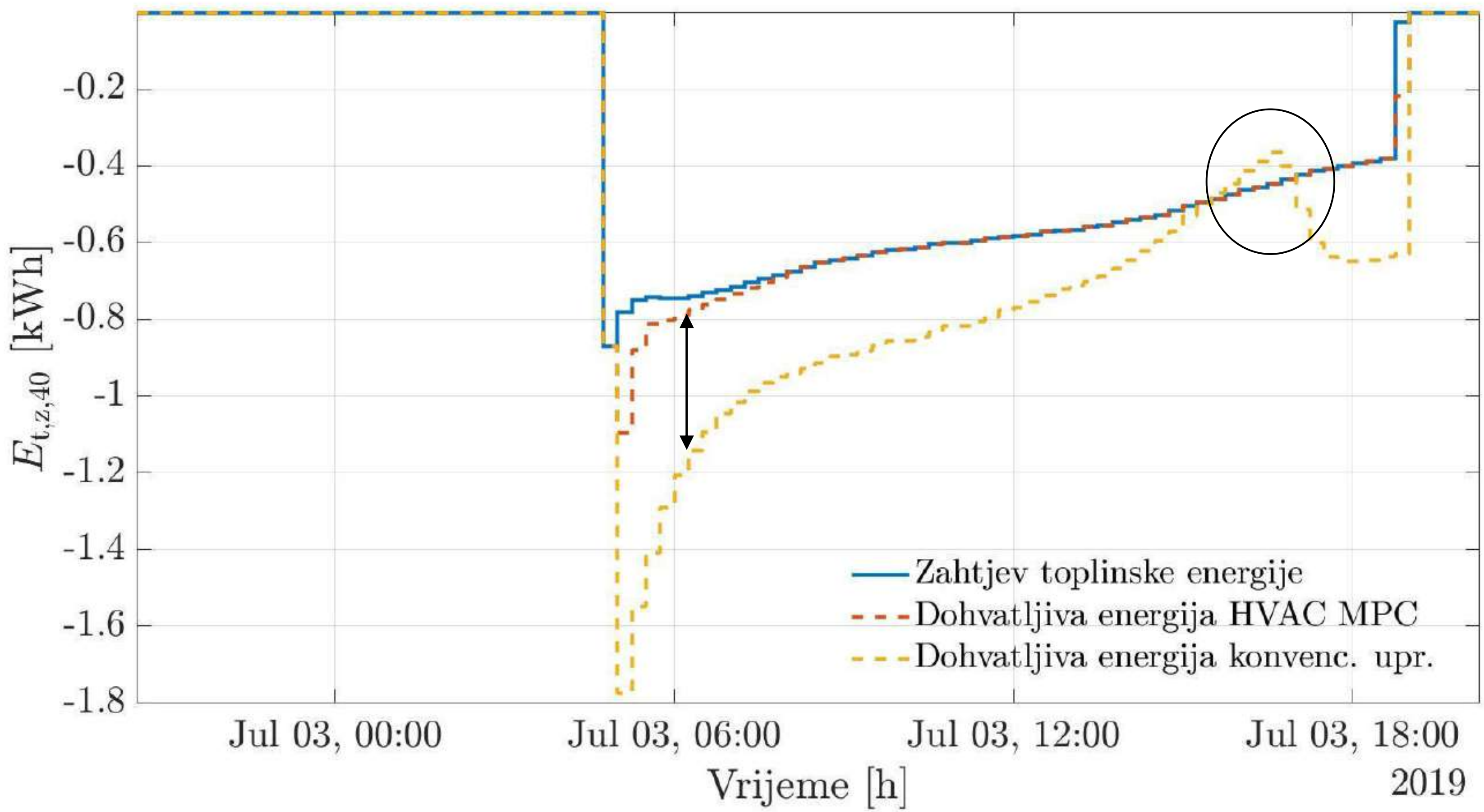
- Considered time-span: 2-3 July 2019
- Comparison with conventional controller – fixed starting temperature

HVAC MPC – results of online modules (1)



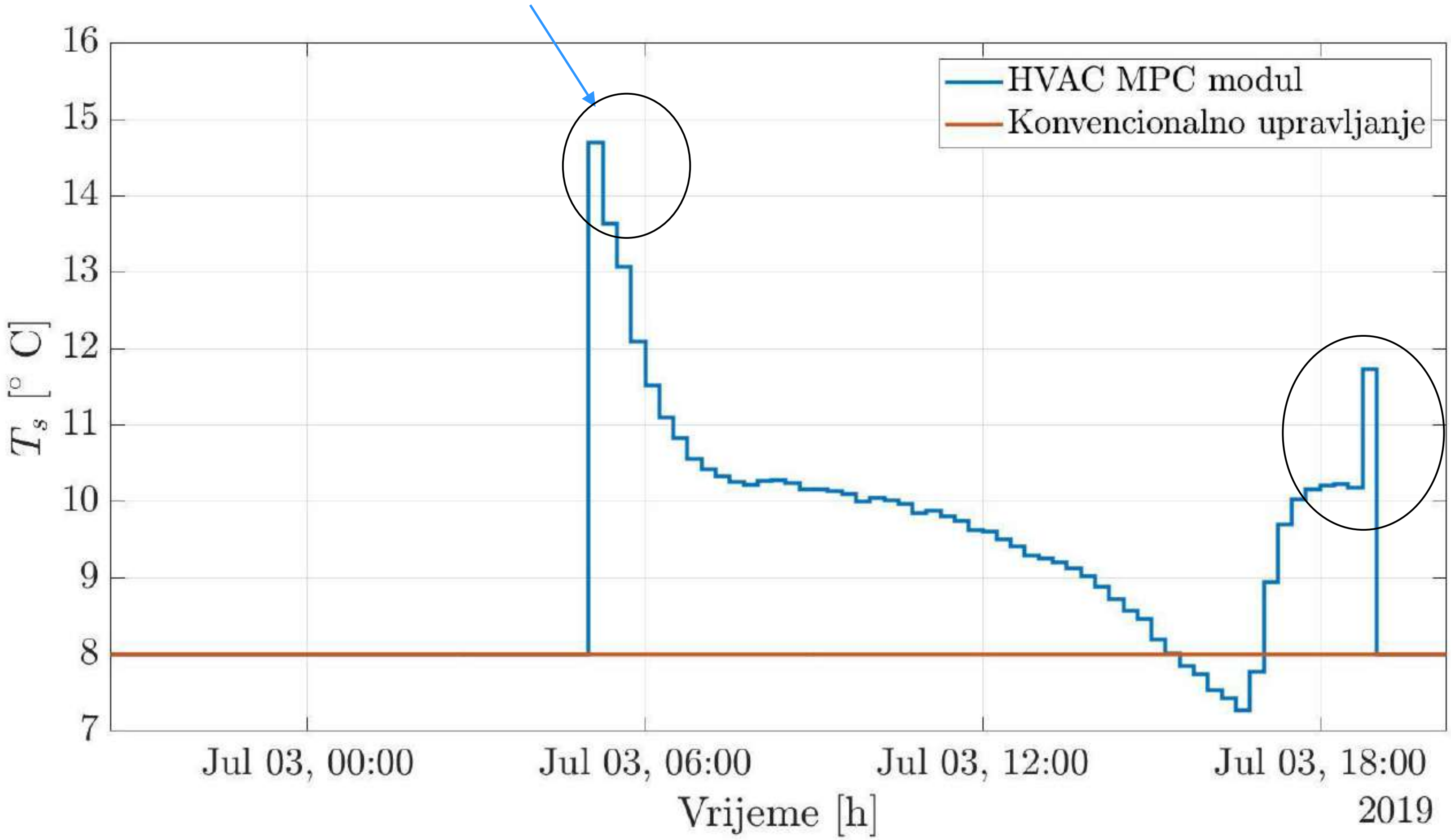
HVAC MPC – results of online module (2)

- Attainable vs. required heating energies for a sample zone



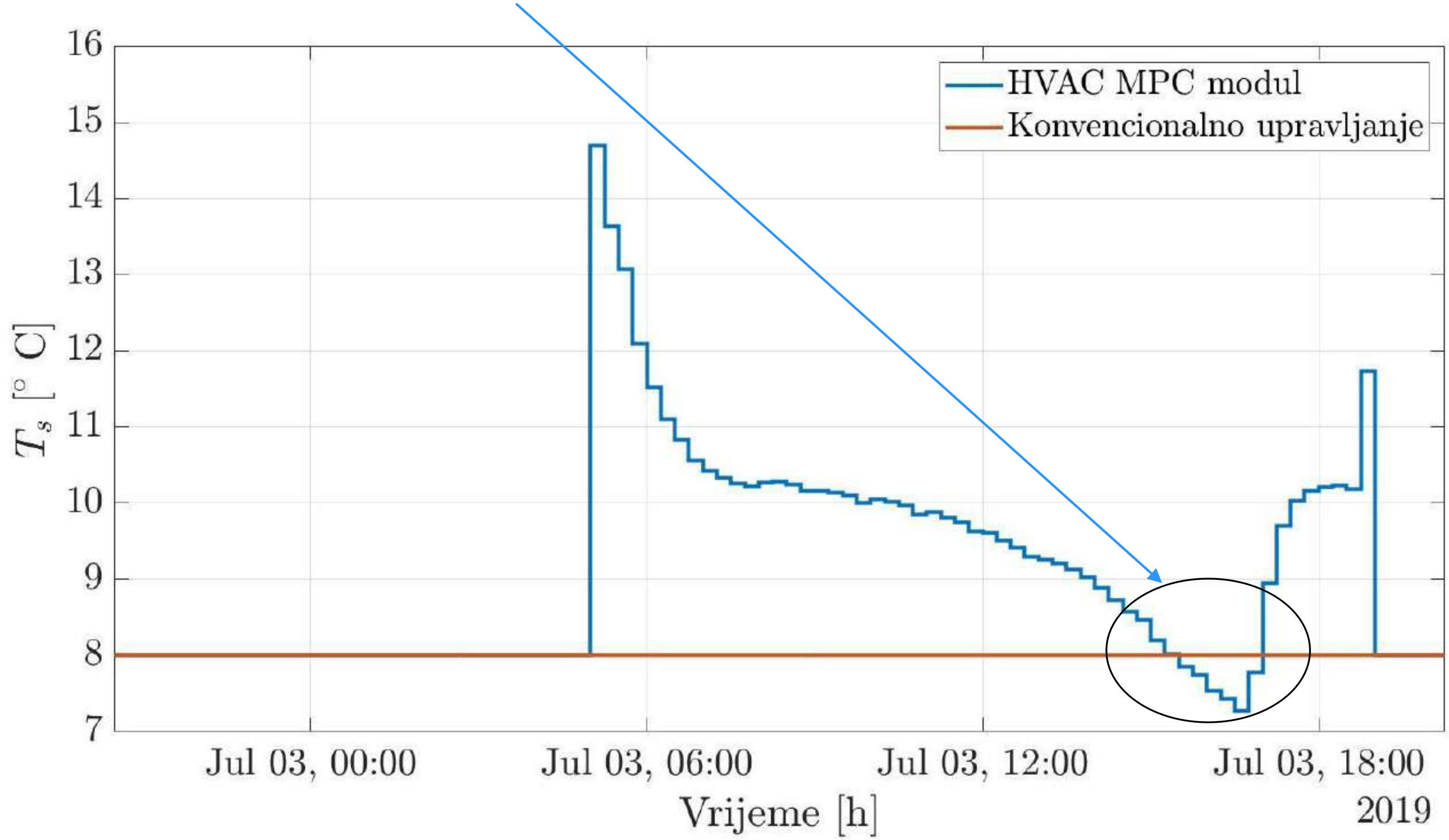
HVAC MPC – results of online module (3)

- Rise of starting temp. → reduced heat load



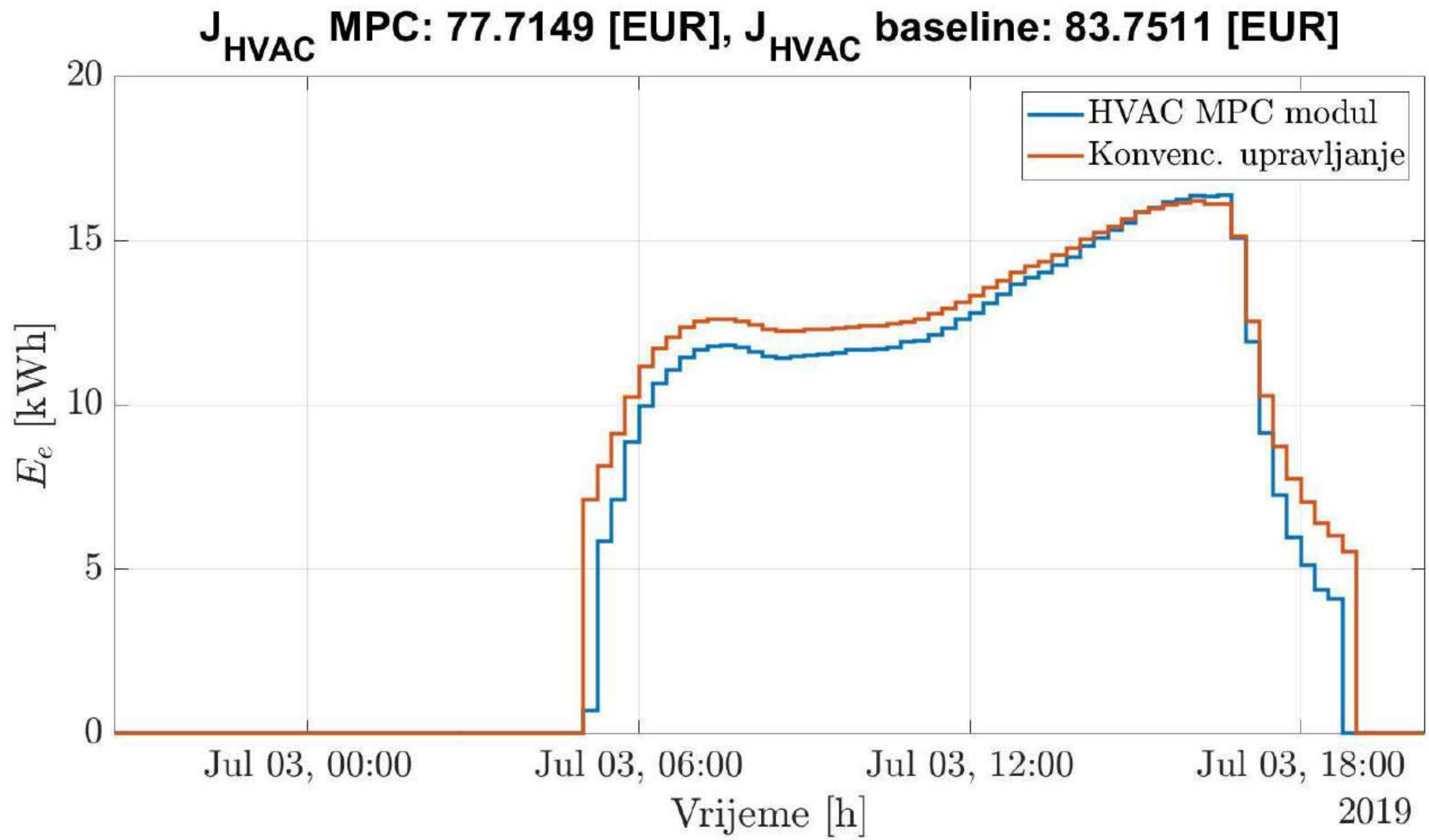
HVAC MPC – results of online module (4)

- Fall of start temp. → increased heat load



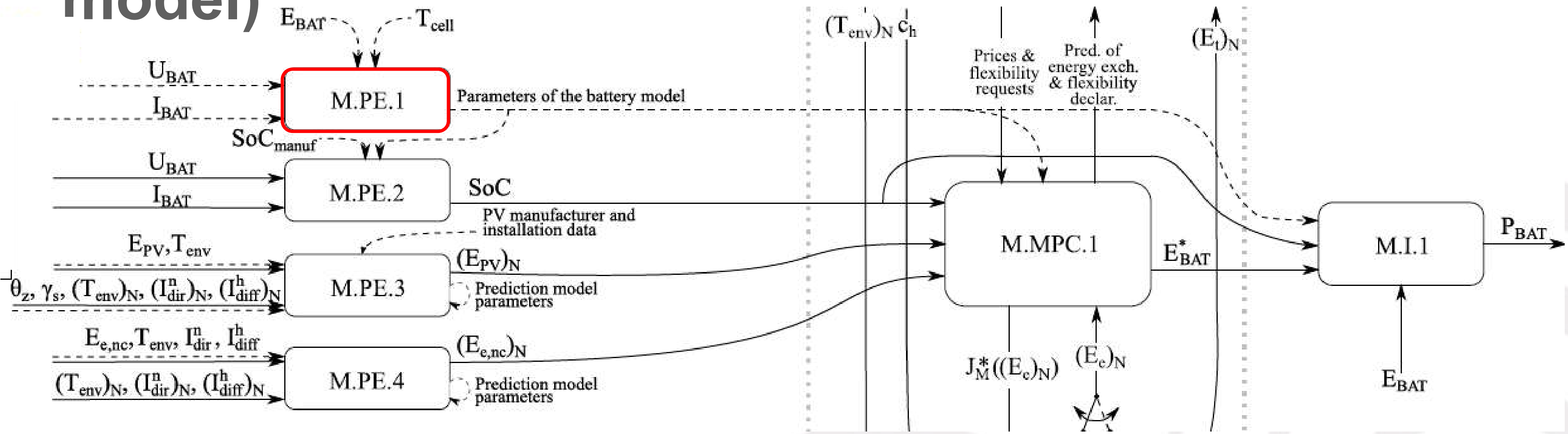
HVAC MPC – results of online module (5)

- HVAC MPC consumption reduction **-8%**



Microgrid level

M PE 1
(estimation of battery system mathematical model)



Inputs

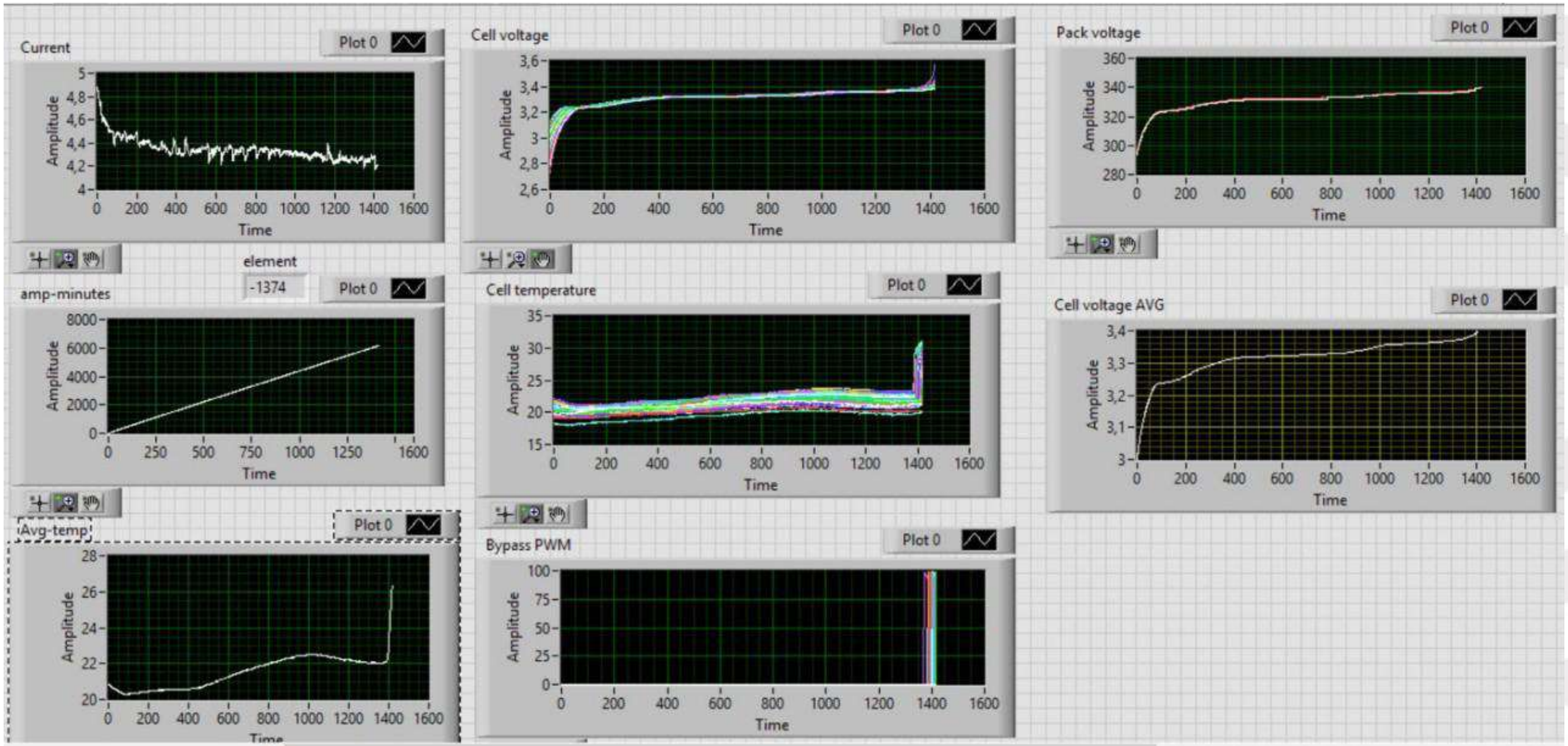
- Measurements from the battery system: voltages and currents on AC and DC side, cells temperature

Izlazi

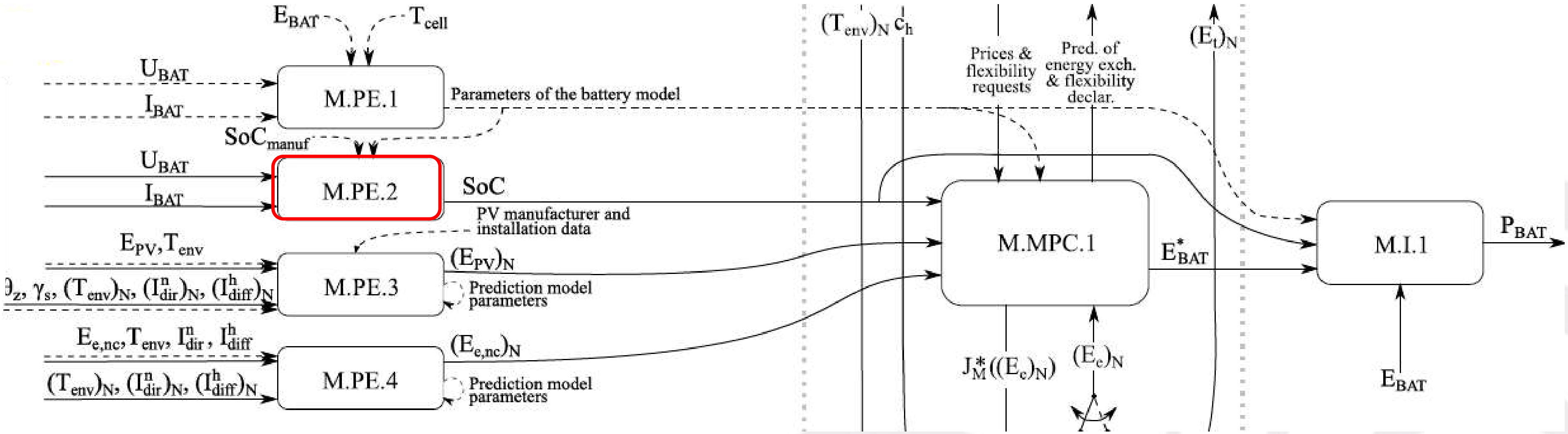
- Battery capacity
- Battery system efficiency

M PE 1

- Performed identification experiments
- Possible also analysis of historical data from regular system operation



M PE 2
(estimation of battery state of charge)



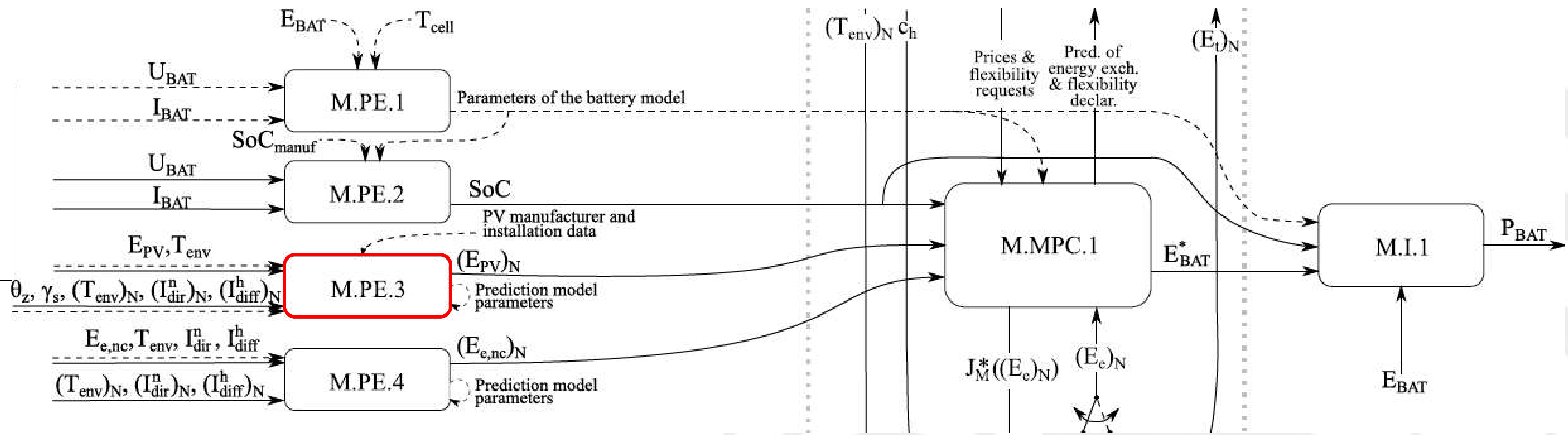
Inputs

- Measurements from the battery system: voltages and currents on AC and DC side
- Parameters of battery system mathematical model

Outputs

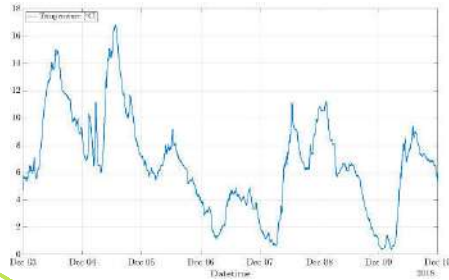
- Battery state of charge (SoC)

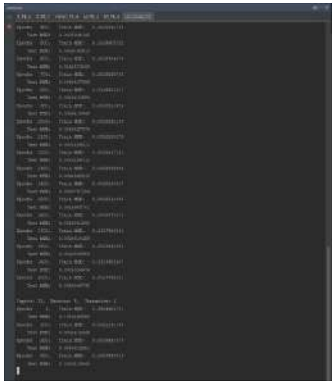
M PE 3 (prediction of photovoltaic system production)



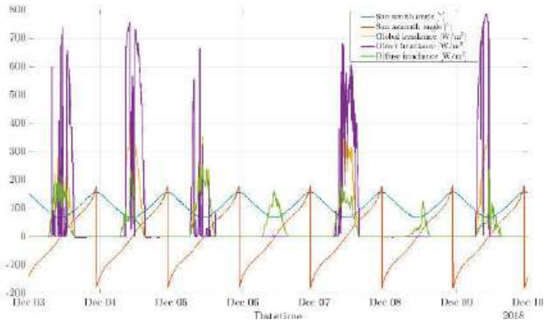
M PE 3 – off-line initialization

Historical meteo measurements:
- Air temperature
- Direct and diffuse solar irradiance
- Solar azimuth nd zenith angles



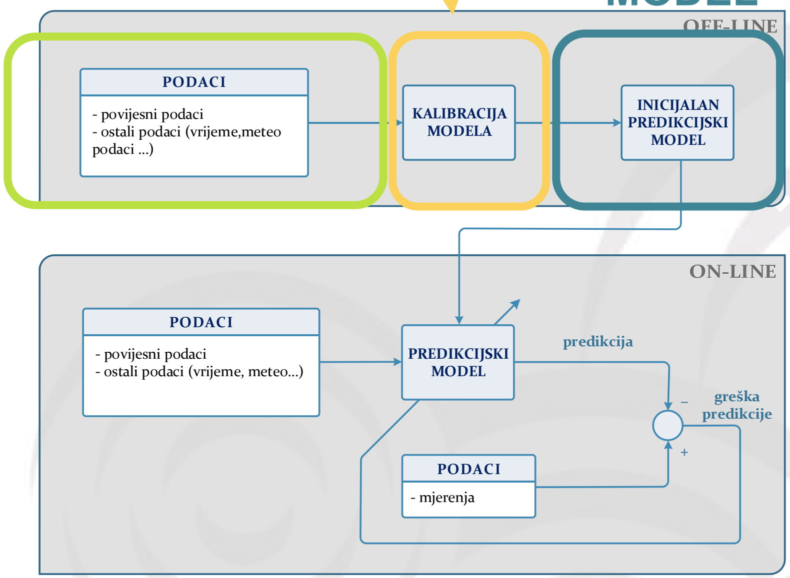


Locally stored: inputsXY_neuronsZ.net

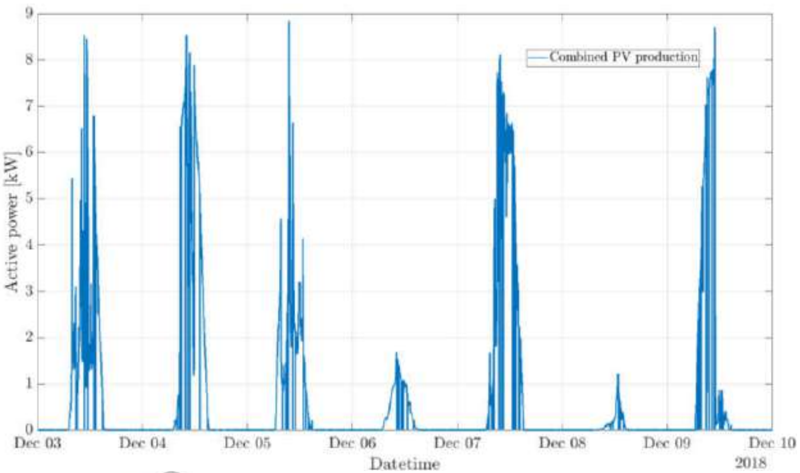


MODULE INPUTS

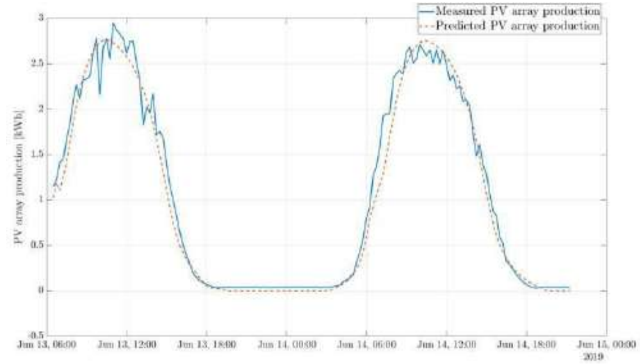
MODEL



Historical photovoltaic system production



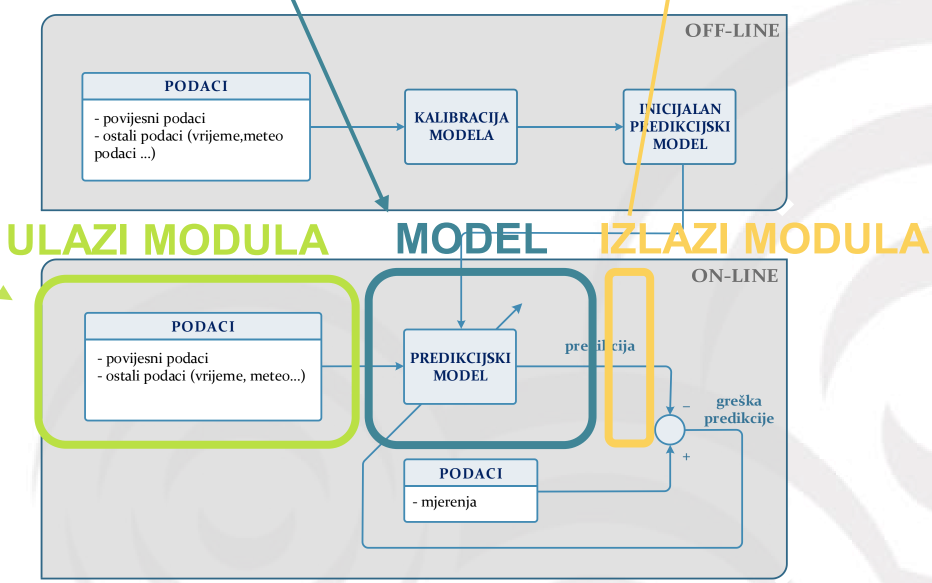
M PE 3 – on-line operation



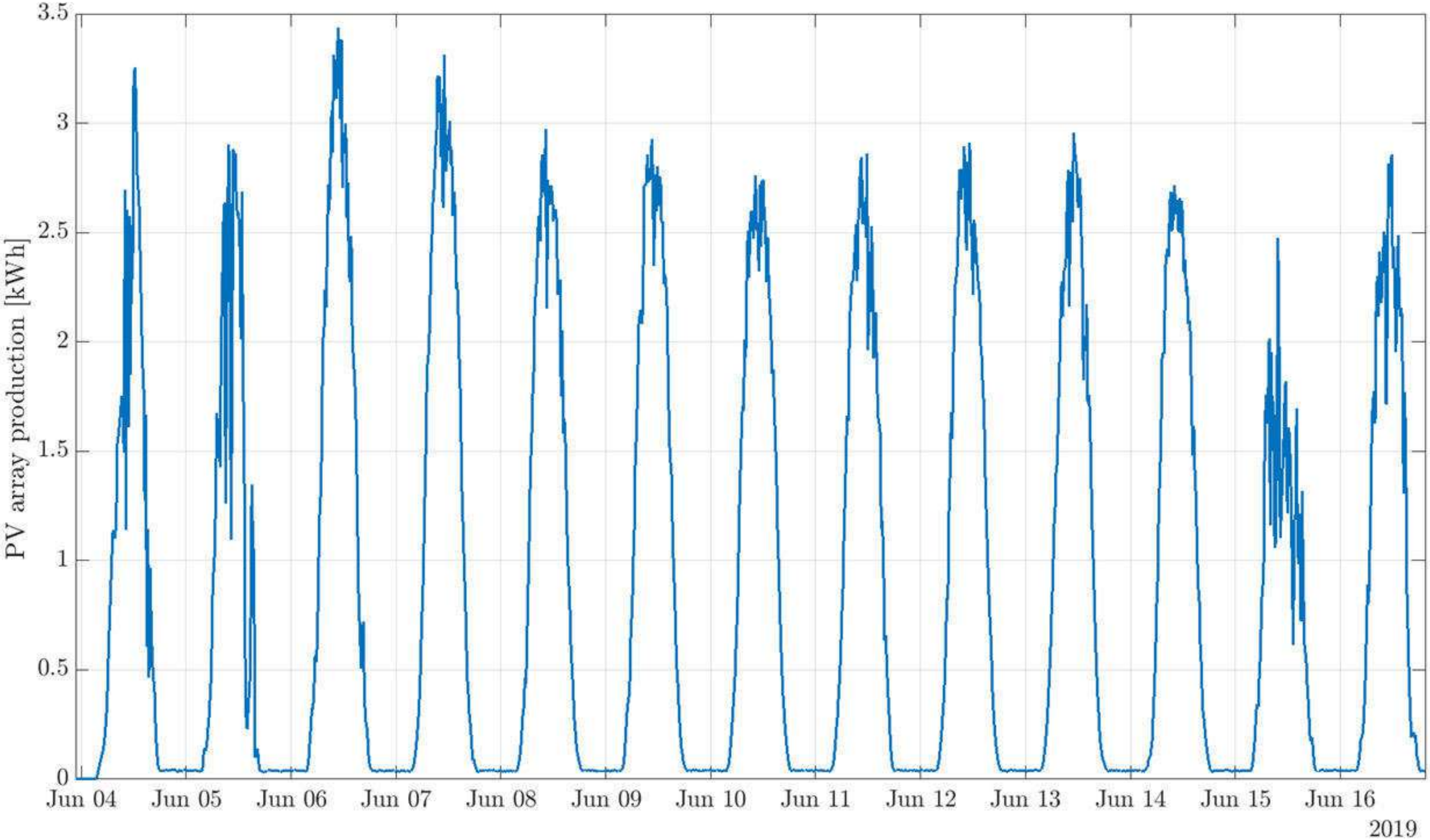
Regressor composed of specific historical data samples:

- solar_zenith_angle(t-1,…,t-3)
- solar_azimuth_angle(t-1,…,t-3)
- temperature(t-1,…,t-3)
- direct irradiance(t-1,…,t-3)
- diffuse irradiance(t-1,…,t-3)

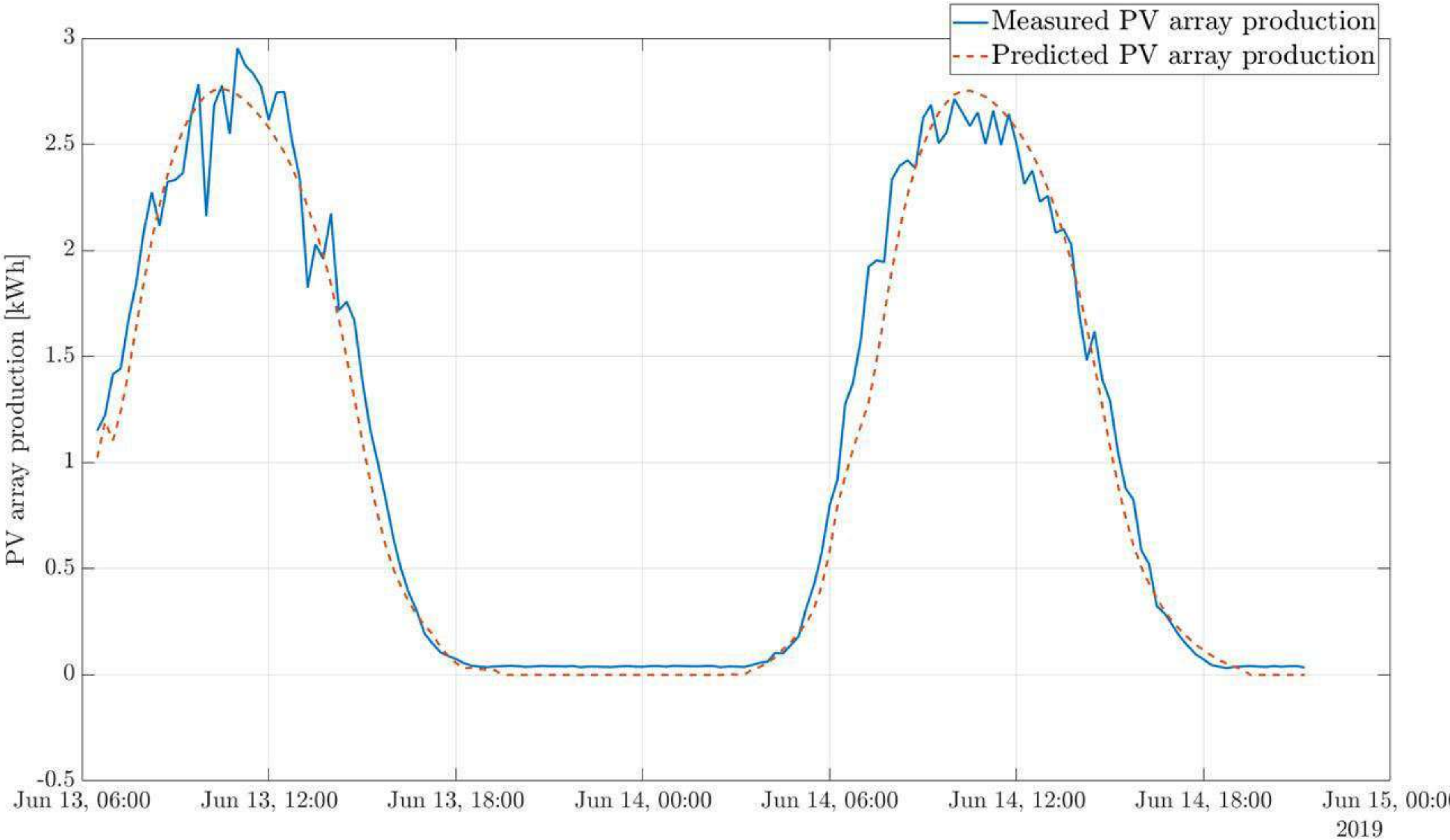
Locally stored:
inputsXY_neuronsZ.net



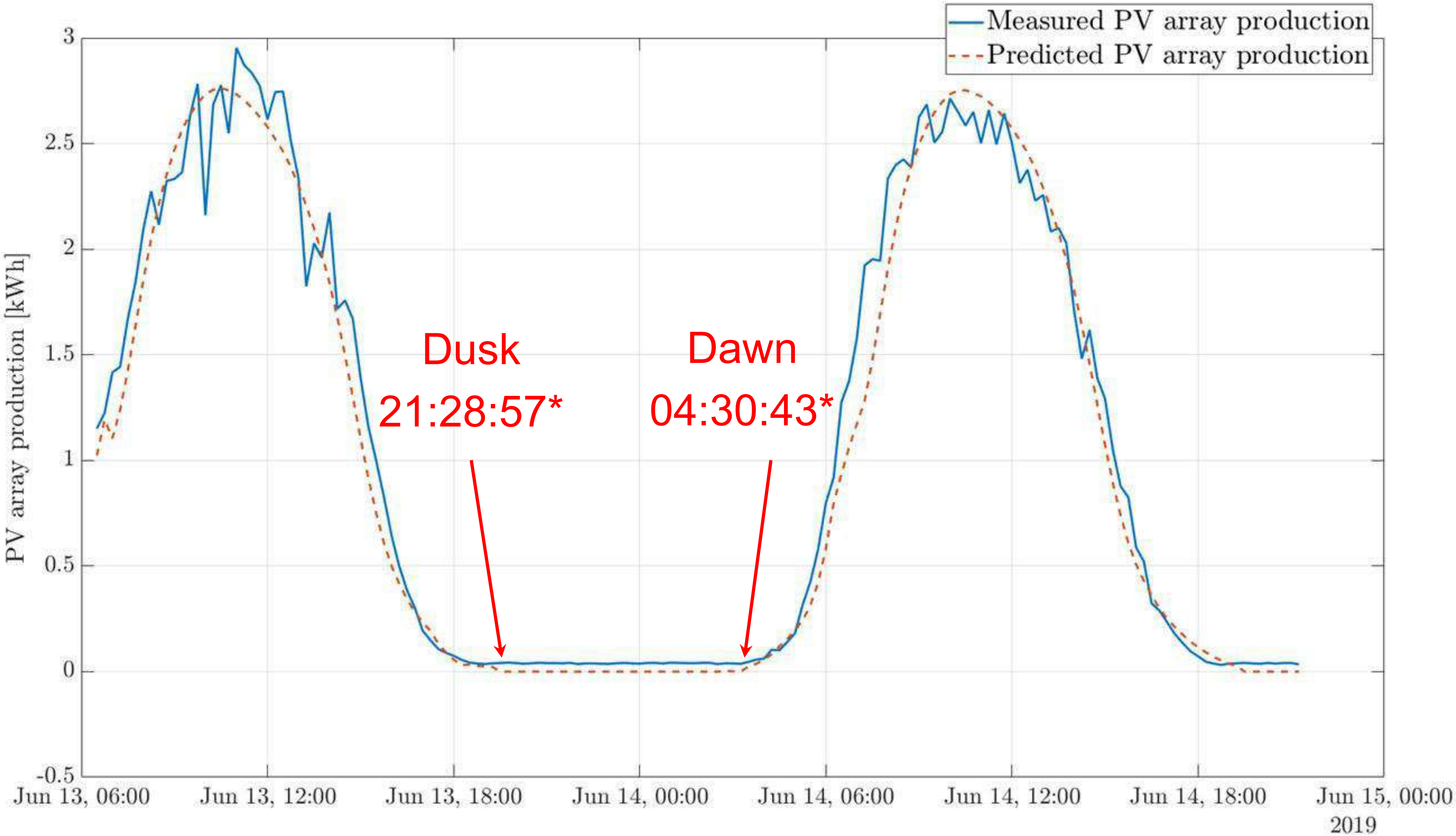
M PE 3 – example of historical production



M PE 3 – example of generated predictions

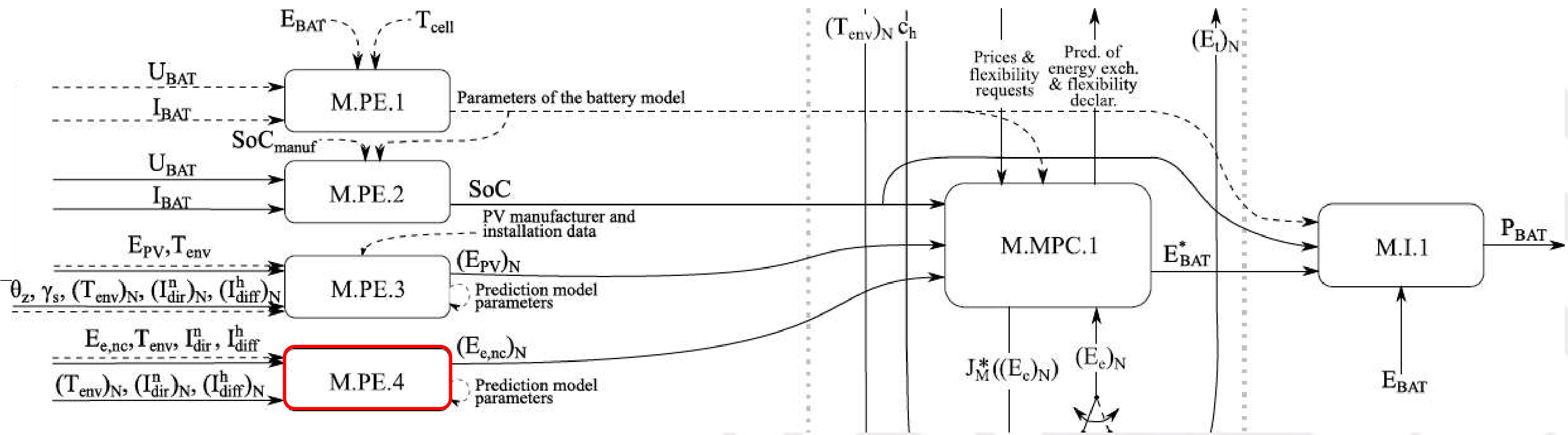


M PE 3 – example of generated predictions



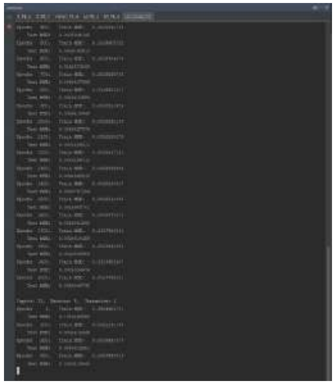
*local time zone:
UTC + 02:00

M PE 4 (prediction of non-controllable consumption on microgrid level)



Danube Transnational Programme
3Smart

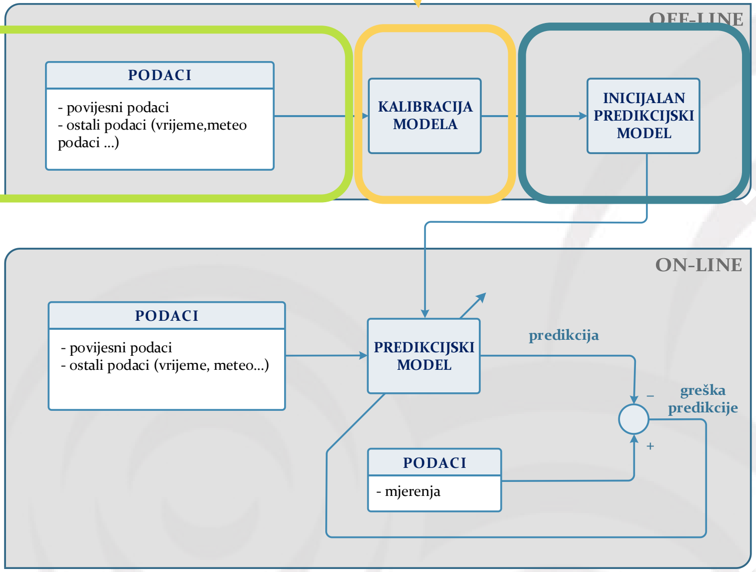
M PE 4 – off-line initialization



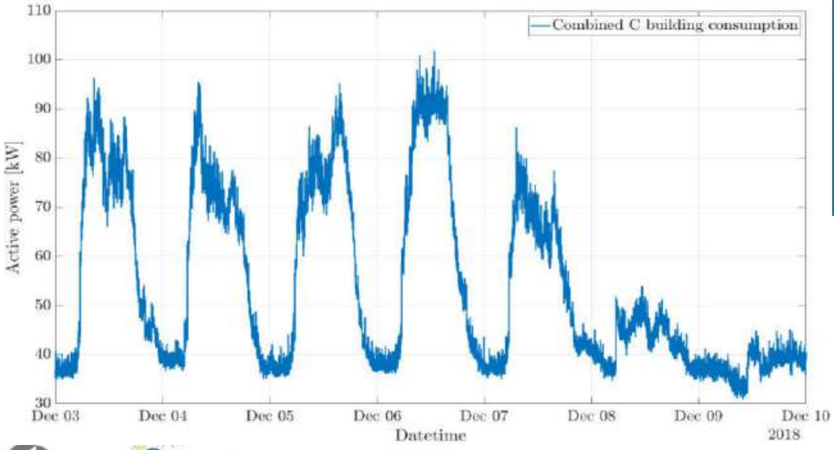
Locally stored:
inputsXY_neuronsZ.net

MODULE INPUTS

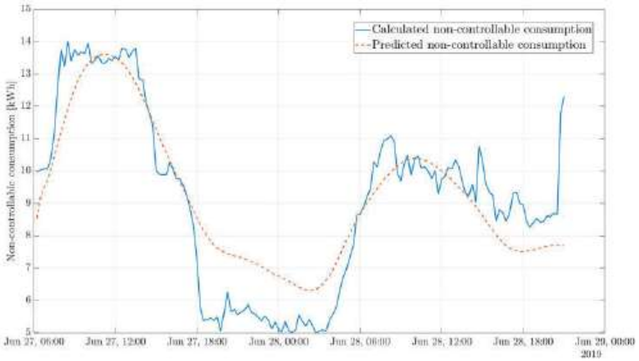
MODEL



Historical non-controllable consumption **(lighting, office equipment, additional air conditioners…)**



M PE 4 – on-line operation

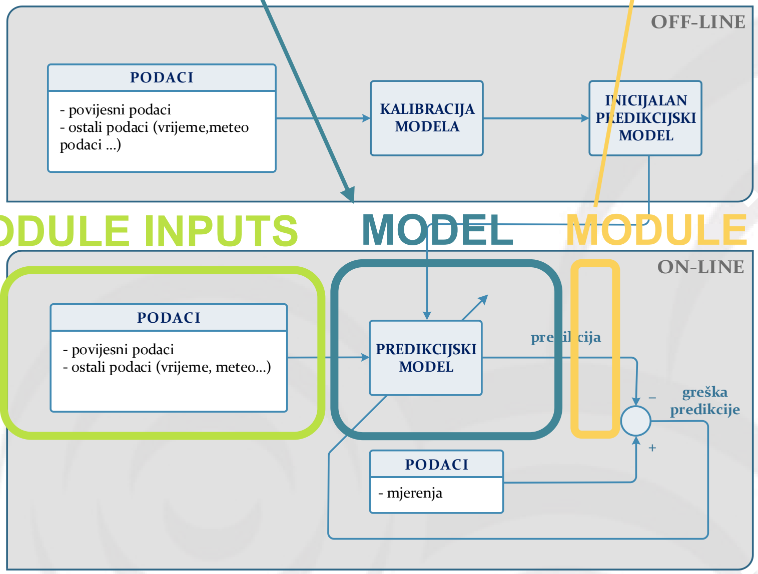


Locally stored:
inputsXY_neuronsZ.net

MODULE INPUTS

MODEL

MODULE OUTPUTS

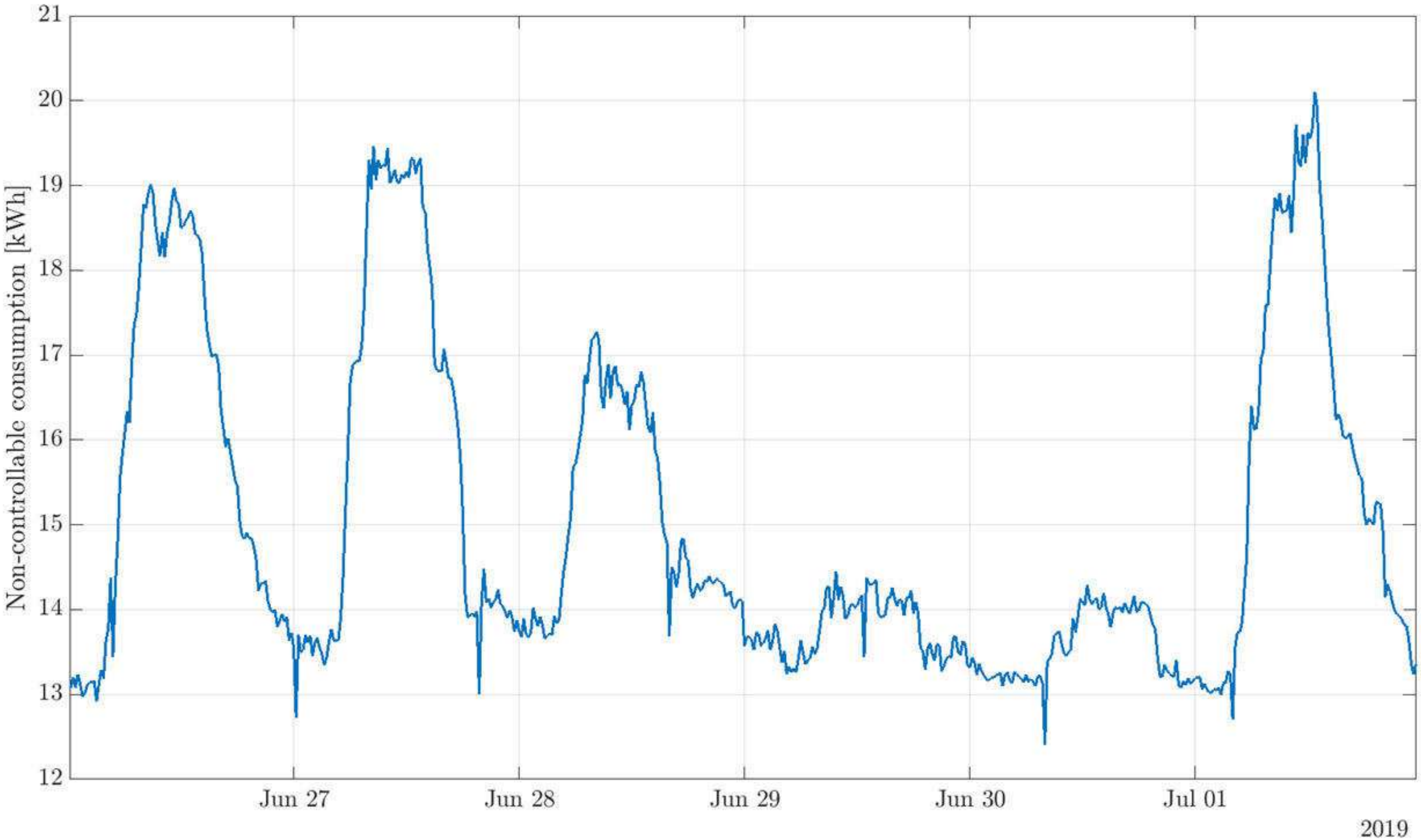


Regressor composed of specific historical data samples:

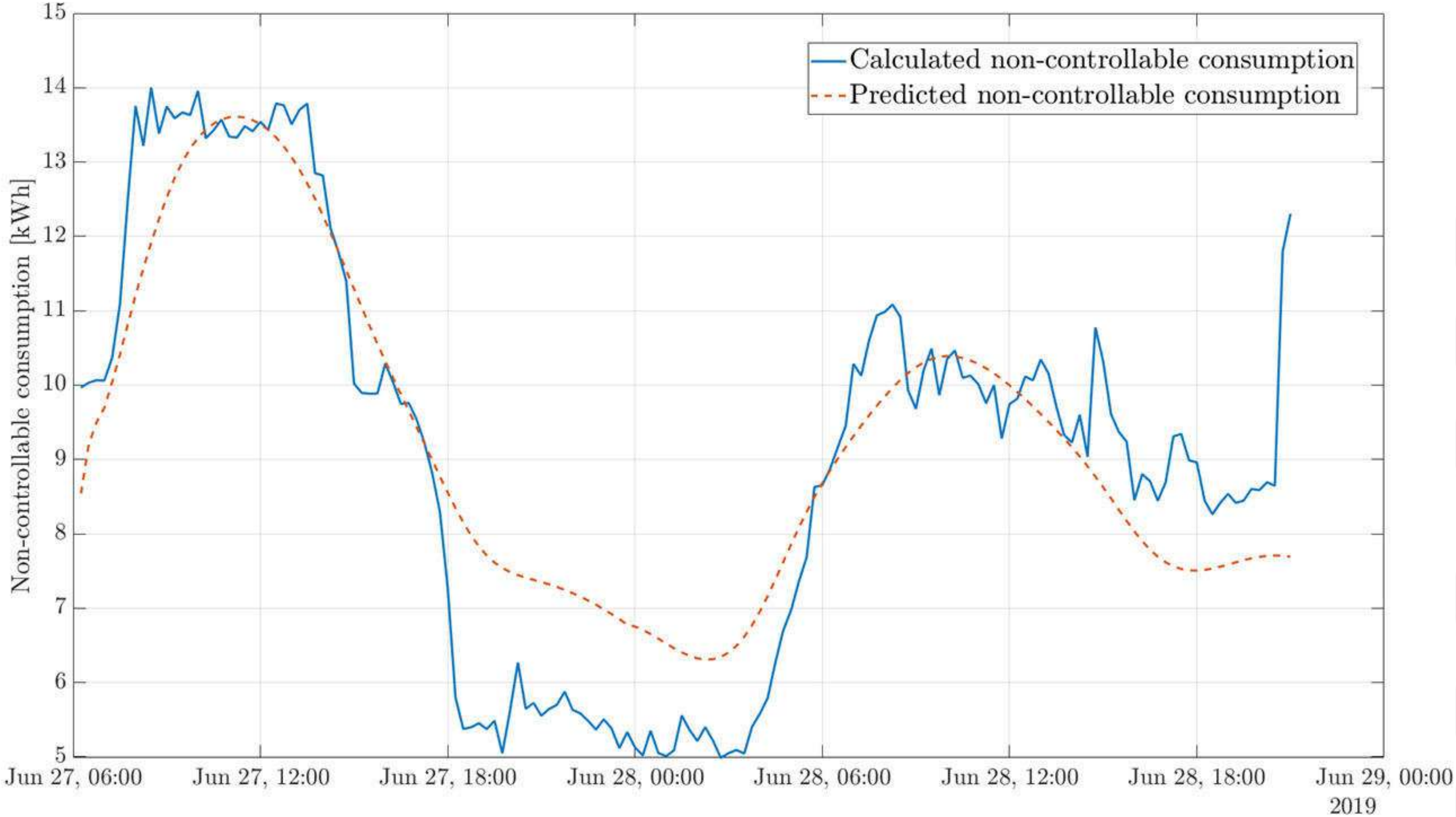
- non-controllable consumption(t-1,…,t-5)
- non-controllable consumption(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

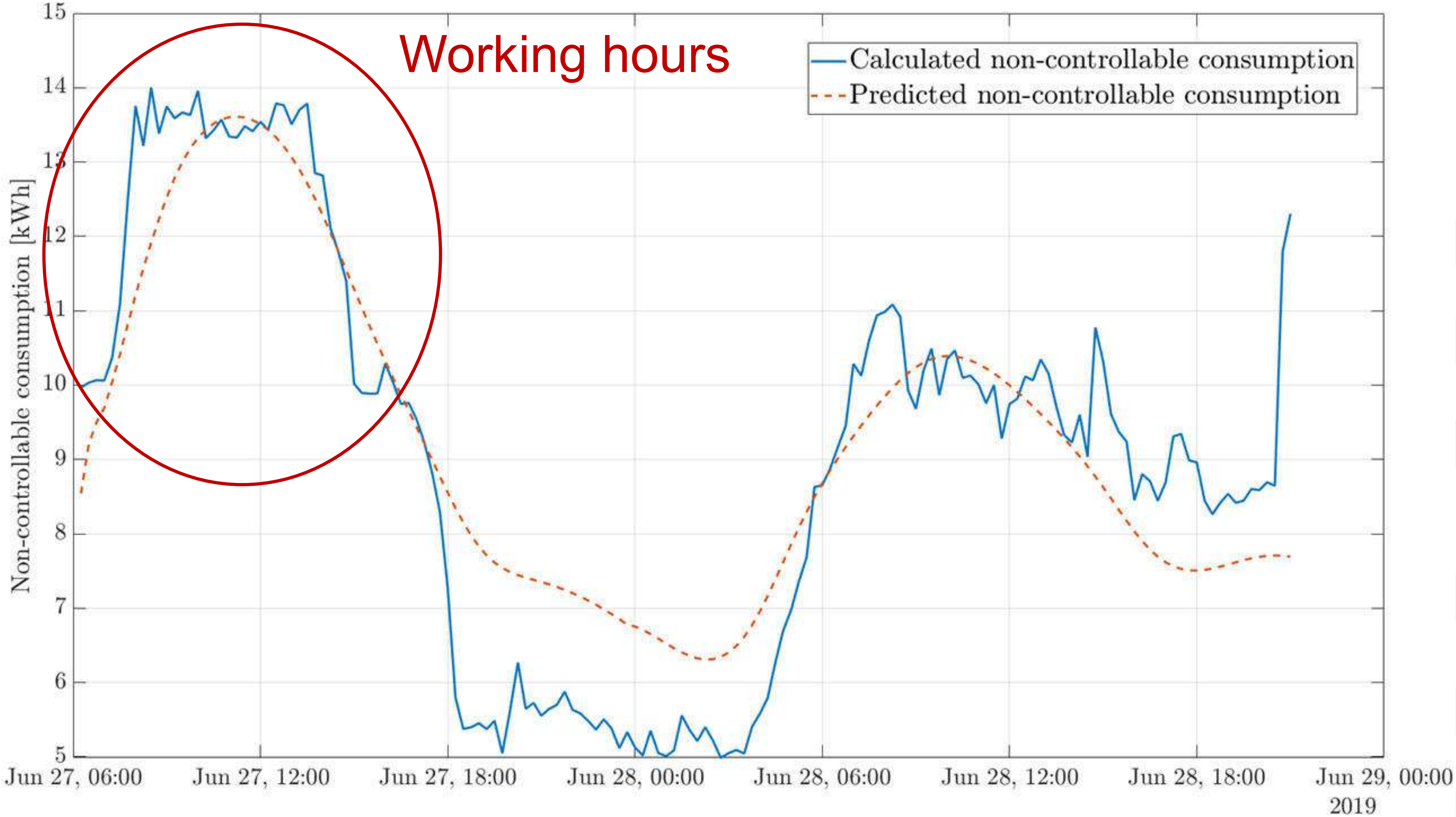
M PE 4 – example of historical consumption



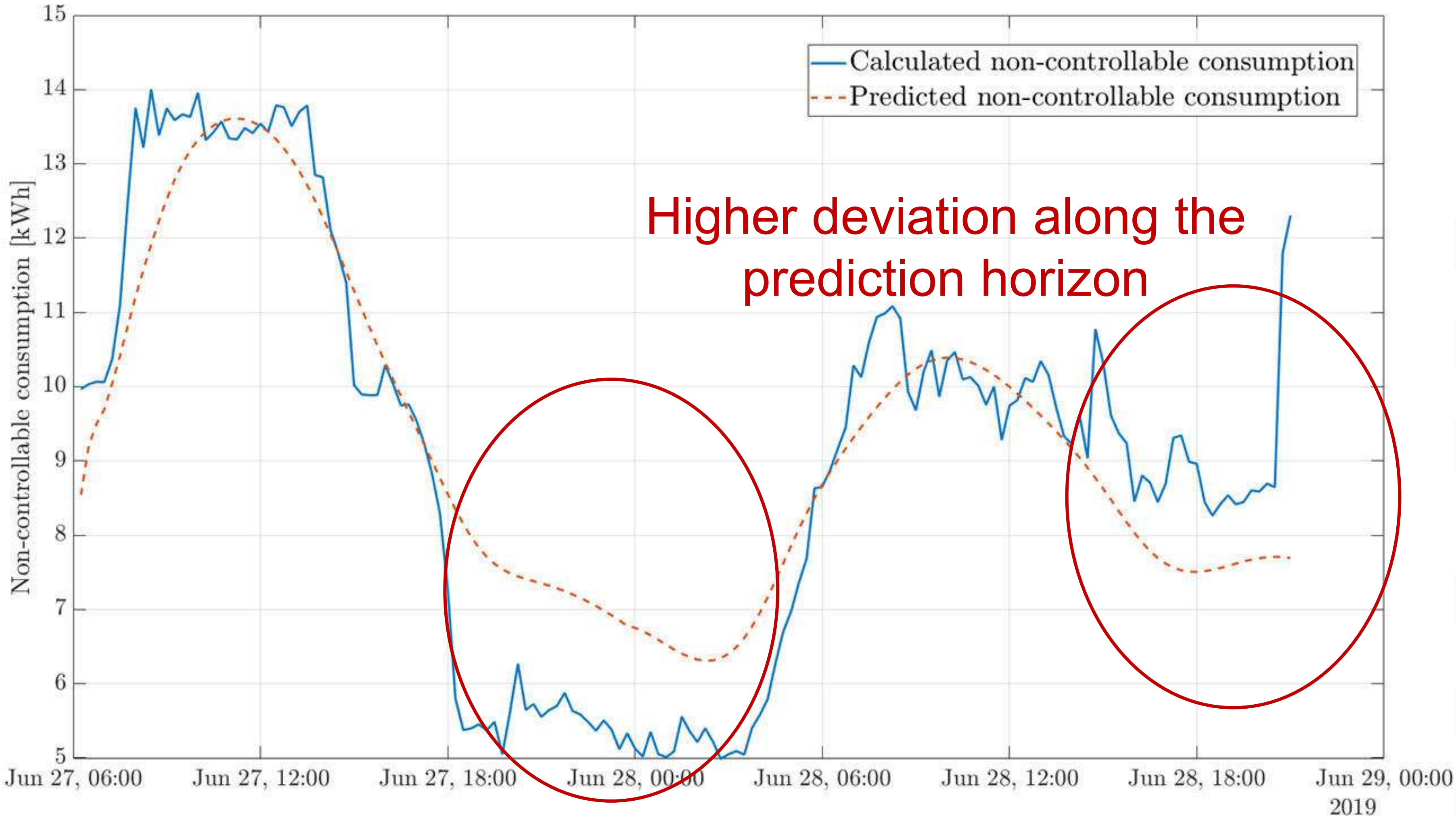
M PE 4 – primjer generirane predikcije (27.06. 08:00)



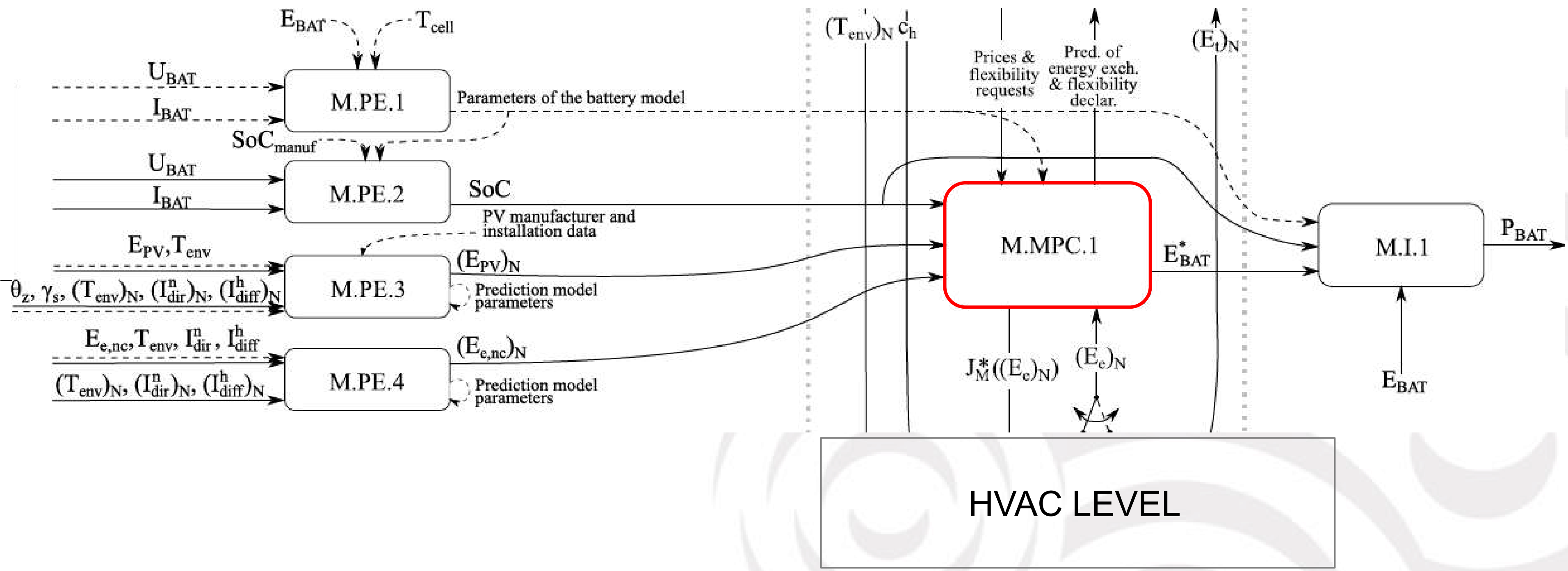
M PE 4 – example of generated predictions



M PE 4 – example of generated prediction



M MPC 1


E_{BAT}
T_{cell}
U_{BAT}
I_{BAT}
M.PE.1
Parameters of the battery model
SoC_{manuf}
U_{BAT}
I_{BAT}
M.PE.2
SoC
PV manufacturer and installation data
E_{PV}, T_{env}
$\theta_z, \gamma_s, (T_{env})_N, (I^n_{dir})_N, (I^h_{diff})_N$
M.PE.3
$(E_{PV})_N$
Prediction model parameters
$E_{e,nc}, T_{env}, I^n_{dir}, I^h_{diff}$
$(T_{env})_N, (I^n_{dir})_N, (I^h_{diff})_N$
M.PE.4
$(E_{e,nc})_N$
Prediction model parameters
$(T_{env})_N$ c_h
Prices & flexibility requests
Pred. of energy exch. & flexibility declar.
$(E_t)_N$
M.MPC.1
E^*_{BAT}
$J^*_M((E_e)_N)$
$(E_e)_N$
M.I.1
P_{BAT}
E_{BAT}
HVAC LEVEL

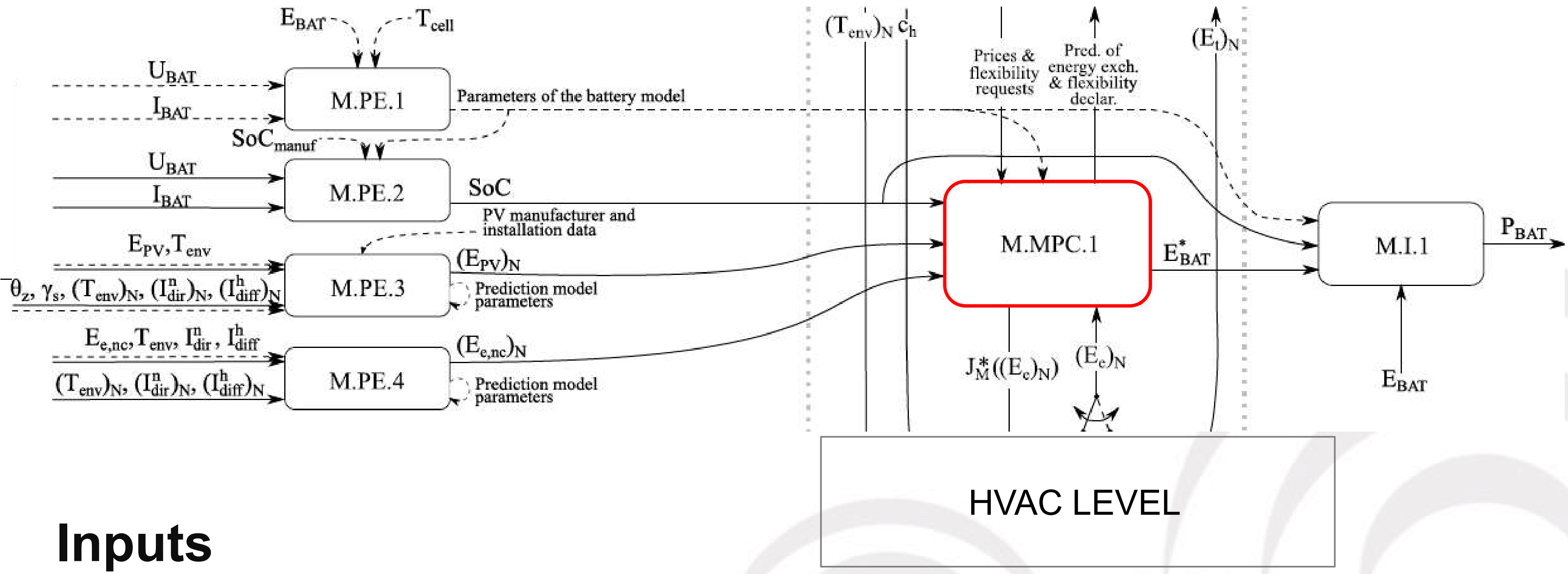
M MPC 1 – provision of flexibility service

- Long-term flexibility reservation
  - Intervals of flexibility, reserved power
  - Off-line computation
- Activation of flexibility must be within the frame of the long-term contract!
  - Day-ahead activation – announced day ahead, for the whole prediction horizon (for tomorrow)
  - Intra-day activation – for few next coming 15-min intervals
  - Penals for not fulfilling the activation request

M MPC 1 – schedule of execution of the short-term module

- Before the prices arrive for next day:
  - Computation of informative consumption profile
- After electricity prices have arrived:
  - Computaation of day-ahead declared cosnumption profile (binding, reference profile for flexibility!)
- Every 15 minutes:
  - acception of flexibility requests
  - ensuring to fulfill the grid requirements and the declared consumption profile
  - price-optimal microgrid operation
  - **command computation**

M MPC 1 – data flow



Inputs

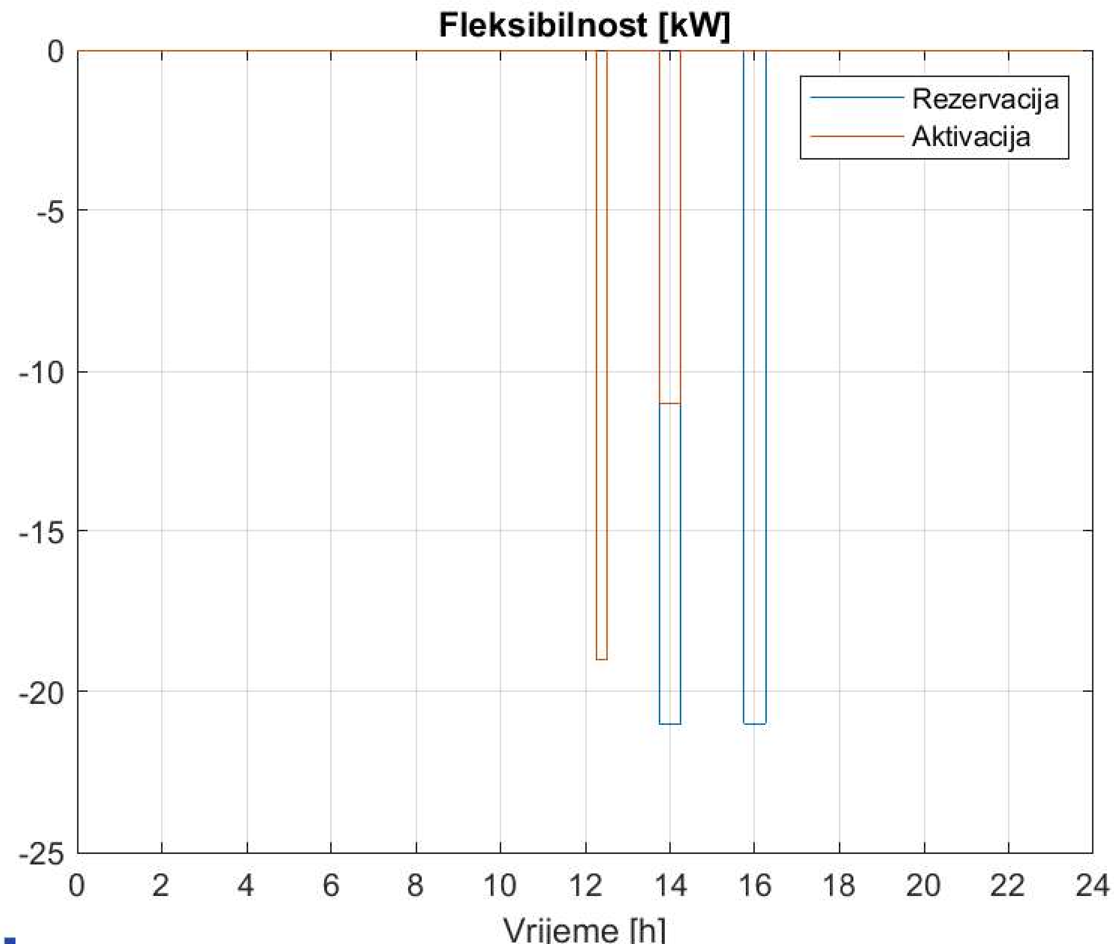
- Predicted non-contr consumption
- Predicted central HVAC level consumption
- Estimated battery model
- Battery measurements
- Prices and grid requests

Outputs

- Power reference → battery
- Coordination data → HVAC
- Prediction of consumption → grid

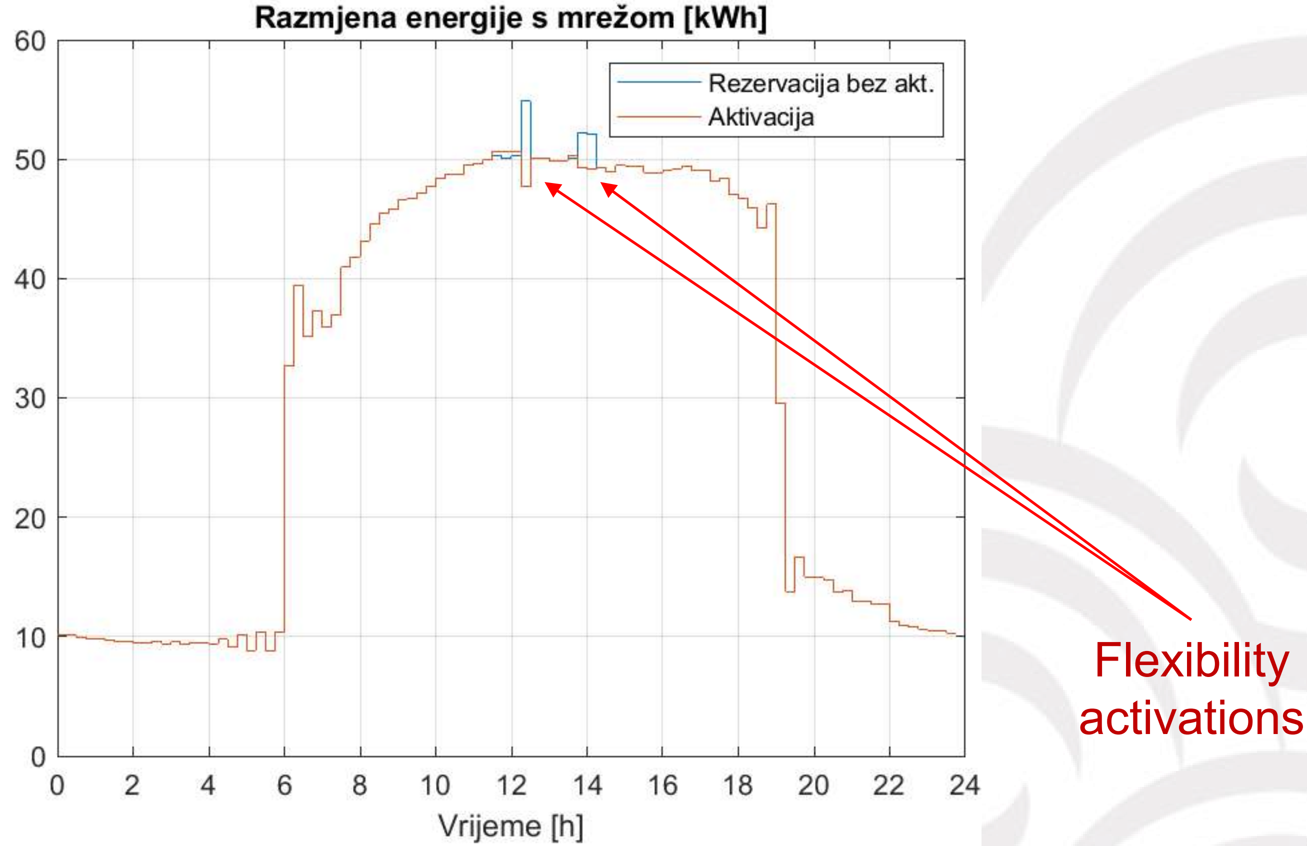
M MPC 1 – results of short-term activation

- Activated flexibility



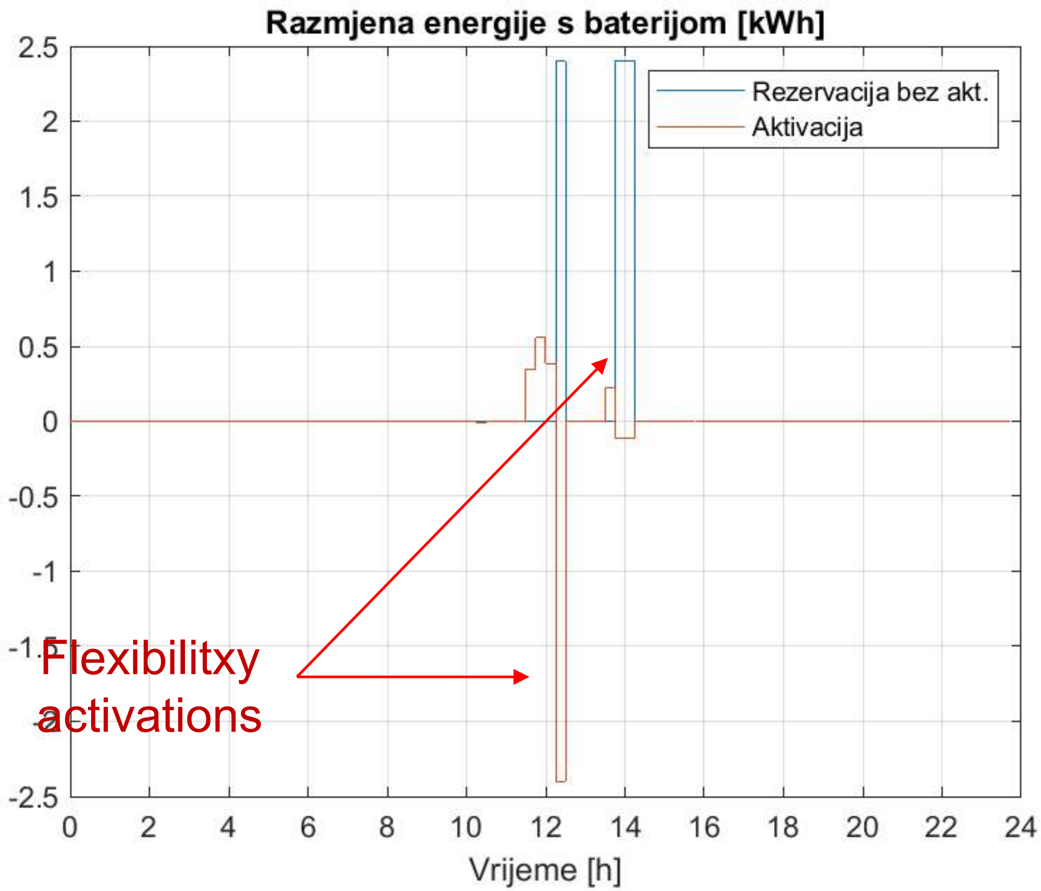
M MPC 1 – results of short-term computation

- Energy exchange with the grid – declared profile and profile with activation

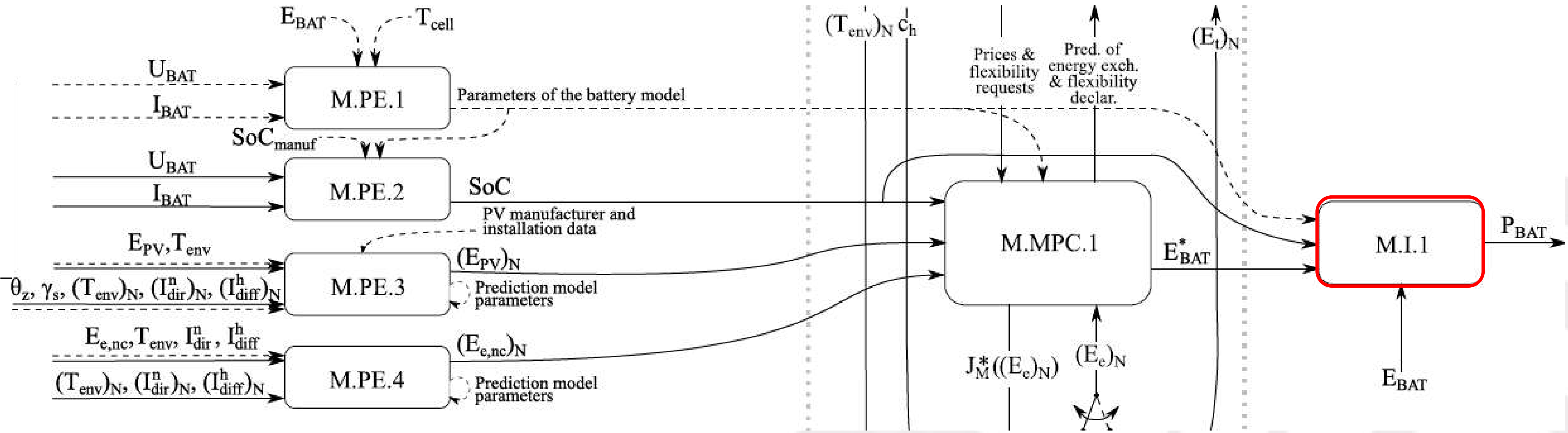


M MPC 1 – results of short-term computation

- Energy exchange with the battery system



Battery system interface module (M I 1)



- Execution every minute
- Additional control loop – ensuring to fulfill the energy request posed for energy exchange with the battery system

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.3.1

Transnational training materials – Pilot study visits to Slovenia – Pilot study visit No. 2

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
Project Start Date	1 January 2017
Project Duration	30 months
Work Package	6
Task	6.3
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 23 December 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, E3, IDRIJA, ElektroP, EON, UNIBGFME, SVEMOFSR
Authors (Partners)	Mario Vašak, Tomislav Capuder, Vinko Lešić, Anita Martinčević, Hrvoje Novak, Danko Marušić, Nikola Hure, Paula Perović (UNIZGFER), Marko Baša, Alan Križaj (E3), Tadej Rupnik (IDRIJA), Nina Carli (ElektroP), Gabor Peter (EON), Vladimir Jovanović, Nebojša Manić (UNIBGFME), Ivan Bevanda, Petar Marić (SVEMOFSR)
Contact person	Tadej Rupnik (IDRIJA)
Abstract (for dissemination)	This document contains the minutes of the second study visit to the Slovenian pilot in 3Smart. The pilot consists of a pilot building which is primary school and sports centre in Idrija and the pilot electricity distribution grid around the building. On the pilot study visits the pilot leaders and hosts together with developers for different modules on the pilot site have performed demonstration to the consortium of functioning of different installations performed on the pilot and of the installed 3Smart modules.
Keyword List	building-side energy management system, grid-side management, pilot installations, 3Smart IT environment, 3Smart database

Revision history

Revision	Date	Description	Author (Organization)
v1.0	23 December 2019	Prepared materials from the second pilot study visit in the presentation form	Mario Vašak (UNIZGFER)

Table of Contents

Executive summary

The 3Smart project deals with transnational development of integrated energy management of buildings and energy distribution grids in real time. To substantiate knowledge transfer between partners, to synchronize developments and demonstrate the installation procedure to developers, pilots leaders and pilots hosts, a series of transnational trainings is organized, first for getting acquainted with the software modules for energy management, and then for getting acquainted with performed pilot installations and modules operation on the pilot site.

This deliverable provides minutes and materials from the pilot study visits to the 3Smart pilot in Slovenia that consists of the primary school and sports centre building in Idrija and of the electricity distribution grid around the building. The visits were split in two parts for each pilot site – this first part of the deliverable for the Slovenian pilot site concerns the second pilot study visit.

1. Minutes from the second pilot study visit to the 3Smart pilot in Slovenia

Venue: Idrija Municipality Administration, Mestni trg 1, Idrija – Municipal Hall

Date: 13 November 2019 (Wednesday)

Time	Place	Event
09:00-11:00	Municipal Hall in the First floor	**Session No. 1**
11:00-11:15	Municipal Hall in the First floor	Coffee break
11:15-13:00	Municipal Hall in the First floor	**Session No. 2**
13:00-14:00	Gostilna Škafar; Ulica sv. Barbare 9, Idrija	Lunch
14:00-15:00	Municipal Hall in the First floor	**Session No. 3**
15:00-15:15	Municipal Hall in the First floor	Coffee break
15:15-17:00	Municipal Hall in the First floor	**Session No. 4**
20:00-22:00	Restaurant	Working dinner

More details on individual sessions:

Session No. 1

After presentation of the pilot current status given by pilot leaders and hosts, the pilot study visit focussed on performance of the 3Smart modules in comparison with the conventional control. First the performance on the zone level was discussed. The presentation is given in Annex 1.

Session No. 2

Session 2 continued with the discussion of the performance on the zone level, and then it was continued with the discussion of the 3Smart modules performance on the central HVAC level. The presentation on this part is also contained in Annex 1.

Session No. 3

Session 3 continued with the discussion of the performance on the microgrid level which is on Idrija very specific as it joins the heating energy and electricity flows. The presentation on the microgrid part is also given in Annex 1.

Session No. 4

Session 4 was used for discussion on the results obtained and preparation of the tommorow's public presentation.

Annexes

Annex 1: 3Smart system performance on pilot.

IDRIJA 3Smart model predictive control modules performance

Mario Vašak, Anita Martinčević, Nikola Hure, Danko Marušić, Hrvoje Novak

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SLO pilot study visit No. 2

Idrija, 14 November 2019

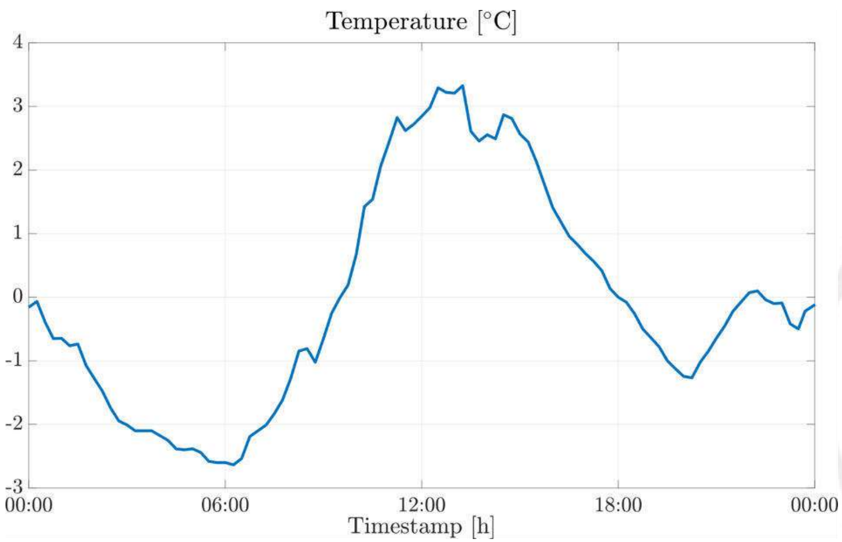
Project co-funded by the European Union

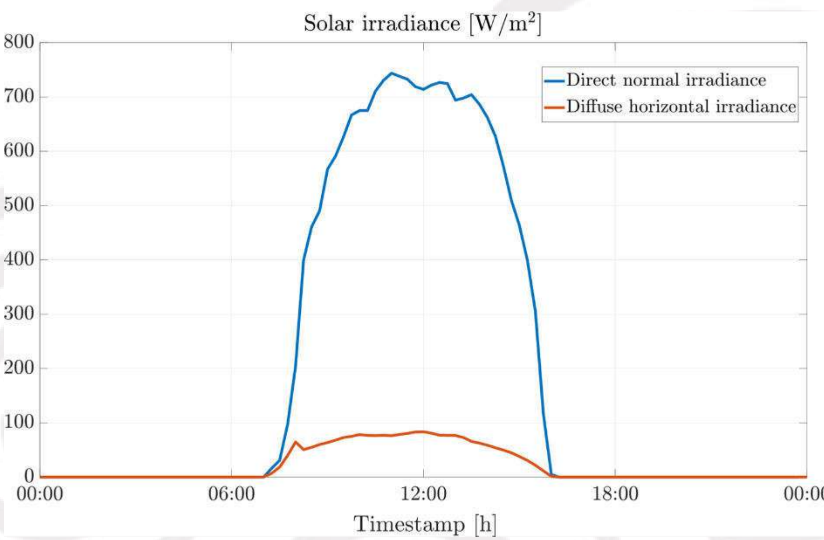
Planning of daily operation and Long-term contracting

- LT calculation performed for typical days in a month
- Typical weather conditions; non-controllable consumption deduced or extracted from historical data
- Accounted flexibility request from the grid
- Must be repeatable: building should be planned to be in the same state at the beginning and at the end of the day
- Computations for Idrija buildings in november and june, sunny work day

Meteorological data

- Environment temperature, direct and diffuse irradiance profile for an average sunny workday in November

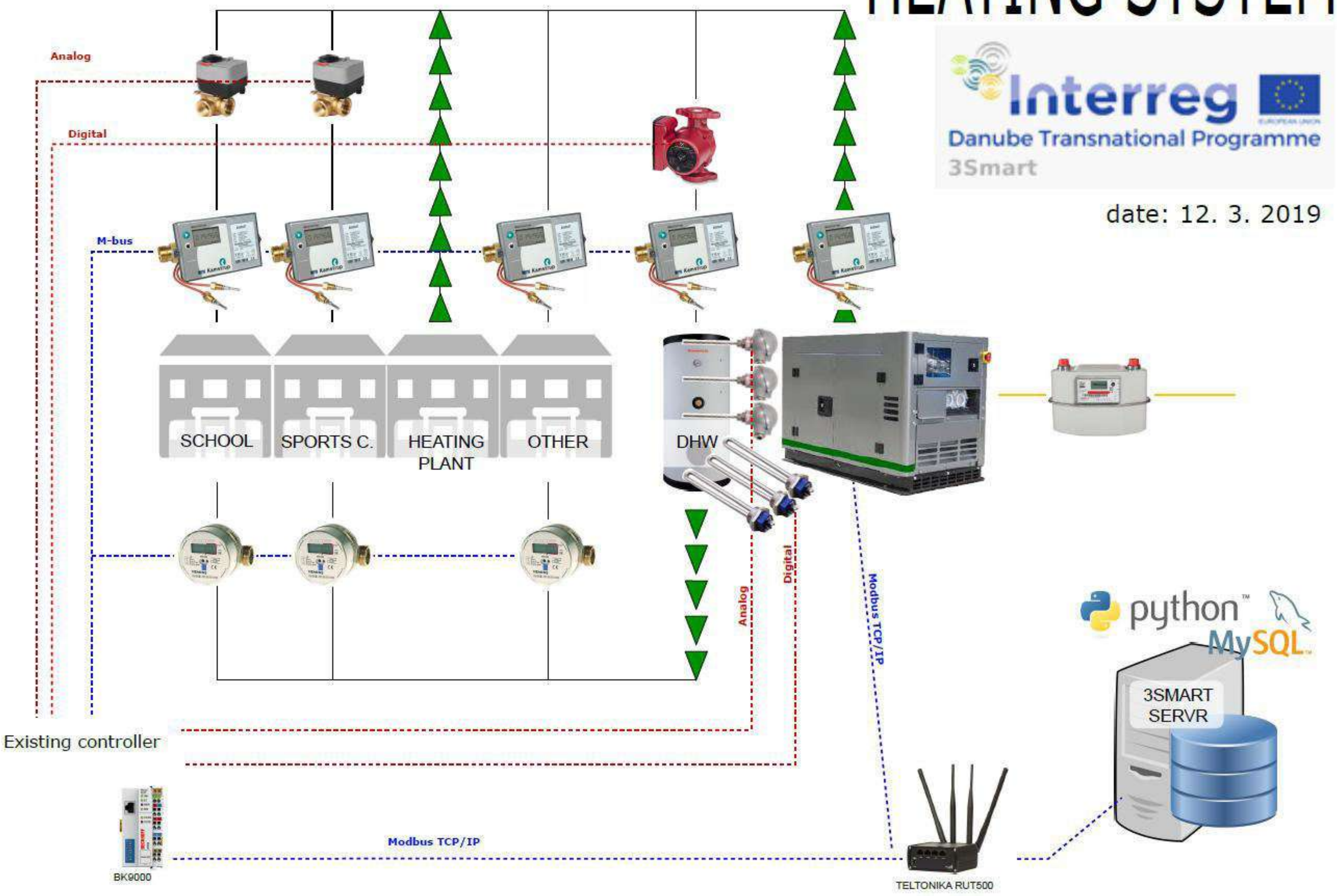




HEATING SYSTEM

Interreg
Danube Transnational Programme
3Smart

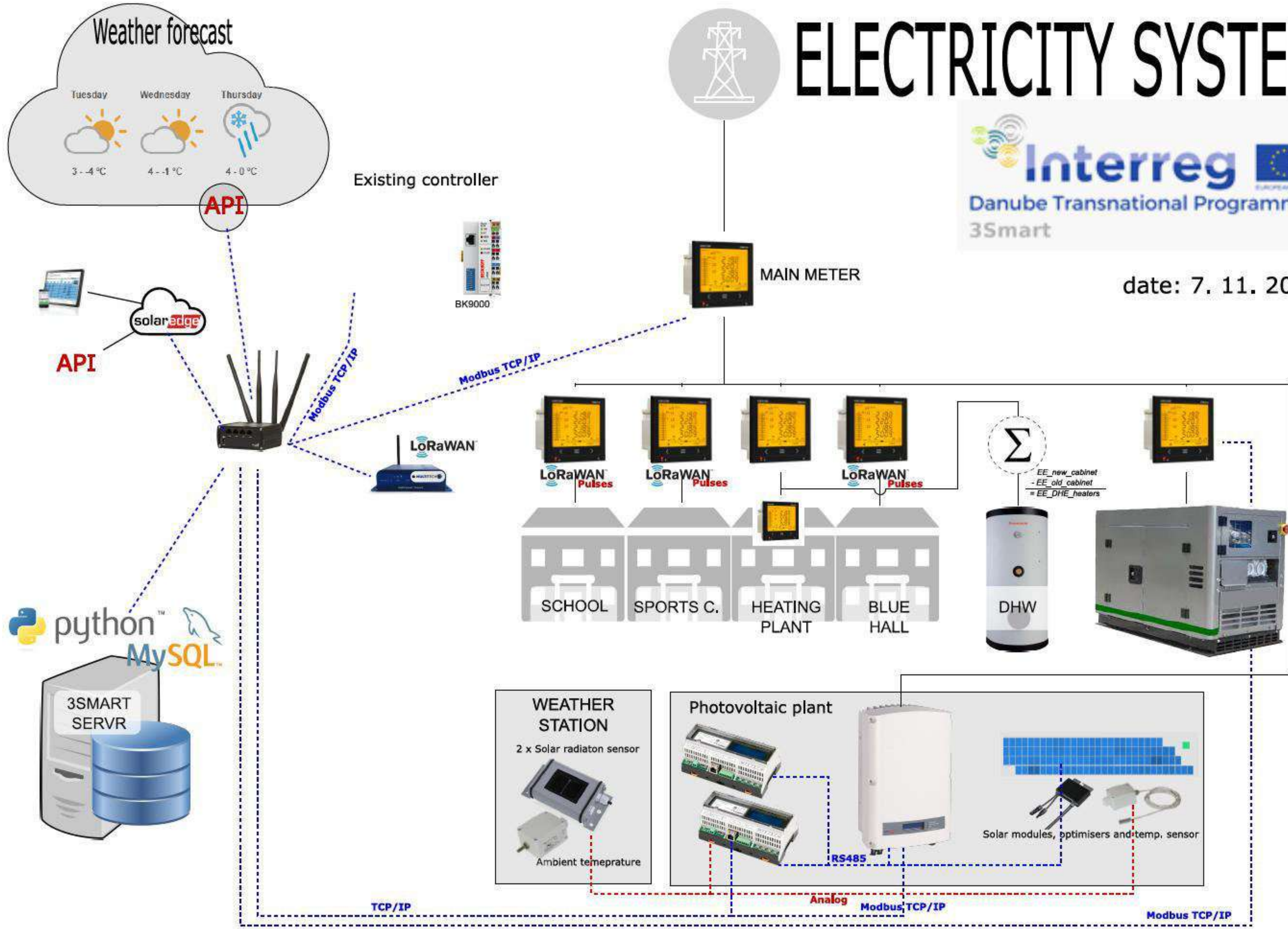
date: 12. 3. 2019



ELECTRICITY SYSTEM

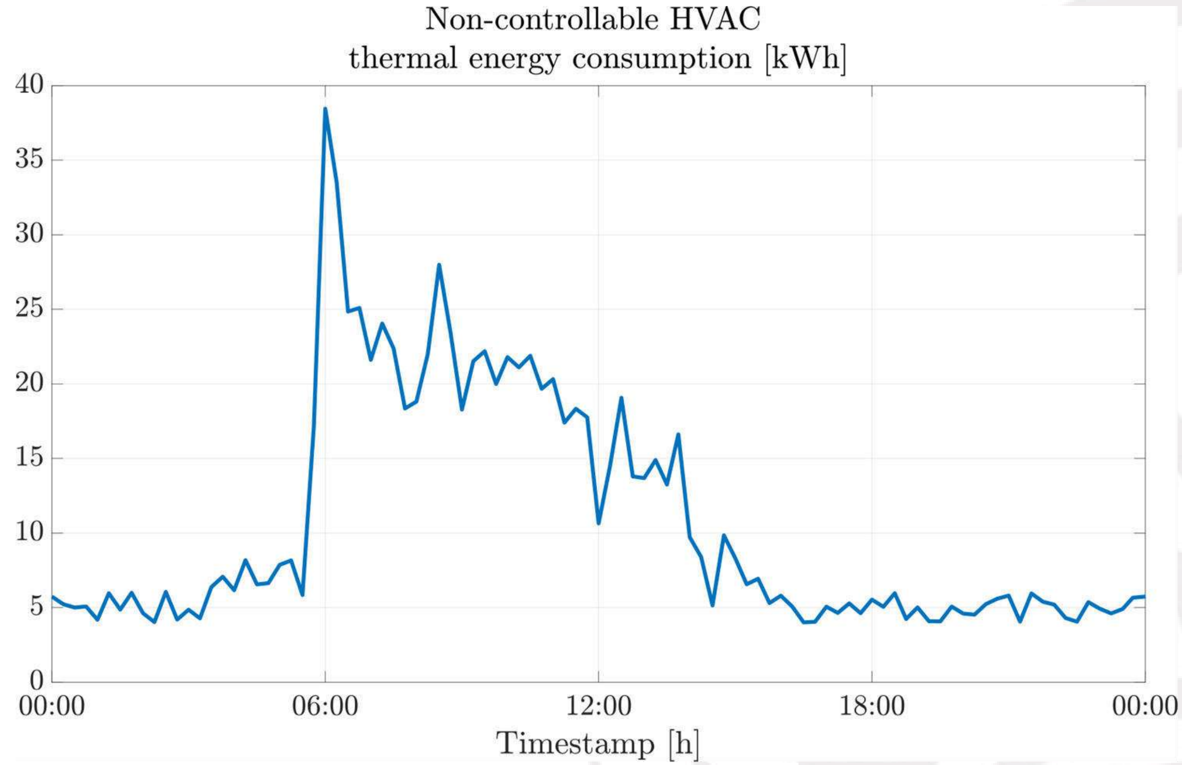
Interreg
Danube Transnational Programme
3Smart

date: 7. 11. 2019



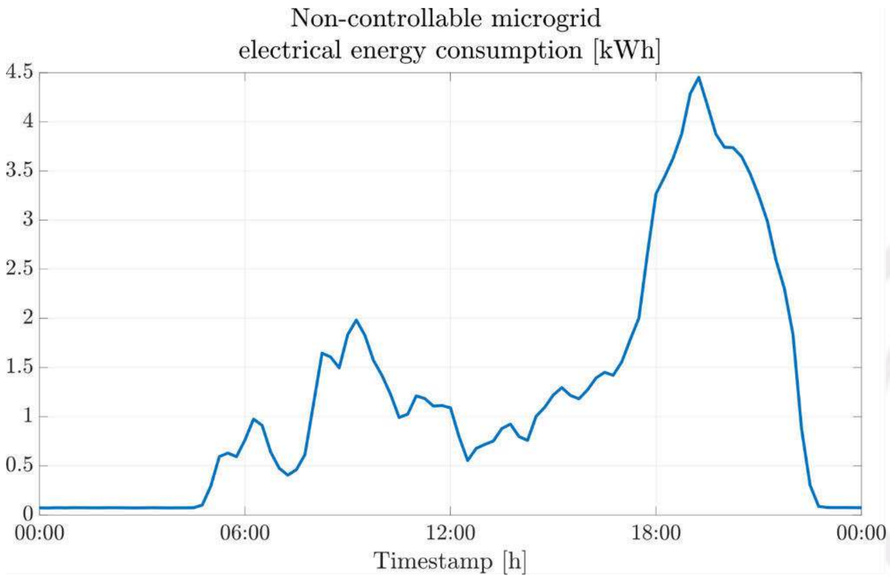
Non-controllable consumptions data - 1

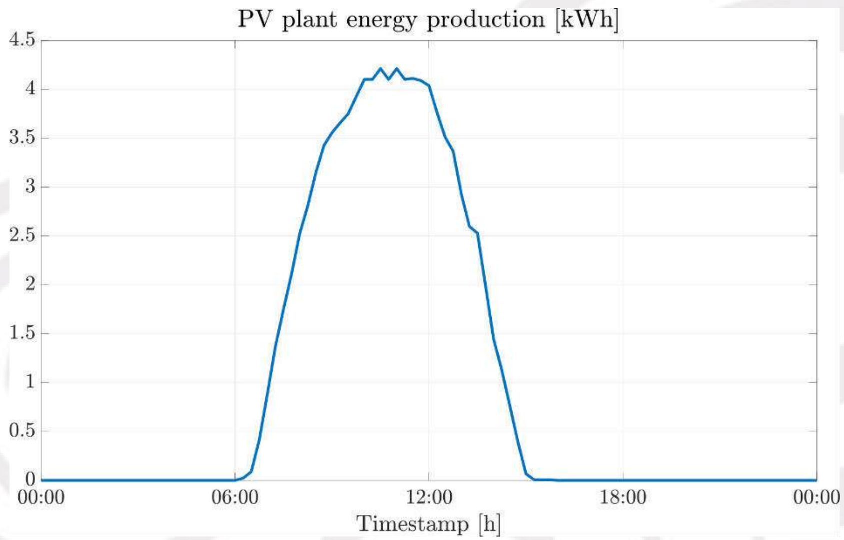
- Non controllable thermal consumption of school and SC for an average sunny workday in November



Non-controllable consumptions data - 2

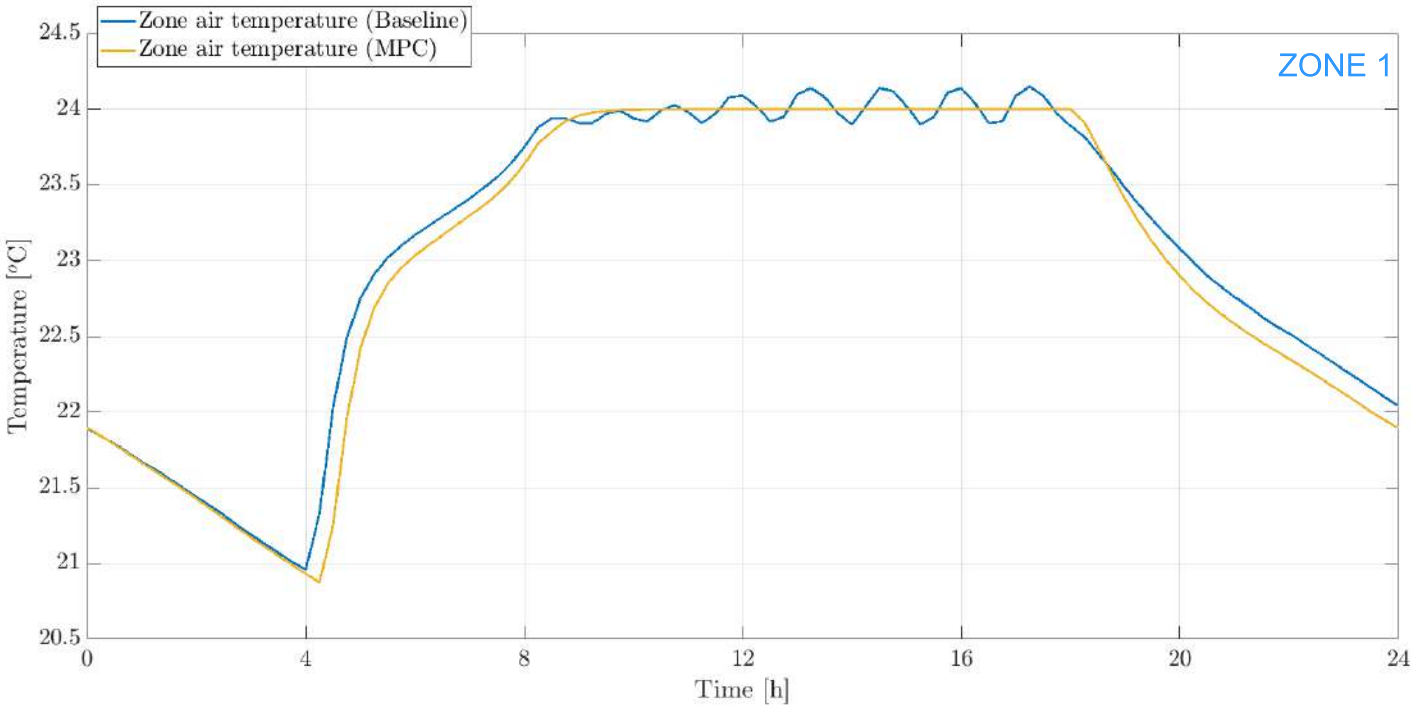
- Microgrid (electrical) level for an average sunny workday in November





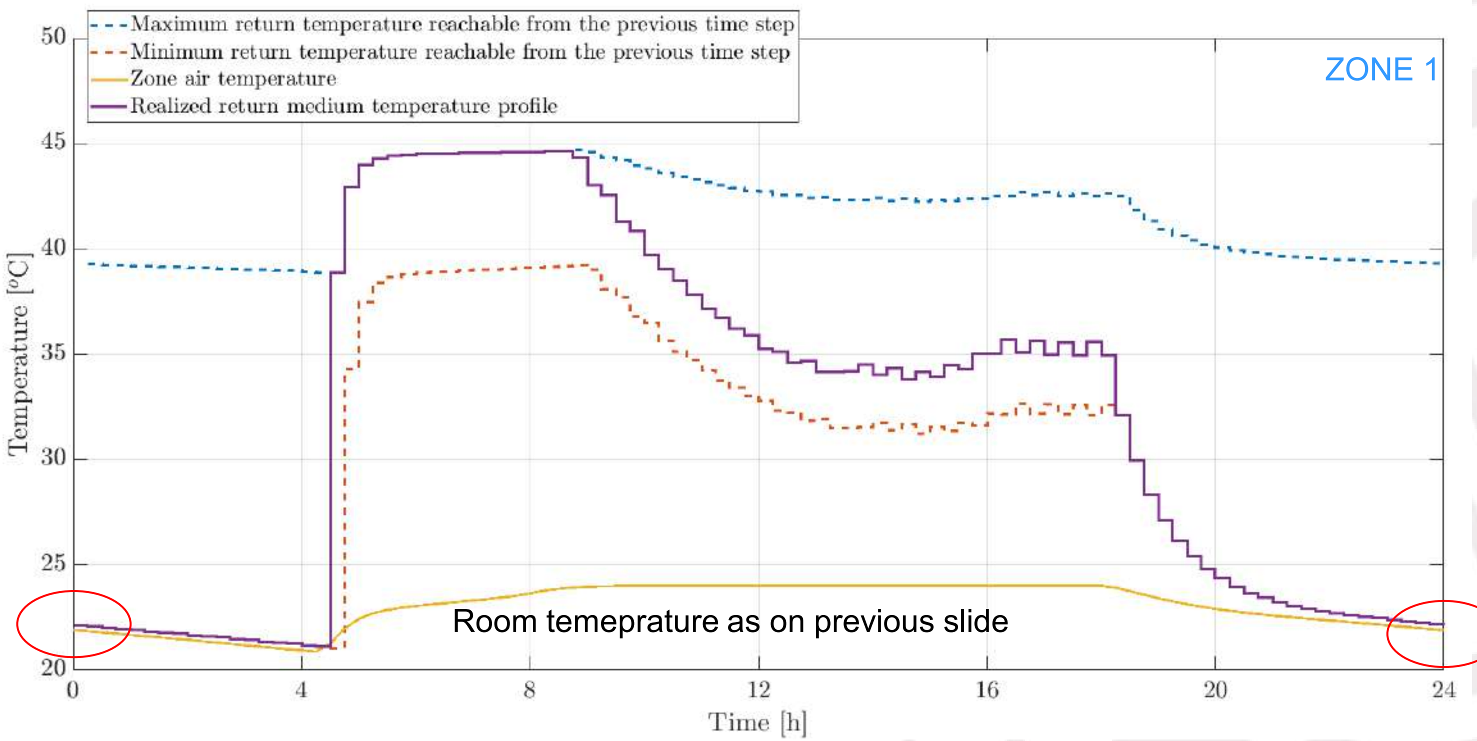
Daily planning of operation on zones level - 1

- COMFORT CONSTRAINTS
  - temperature within 24±0.5°C in interval from 8:00 h to 18:00 h
  - Baseline controller operates on fixed schedule – it starts at 4:00 h to heat up the zones until 8:00 h. (Valve opening proportional to temperature deviation from setpoint).
  - MPC controller decides on its own how early before 8:00 h the heating should start to meet the required comfort demands at 8:00 h



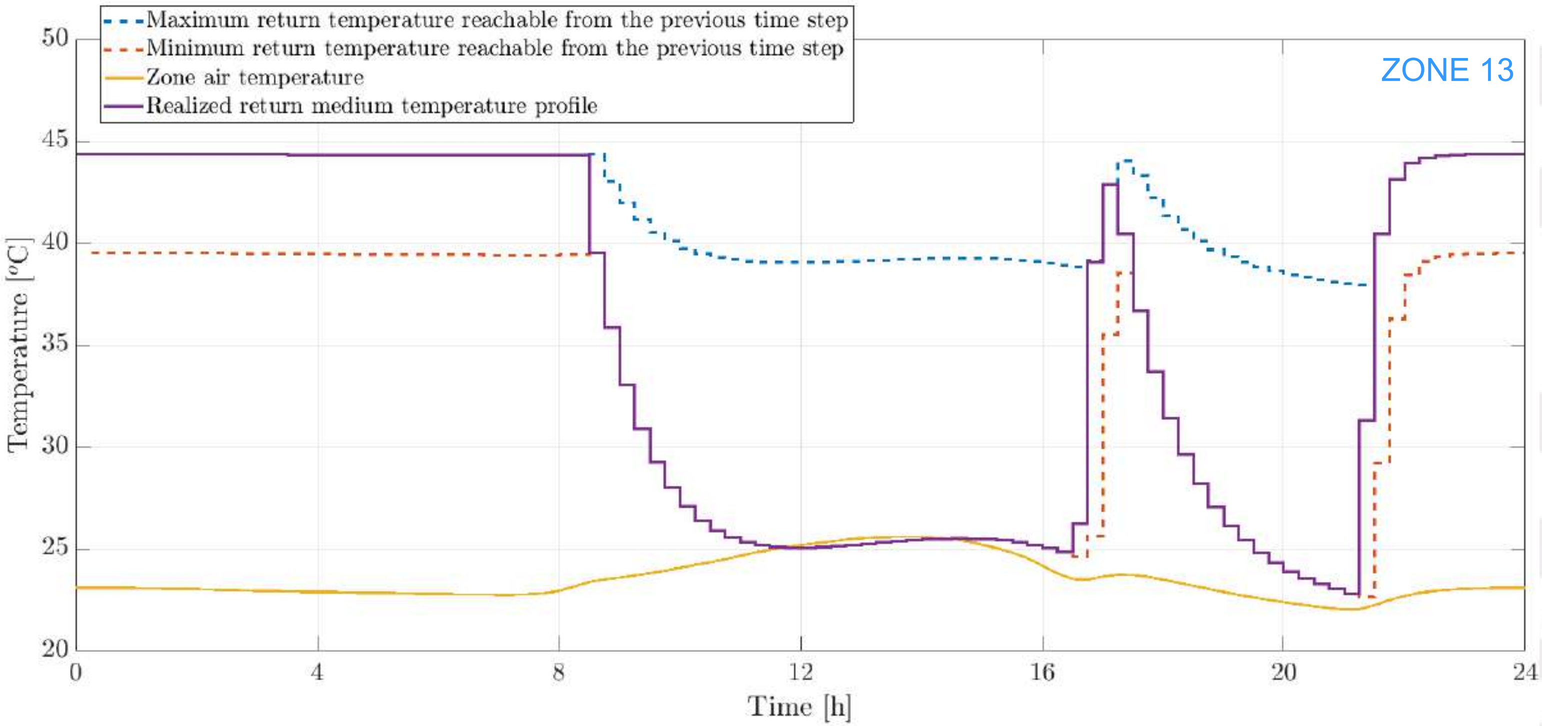
Daily planning of operation on zones level - 2

- OPERATION CONSTRAINTS WHICH ENSURE REPEATABILITY
  - zone air temperate and radiator return medium temperature at 0:00 h has to be the same to the temperature at the end of the planning horizon at 24:00 h
- PHYSICAL RADIATOR CONSTRAINTS
  - Radiator return medium temperature in the next step is limited with temperatures reachable from the current step with fully opened and fully closed valve



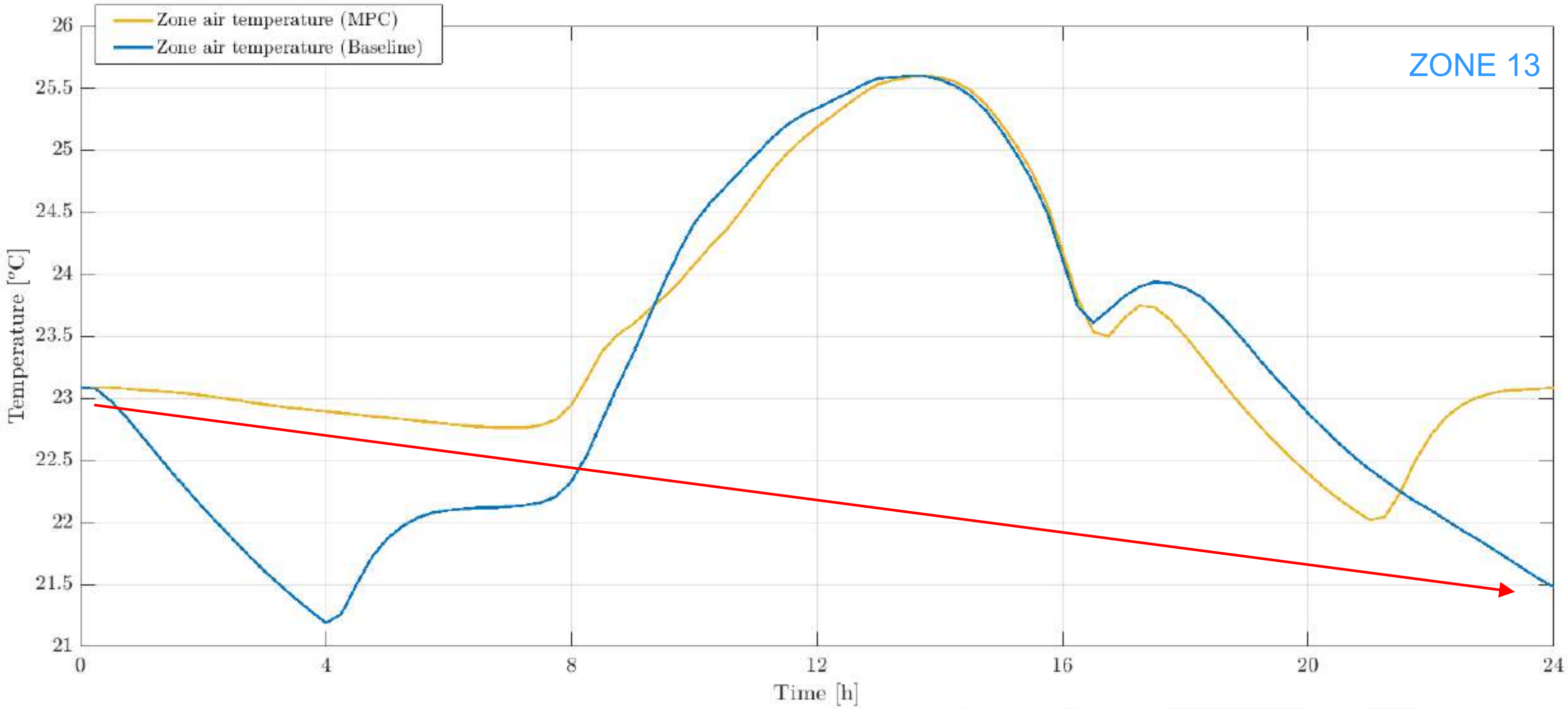
Daily planning of operation on zones level - 3

- OPERATION CONSTRAINTS WHICH ENSURE REPEATABILITY
  - zone air temperate and radiator return medium temperature at 0:00 h has to be the same to the temperature at the end of the planning horizon at 24:00 h
- PHYSICAL RADIATOR CONSTRAINTS
  - Radiator return medium temperature in the next step is limited with temperatures reachable from the current step with fully opened and fully closed valve

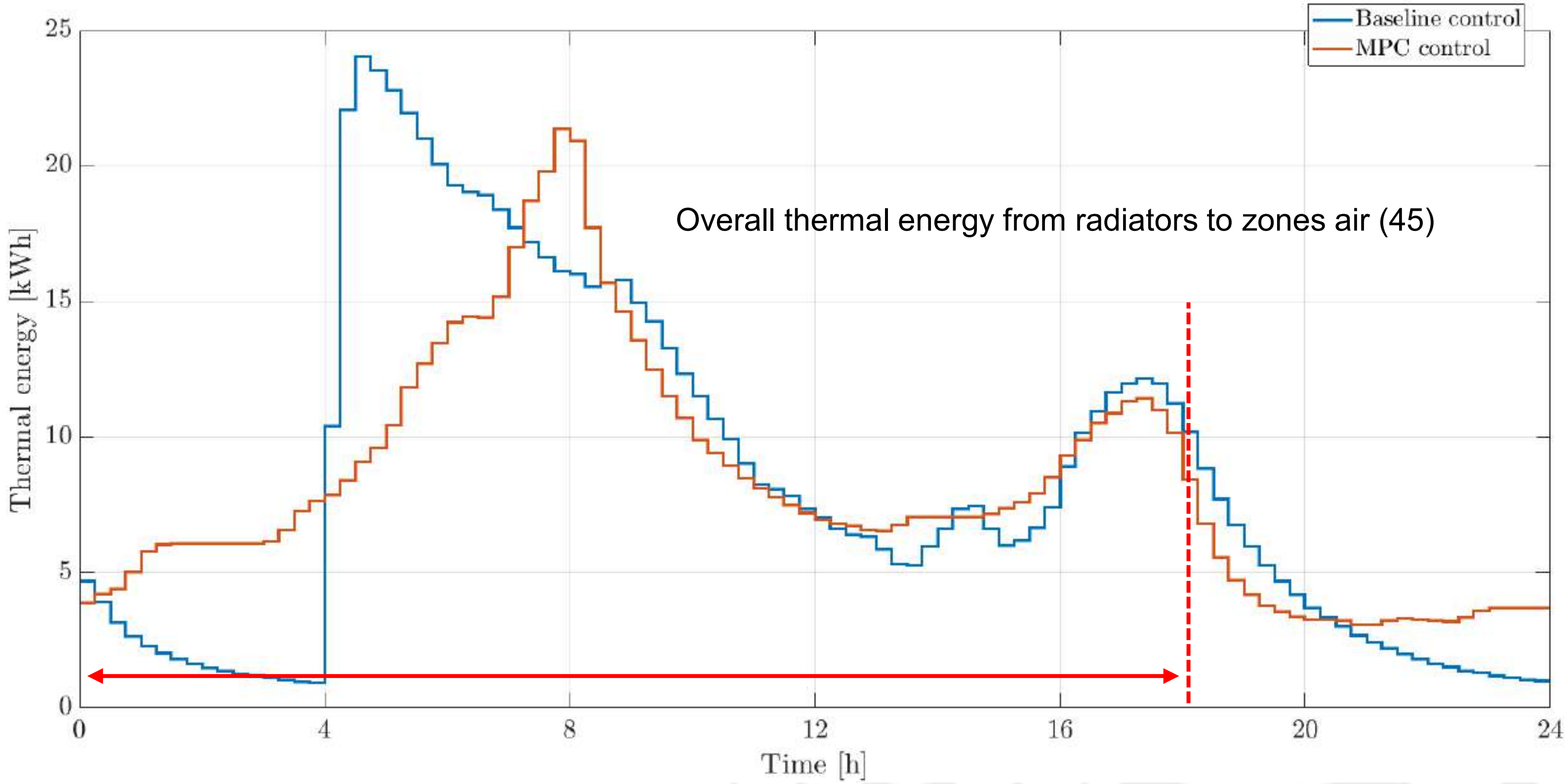


Daily planning of operation on zones level - 4

- OPERATION CONSTRAINTS WHICH ENSURE REPEATABILITY
  - zone air temperate and radiator return medium temperature at 0:00 h has to be the same to the temperature at the end of the planning horizon at 24:00 h
- PHYSICAL RADIATOR CONSTRAINTS
  - Radiator return medium temperature in the next step is limited with temperatures reachable from the current step with fully opened and fully closed valve



Daily planning of operation on zones level - 5

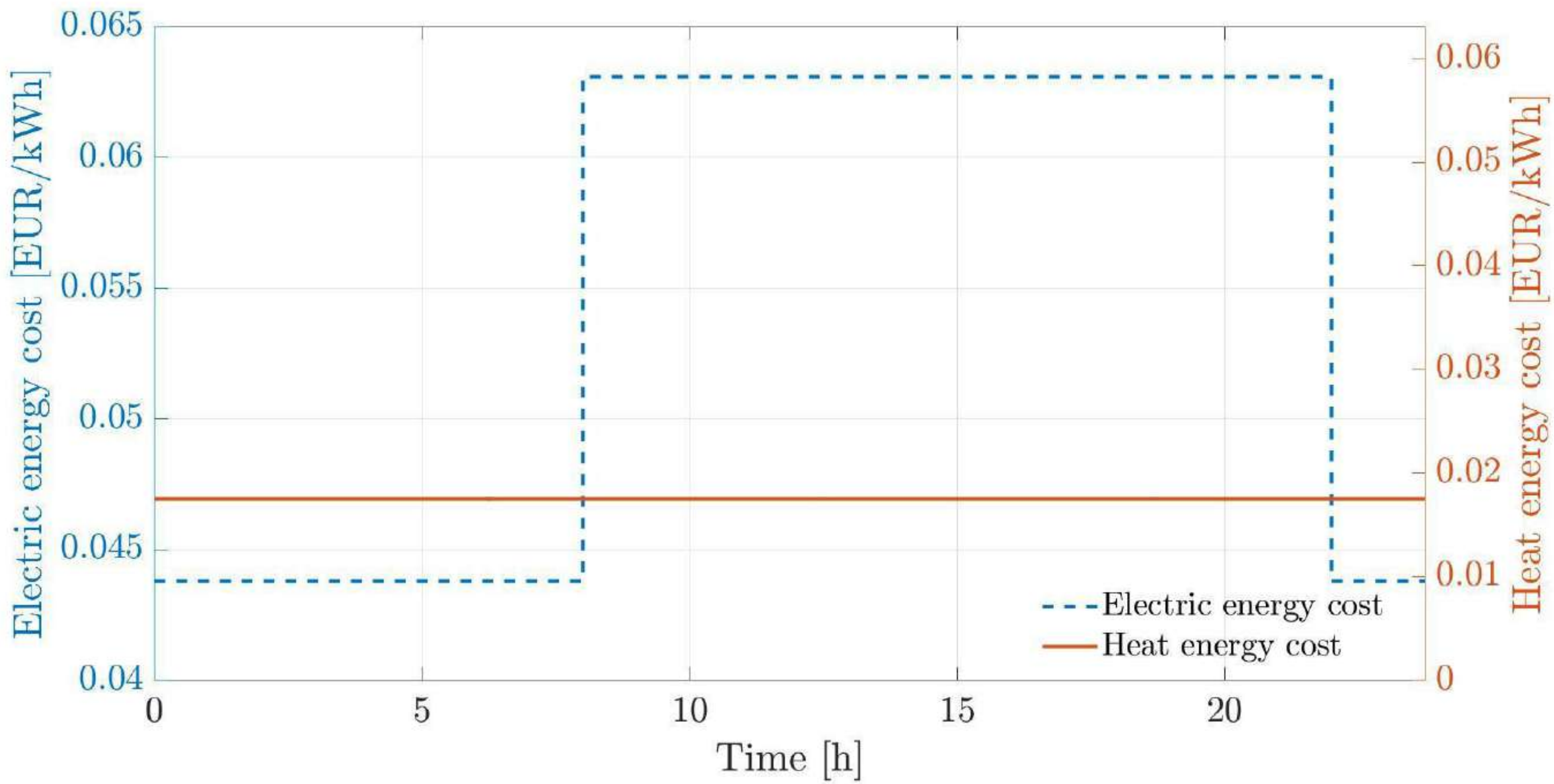


Thermal energy savings: (1.99% in interval from 0:00 h to 18:00 h)

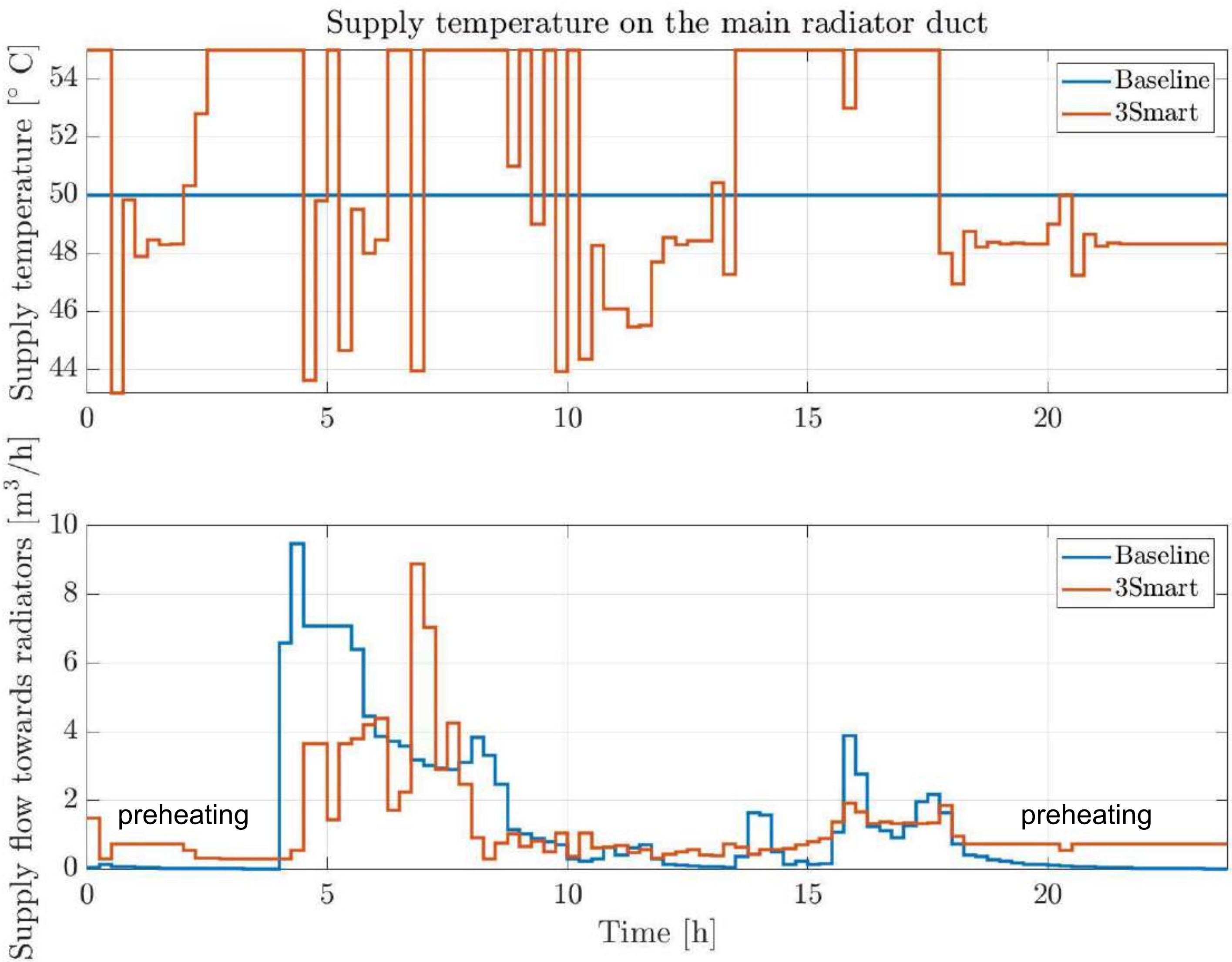
<u>Users' comfort improvement: +10.67%</u>

*Comfort defined as average deviation from SP across all zones during working hours

Daily planning of operation on central HVAC level – 1 (prices)



Daily planning of operation on central HVAC level – 2



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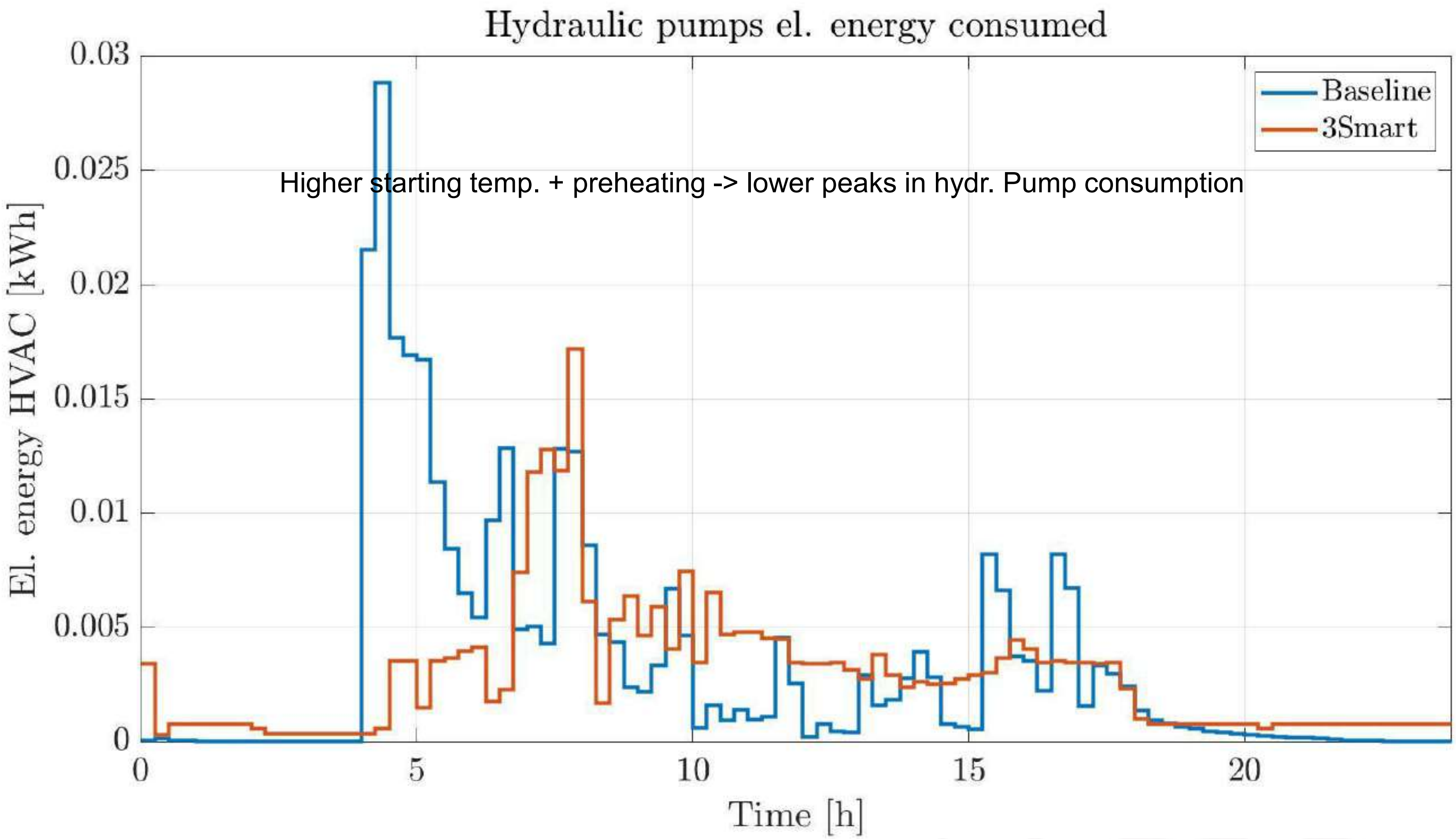
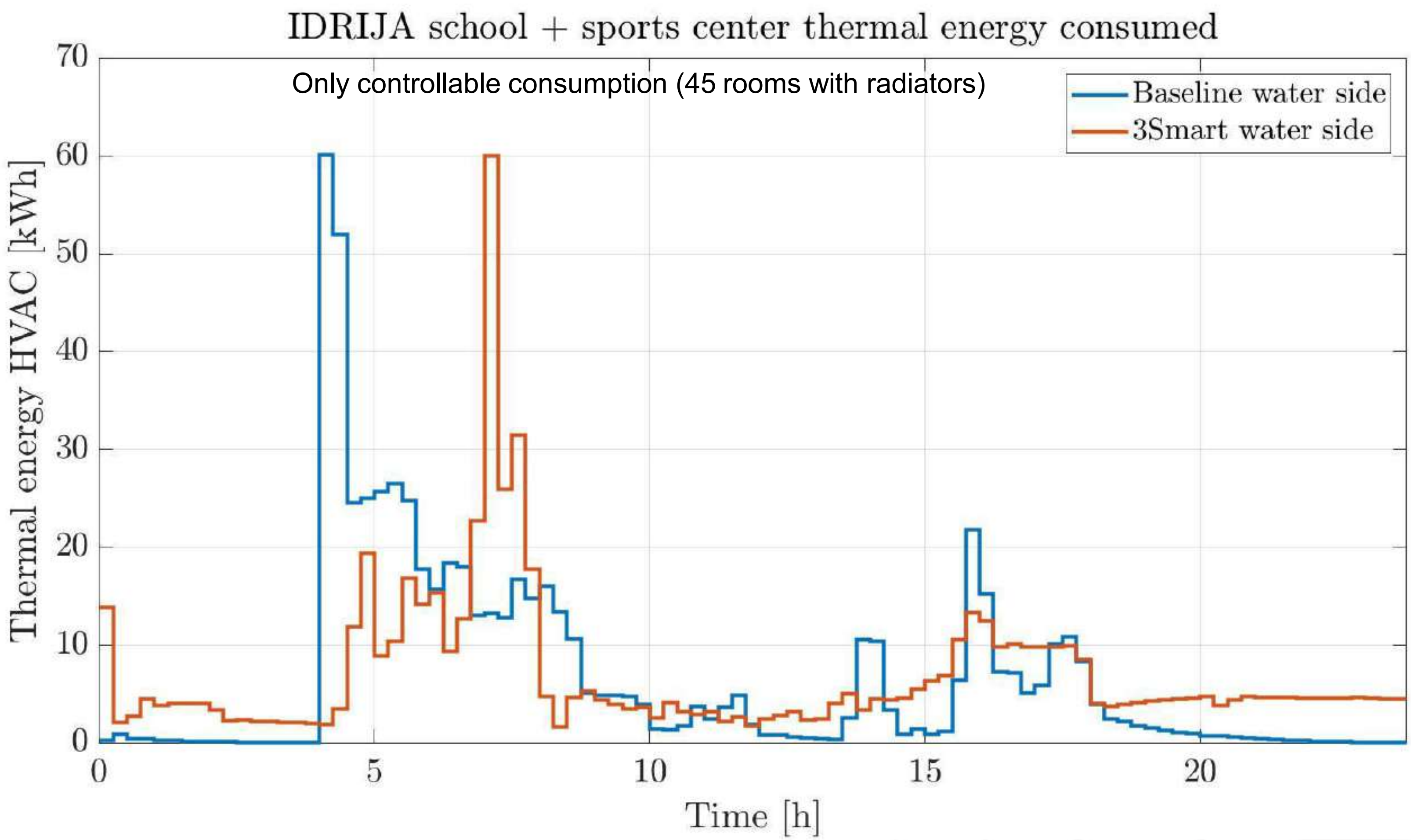
Daily planning of operation on central HVAC level – 3



Daily planning of operation on central HVAC level – 4



Daily planning of operation on central HVAC level – 5 (summary)

	Controllable thermal energy [kWh] 0:00 – 18:00	Controllable electric energy [kWh] 0:00 – 18:00	∑ EUR 0:00 – 18:00
3Smart	556.54 (9.74 EUR)	0.26 (0.0142 EUR)	9.75 (-7.32%)
Baseline	599.54 (10.50 EUR)	0.32 (0.0162 EUR)	10.52

Daily planning of operation on microgrid level - 1

- Microgrid considers main electricity and heat flows for the whole pilot site.
- Scenario for a sunny November workday
- Two-tariff electricity prices
- Returned electrical energy is **not** paid
- Flexibility intervals as required by the grid: 20:30-21:00, 21:15-22:00

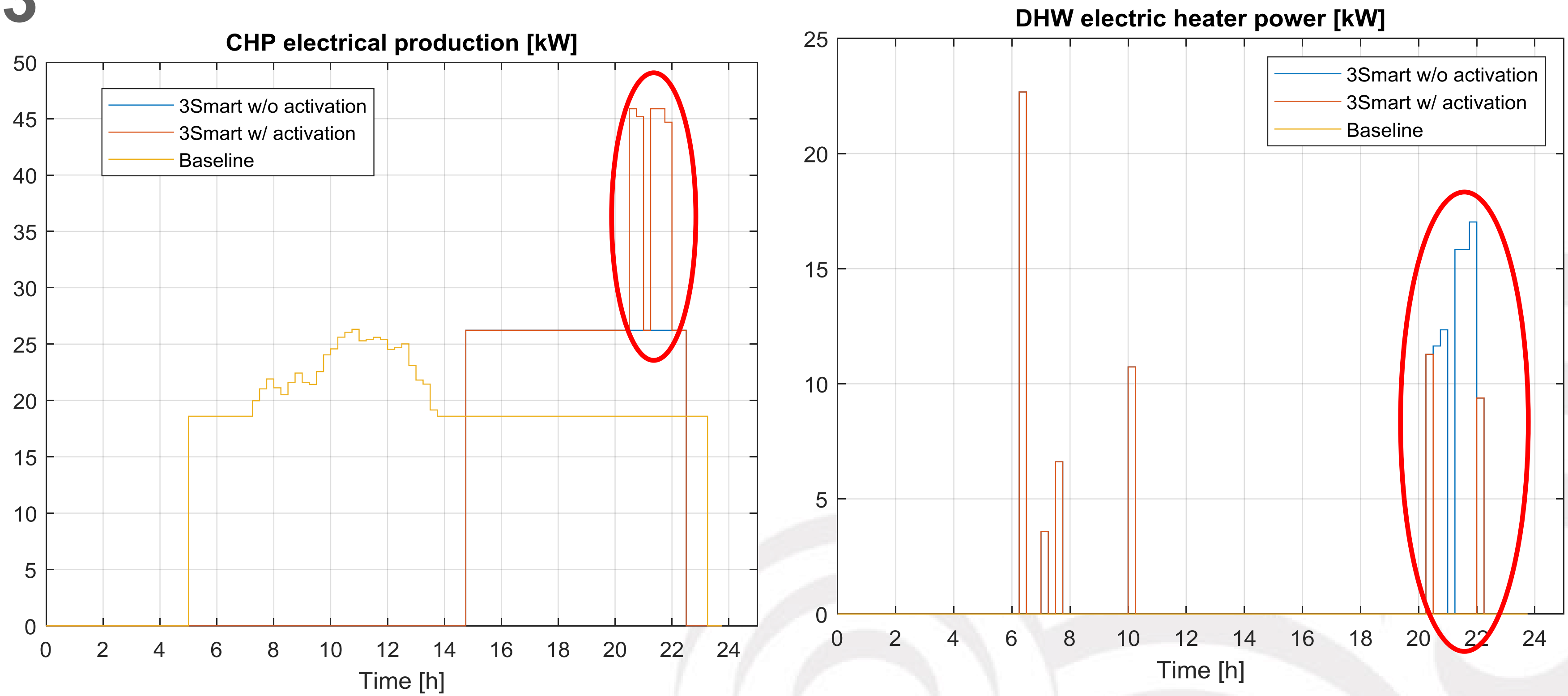
Electricity tariff	Price (€/kWh)	Interval
High	0.0631	07-21
Low	0.0438	21-07

Flexibility reservation reward	0.0793	€/kW/(15min)
Flexibility activation reward	0.3170	€/kWh
Penalty price	0.6340	€/kWh

Daily planning of operation on microgrid level - 2

- Baseline control:
  - Hysteresis control of DHW temperature
    - 45°C setpoint temperature
    - Temperature deviation: +- 5˘C
    - Legionella protection may be included once a week – not included in this scenario
  - CHP working on fixed schedule
    - 05-23h
  - Respecting the operating limits of CHP
    - Minimum operating power: 60% of nominal

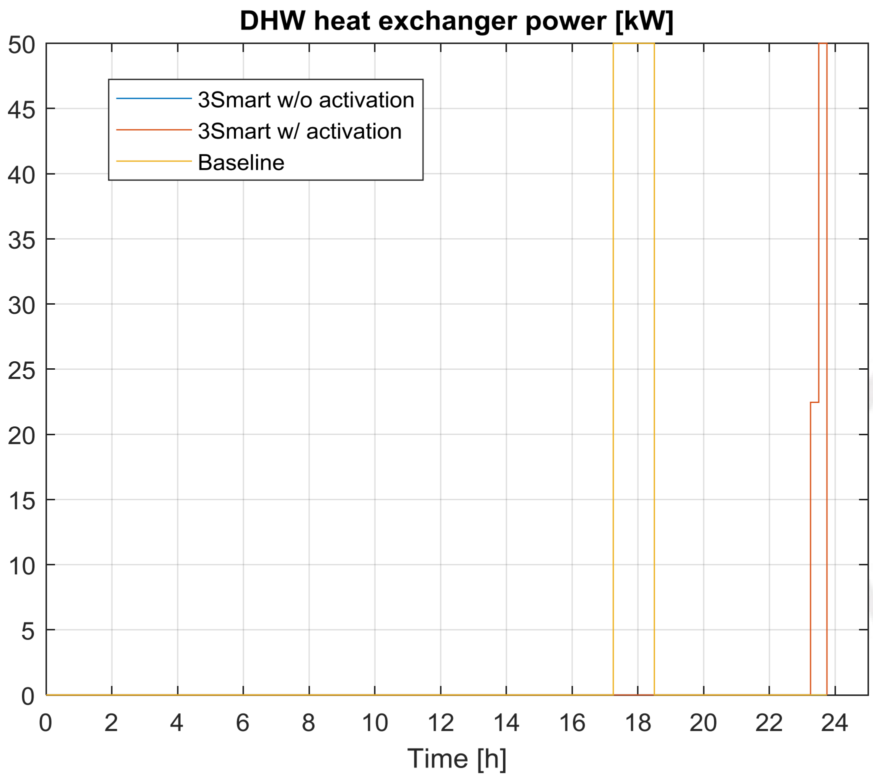
Daily planning of operation on microgrid level - 3

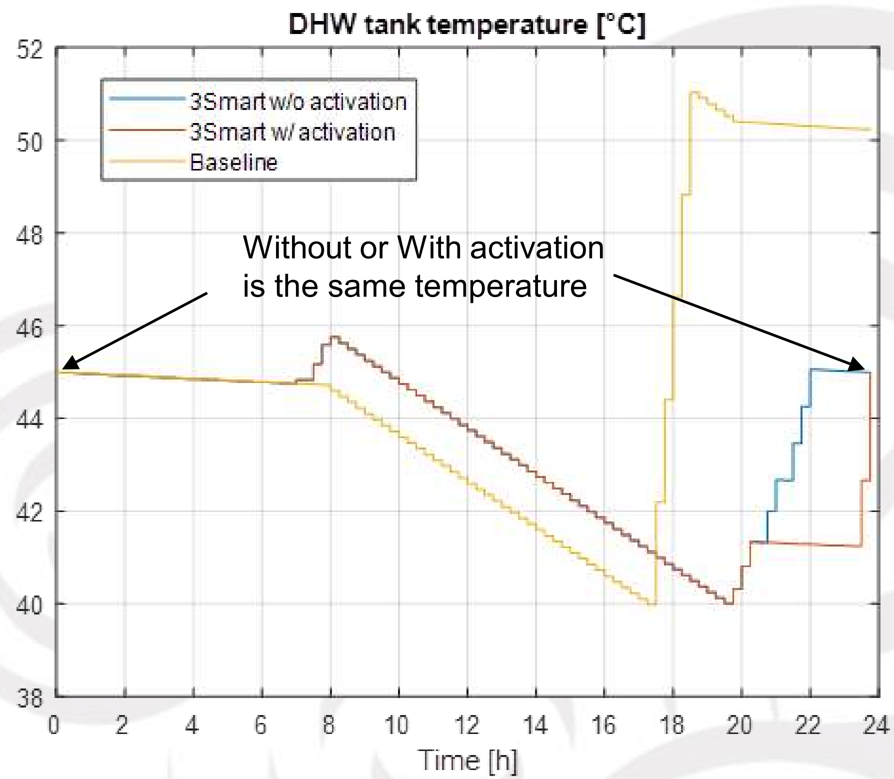


- CHP covers the building consumption when there is no PV production
- Flexibility activation: higher output from CHP

Daily planning of operation on microgrid level - 4

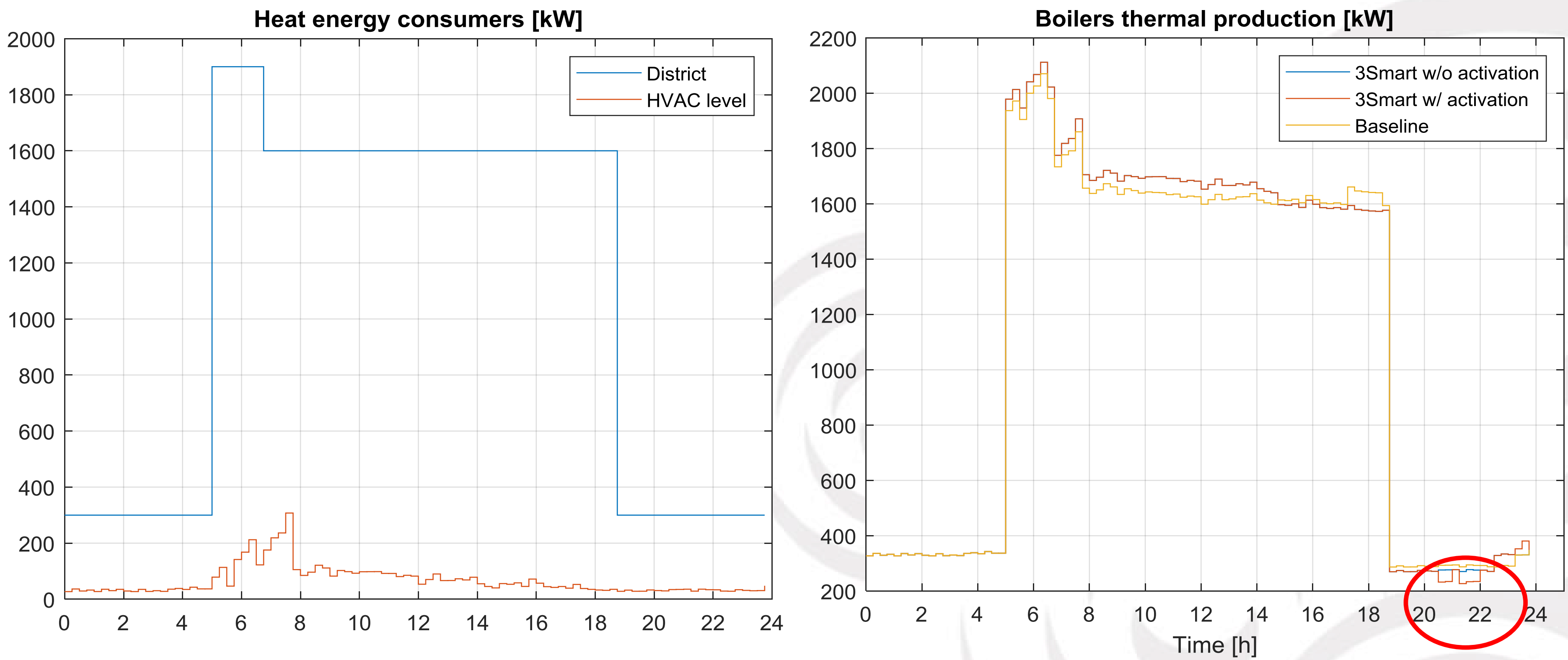
- Flexibility activation: heat exchanger is used for DHW heating instead of electric heaters





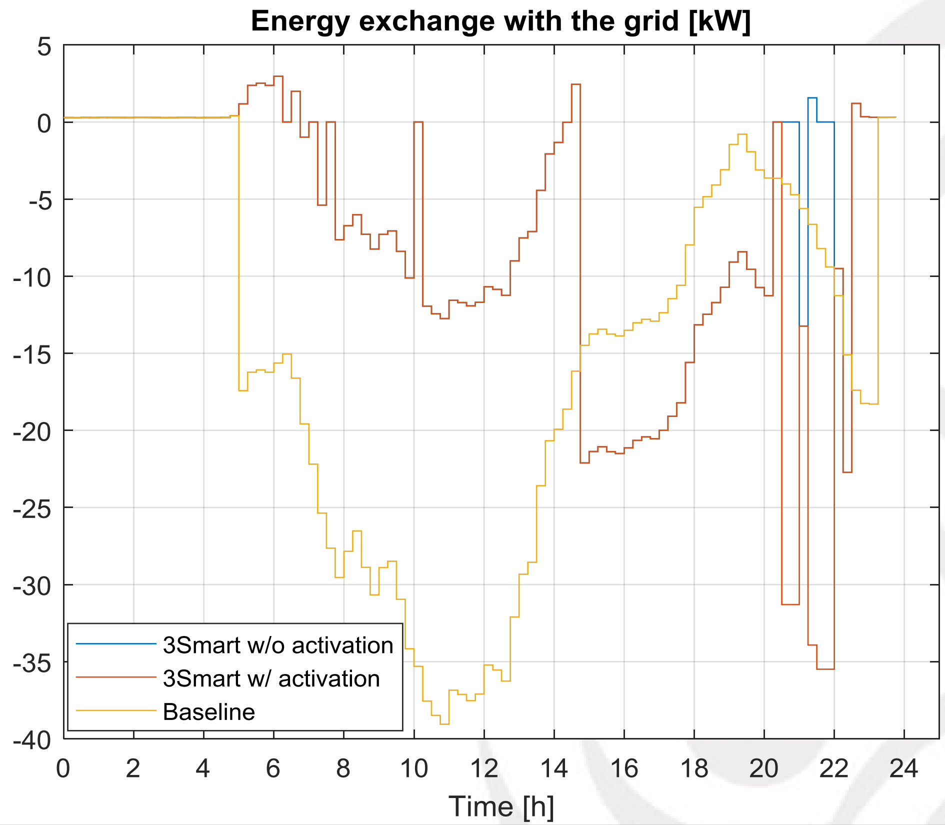
Daily planning of operation on microgrid level - 5

- Profile of district heat consumption
- Boilers cover the heat consumption not covered by CHP



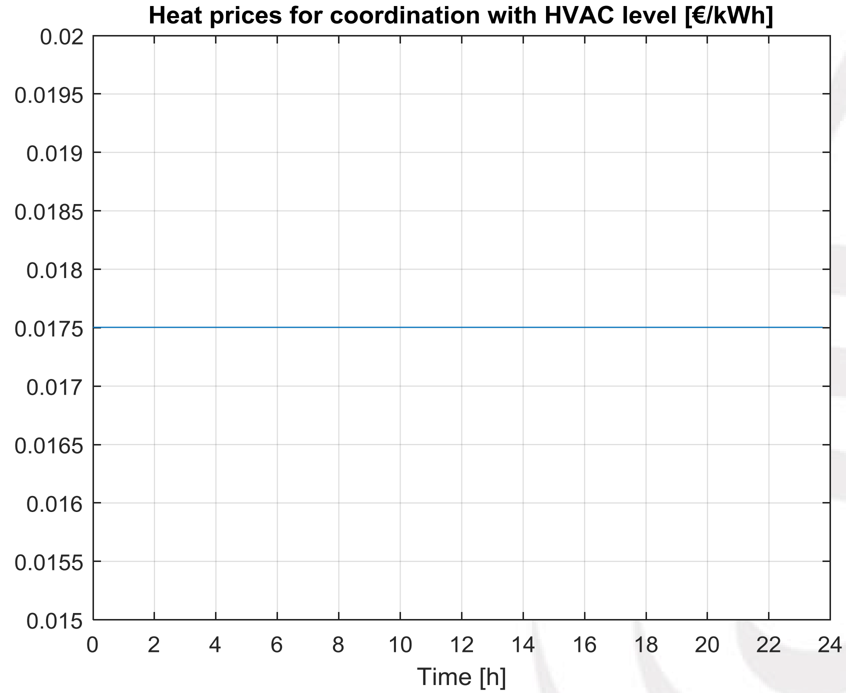
Daily planning of operation on microgrid level - 6

- Baseline control consumes gas and doesn't get revenue from returned electricity
- Difference in energy profiles with and w/o activation → flexibility



Daily planning of operation on microgrid level – 7

- Local pricing of heat from microgrid to HVAC for coordination reasons is constant
- District heating can consume any heat generated by CHP → no need to boost HVAC-level consumption



Daily planning of operation on microgrid level – 8 (summary)

- Pilot daily operating costs (gas + electricity)

Scenario	Total cost (€)
Conventional control	85.97
3Smart without activation	75.26
3Smart with activation	62.73

- Offered flexibility

Flexibility interval	Flexibility amount (kW)
20:30 – 21:00	34.23
21:15 – 22:00	36.86

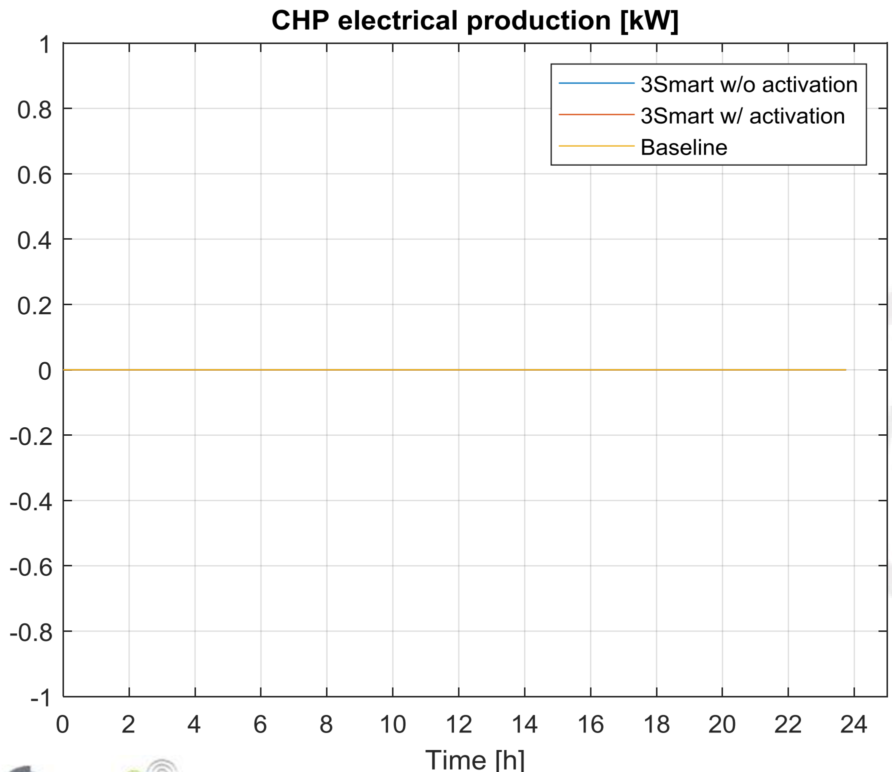
- Contracted peak power: 2.94 kW

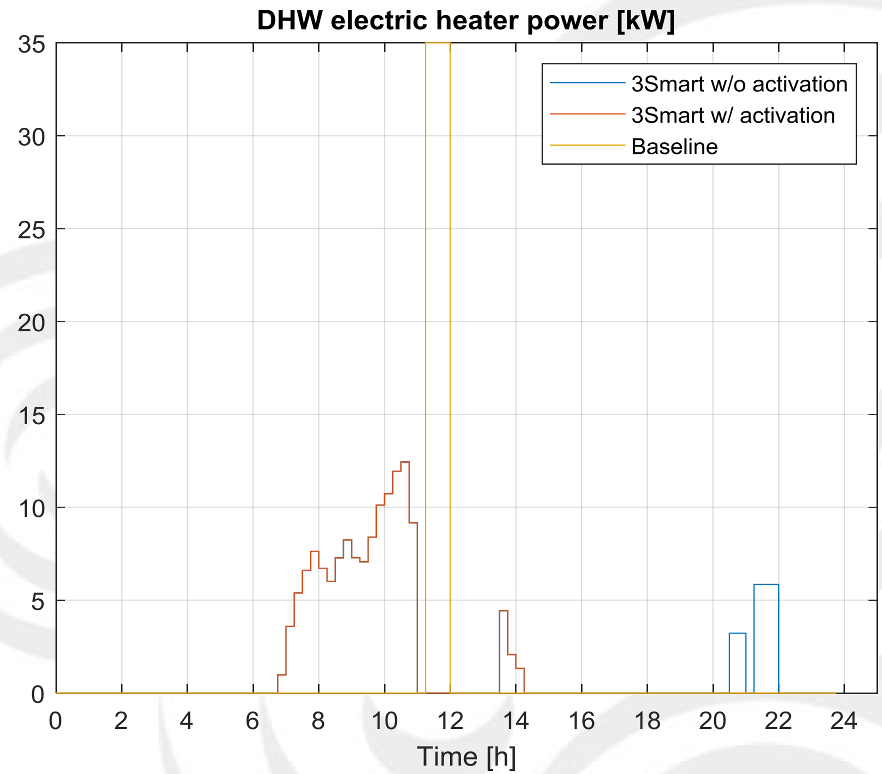
Daily planning of operation on microgrid level – 9 (summer scenario)

- Sunny workday in June
- Heating load: DHW only, no space heating
  - Only microgrid level operable
- Flexibility intervals: 20:30-21:00, 21:15-22.00

Daily planning of operation on microgrid level – 9 (summer scenario)

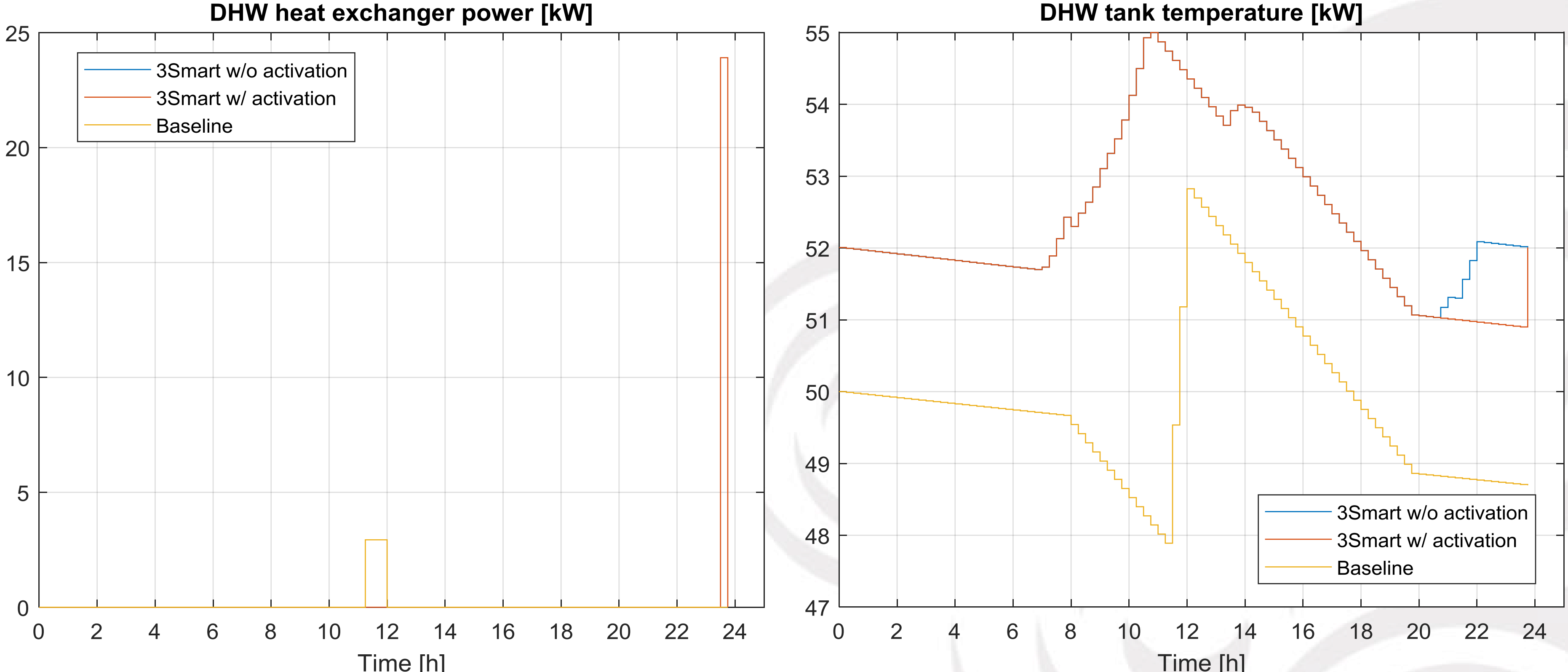
- PV covers the electrical consumption during the day
- Heating load is very low → CHP cannot operate
- Electric heater uses excess PV energy



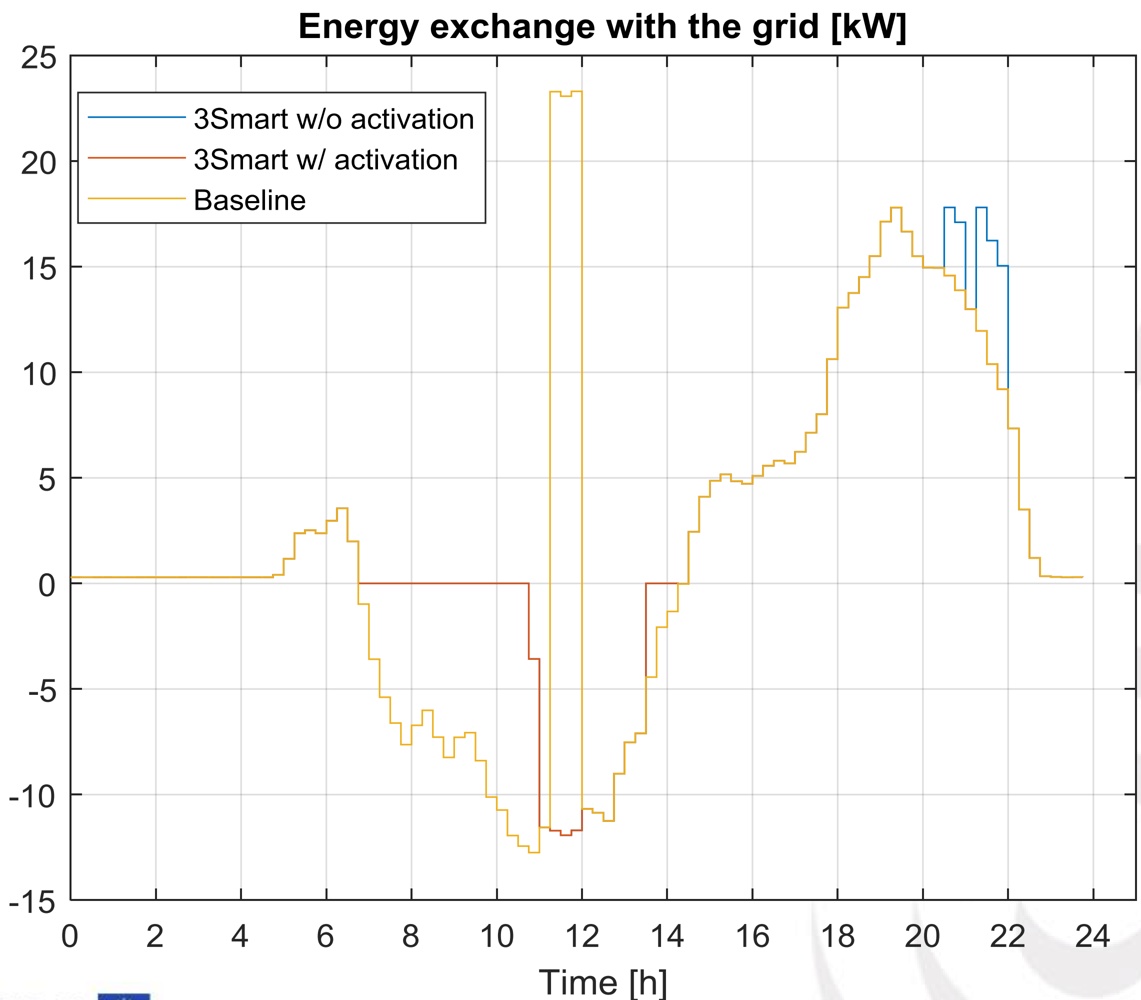


Daily planning of operation on microgrid level – 10 (summer scenario)

- Flexibility provided using the electric heater only;
- Repeatability condition on DHW temperature → second flexibility offer much smaller

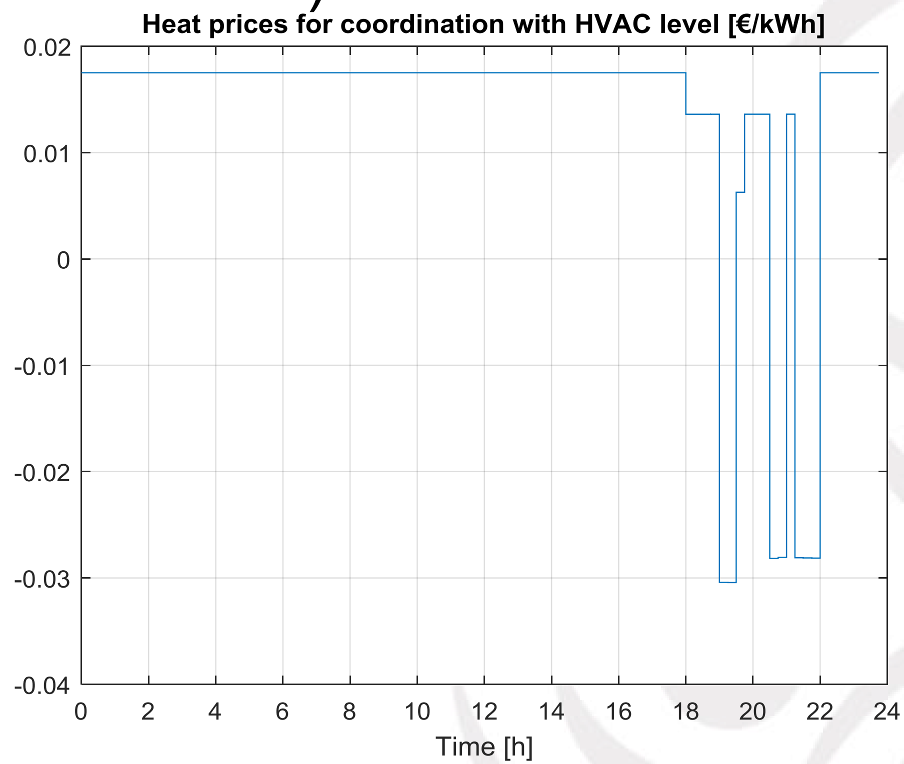


Daily planning of operation on microgrid level – 11 (summer scenario)



Daily planning of operation on microgrid level – 12 (summer)

- Incentive for HVAC to increase consumption
- Non-heating season → no coordination!
- Incentive will be used in heating season, when there is a small heating load (spring and autumn)



Daily planning of operation on microgrid level – 13 (summary for the summer)

- Building daily operating costs

Scenario	Total cost (€)
Conventional control	12.60
3Smart without activation	9.65
3Smart with activation	8.04

- Offered flexibility

Flexibility interval	Flexibility amount (kW)
20:30 – 21:00	3.23
21:15 – 22:00	7.93

- Contracted peak power: 17.81 kW

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.3.1

Transnational training materials – Pilot study visits to Austria – Pilot study visit No. 2

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Work Package	6
Task	6.3
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 23 Decmber 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, EEE, STREM, EnergyG, UNIDEBTTK, EON, UNIBGFME, SVEMOFSR
Authors (Partners)	Mario Vašak, Tomislav Capuder, Vinko Lešić, Anita Martinčević, Hrvoje Novak, Danko Marušić, Nikola Hure, Paula Perović (UNIZGFER), Andre Moser (EEE), Bernhard Deutsch (STREM), Markus Resch, Martin Zloklikovits (EnergyG), Arpad Racz (UNIDEBTTK), Gabor Peter (EON), Vladimir Jovanović (UNIBGFME), Ivan Bevanda, Petar Marić (SVEMOFSR)
Contact person	Andrea Moser (EEE)
Abstract (for dissemination)	This document contains the minutes of the study visits to the Austrian pilot in 3Smart. The pilot consists of two pilot buildings – primary school and retirement and care centre in Strem – and of the pilot electricity distribution grid around the buildings. On the pilot study visits the pilot leaders and hosts together with developers for different modules on the pilot site have discussed the necessary steps for the modules installations on the pilot and the 3Smart modules functioning on the pilot sites.
Keyword List	building-side energy management system, grid-side management, pilot installations, 3Smart IT environment, 3Smart database

Revision history

Revision	Date	Description	Author (Organization)
v1.0	23 December 2019	Entered the minutes from the second study visit to the Austrian pilot in the deliverable form	Mario Vašak (UNIZGFER)

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Executive summary

The 3Smart project deals with transnational development of integrated energy management of buildings and energy distribution grids in real time. To substantiate knowledge transfer between partners, to synchronize developments and demonstrate the installation procedure to developers, pilots leaders and pilots hosts, a series of transnational trainings is organized, first for getting acquainted with the software modules for energy management, and then for getting acquainted with performed pilot installations and modules operation on the pilot site.

This deliverable provides minutes and materials from the pilot study visits to the 3Smart pilot in Austria that consists of the primary school and retirement and care centre in Strem and of the electricity distribution grid around the buildings. The visits were split in two parts for each pilot site – this second part of the deliverable for the Austrian pilot site concerns the second pilot study visit.

1. Minutes from the second pilot study visit to the 3Smart pilot in Austria

Time: June 12, 2019

Venue: Technology Center Güssing (TC), 7540 Güssing, Europastraße 1

June 12, 2019 (Wednesday)

Time	Place	Event
09:00-11:00	TC Güssing, seminar room ground floor	2nd pilot study visit – technical discussions in the meeting room between developers, IT expert and building subcontractor /parallel session organized for non-developers interested in pilot installations visit
11:00-11:15	TC Güssing, seminar room ground floor	Coffee break
11:15-13:00	TC Güssing, seminar room ground floor	2nd pilot study visit – technical discussions in the meeting room between developers, IT expert and building subcontractor / parallel session organized for non-developers interested in pilot installations visit
13:00-14:00	Restaurant beside the seminar room	Lunch

Grid side:

Markus Resch presented the progress of grid related activities since the first pilot study visit in March 2019 (Annex 1). He gave an update about the installation and testing of short- and long- term modules. Also Paula has presented the status with modules putting into function on AT pilot grid.

Building side:

The discussion topics on the pilot building side have been:

1. Status on the IT equipment
    - status database and fetching data
    - status communication with the WAGO controller
    - status access from outside
2. Modules installation
    - actual identification procedures & results
    - open issues (connection to and control of devices)
    - order of modules installation

Results of identification performed on collected buildings data for radiators in school and floor heating in retirement and care centre (Z.PE.2 and Z.PE.3) are provided and discussed (Annex 3).

Z.PE.4 is done, needs to be entered into the database when it is ready.

For prediction modules that need to provide data on non-controllable variables for functioning of MPC (Z.PE.6 & Z.PE.7, HVAC.PE.4, M.PE.4), it was discussed how to select data for a typical day in the heating season to enable computations of predictive control based modules. The procedures how to do it based on measured data from smart meters were assessed.

The predictive controls results will be prepared in Period 6 and presented on the public presentation for the Austrian pilot.

List of Annexes:

Annex 1: Grid-side status on the AT pilot and planning

Annex 2: Results of identification of radiators and floor heating elements in school and retirement and care centre

Presentation of the performed installations and realized IT infrastructure in the pilot grid

Martin Zloklikovits / Markus Resch

Energie Güssing

martin.zloklikovits@htg.at / markus.resch@e-guessing.at

3Smart – Second Pilot Study Strem

11.06.-12.06.2019

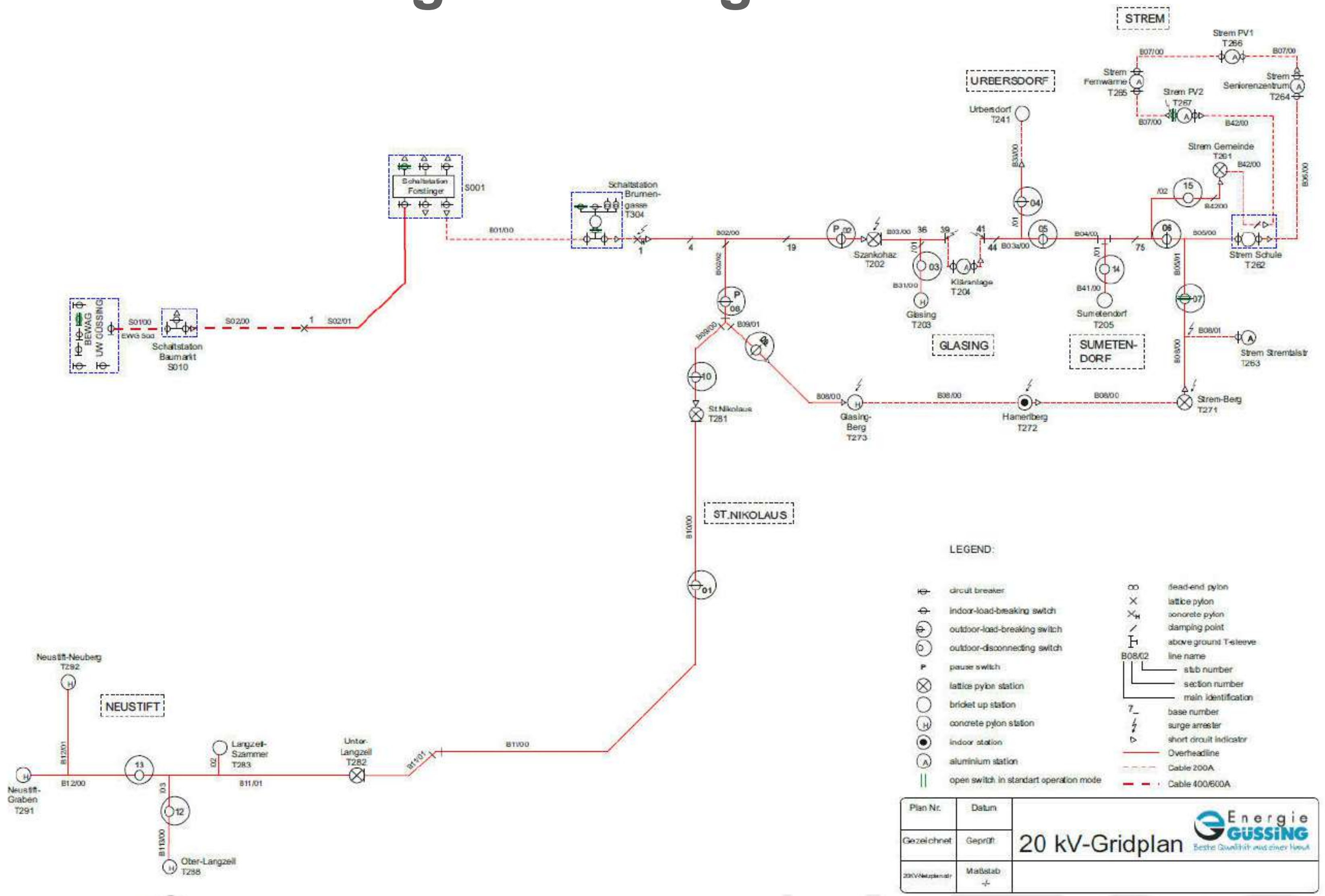
Energie GÜSSING

Interreg
EUROPEAN UNION
Danube Transnational Programme
3Smart

Project co-funded by the European Union

Grid Measurements

Grid Model Energie Güssing



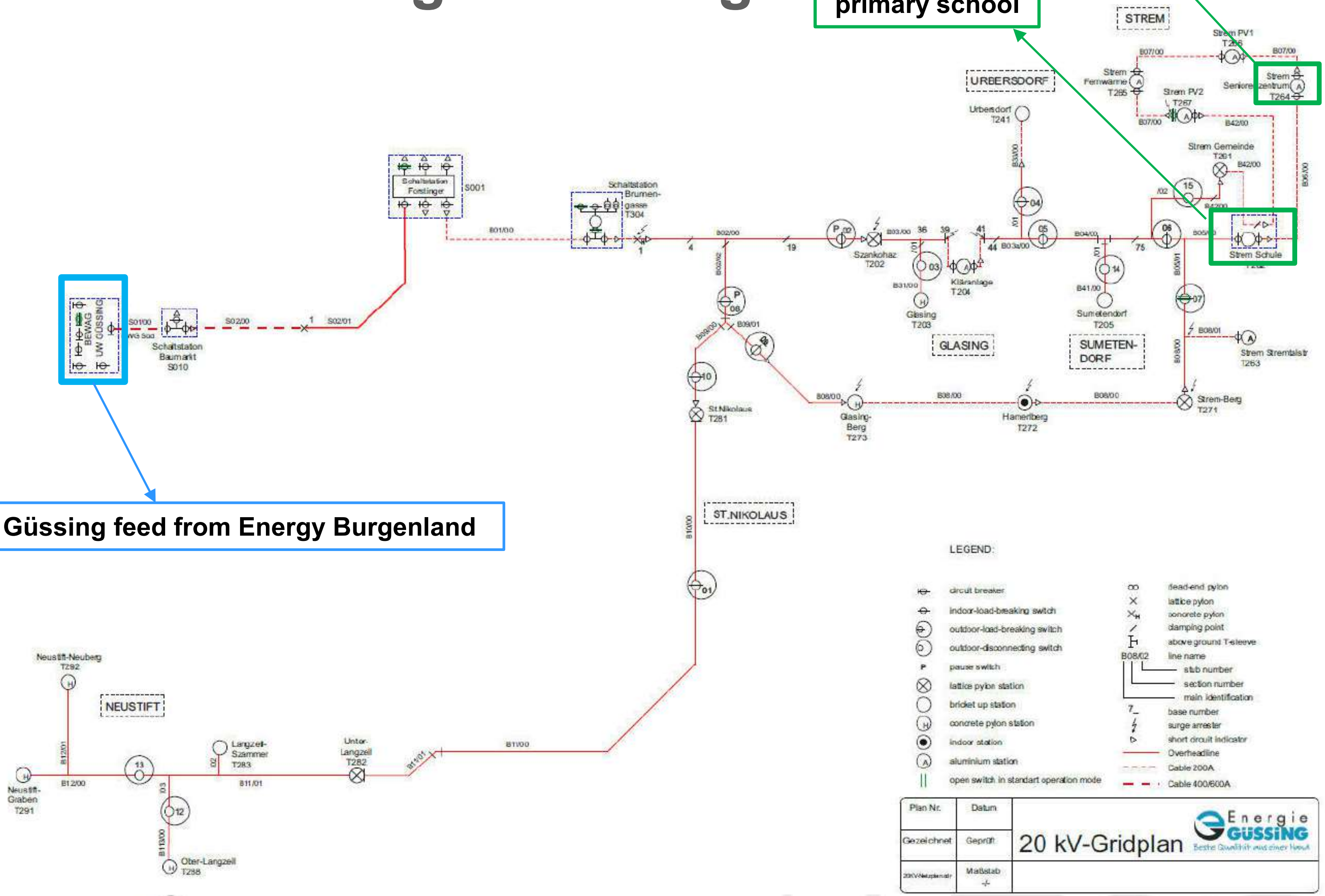
Energie GÜSSING

Interreg
Danube Transnational Programme
3Smart

Grid Model Energie Güssing

retirement and care center center

primary school



Energy Güssing feed from Energy Burgenland

Energie GÜSSING

Interreg Danube Transnational Programme 3Smart

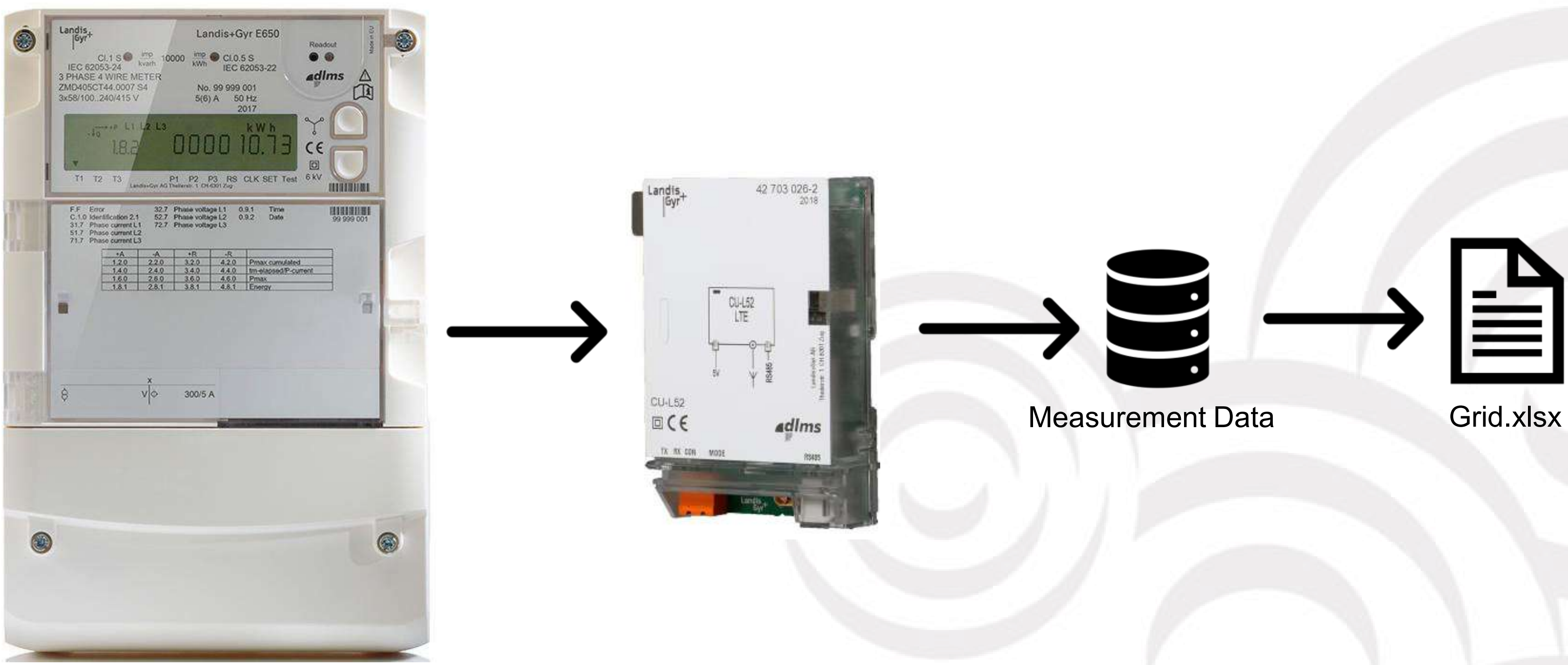
Grid Measurements

- Rollout of new electricity meters in transformerstations

- P+
- P-
- Q+
- Q-
- S+
- S-
- U1
- U2
- U3
- f

Grid Measurements

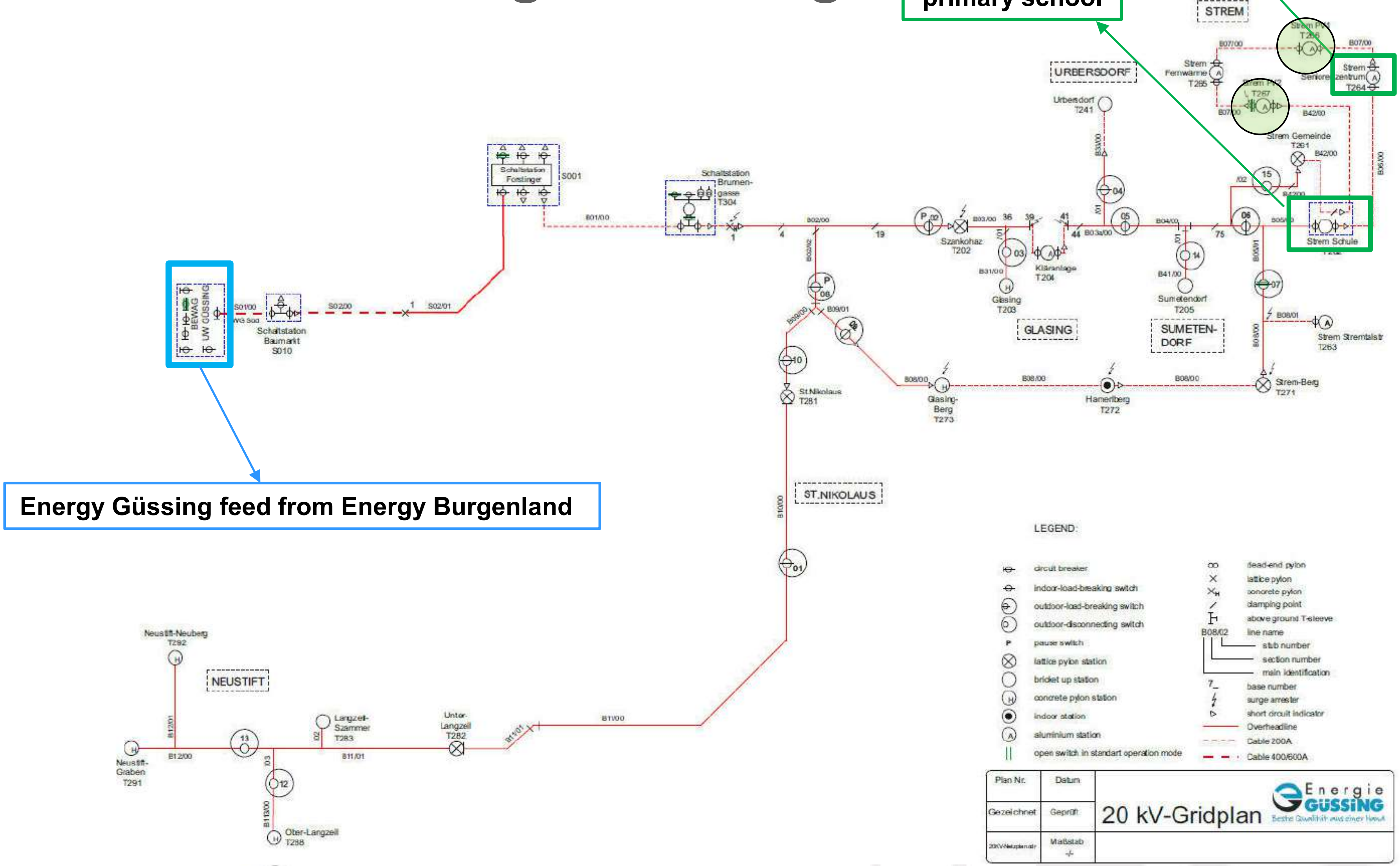
- Replacement of the synthetic load profiles with real measurement data in progress



Energie GÜSSING

Interreg Danube Transnational Programme 3Smart

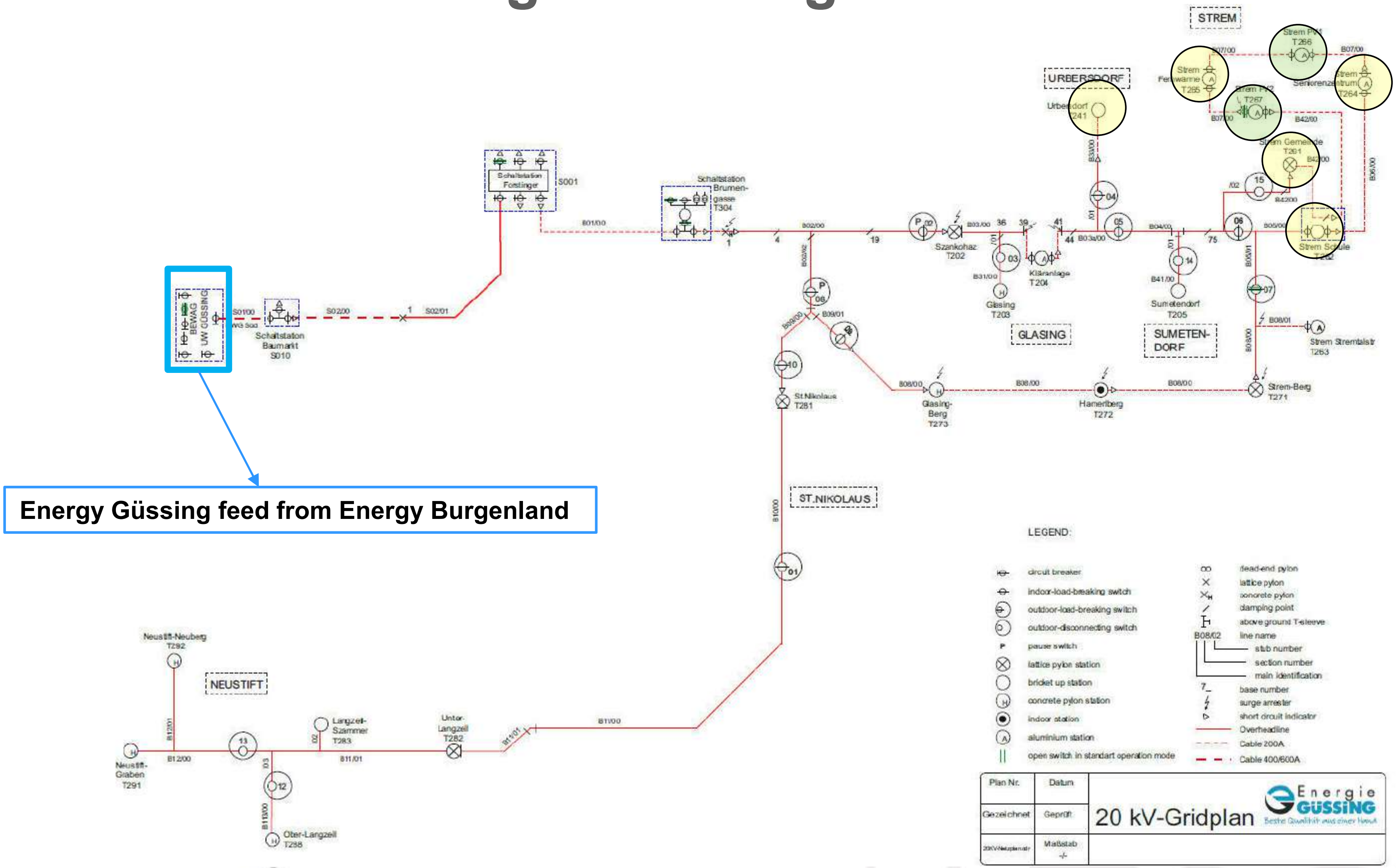
Grid Model Energie Güssing



Energie GÜSSING

Interreg Danube Transnational Programme 3Smart

Grid Model Energie Güssing



Measurement Data

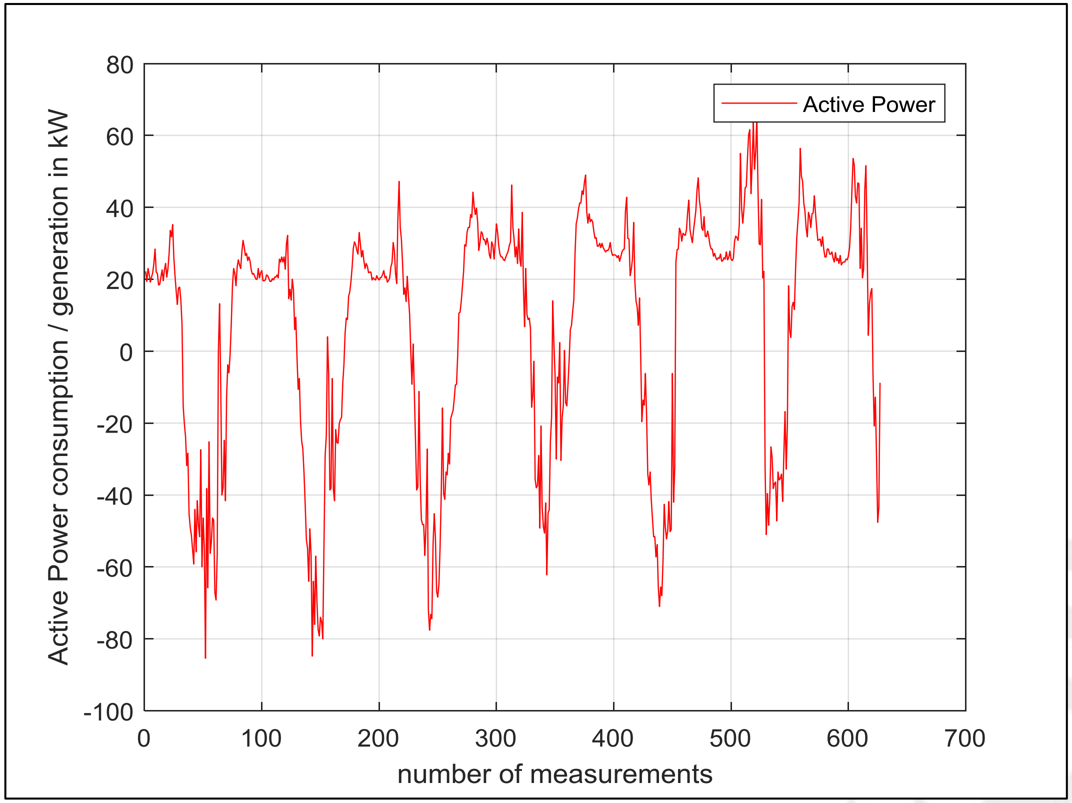
- 15 minutes values stored in load profile of the Smart Meter
- Possible to read out more detailed information directly on the Smart Meter (for example: power factor, voltage & current phase-angles, maximum values stored, etc…)

Wandlerkonstante 200		Energie Wirk +	Energie Wirk -	Energie Blind +	Energie Blind -	Energie Schein +	Energie Schein -	Leistung Wirk +	Leistung Wirk -	Leistung Blind -	Leistung Blind	Leistung Schein +	Leistung Schein -	Wirkleistung Momentan	Blindleistung Momentan	Scheinleistung Momentan	UL1	UL2	UL3	Netzfrequenz
Time [tm = 15 min]	EDIS Status	1.8.0 [kWh]	2.8.0 [kWh]	3.8.0 [kvarh]	4.8.0 [kvarh]	9.8.0 [kVAh]	10.8.0 [kVAh]	1.5.0 [kW]	2.5.0 [kW]	3.5.0 [kvar]	4.5.0 [kvar]	9.5.0 [kVA]	10.5.0 [kVA]	16.7.0 [kW]	131.7.0 [kvar]	9.7.0 [kVA]	32.7 [V]	52.7 [V]	72.7 [V]	14.7 [Hz]
2019-05-31 11:45:00	0008	5452.18	1714.88	1782.09	0.01	5687.20	1826.12	22.80	0.00	5.20	0.00	23.40	0.00	22.00	4.00	22.00	235.03	234.70	234.39	50.00
2019-05-31 12:00:00	0008	5457.72	1714.88	1783.55	0.01	5692.94	1826.12	22.20	0.00	6.00	0.00	23.00	0.00	22.00	4.00	22.00	235.08	234.40	234.18	49.98
2019-05-31 12:15:00	0008	5462.56	1714.88	1784.56	0.01	5697.89	1826.12	19.40	0.00	4.00	0.00	19.80	0.00	18.00	4.00	18.00	235.82	235.37	235.29	49.98
2019-05-31 12:30:00	0008	5468.31	1714.88	1785.82	0.01	5703.79	1826.12	23.00	0.00	5.00	0.00	23.60	0.00	22.00	4.00	22.00	235.36	234.92	235.21	50.00
2019-05-31 12:45:00	0008	5473.68	1714.88	1787.14	0.01	5709.32	1826.12	21.40	0.00	5.20	0.00	22.20	0.00	20.00	4.00	22.00	235.52	235.48	235.39	49.97
2019-05-31 13:00:00	0008	5478.47	1714.88	1788.06	0.01	5714.21	1826.12	19.20	0.00	3.80	0.00	19.60	0.00	18.00	2.00	18.00	236.06	235.32	235.37	49.98
2019-05-31 13:15:00	0008	5483.63	1714.88	1789.30	0.01	5719.52	1826.12	20.60	0.00	4.80	0.00	21.20	0.00	20.00	4.00	20.00	235.53	235.51	235.18	49.97
2019-05-31 13:30:00	0008	5489.05	1714.88	1790.63	0.01	5725.11	1826.12	21.80	0.00	5.40	0.00	22.40	0.00	20.00	4.00	22.00	235.72	235.36	235.26	49.98
2019-05-31 13:45:00	0008	5495.19	1714.88	1792.47	0.01	5731.52	1826.12	24.40	0.00	7.40	0.00	25.60	0.00	24.00	6.00	24.00	236.14	236.03	235.55	49.99
2019-05-31 14:00:00	0008	5502.25	1714.88	1794.89	0.01	5738.99	1826.12	28.40	0.00	9.60	0.00	29.80	0.00	28.00	8.00	28.00	236.50	236.40	236.30	49.99
2019-05-31 14:15:00	0008	5507.75	1714.88	1796.41	0.01	5744.69	1826.12	22.00	0.00	6.20	0.00	22.80	0.00	20.00	6.00	22.00	236.95	236.83	236.99	49.99
2019-05-31 14:30:00	0008	5513.15	1714.88	1797.61	0.01	5750.23	1826.12	21.60	0.00	4.80	0.00	22.20	0.00	20.00	4.00	22.00	237.28	237.16	237.03	50.00
2019-05-31 14:45:00	0008	5517.77	1714.88	1798.34	0.01	5754.90	1826.12	18.40	0.00	2.80	0.00	18.60	0.00	18.00	2.00	18.00	237.13	237.27	237.07	49.99
2019-05-31 15:00:00	0008	5522.43	1714.88	1799.11	0.01	5759.63	1826.12	18.60	0.00	3.20	0.00	19.00	0.00	18.00	2.00	18.00	237.98	237.83	237.97	50.00
2019-05-31 15:15:00	0008	5527.57	1714.88	1800.26	0.01	5764.91	1826.12	20.60	0.00	4.60	0.00	21.20	0.00	20.00	4.00	20.00	238.24	237.73	237.89	49.99
2019-05-31 15:30:00	0008	5533.21	1714.88	1801.36	0.01	5770.66	1826.12	22.60	0.00	4.40	0.00	23.00	0.00	22.00	4.00	22.00	237.26	236.59	236.51	50.00
2019-05-31 15:45:00	0008	5538.13	1714.88	1802.23	0.01	5775.66	1826.12	19.60	0.00	3.40	0.00	20.00	0.00	18.00	2.00	20.00	237.26	236.62	236.87	49.98
2019-05-31 16:00:00	0008	5543.79	1714.88	1803.63	0.01	5781.51	1826.12	22.60	0.00	5.60	0.00	23.40	0.00	22.00	4.00	22.00	235.96	235.53	235.75	50.00
2019-05-31 16:15:00	0008	5549.86	1714.88	1804.98	0.01	5787.73	1826.12	24.40	0.00	5.40	0.00	24.80	0.00	24.00	4.00	24.00	235.12	234.95	234.68	50.00
2019-05-31 16:30:00	0008	5555.03	1714.88	1806.12	0.01	5793.03	1826.12	20.60	0.00	4.60	0.00	21.20	0.00	20.00	4.00	20.00	235.95	235.86	235.38	50.00
2019-05-31 16:45:00	0008	5560.77	1714.88	1807.30	0.01	5798.90	1826.12	23.00	0.00	4.60	0.00	23.60	0.00	22.00	4.00	22.00	235.66	235.70	235.49	49.98
2019-05-31 17:00:00	0008	5567.59	1714.88	1809.02	0.01	5805.96	1826.12	27.20	0.00	7.00	0.00	28.20	0.00	26.00	6.00	28.00	236.21	235.90	235.80	49.99
2019-05-31 17:15:00	0008	5575.99	1714.88	1810.80	0.01	5814.56	1826.12	33.60	0.00	7.20	0.00	34.40	0.00	32.00	6.00	34.00	236.31	235.99	235.81	50.01
2019-05-31 17:30:00	0008	5583.92	1714.88	1812.38	0.01	5822.66	1826.12	31.80	0.00	6.20	0.00	32.40	0.00	30.00	6.00	32.00	236.49	236.00	236.01	49.99
2019-05-31 17:45:00	0008	5592.73	1714.88	1814.42	0.01	5831.71	1826.12	35.20	0.00	8.20	0.00	36.20	0.00	34.00	8.00	36.00	236.69	236.01	236.08	49.98
2019-05-31 18:00:00	0008	5599.29	1714.88	1816.46	0.01	5838.60	1826.12	26.20	0.00	8.20	0.00	27.60	0.00	26.00	8.00	26.00	236.33	235.80	236.08	49.99
2019-05-31 18:15:00	0008	5604.53	1714.88	1818.27	0.01	5844.15	1826.12	21.00	0.00	7.20	0.00	22.00	0.00	20.00	6.00	22.00	235.85	235.54	235.68	50.01
2019-05-31 18:30:00	0008	5608.74	1714.88	1819.95	0.01	5848.71	1826.12	16.80	0.00	6.60	0.00	18.40	0.00	16.00	6.00	18.00	235.80	234.95	235.13	49.98
2019-05-31 18:45:00	0008	5611.99	1714.89	1822.12	0.01	5852.75	1826.14	13.00	0.00	8.80	0.00	16.00	0.00	12.00	8.00	16.00	236.10	235.07	235.21	49.98
2019-05-31 19:00:00	0008	5616.37	1714.89	1824.19	0.01	5857.62	1826.14	17.60	0.00	8.20	0.00	19.60	0.00	16.00	8.00	18.00	236.51	235.40	235.71	49.97
2019-05-31 19:15:00	0008	5620.87	1714.91	1826.09	0.01	5862.71	1826.26	18.00	0.20	7.60	0.00	20.40	0.60	18.00	6.00	20.00	236.18	235.34	236.07	50.00
2019-05-31 19:30:00	0008	5624.42	1714.94	1828.63	0.01	5867.18	1826.32	14.20	0.00	10.20	0.00	17.80	0.20	14.00	10.00	18.00	236.03	235.59	235.88	49.99

Energie GÜSSING

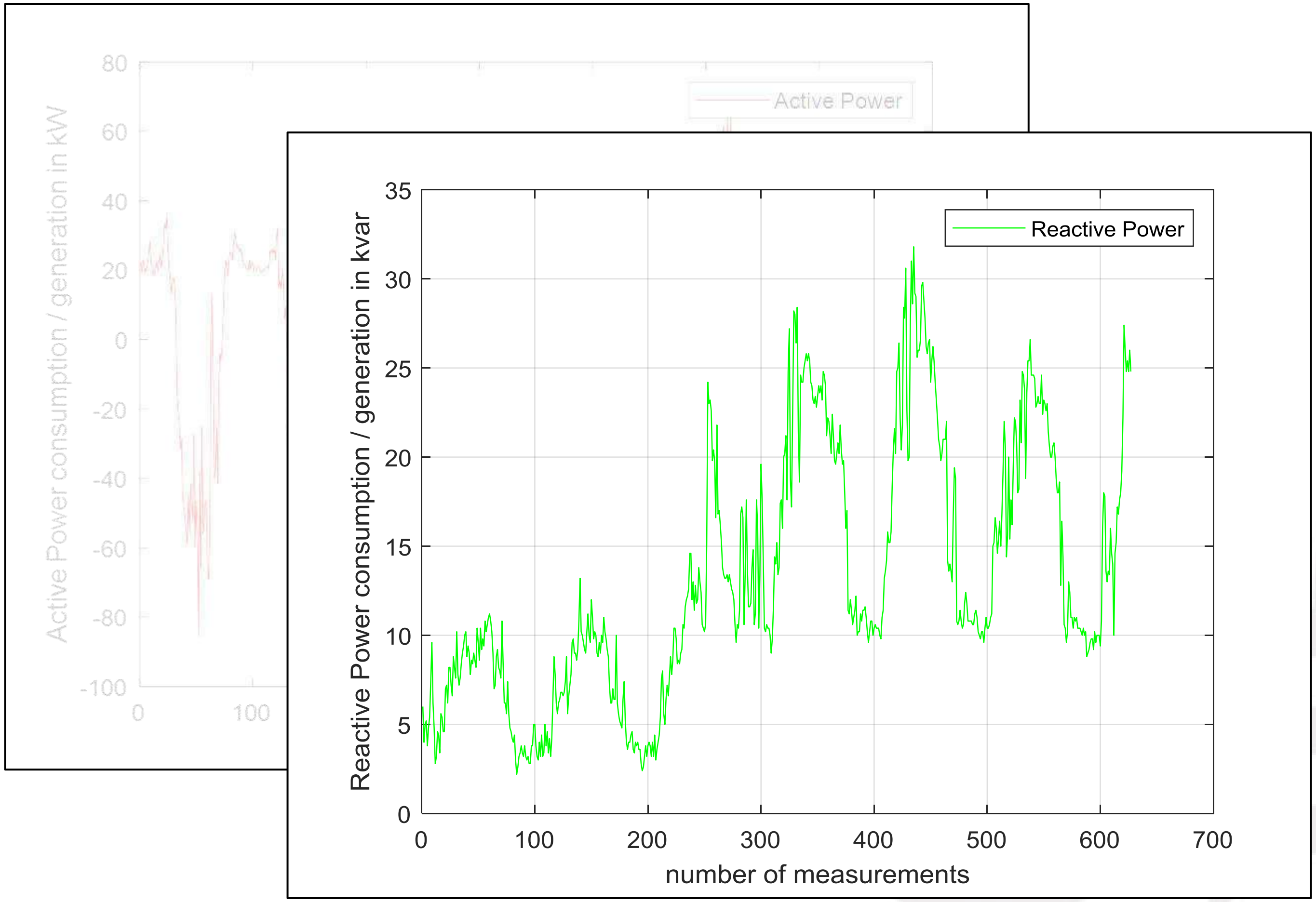
Interreg Danube Transnational Programme 3Smart

Measurement Data

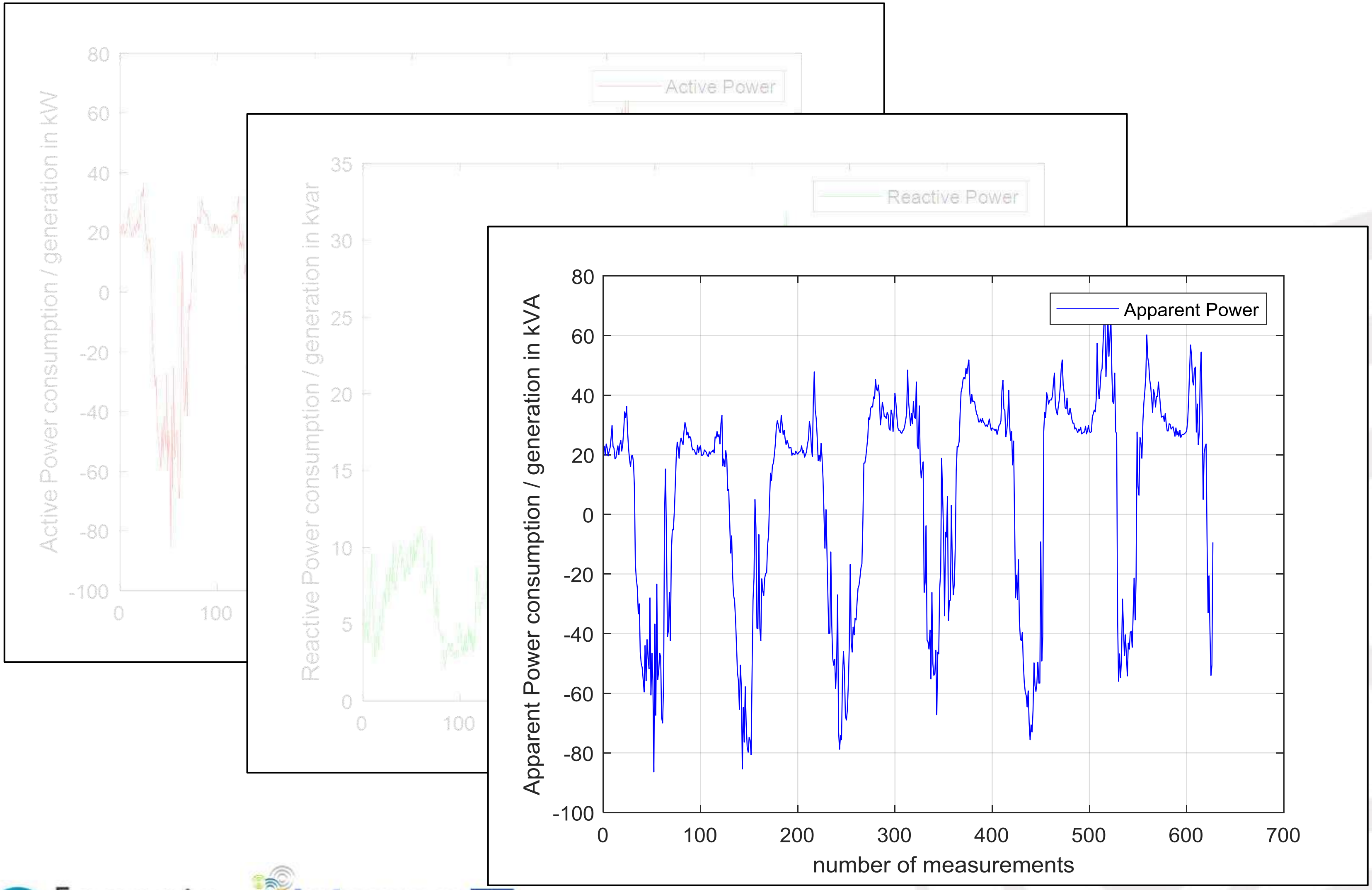


Energie GÜSSING
Interreg Danube Transnational Programme
3Smart

Measurement Data



Measurement Data



TO DO – 3 SMART Server

- Update ACOPF
- Update data stored in the SQL database concerning buildings/grid
- Update load profiles by using real measured data

- → to be done after this presentation today

Energie GÜSSING
Interreg Danube Transnational Programme
3Smart

Parameters of the identified radiators model in the primary school in Strem							
Room	Return medium sensor calibration coefficients: Tw,out,real=c1*Tw,out,measured+c2 [°C]		Dynamic radiator/radiators model in the room: dTw,out/dt=a*xV/100*(Tw,in-Tw,out)-b*(Tw,out-Tair) [°C/s]		Power to air model of the radiator/radiators in the room: P=k1*xV/100*Tw,in+(k2+k1*(1-xV/100))*Tw,out+k3*Tair [kW]		
	c1	c2 [°C]	a [1/s]	b [1/s]	k1 [kW/°C]	k2 [kW/°C]	k3 [kW/°C]
Z-8	2,012929263	-25,323231582	0,001045702	0,000171180	0,015052510	0,021533159	-0,036585670
Supply line losses	T(x) = T(x=0) * exp(-r1*x)+20°C*(1-exp(-r1*x)) [°C]						
	r1 [1/m)]						
Duct North	0,000404657						

Parameters of the floor heating/cooling circuits in the retirement and care centre pilot building in Strem					
Room	Dynamic radiator/radiators model in the room: dTw,out/dt=a*xV/100*(Tw,in-Tw,out)-b*(Tw,out-Tair) [°C/s]		Power to air model of the radiator/radiators in the room: P=k1*xV/100*Tw,in+(k2+k1*(1-xV/100))*Tw,out+k3*Tair [kW]		
	a [1/s]	b [1/s]	k1 [kW/°C]	k2 [kW/°C]	k3 [kW/°C]
2 circles in room	0,000038580	0,000030864	0,030105021	0,043066319	-0,073171339
6 circles in room	0,000038580	0,000030864	0,090315062	0,129198956	-0,219514018
8 circles in room	0,000038580	0,000030864	0,120420083	0,172265274	-0,292685357

Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.3.1

Transnational training materials – Pilot study visits to Bosnia and Herzegovina – Pilot study visit No. 2

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
Project Start Date	1 January 2017
Project Duration	30 months
Work Package	6
Task	6.3
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 23 December 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, UNIDEBTTK, EON, UNIBGFME, EPHZHB, SVEMOFSR
Authors (Partners)	Mario Vašak, Tomislav Capuder, Vinko Lešić, Anita Martinčević, Hrvoje Novak, Danko Marušić, Nikola Hure, Paula Mamić (UNIZGFER), Arpad Racz (UNIDEBTTK), Gabor Peter (EON), Vladimir Jovanović (UNIBGFME), Mile Međugorac, Marin Bakula, Nikolina Ćorluka (EPHZHB), Ivan Bevanda, Petar Marić (SVEMOFSR)
Contact person	Mile Međugorac (EPHZHB)
Abstract (for dissemination)	This document contains the minutes of the second study visit to the Bosnia and Herzegovina pilot in 3Smart. It consists of a pilot building – the EPHZHB building in Tomislavgrad – and of the pilot electricity distribution grid around the building. On the pilot study visits the pilot leaders and hosts together with developers for different modules on the pilot site have performed demonstration to the consortium of functioning of different installations performed on the pilot and of the installed 3Smart modules.
Keyword List	building-side energy management system, grid-side management, pilot installations, 3Smart IT environment, 3Smart database

Revision history

Revision	Date	Description	Author (Organization)
v1.0	23 December 2019	Prepared the minutes in publishable form	Mario Vašak (UNIZGFER)

Table of Contents

Executive summary

The 3Smart project deals with transnational development of integrated energy management of buildings and energy distribution grids in real time. To substantiate knowledge transfer between partners, to synchronize developments and demonstrate the installation procedure to developers, pilots leaders and pilots hosts, a series of transnational trainings is organized, first for getting acquainted with the software modules for energy management, and then for getting acquainted with performed pilot installations and modules operation on the pilot site.

This deliverable provides minutes and materials from the pilot study visits to the 3Smart pilot in Bosnia and Herzegovina that consists of EPHZHB building in Tomislavgrad and of the electricity distribution grid around this building. The visits were split in two parts for each pilot site – this second part of the deliverable for the Bosnia and Herzegovinian pilot site concerns the second pilot study visit.

1. Minutes from the second pilot study visit to the 3Smart pilot in Bosnia and Herzegovina

Time: 17 July 2019

Venue: JP Elektroprivreda HZHB d.d. Mostar building, Mile Budaka 106A, 88000 Mostar, Bosnia and Herzegovina

July 17, 2019 (Wednesday)

Time	Place	Event
09:00-11:00	Conference room on the Ground floor	Session No. 1
11:00-11:15	In front of Conference room on the Ground floor	Coffee break
11:15-13:00	Conference room on the Ground floor	Session No. 2
13:00-14:00	Restaurant on Third floor	Lunch
14:00-16:00	Conference room on the Ground floor	Session No. 3
16:00-16:15	In front of Conference room on the Ground floor	Coffee break
16:15-17:00	Conference room on the Ground floor	Session No. 4
20:00-22:00	Restaurant Del Rio	Working dinner

More details on individual sessions:

Session No. 1

Current status of EPHZHB pilot building and pilot grid was assessed shortly by Mile Medjugorac. Then followed the analysis of building daily operation on the grid for the set flexibility conditions from the grid, and the related flexibility bid by the building. The analysis started from the zone level. The results are provided in Annex 1.

Session No. 2

The analysis of building daily operation continued with the analysis on the central HVAC and microgrid level. The results are also found in Annex 1. Signidicant overall saving possibilities are assessed.

Session No. 3

The pilot study visit in session 3 continued with analysis of installed modules on site, on all three levels of the building. The modules performance is also provided in Annex 1. The grid modules operation was already shown on the pilot study visit No 1.

Session No. 4

The last session was reserved for discussions on the results and the preparations for the public presentation of the results the next day.

List of annexes:

Annex 1. Analysis and demonstration of 3Smart modules operation on Bosnia and Herzegovinian pilot

Analysis and demonstration of 3Smart modules operation on Bosnia and Herzegovinian pilot

Prof. dr. sc. Mario Vašak, Anita Martinčević, dr.sc. Nikola Hure, Danko Marušić, dr. sc. Hrvoje Novak, Arpad Racz, Prof. dr. sc. Vladimir Jovanović

University of Zagreb Faculty of Electrical Engineering and Computing
University of Debrecen
University of Belgrade Faculty of Mechanical Engineering

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Study visit No. 2 to the 3Smart pilot in Bosnia and Herzegovina

Mostar, 17 July 2019

Interreg
Danube Transnational Programme
3Smart

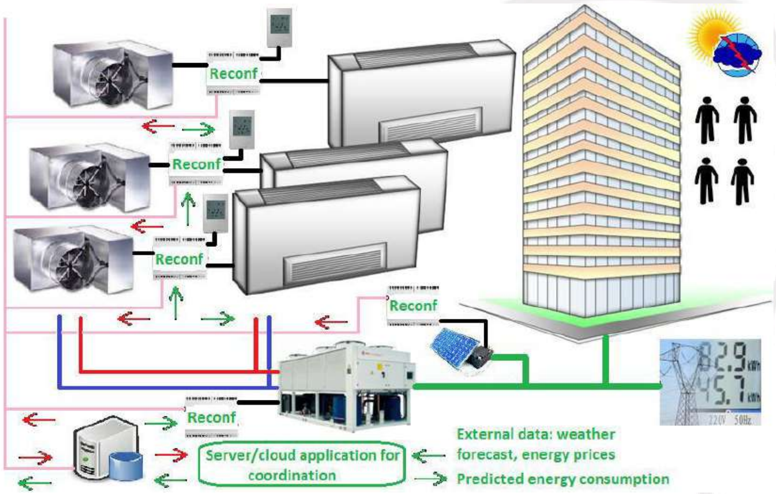
UNIVERSITY OF ZAGREB
FACULTY OF ELECTRICAL ENGINEERING AND COMPUTING

Project sufinanciran sredstvima Europske unije

Planning of optimal building operation

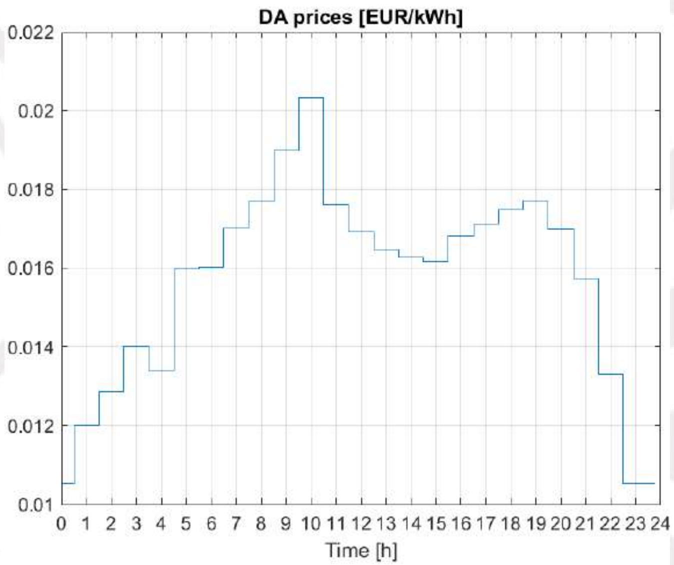
– **Possibility of optimal building operation planning for characteristic days**

- Estimate of interventions pay-off on different levels and the gains obtained due to their coordination
- Planning of optimal flexibility power amount for interaction with the distribution grid (**demand response**)



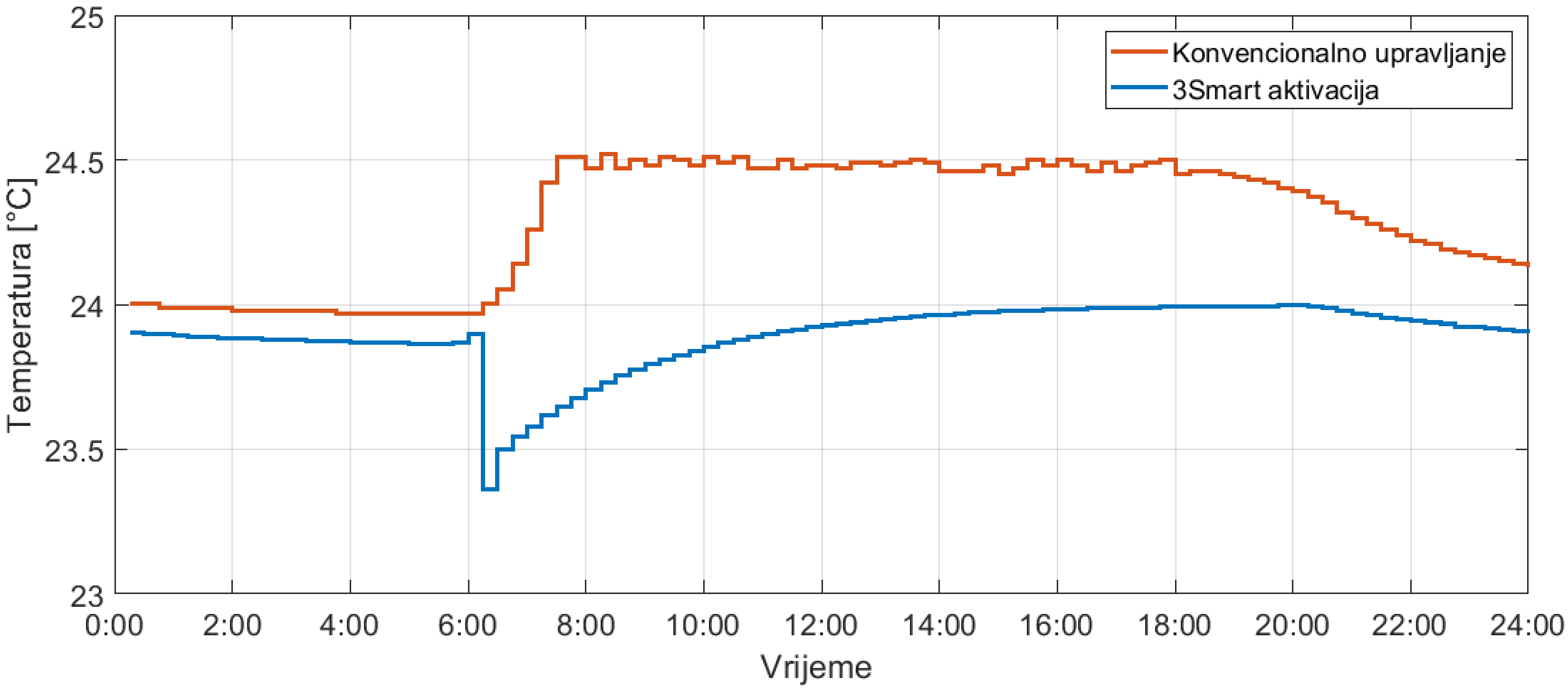
Analysis of the 3Smart system operation

- Conditions: sunny workday in July
- Questions:
  - What is the optimal way of building daily operation?
    - When and how much to cool each individual zone, when and how much to cool the cooling medium, when and how much to charge/discharge the battery?
  - For which offered flexibility is the building operational cost minimal?
  - How much is the optimal operation way better than the conventional?
- Flexibility intervals (long-term grid):
  - 13:00-13:30
  - 13:45-16:00
- Flexibility prices (long-term grid)
  - reservation: 0.0021 EUR/kW/15 min
  - activation: 0.0084 EUR/kWh
  - penalty: 0.0168 EUR/kWh



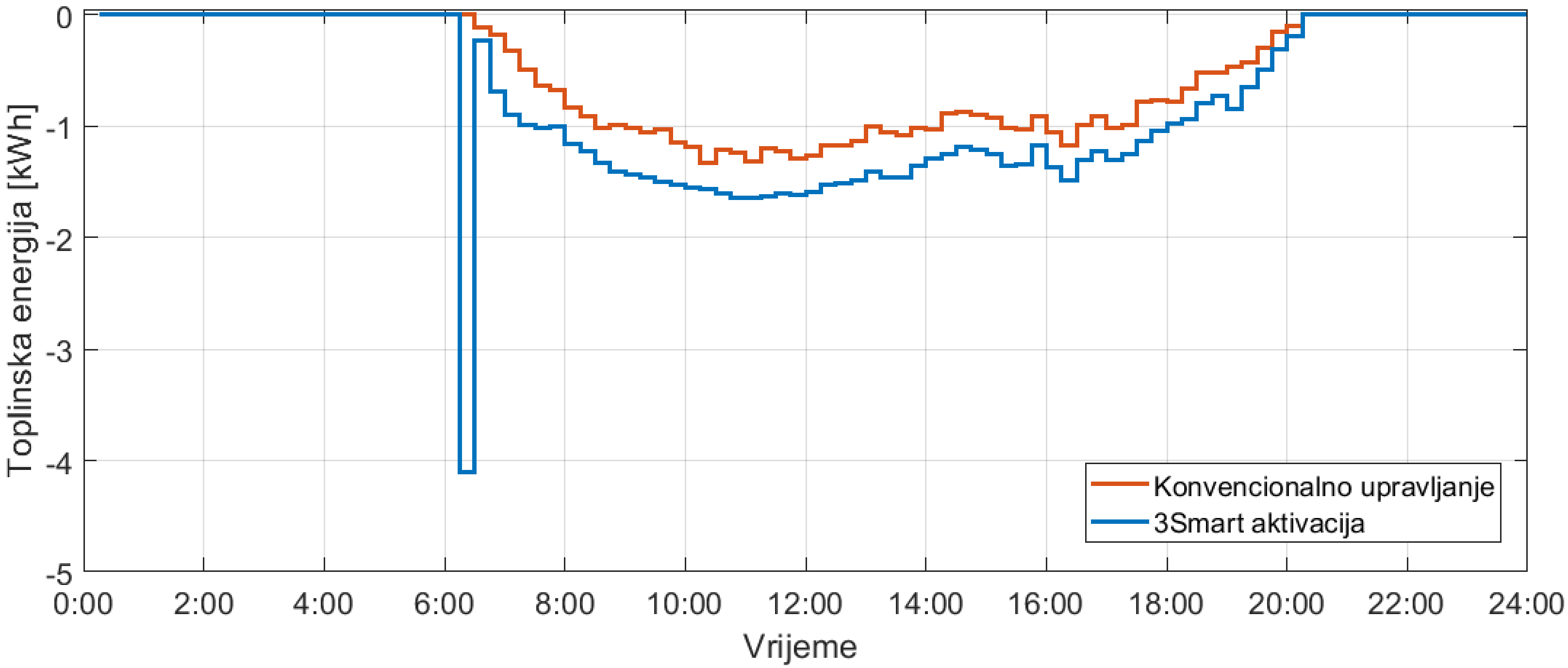
Analysis of the 3Smart system operation – zone level (1)

- Temperature setpoint: 24°C (allowed deviation +/- 0.5 °C)



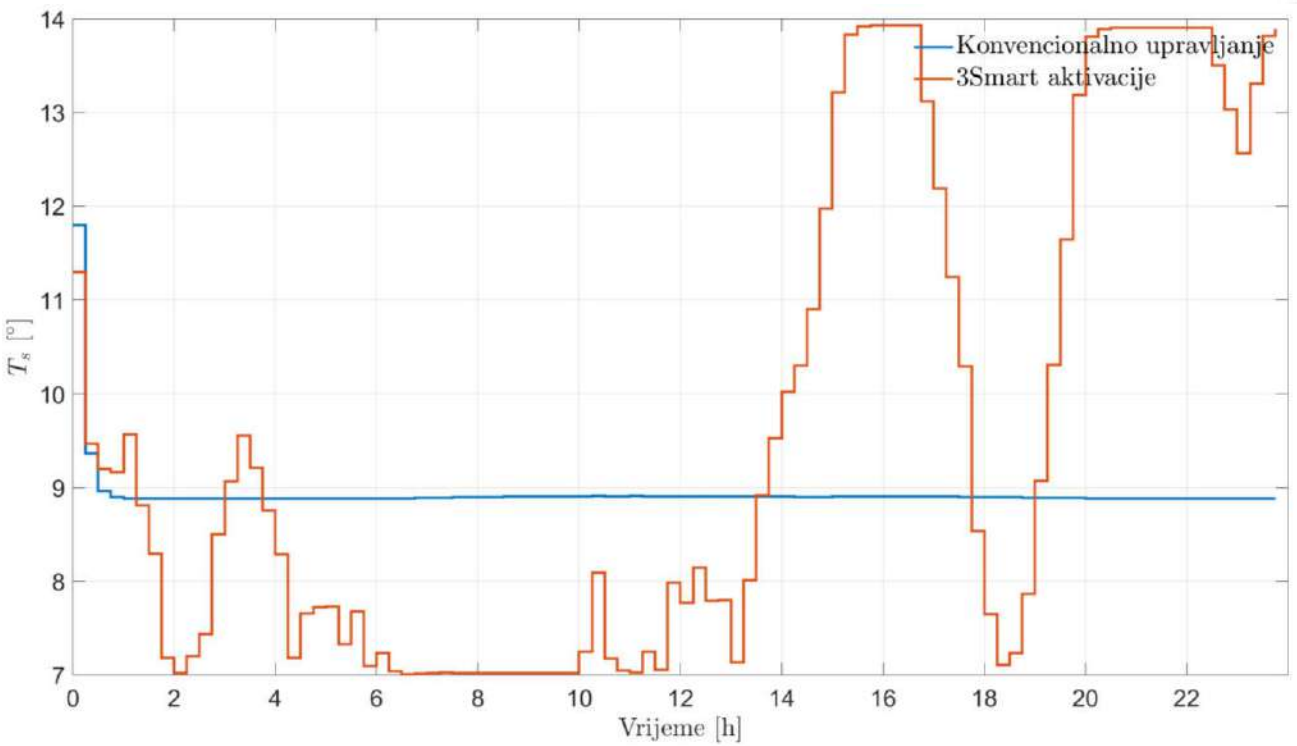
Analysis of the 3Smart system operation – zone level (2)

- The summed up cooling energy towards zone air for all zones



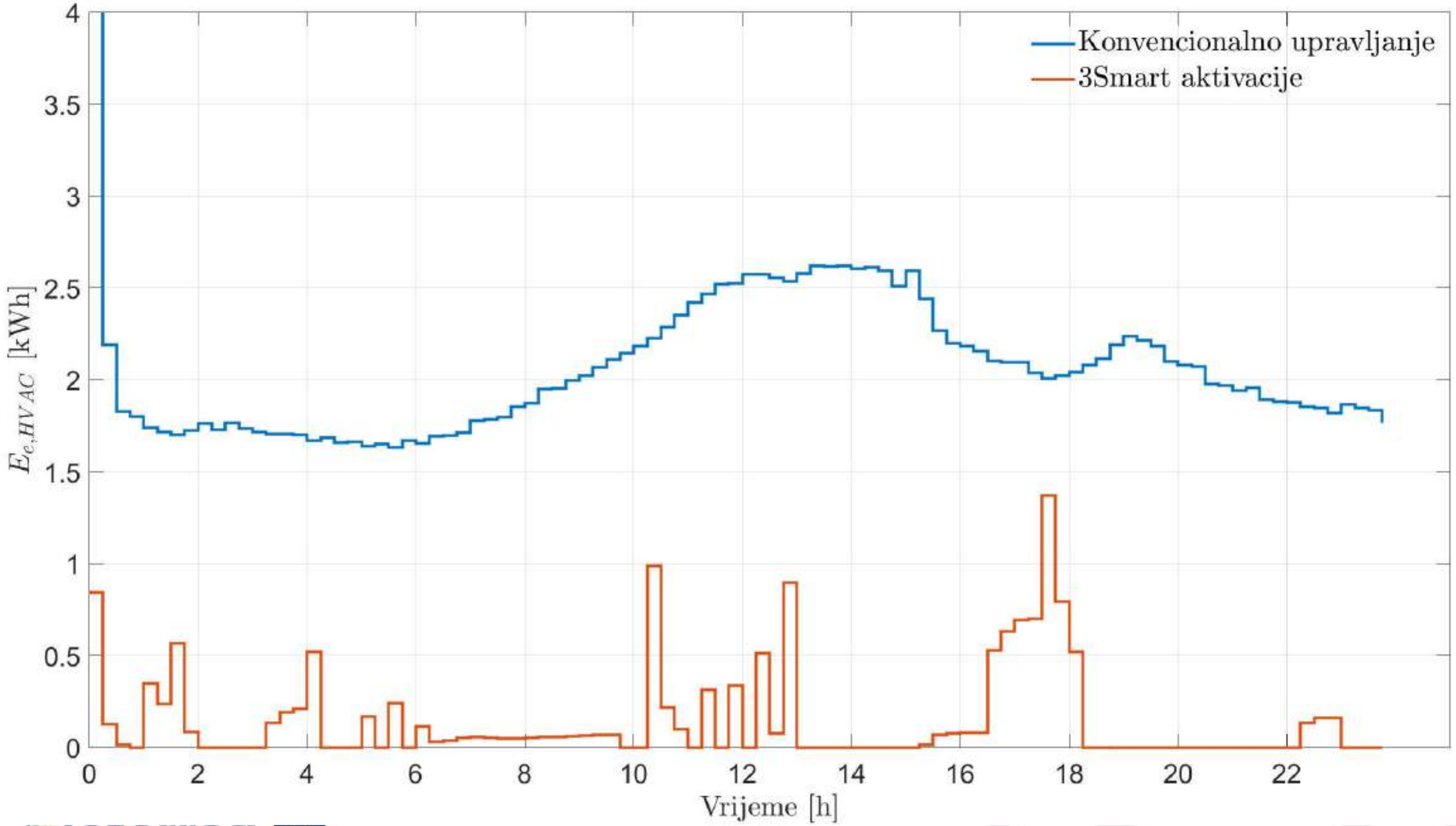
Analysis of the 3Smart system operation – central HVAC level (1)

- Starting cooling medium temperature from the buffer tank



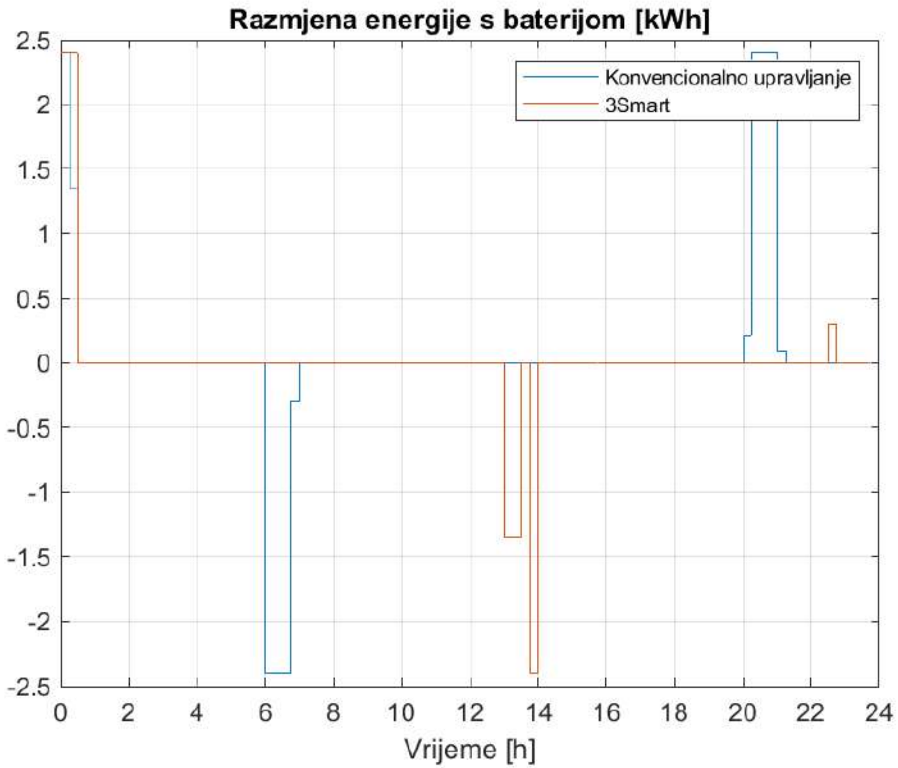
Analysis of the 3Smart system operation – central HVAC level (2)

- Electricity consumed on chiller and fan coils fans



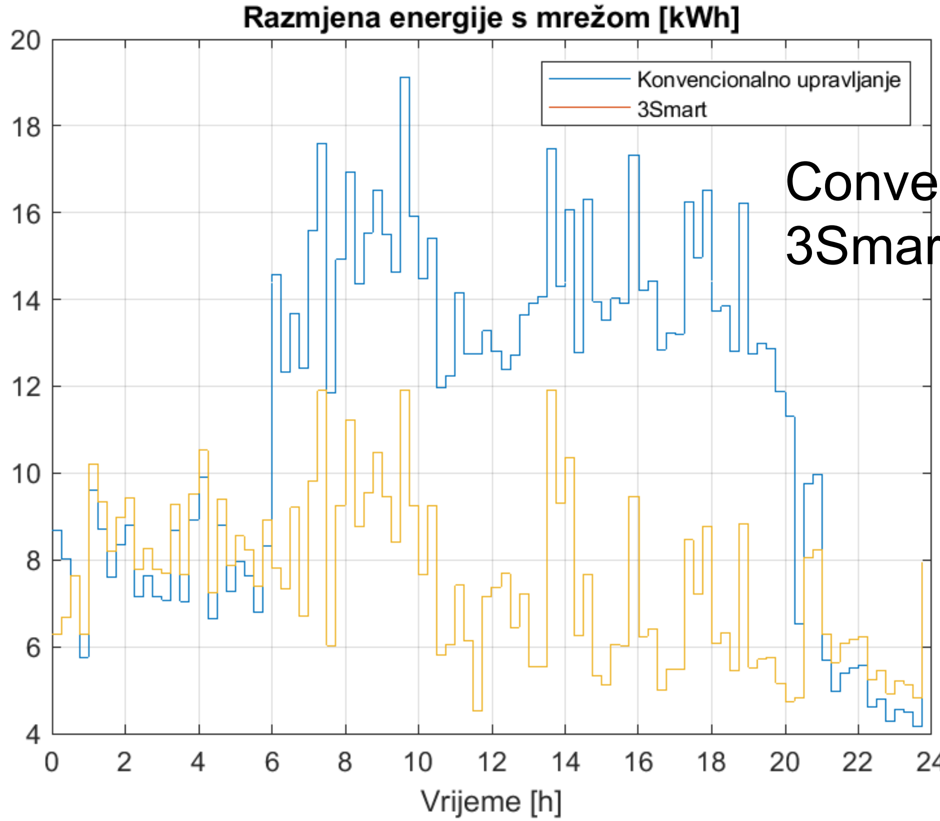
Analysis of the 3Smart system operation – microgrid level (1)

- Energy exchange with the battery system (+ -- battery charging; - -- battery discharing)



Analysis of the 3Smart system operation – microgrid level without photovoltaic power plant

- Energy exchange with the grid



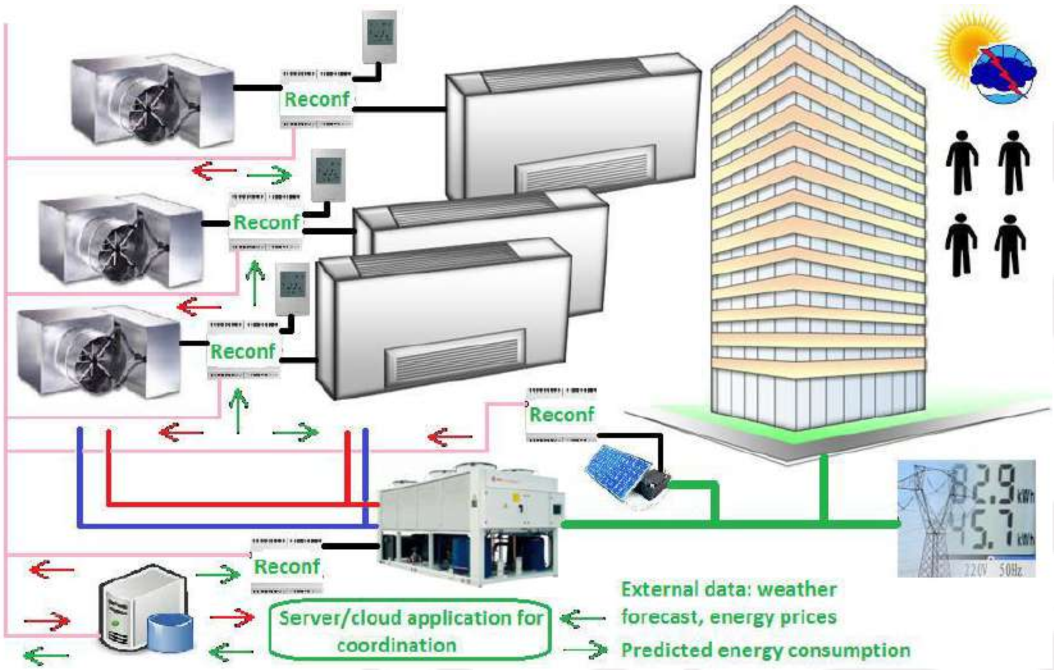
Conventional: 270 kWh
3Smart: 170 kWh

Demonstration of modules operation on EPHZHB building

Service of coordination and demand response

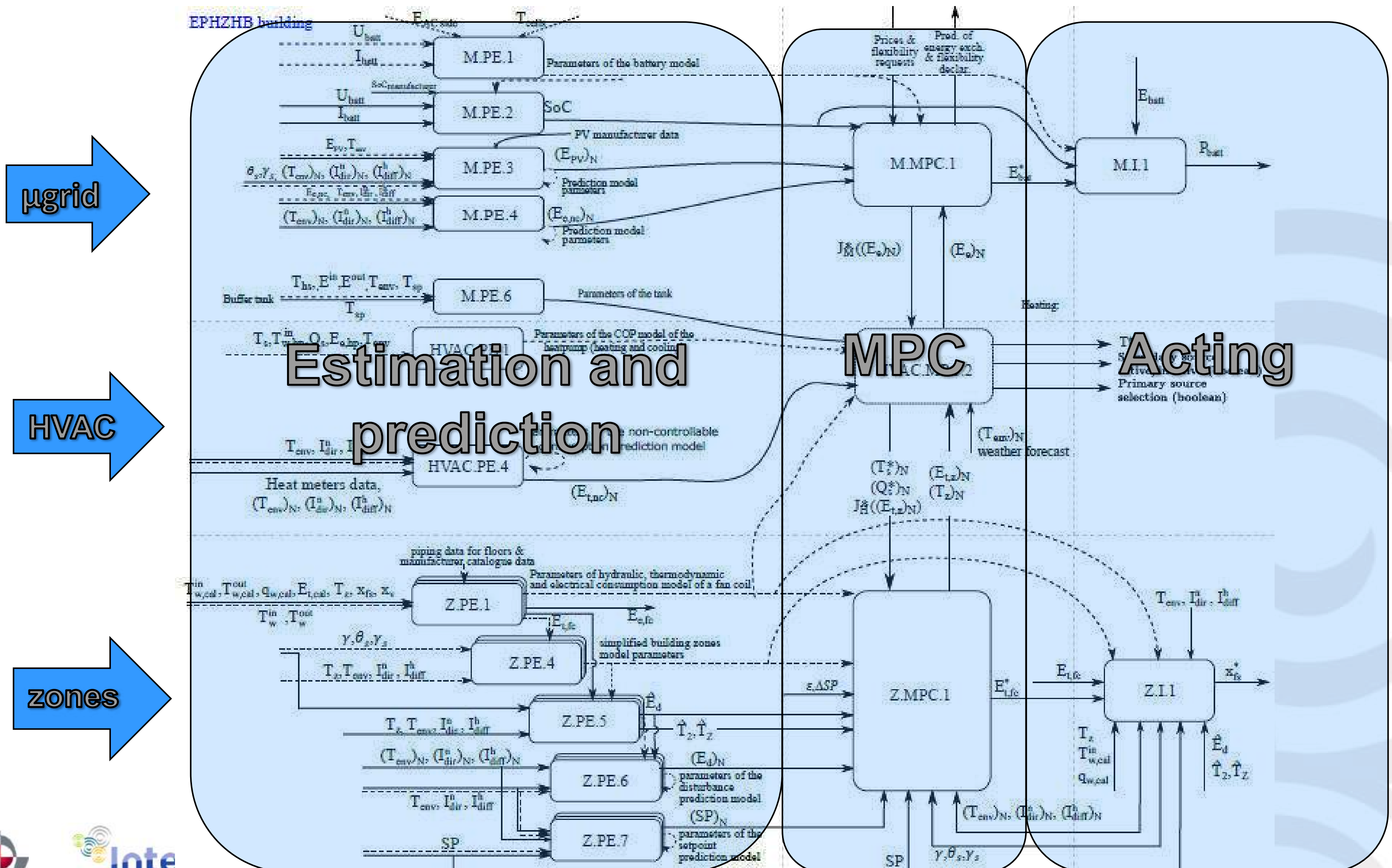
– **Modularity of the coordination service**

- Software modules for different functionality levels in the building



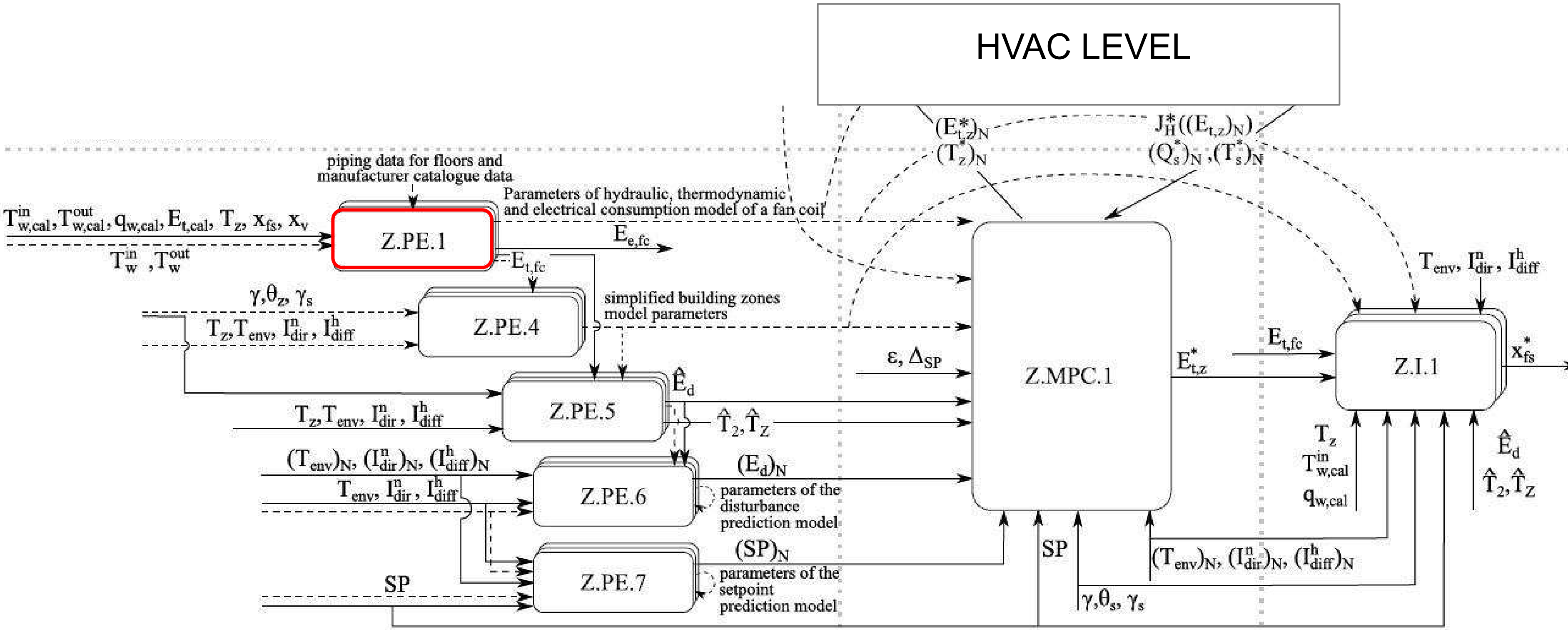
- Mutually coordinated in any configuration

Organization of the 3Smart tool on EPHZHB building



Zones level

Z.PE.1 – offline
(fan coil identification submodule)



Danube Transnational Programme
3Smart

Z.PE.1 – offline
(fan coil identification submodule)

Running only once

- Identification of **installations hydraulic model**

Medium flow measurement from the considered duct calorimeter → **Hydraulic fan coil model** → Medium flow through the fan coil
Valve position → **Hydraulic fan coil model**

- Identification of **thermodynamic fan coils models**

Inputs to **Thermodynamic fan coil model**:
Supply water temperature (calorimeter) →
Return medium temperature →
Fan state →
Valve position →
Medium flow through the coil →
Zone temperature →

Thermodynamic fan coil model → Thermal energy exerted into zone

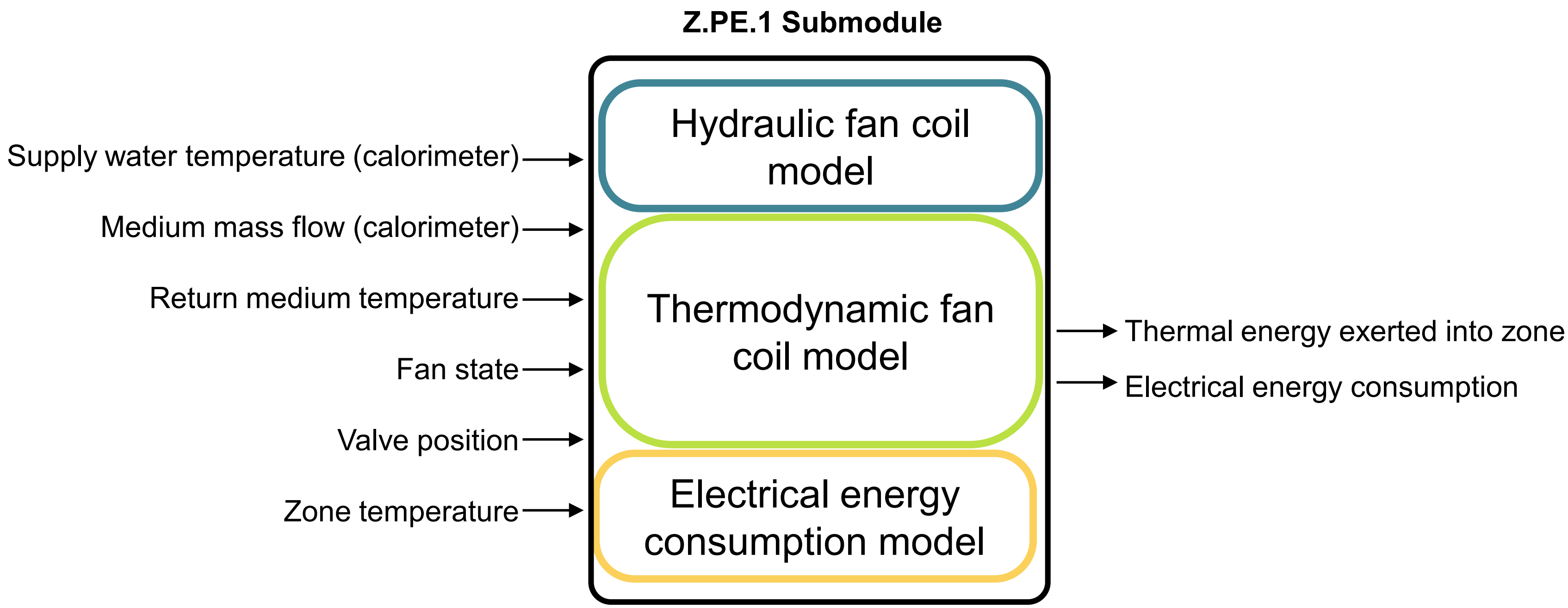
- Identification of **electricity consumption models of fan coils fans**

Fan state → **Electrical energy consumption model** → Electrical energy consumption

Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

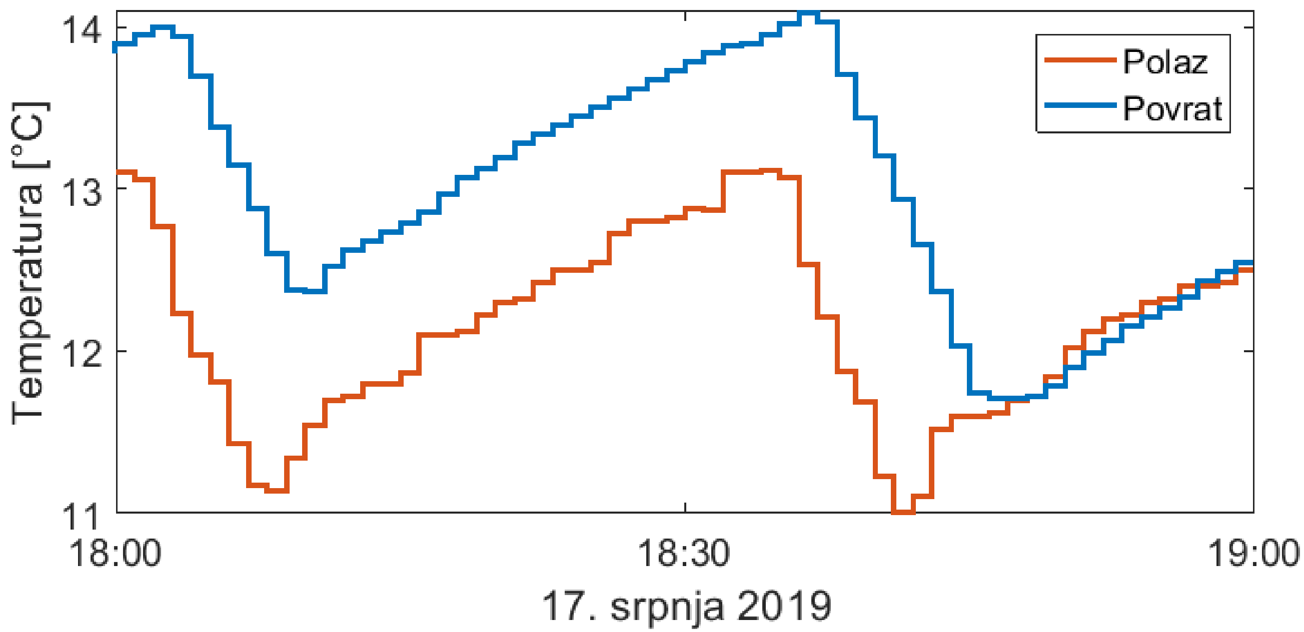
Running every 1 min



Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

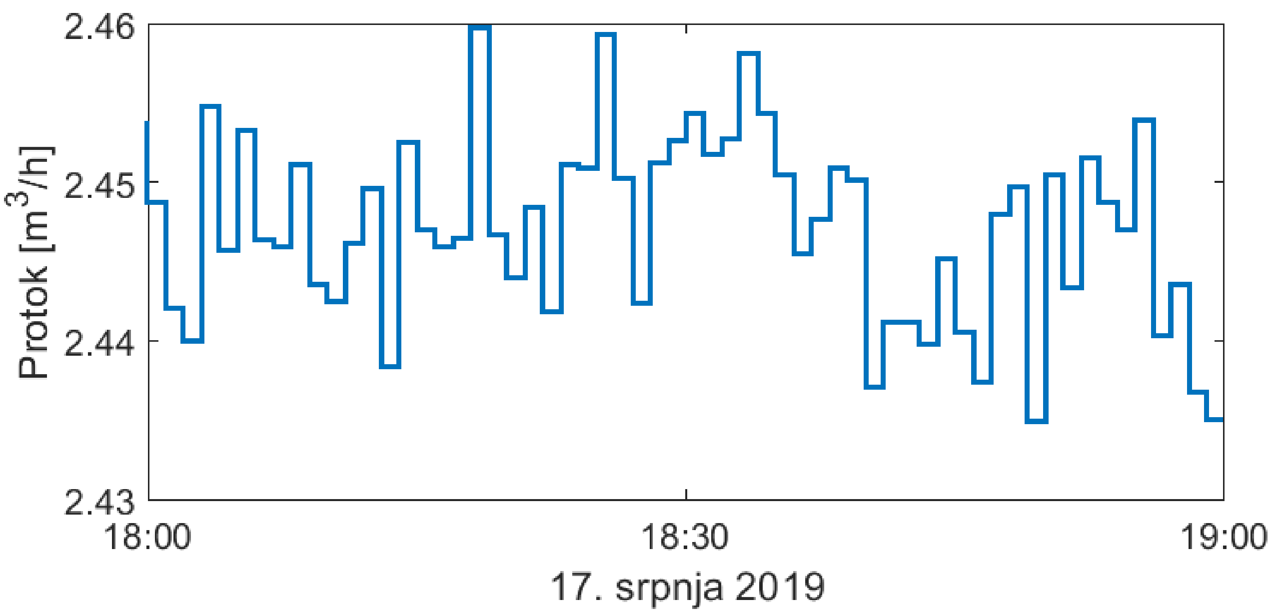
INPUT 1: current measurement of starting and return medium temperature for heating/cooling



Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

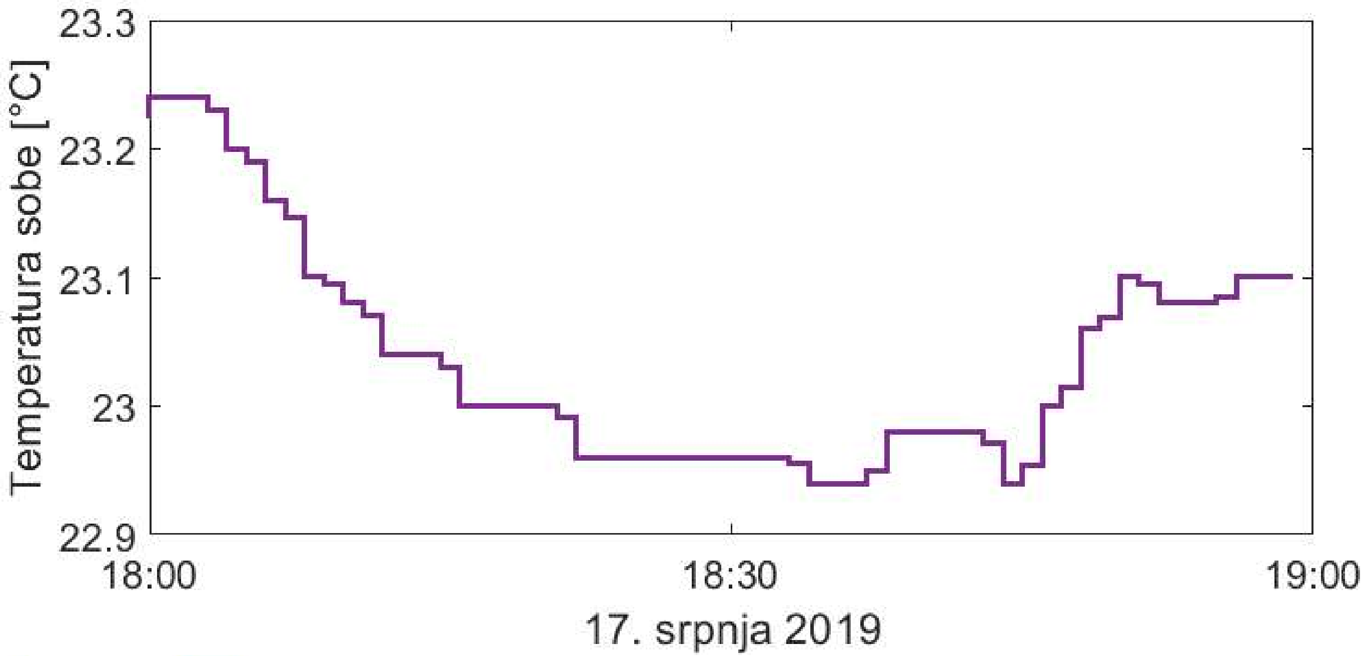
INPUT 1: current measurement of starting and return medium temperature for heating/cooling
INPUT 2: current measurement of medium flow



Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

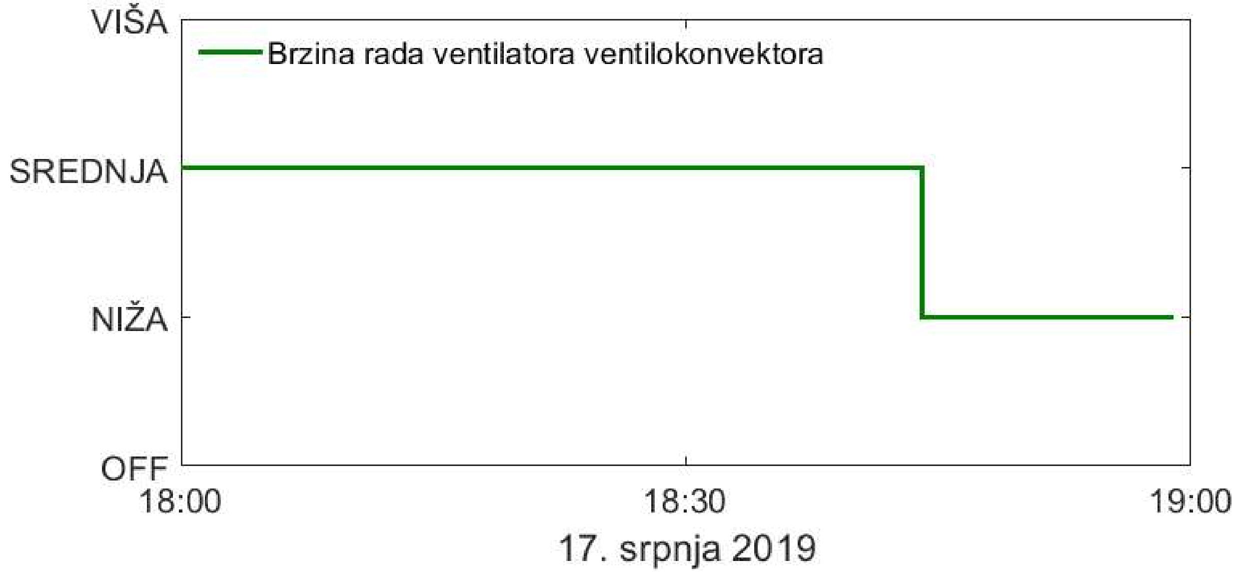
INPUT 1: current measurement of starting and return medium temperature for heating/cooling
INPUT 2: current measurement of medium flow
INPUT 3: current measurement of room air



Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

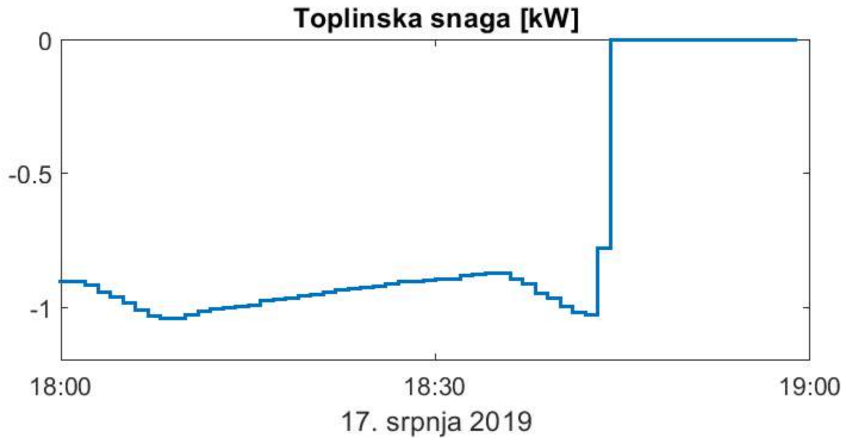
INPUT 1: current measurement of starting and return medium temperature for heating/cooling
INPUT 2: current measurement of medium flow
INPUT 3: current measurement of room air
INPUT 4: current measurement of fan coil fan speed

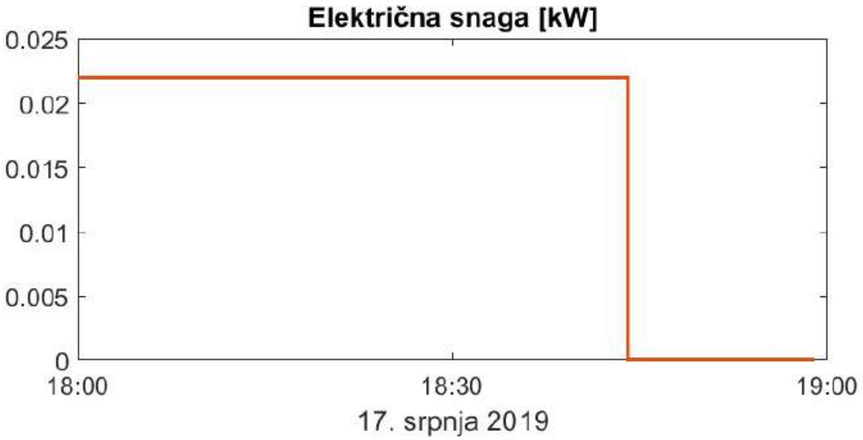


Z.PE.1 – online
(fan coil identification submodule)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coils every minute for every fan coil is computed energy exerted to room air and electricity consumption of fan

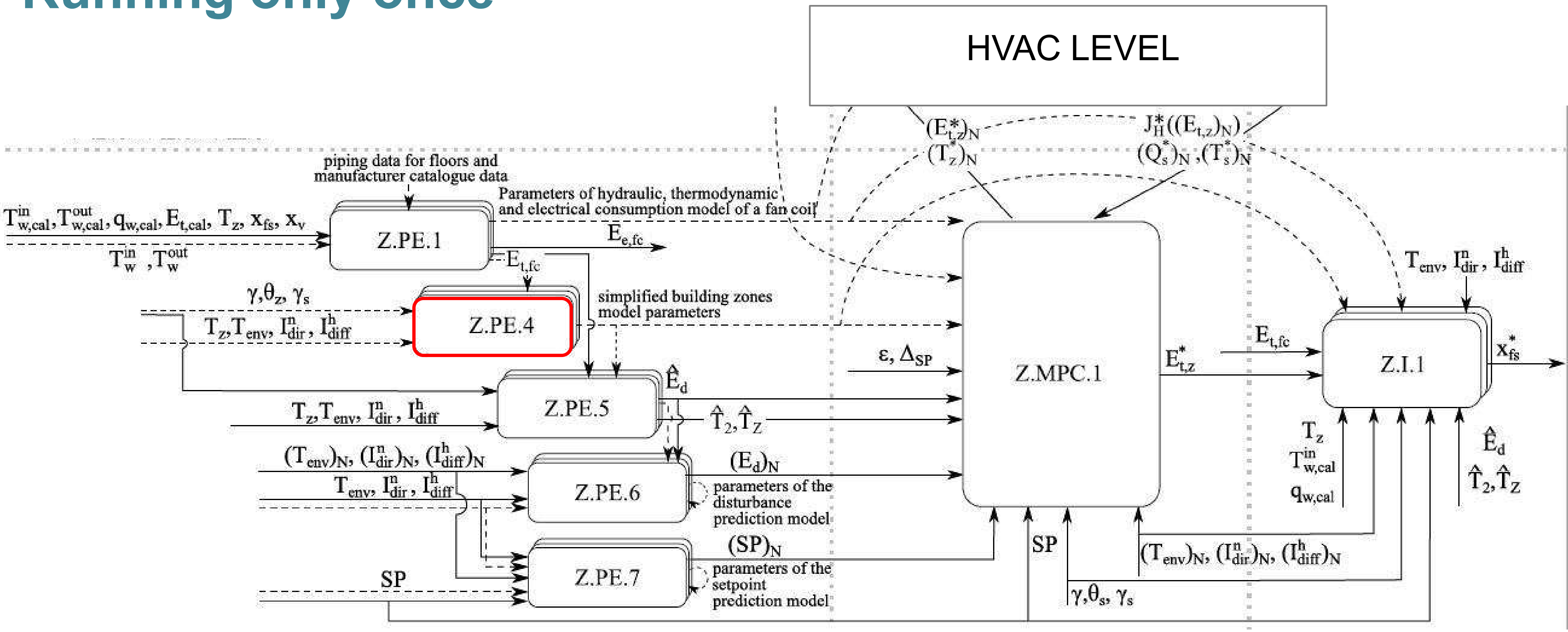
OUTPUT 1: heating energy exerted to room air
OUTPUT 2: electricity consumption of fan coil





Zone PE 4
(submodule for identification of a simplified building thermodynamic model)

Running only once



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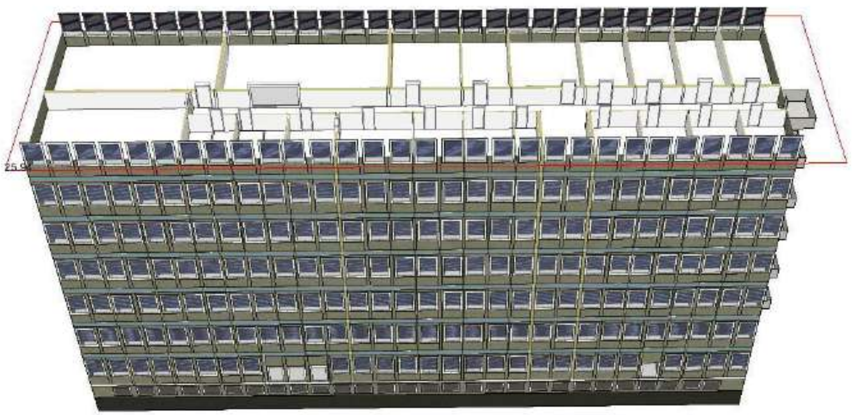
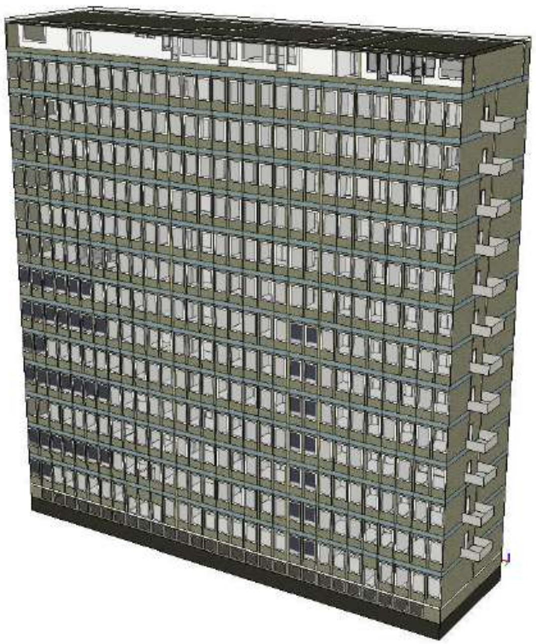
Zone PE 4

(submodule for identification of a simplified building thermodynamic model)

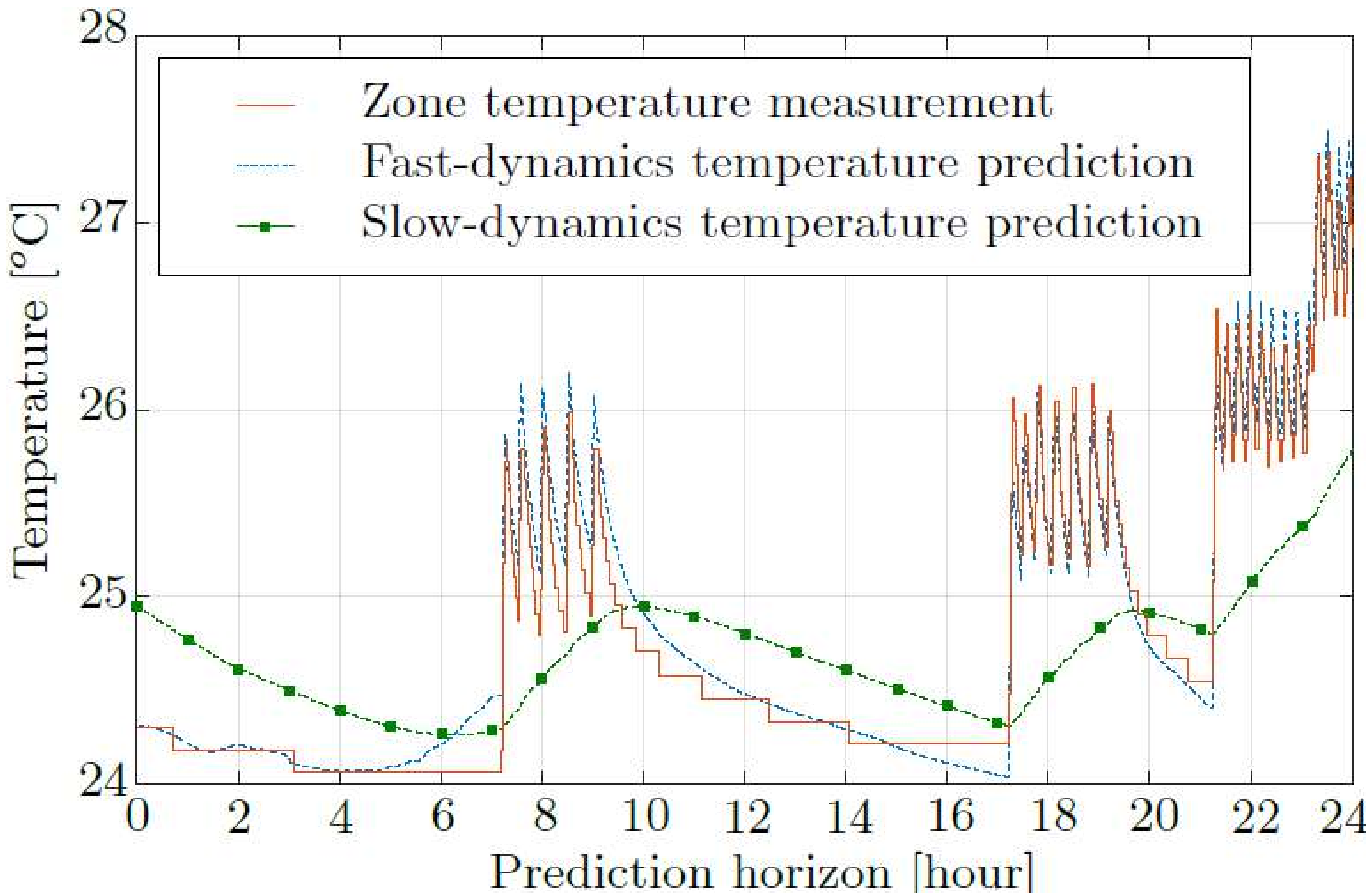
INPUTS: historical measurements of temperatures in building rooms, historical measurements of outdoor weather conditions, historical estimates of heating energies exerted to rooms' air / <u>responses of the building model in a simulation tool</u>

OUTPUTS: parameters of a simplified thermodynamic model of the building





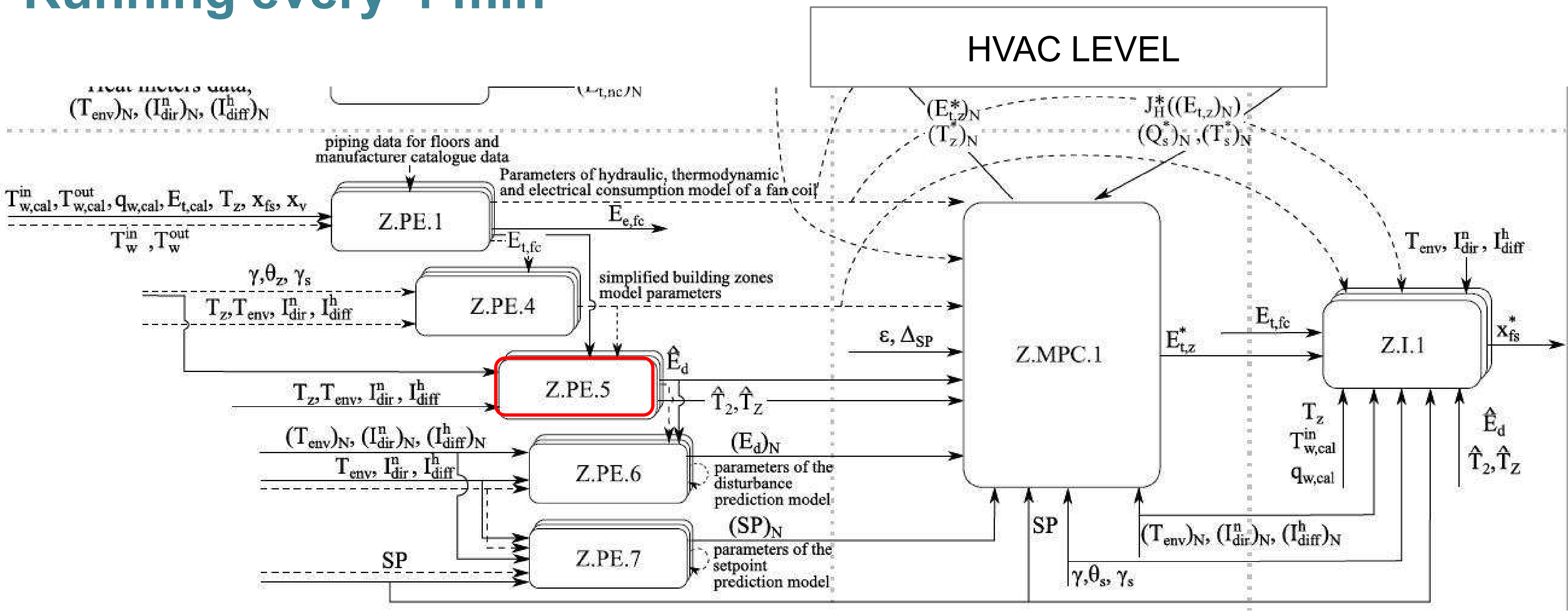
Zone PE 4
(submodule for identification of a simplified building thermodynamic model)



Zone PE 5

(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

Running every 1 min



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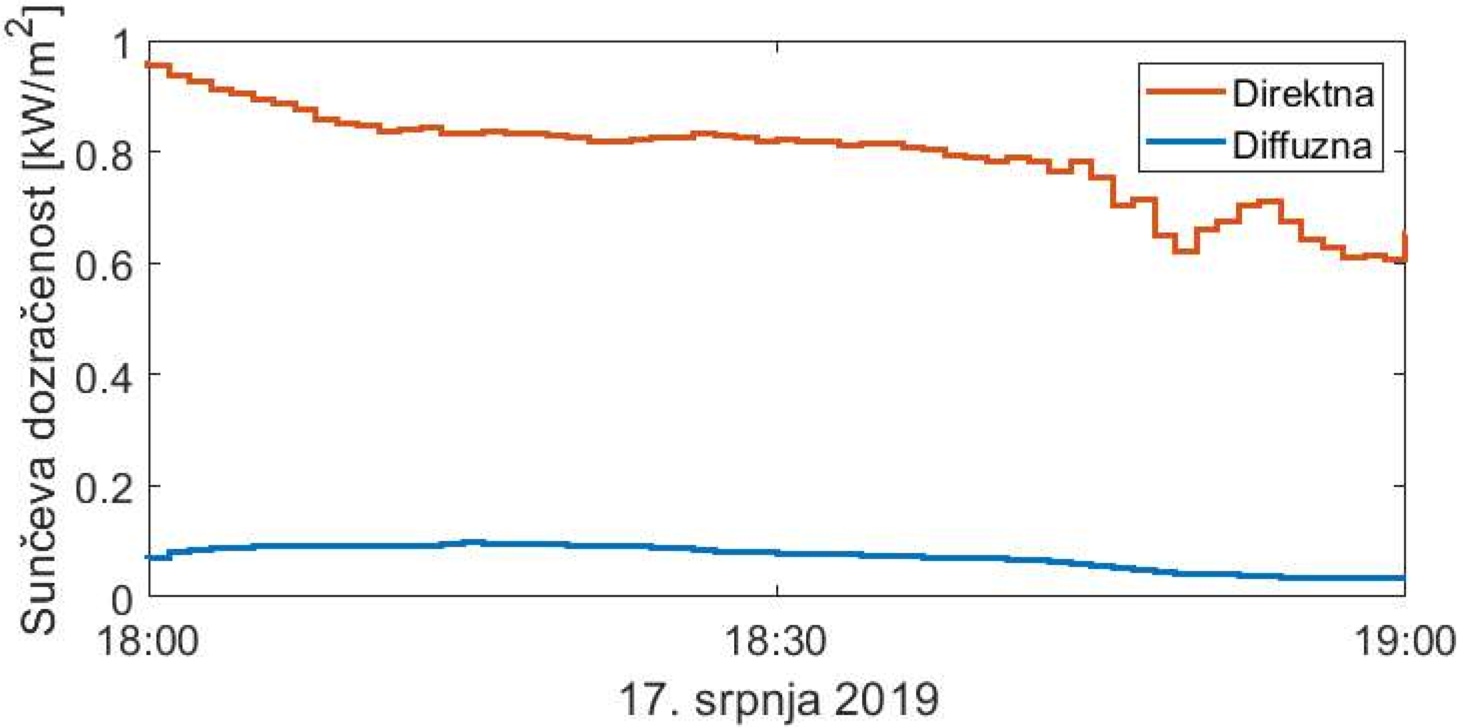
Zone PE 5
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

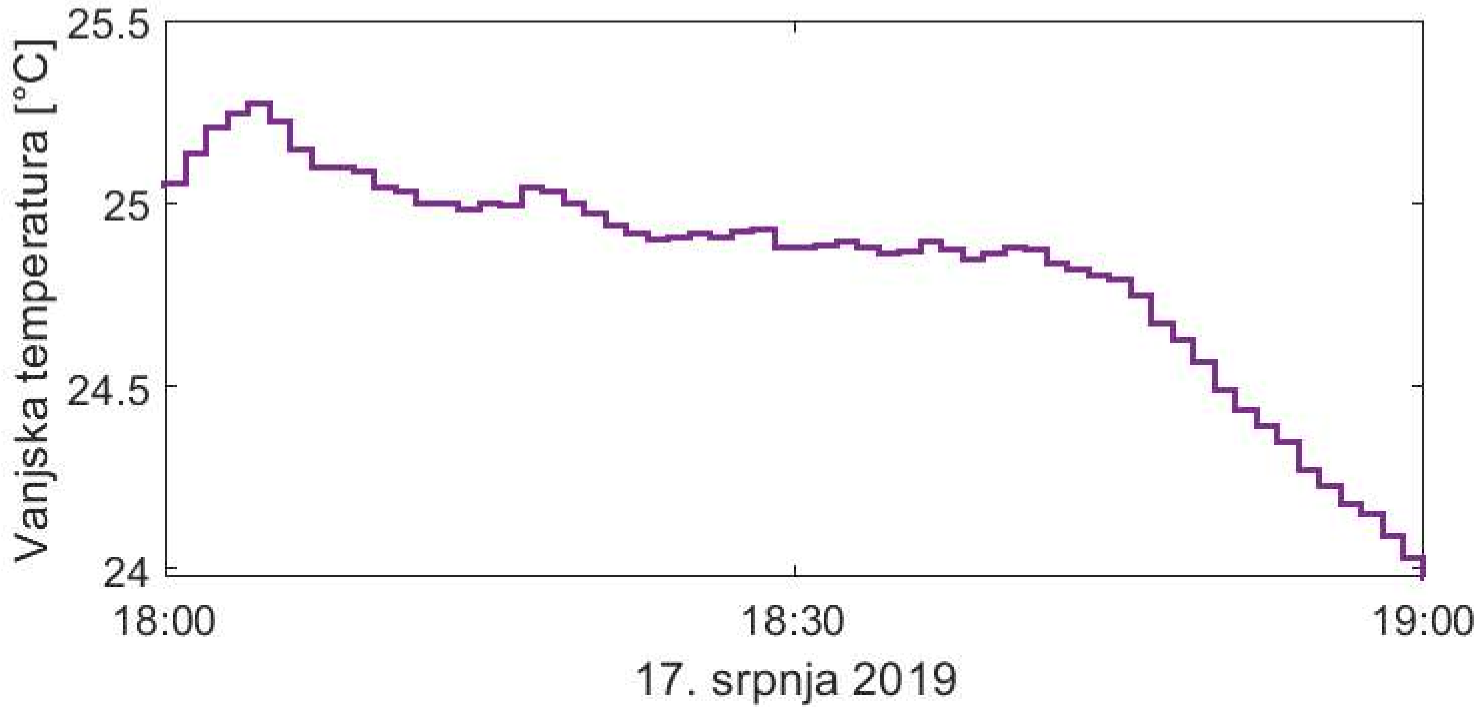
INPUT 1: current measurement of direct and diffuse solar irradiance



Zone PE 5

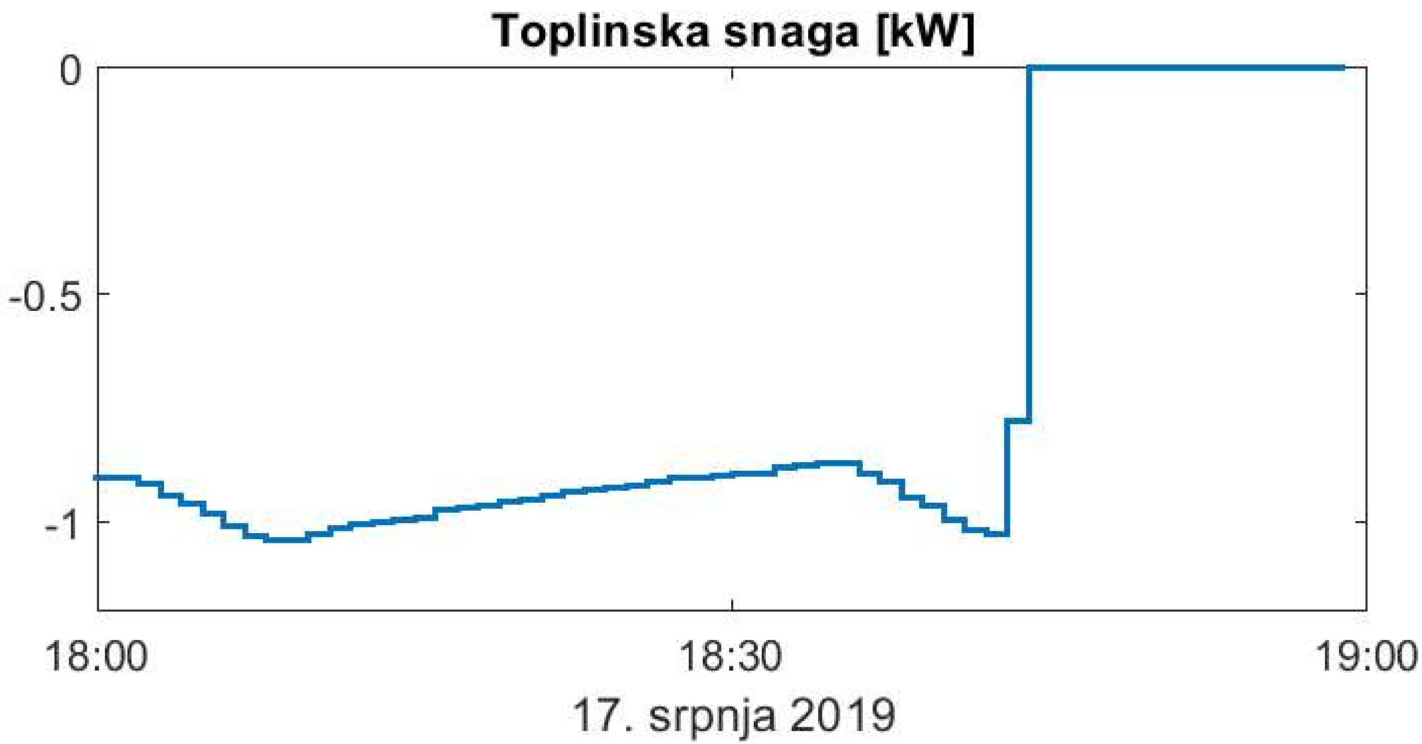
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

INPUT 1: current measurement of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature



Zone PE 5
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

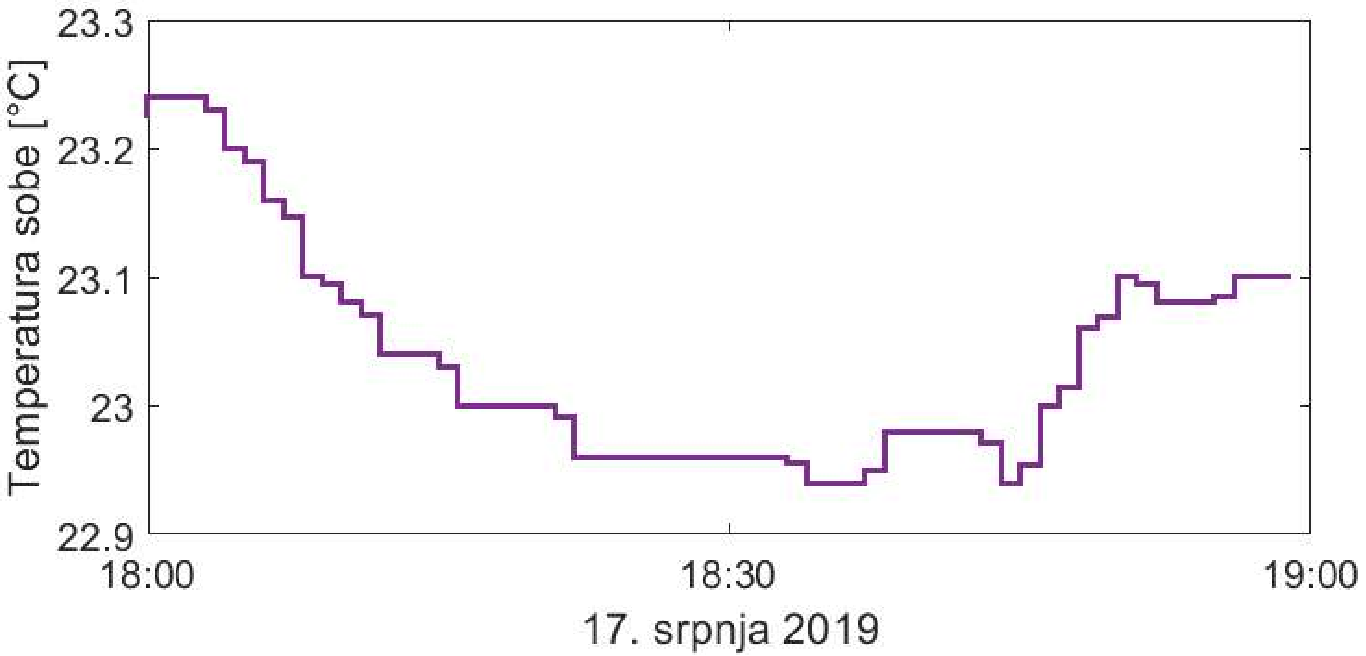
INPUT 1: current measurement of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature
INPUT 3: current measurement of heating power inserted in the zone (Zone PE 1 submodule)



Zone PE 5

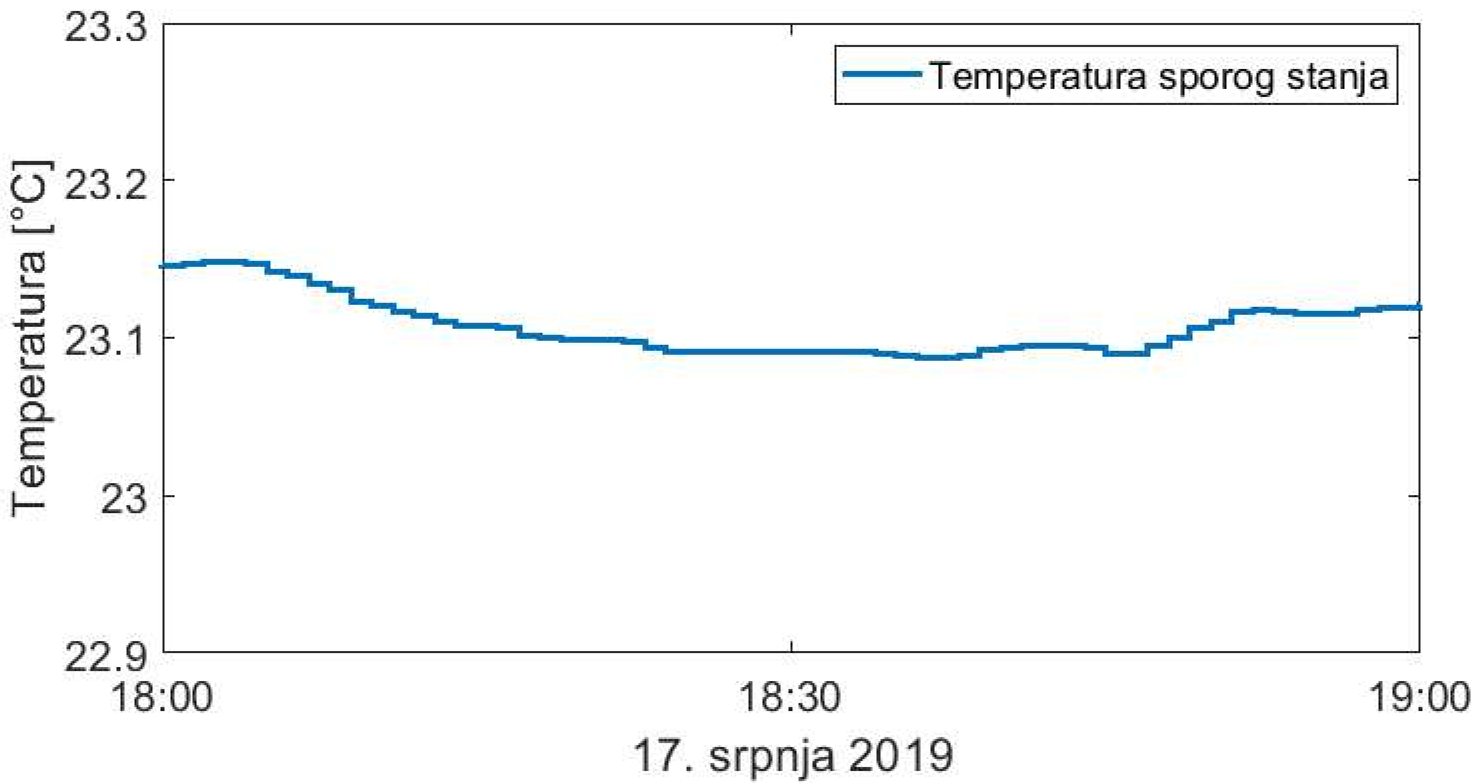
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

INPUT 1: current measurement of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature
INPUT 3: current measurement of heating power inserted in the zone (Zone PE 1 submodule)
INPUT 4: current measurement of room temperature



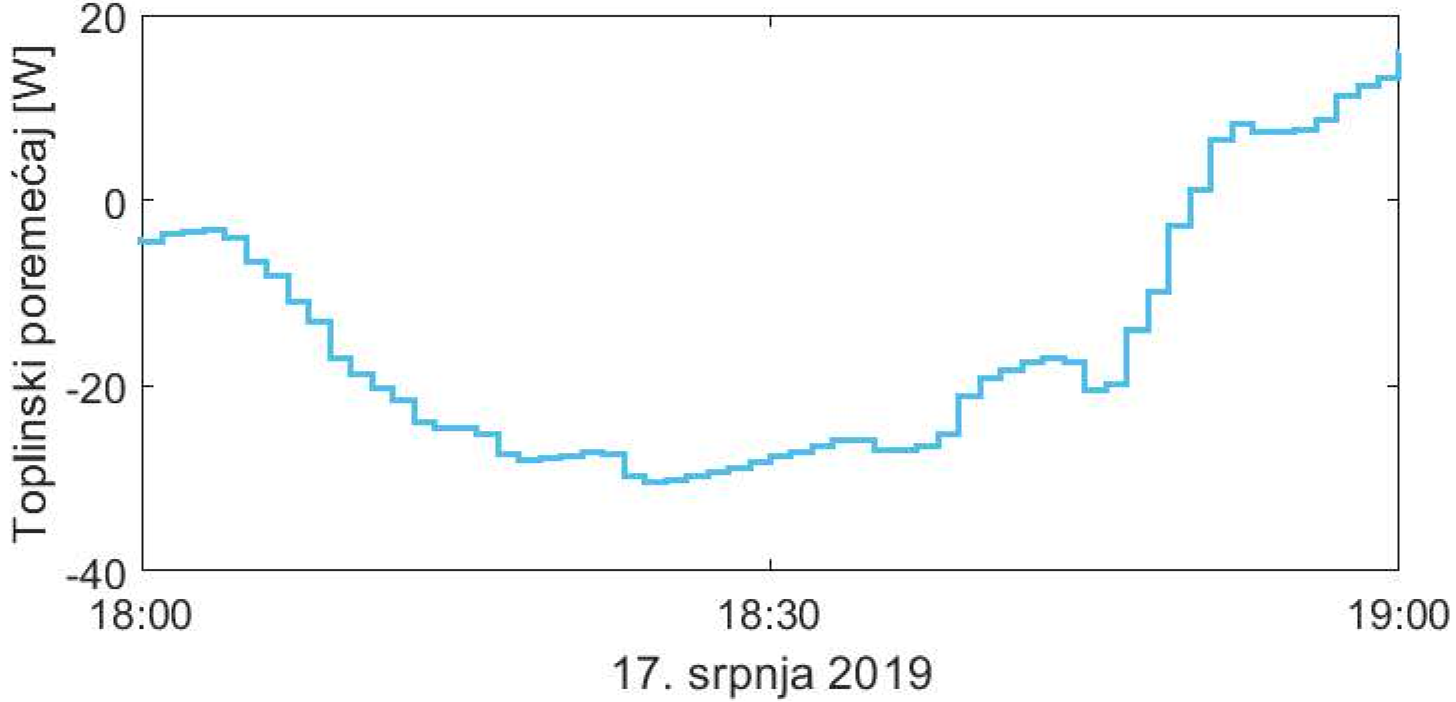
Zone PE 5
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

OUTPUT 1: Estimated current slow dynamics temperature

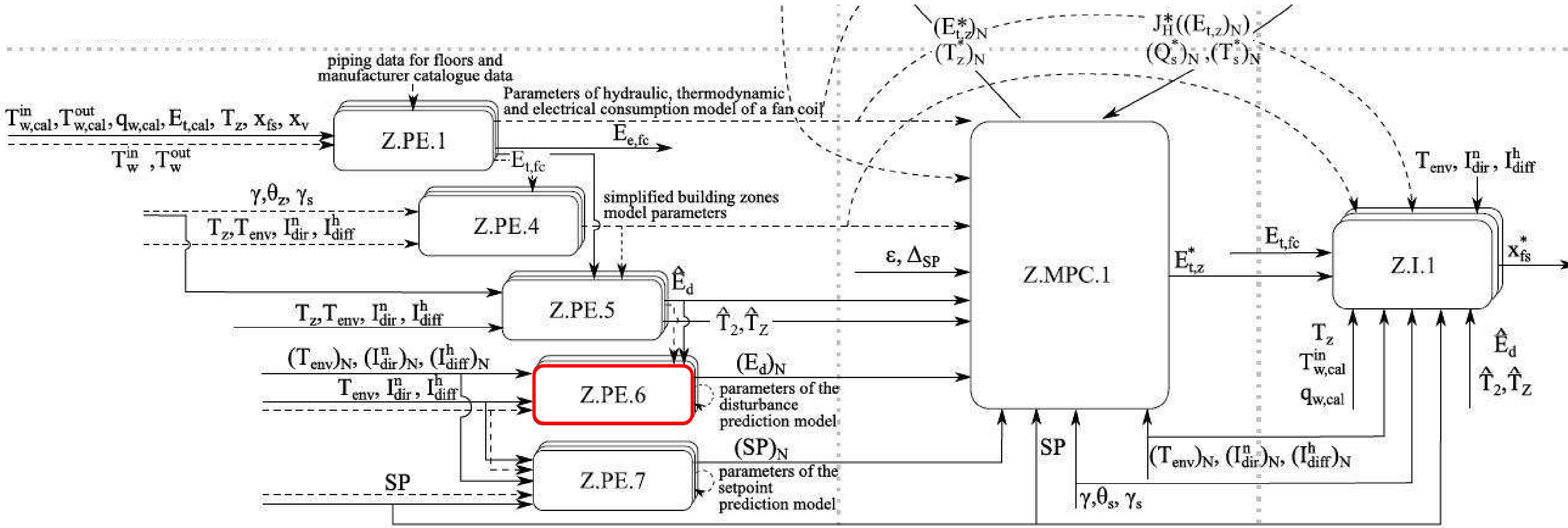


Zone PE 5
(submodule for estimation of non-measurable temperature states and heat disturbances in building zones)

OUTPUT 1: Estimated current slow dynamics temperature
OUTPUT 2: Estimated current value of heat disturbance

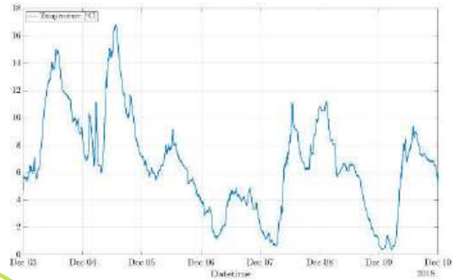


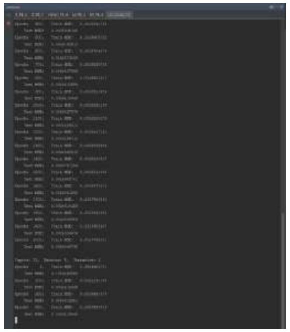
Zone PE 6
(submodule for prediction of heat disturbance in a zone)



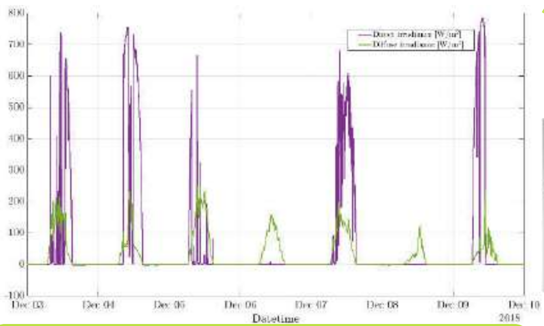
Zone PE 6 – off-line initialization

Historical **meteo measurements**:
- Air temperature
- Direct and diffuse solar irradiance



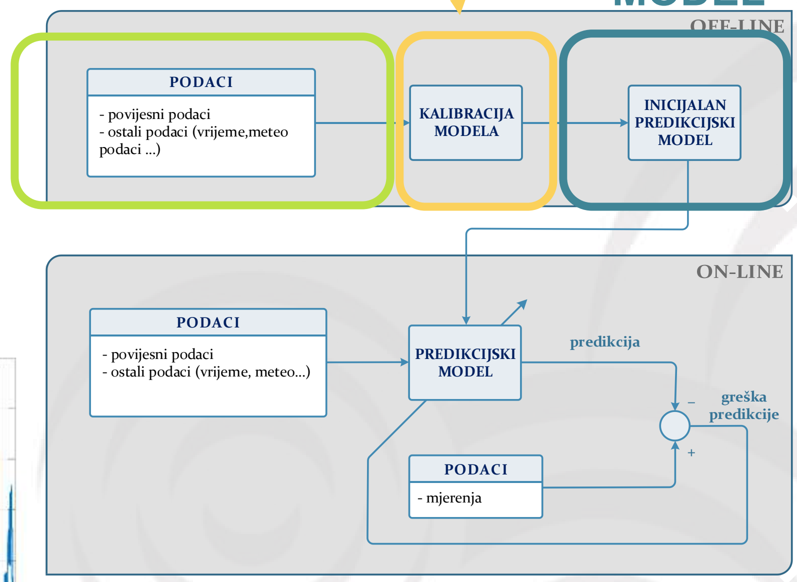


Locally stored: inputsXY_neuronsZ.net

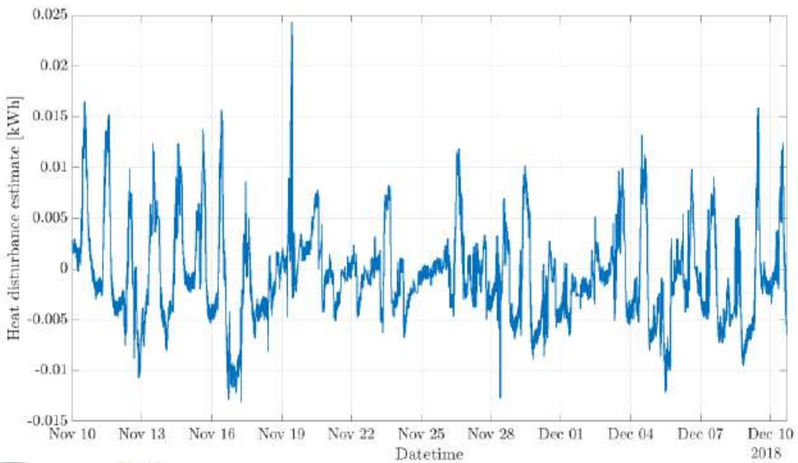


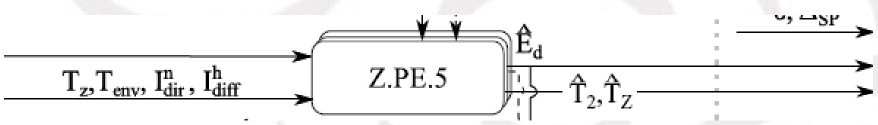
MODULE INPUTS

MODEL

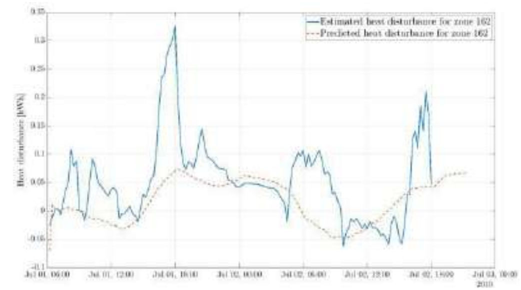


Historical values of **estimated heat disturbance (Z.PE.5)**





Zone PE 6 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor composed of specific historical samples of input data:

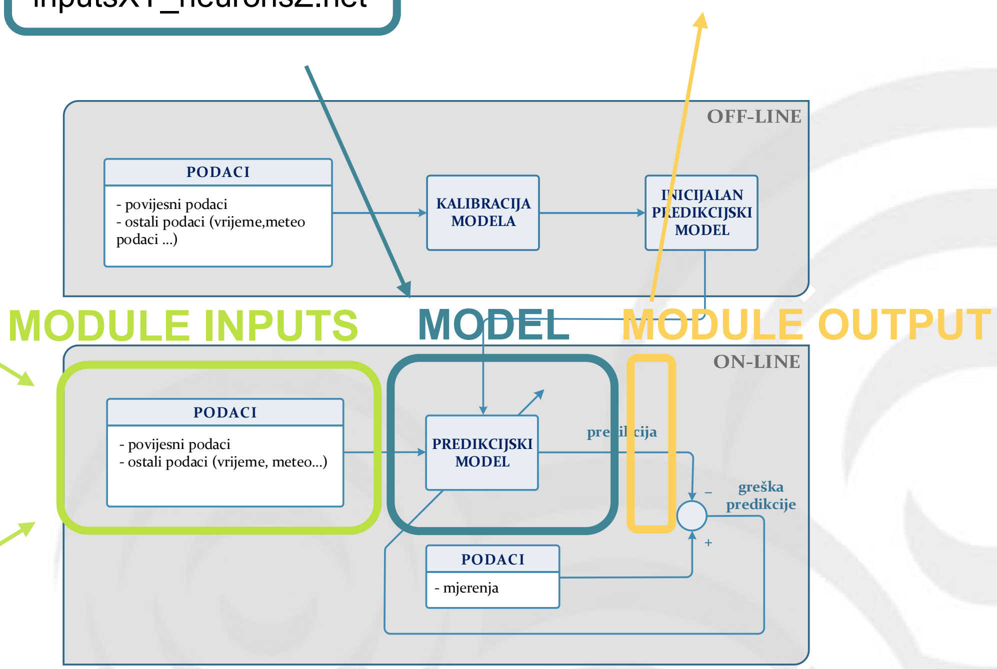
- heat disturbance(t-1,…,t-5)
- heat disturbance(t-670,…,t-674)

time determinants:
- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

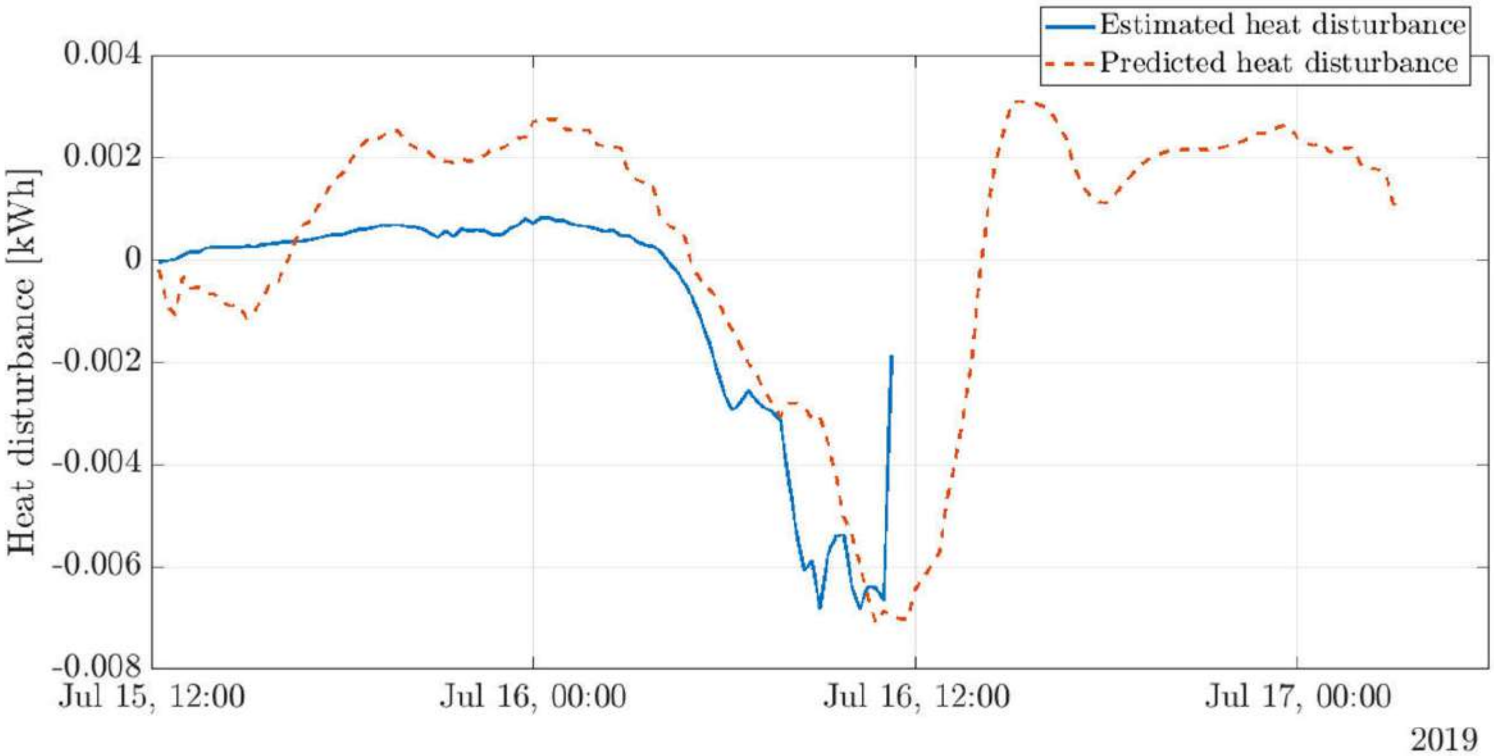
- air temperature(t-1,…,t-3)
- air temperature(t-671,…,t-673)

- direct irradiance(t-1,…,t-3)
- direct irradiance(t-671,…,t-673)

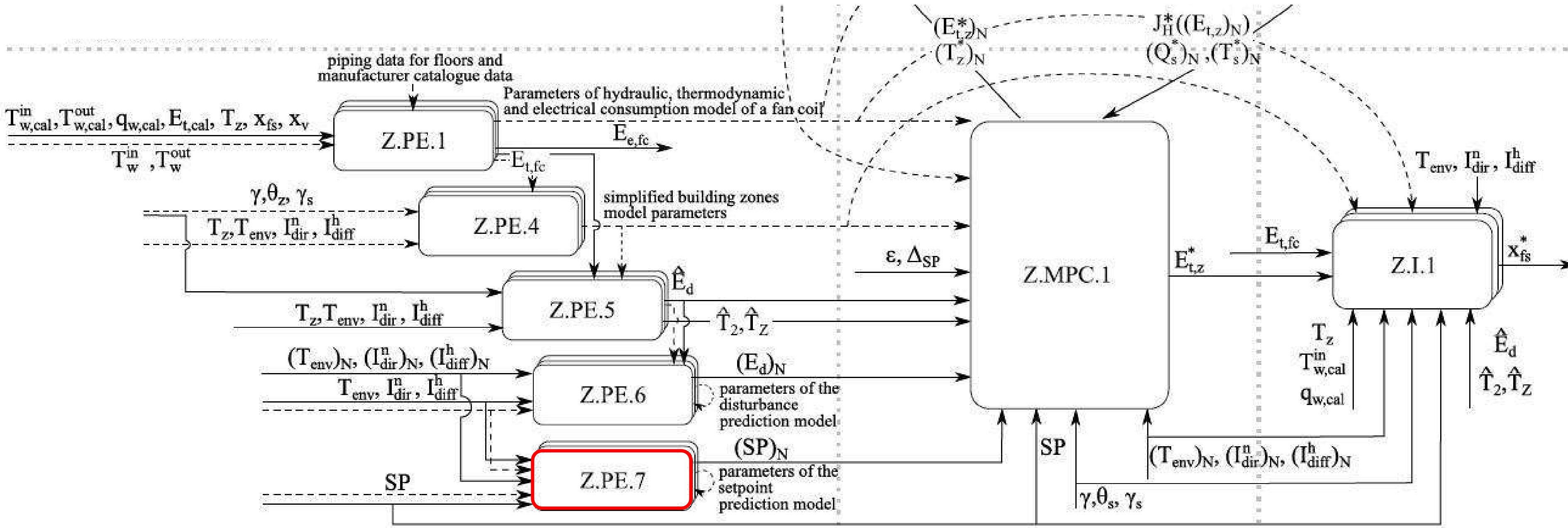
- diffuse irradiance(t-1,…,t-3)
- diffuse irradiance (t-671,…,t-673)



Zone PE 6 – example of generated prediction



Zone PE 7 (submodule for prediction of reference temperature value in a zone)



Zone PE 7 – given reference temperature value

MODULE INPUTS

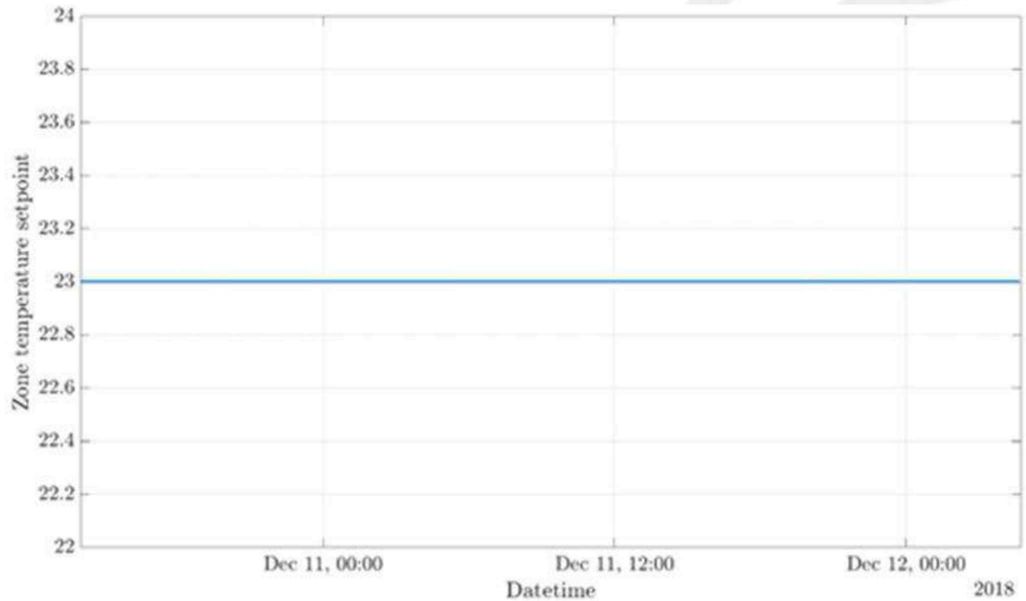
Current given reference temperature value in a zone

MODUL

Zone PE 7

MODULE OUTPUTS

Assumed the same value along the prediction horizon



Zone PE 7 – stand-by/manual operation mode

ULAZI MODULA

Current given reference temperature value in a zone

→

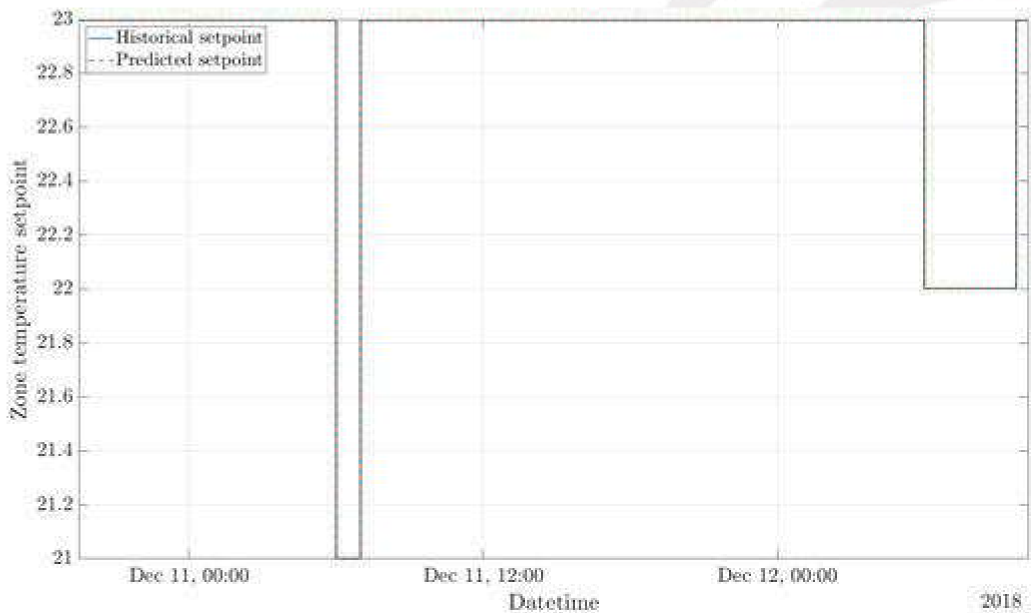
MODUL

Zone PE 7

→

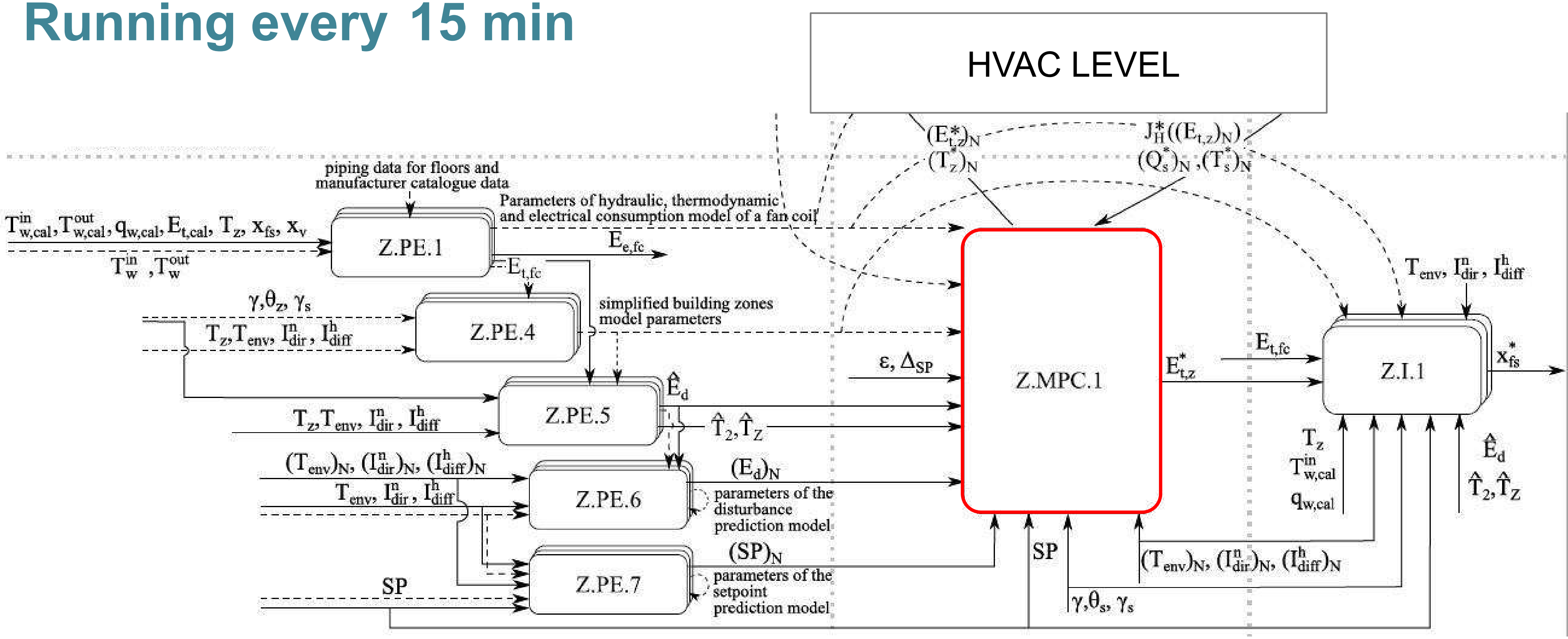
IZLAZI MODULA

Historical reference temperature value



Zone MPC 1
(module for model predictive control of comfort in building zones)

Running every 15 min



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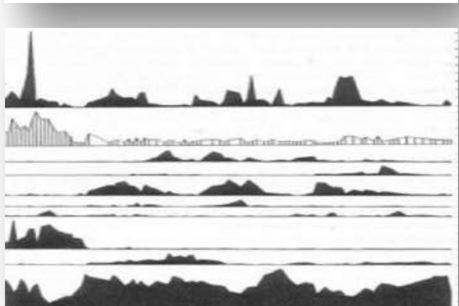
Zone MPC 1

(module for model predictive control of comfort in building zones)

Optimization of temperature in building rooms on a horizon of future 12 – 36 h with sampling time of 15 min

1 pm	Showers	54°	FEELS LIKE 49°	HUMIDITY 64%	PRECIP 60%	WIND NNW at 18 mph
2 pm	Showers	54°	FEELS LIKE 49°	HUMIDITY 64%	PRECIP 60%	WIND NNW at 19 mph
3 pm	Showers	54°	FEELS LIKE 49°	HUMIDITY 61%	PRECIP 60%	WIND NNW at 19 mph
4 pm	Showers	54°	FEELS LIKE 49°	HUMIDITY 59%	PRECIP 60%	WIND NNW at 19 mph



MATHEMATICAL OPTIMIZATION

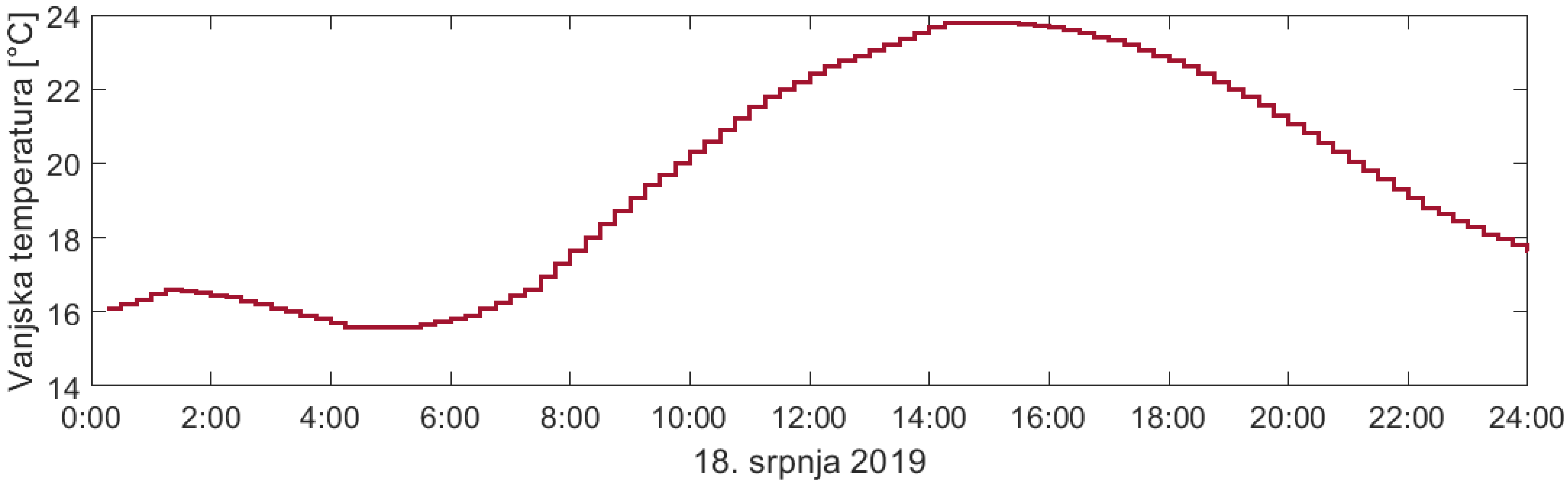
Optimal profile of energy consumption in building zones

Optimal temperature profile in building zones

Zone MPC 1

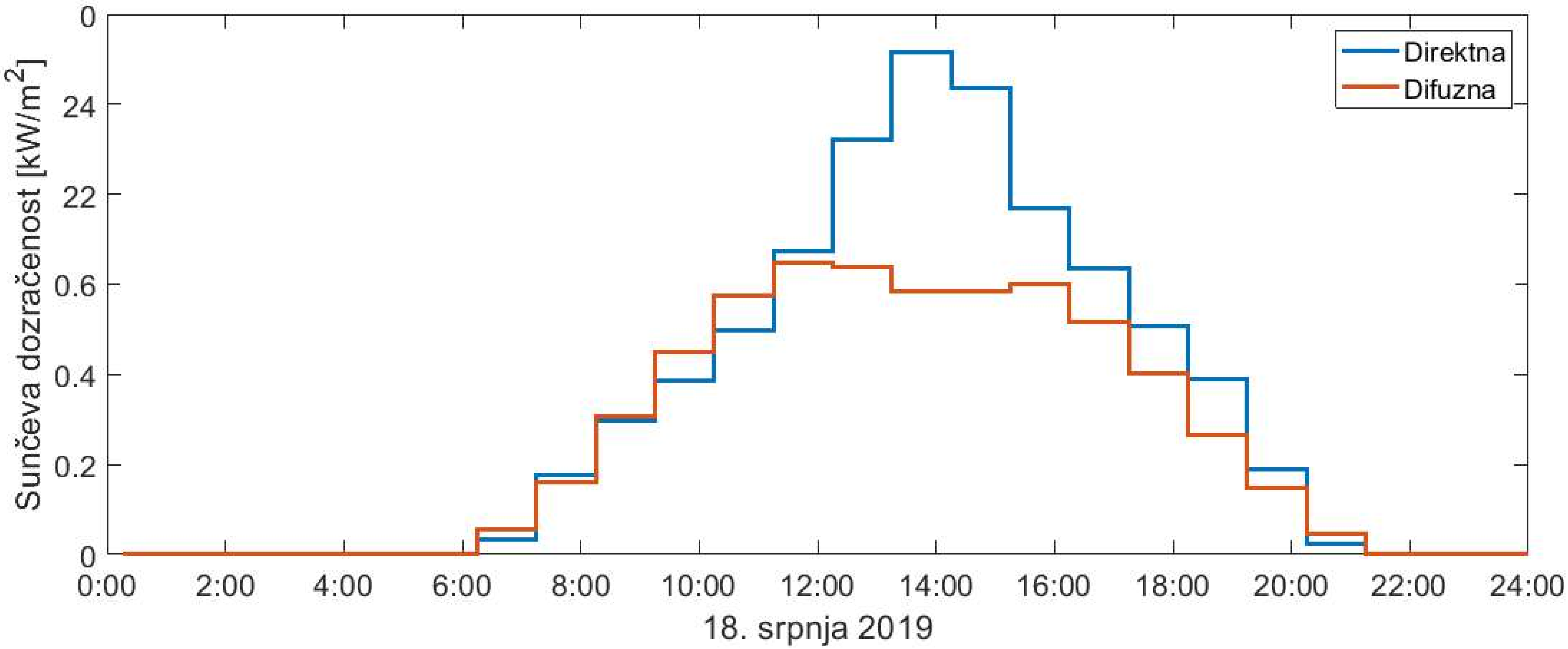
(module for model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance



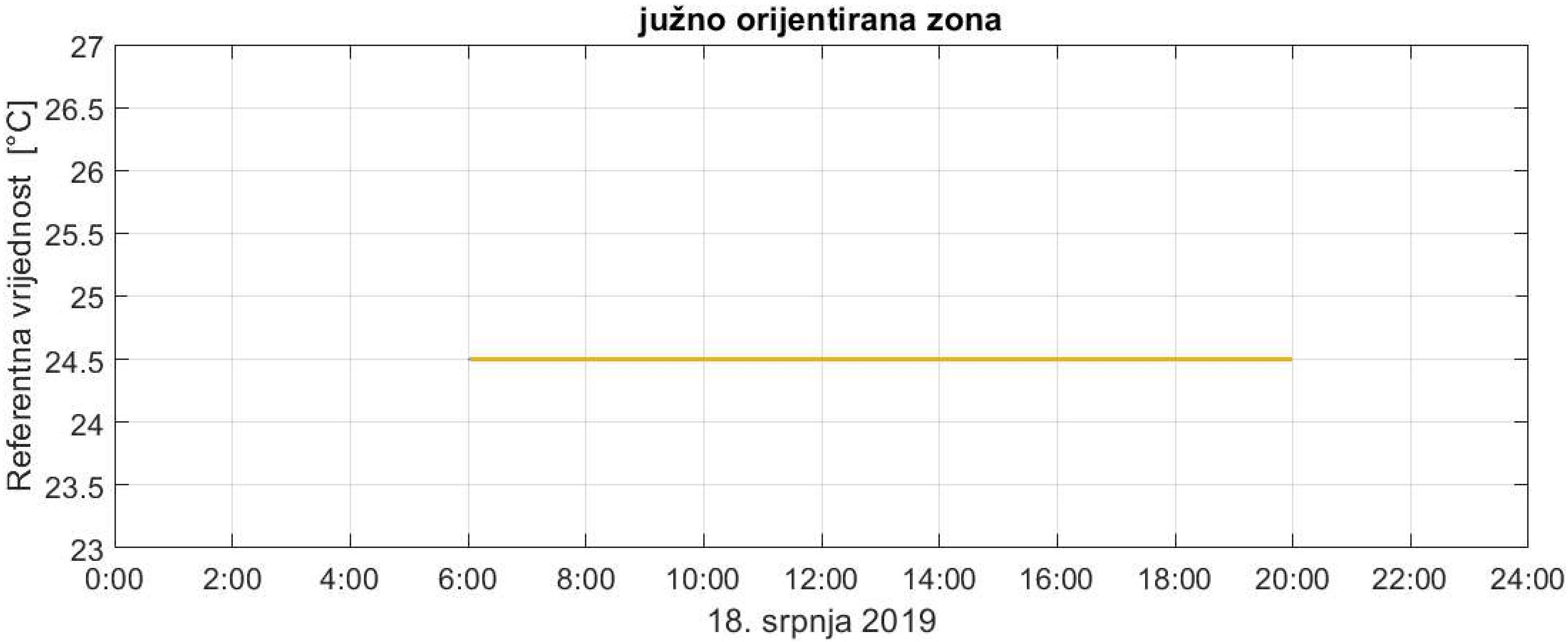
Zone MPC 1
(module for model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance



Zone MPC 1
(module for model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance
INPUT 3: Prediction of user behaviour 12-36 h in advance



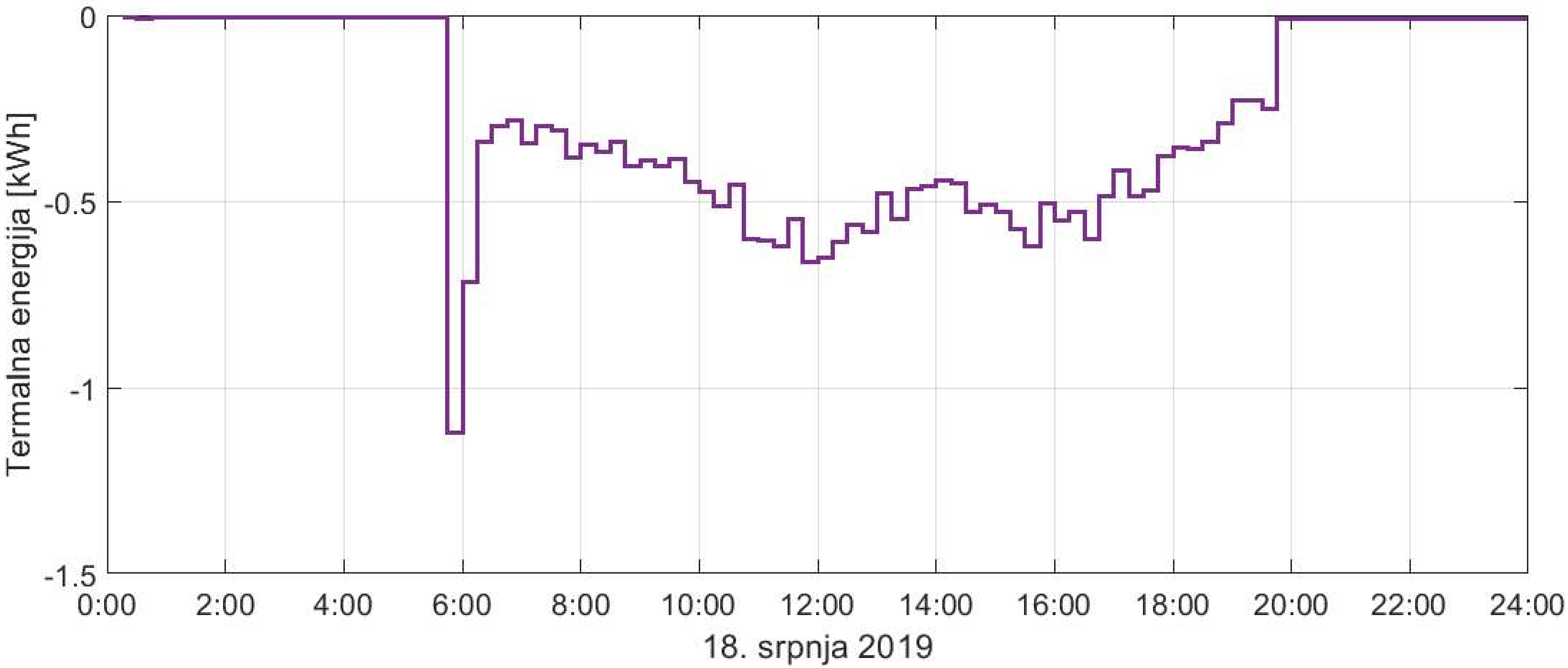
Zone MPC 1

(module for model predictive control of comfort in building zones)

INPUT 1: Prediction of outdoor temperature 12-36 h in advance
INPUT 2: Prediction of solar irradiance (direct and diffuse) 12-36 h in advance
INPUT 3: Prediction of user behaviour 12-36 h in advance
INPUT 4: Prediction of heat disturbance 12-36 h in advance
OTHER INPUTS: Price of heating energy, comfort requests, mathematical models,…

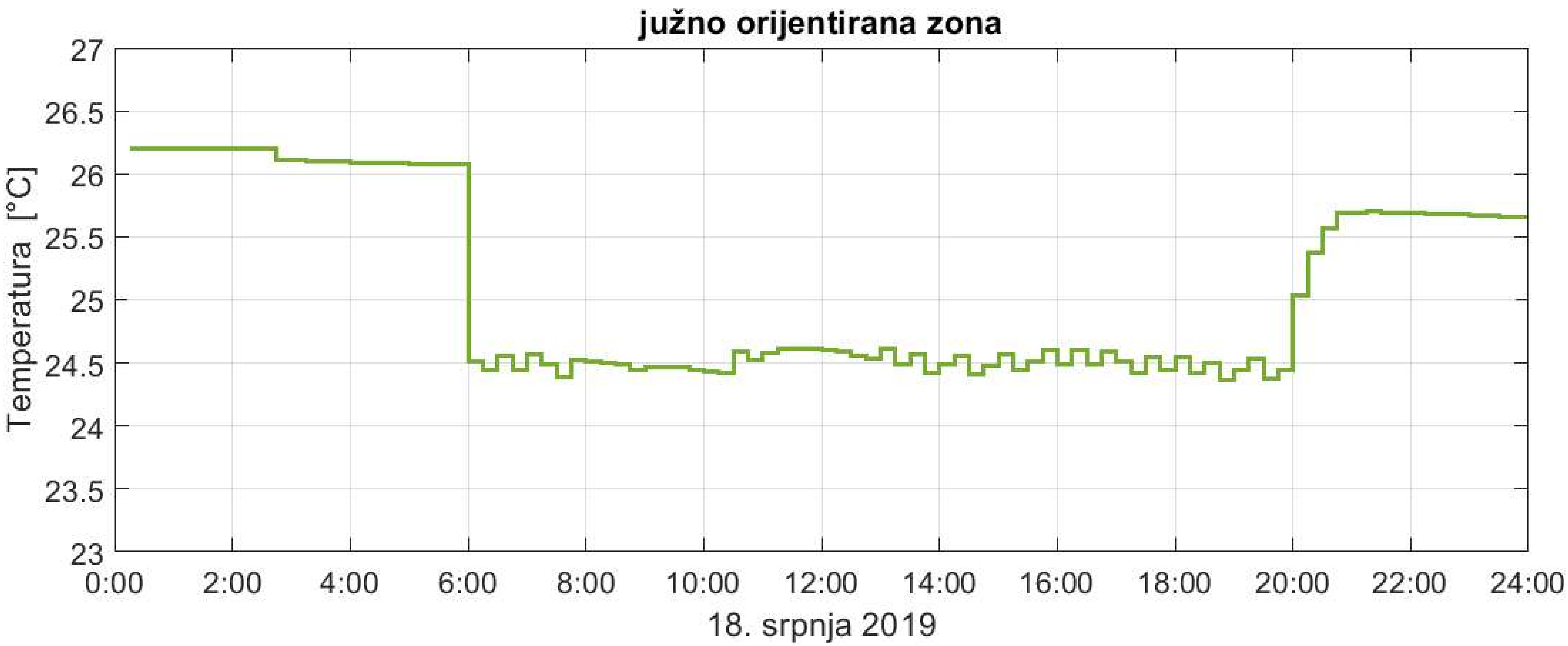
Zone MPC 1
(module for model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of heating energy consumption in a building 12-36 h in advance



Zone MPC 1
(module for model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of heating energy consumption in a building 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building rooms 12-36 h in advance

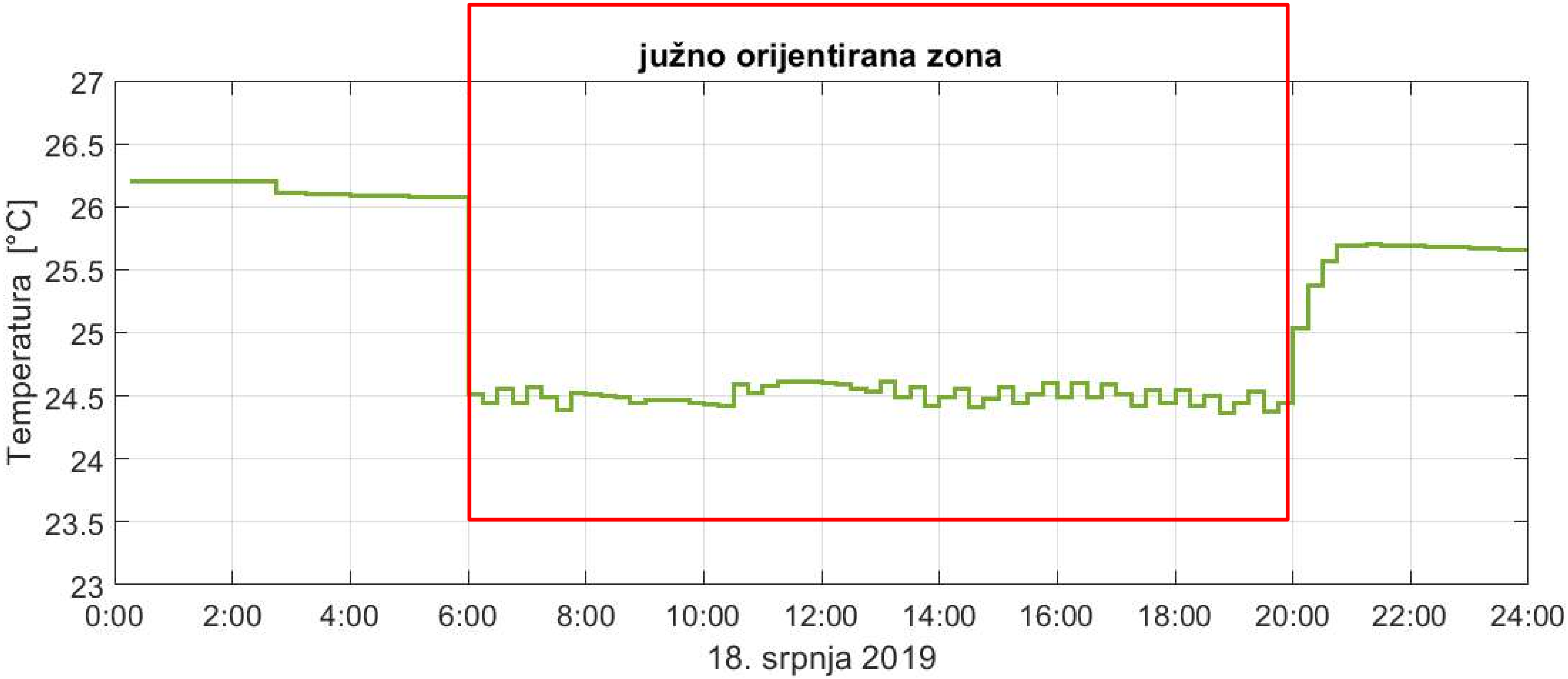


Zone MPC 1

(module for model predictive control of comfort in building zones)

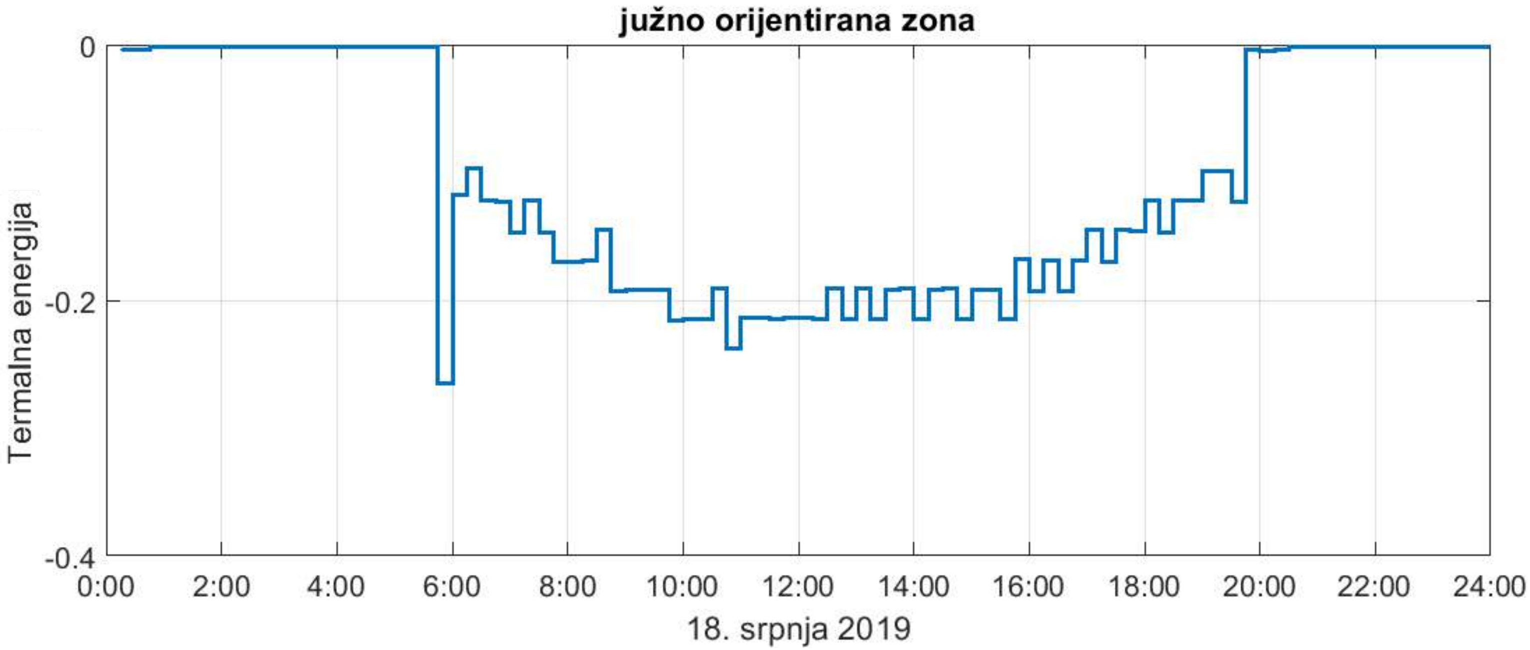
OUTPUT 1: Optimal profile of heating energy consumption in a building 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building rooms 12-36 h in advance

COMFORT SECURED



Zone MPC 1
(module for model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of heating energy consumption in a building 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building rooms 12-36 h in advance
OUTPUT 3: Optimal profile of heating energy consumption in building rooms 12-36 h in advance

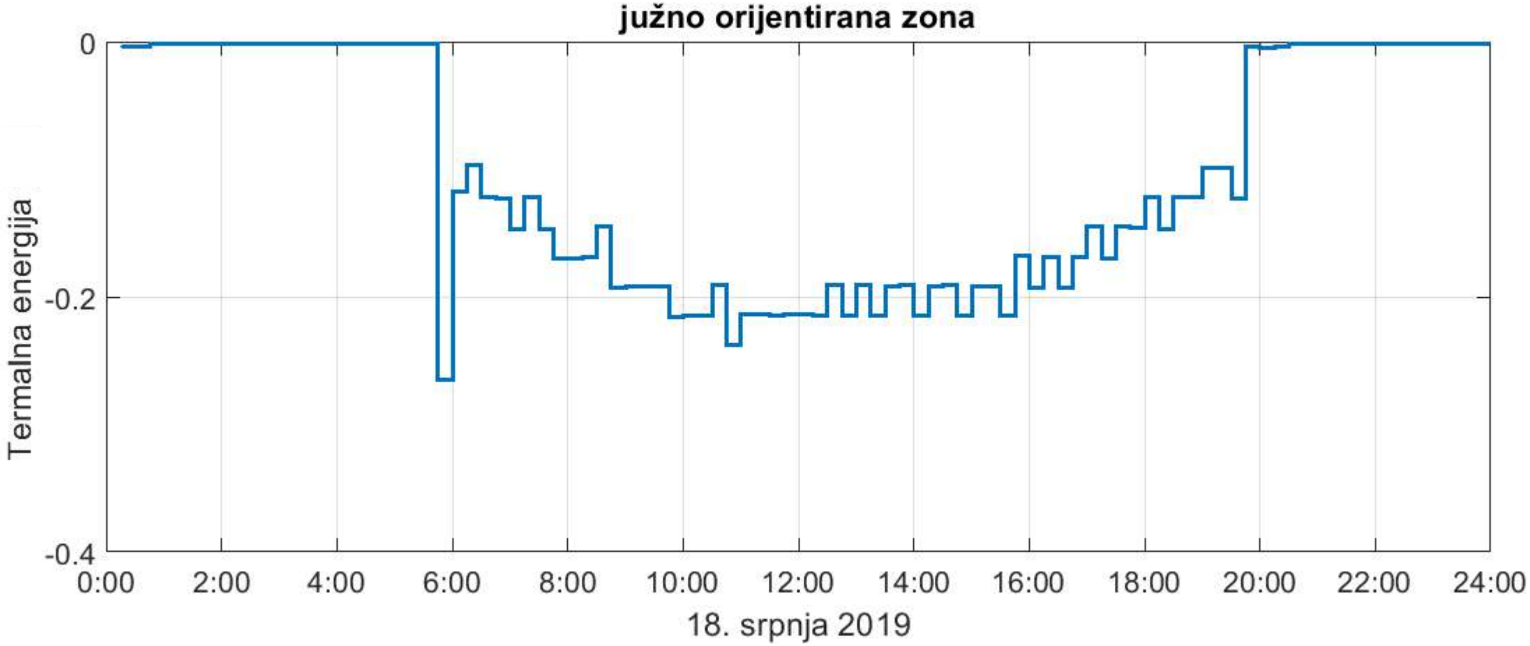


Zone MPC 1

(module for model predictive control of comfort in building zones)

OUTPUT 1: Optimal profile of heating energy consumption in a building 12-36 h in advance
OUTPUT 2: Optimal profile of temperature in building rooms 12-36 h in advance
OUTPUT 3: Optimal profile of heating energy consumption in building rooms 12-36 h in advance

How to realize that the computed amount of energy is exerted to individual rooms air by fan coils in each 15 min time interval?



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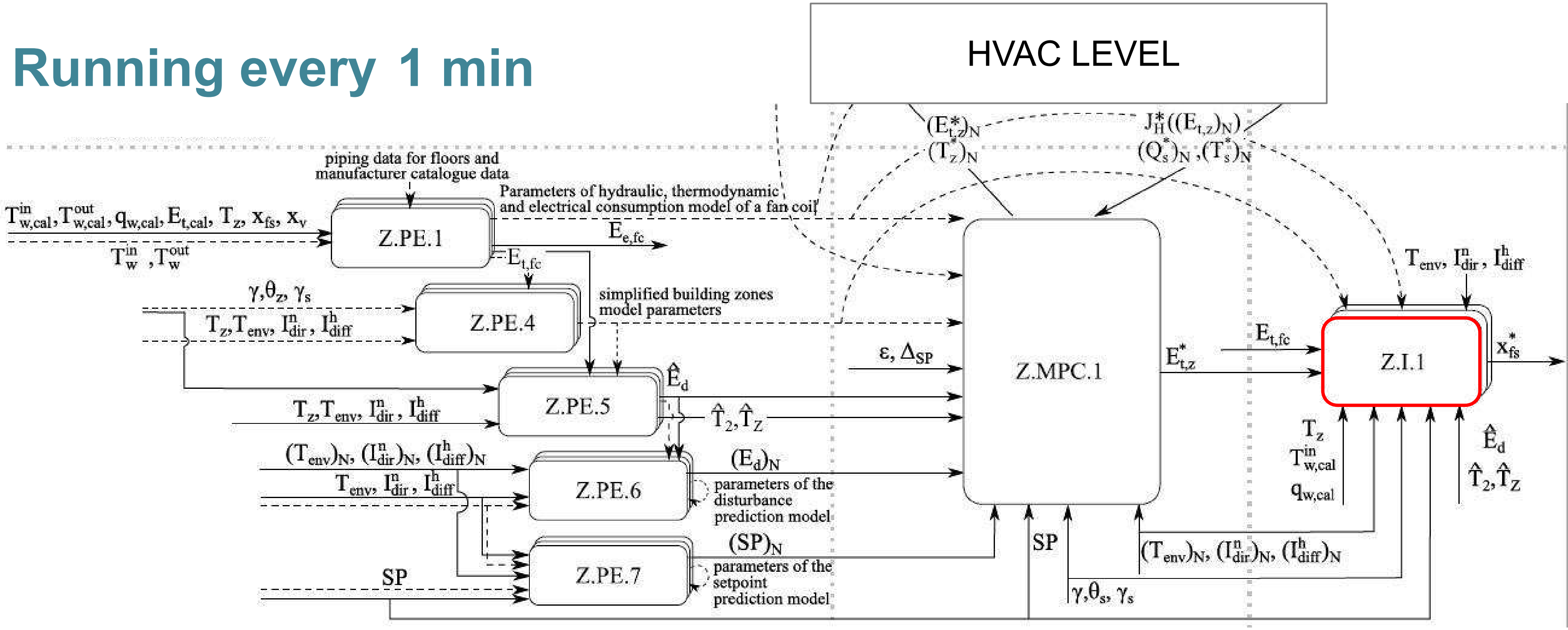
Zone Interface 1

(module for control of energy from fan coils)

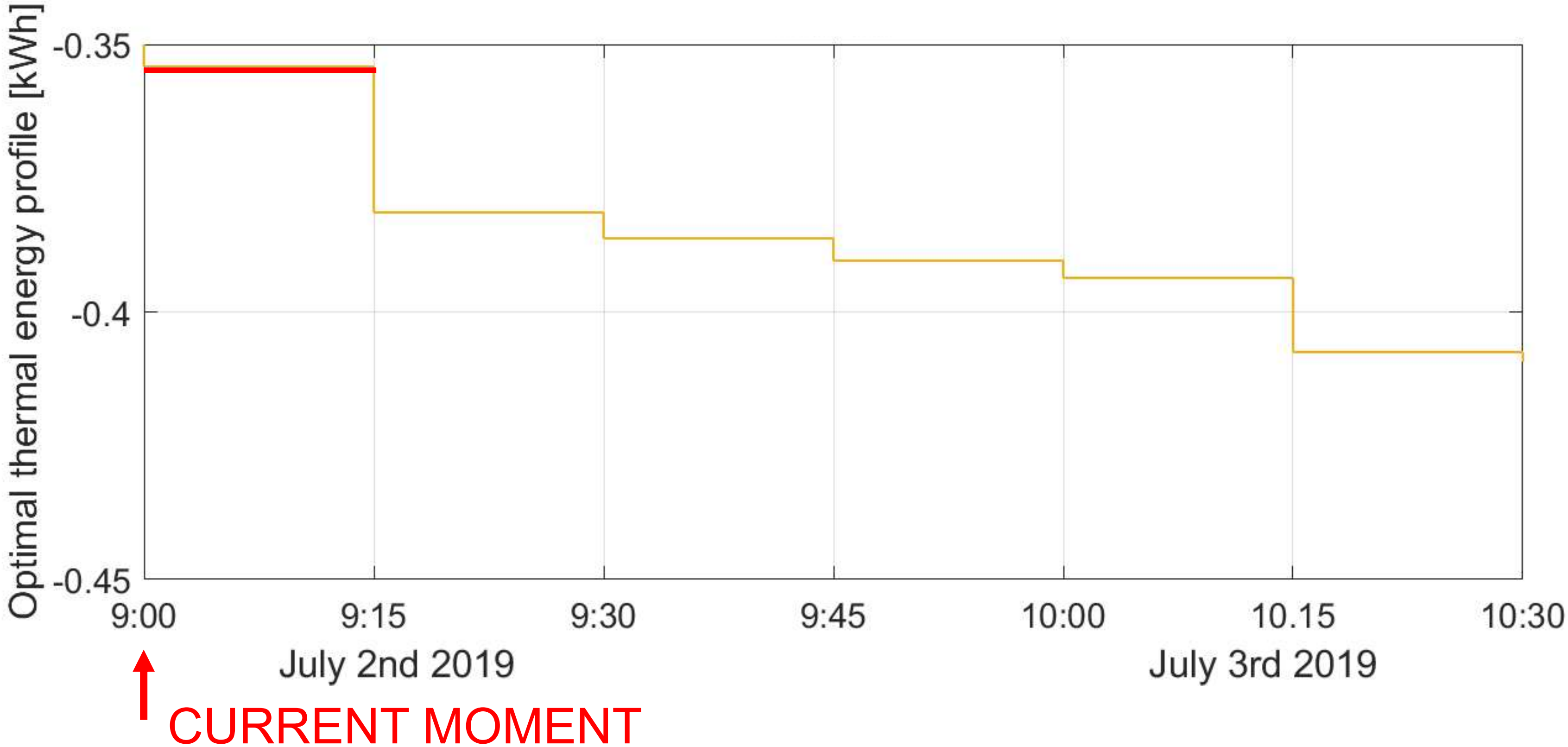
Running every 1 min



Zone Interface 1

(module for control of energy from fan coils)

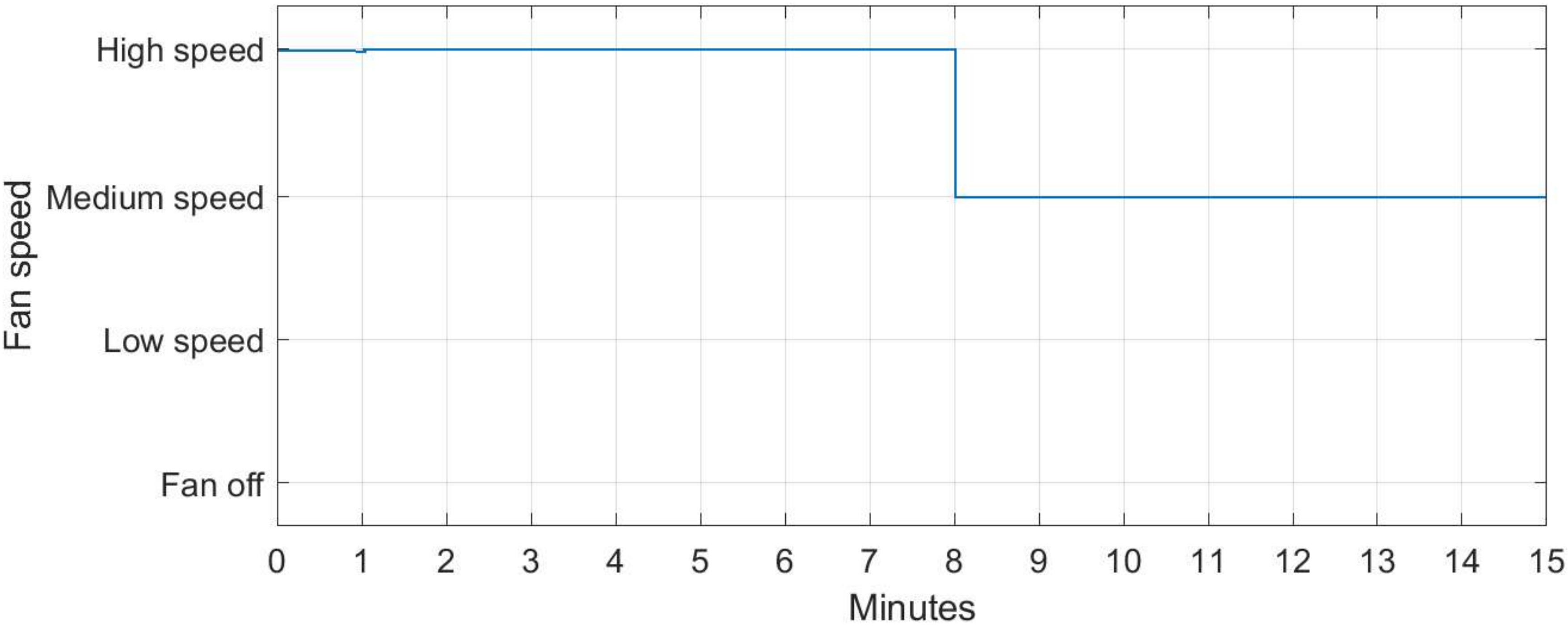
INPUTS: requested heating energy computed by Z.MPC.1 that needs to be exerted from fan coil to room air in the next 15 min, current temperature and flow measurement on the heating/cooling medium, current zone measurements, current measurements of outdoor weather conditions, currently estimated heat disturbance (Z.PE.5), …



Zone Interface 1
(module for control of energy from fan coils)

OUTPUT

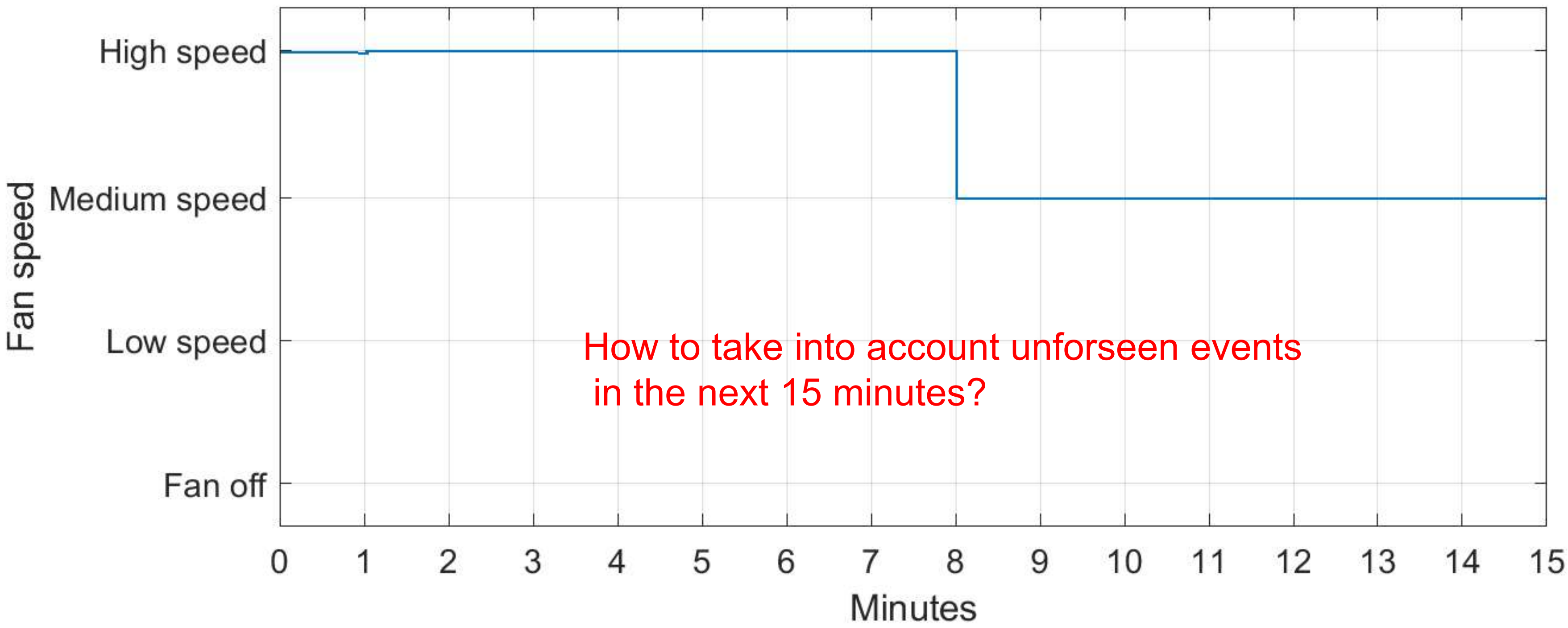
OPTIMAL FAN COIL OPERATION PROFILE UP TO THE NEXT 15 min SAMPLING INSTANT



Zone Interface 1
(module for control of energy from fan coils)

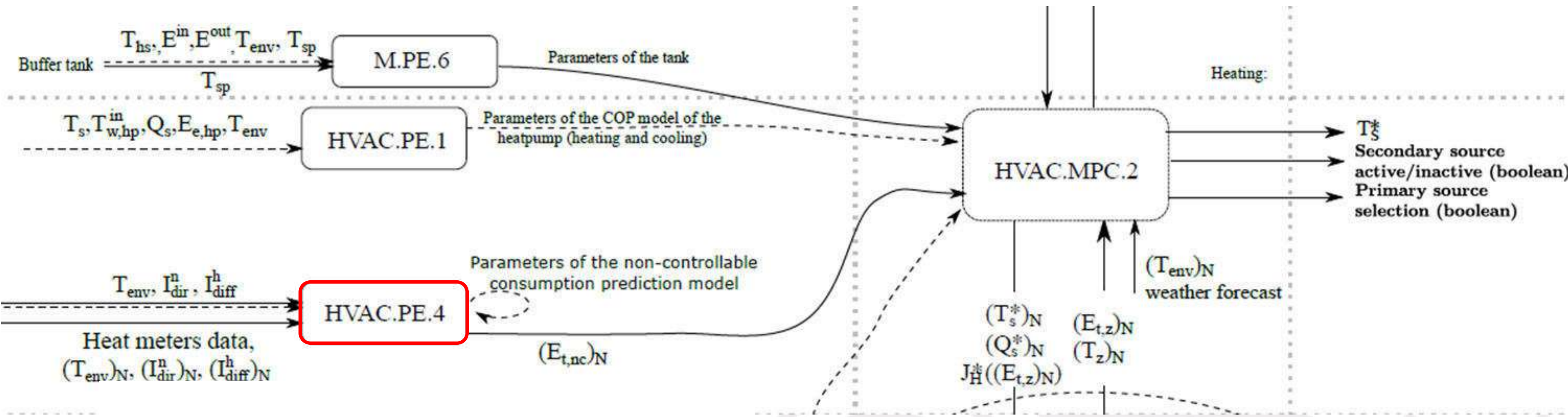
OUTPUT

OPTIMAL FAN COIL OPERATION PROFILE UP TO THE NEXT 15 min SAMPLING INSTANT

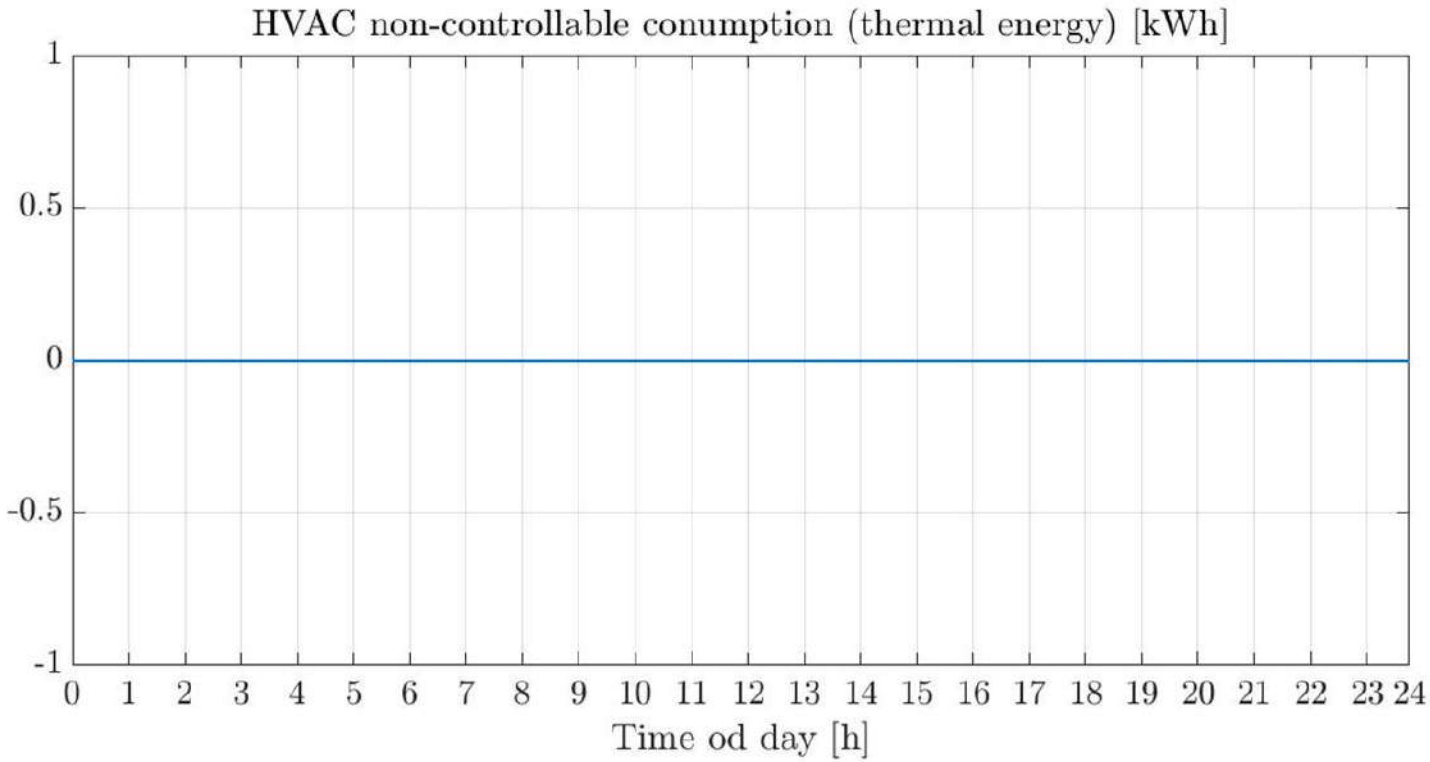


Central HVAC level

HVAC PE 4
(prediction of non-controllable heating energy consumption on the central HVAC level)



HVAC PE 4 – not used in the cooling period



M PE 6
(estimation of parameters of the mathematical model of the cooling medium buffer tank)

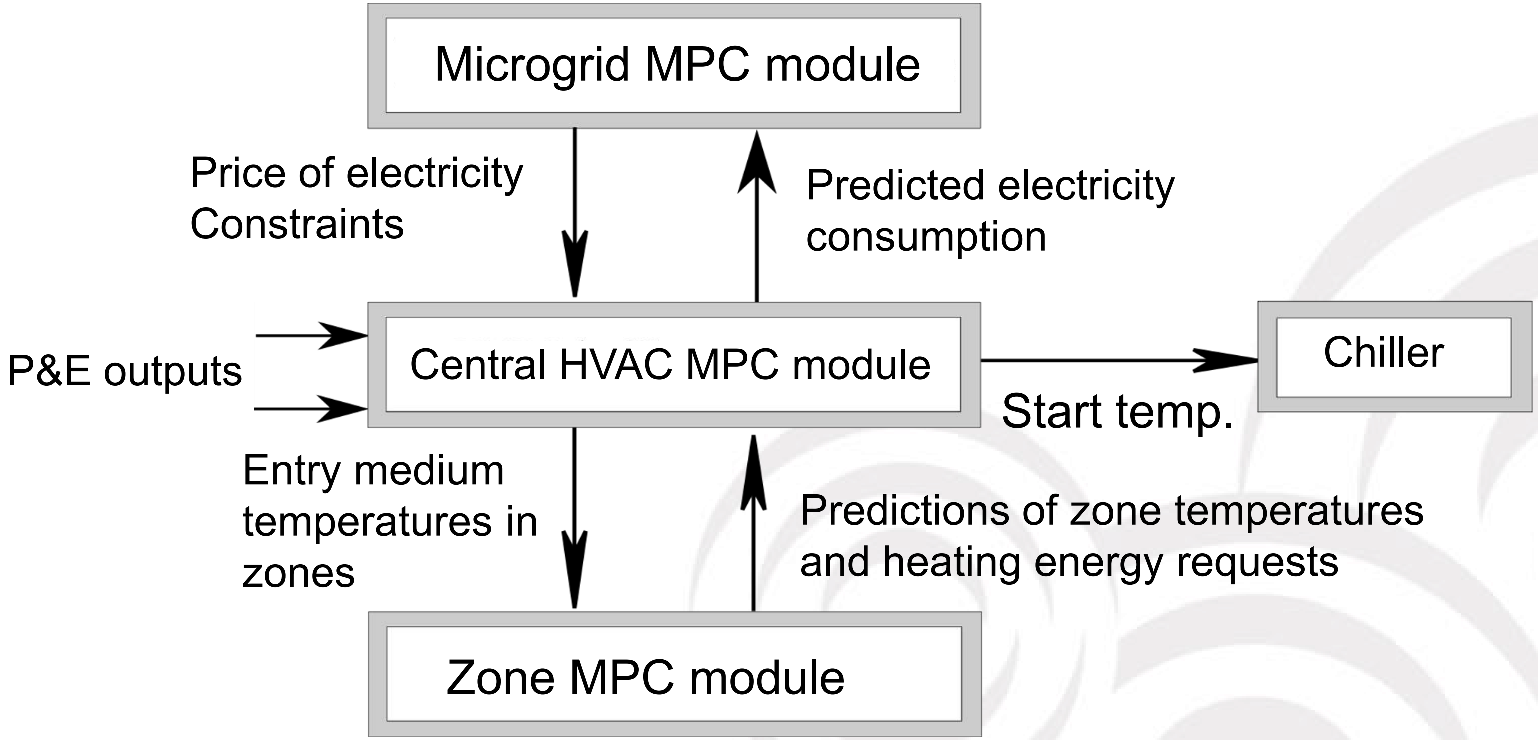
Inputs

- Temperature of the starting medium
- Temperature around the tank
- Measured input energy
- Measured output energy

Outputs

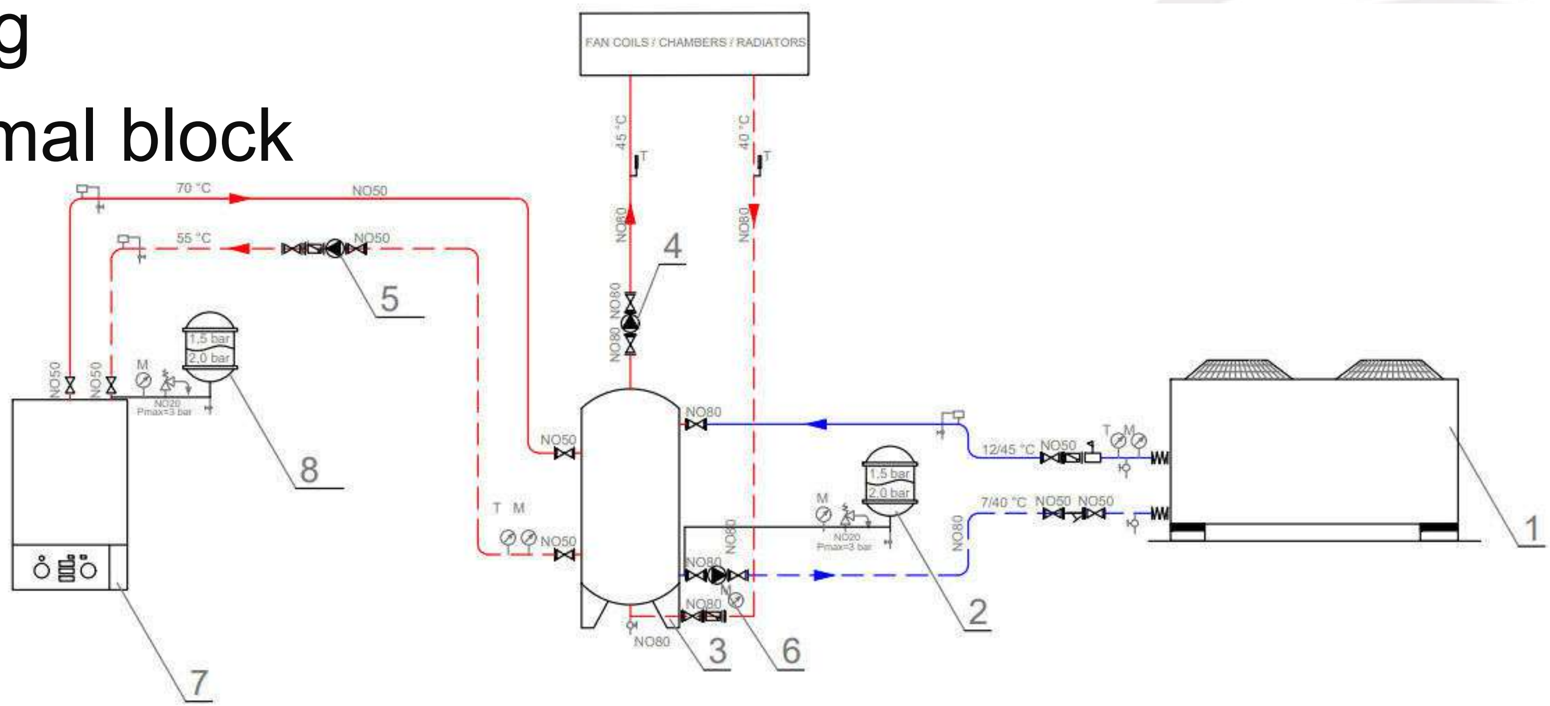
- Parameters of the buffer tank mathematical model

HVAC MPC within the modular structure



Conceptual scheme of the HVAC system at EPHZHB

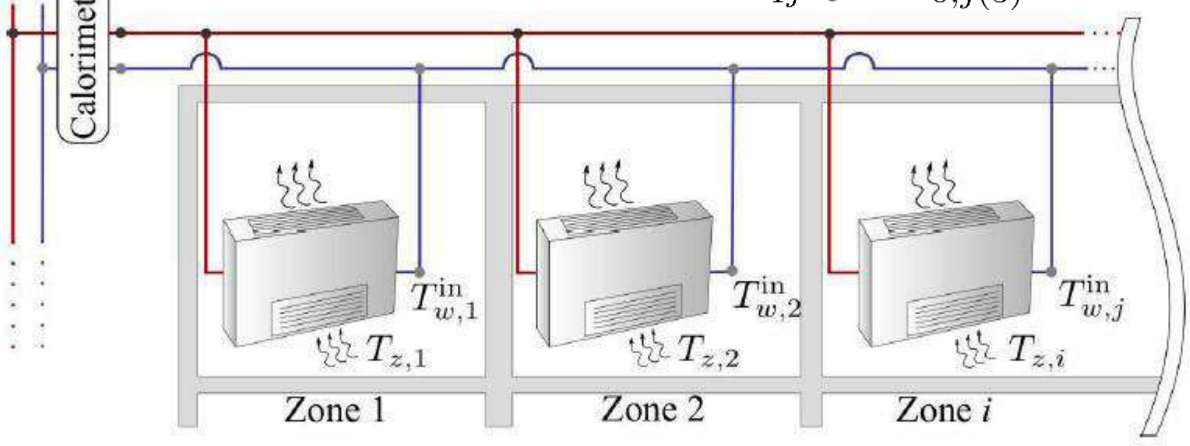
- Controllable zones + non-controllable load
- Buffer tank
- Heat pump
- Piping
- Thermal block



Submodels of the central HVAC system

- COP model of the chiller (HVAC.PE.1), $COP(T_o, P_t)$
- Fan coils from Z.PE.1
- Model for heating medium temperature drop in piping
- Non-controllable load
- Buffer tank

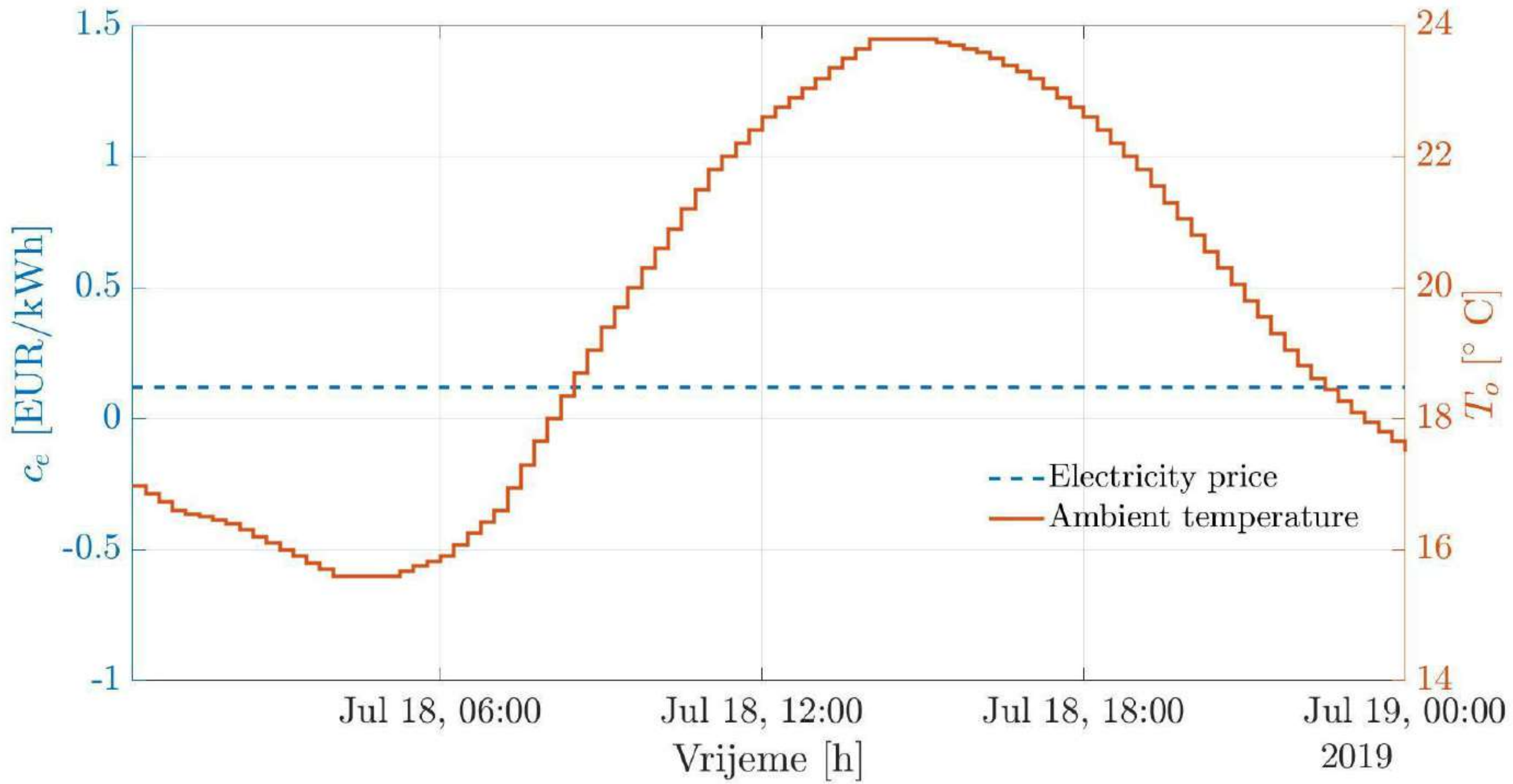
$$E_{t,fc,j(3)} = T_d \frac{2q_j c_s U_{0,j(3)}(T^{\mathrm{in}}_{\mathrm{w},j} - T_{z,i})}{2q_j c_s + U_{0,j(3)}}$$



Online HVAC MPC scenario

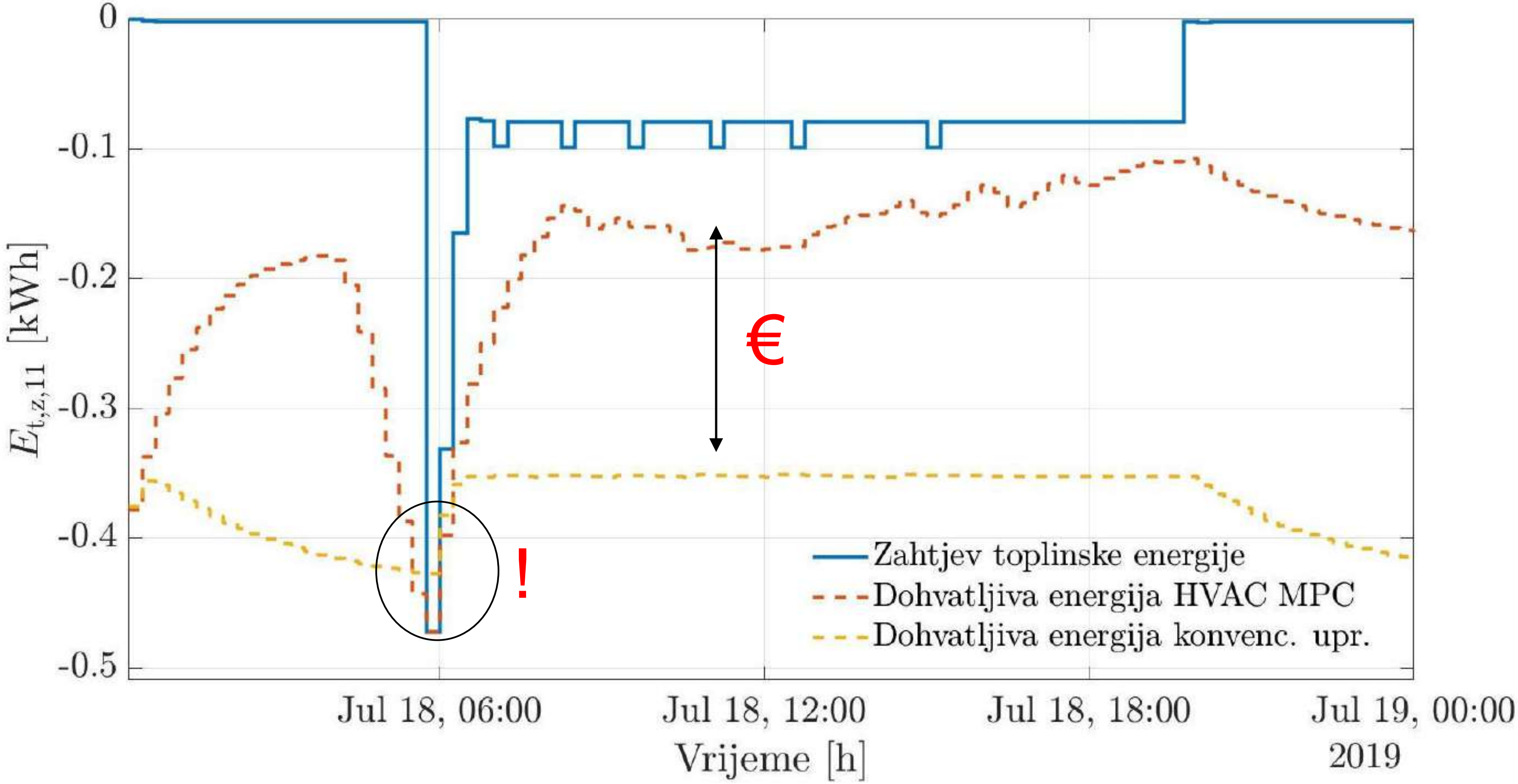
- Considered next day: 18 July 2019
- Comparison with conventional control – fixed starting temperature

HVAC MPC – online module results (1)



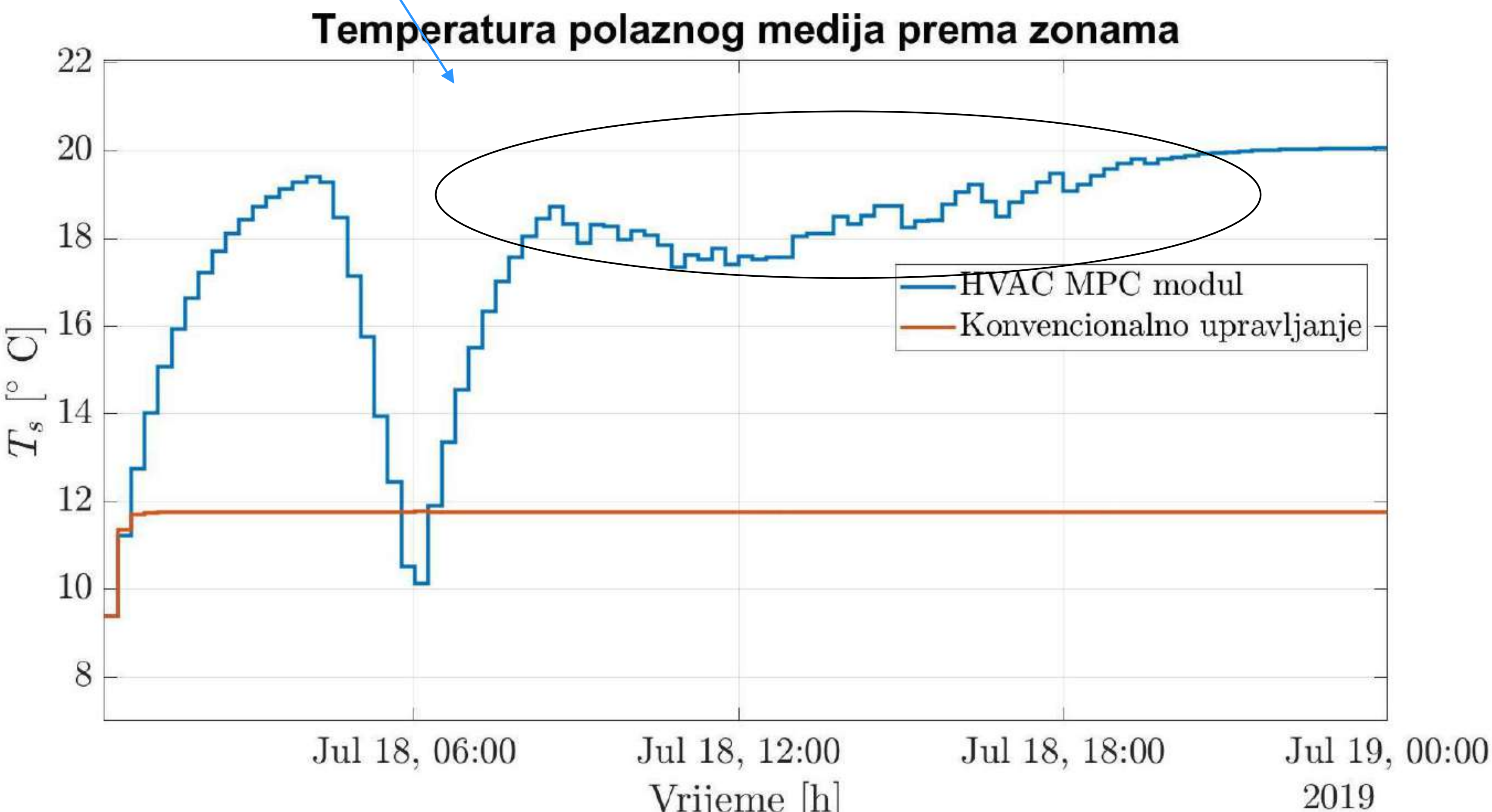
HVAC MPC – online module results (2)

- Attainable heating energy provided by MPC follows the zones requests



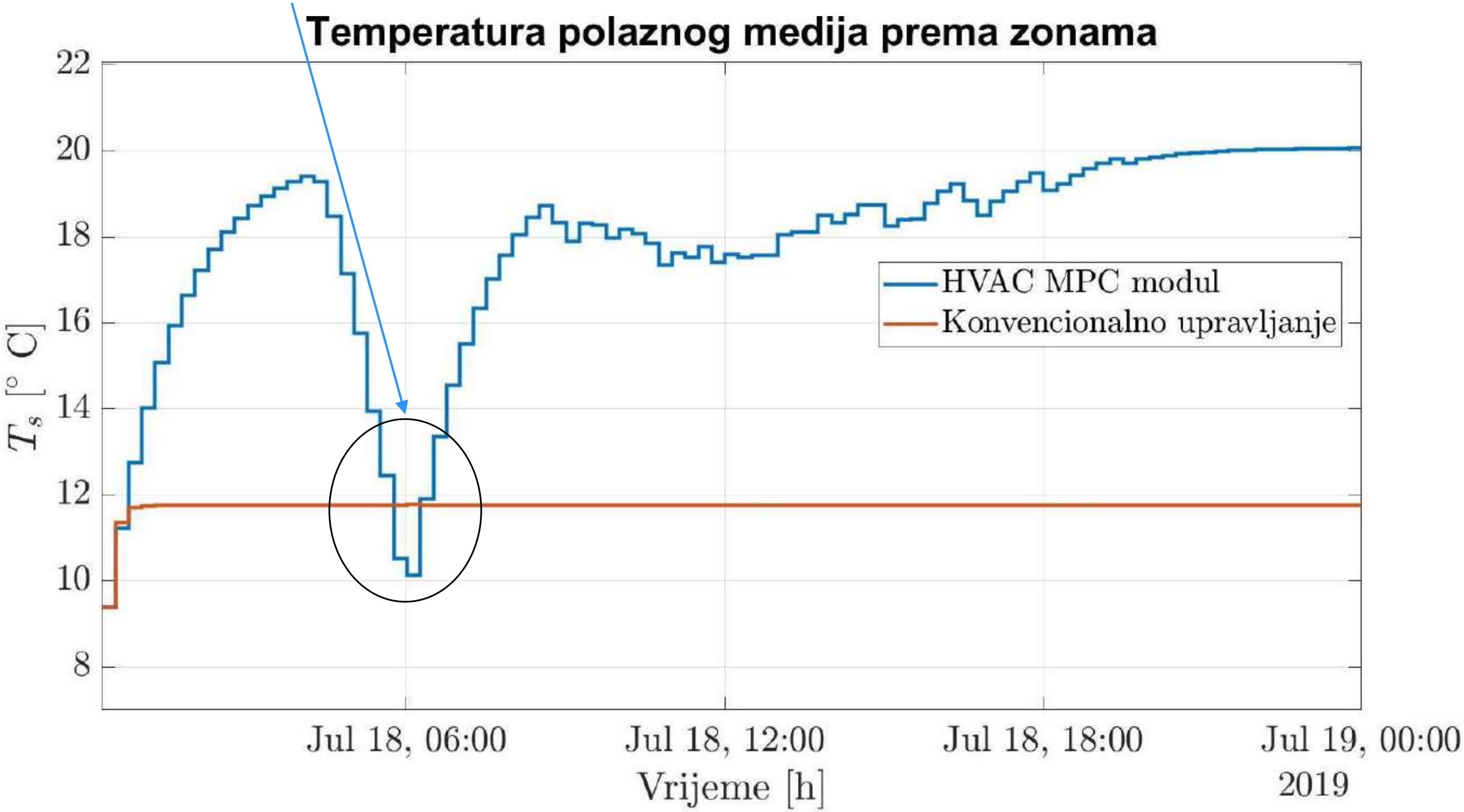
HVAC MPC – online module results (3)

- Rise of the starting temperature → reduced cooling load



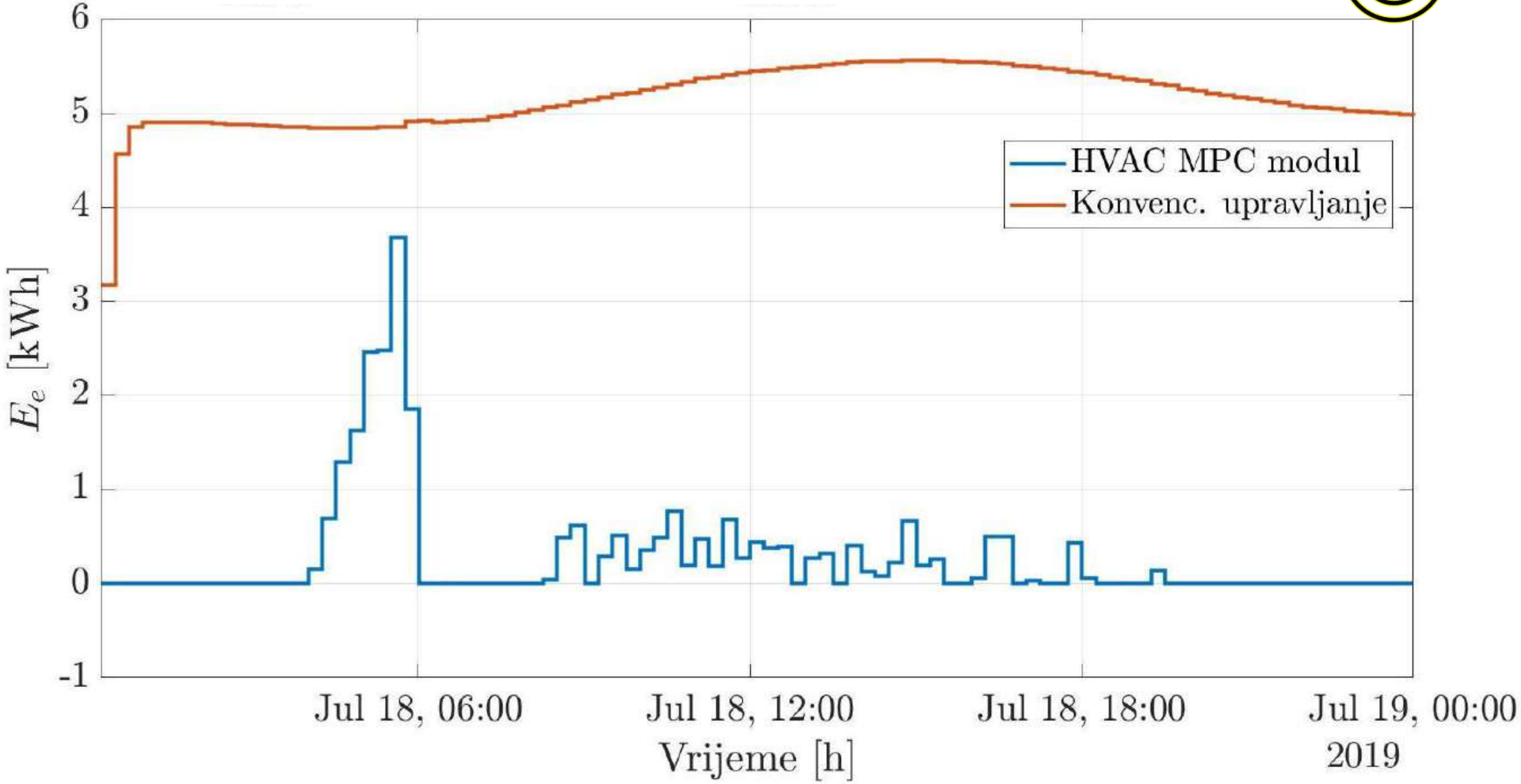
HVAC MPC – online module results (4)

- Fall of the starting temperature → increased cooling load



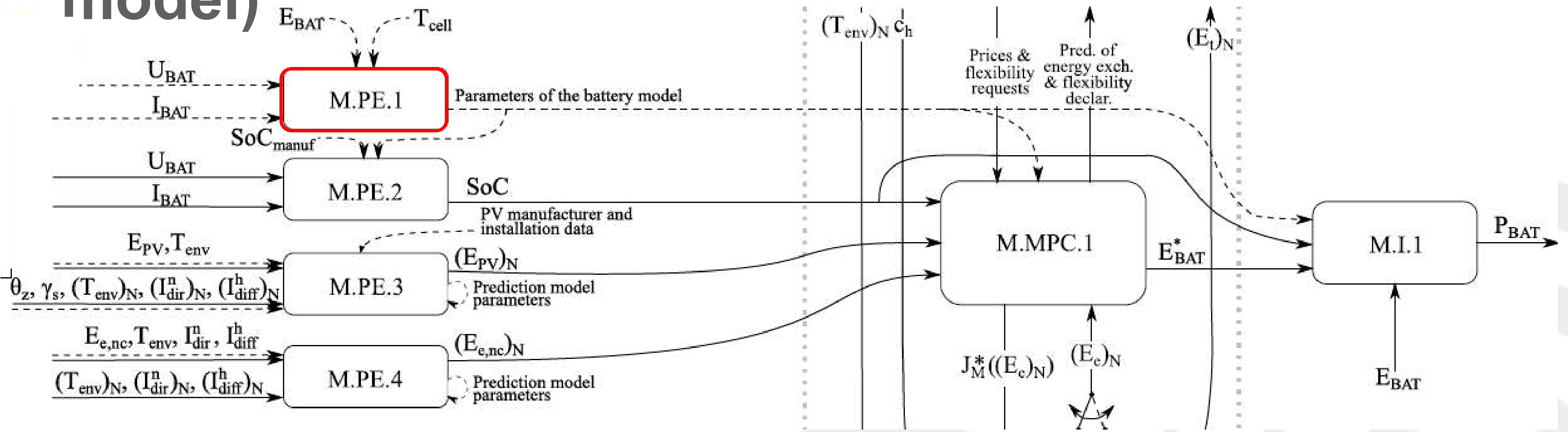
HVAC MPC – online module results (5)

Electricity consumed on the central HVAC level – chiller + fan coils fans:



Microgrid level

M PE 1 (estimation of the battery system mathematical model)



Inputs

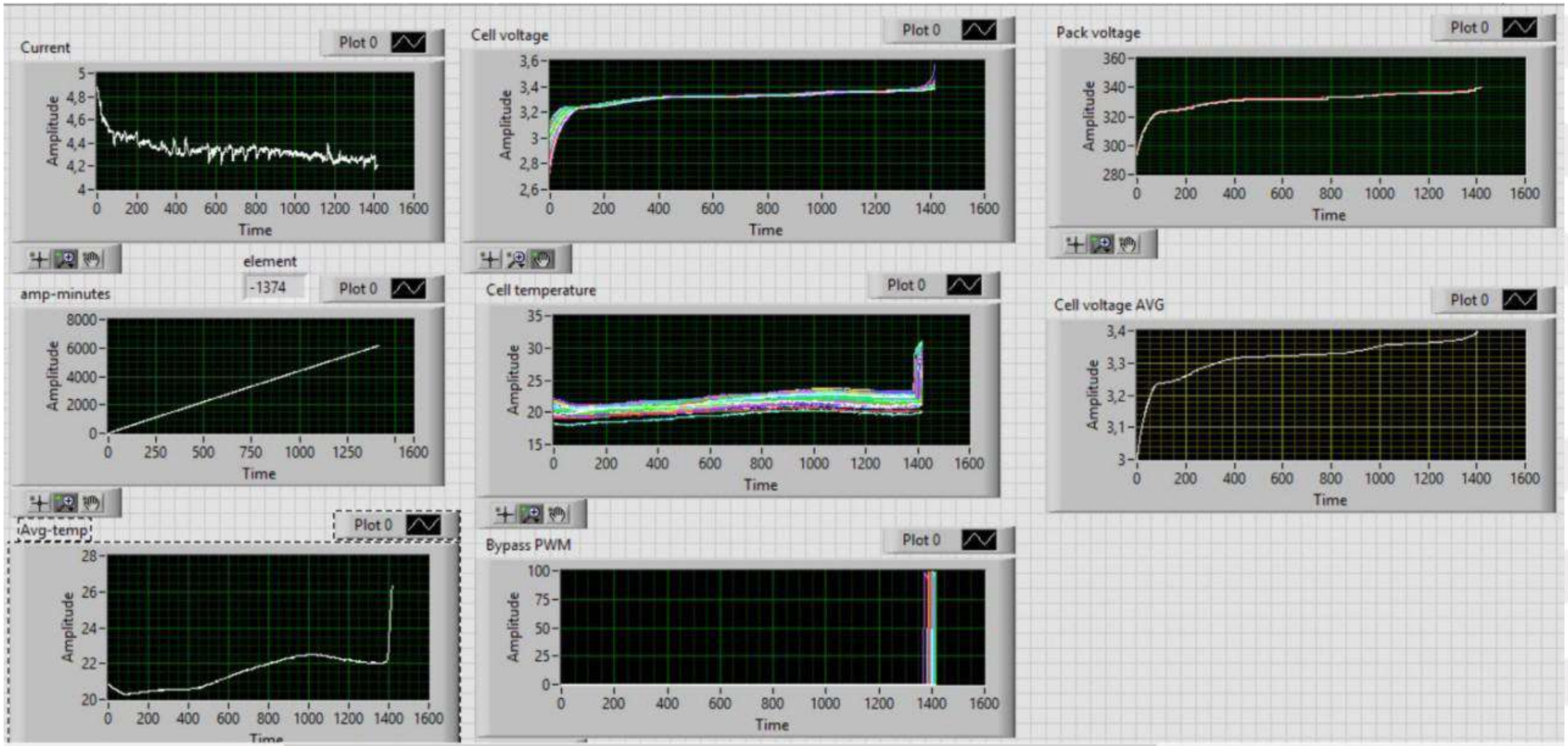
- Measurements from the battery system: voltages and currents on AC and DC side, cells temperature

Outputs

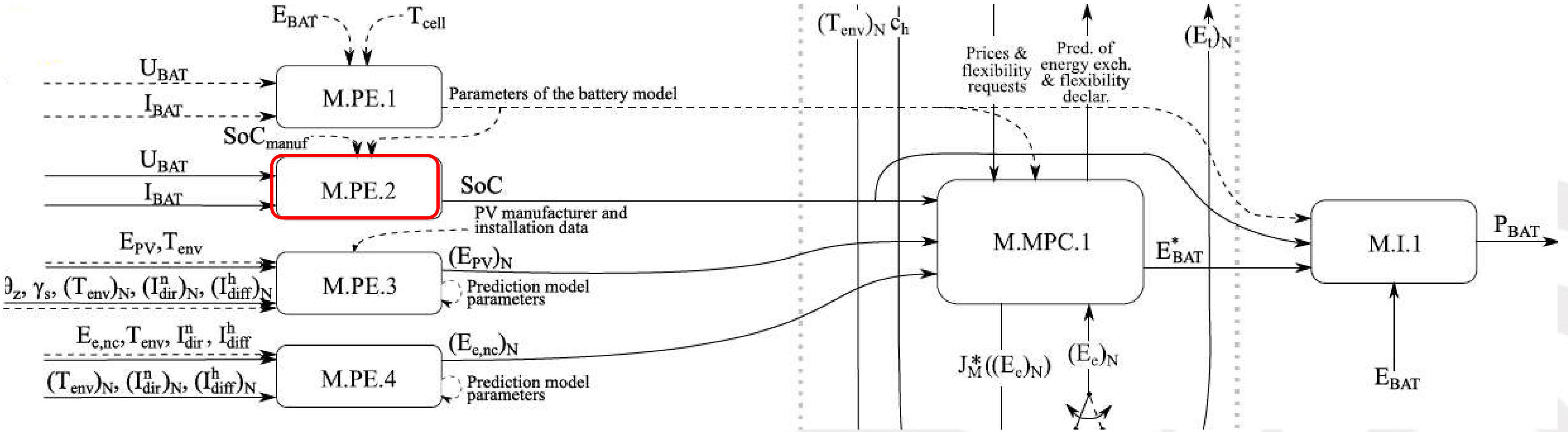
- Battery capacity
- Battery system efficiency

M PE 1

- Performed identification experiments
- Also possible analysis of historical data obtained from regular system operation



M PE 2
(estimation of battery state of charge)



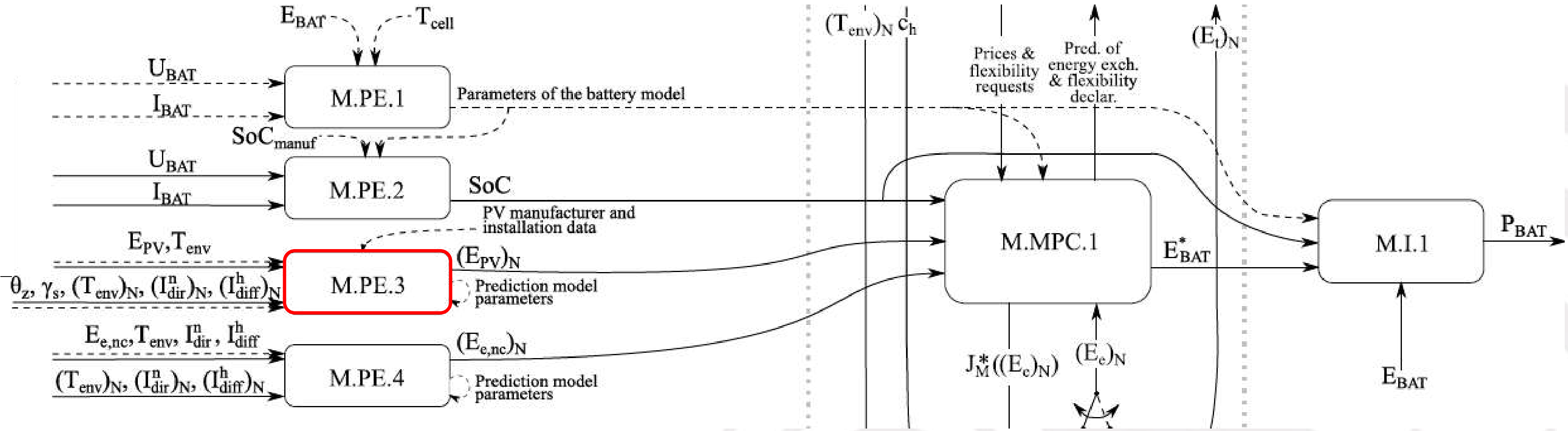
Inputs

- Measurements from the battery system: voltages and currents on AC and DC side
- Parameters of the battery mathematical model

Izlazi

- Battery state of charge (SoC)

M PE 3
(prediction of the photvoltaic system production)



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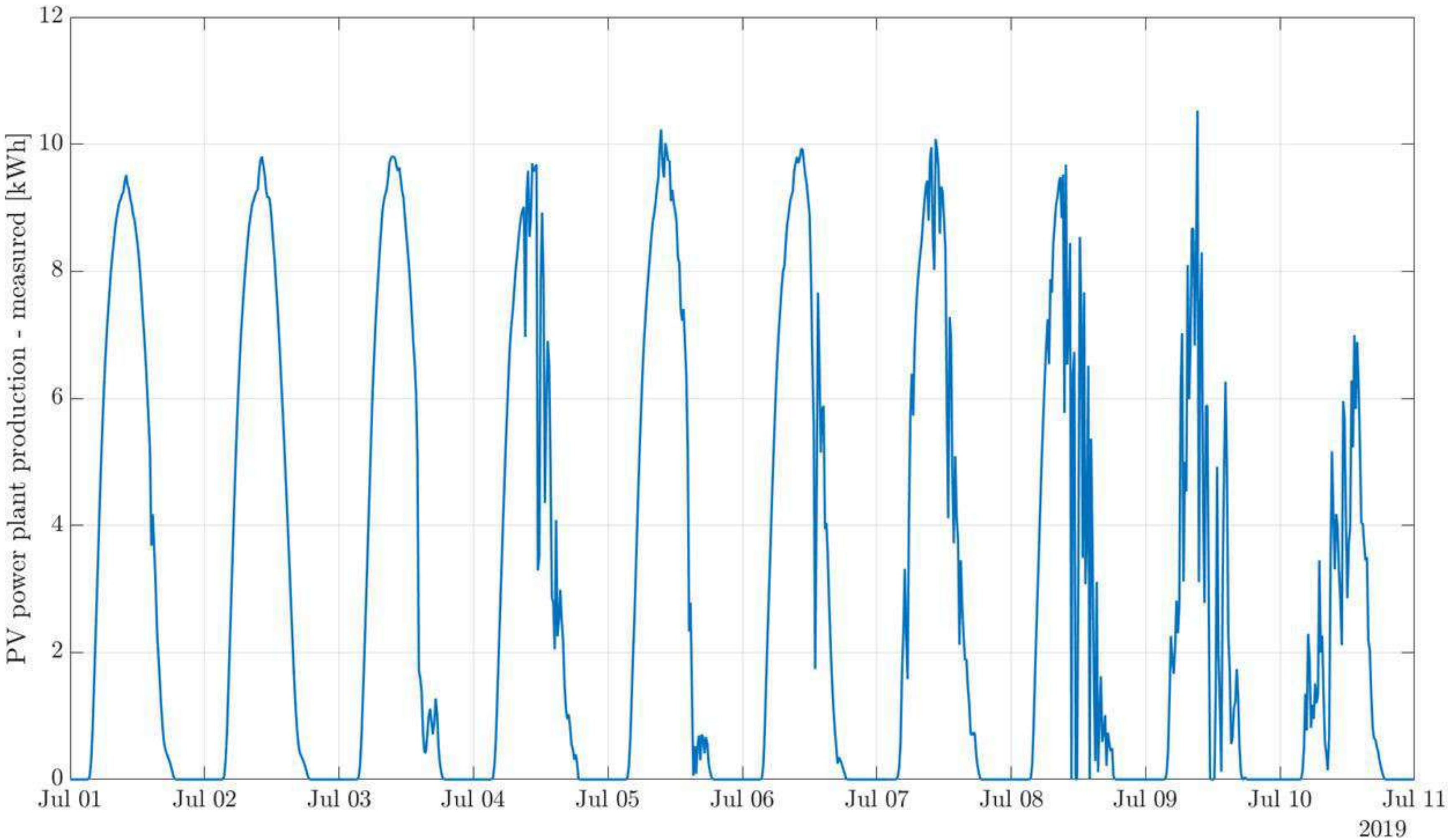
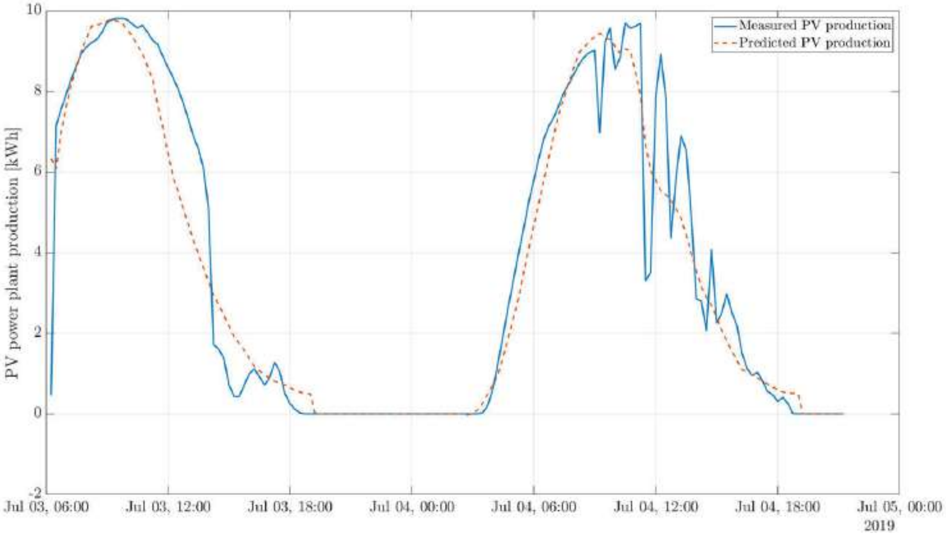
M PE 3 – example of historical production

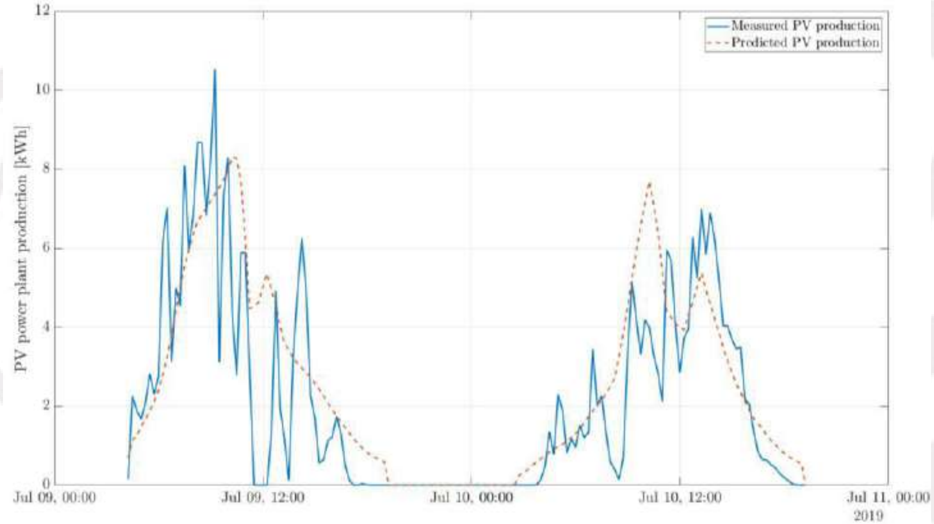


M PE 3 – example of generated prediction

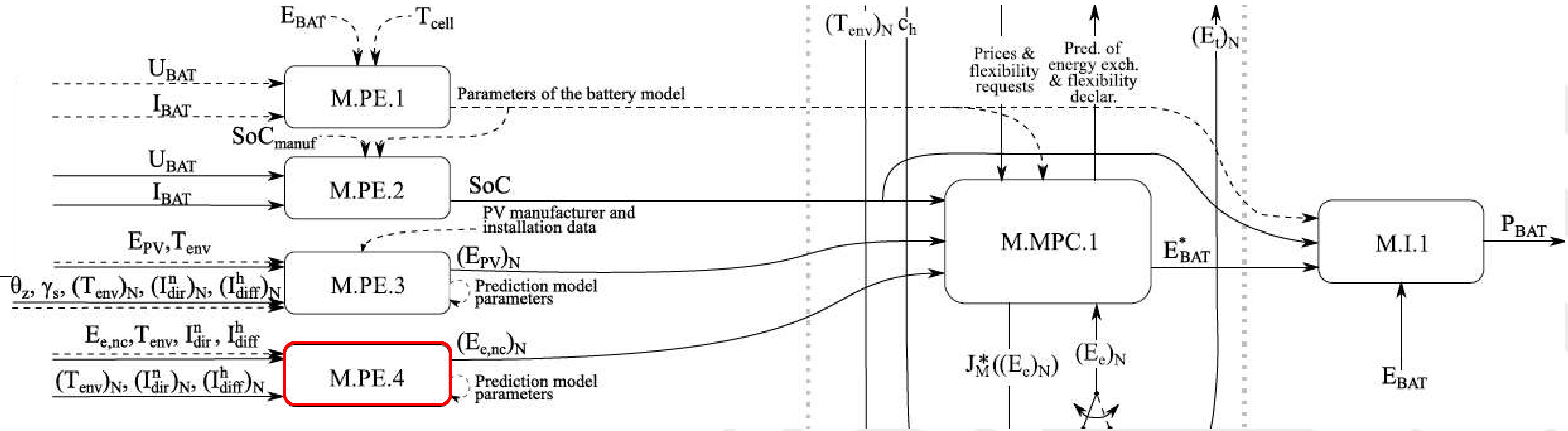


- sunny weather

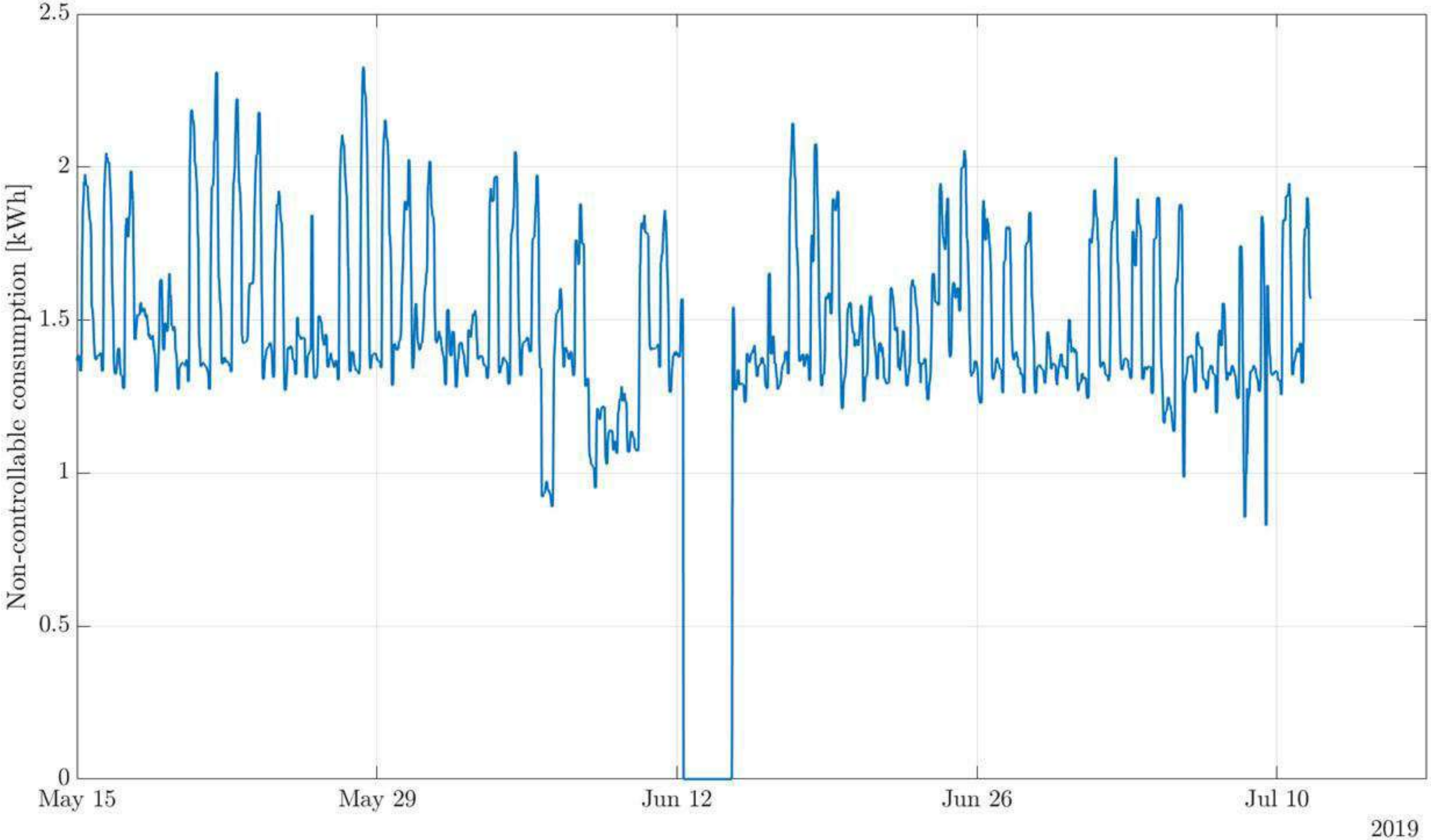
- cloudy weather



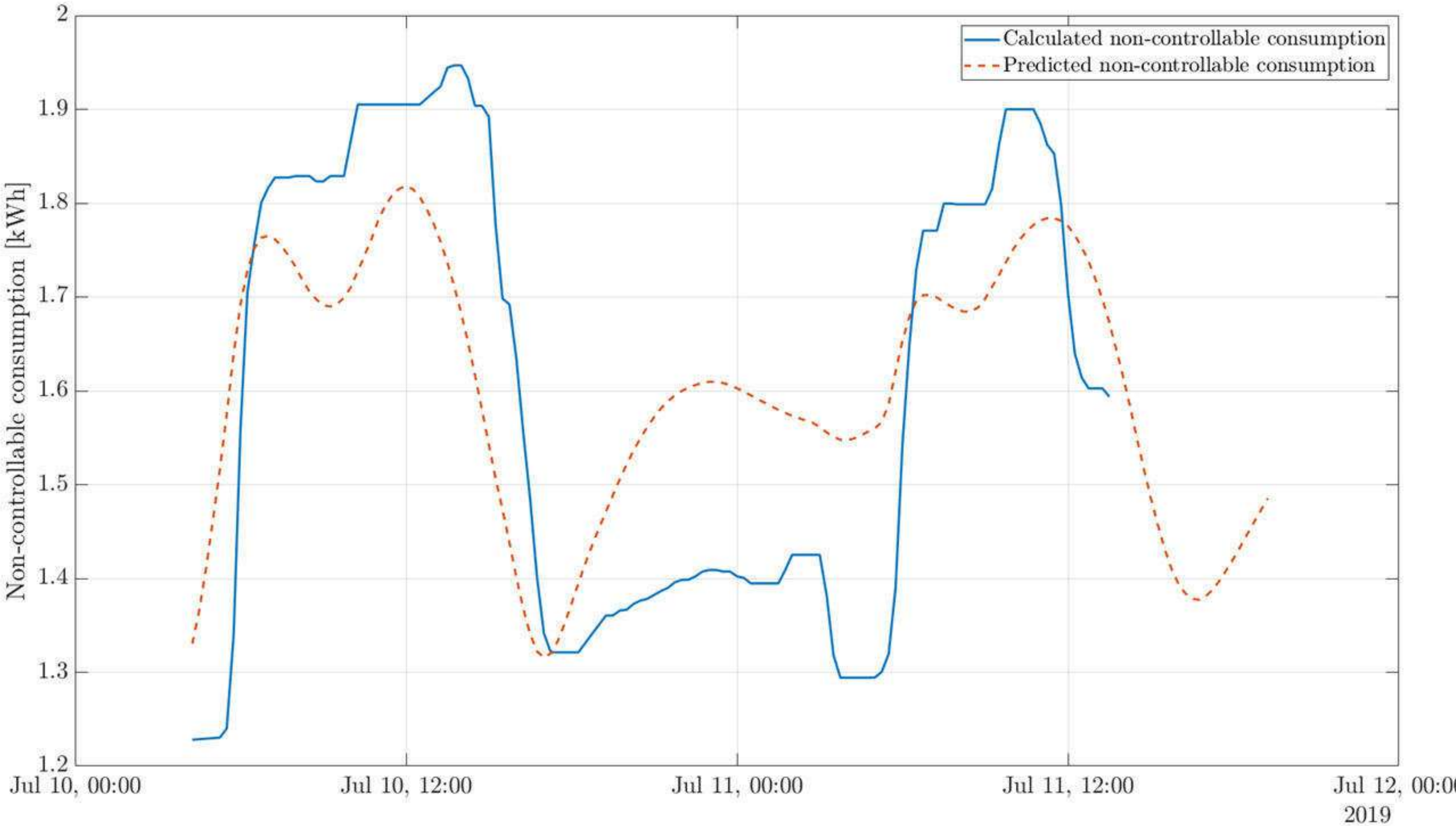
M PE 4
(prediction of the non-controllable consumption on the microgrid level)



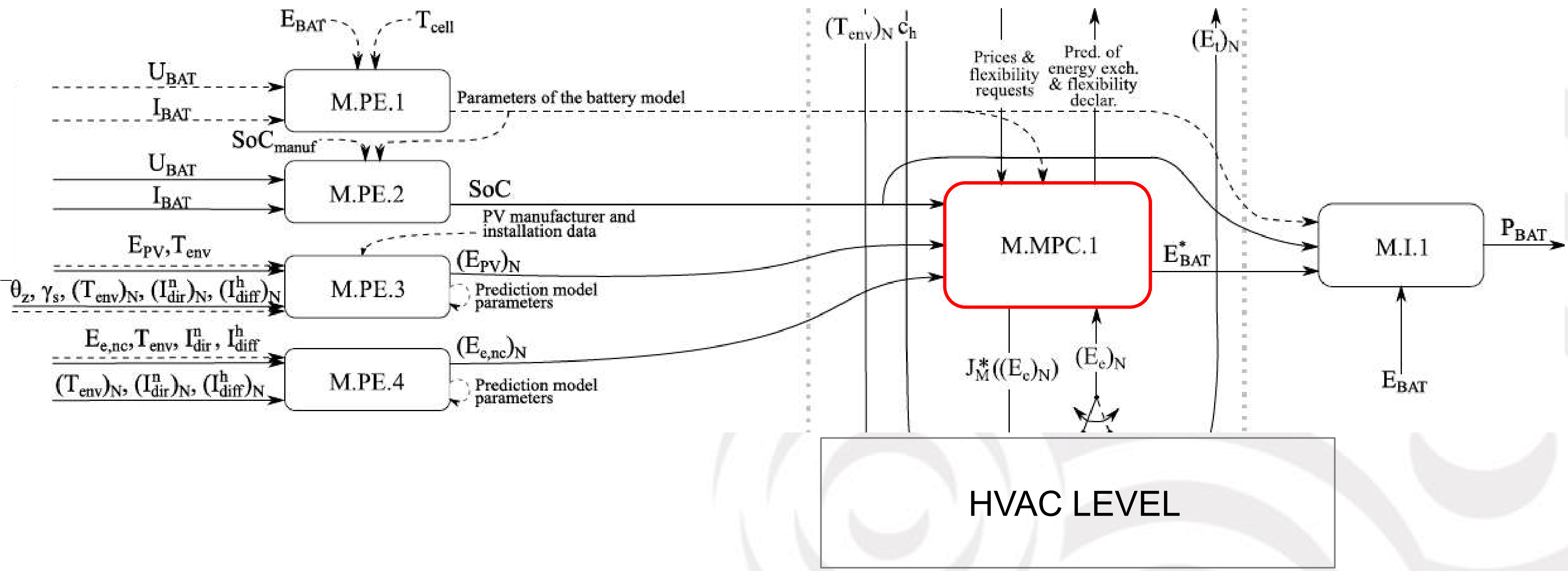
M PE 4 – example of the historical consumption



M PE 4 – example of generated prediction

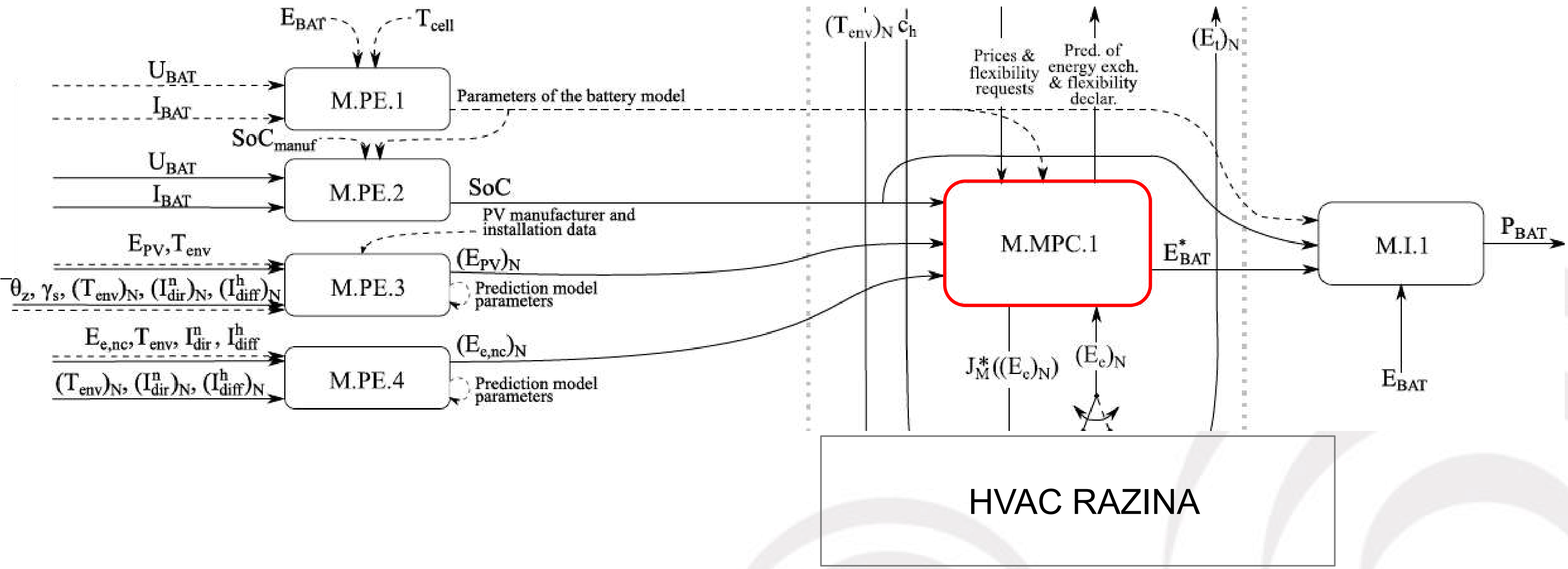


M MPC 1



E_{BAT}
T_{cell}
U_{BAT}
I_{BAT}
M.PE.1
Parameters of the battery model
SoC_{manuf}
U_{BAT}
I_{BAT}
M.PE.2
SoC
PV manufacturer and installation data
E_{PV}, T_{env}
θ_z, γ_s, $(T_{env})_N$, $(I^n_{dir})_N$, $(I^h_{diff})_N$
M.PE.3
$(E_{PV})_N$
Prediction model parameters
$E_{e,nc}, T_{env}, I^n_{dir}, I^h_{diff}$
$(T_{env})_N$, $(I^n_{dir})_N$, $(I^h_{diff})_N$
M.PE.4
$(E_{e,nc})_N$
Prediction model parameters
$(T_{env})_N$ c_h
Prices & flexibility requests
Pred. of energy exch. & flexibility declar.
$(E_t)_N$
M.MPC.1
E^*_{BAT}
$J^*_M((E_e)_N)$
$(E_e)_N$
M.I.1
P_{BAT}
E_{BAT}
HVAC LEVEL

M MPC 1 – data exchange



Inputs

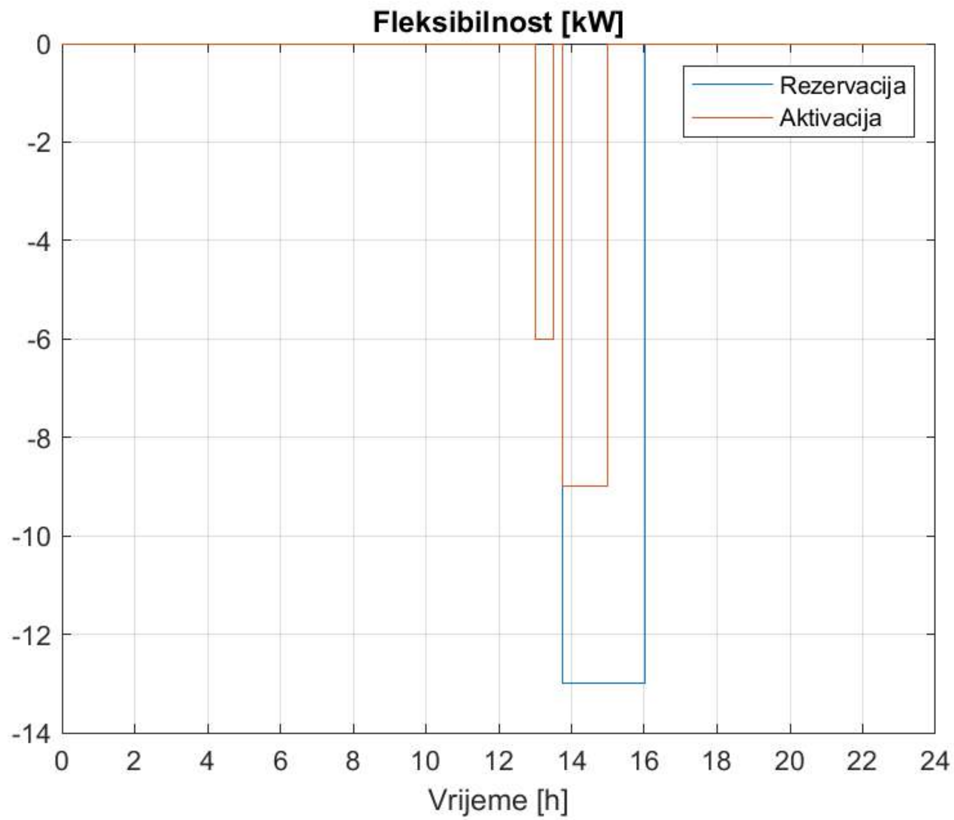
- Prediction of non-controllable consumption
- Estimated battery model and SoC
- Prices and requests from the grid, flexibility provision contract

Outputs

- Power reference → battery
- Coordination data → HVAC
- Prediction of ahead consumption (12-36 h) → grid

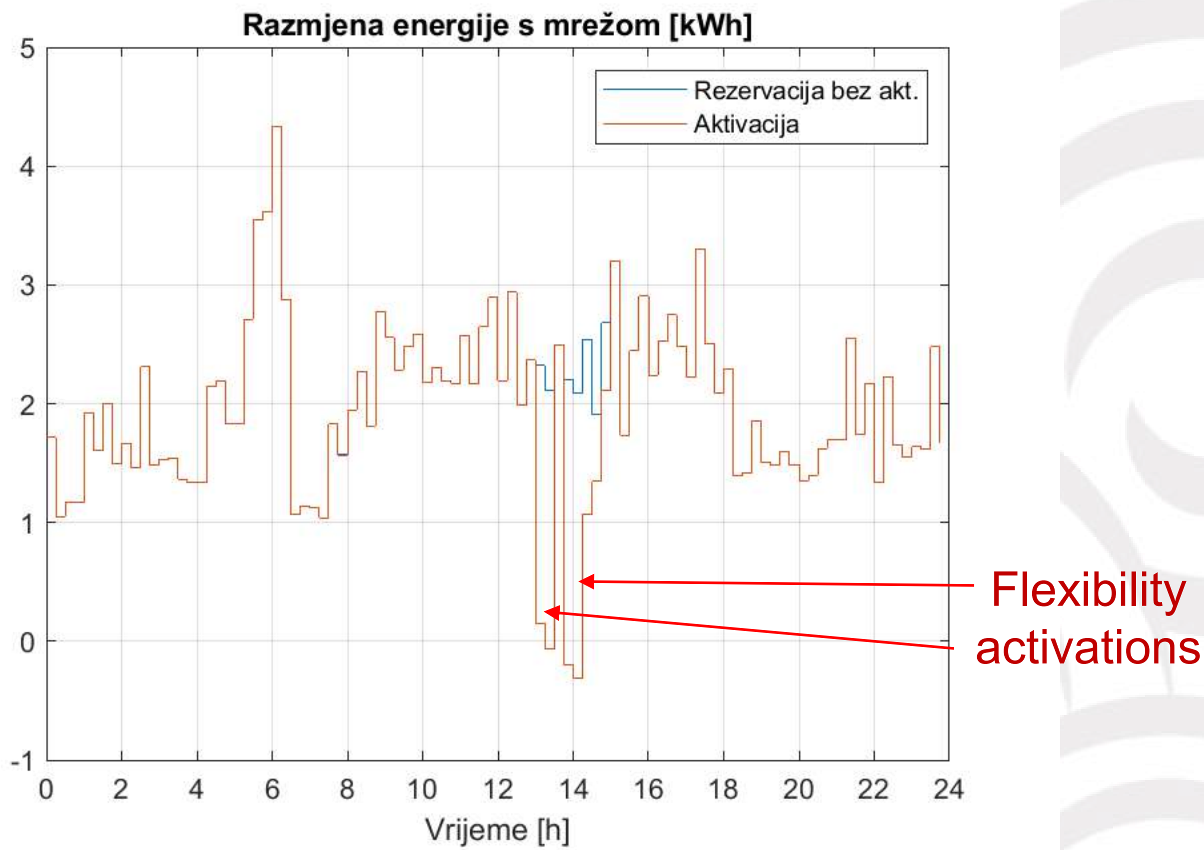
M MPC 1 – flexibility requests from the grid

- Flexibility requests vs. contracted (reserved) flexibility amounts



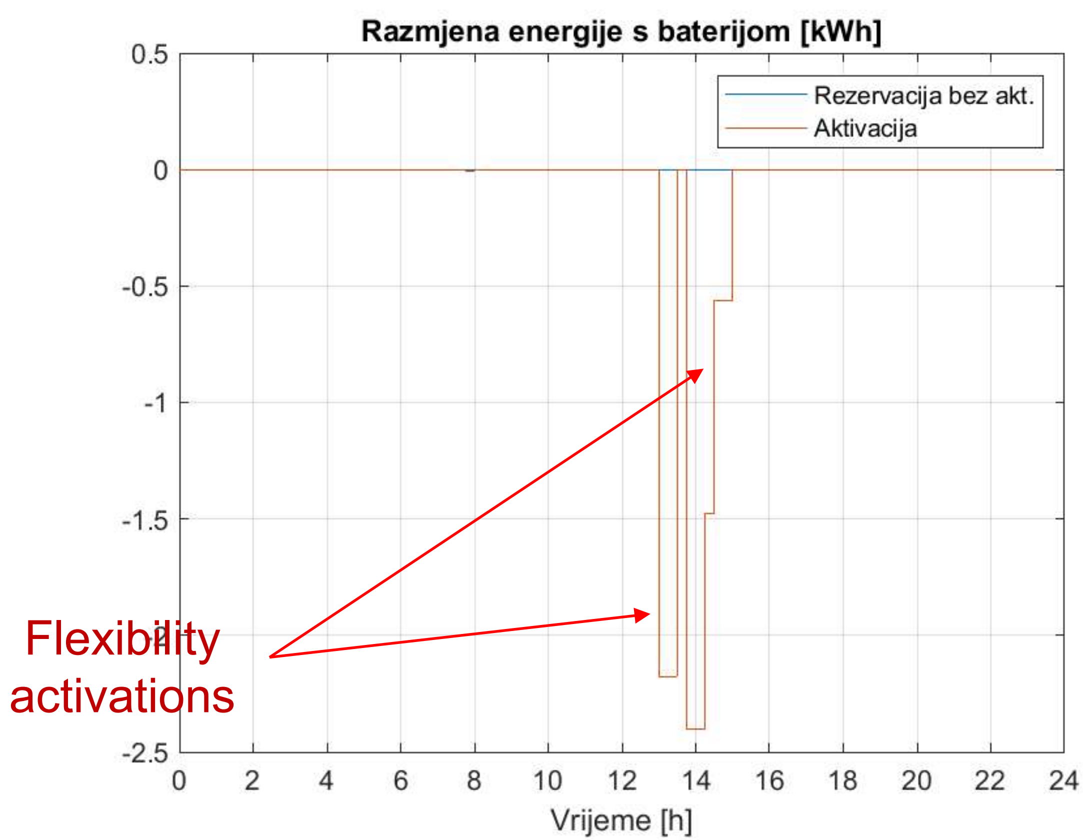
M MPC 1 – computation results

Energy exchange with the grid – predicted vs. realized based on also respecting flexibility activation requests

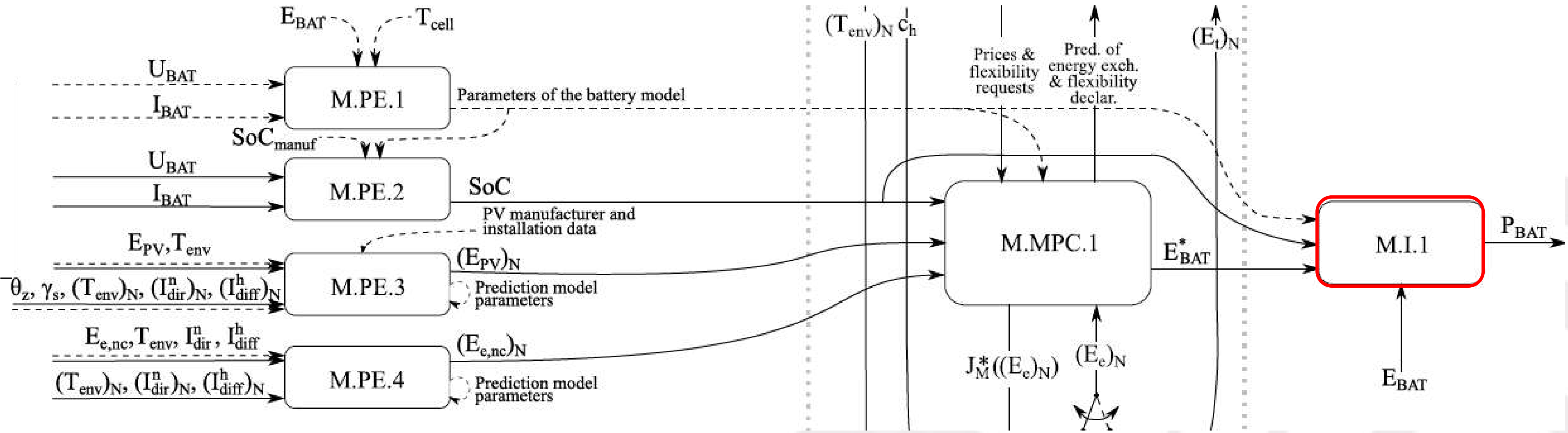


M MPC 1 – computation results

Energy exchange with the battery system (+ -- charging, - -- discharging)



Interface module towards the battery system (M I 1)



- Execution every minute
- Additional control loop – ensuring that the energy exchange request towards the battery system is fulfilled

Acknowledgment

The presented research results are obtained within the project Smart Building – Smart Grid – Smart City (3Smart) co-funded by the European Union from European Regional Development Fund and Institute for Pre-Accession Assistance through Interreg Danube Transnational Programme (DTP1-502-3.2-3Smart), in the amount of maximum 3.222.641,90 EUR.

3SMART PROJECT WEB PAGE

http://www.interreg-danube.eu/3smart

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Project Deliverable Report

Smart Building – Smart Grid – Smart City

http://www.interreg-danube.eu/3smart

DELIVERABLE D6.3.1

Transnational training materials – Pilot study visits to Hungary – Pilot study visit No. 2

Project Acronym	3Smart
Grant Agreement No.	DTP1-502-3.2-3Smart
Funding Scheme	Interreg Danube Transnational Programme
Project Start Date	1 January 2017
Project Duration	36 months
Work Package	6
Task	6.3
Date of delivery	**Contractual:** 31 December 2019 **Actual:** 23 December 2019
Code name	**Version:** 1.0 Final ☒ Final draft ☐ Draft ☐
Type of deliverable	Report
Security	Public
Deliverable participants	UNIZGFER, UNIDEBTTK, EON, UNIBGFME
Authors (Partners)	Mario Vašak, Tomislav Capuder, Vinko Lešić, Anita Martinčević, Hrvoje Novak, Danko Marušić, Nikola Hure, Paula Mamić (UNIZGFER), Arpad Racz, Andras Mucsi (UNIDEBTTK), Gabor Peter, Kata Santa (EON), Vladimir Jovanović (UNIBGFME)
Contact person	Arpad Racz (UNIZGFER)
Abstract (for dissemination)	This document contains the minutes of the second study visit to the Hungarian pilot in 3Smart. The pilot consists of a pilot building – EON headquarter building in Debrecen – and the pilot electricity distribution grid around the building. On the pilot study visits the pilot leaders and hosts together with developers for different modules on the pilot site have performed demonstration to the consortium of functioning of different installations performed on the pilot and of the installed 3Smart modules.
Keyword List	building-side energy management system, grid-side management, pilot installations, 3Smart IT environment, 3Smart database

Revision history

Revision	Date	Description	Author (Organization)
v1.0	23 December 2019	Prepared the minutes in publishable form	Mario Vašak (UNIZGFER)

Table of Contents

Executive summary

The 3Smart project deals with transnational development of integrated energy management of buildings and energy distribution grids in real time. To substantiate knowledge transfer between partners, to synchronize developments and demonstrate the installation procedure to developers, pilots leaders and pilots hosts, a series of transnational trainings is organized, first for getting acquainted with the software modules for energy management, and then for getting acquainted with performed pilot installations and modules operation on the pilot site.

This deliverable provides minutes and materials from the pilot study visits to the 3Smart pilot in Hungary that consists of EON building in Debrecen and of the electricity distribution grid around this building. The visits were split in two parts for each pilot site – this second part of the deliverable for the Hungarian pilot site concerns the second pilot study visit.

1. Minutes from the second pilot study visit to the 3Smart pilot in Hungary

Venue: E.ON Tiszántúli Áramhálózati Zrt, Kossuth Lajos utca 41, 4024 Debrecen, Hungary

Date: 4 September 2019 (Wednesday)

Time	Place	Event
09:00-11:00	Conference room on the Ground floor	**Session No. 1**
11:00-11:15	In front of Conference room on the Ground floor	Coffee break
11:15-13:00	Conference room on the Ground floor	**Session No. 2**
13:00-14:00	Restaurant on the Ground floor	Lunch
14:00-15:00	Conference room on the Ground floor	**Session No. 3**
15:00-15:15	In front of Conference room on the Ground floor	Coffee break
15:15-17:00	Conference room on the Ground floor	**Session No. 4**
20:00-22:00	Restaurant “Before” Bar	Working dinner

More details on individual sessions:

Session No. 1

Current status of the Hungarian pilot – EON building and EON grid – was assessed. Then followed the presentation of results obtained for of daily building-grid interaction at business day in September. The analysis started with the central HVAC level where the optimization is first performed. The results are provided in Annex 1.

Session No. 2

The discussion in this session continued with analysis of optimally planned daily operation on the microgrid level The results are provided in Annex 1 also.

Further the on-line operation of the installed modules was analyzed. The analysis started for the zone-level modules. The results are in Annex 1.

Session No. 3

This session finally concerned the on-line operation of central HVAC and microgrid level modules. It is also provided in Annex 1.

Session No. 4

The last session was used for discussions on the results obtained and for the preparation for the public pilot presentation the next day.

List of Annexes

1. Analysis and demonstration of performance of the 3Smat modules on the Hungarian pilot site

3Smart concept on EON buildings complex: analysis, installation, demonstration

Prof. Mario Vašak, Anita Martinčević, dr. Nikola Hure, Danko Marušić, dr. Hrvoje Novak, Prof. Vladimir Jovanovic, Arpad Racz, Andras Muczi,

University of Zagreb Faculty of Electrical Engineering and Computing

University of Belgrade Faculty of Mechanical Engineering

University of Debrecen

mario.vasak@fer.hr

Study visit No. 2 to the 3Smart pilot in Hungary

Debrecen, 4 September 2019

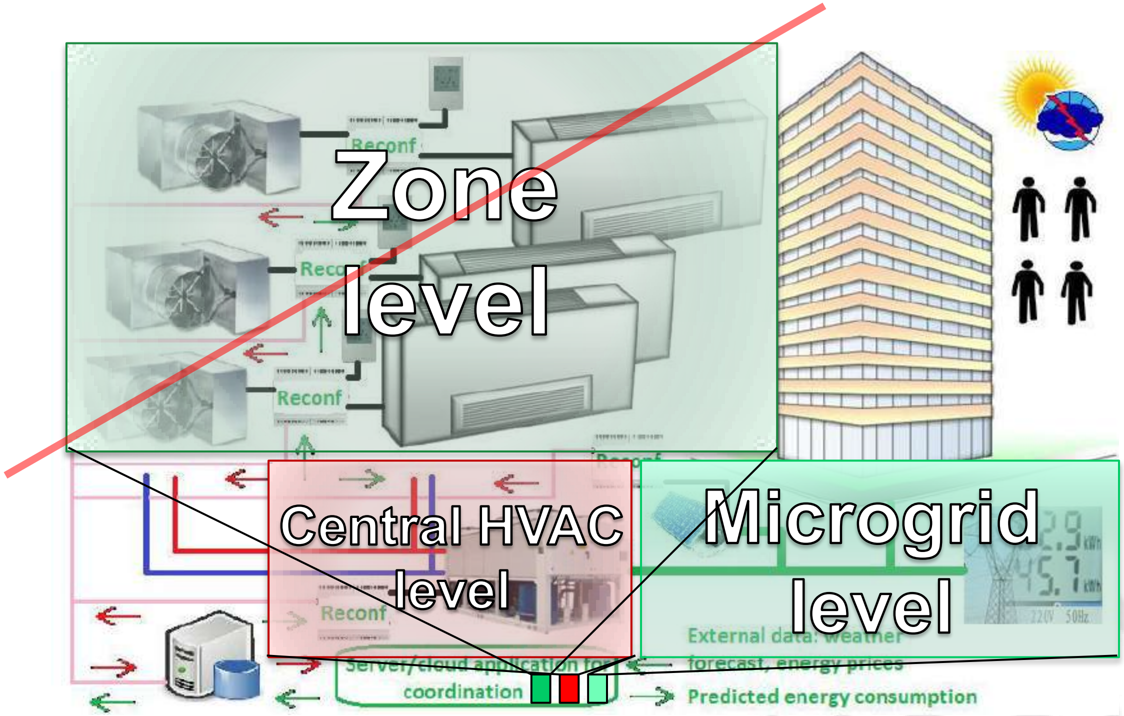
Interreg Danube Transnational Programme 3Smart

EUROPEAN UNION

UNIVERSITY OF ZAGREB FACULTY OF ELECTRICAL ENGINEERING AND COMPUTING

Project sufinanciran sredstvima Europske unije

3Smart concept in EON buildings complex



- No control interventions on the zone level are performed, only predictions/estimations necessary for the central HVAC level

3Smart concept on EON buildings complex (1)

- Zone level:
  - Just monitoring of energy consumption on fan coils and room temperatures measurement
  - Coordination with the central HVAC level:
    - Provided: Prediction of heating energy consumption and temperatures in all zones, 12-36 hours ahead

3Smart concept on EON buildings complex (2)

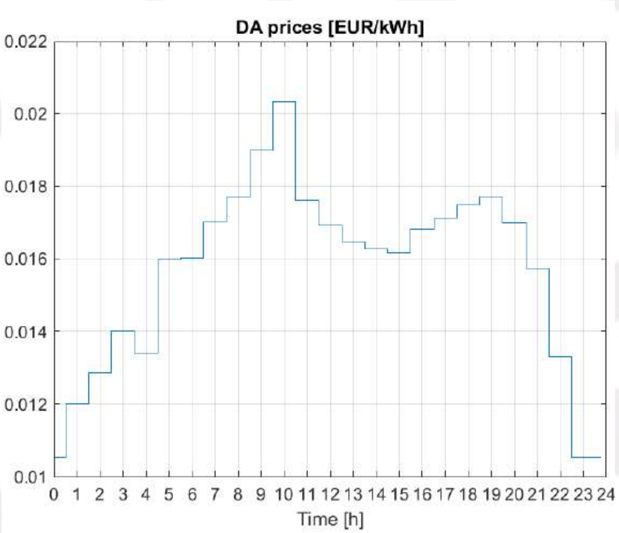
- Central HVAC level:
  - Control of starting temperatures in all 4 heating/cooling circuits towards the building
    - Goal: As low as possible total cumulative price of the heating energy from the distribution network and electricity for building climatization
    - Constraints: Enable all zones to be supplied with a conditioned medium of temperature sufficient to fill its predicted energy needs
    - Coordination with the microgrid level:
      - Obtained: Optimized electricity prices for small shift in electricity consumption for climatization
      - Given: Prediction of electricity consumption

3Smart concept on EON buildings complex (3)

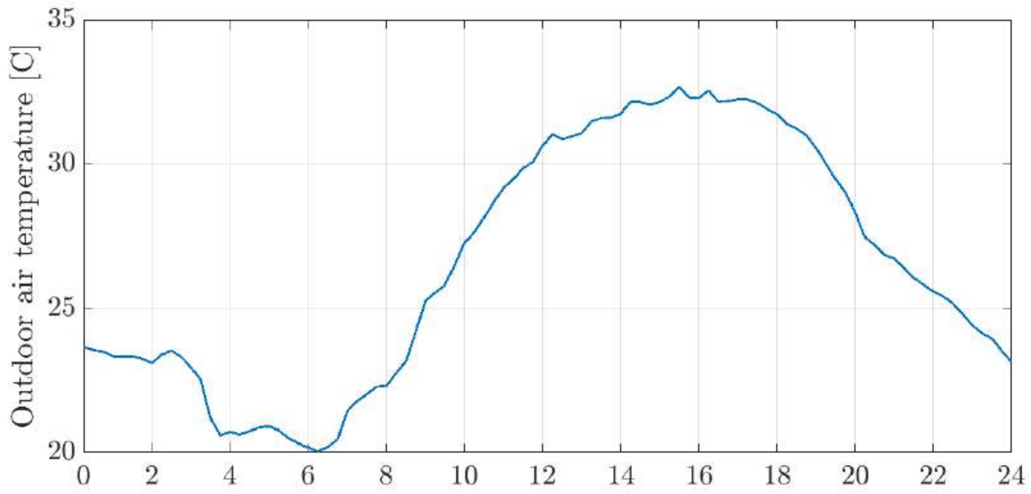
- Microgrid:
  - Control of PV system production between 0 and maximum, heating of cellar rooms with electric heaters
    - Goal: As low as possible total energy cost for the building, including demand response opportunities
    - Conditions: Long-term contract for demand response; Kept temperature in cellar rooms within limits
  - Optimal engagement of the controllable remainder of the system, in accordance with taken prices and grid energy exchange conditions
    - Accounted non-controllable electric energy consumption

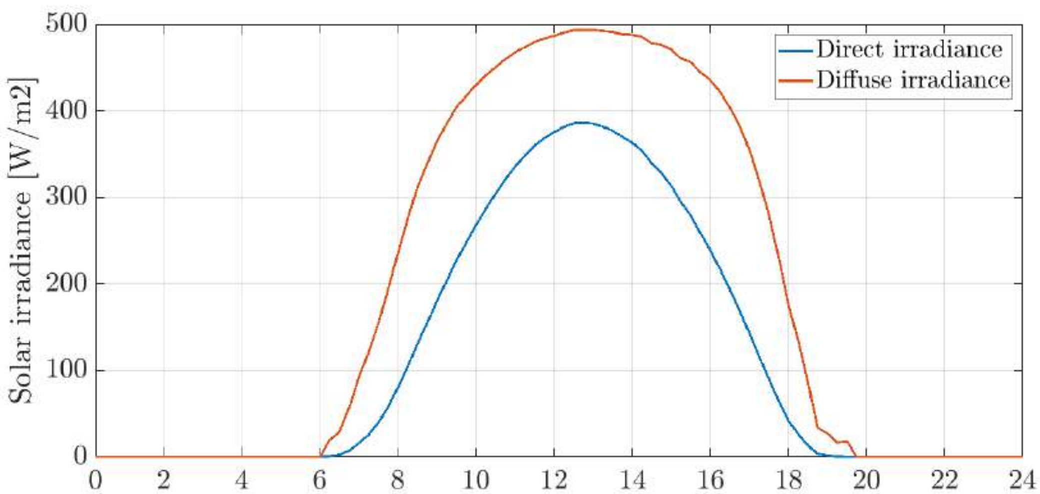
Analysis of operation on EON buildings complex (1)

- Conditions: sunny workday in August
- Questions:
  - What is the economically optimal way of daily building operation?
    - When and how much to cool the medium, when and how much to dimm the photovoltaics, when and how much to use electric heaters in the cellar?
  - With which offered flexibility is the building operation cost minimal?
  - How much is the optimal operation better than the conventional one?
- Flexibility interval: 13:45-16:15
- Flexibility prices:
  - rezervation: 0.015 EUR/kW/15 min
  - activation: 0.061 EUR/kWh
  - penalty: 0.122 EUR/kWh

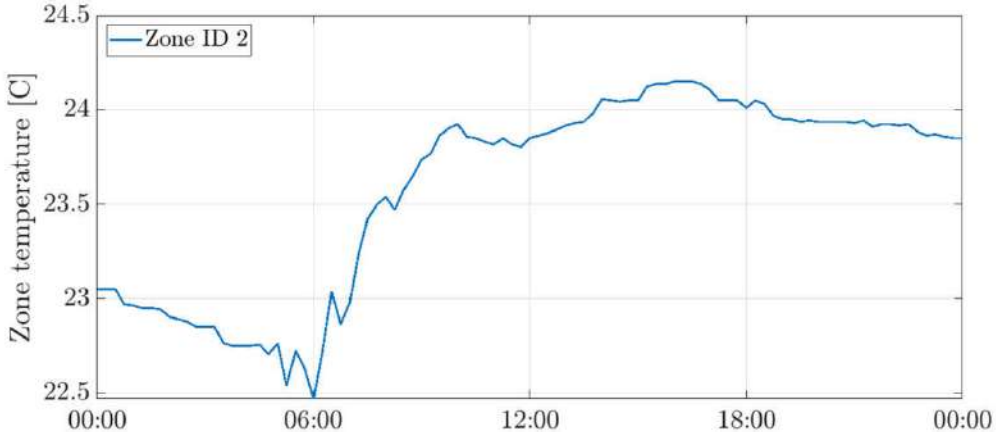


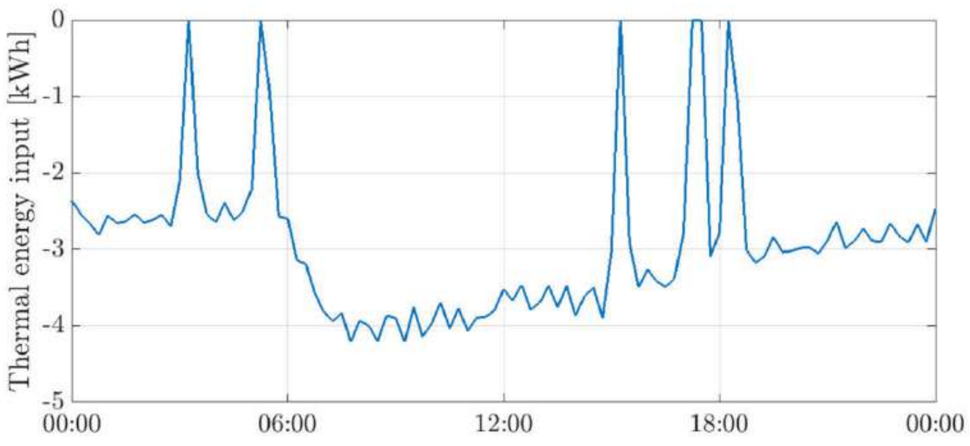
Analysis of operation on EON buildings complex (2)



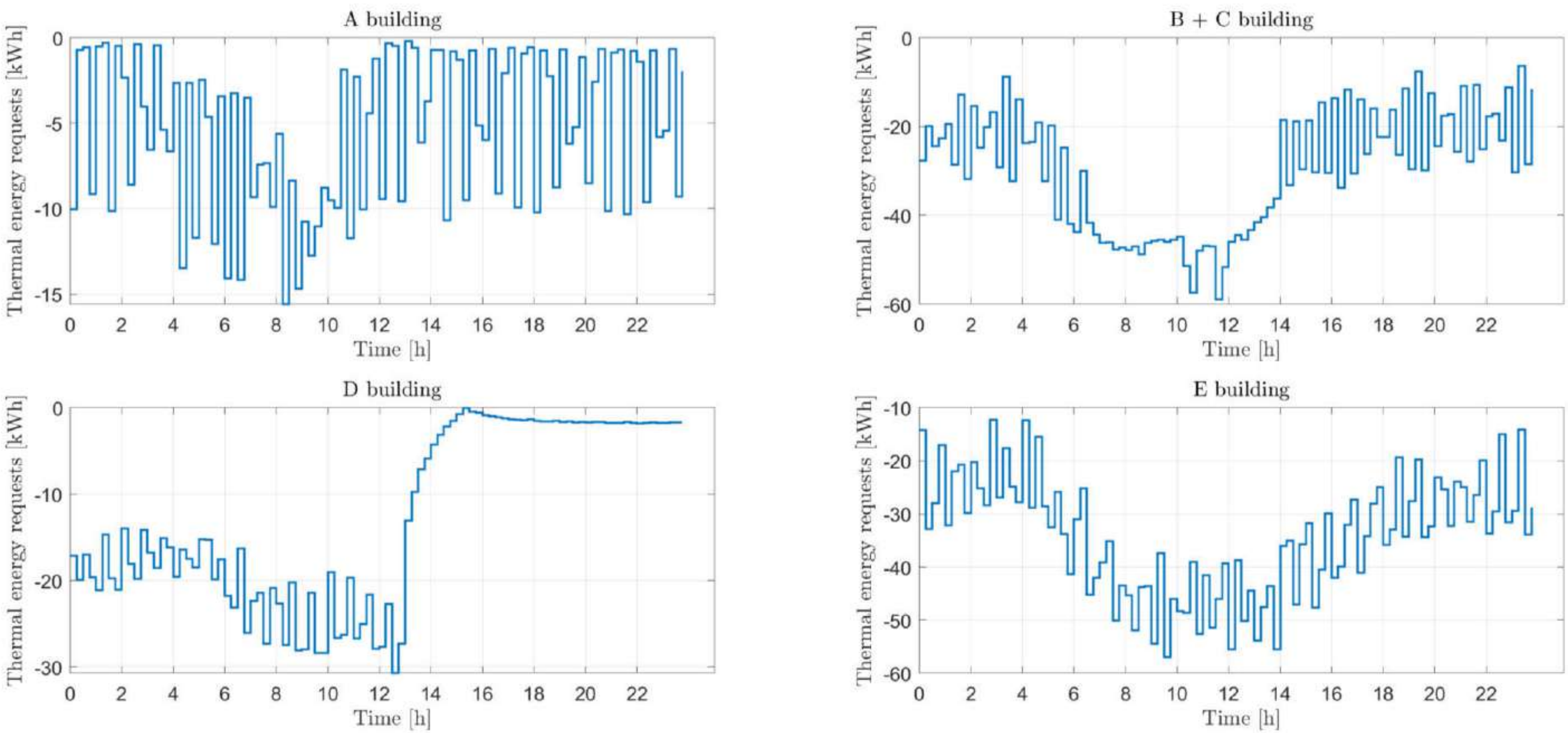


Analysis of operation on EON buildings complex (2)



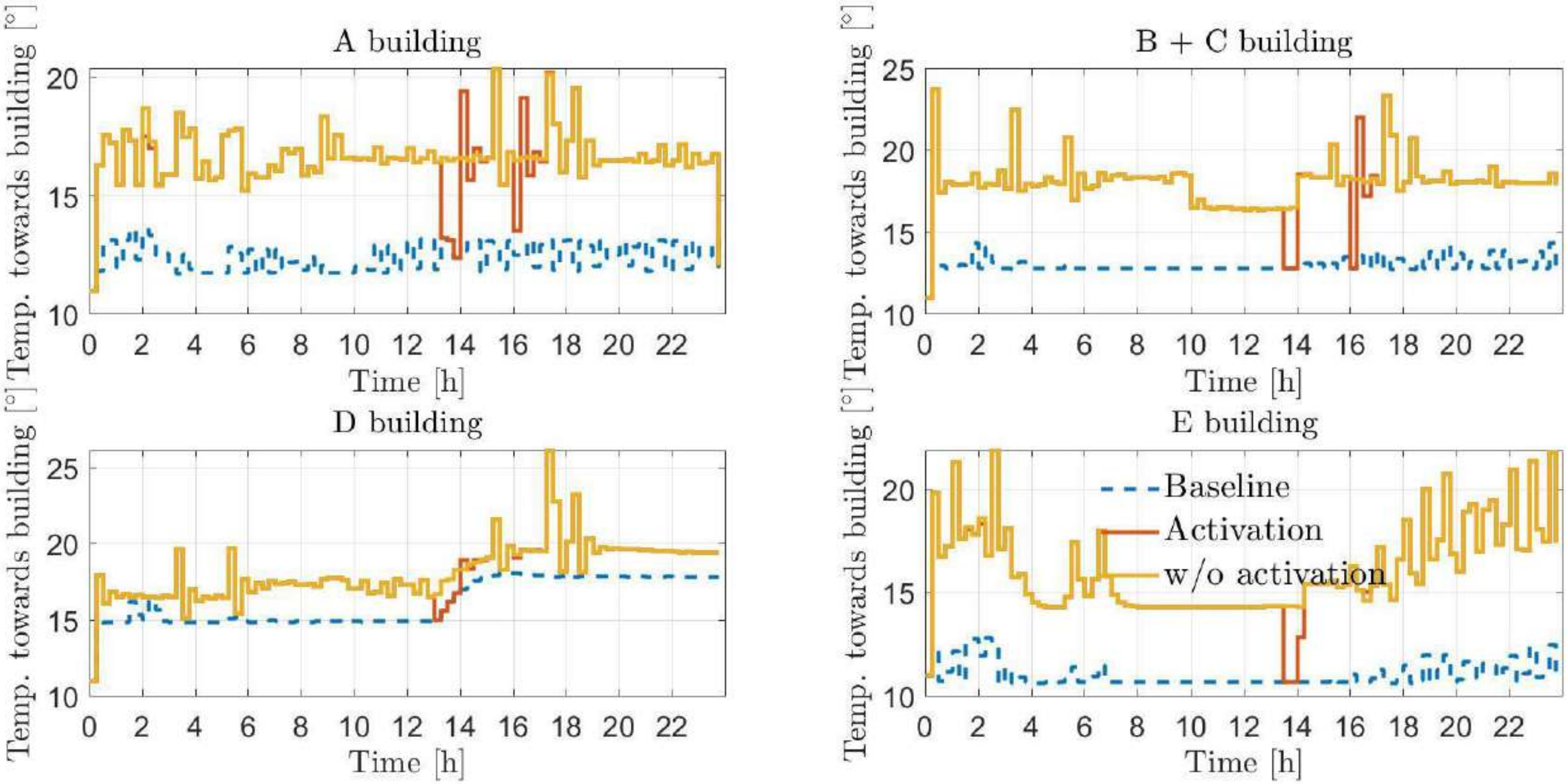


Analysis of operation on EON buildings complex (3)



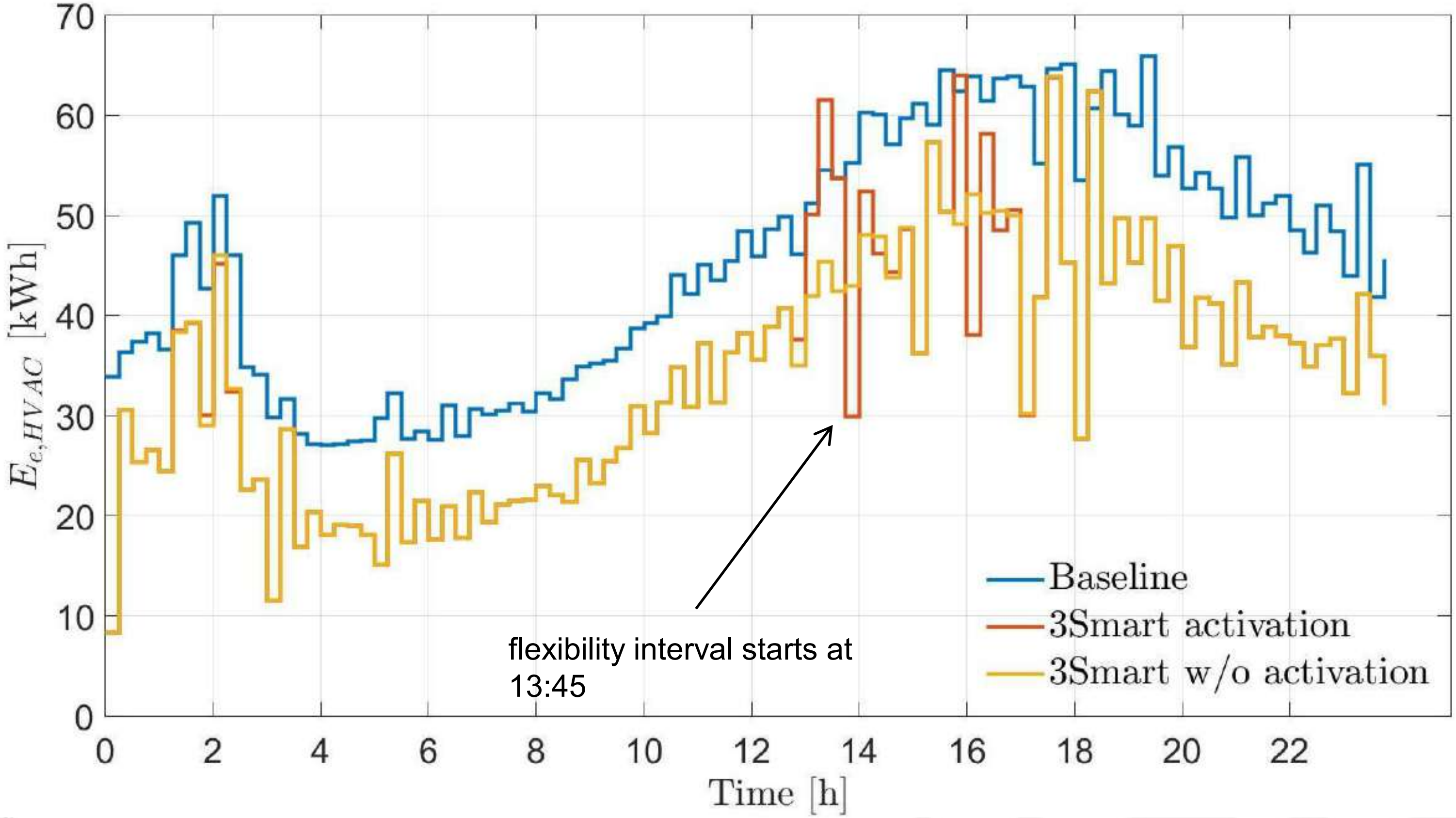
Analysis of operation on EON buildings complex (4)

- Central HVAC system optimized starting temperature profiles: conventional (blue), optimal with activation (red), optimal without activation (yellow)

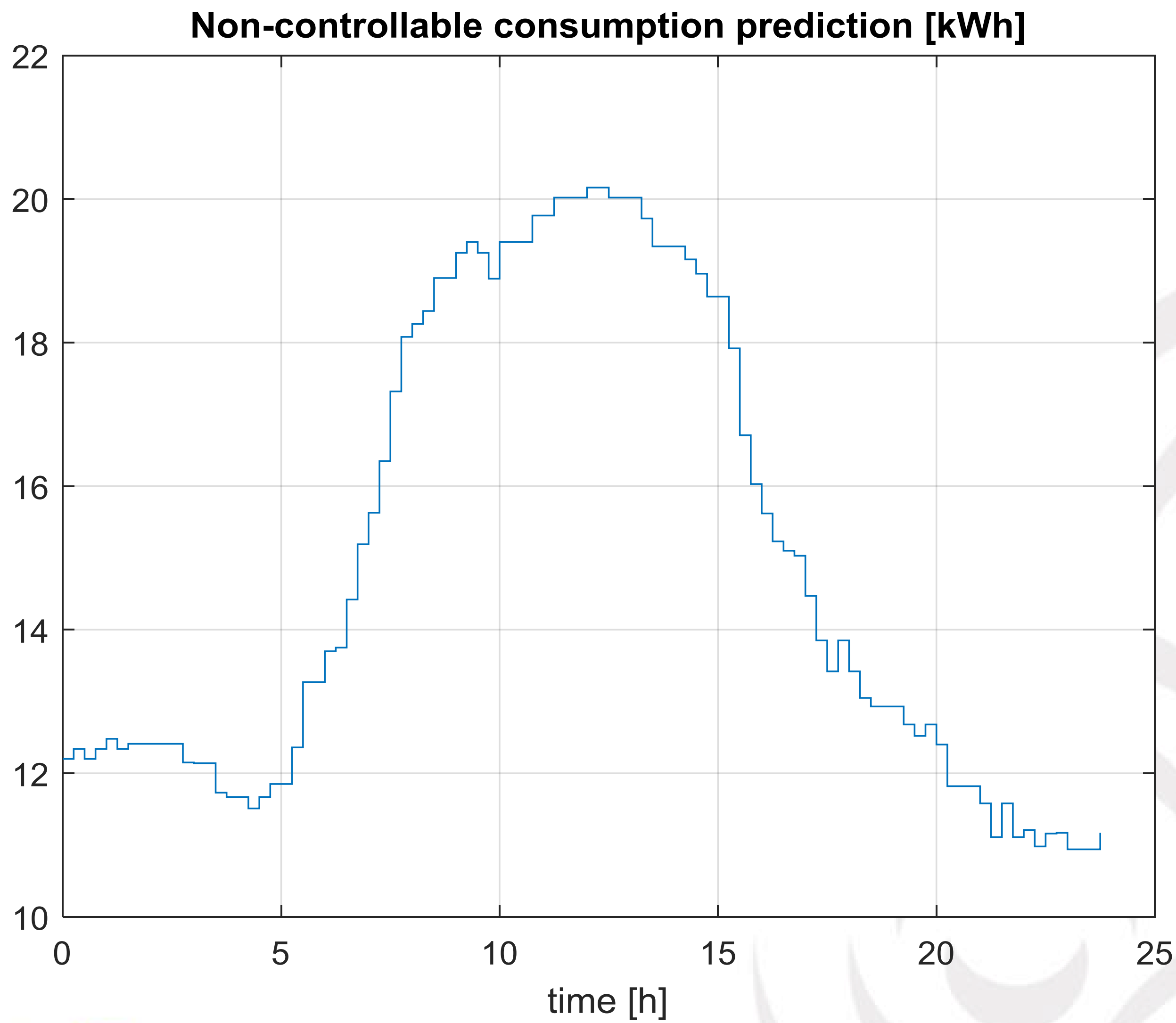


Analysis of operation on EON buildings complex (5)

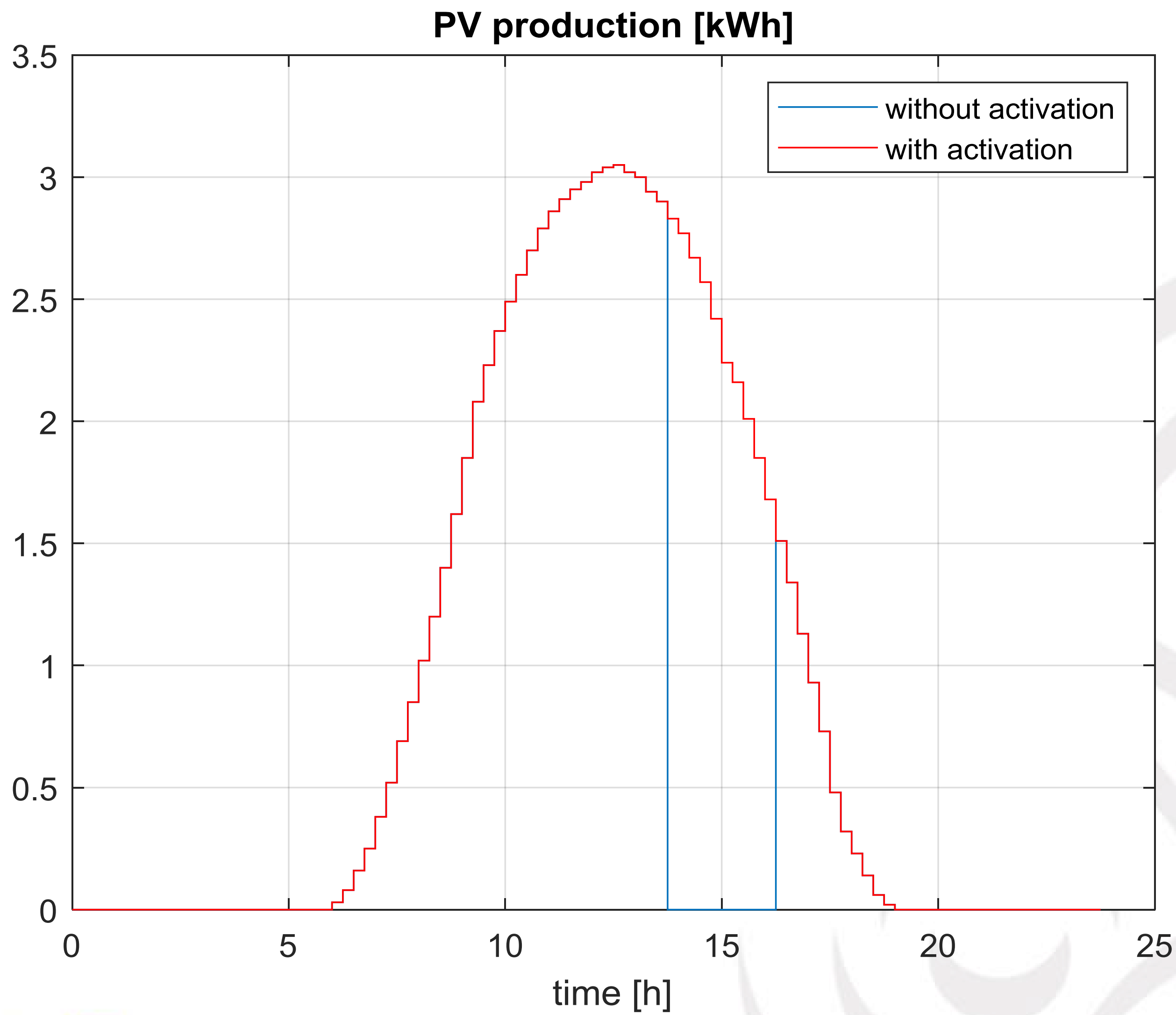
- Electricity demand from the climatization system



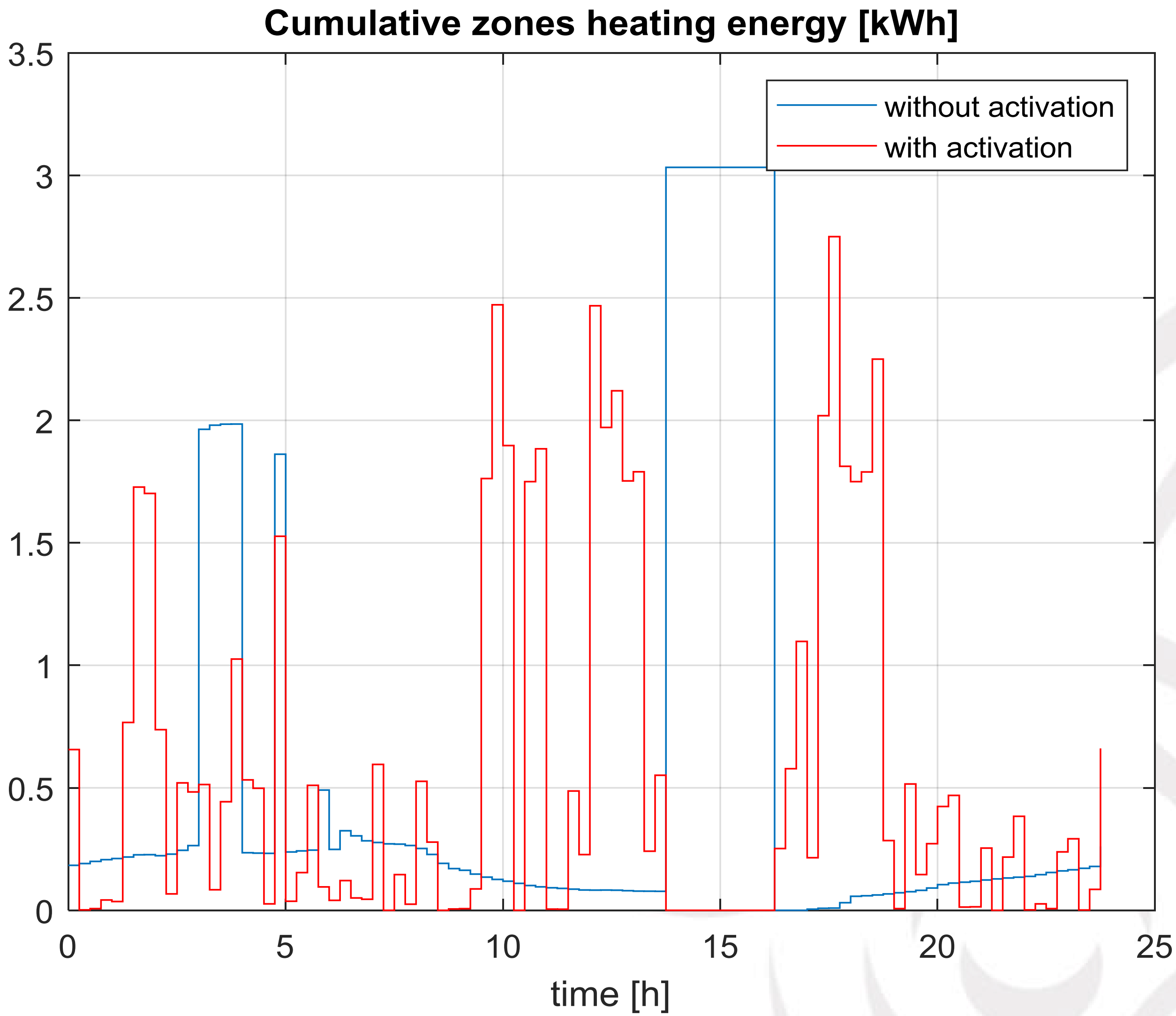
Analysis of operation on EON buildings complex (6)



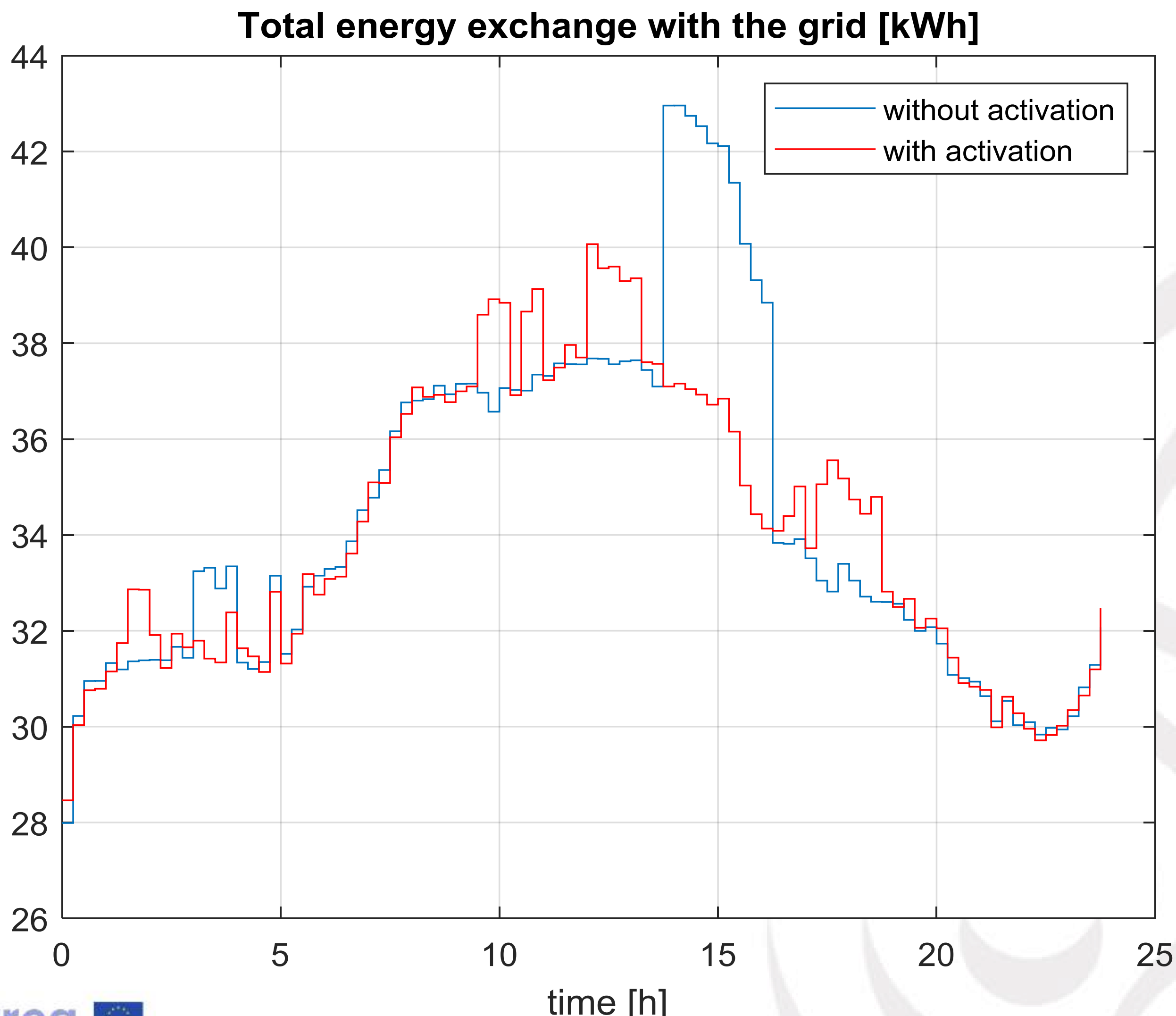
Analysis of operation on EON buildings complex (7)



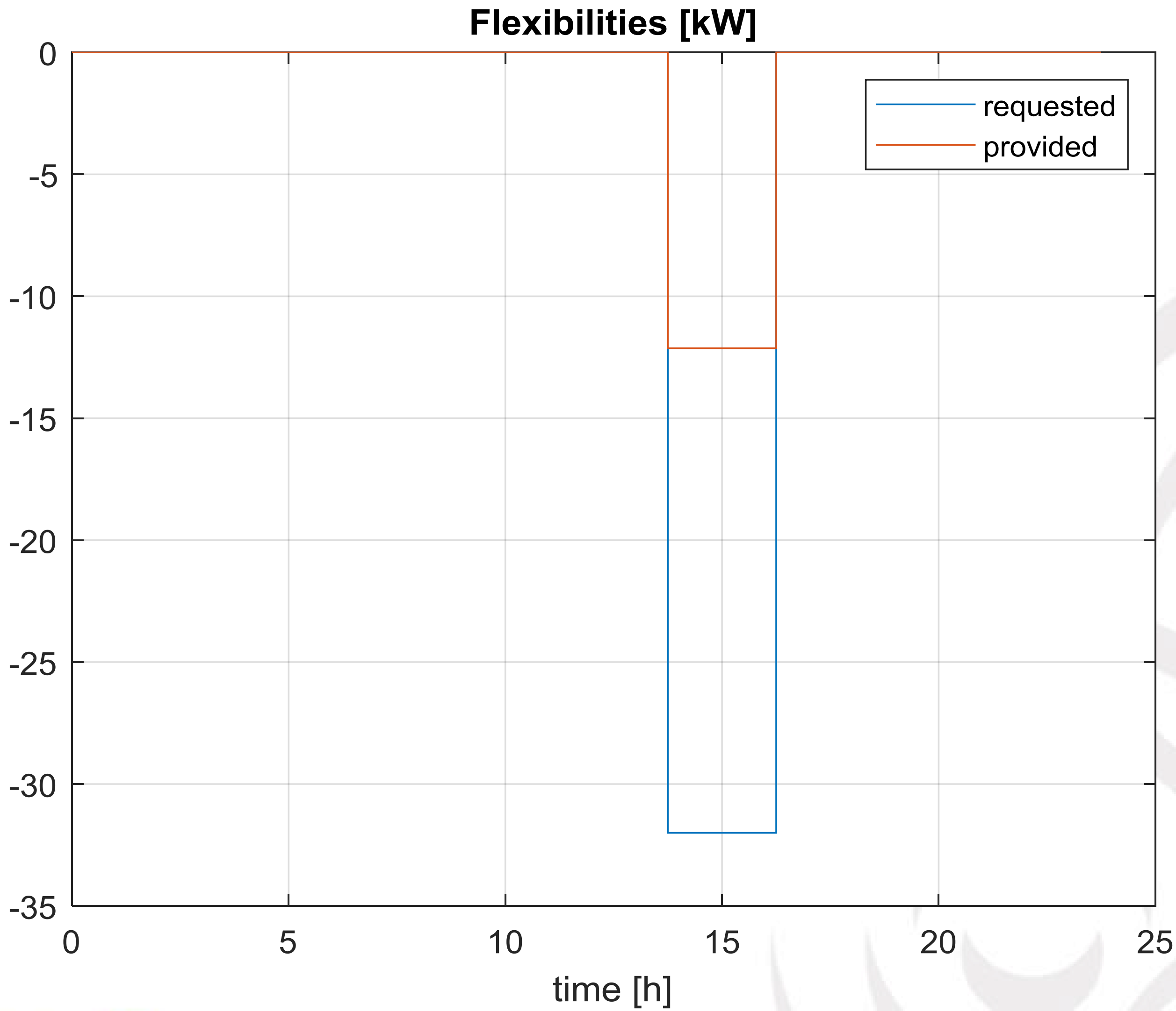
Analysis of operation on EON buildings complex (8)



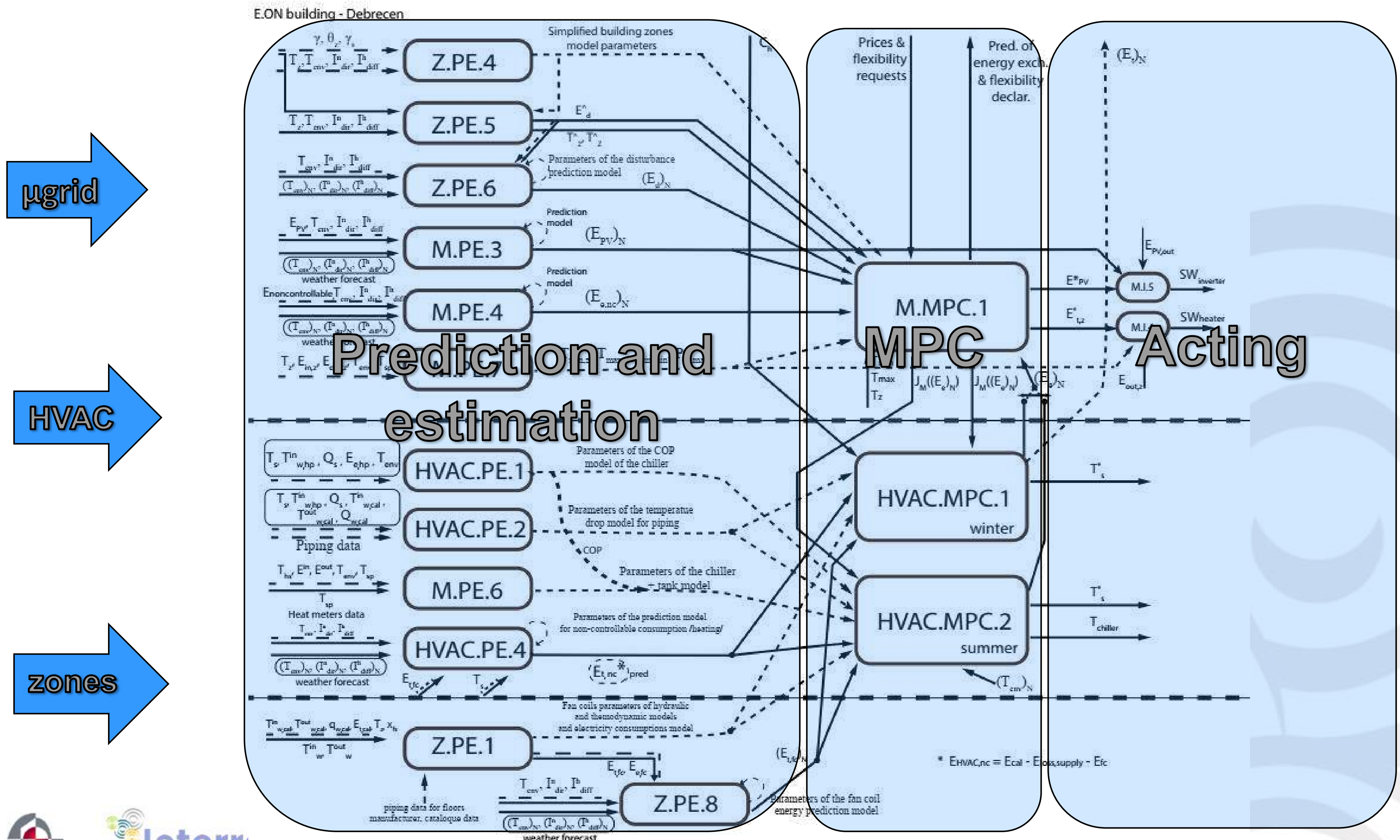
Analysis of operation on EON buildings complex (9)



Analysis of operation on EON buildings complex (10)



Organization of the 3Smart tool on EON building



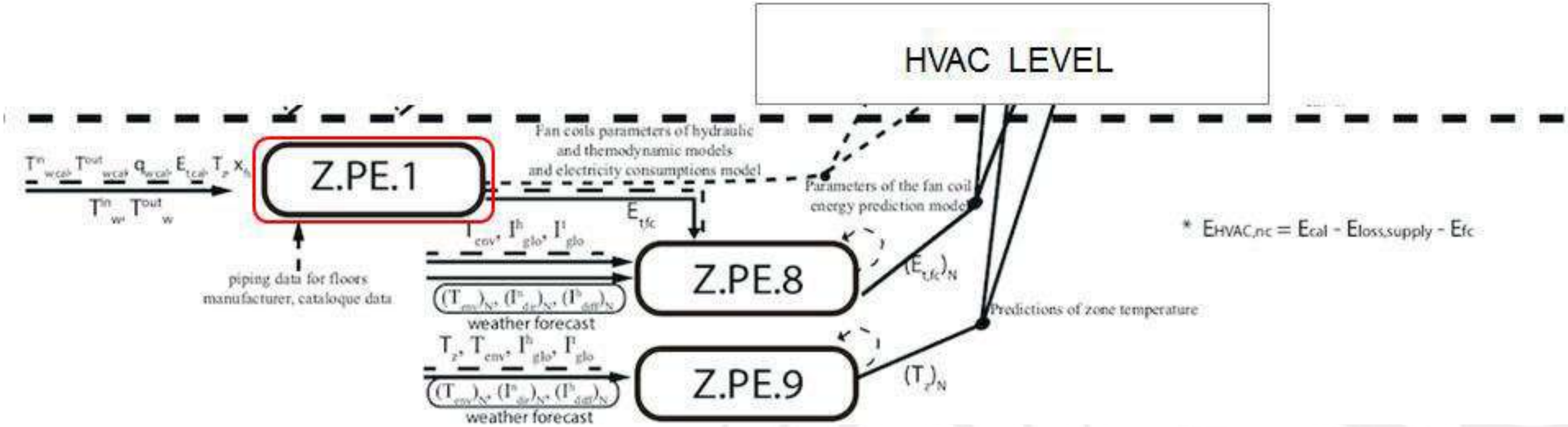
Requirements for interventions in the building

- Software-based choice of building parts that are being coordinated
  - central HVAC or microgrid or both
- Simple and automated return to classical controls if needed
  - control actions with time stamp
- Data sampling from the building with time resolution ~1 min in the 3Smart database
- Control commands from the 3Smart database propagate to target devices in the building automation system
- Non-disturbing local control circuits in HVAC/μgrid

Demonstration of 3Smart modules operation on EON buildings complex

Zone level

Z.PE.1 – offline
(fan coil identification submodule)



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Z.PE.1 – offline

(MODULE FOR FAN COIL MODEL IDENTIFICATION)

Running just once

- Identification of the **hydraulic model of installations**

Medium flow measurement from the considered duct calorimeter →
Valve position →

Hydraulic fan coil model

→ Medium flow through the fan coil

- Identification of **fan coil thermodynamic model**

Supply water temperature (calorimeter) →
Return medium temperature →
Fan state →
Valve position →
Medium flow through the coil →
Zone temperature →

Thermodynamic fan coil model

→ Thermal energy exerted into zone

- Identification of a **electrical energy consumption model** of a fan coil

Fan state →

Electrical energy consumption model

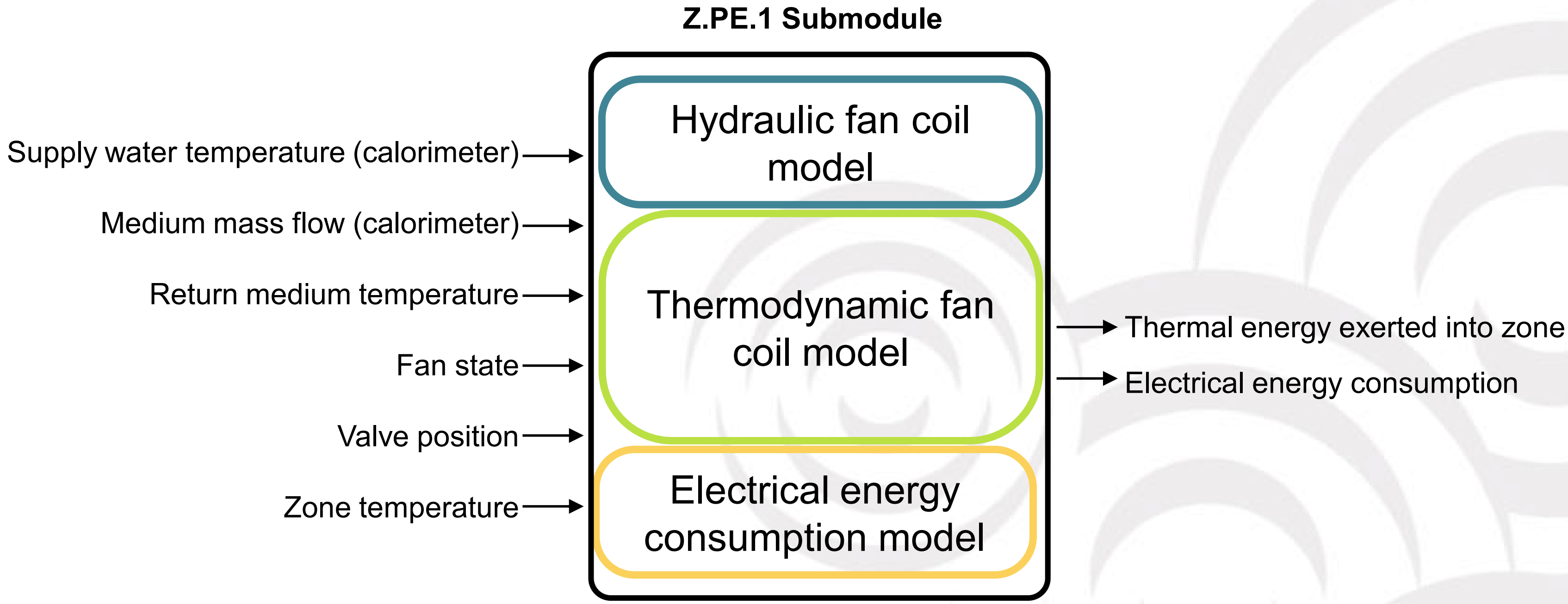
→ Electrical energy consumption

Z.PE.1 – online

(MODULE FOR ESTIMATING THERMAL AND ELECTRICAL ENERGY CONSUMPTION)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

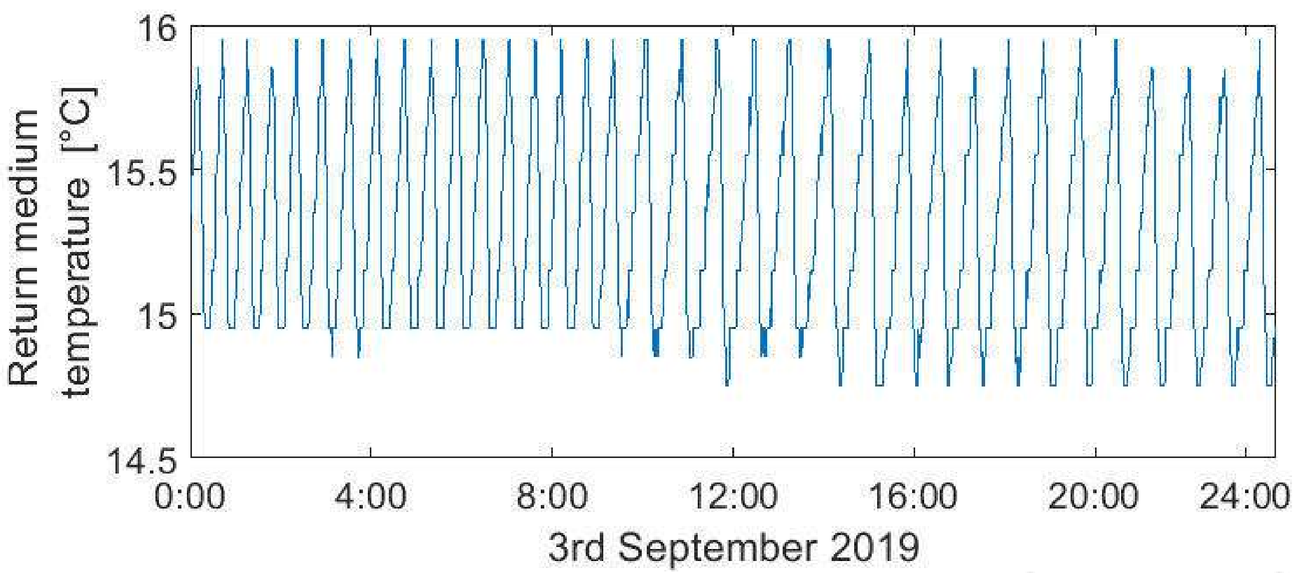
Running every 1 min



Z.PE.1 – online
(MODULE FOR ESTIMATING THERMAL AND ELECTRICAL ENERGY CONSUMPTION)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

INPUT 1: current return medium temperature measurement



Z.PE.1 – online

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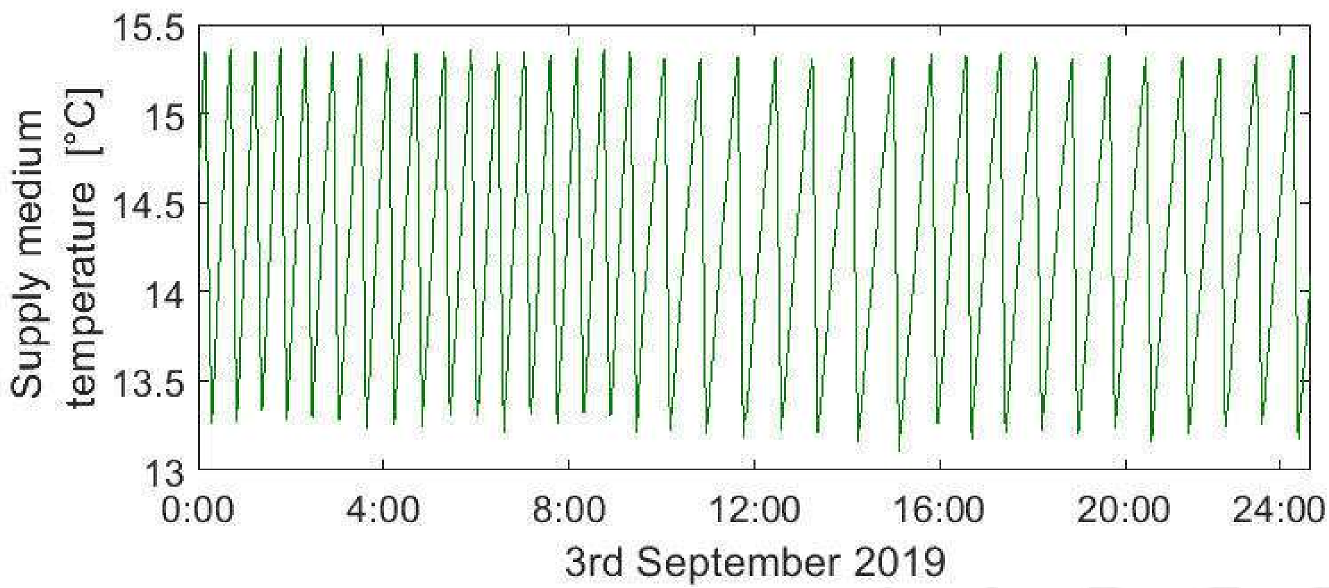
- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

INPUT 1: current return medium temperature measurement
INPUT 2: current measurement of medium starting temperature
INPUT 3: current measurement of flow



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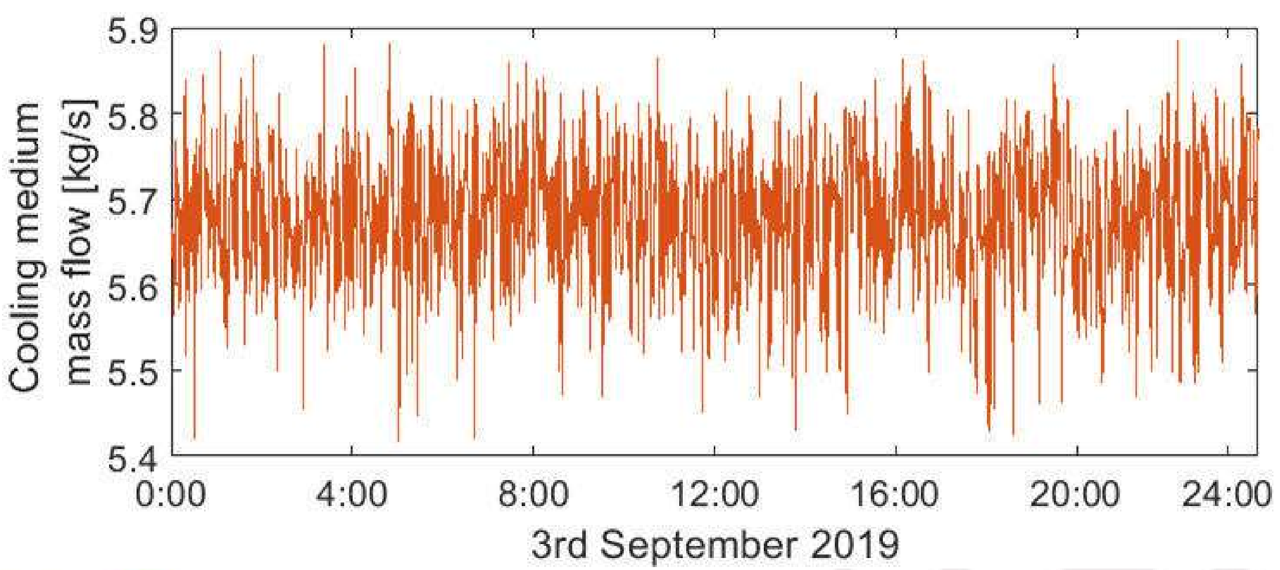
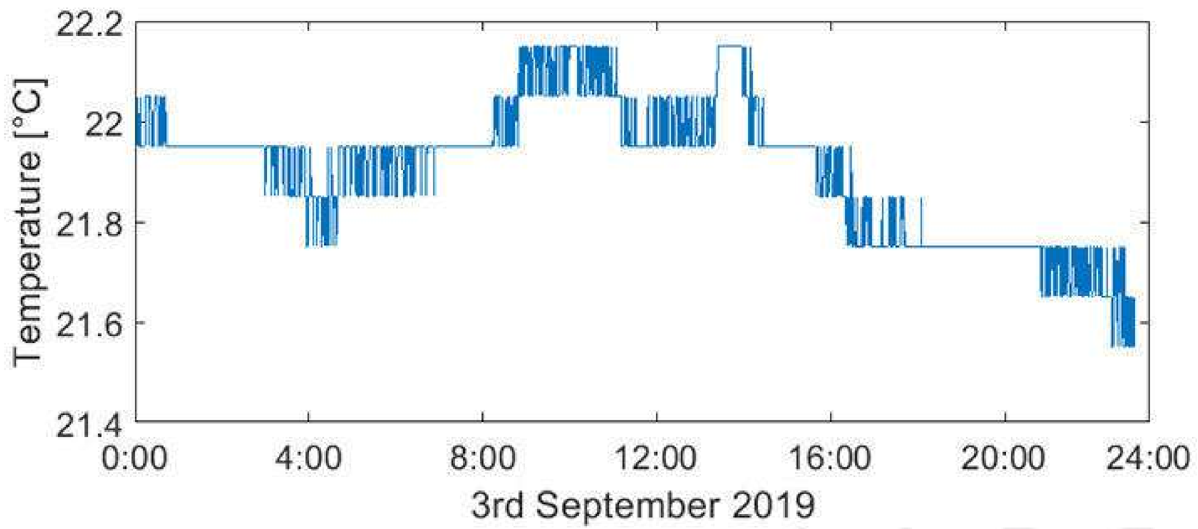


Z.PE.1 – online

(MODULE FOR ESTIMATING THERMAL AND ELECTRICAL ENERGY CONSUMPTION)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

INPUT 1: current return medium temperature measurement
INPUT 2: current measurement of medium starting temperature
INPUT 3: current measurement of flow
INPUT 4: current room temperature

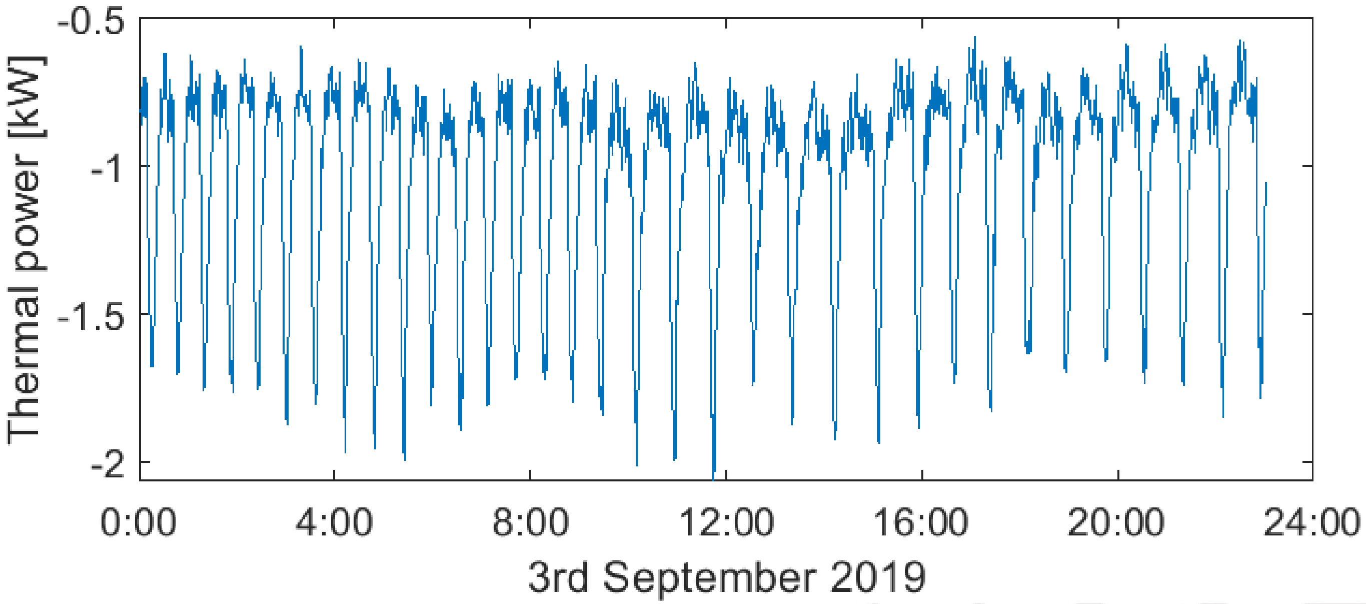


Z.PE.1 – online

(MODULE FOR ESTIMATING THERMAL AND ELECTRICAL ENERGY CONSUMPTION)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

OUTPUT 1: heating energy exerted in the room from fan coils

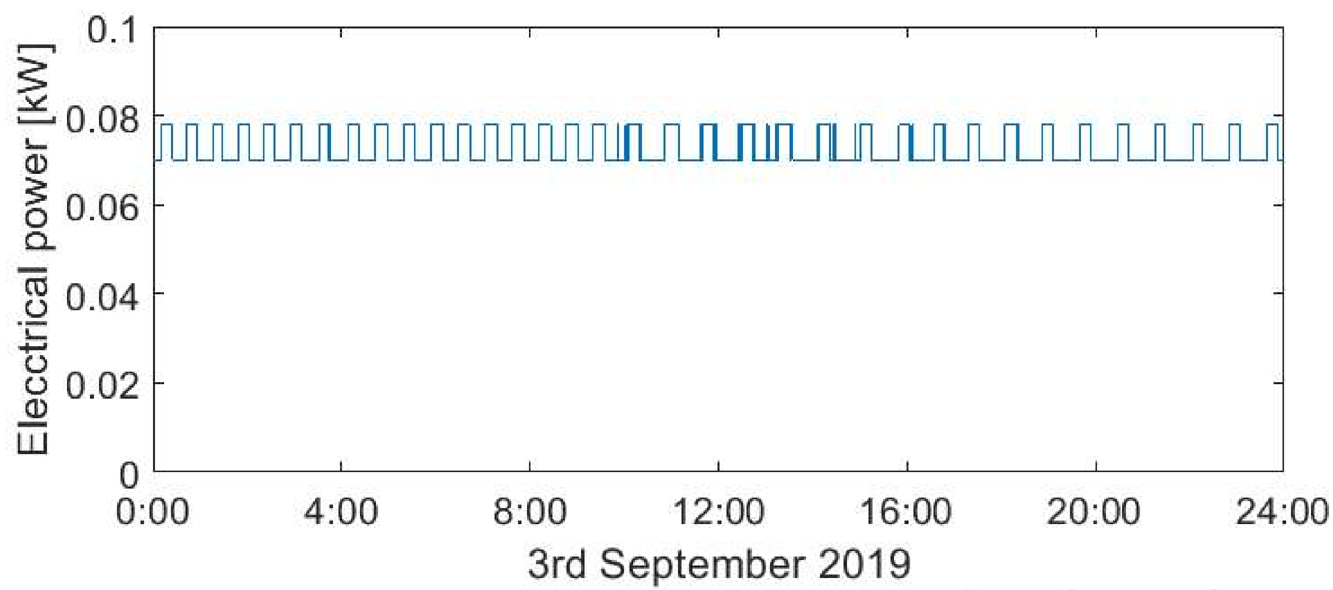


Z.PE.1 – online

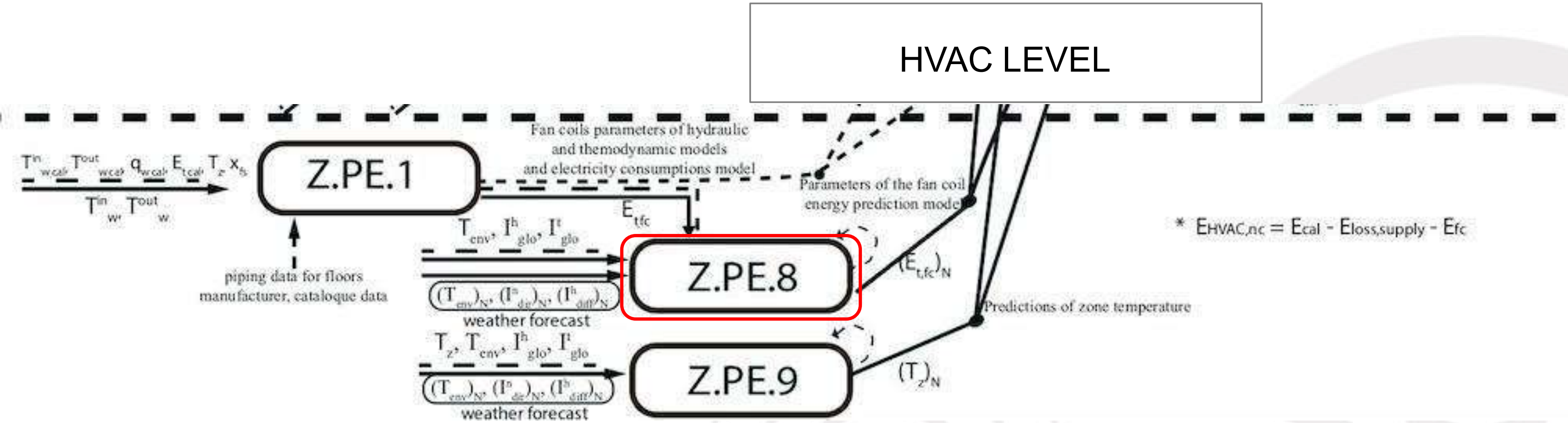
(MODULE FOR ESTIMATING THERMAL AND ELECTRICAL ENERGY CONSUMPTION)

- By using **hydraulic, thermodynamic and electricity consumption model** of fan coil the overall heating energy inserted into the zone as well as eelctrical energy consumption of the fan are determined

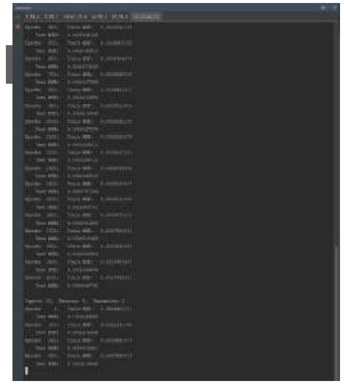
OUTPUT 1: heating energy exerted in the room from fan coils
OUTPUT 2: electricity consumption of the fan coil



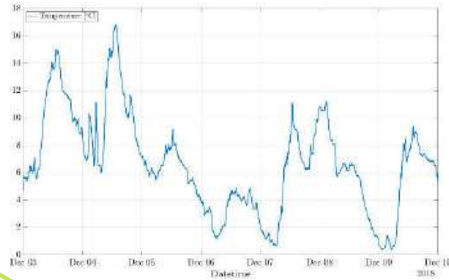
Zone PE 8
(prediction of zone thermal energy input)



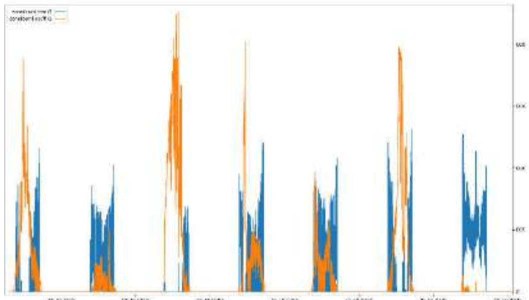
Zone PE 8 – off-line initialization



Historical meteorological measurements:
- Air temperature
- Global and tilted solar irradiance

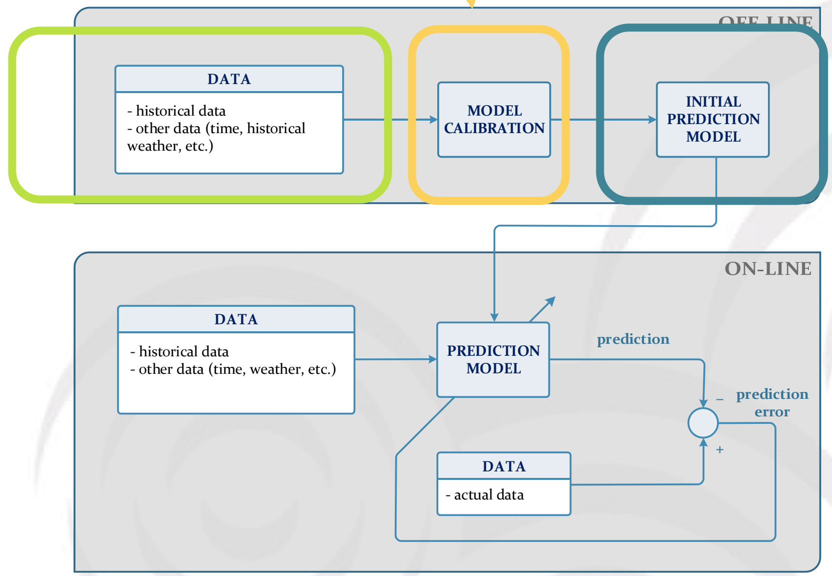


Locally stored: inputsXY_neuronsZ.net

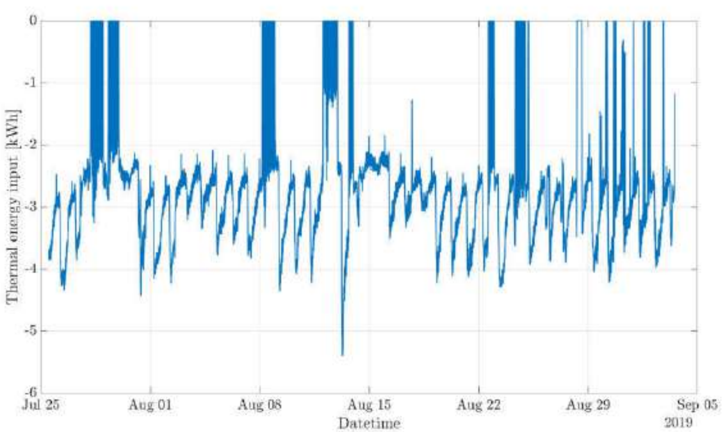


Module inputs

MODEL



Historical values of zone thermal energy input (Z.PE.1)



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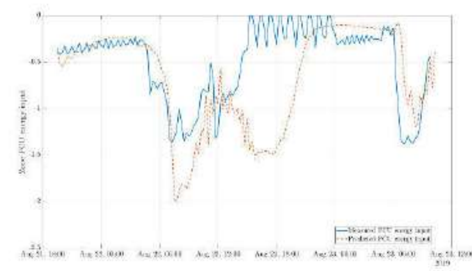
Zone PE 8 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor constituted of specific historic intervals of data:

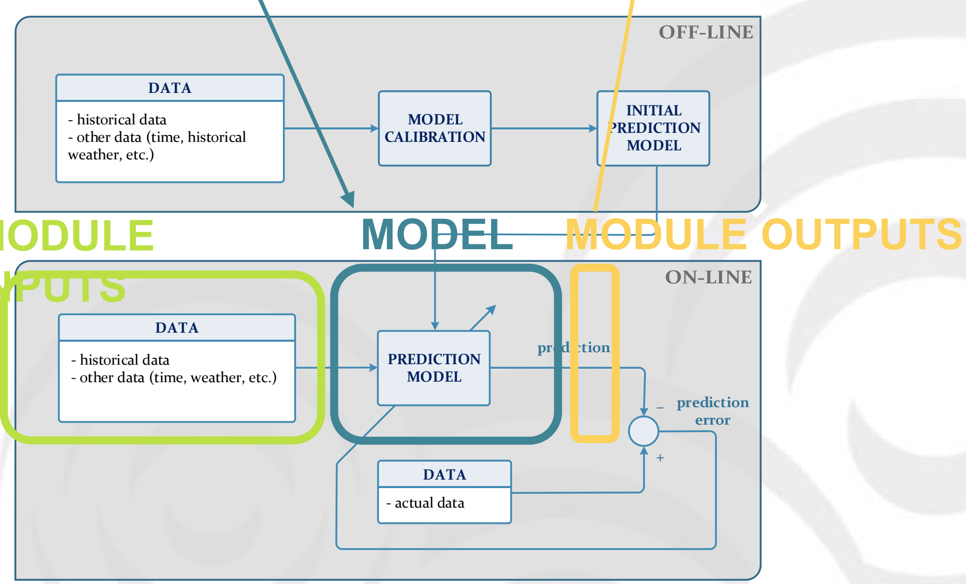
- zone_thermal_energy(t-1,…,t-5)
- zone_thermal_energy(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

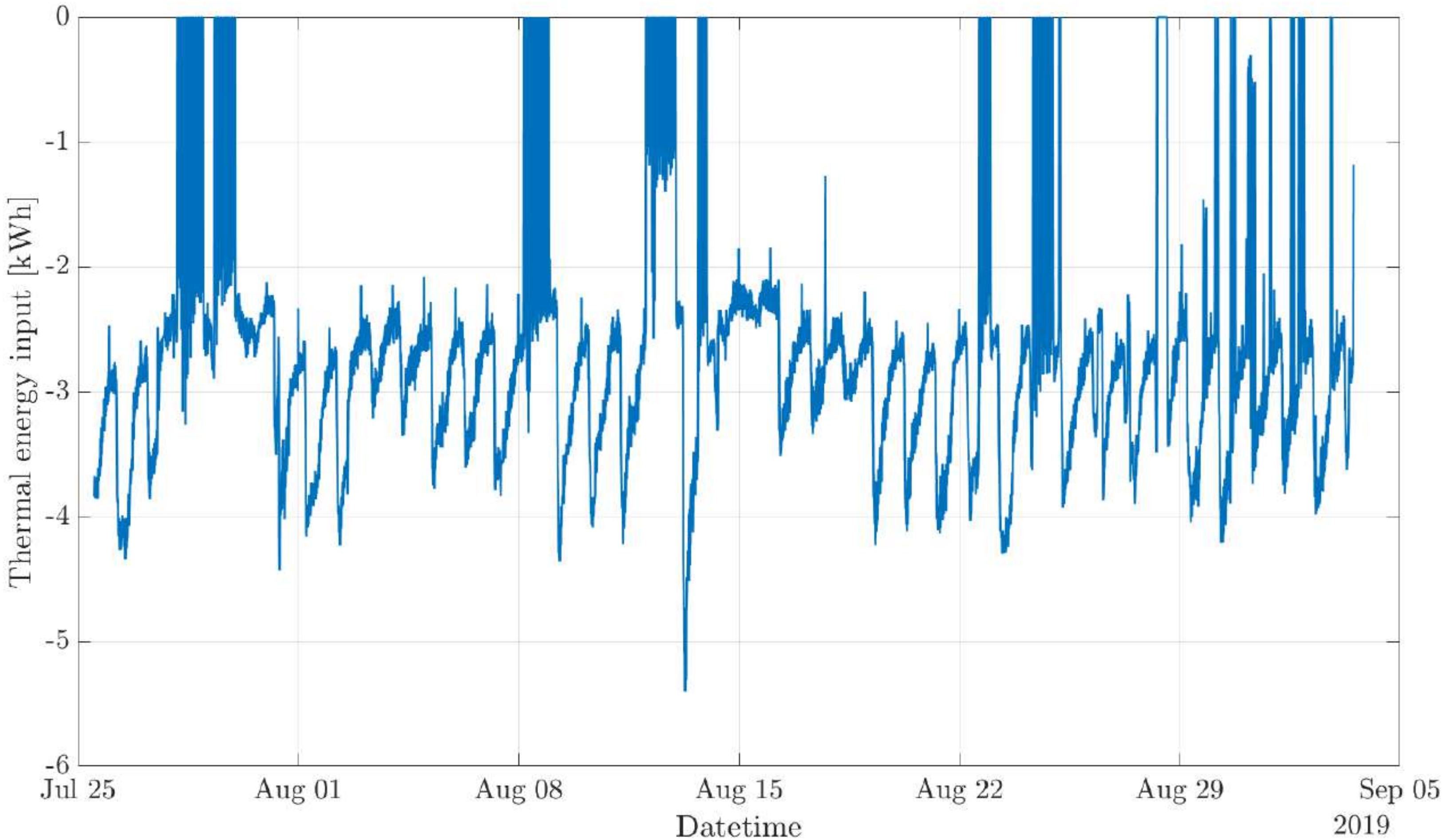
- air temperature(t-1,…,t-3)
- air temperature(t-671,…,t-673)

- global irradiance(t-1,…,t-3)
- global irradiance(t-671,…,t-673)

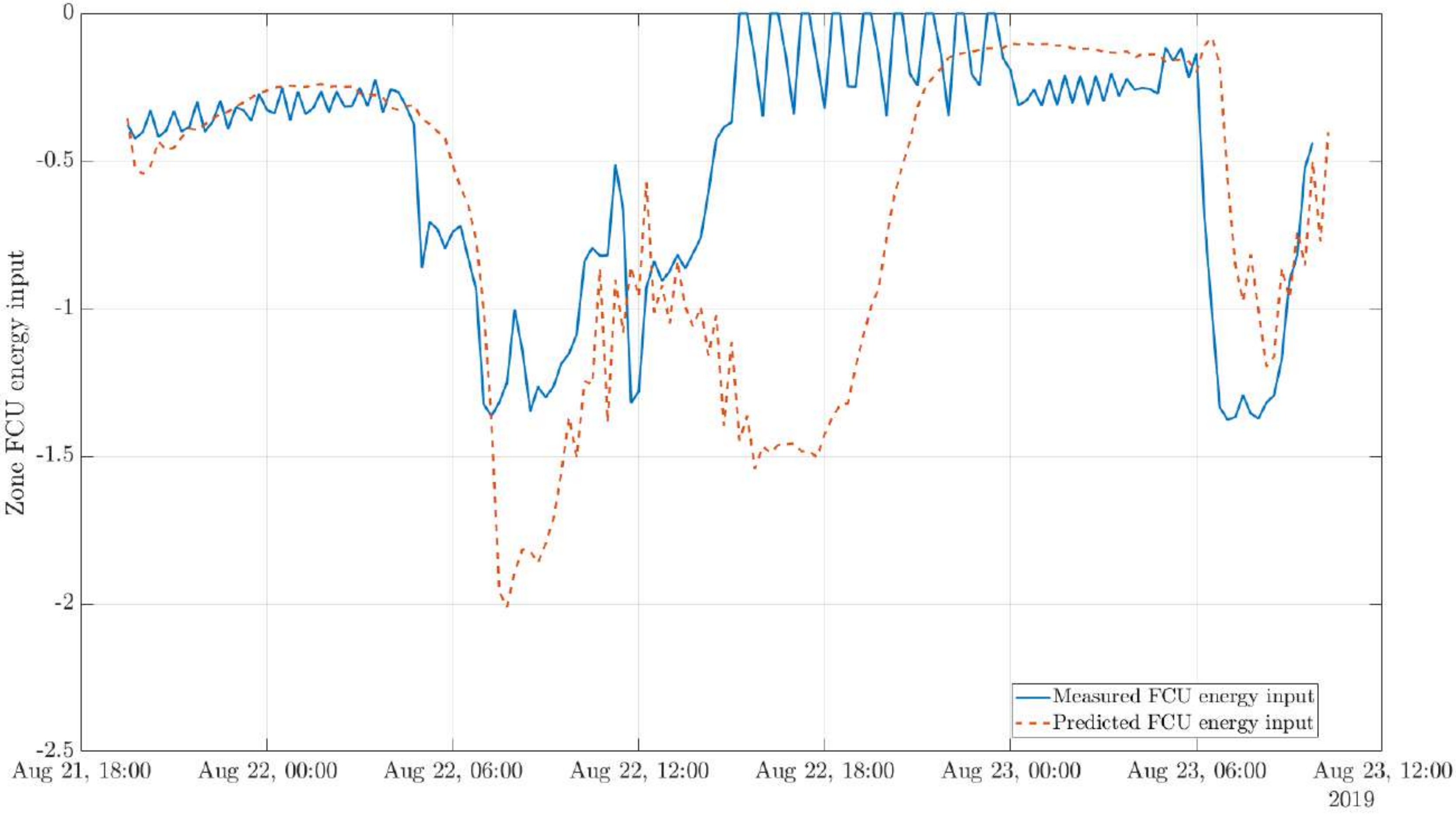
- tilted irradiance(t-1,…,t-3)
- tilted irradiance (t-671,…,t-673)



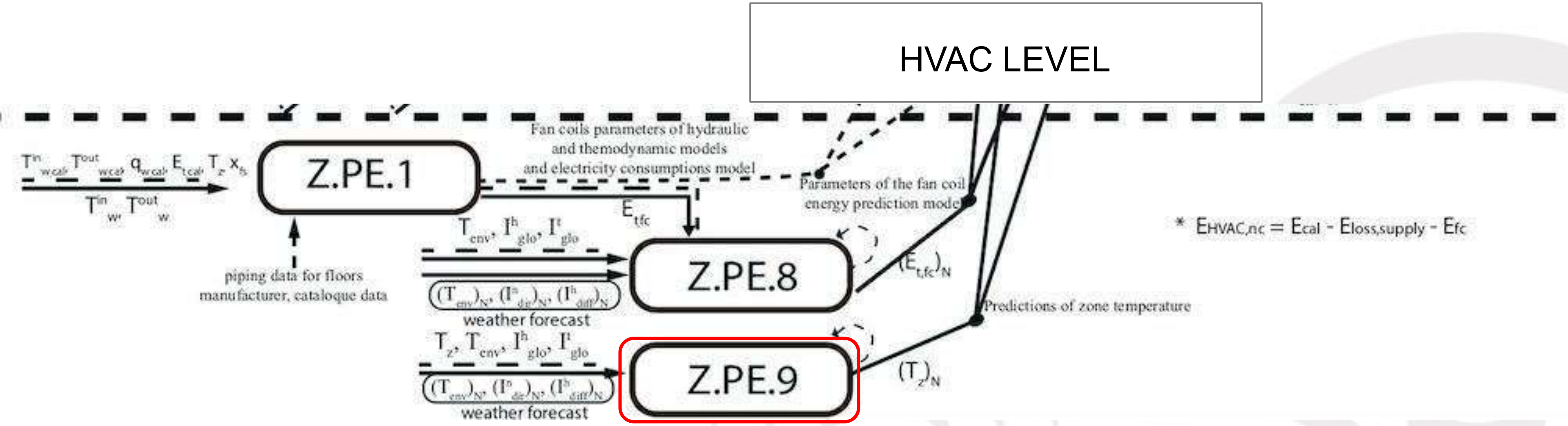
Zone PE 8 – example of historical zone thermal energy input



Zone PE 8 – example of generated prediction

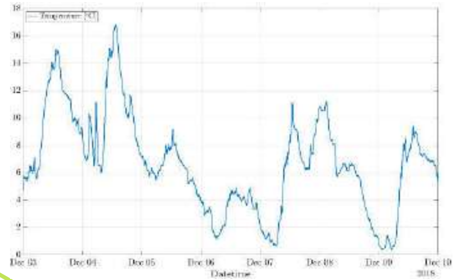


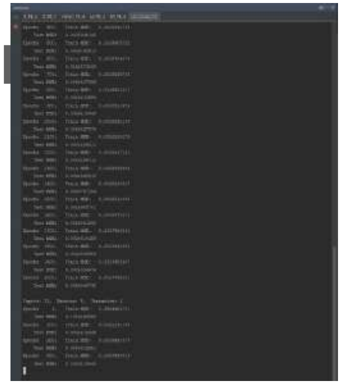
Zone PE 9
(prediction of zone temperature)



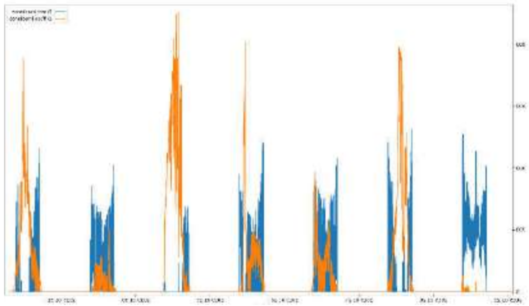
Zone PE 9 – off-line initialization

Historical meteorological measurements:
- Air temperature
- Global and tilted solar irradiance

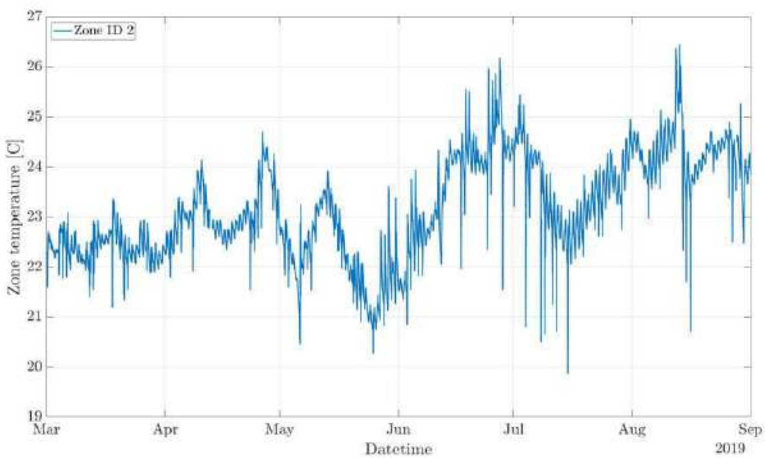




Locally stored: inputsXY_neuronsZ.net

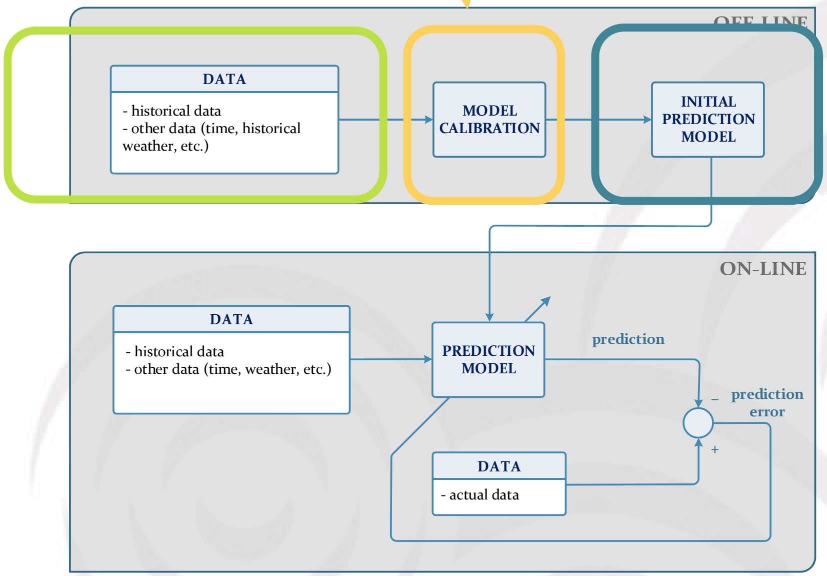


Historical values of measured zone temperature

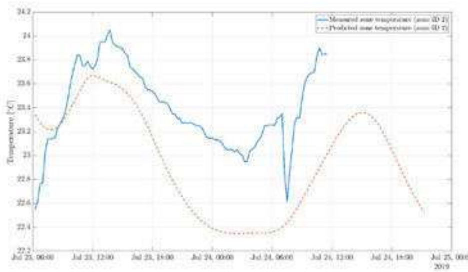


Module inputs

MODEL



Zone PE 9 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor constituted of specific historic intervals of data:

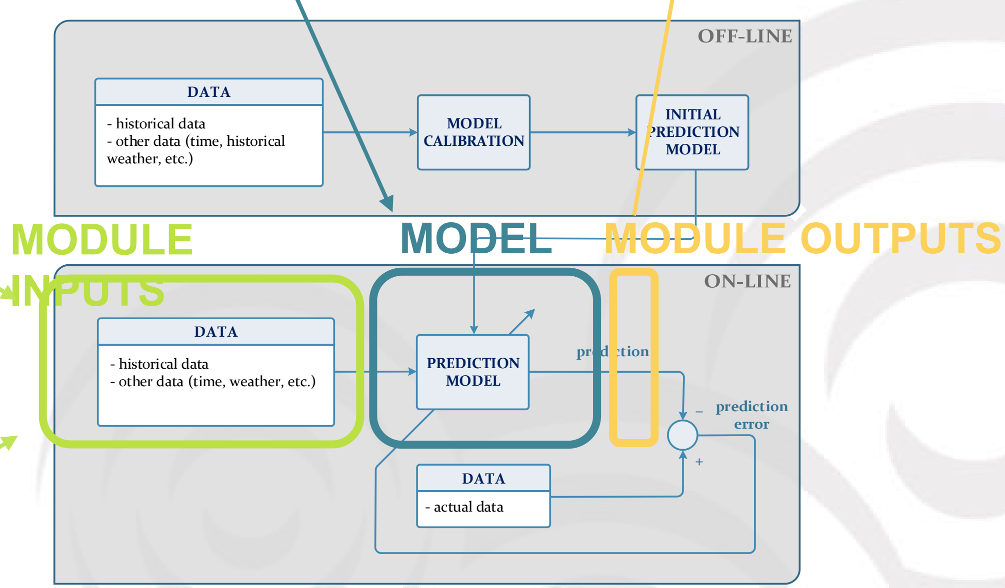
- zone_temperature(t-1,…,t-5)
- zone_temperature(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

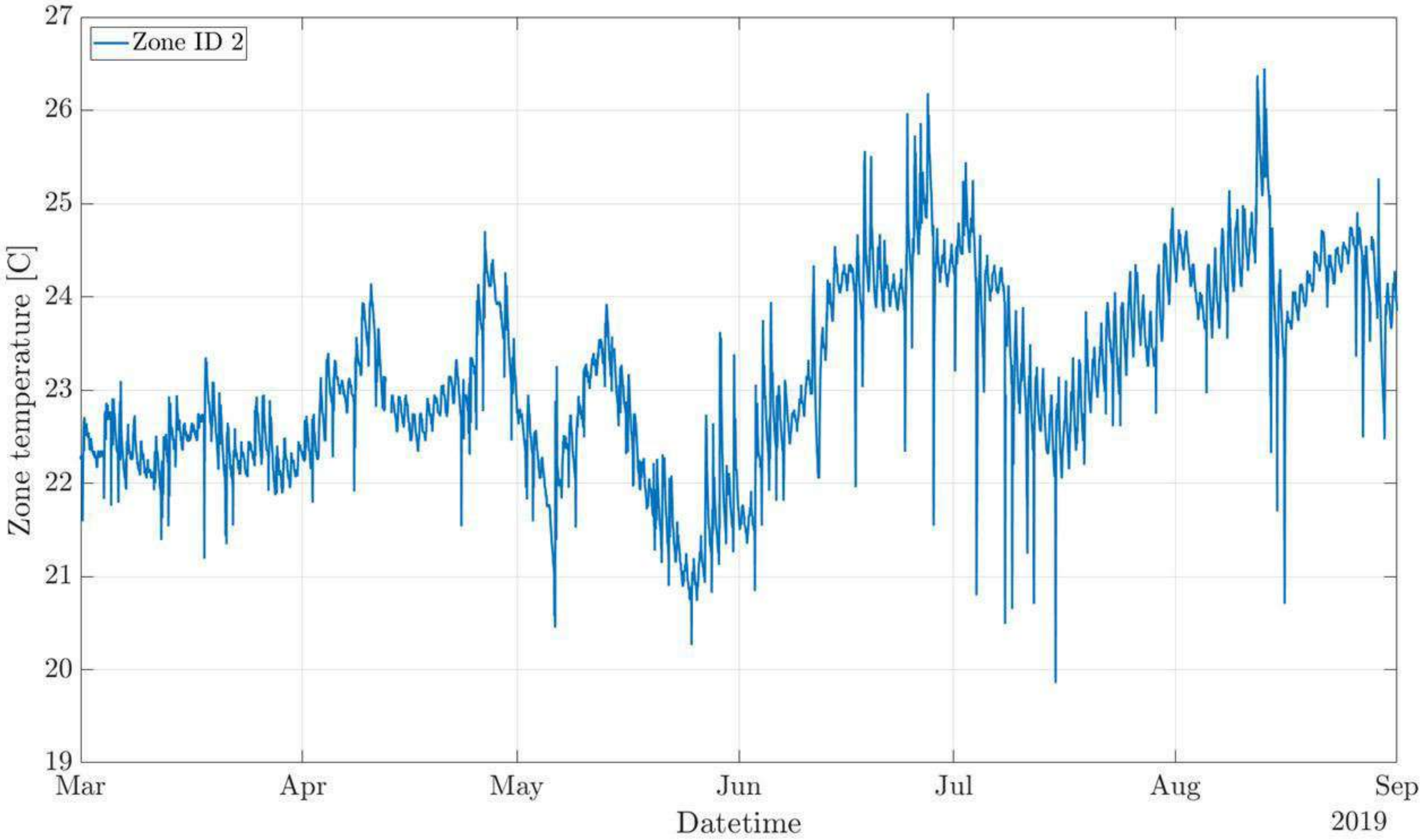
- air temperature(t-1,…,t-3)
- air temperature(t-671,…,t-673)

- global irradiance(t-1,…,t-3)
- global irradiance(t-671,…,t-673)

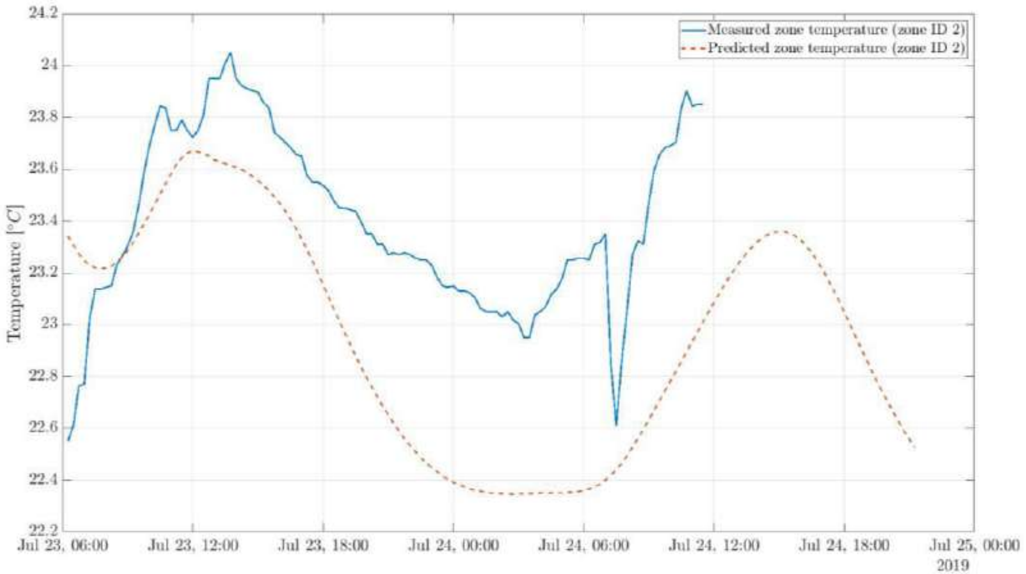
- tilted irradiance(t-1,…,t-3)
- tilted irradiance (t-671,…,t-673)

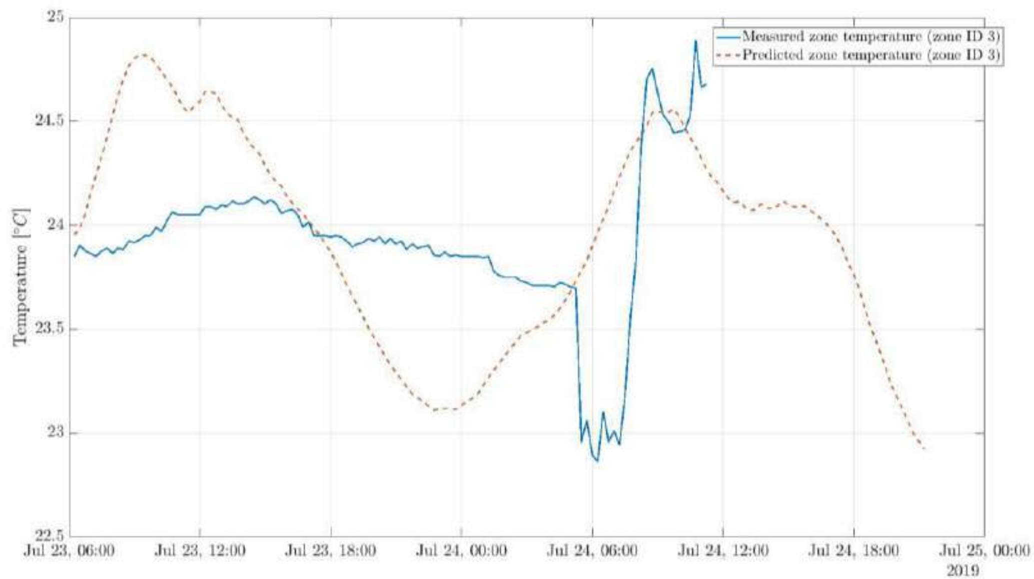


Zone PE 9 – example of historical zone temperature measurements



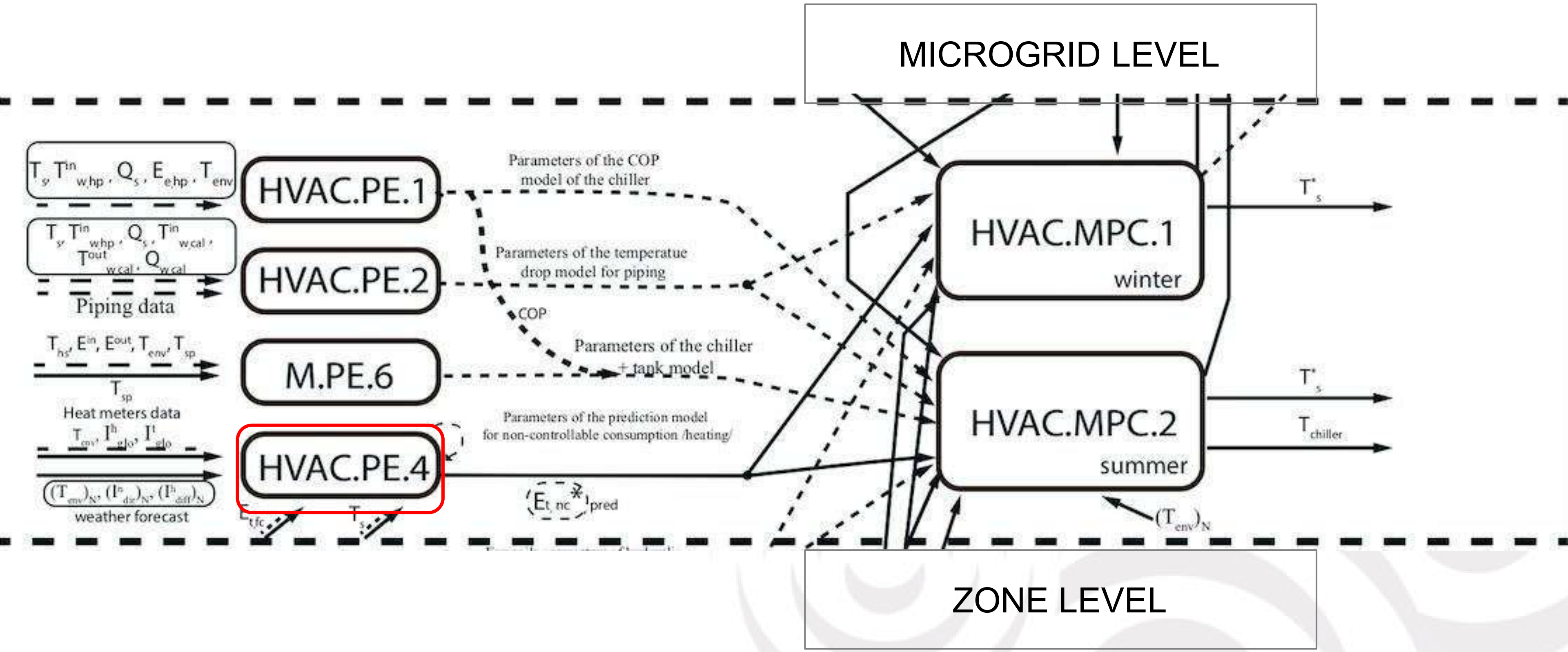
Zone PE 9 – examples of generated predictions





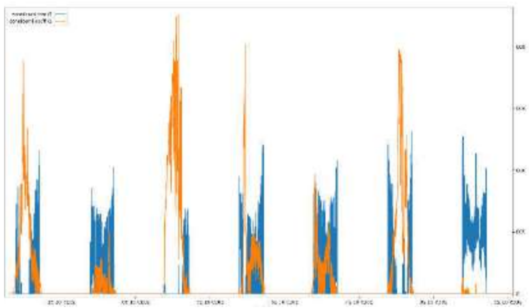
HVAC level

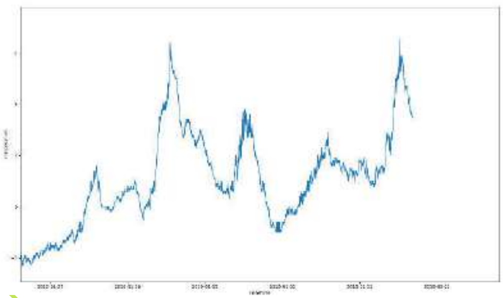
HVAC PE 4
(prediction of non-controlable heat consumption)

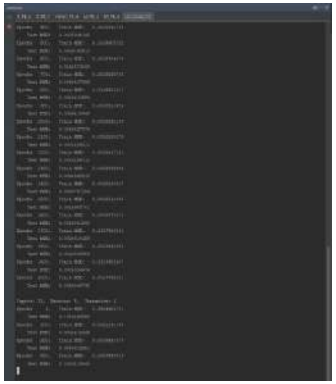


HVAC PE 4 – off-line initialization

Historical **weather measurements**:
- Temperature
- Global, tilted global solar irradiance

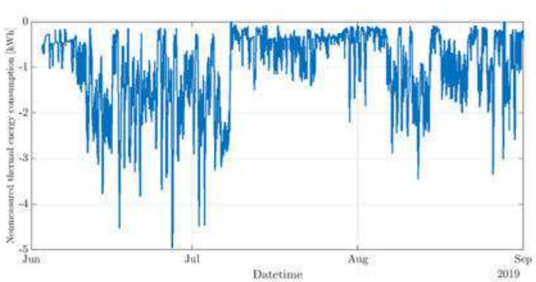


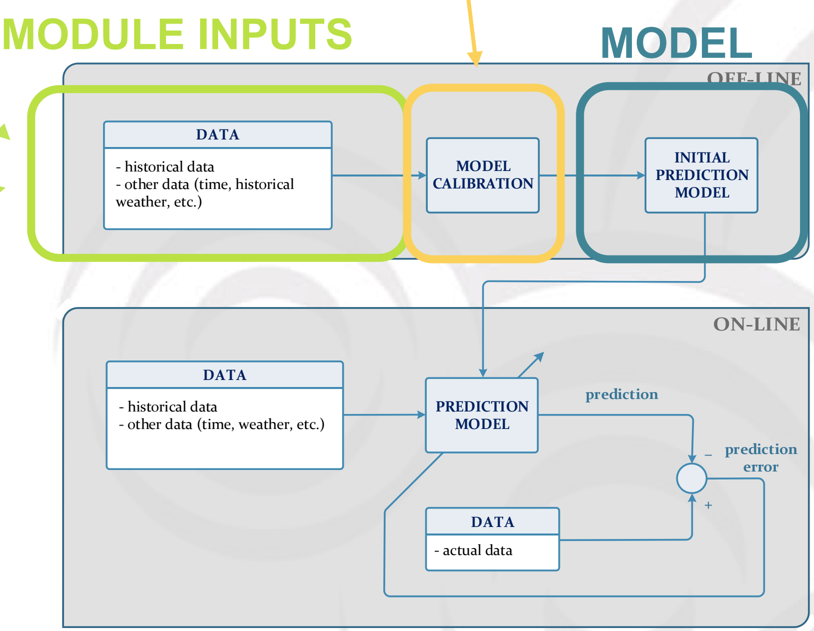




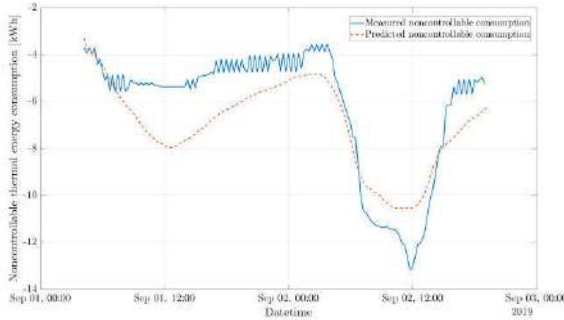
Locally stored: inputsXY_neuronsZ.net

Historical **non-controllable consumption**





HVAC.PE.4 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor constituted of specific historic intervals of data:

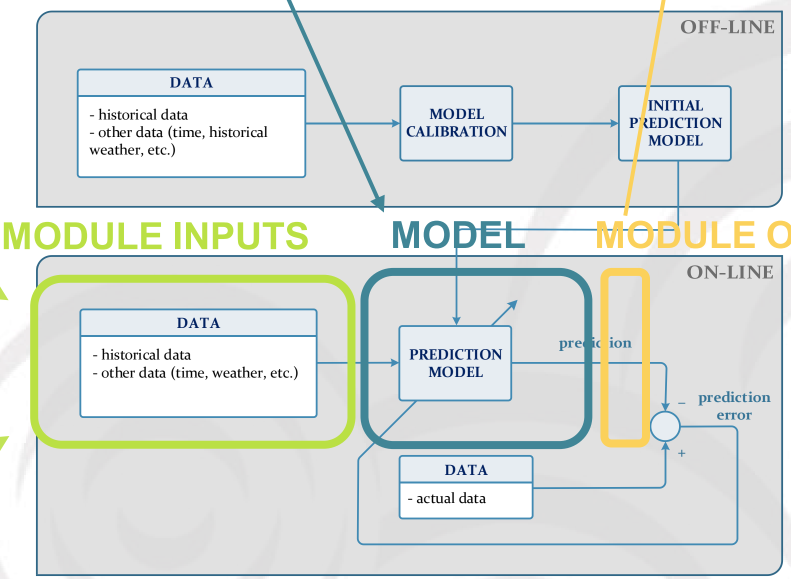
- nonmeasurable_consumption(t-1,…,t-5)
- nonmeasurable_consumption(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

- air_temperature(t-1,…,t-3)
- air_temperature(t-671,…,t-673)

- global irradiance(t-1,…,t-3)
- global irradiance(t-671,…,t-673)

- tilted irradiance(t-1,…,t-3)
- tilted irradiance (t-671,…,t-673)



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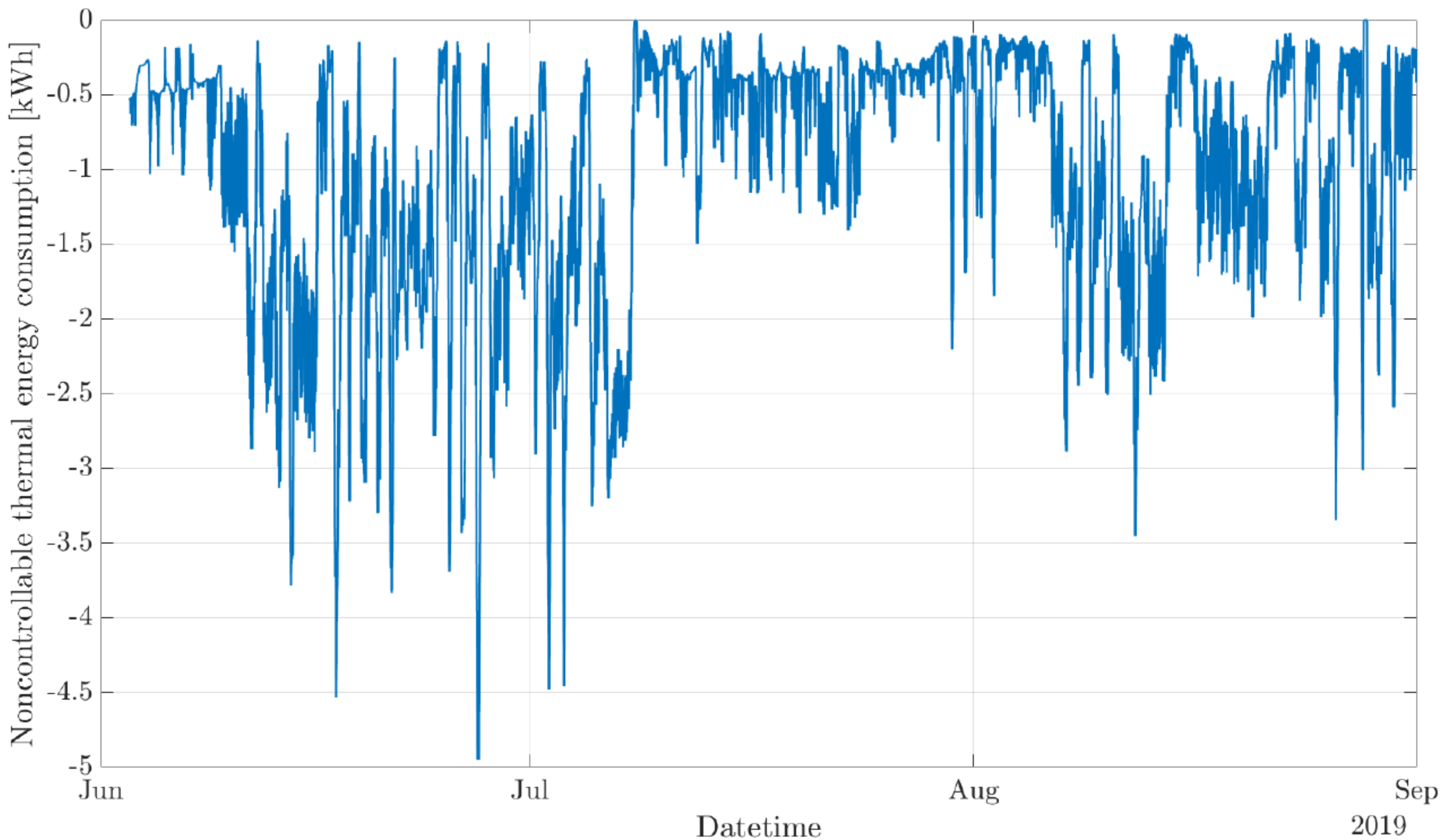
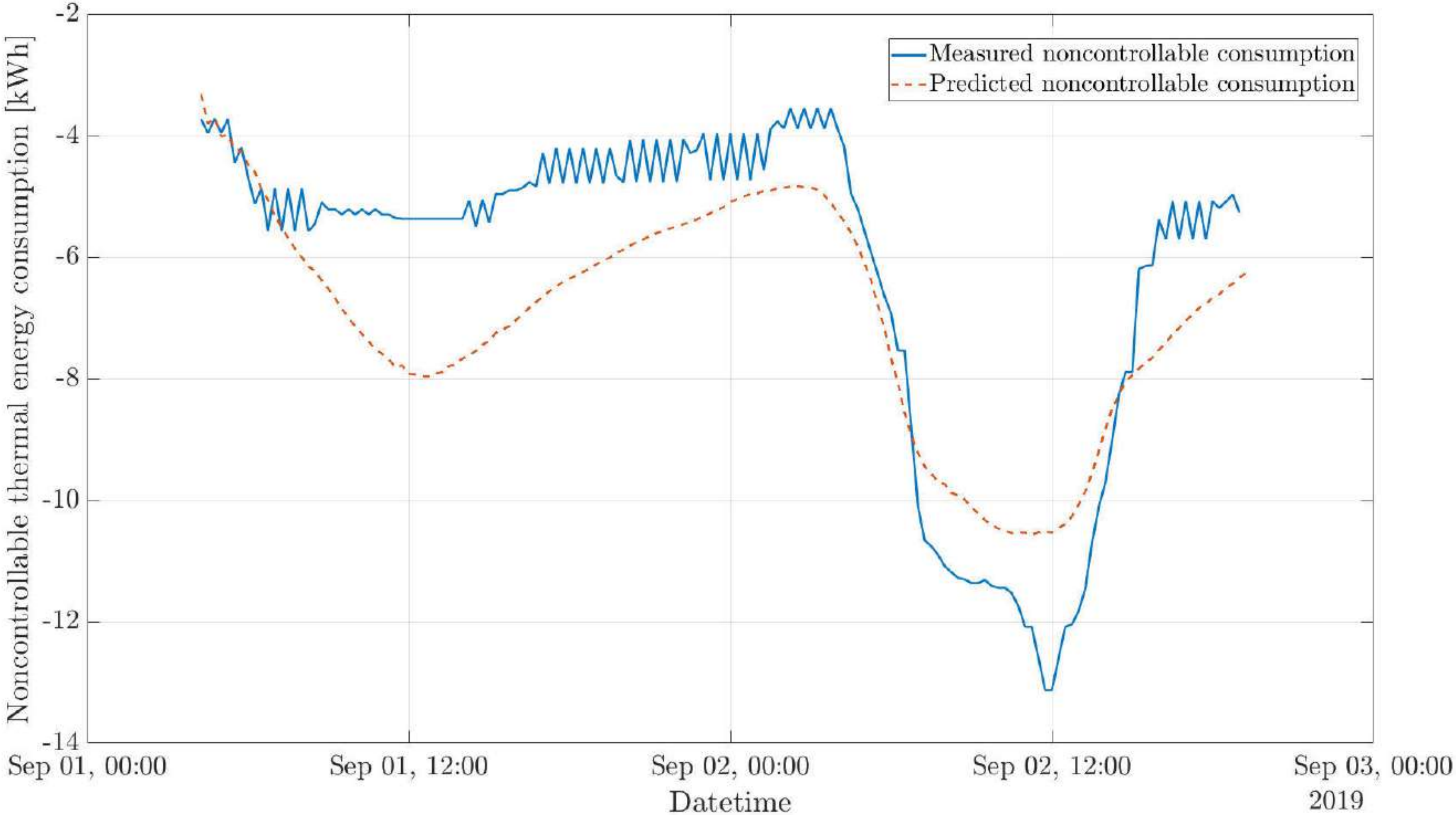
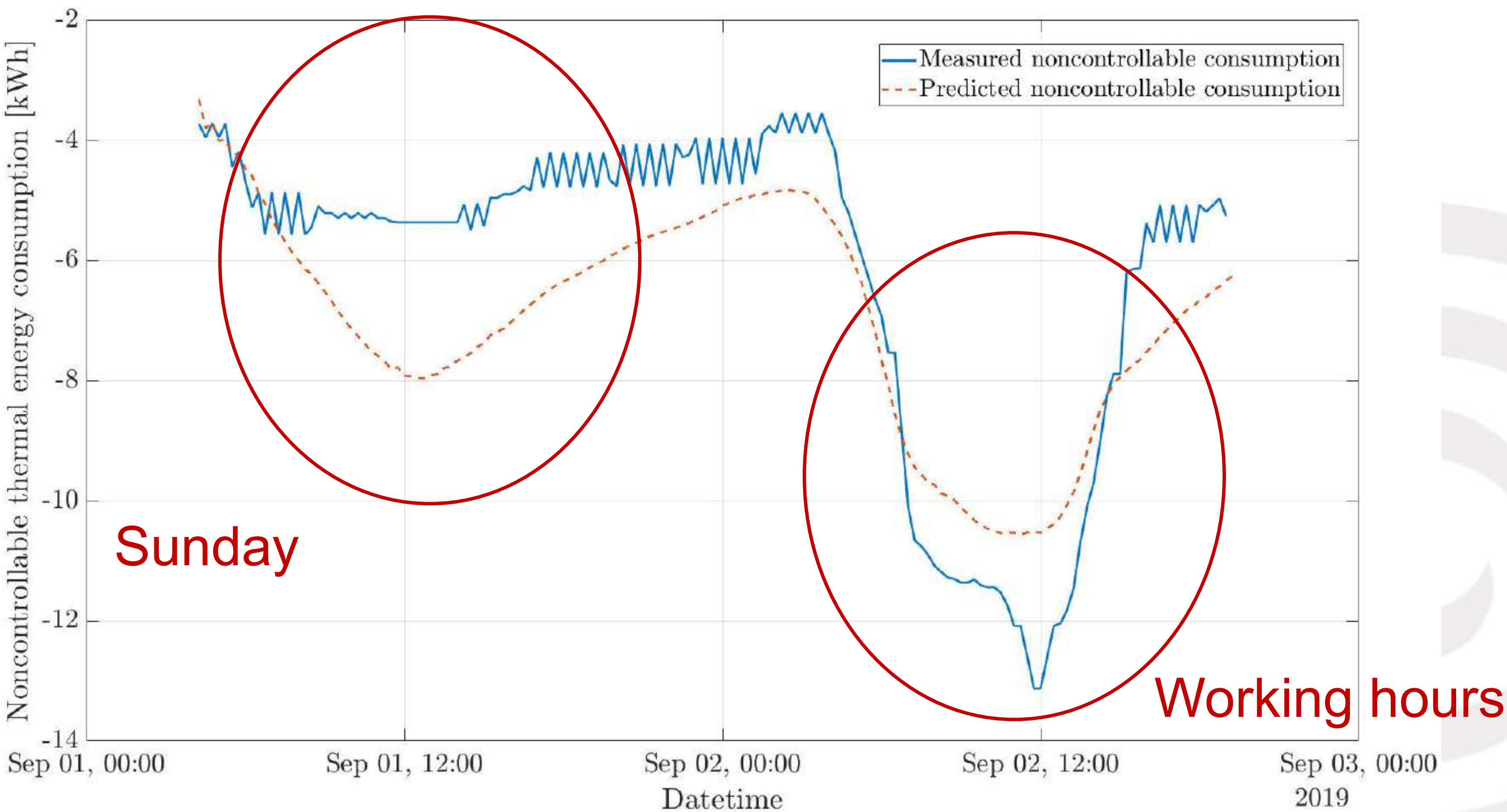
HVAC PE 4 – example of historical consumption



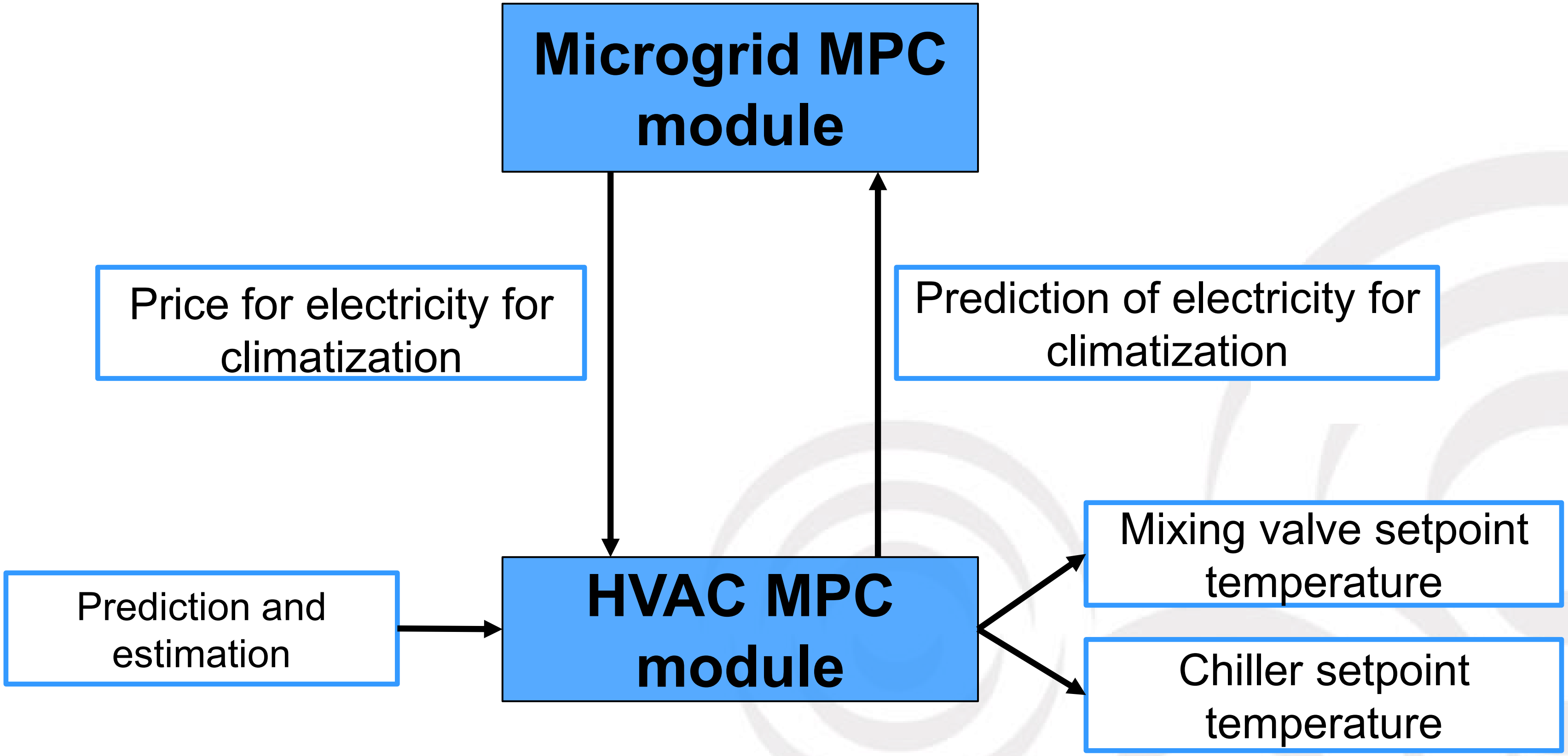
HVAC PE 4 – example of generated prediction



HVAC PE 4 – example of generated prediction

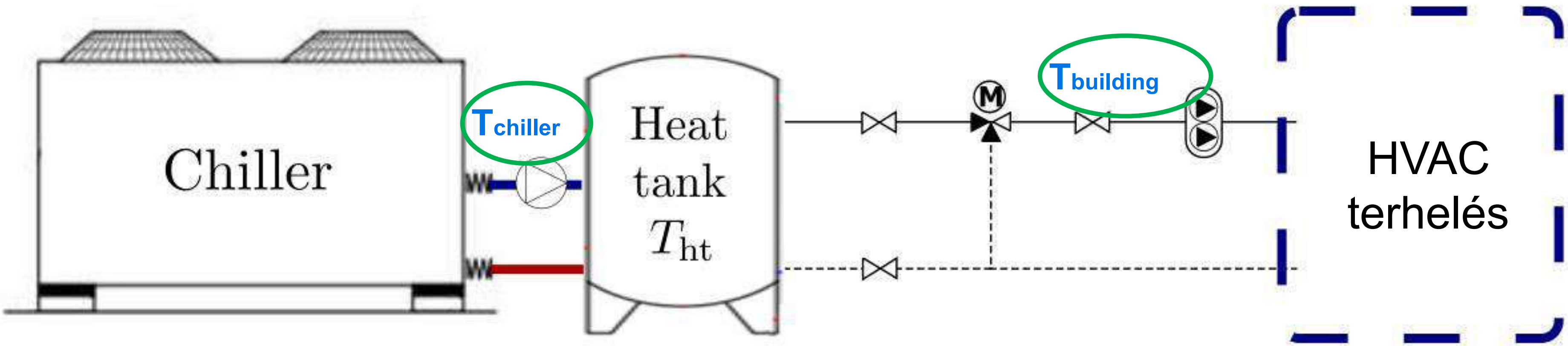


HVAC MPC module



Conceptual scheme of HVAC system at EON

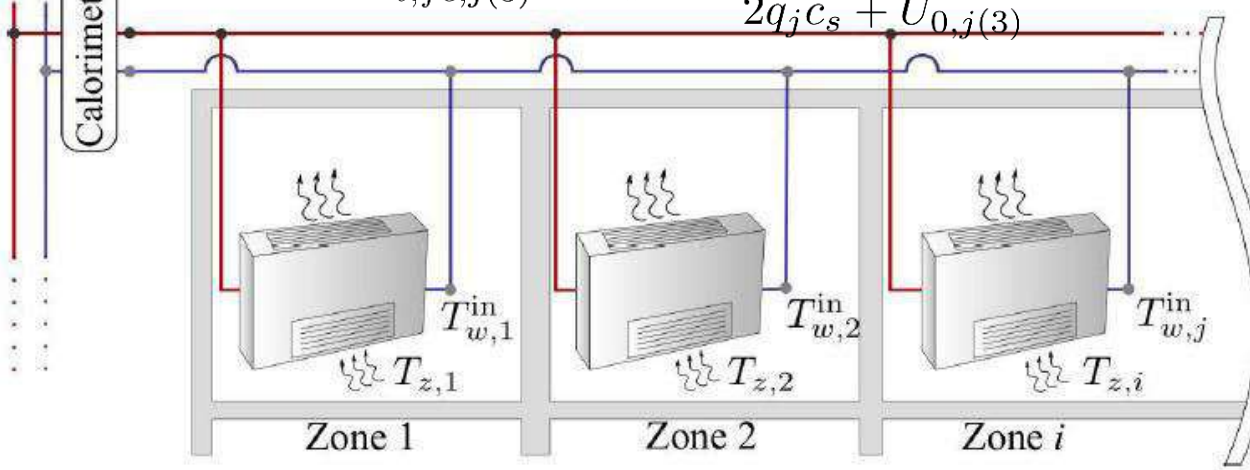
- 4 heating circuits



Submodels of the HVAC system

- COP model of the chiller, $COP(T_o, P_t)$
- Piping heat losses, flows
- Fan coils in zones
- Flows through fan coils
- Temperature model for the medium enterin the fan coil
- Non-controllable load
- Heat tank

$$E_{t,fc,j(3)} = T_d \frac{2q_j c_s U_{0,j(3)}(T^{\text{in}}_{\text{w},j} - T_{z,i})}{2q_j c_s + U_{0,j(3)}}$$



HVAC MPC problem

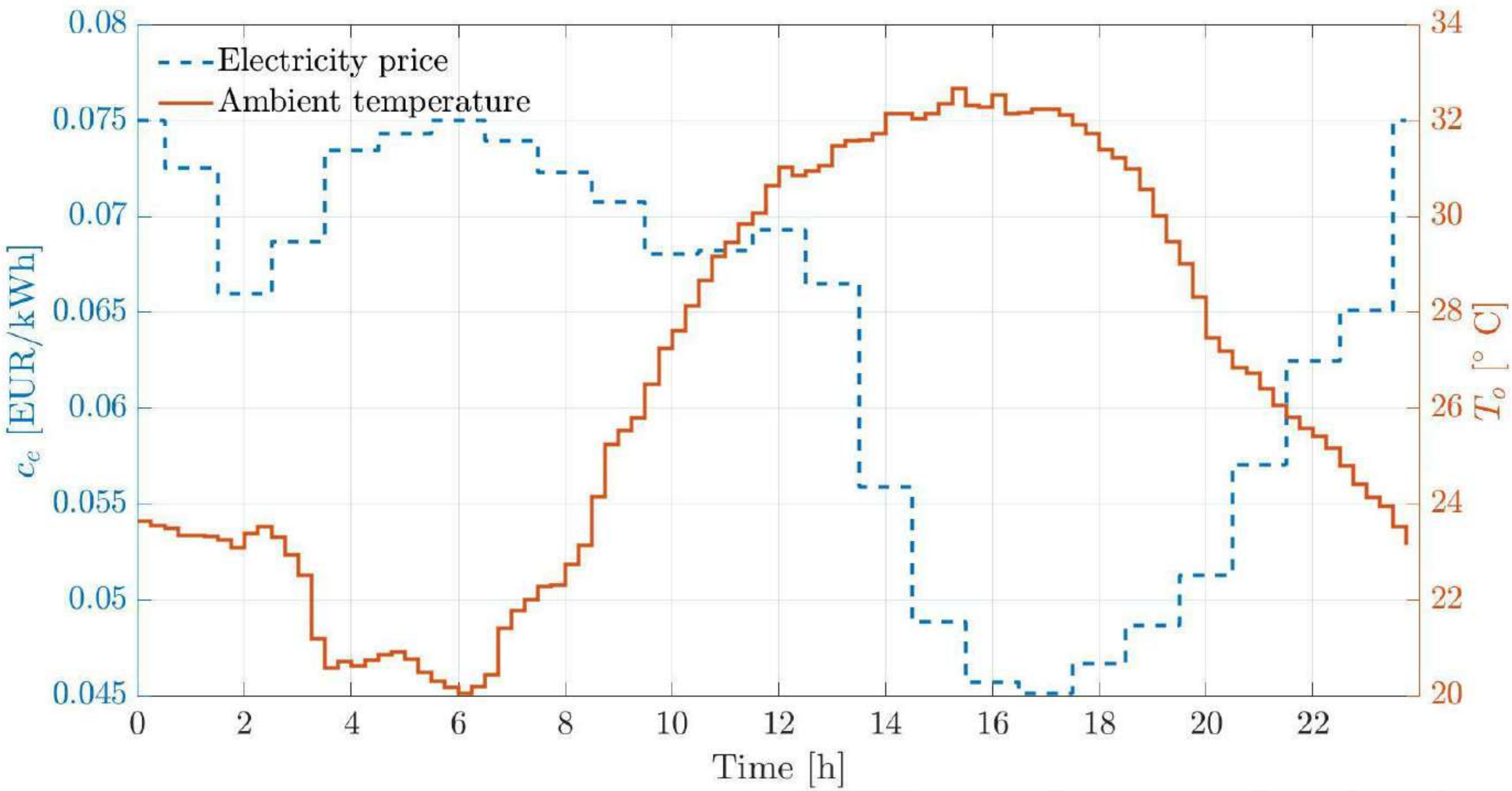
INPUTS: prediction of zones, outdoor temperature etc.	Optimization →	OUTPUTS: prediction of starting temperature and electricity ocnsumption for climatization

- HVAC operation price = price for electricity
- Constraints:
  - starting temperature
  - chillers loading
  - heat requirements in zones
  - electricity consumption

Online HVAC MPC scenario

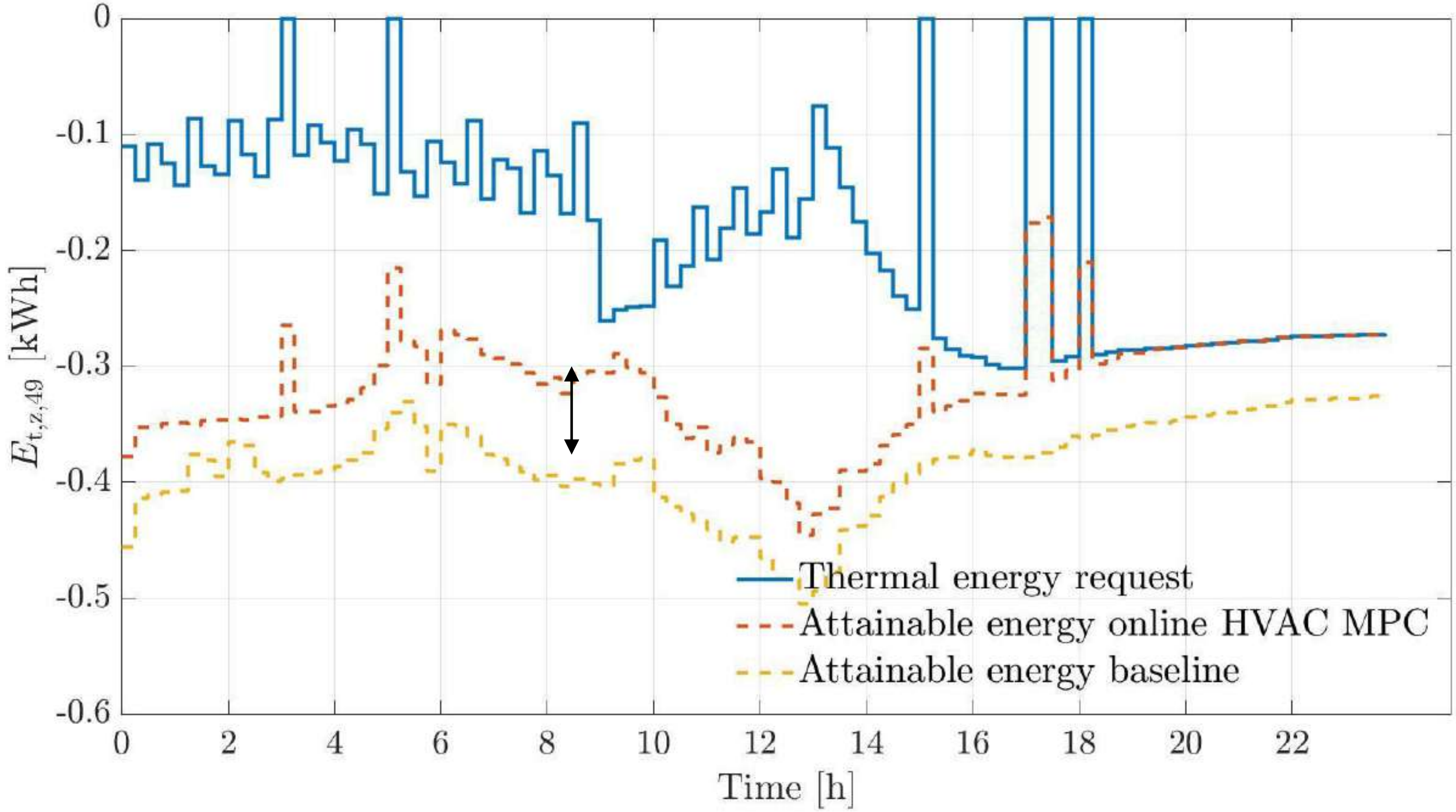
- Comparison with conventioanl controller – fixed starting temperature

HVAC MPC – results of online operation (1)



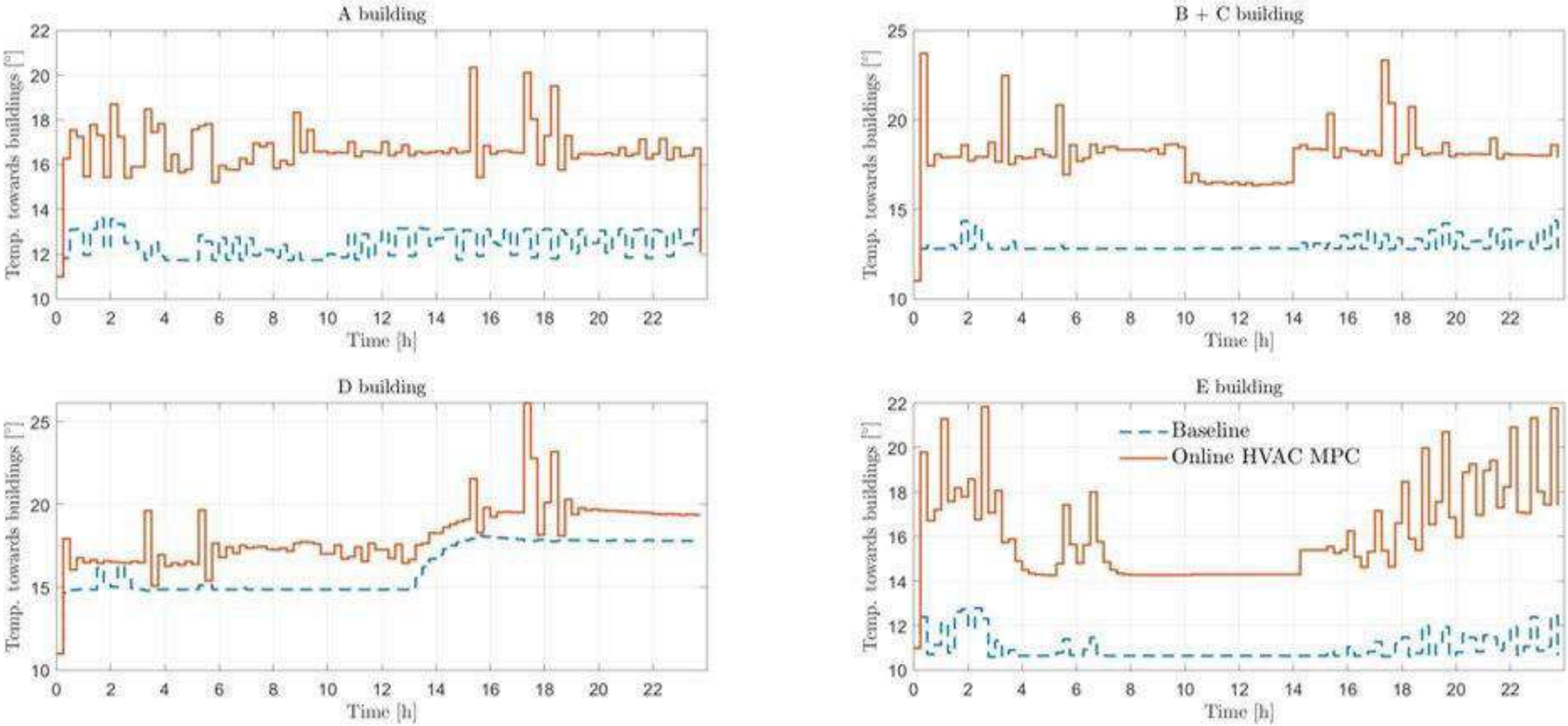
HVAC MPC – results of online operation (2)

- Cooling energy provided by MPC follows the request from the zones



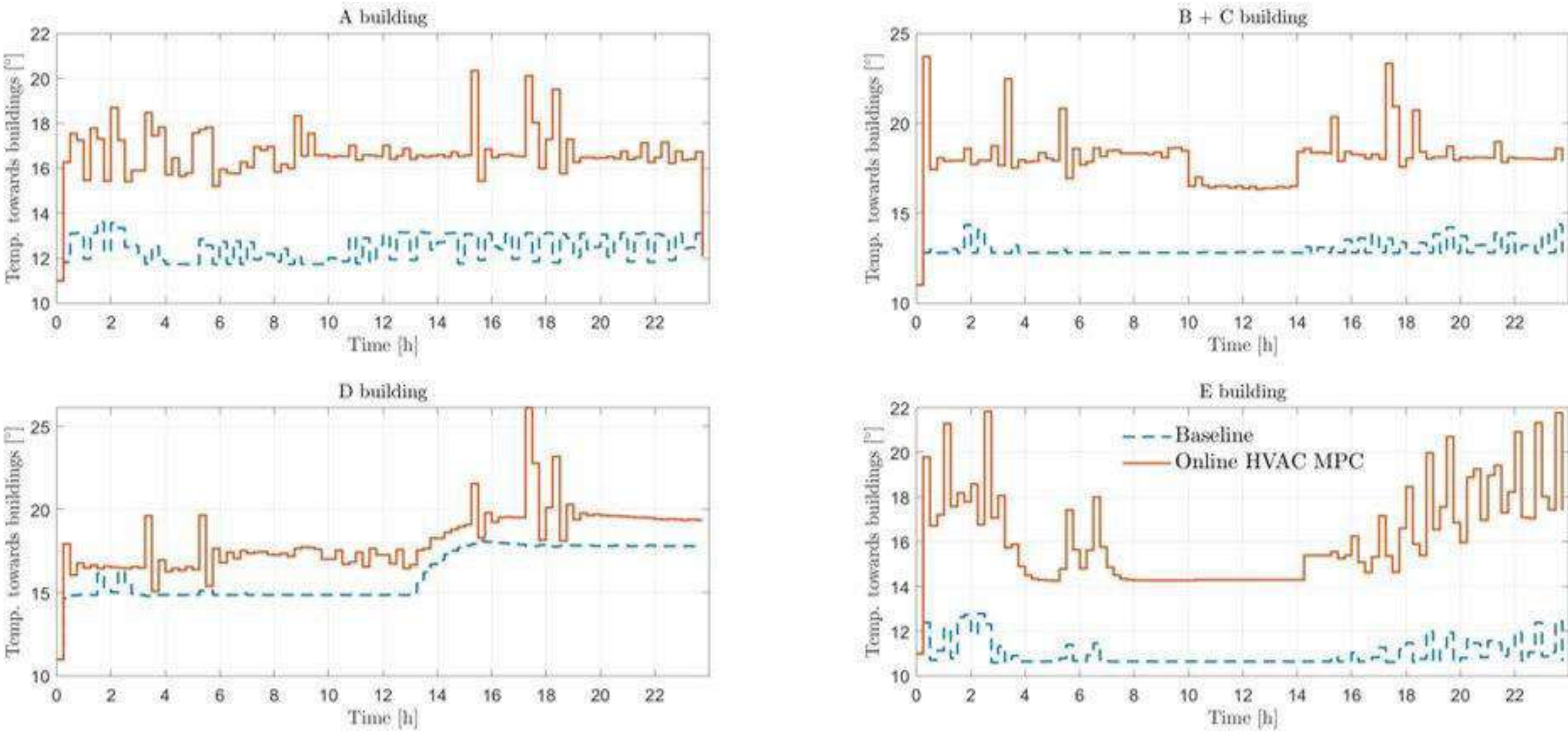
HVAC MPC – results of online operation (3)

- <u>Rise of starting temperature</u> → lowered load



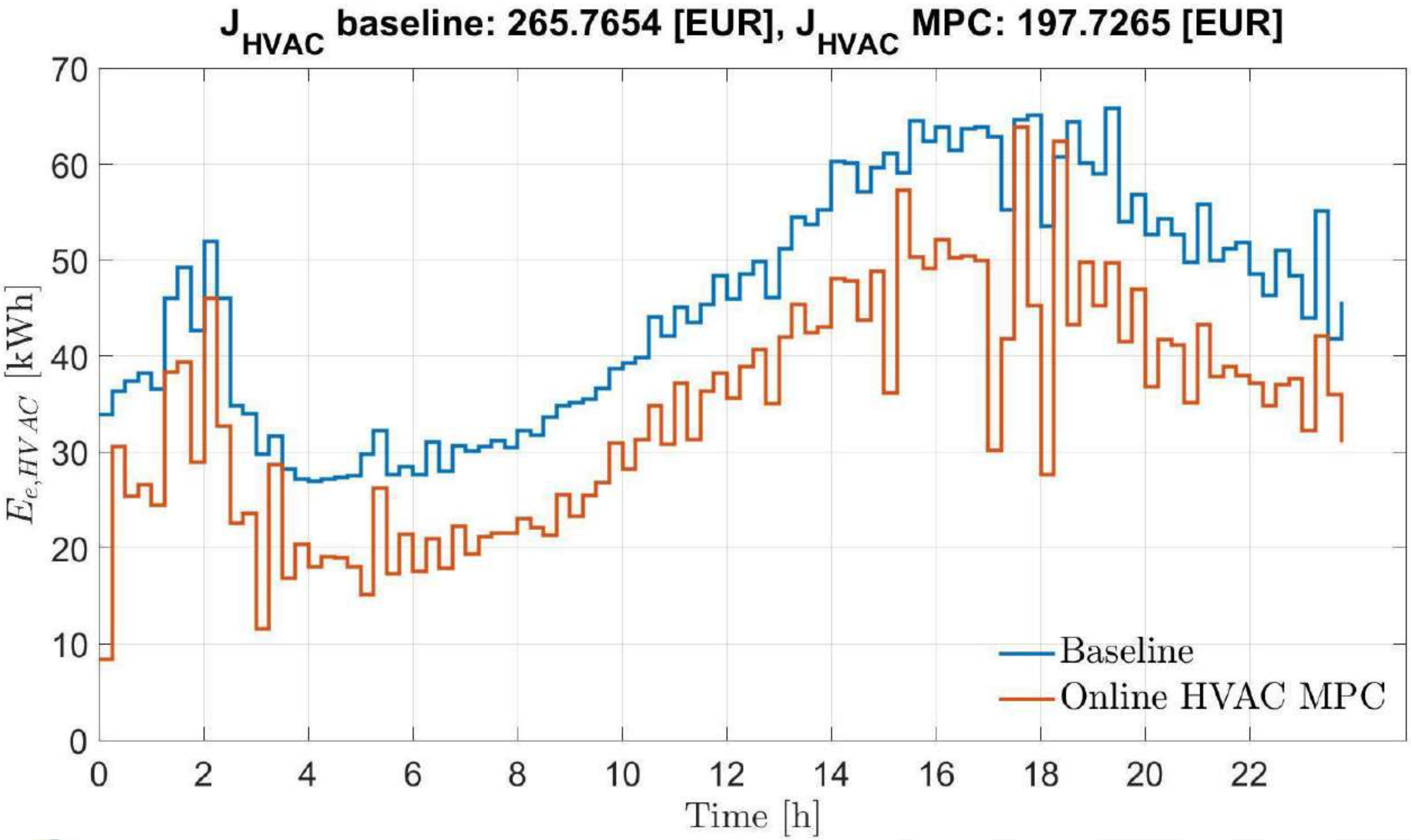
HVAC MPC – results of online operation (4)

- Decline of starting temp. → increased load



HVAC MPC – results of online operation (4)

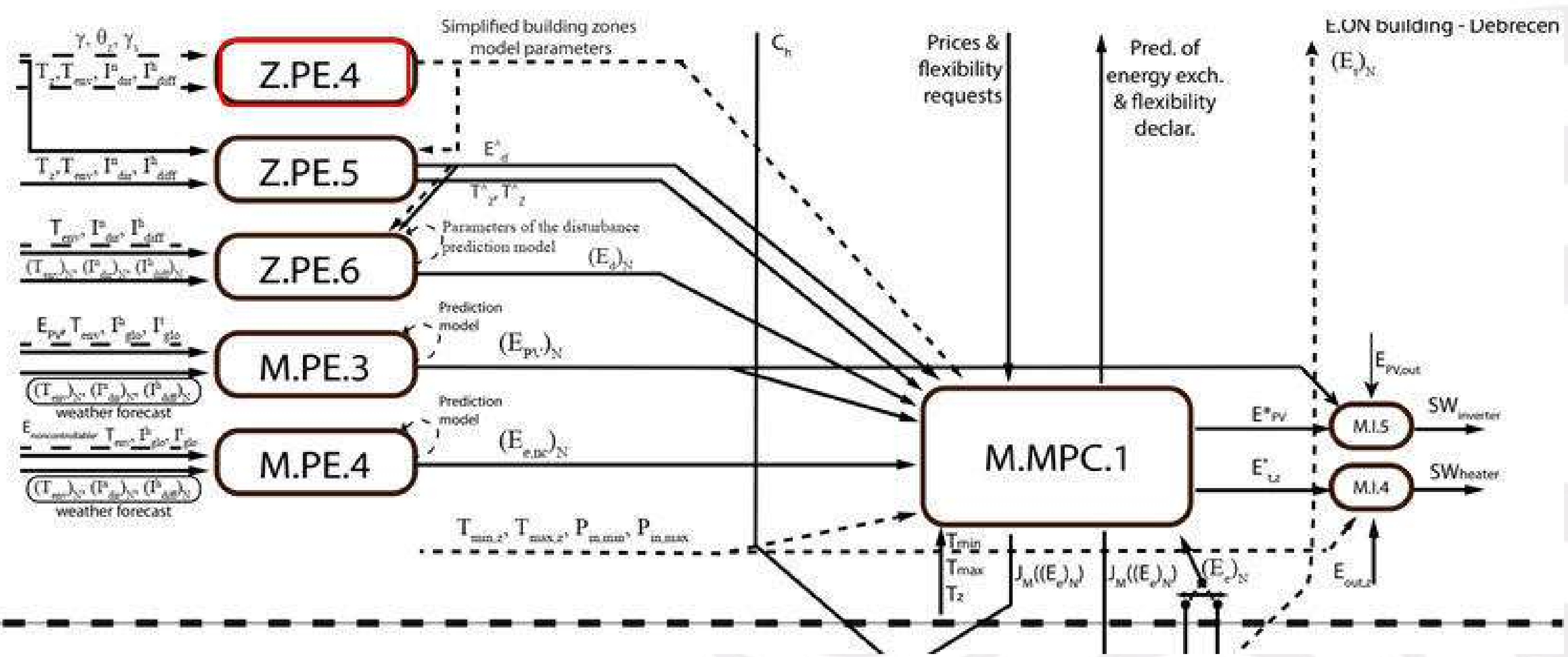
- HVAC MPC effect on consumption -**25%**



Microgrid level

Zone PE 4
(identification of the simplified building thermodynamic model)

Running just once

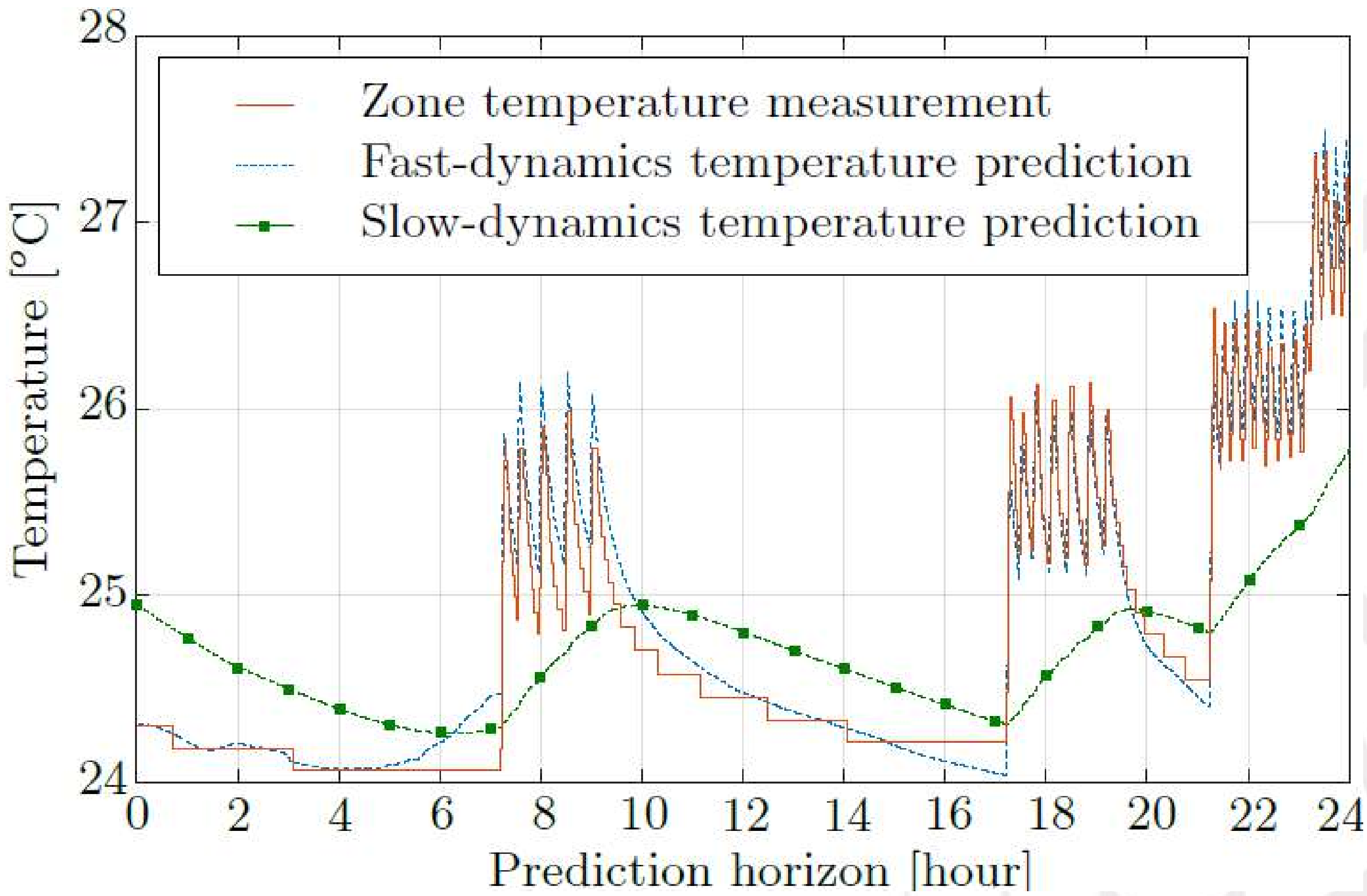


Zone PE 4

(MODULE FOR IDENTIFICATION OF A SIMPLIFIED BUILDING MATHEMATICAL MODEL)

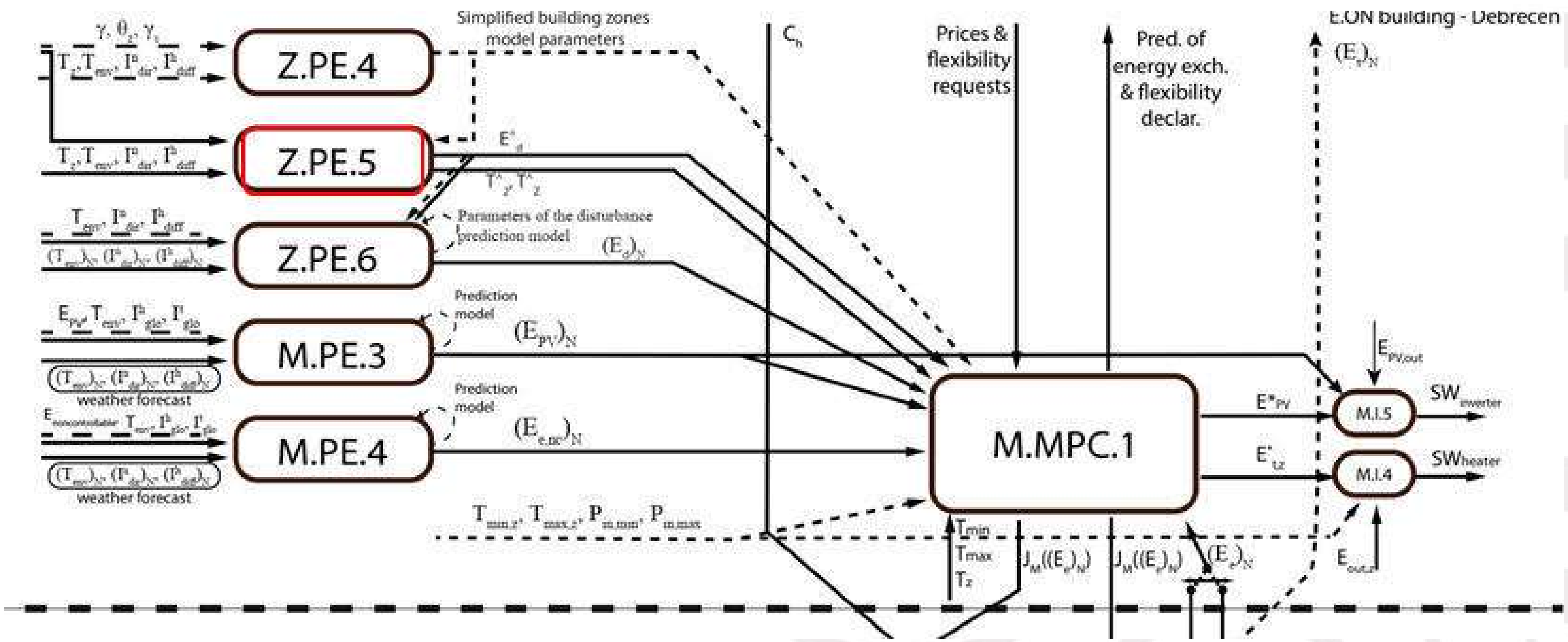
INPUTS: hsitorical temperature measurements, historical outdoor temperature measurements, historical heating power from heating/cooling elements
OUTPUTS: parameters of the building mathematical model

Zone PE 4
(MODULE FOR IDENTIFICATION OF A SIMPLIFIED BUILDING MATHEMATICAL MODEL)



Zone PE 5
(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

Running every 1 min



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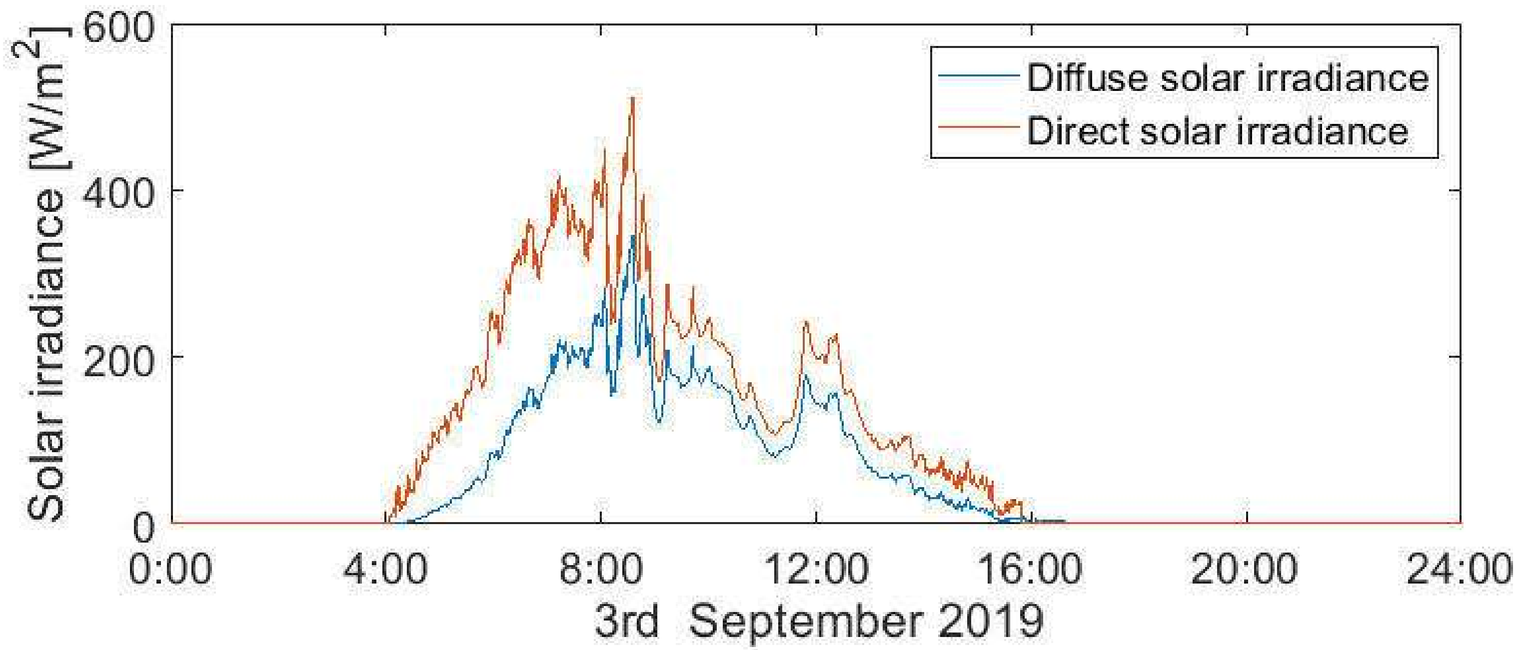
Zone PE 5

(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

INPUT 1: current measurement/estimate of direct and diffuse solar irradiance

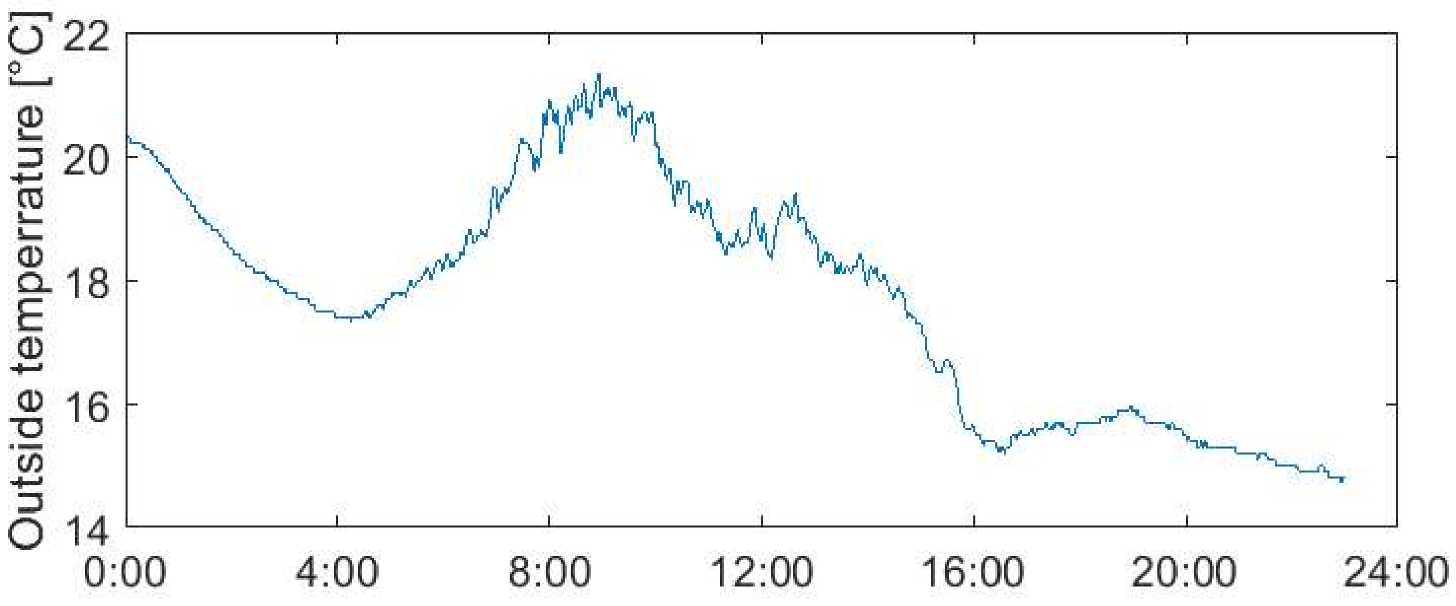


Zone PE 5

(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

INPUT 1: current measurement/estimate of direct and diffuse solar irradiance

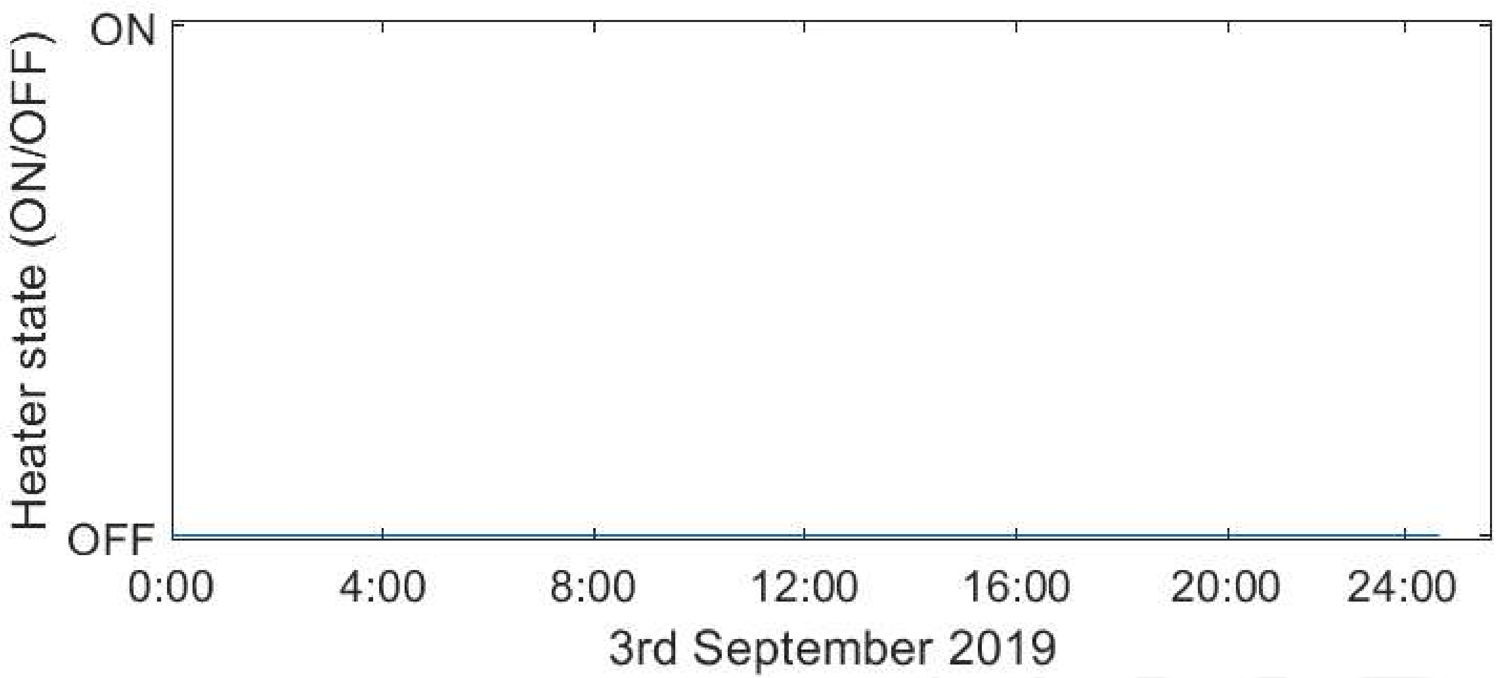
INPUT 2: current measurement of outdoor temperature



Zone PE 5

(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

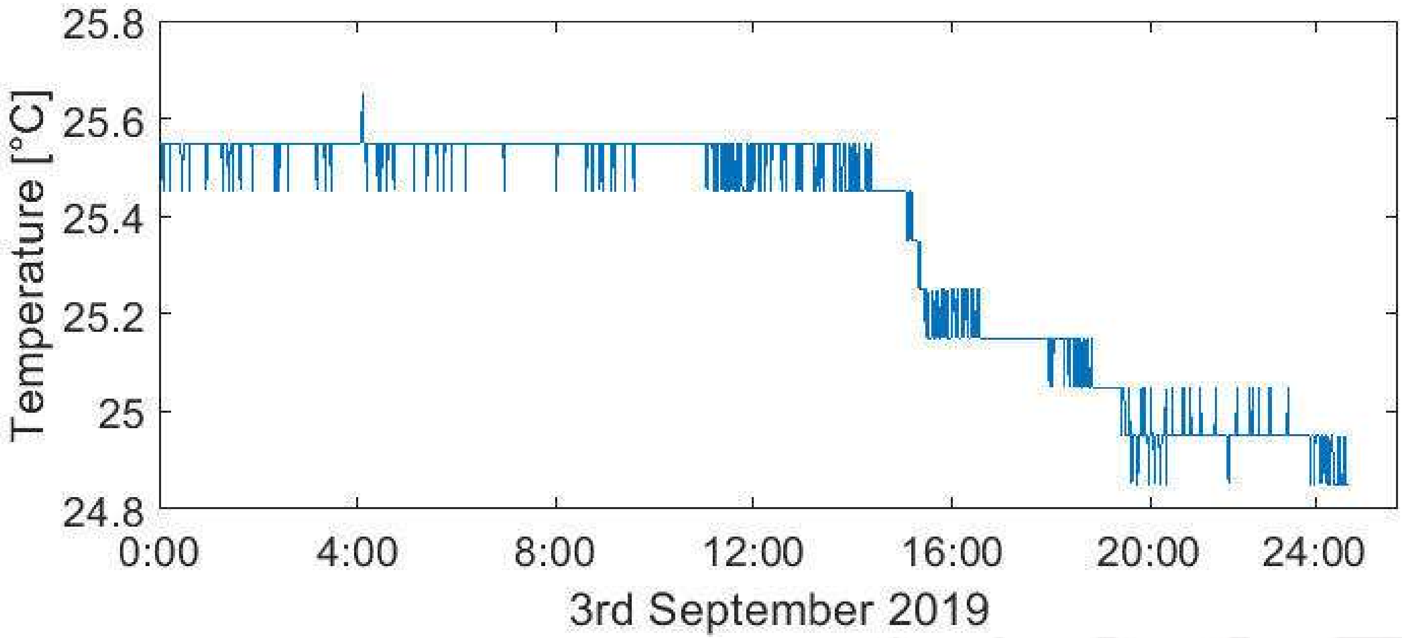
INPUT 1: current measurement/estimate of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature
INPUT 3: current state of heating/cooling elements



Zone PE 5

(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

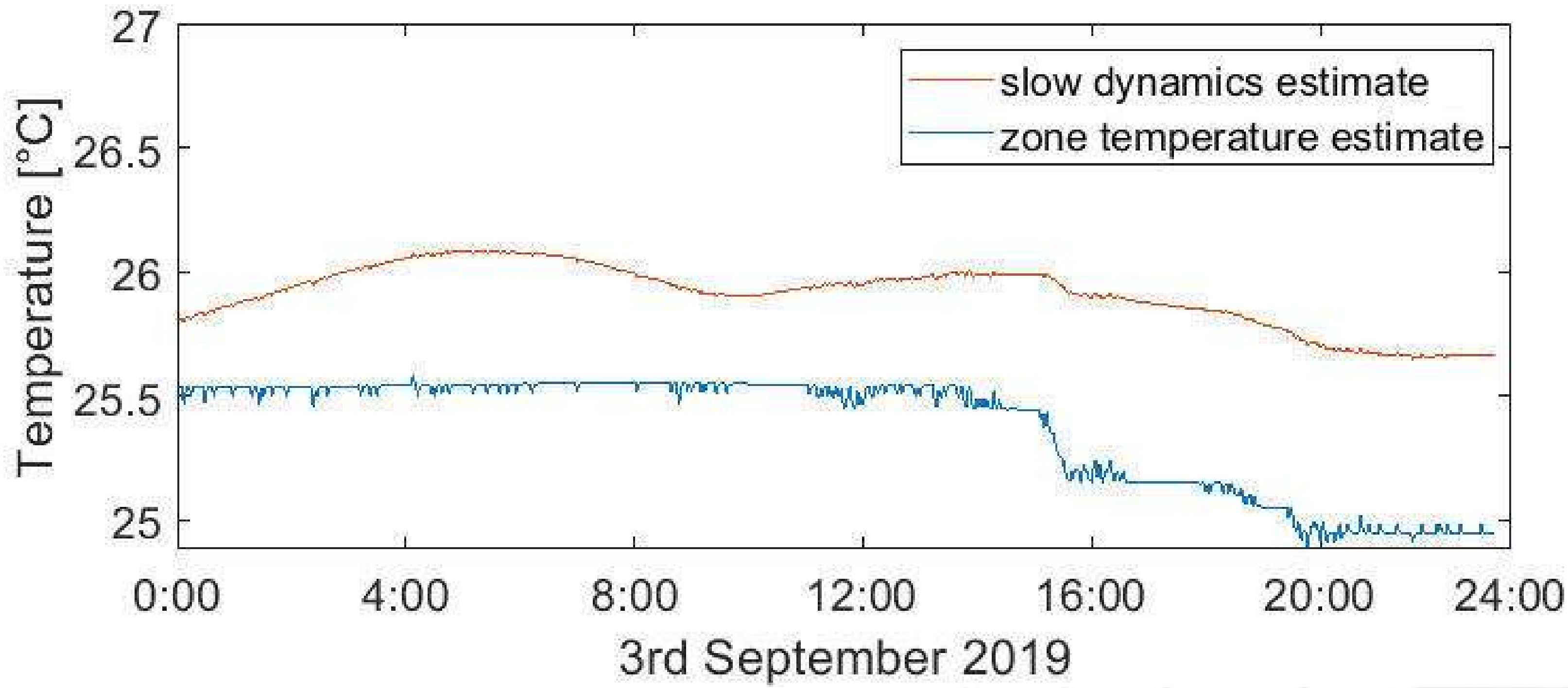
INPUT 1: current measurement/estimate of direct and diffuse solar irradiance
INPUT 2: current measurement of outdoor temperature
INPUT 3: current state of heating/cooling elements
INPUT 4: current measurement of zone temperature



Zone PE 5

(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

OUTPUT 1: Estimated current slow dynamics temperature

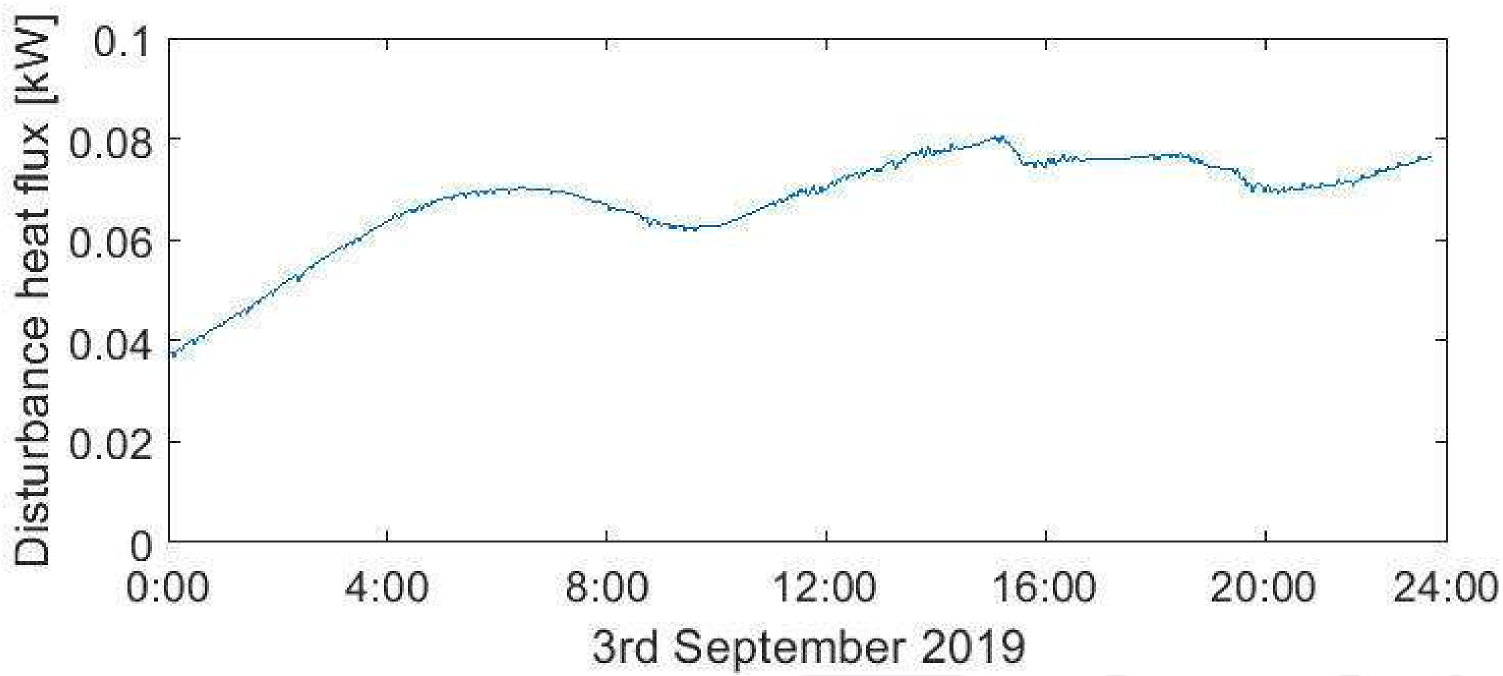


Zone PE 5

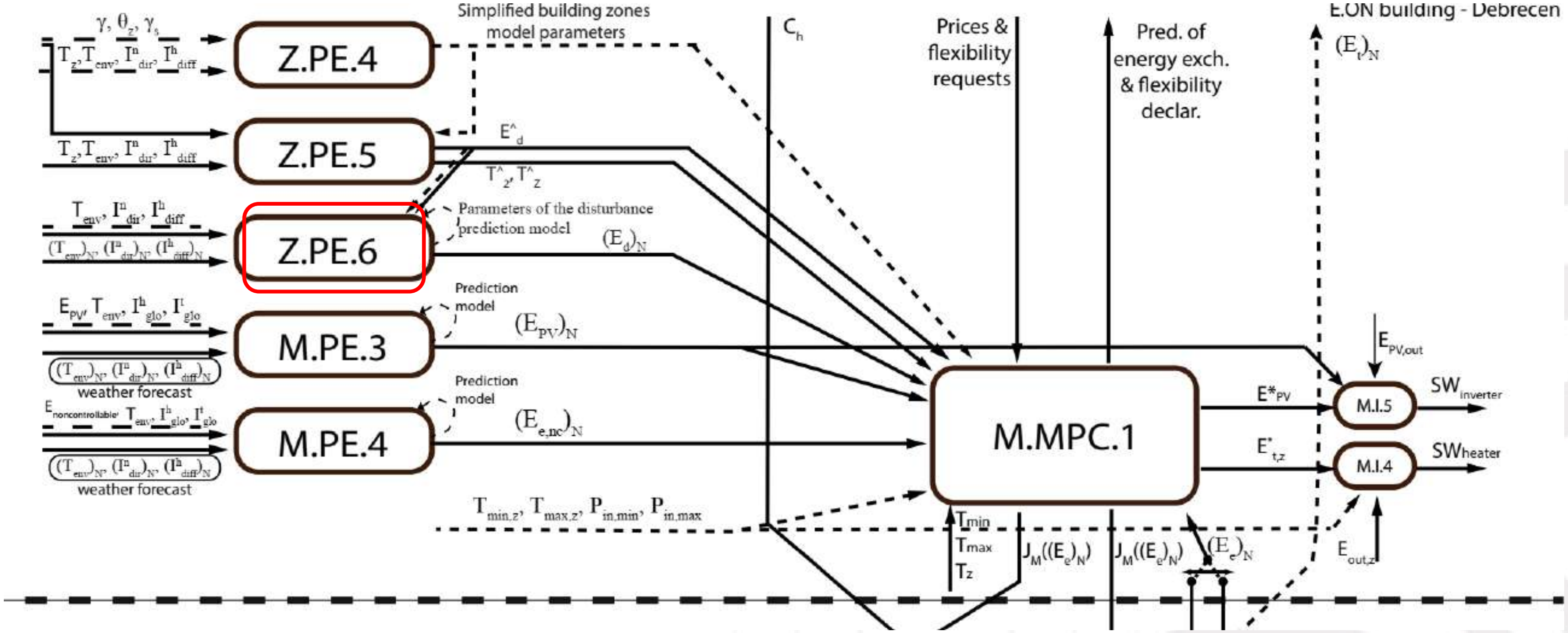
(MODULE FOR ESTIMATION OF NONMEASURABLE STATES OF THE BUILDING MODEL AND THE HEAT DISTURBANCES IN BUILDING ZONES)

OUTPUT 1: Estimated current slow dynamics temperature

OUTPUT 2: Estimated current heat distrubance value

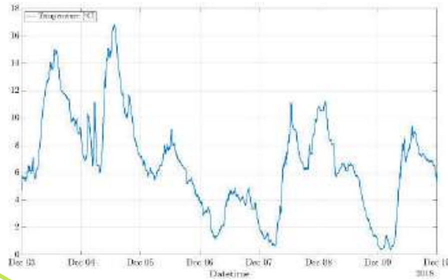


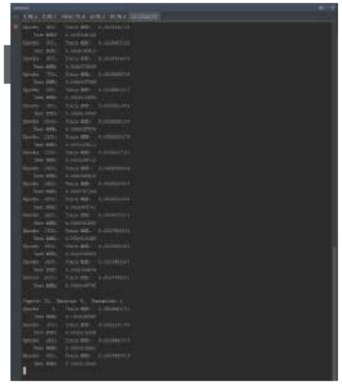
Zone PE 6
(prediction of heat distrubances in zones)

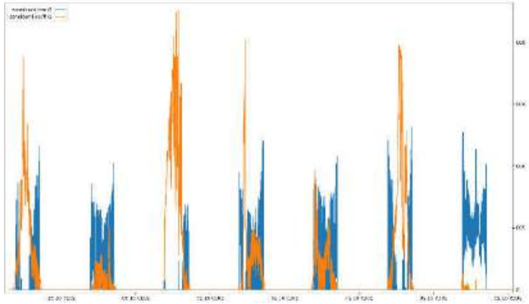


Zone PE 6 – off-line initialization

Historical meteorological measurements:
- Air temperature
- Global and tilted solar irradiance



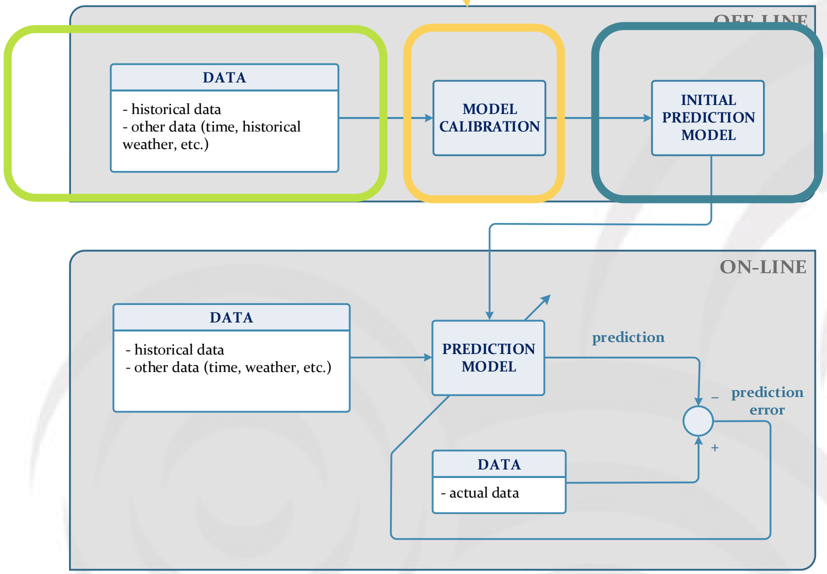




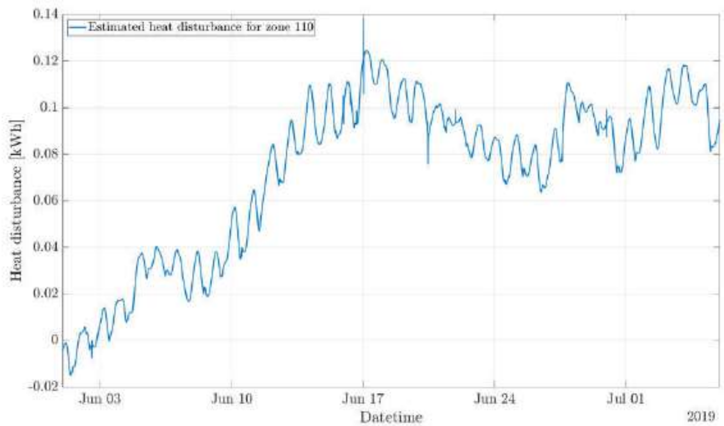
Locally stored: inputsXY_neuronsZ.net

MODULE INPUTS

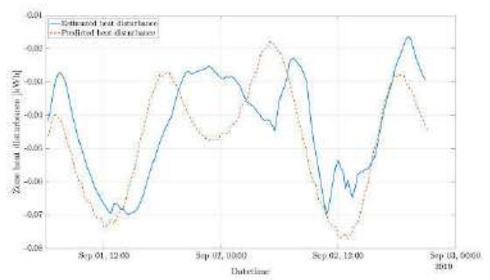
MODEL



Historical values of estimated heat disturbance **(Z.PE.5)**



Zone PE 6 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

Regressor constituted of specific historic intervals of data:

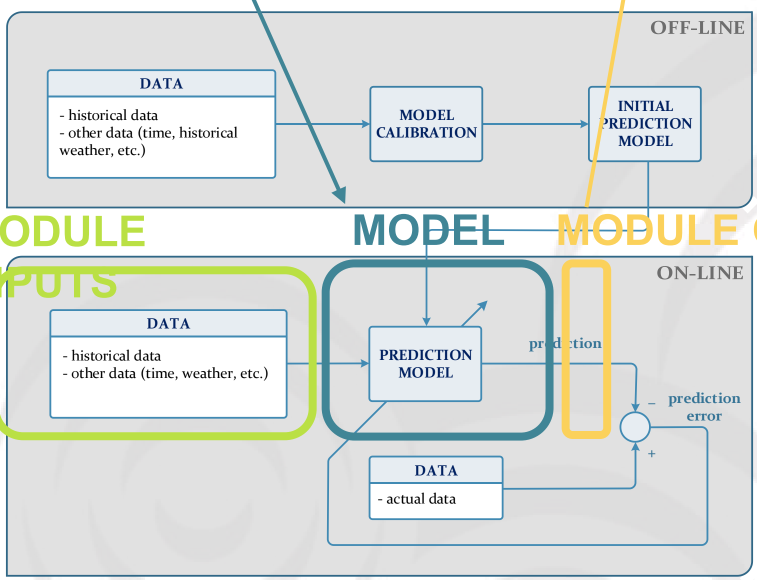
- heat disturbance(t-1,…,t-5)
- heat disturbance(t-670,…,t-674)

- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

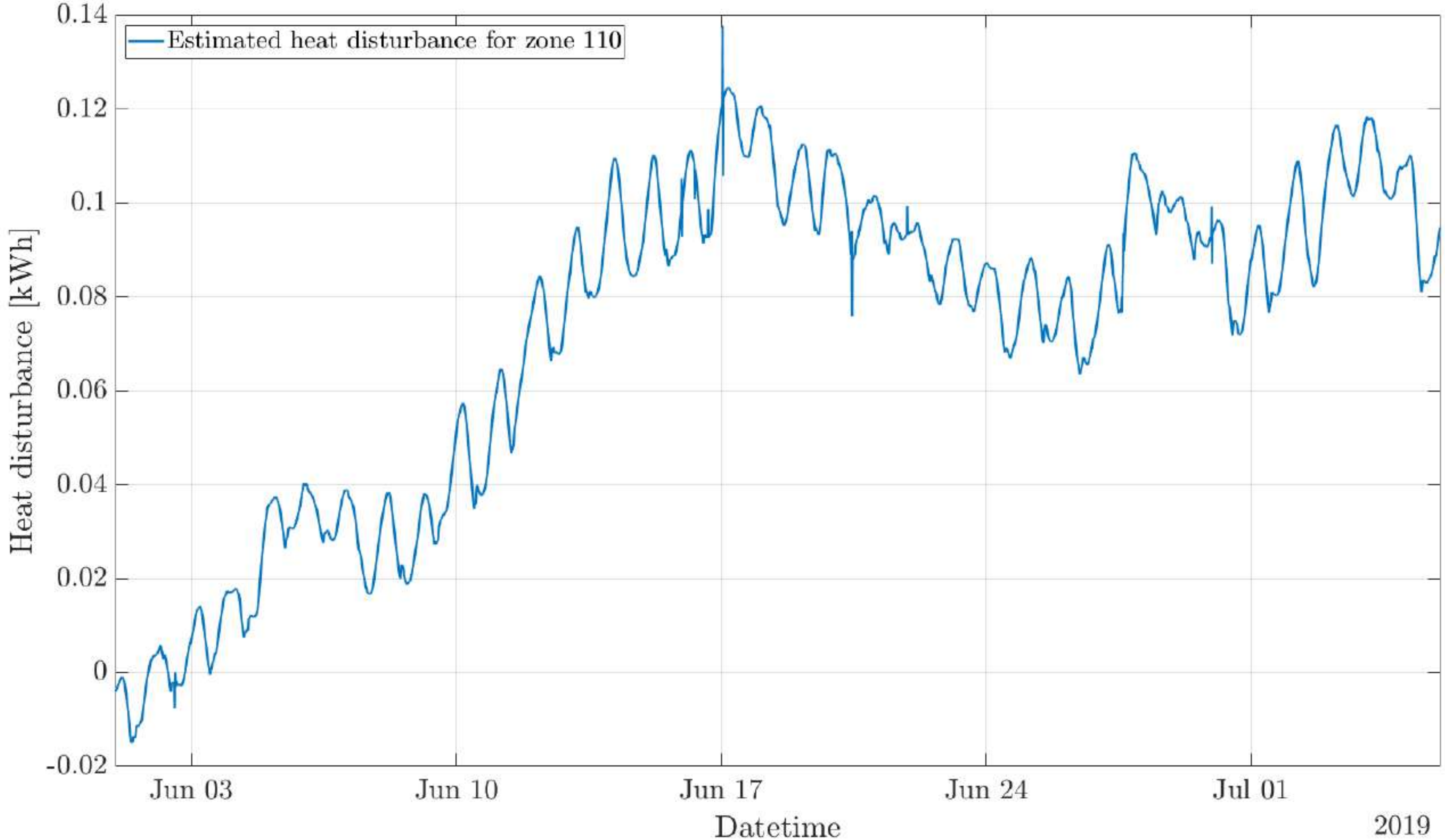
- air temperature(t-1,…,t-3)
- air temperature(t-671,…,t-673)

- global irradiance(t-1,…,t-3)
- global irradiance(t-671,…,t-673)

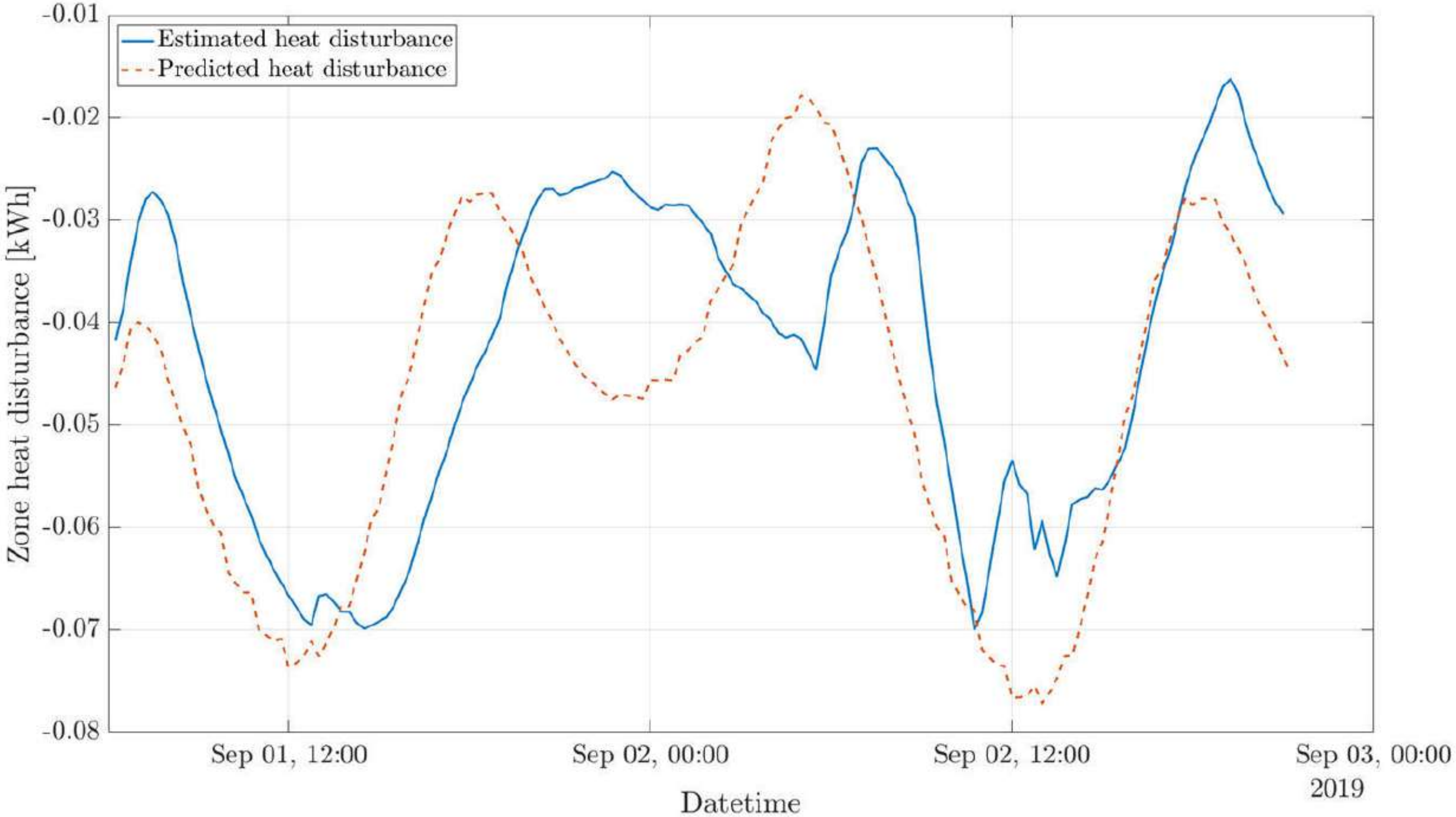
- tilted irradiance(t-1,…,t-3)
- tilted irradiance (t-671,…,t-673)



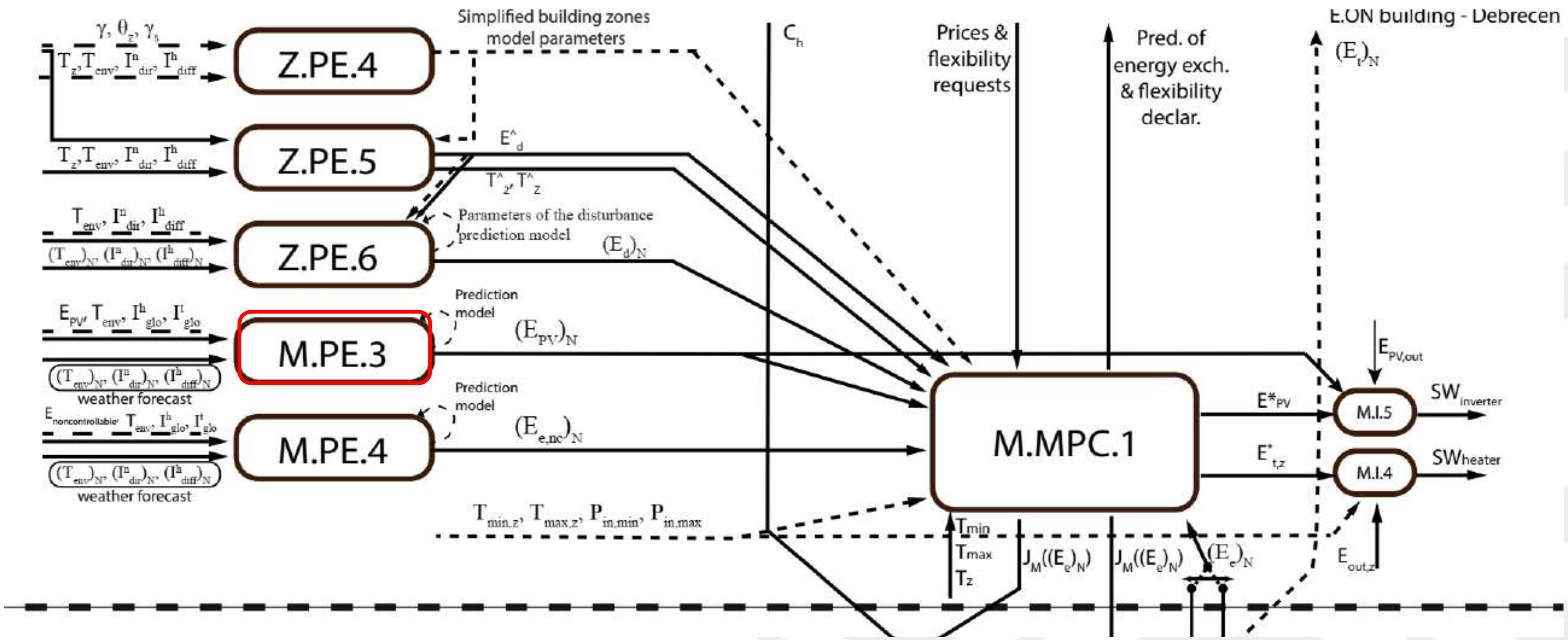
Zone PE 6 – example of historical values



Zone PE 6 – example of generated prediction



M PE 3
(prediction of maximum available photovltaic system production)



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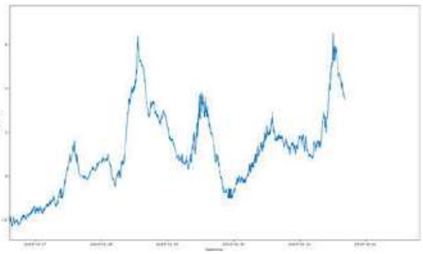
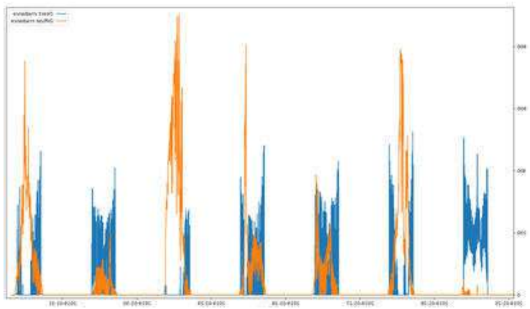
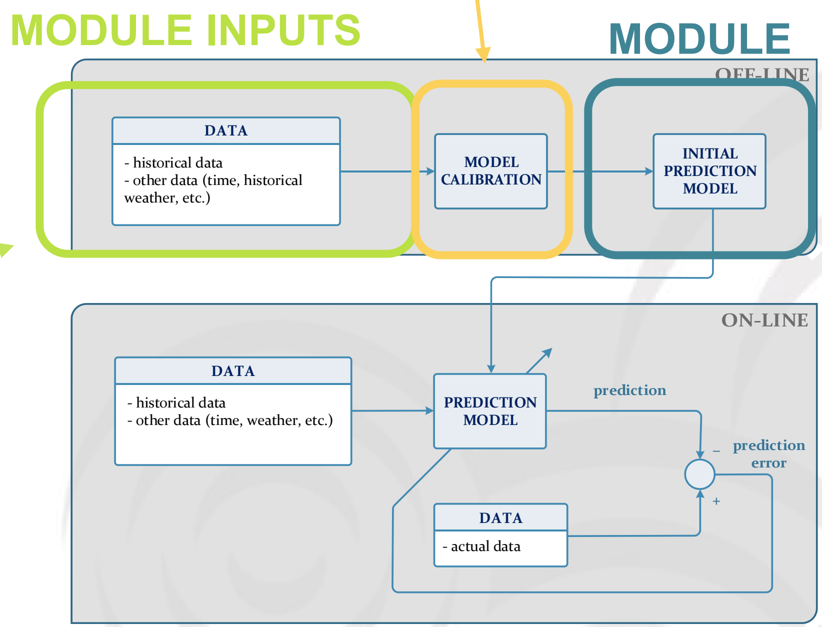
M PE 3 – off-line initialization



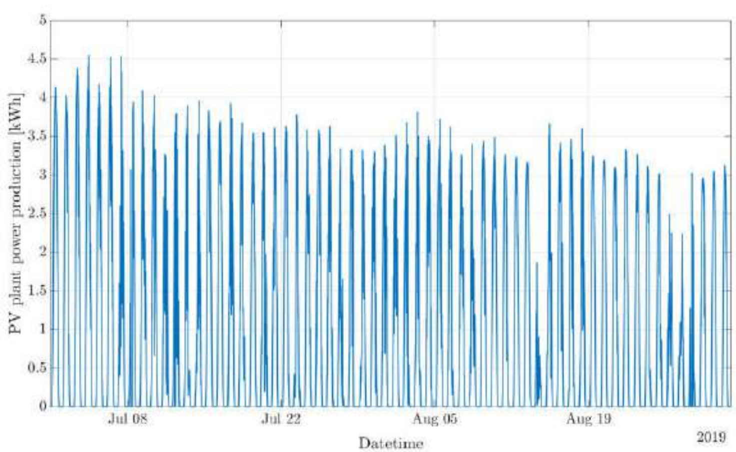
Historical **weather measurements**:
- Temperature
- Direct, diffuse solar irradiance
- Solar zenith and azimuth



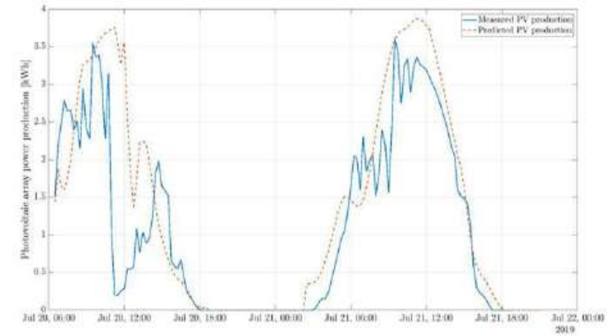
Locally stored: inputsXY_neuronsZ.net



Historical **PV production data**



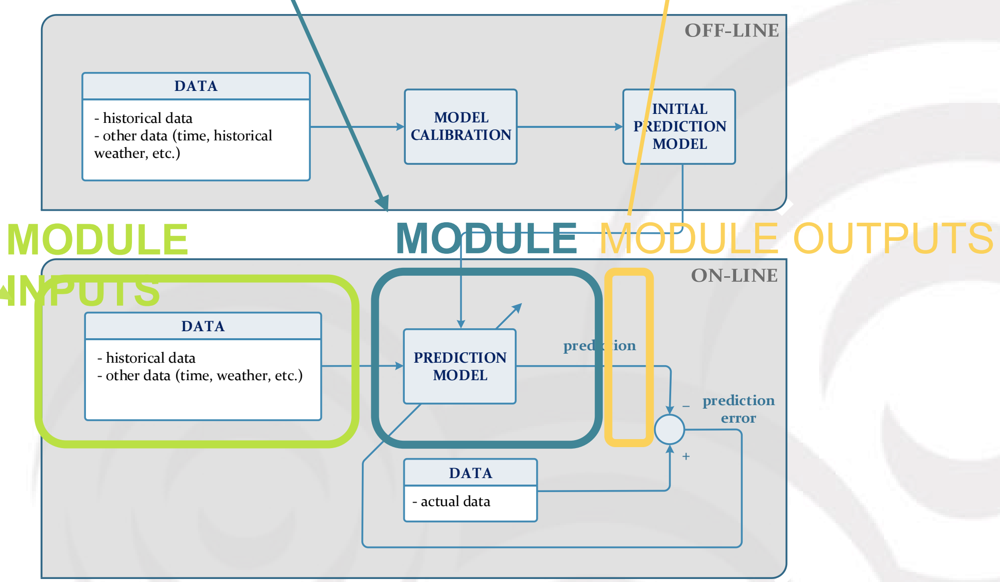
M PE 3 – on-line operation



Regressor created from specific historical intervals of data:

- solar_zenith(t-1,…,t-3)
- solar_azimuth(t-1,…,t-3)
- temperature(t-1,…,t-3)
- direct irradiance(t-1,…,t-3)
- diffuse irradiance(t-1,…,t-3)

Locally stored:
inputsXY_neuronsZ.net



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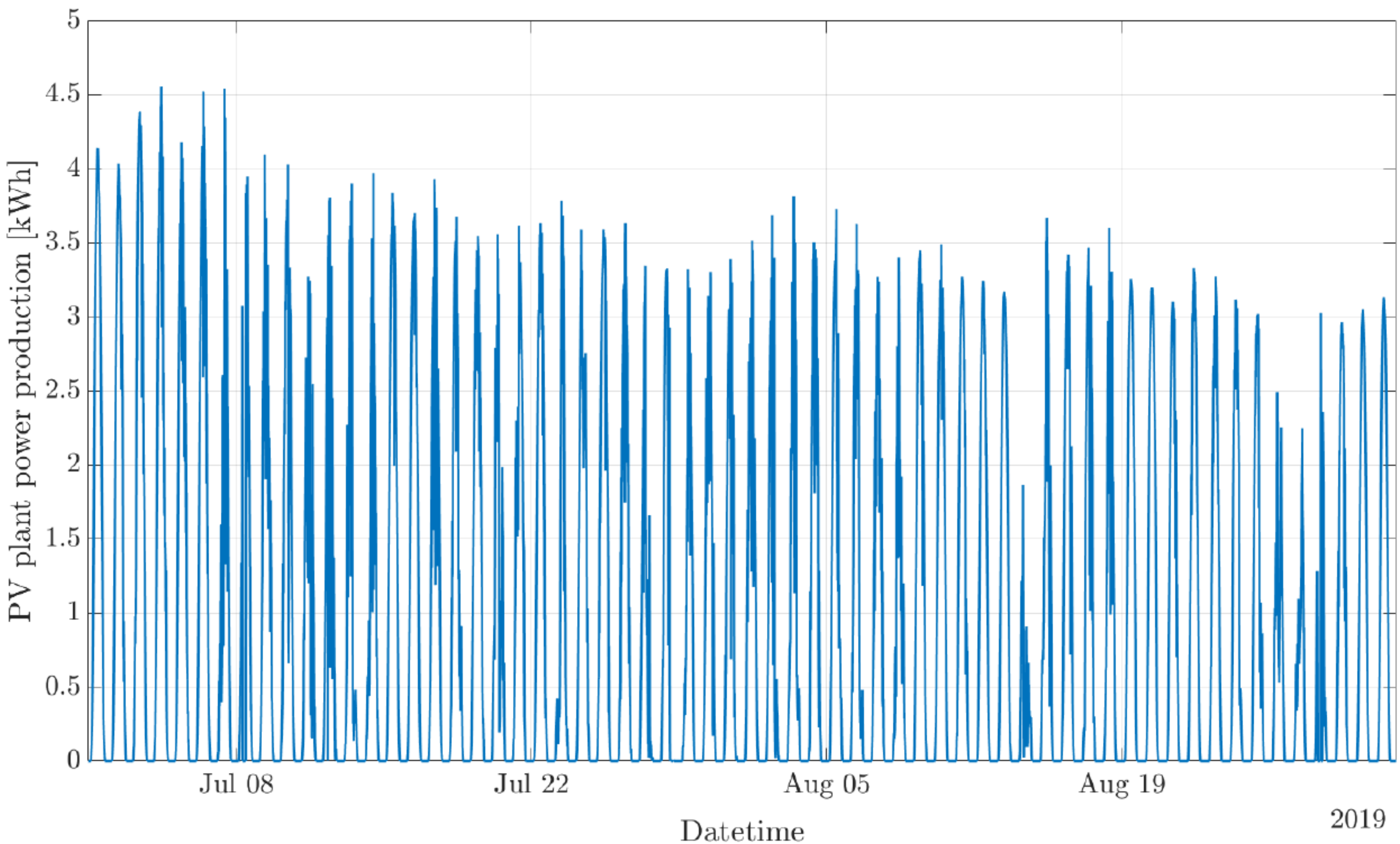
M PE 3 – example of historical production



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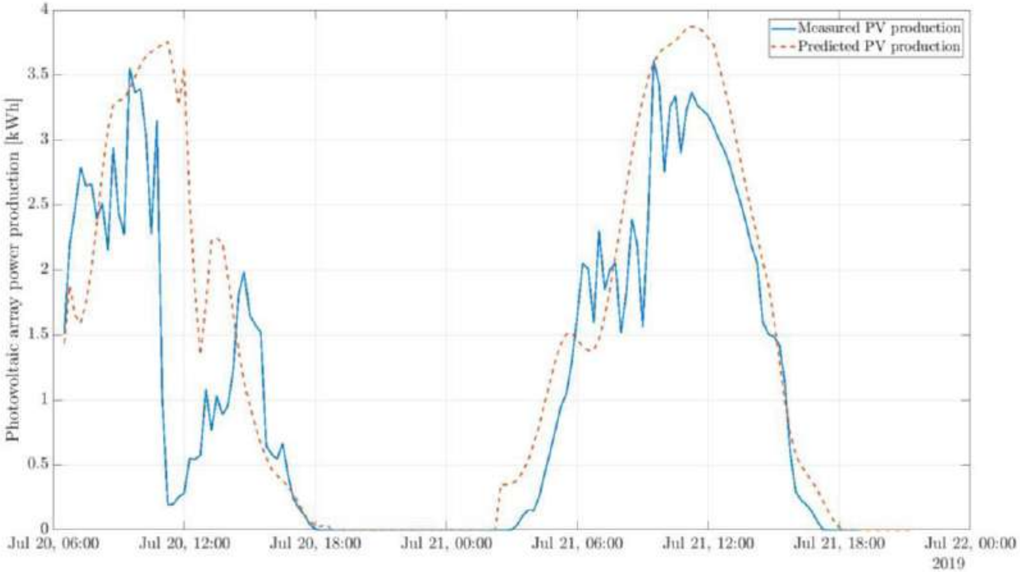
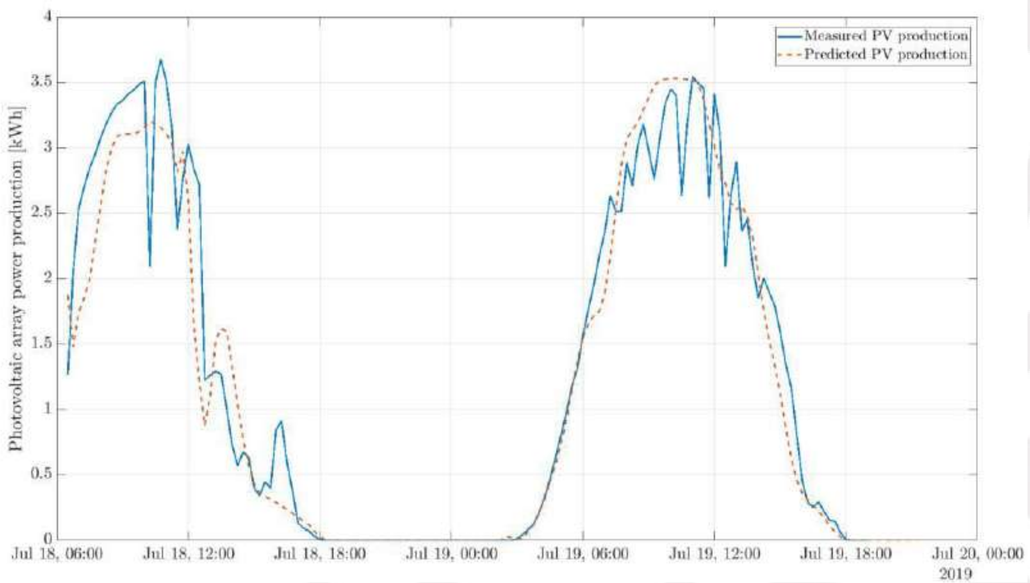
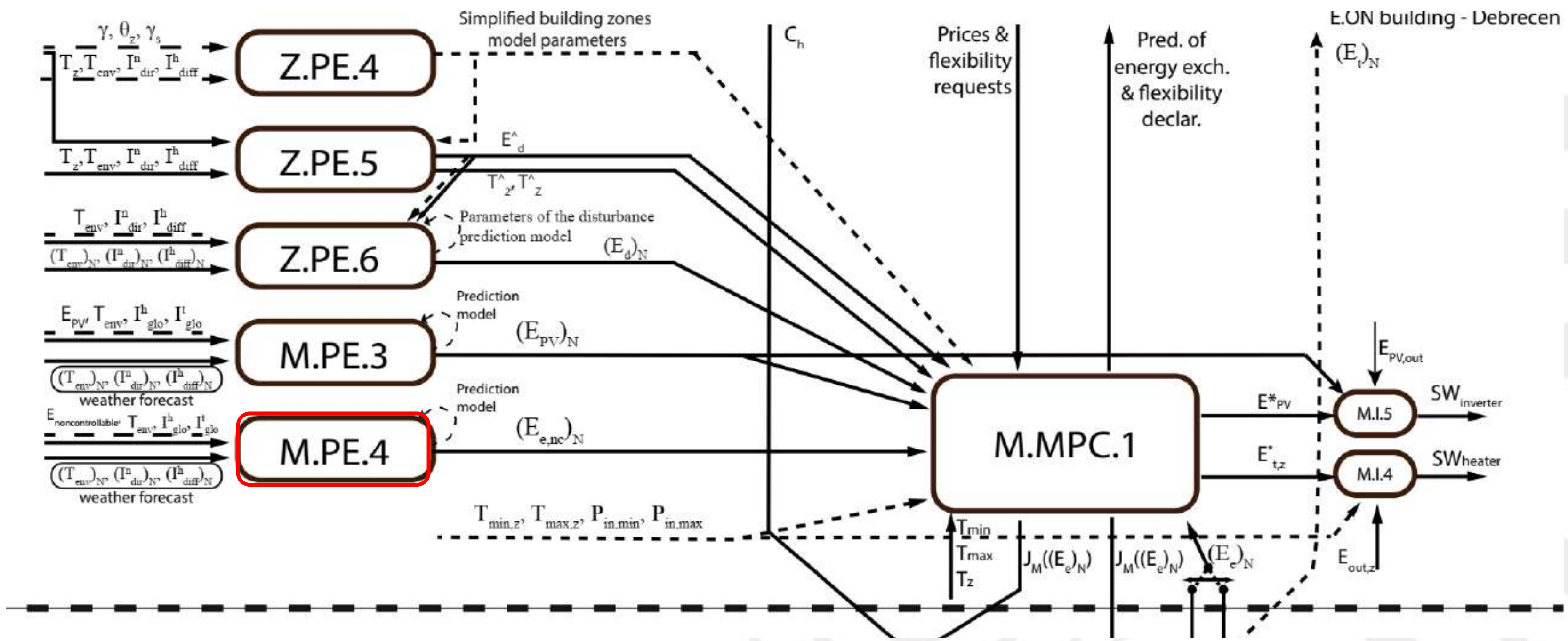
M PE 3 – example of generated prediction



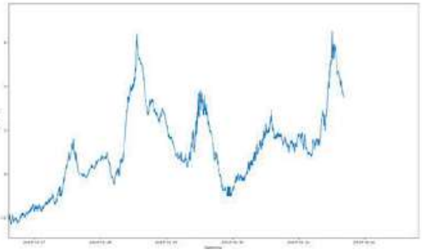


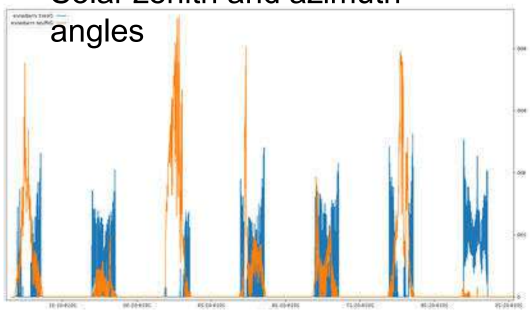
M PE 4
(prediction of non-controllable electricity consumption)



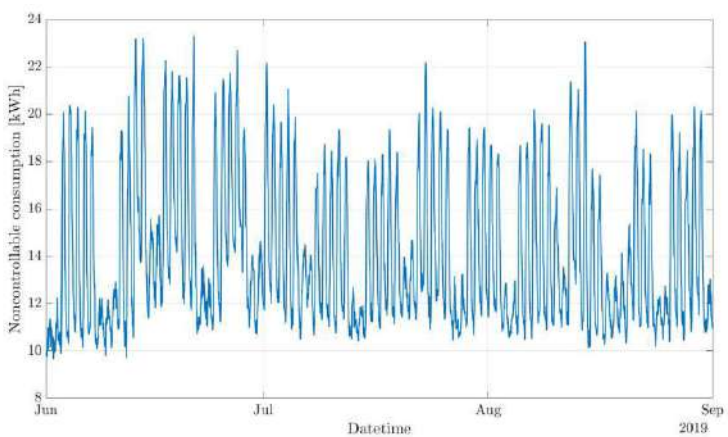
M PE 4 – off-line initialization

Historical **weather measurements**:
- Temperature
- Direct, diffuse solar irradiance
- Solar zenith and azimuth angles





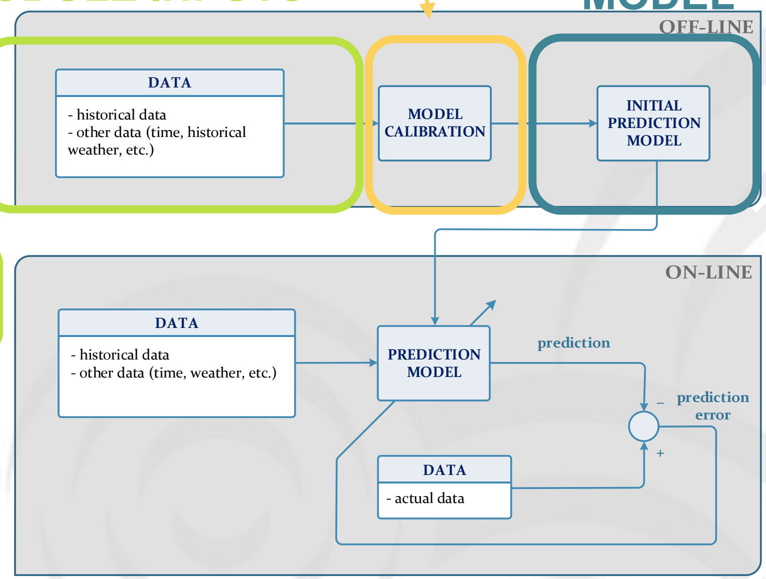
Historical non-controllable consumption **(lighting, office equipment, additional air conditioners…)**



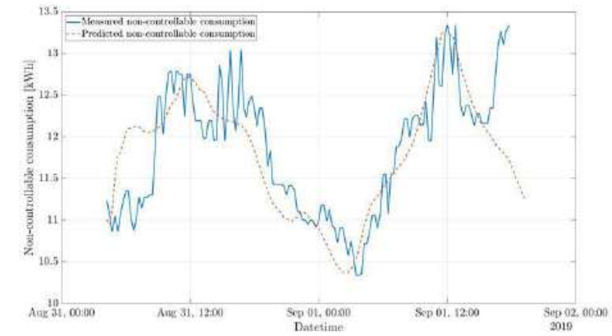
MODULE INPUTS

MODEL

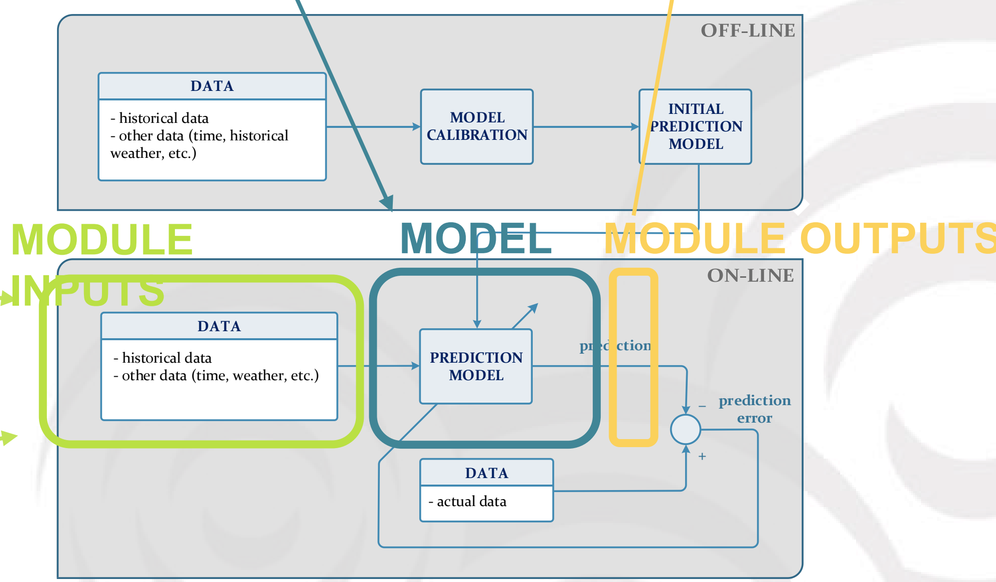
Locally stored: inputsXY_neuronsZ.net



M PE 4 – on-line operation



Locally stored:
inputsXY_neuronsZ.net

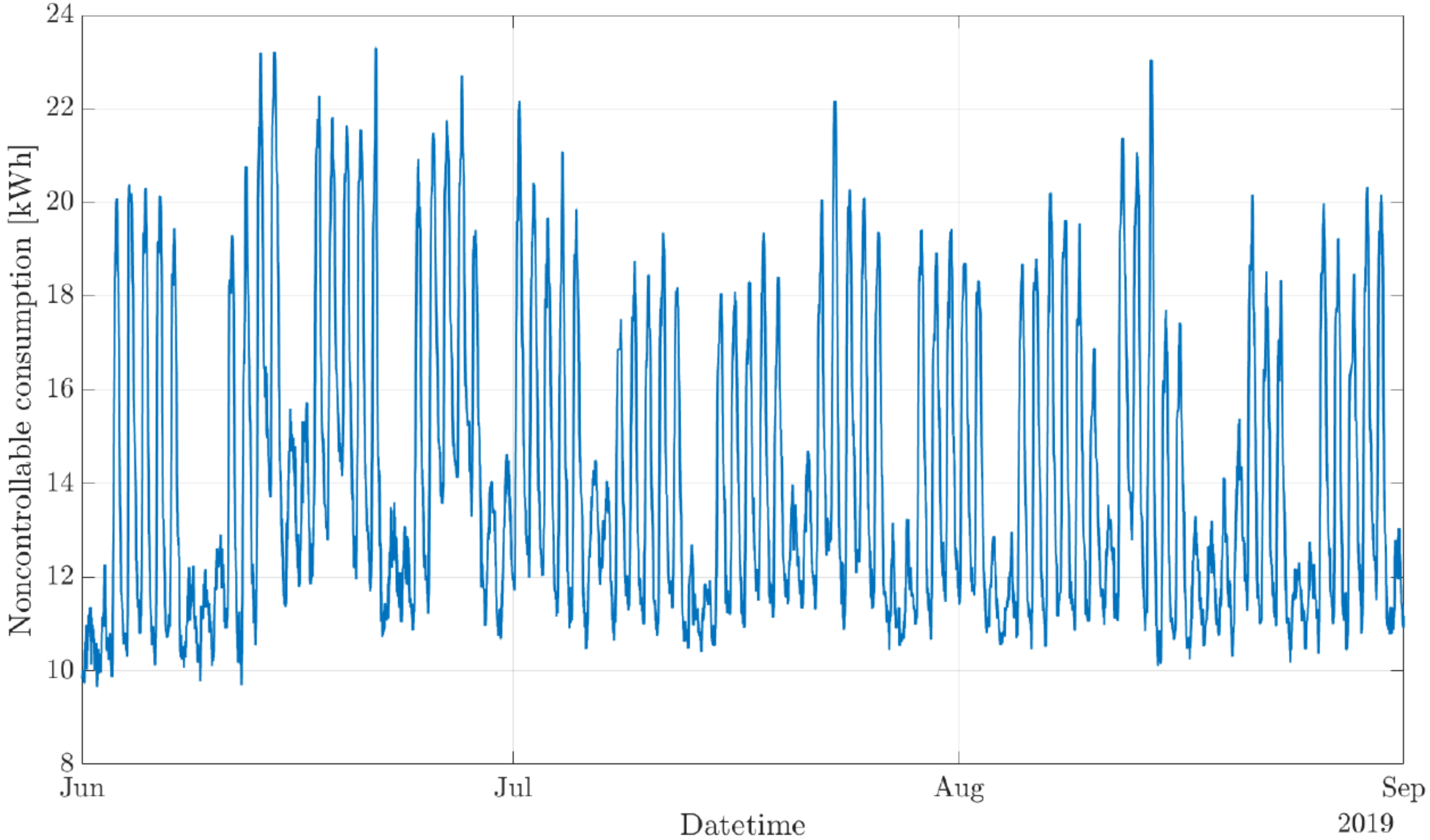


Regressor composed of historical data :

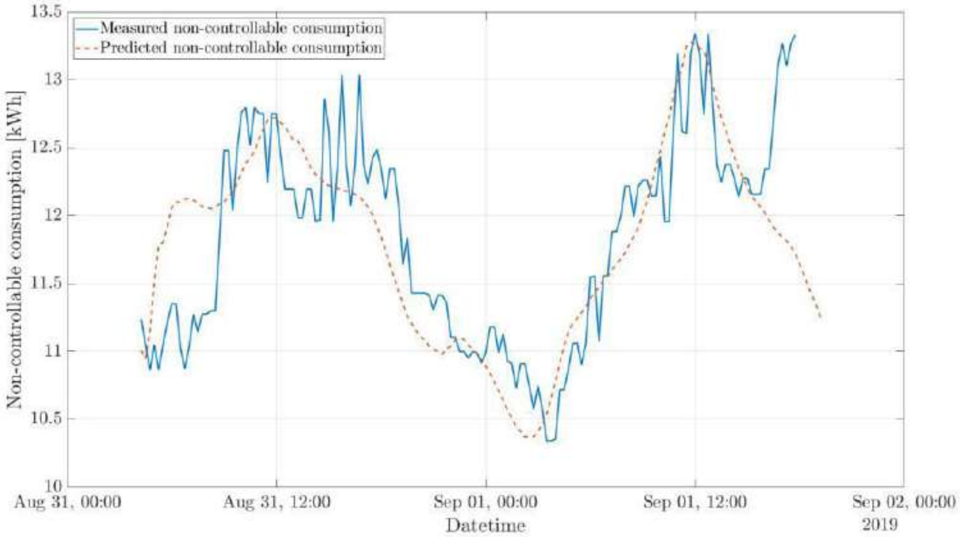
- noncontrollable consumption(t-1,…,t-5)
- noncontrollable consumption(t-670,…,t-674)

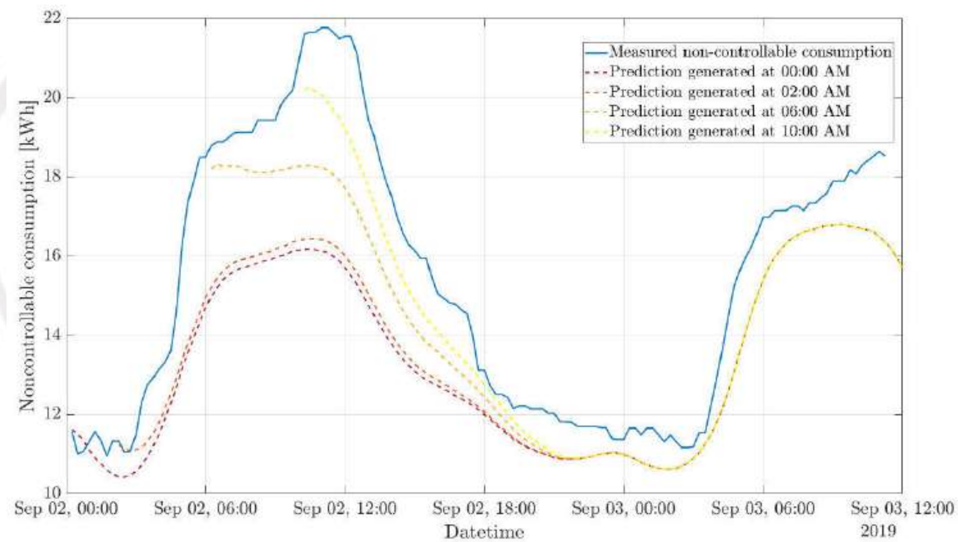
- tau_s_d, tau_c_d
- tau_s_w, tau_c_w
- tau_s_y, tau_c_y

M PE 4 – example of historical consumption

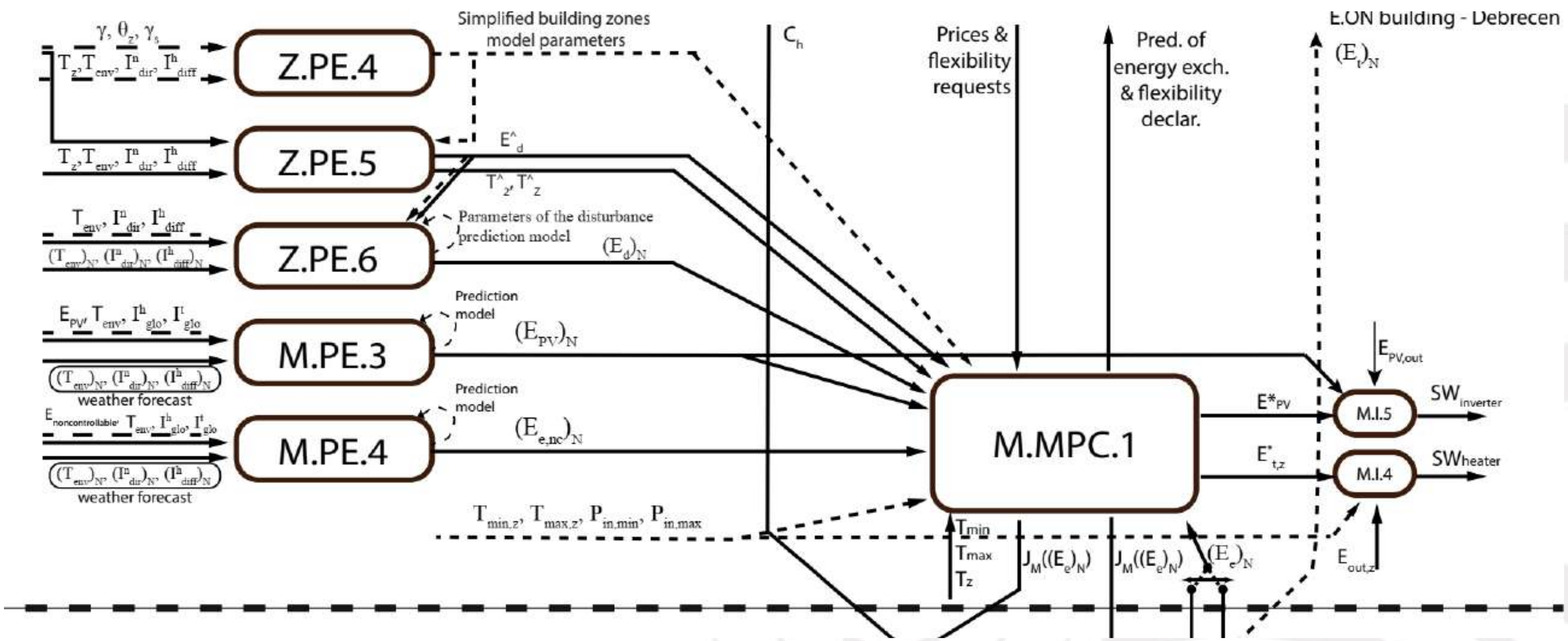


M PE 4 – example of generated prediction





M MPC 1



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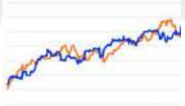
Module of model predictive control for microgrid (M MPC 1)

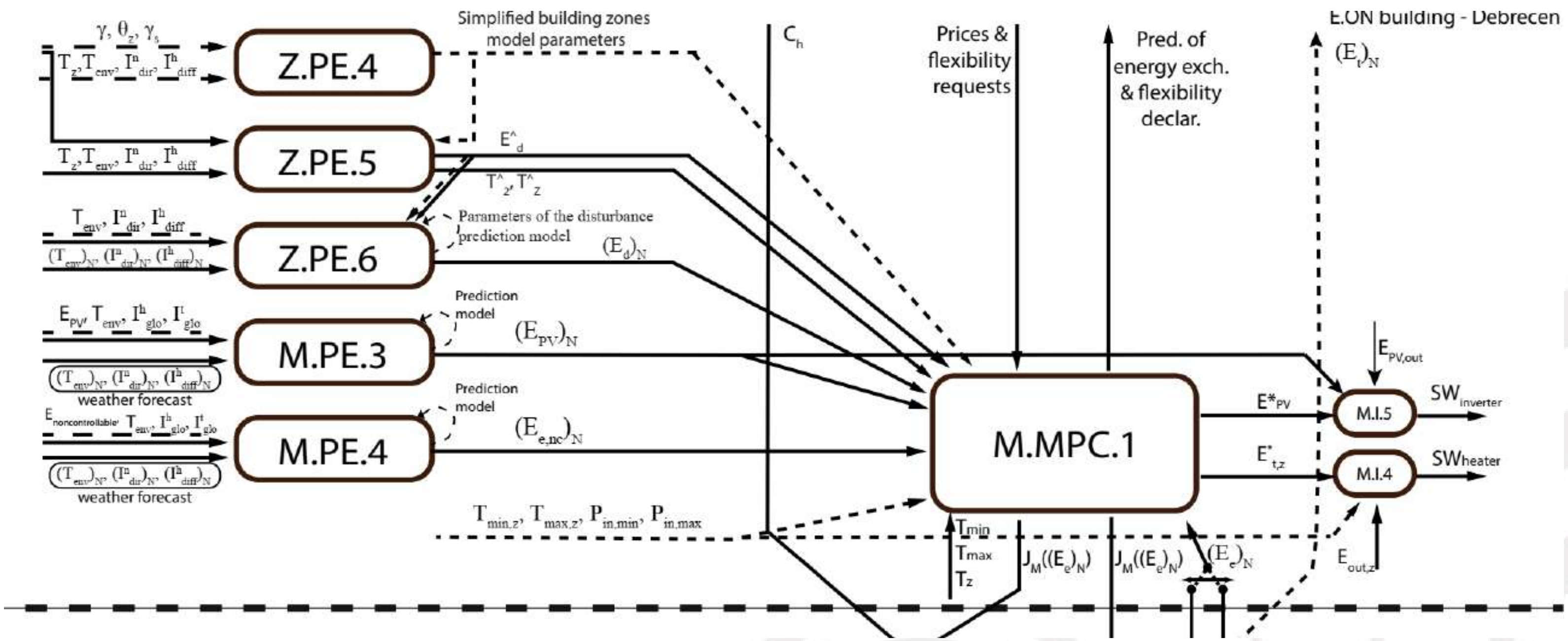
- M.MPC.1 enables the following:
  - Prediction of daily consumption
  - Following the declared daily consumption profile
  - Flexibility services for the grid
- Minimization of total building operating cost:

$$J = J_{DA} + J_{MP} + J_{IDf} + J_{flex} + J_{HVAC}$$





M MPC 1 – data flow



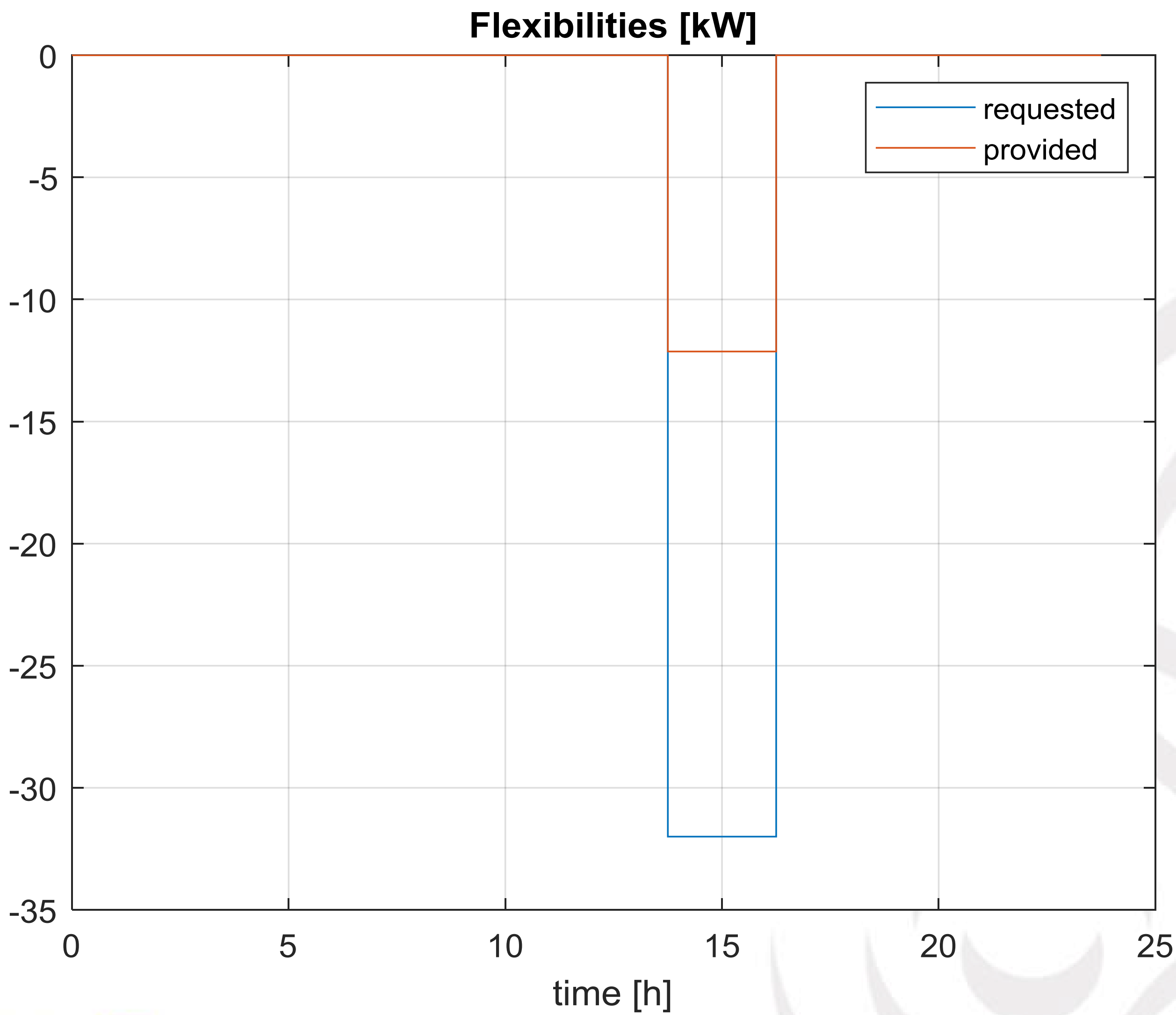
Inputs

- Prediction of non-controllable and HVAC electricity consumption and PV production
- Current state of cellar rooms with heaters
- Prices and requests from the grid

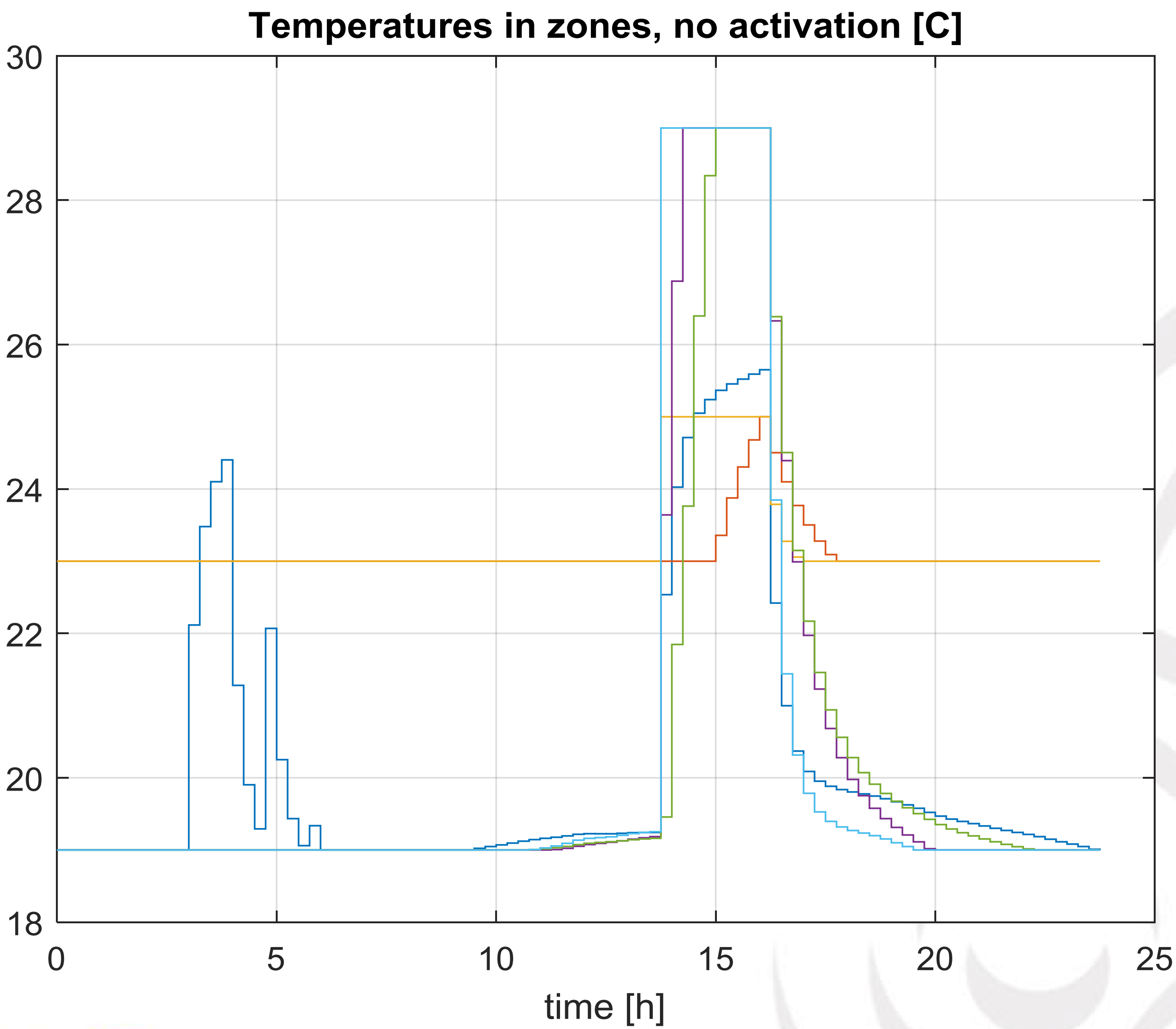
Outputs

- Energy references for heaters
- Energy references for PV
- Prediction of consumption → grid

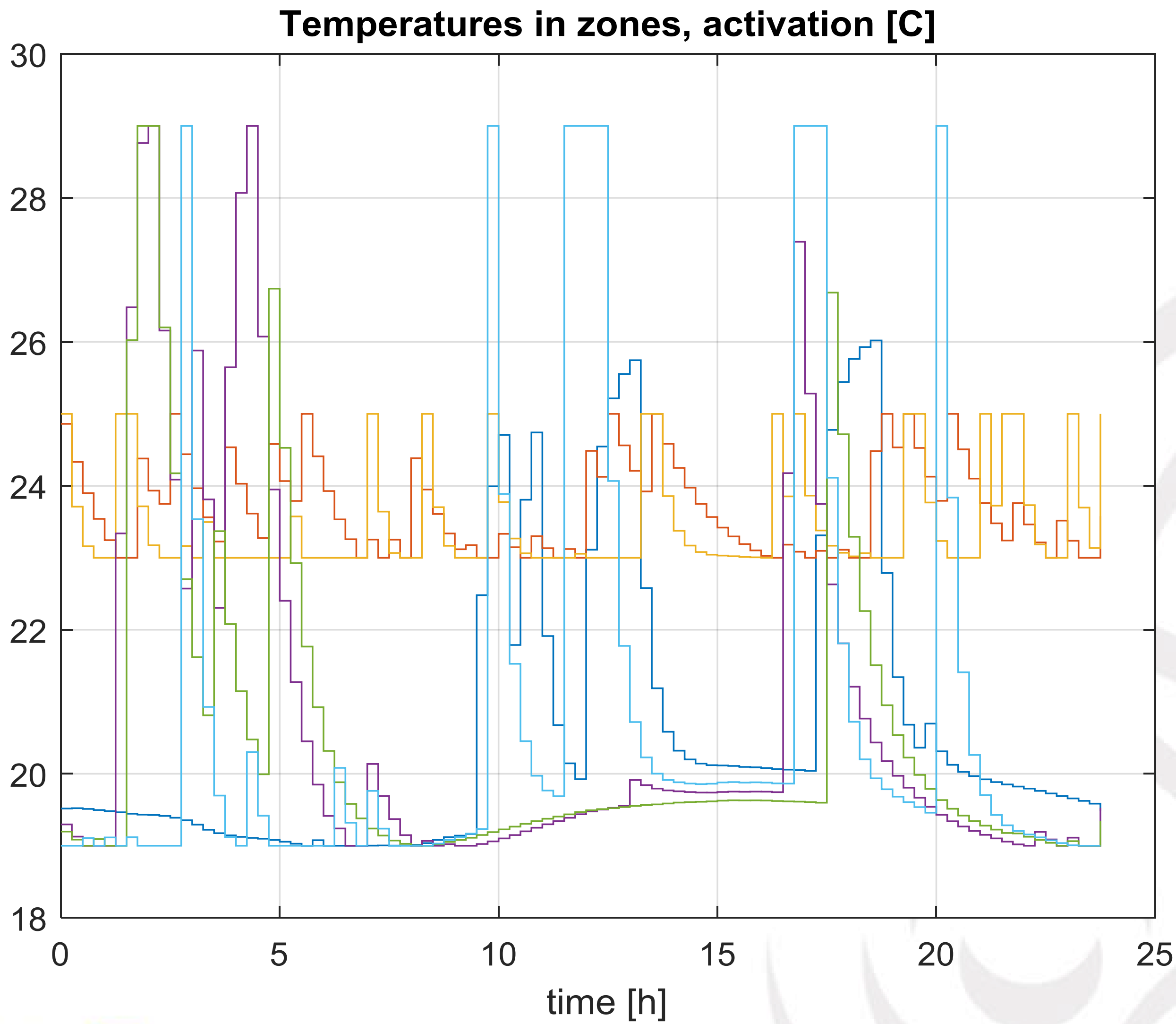
M MPC 1 – results of operation (1)



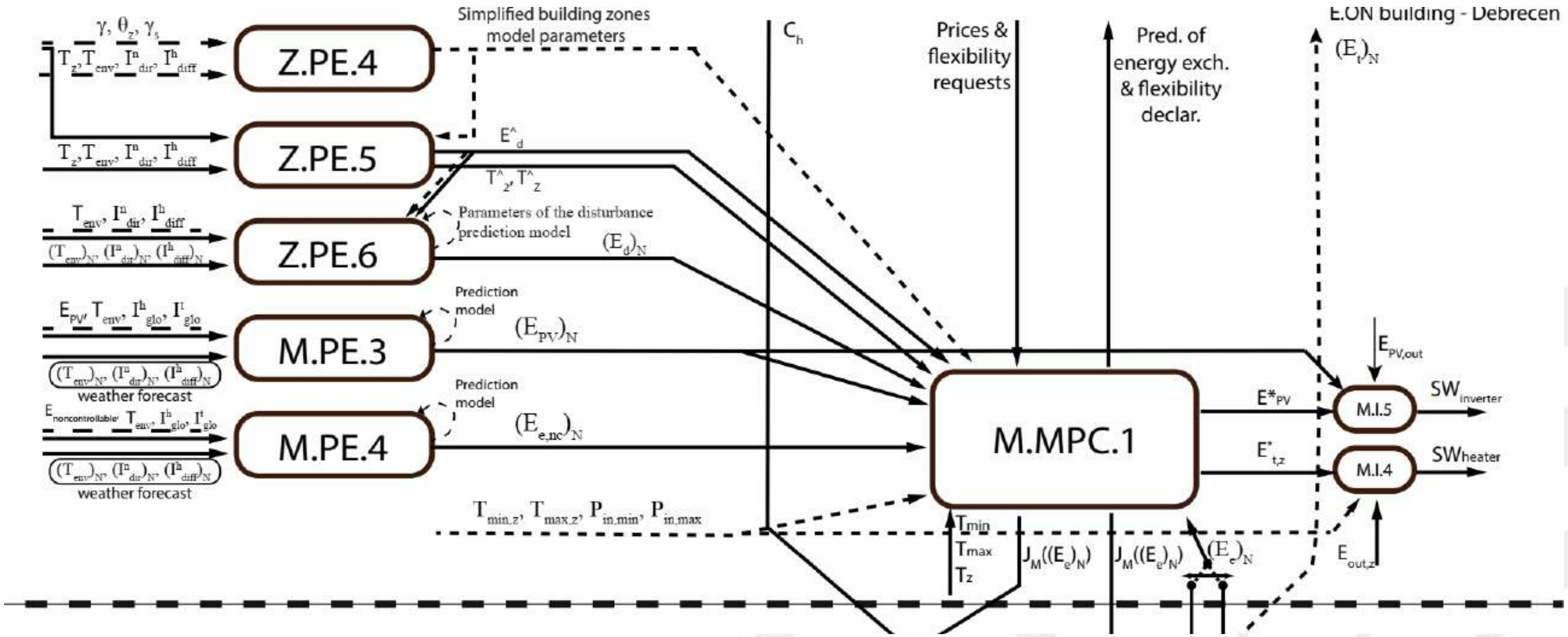
M MPC 1 – results of operation (2)



M MPC 1 – results of operation (3)

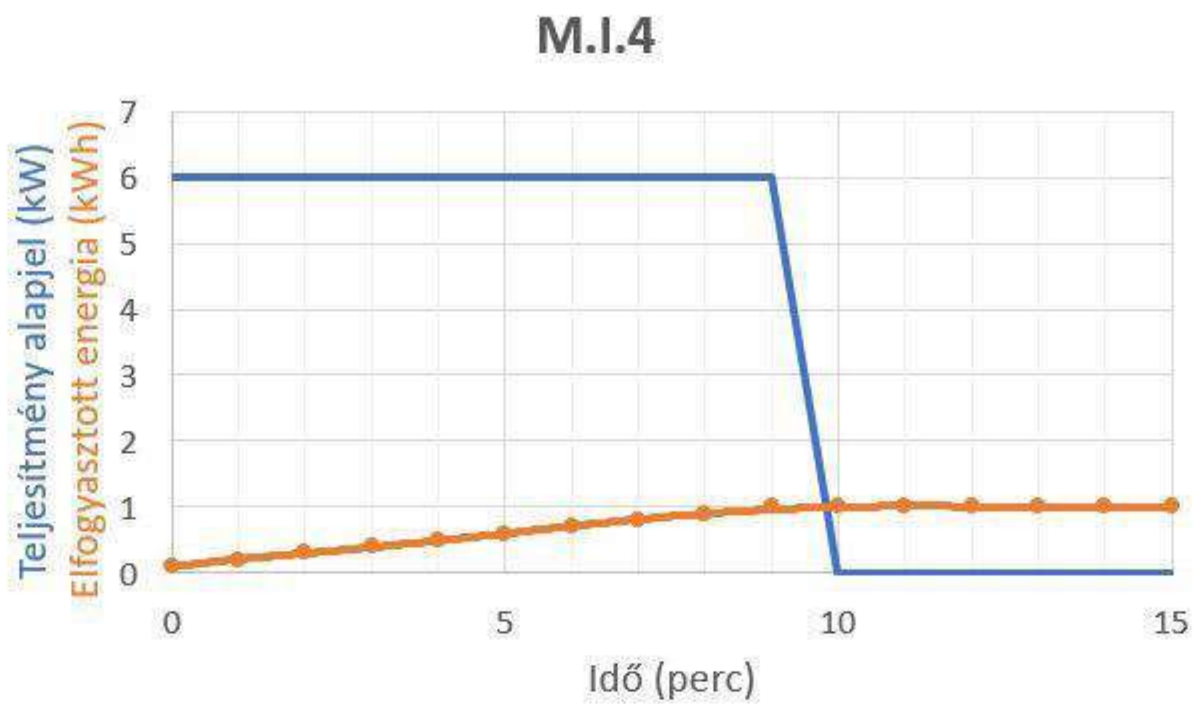


Interfacing modules

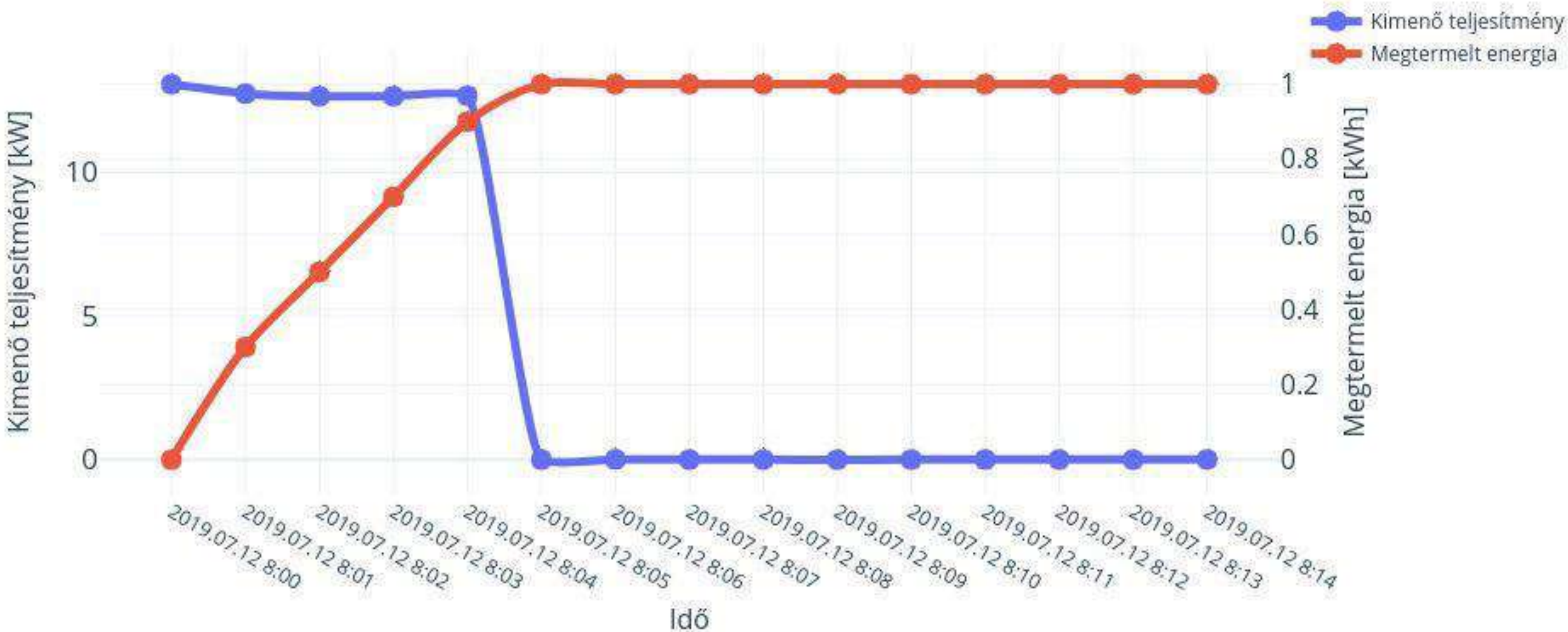


- Execution every minute
- Ensure energy flow according to MPC commands on 15 minutes level

M I 4 – interface for electric heaters



M I 5 – interface for PV plant



Acknowledgment

The presented research results are obtained within the project Smart Building – Smart Grid – Smart City (3Smart) co-funded by the European Union from European Regional Development Fund and Institute for Pre-Accession Assistance through Interreg Danube Transnational Programme (DTP1-502-3.2-3Smart), in the amount of maximum 3.222.641,90 EUR.

3SMART PROJECT WEB PAGE

http://www.interreg-danube.eu/3smart

Disclaimer

The contents of this presentation are the sole responsibility of its authors and do not necessarily reflect the views of the European Union.

Output Quality Report

Output title: T4.1 Transnational training activities	
Type of output:	☑ Documented learning interaction ☐ Strategy/ Action Plan ☐ Tool ☐ Pilot action
Contribution to PO indicator:	**P07 No. of documented learning interactions in finalised operations**

Summary of the output
The output contains documented learning interactions performed during pilot study visits to the 3Smart locations for piloting of the developed modular tool for integrated grid-building energy management including demand response. Pilot study visits were attended by the members of the 3Smart consortium and for each pilot they were organized in two rounds. In the first round the pilot hosts explained the interventions performed while modules developers explained the needed steps for installation of the modules. In the second round the hosts explained the progress with modules installations while the developers presented the results of modules operation on data from the building. The documented learning interactions are organized as short explanation of how the learning interaction took place (minutes) which refer to presentation materials as annexes. For each round of pilot study visits a separate document is provided which contains the interactions from all five pilots of the 3Smart project –in Croatia, Slovenia, Austria, Bosnia and Herzegovina and Hungary. The reader can by passing through this documentation get a basic insight into the pilots organization and 3Smart platform operation on them.

Added value
The output provides the information on pilots initial state, preparation actions for putting in place the 3Smart platform on the site, the architecture of the modular 3Smart system for a particular site i.e. which modules it contains to exhibit smart operation of the building or grid, needed steps for installation of modules as well as modules performance in operation. The documentation provided was created by experts in particular fields to be understandable also to non-experts in that field. In this way, already within the consortium, which gathers versatile expertises, the information provided needed to be simple and easy to understand. The transnational context in which the materials arose ensures also its transnational relevance and can be used as a reference to interested stakeholders all across the Danube region and wider.
Applicability and replicability
The output can be used for a picturesque introduction to what was done on the project and to easily grasp the steps needed for replication of the 3Smart platform for energy management and demand response in a particular setup of a building or a grid. Different technologies in buildings were encompassed both on the level of zones (fan coils, radiators, floor heating/cooling), the central heating/cooling medium preparation (heat exchangers, heat pumps) and in shaping the overall energy flows between buildings and external grids (from nothing, which is also a viable option, to PV systems, batteries, CHPs, electric heaters, etc.). These varieties of implementation show the flexibility of the developed tool for adaptation at some new replication site, even in case it has some totally different configuration from any of the pilots.
Suggestions for improvement, if applicable
The output is useful to get an overview and impression how the 3Smart platform can be installed and what it can bring to a certain building or grid or even to a more complex setups. Especially useful are the estimations of gains which are also more concisely provided in other outputs, like Output T4.3 (presentations to stakeholders). This output can be considered as a useful interim material to get a gradual introduction into the 3Smart project developments. Considering the existence of more detailed written deliverables and outputs and that this is a material to get an overall impression on variety of implementation possibilities for 3Smart, I have no particular suggestions for improvement.

Output Quality Level	☐ Low ☐ Average ☐ Good ☑ Excellent

Name of the Quality Manager

Prof. dr. Mato Baotić

Signature of the Quality Manager

Mato Baotić