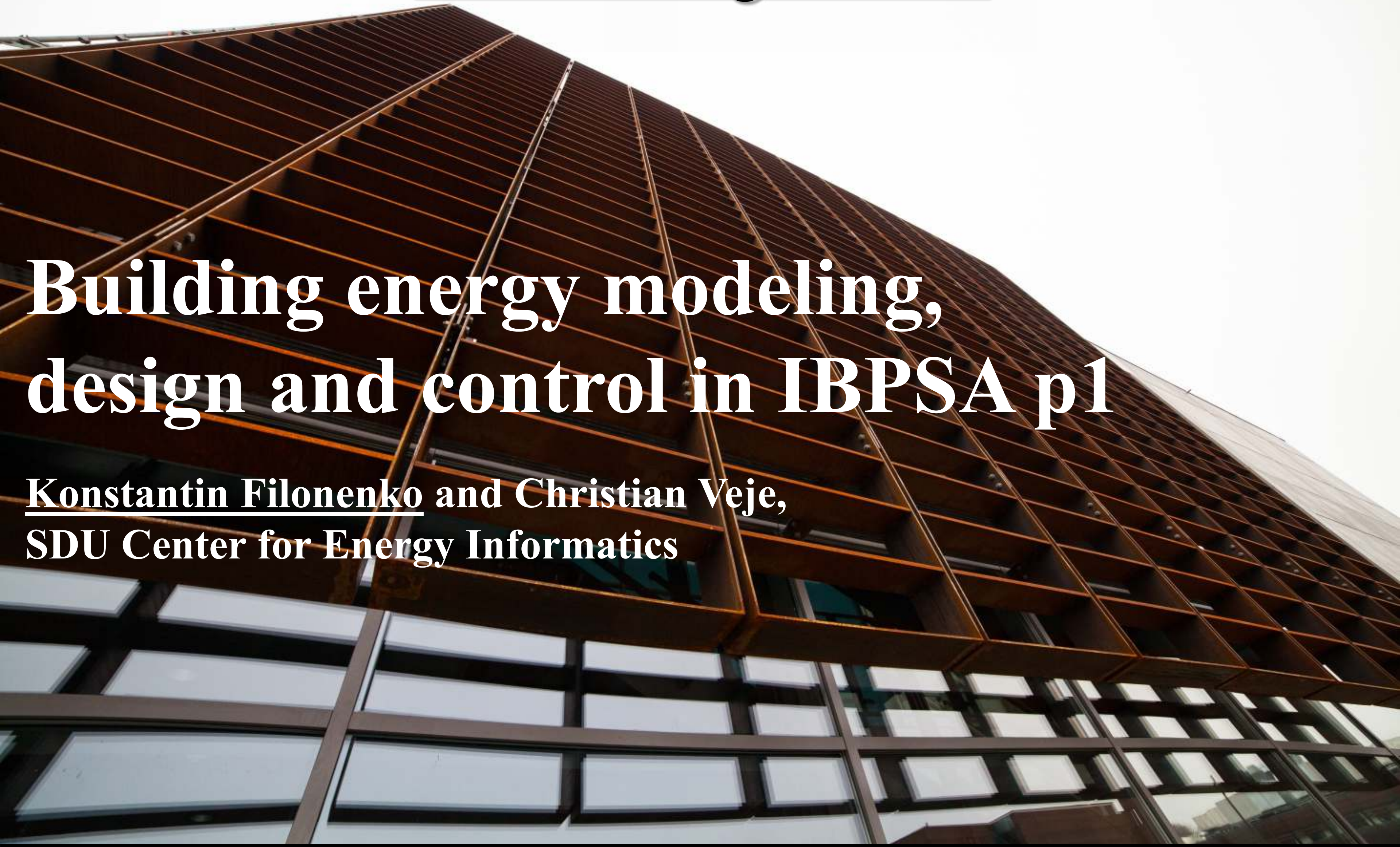
Danvak Dagen 2020



Building energy modeling, design and control in IBPSA p1

Konstantin Filonenko and Christian Veje,
SDU Center for Energy Informatics

Konstantin Filonenko
kfi@mmmi.sdu.dk

September 1, 2020

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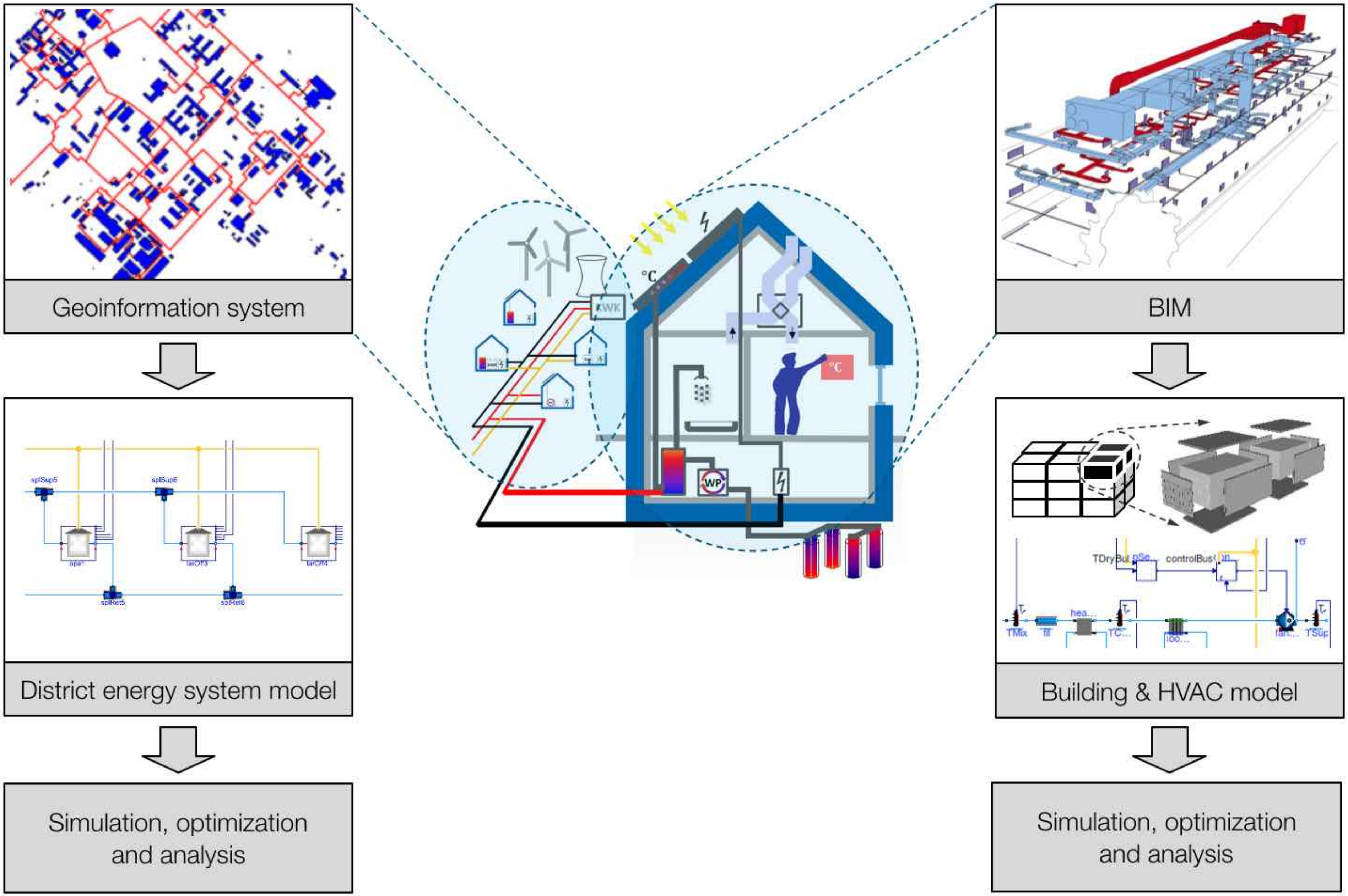
IBPSA project 1

- The first project of the **International Building Performance Simulation Association (IBPSA)**
- BIM/GIS and **Modelica framework** for building and community energy system design and operation
- Aim: create open-source software that builds the basis of next generation computing tools for the design and operation of building and **district energy and control systems (DES)**
- Led by Michael Wetter LBNL, Berkeley

IBPSA Project 1

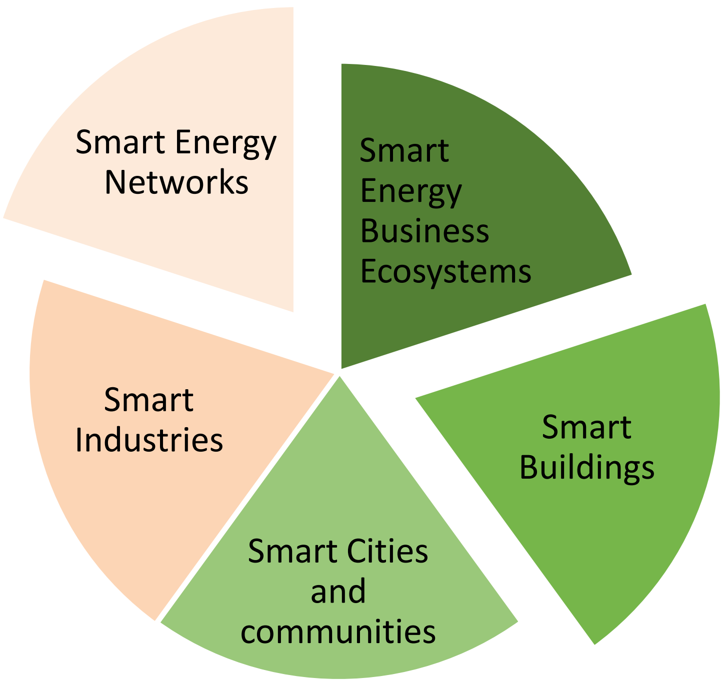


https://ibpsa.github.io/project1/

SDU Center for Energy Informatics (CEI)

- Expertise in modeling, optimization and control of DES technologies
- Continuous contribution to international DES projects (incl. IEA Annex 60 followed by IBPSA p1)
- EUDP funding for IBPSA project 1 participation
- In IBPSA project 1:
  - Developed Modelica-based open-source district energy models
  - Demonstrated capabilities of the tools through real live applications using Functional Mock-Up Interface (FMI).

SDU Center for Energy Informatics (CEI)



IBPSA Project 1

EUDP

IBPSA Project 1 CEI - SDU Participation

Syddansk Universitet | Center for Energy Informatics, Det Tekniske Fakultet

SDU goal in the project: adopt and apply the emerging DES tools for simulation, optimization and control of insdustrial energy systems

Konstantin Filonenko
kfi@mmmi.sdu.dk

Work packages

WP 1.1: Modeling of energy system components (LBNL, Berkeley)

WP 1.2: Building Optimization Performance Tests, MPC (KU Leuven)

WP 2.1: City District Information Modeling (TU Graz)

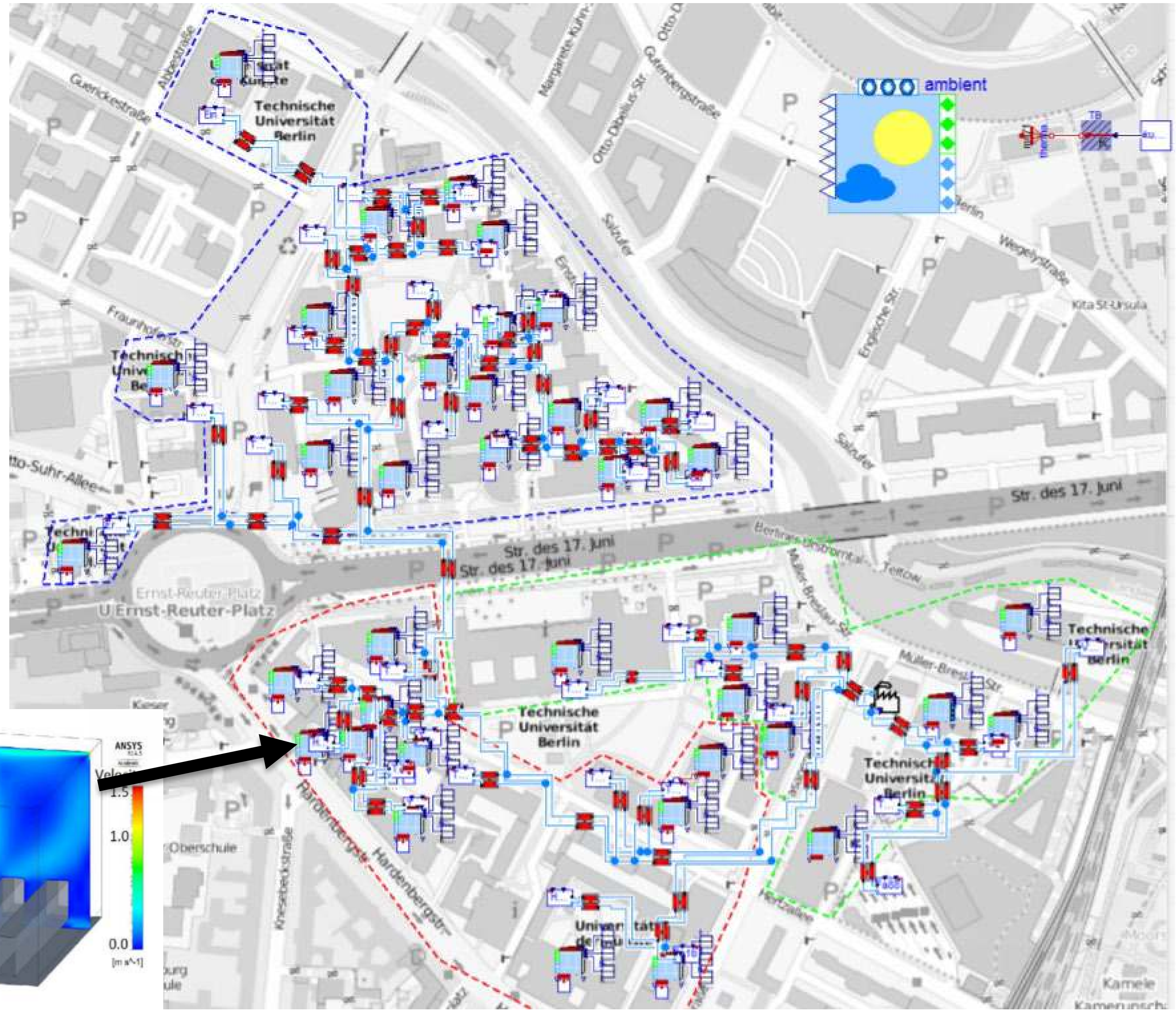
WP 2.2: Building Information Modeling (RWTH Aachen)

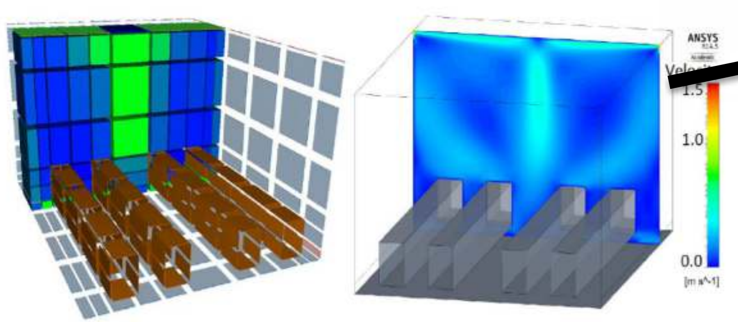
WP 3.1: DESTEST (KU Leuven)

WP 3.2: Applications and case studies (Aalborg University)

WP 1.1: Components and FMI

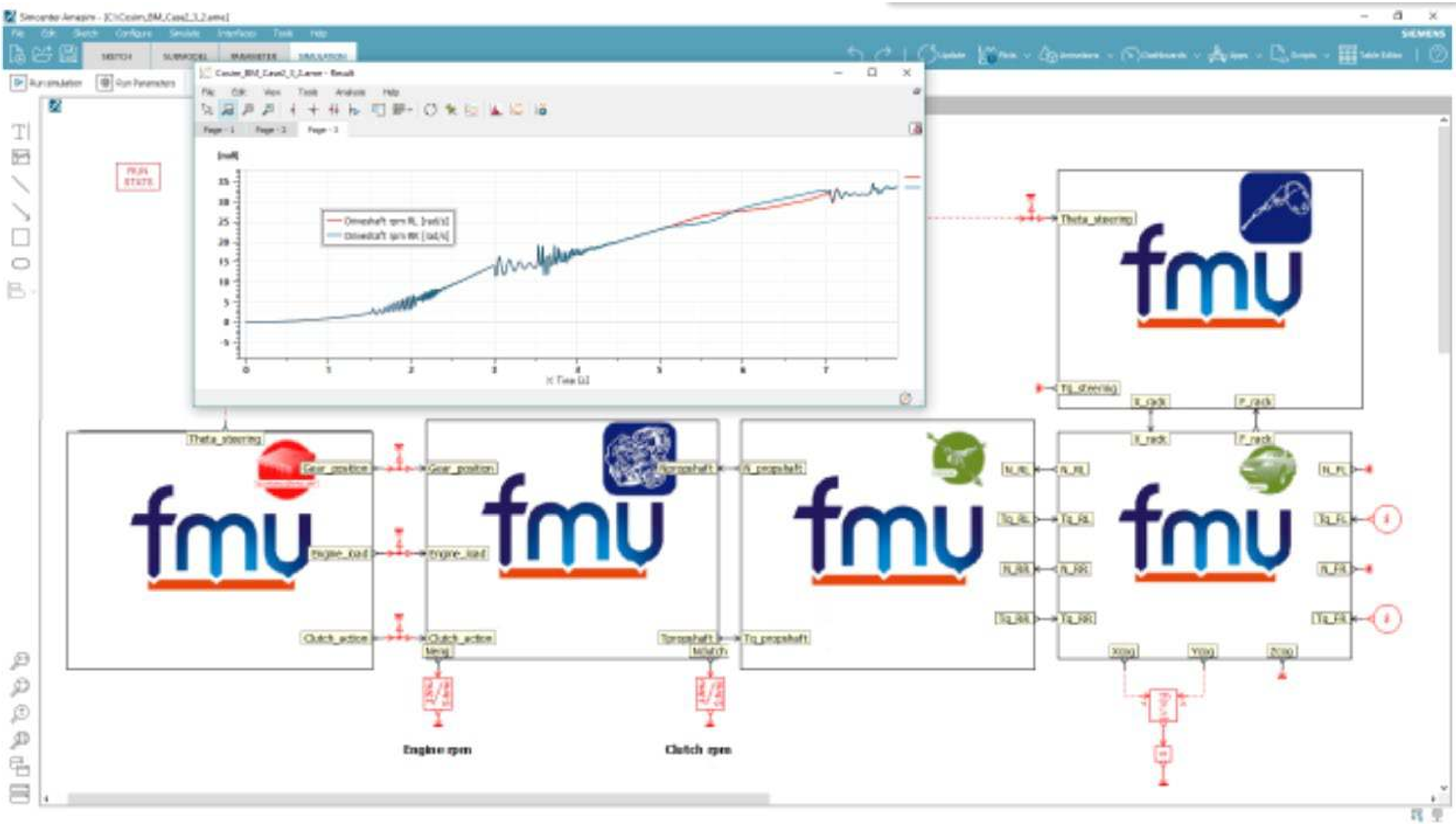
Berlin district case



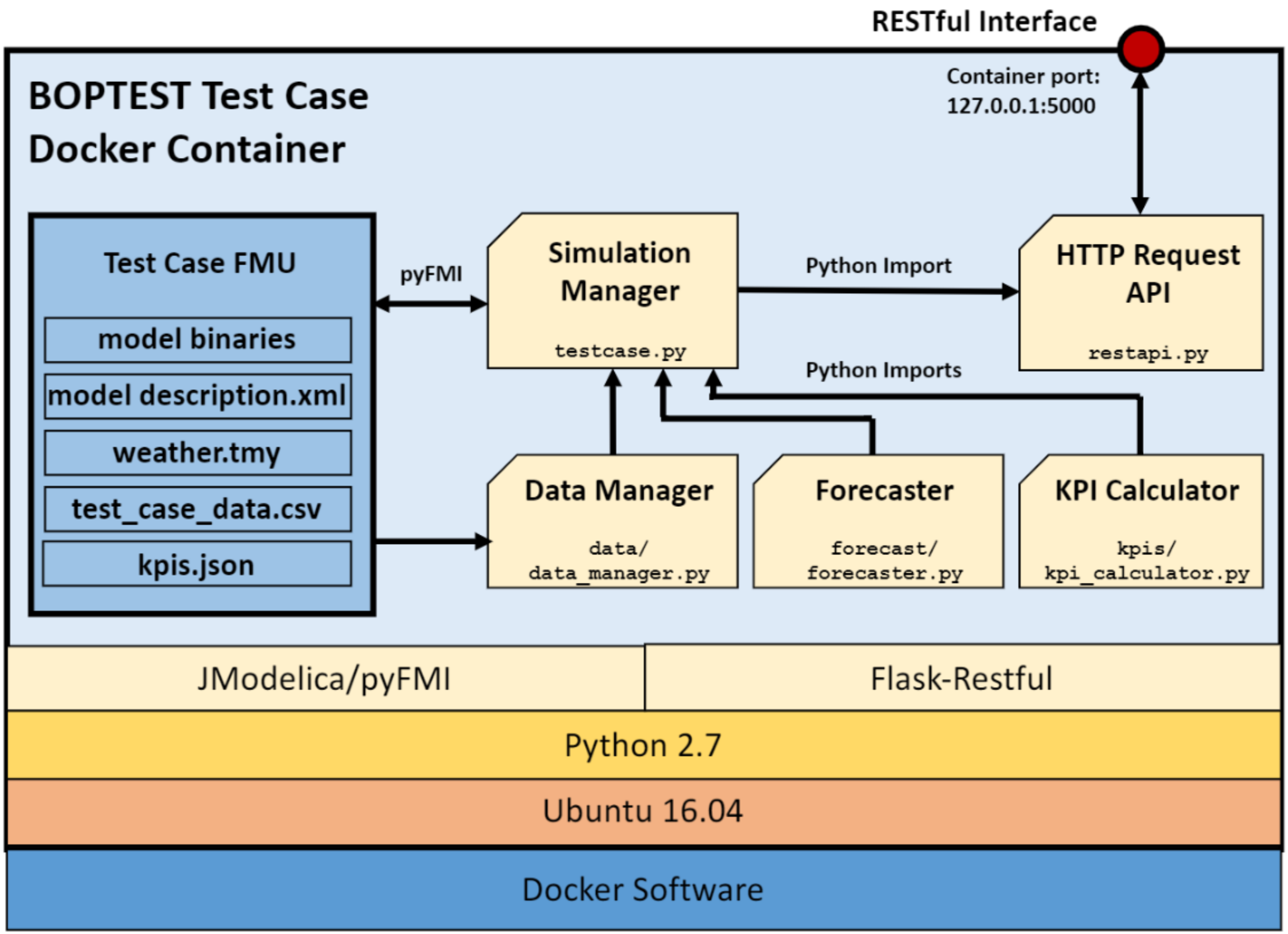


Konstantin Filonenko
kfi@mmmi.sdu.dk

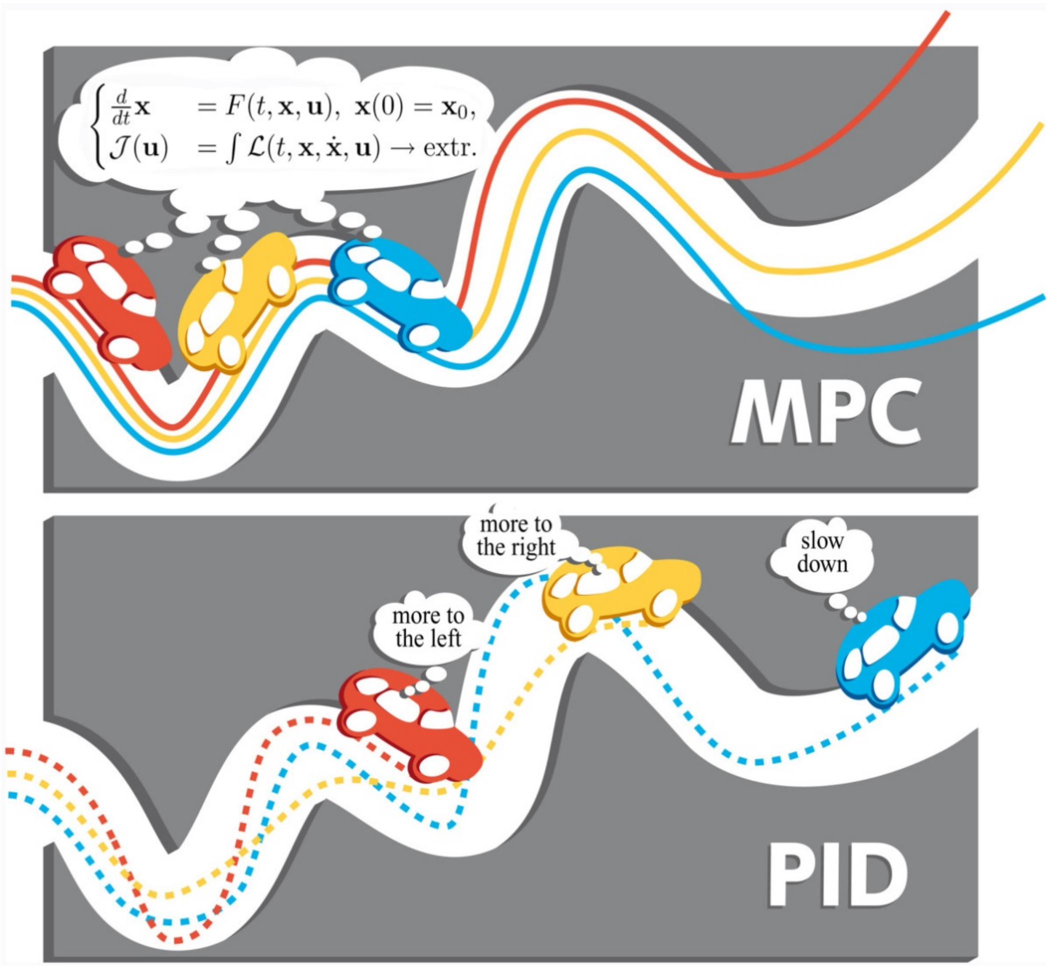
WP 1.1: Components and FMI



WP 1.2: BOBTEST



WP 1.2: Model predictive control



Model Predictive Control (MPC) control strategy adapting to the predicted future conditions

Traditional control strategy reacting to unexpected conditions

Image source: M. Hoekstra, M Vogelzang, E. Verbitsky, M.W.N. Nijtsen, Health technology assessment review: Computerized glucose regulation in the intensive care unit – how to create artificial control, *Critical Care 2009* (13): 223.

Konstantin Filonenko
kfi@mmmi.sdu.dk

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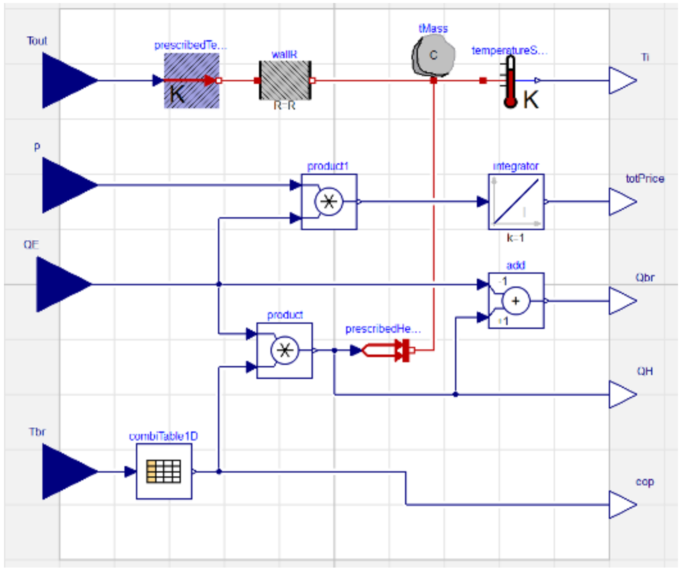
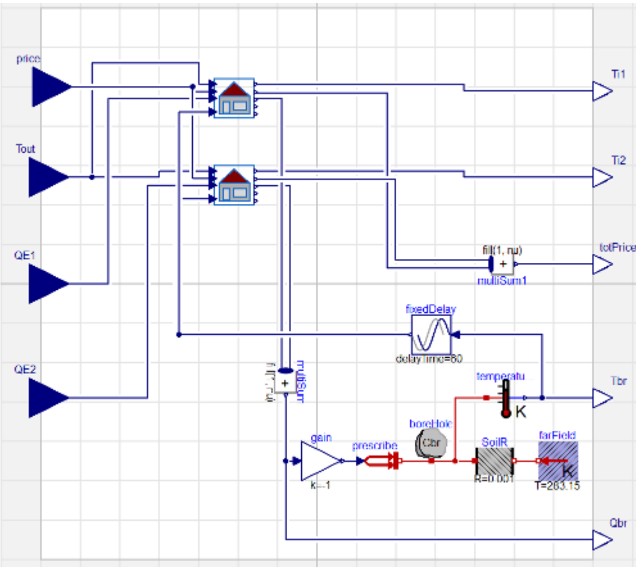
MPC example: control model

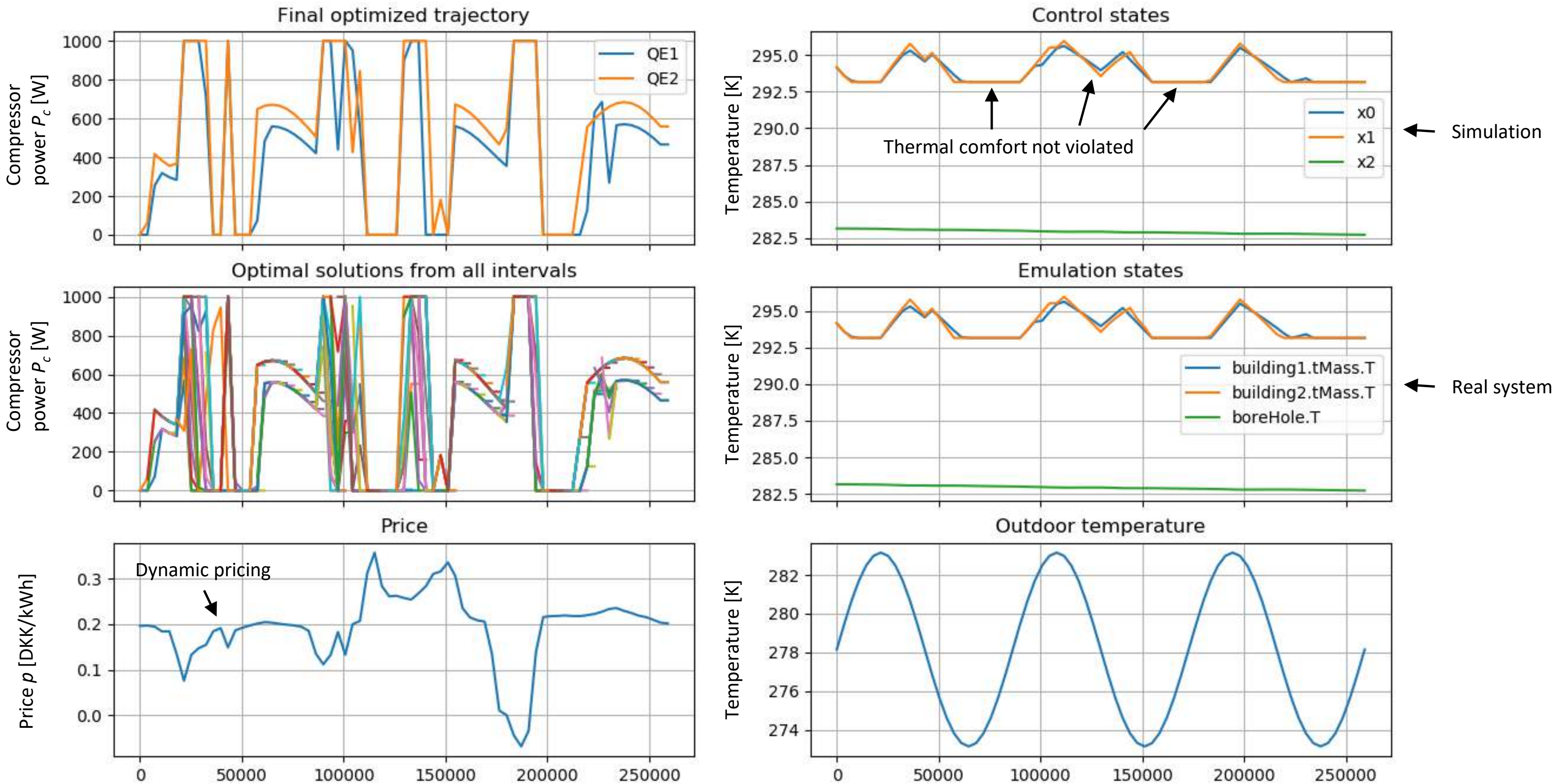


Building



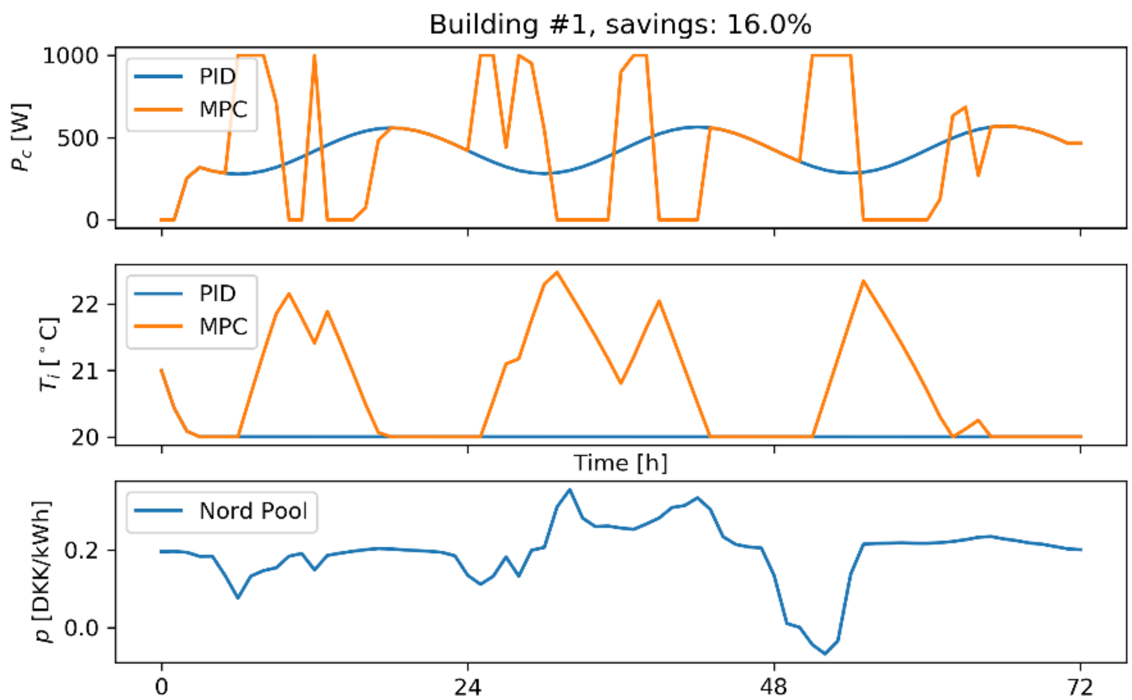
Village

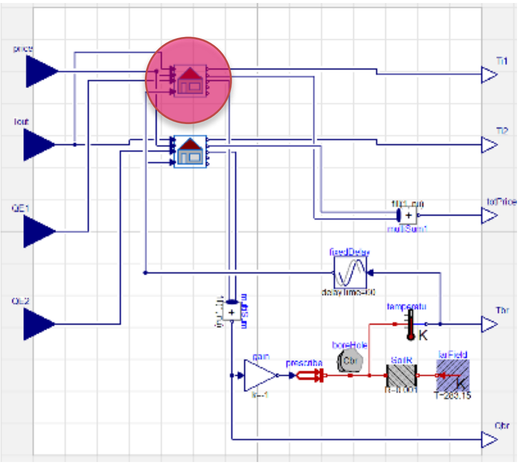
Objective: Minimize total electricity cost for both buildings



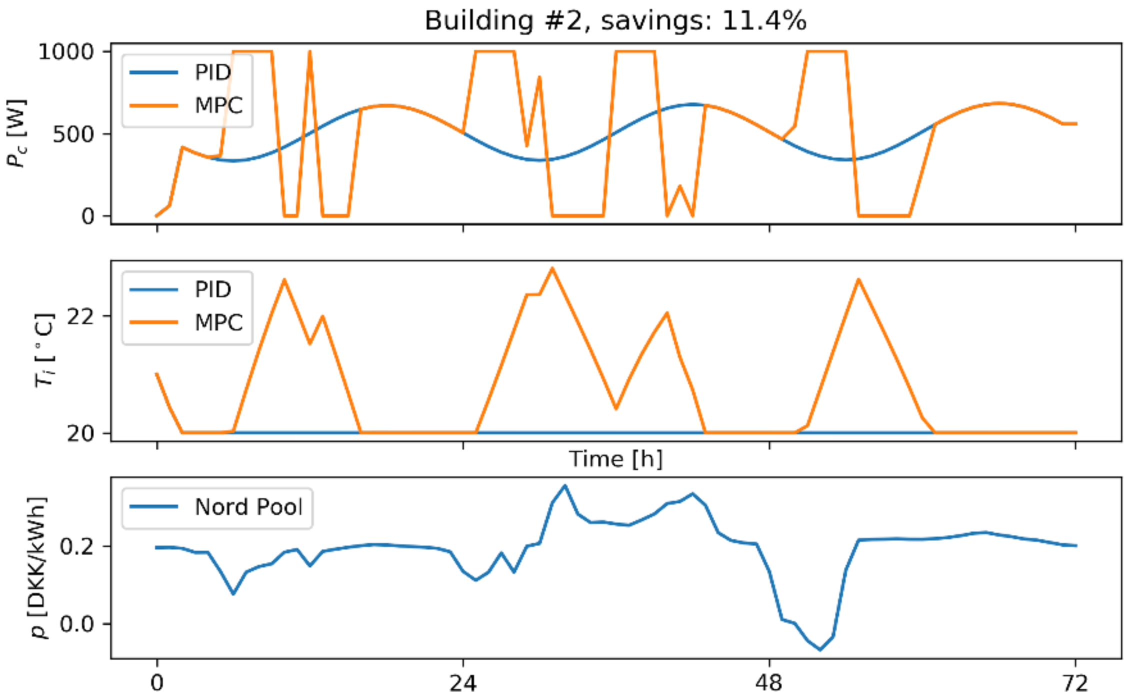
Final optimized trajectory
Compressor power P_c [W]
QE1
QE2
Optimal solutions from all intervals
Compressor power P_c [W]
Price
Price p [DKK/kWh]
Dynamic pricing
Control states
Temperature [K]
x0
x1
x2
Thermal comfort not violated
Simulation
Emulation states
Temperature [K]
building1.tMass.T
building2.tMass.T
boreHole.T
Real system
Outdoor temperature
Temperature [K]

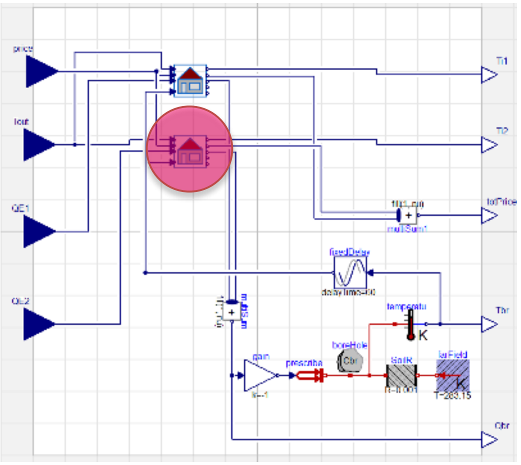
Potential Savings





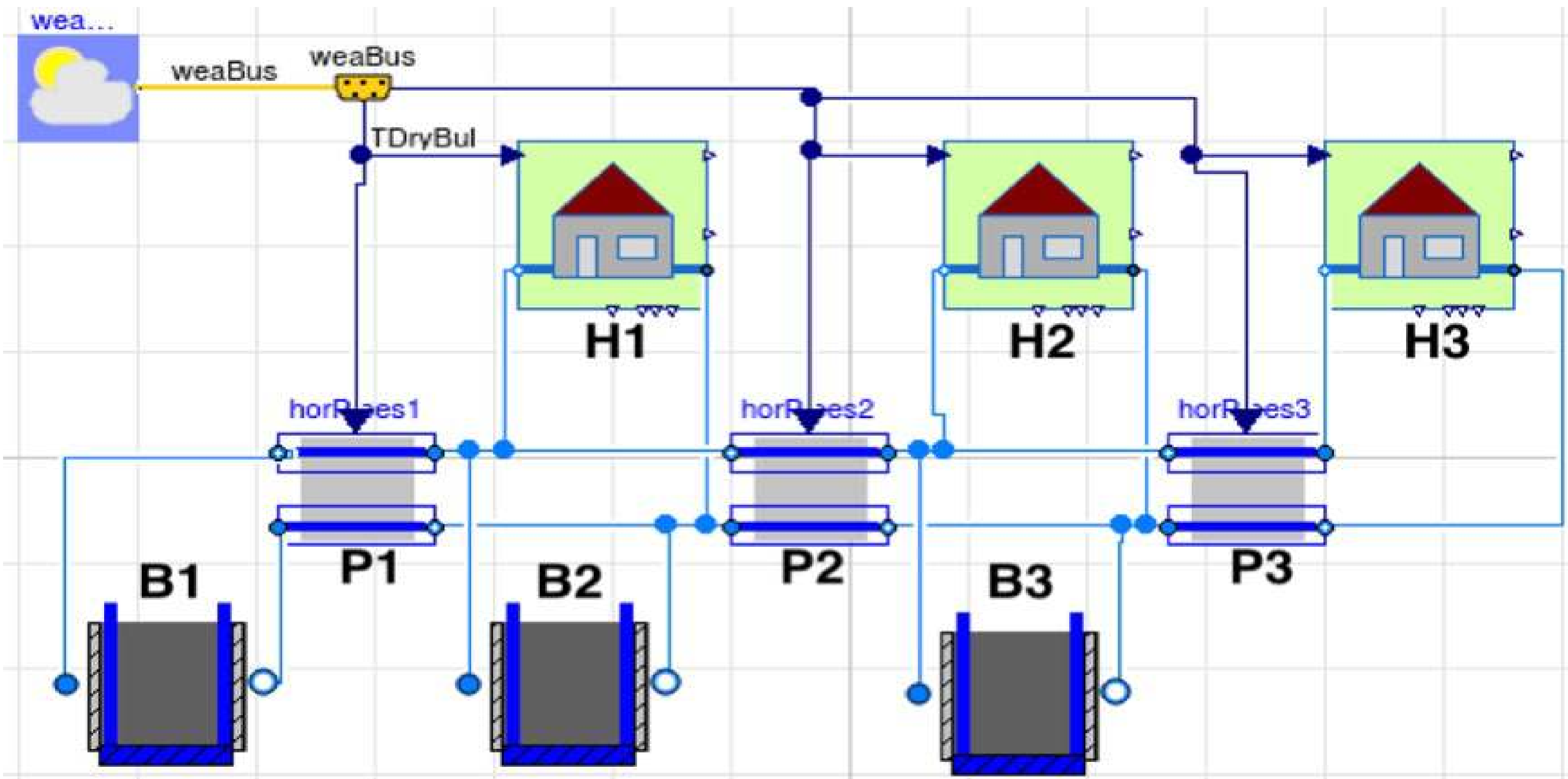
Potential Savings





MPC example: emulation model

- Ground source consumer heat pumps, buried pipes, ambient data



Konstantin Filonenko
kfi@mmmi.sdu.dk

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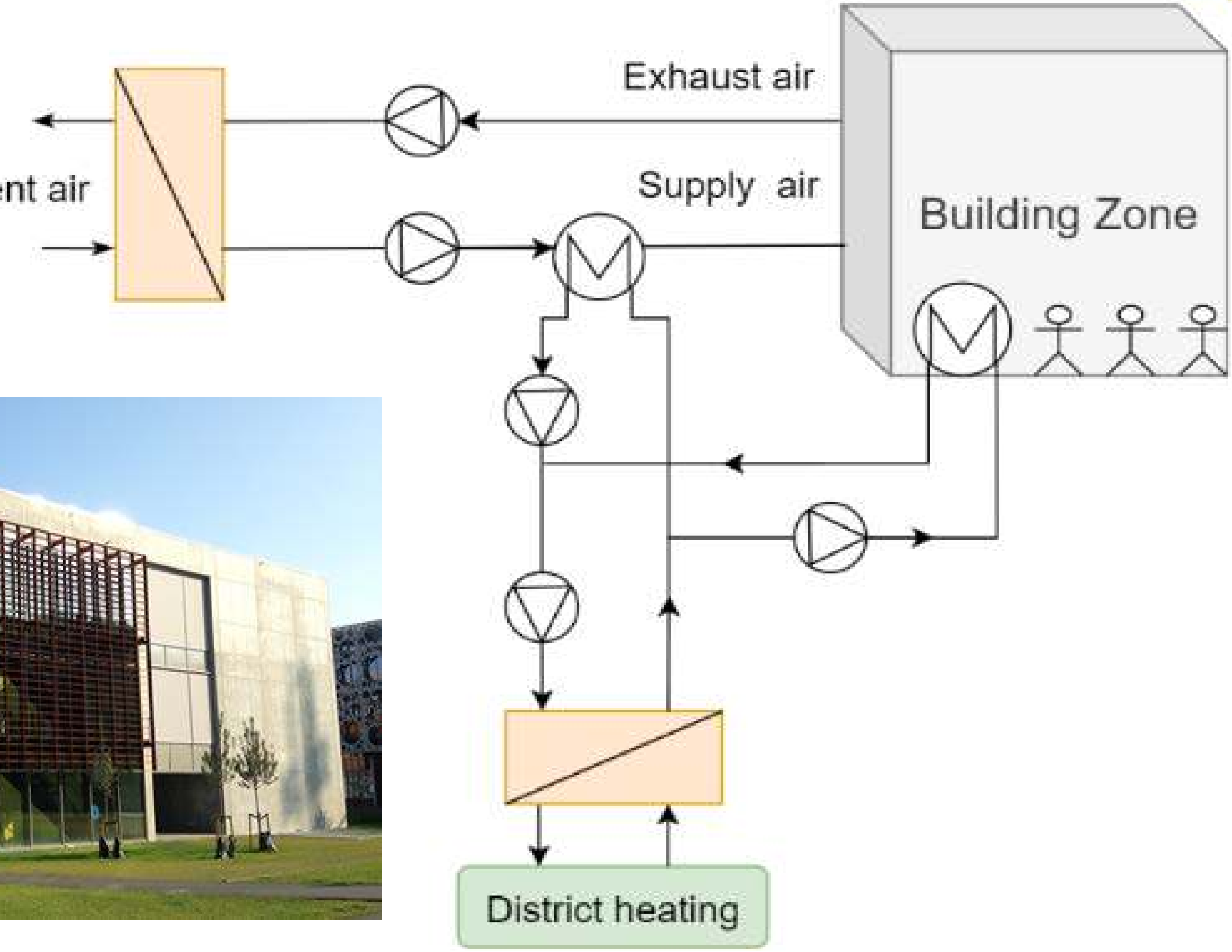
WP 1.2: SDU teaching building OU44

Modelica Buildings Library



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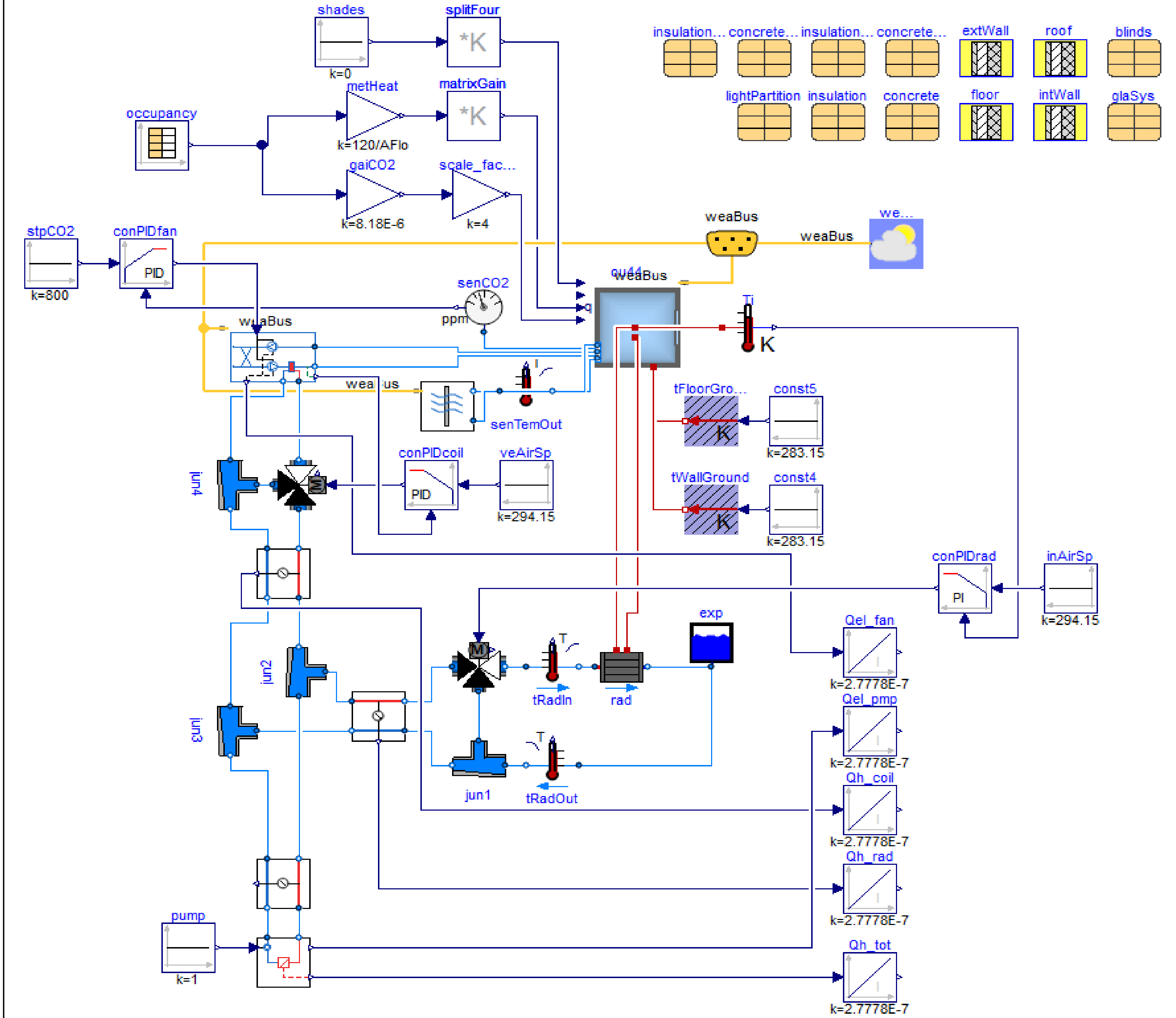
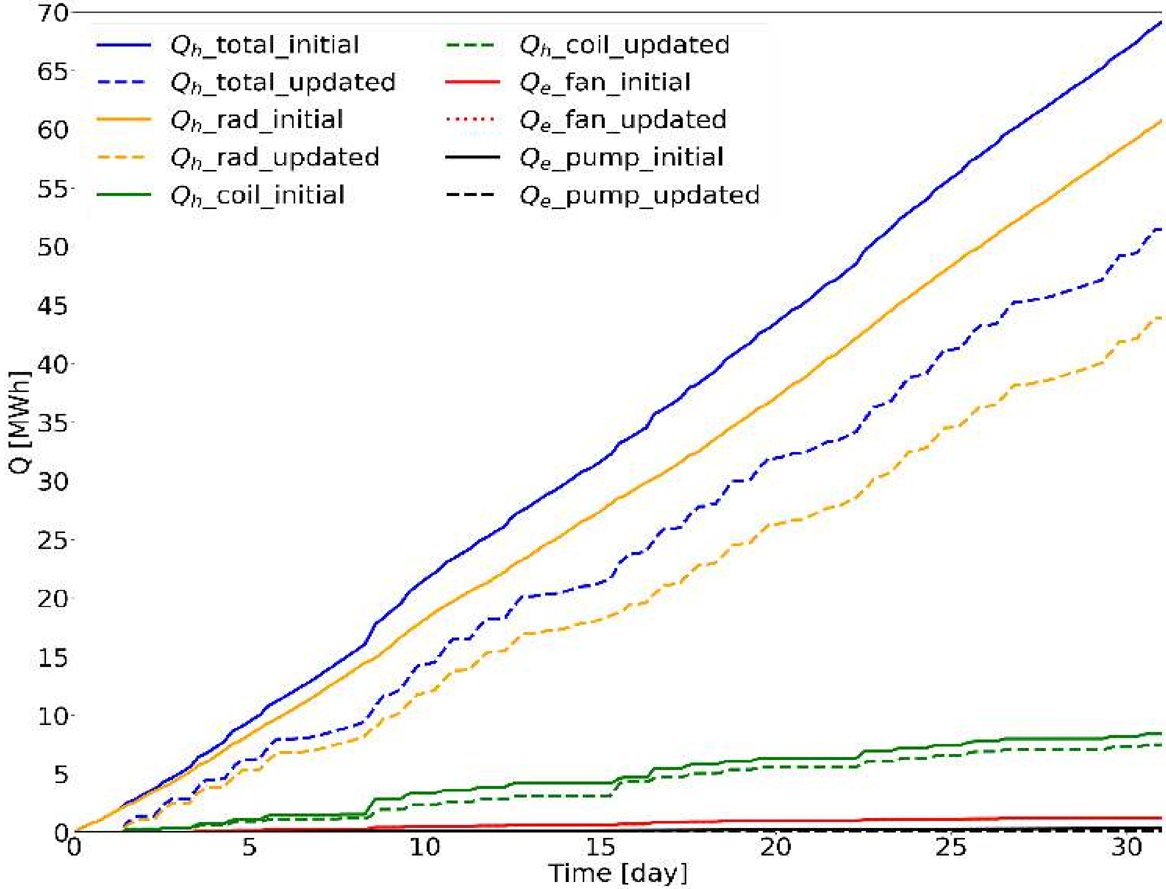
kfi@mmmi.sdu.dk


shades
k=0
splitFour
*K
insulation...
concrete...
insulation...
concrete...
extWall
roof
blinds
lightPartition
insulation
concrete
floor
intWall
glaSys
metHeat
k=120/AFlo
matrixGain
*K
occupancy
gaiCO2
k=8.18E-6
scale_fac...
k=4
weaBus
weaBus
we...
stpCO2
k=800
conPIDfan
PID
senCO2
ppm
weaBus
weaBus
Ti
K
senTemOut
tFloorGro...
const5
k=283.15
tWallGround
const4
k=283.15
jun4
conPIDcoil
PID
veAirSp
k=294.15
conPIDrad
PI
inAirSp
k=294.15
exp
Qel_fan
k=2.7778E-7
jun2
jun3
tRadIn
rad
Qel_pmp
k=2.7778E-7
jun1
tRadOut
Qh_coil
k=2.7778E-7
Qh_rad
k=2.7778E-7
pump
k=1
Qh_tot
k=2.7778E-7

WP 1.2: SDU teaching building OU44

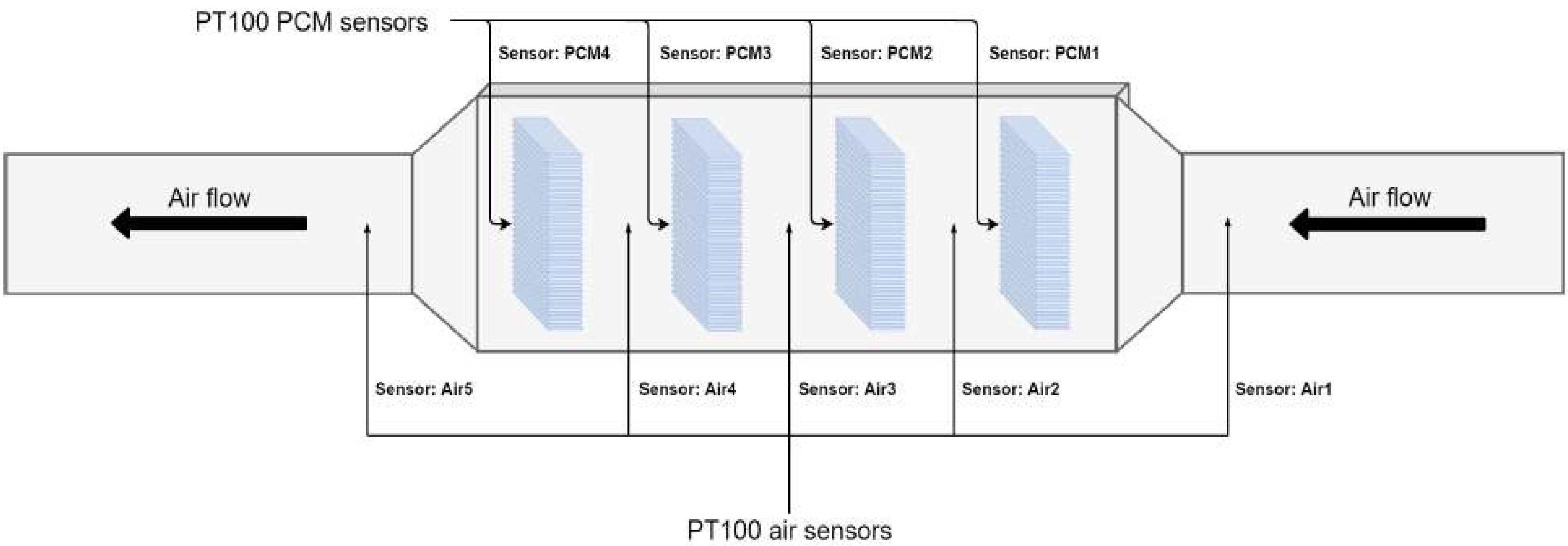
1. Conventional control tuning to reduce consumption
2. Model calibration to comply with IBPSA p1 BOBTEST standards
3. Overwright blocks => coupling to industrial MPC framwork



Konstantin Filonenko
kfi@mmmi.sdu.dk

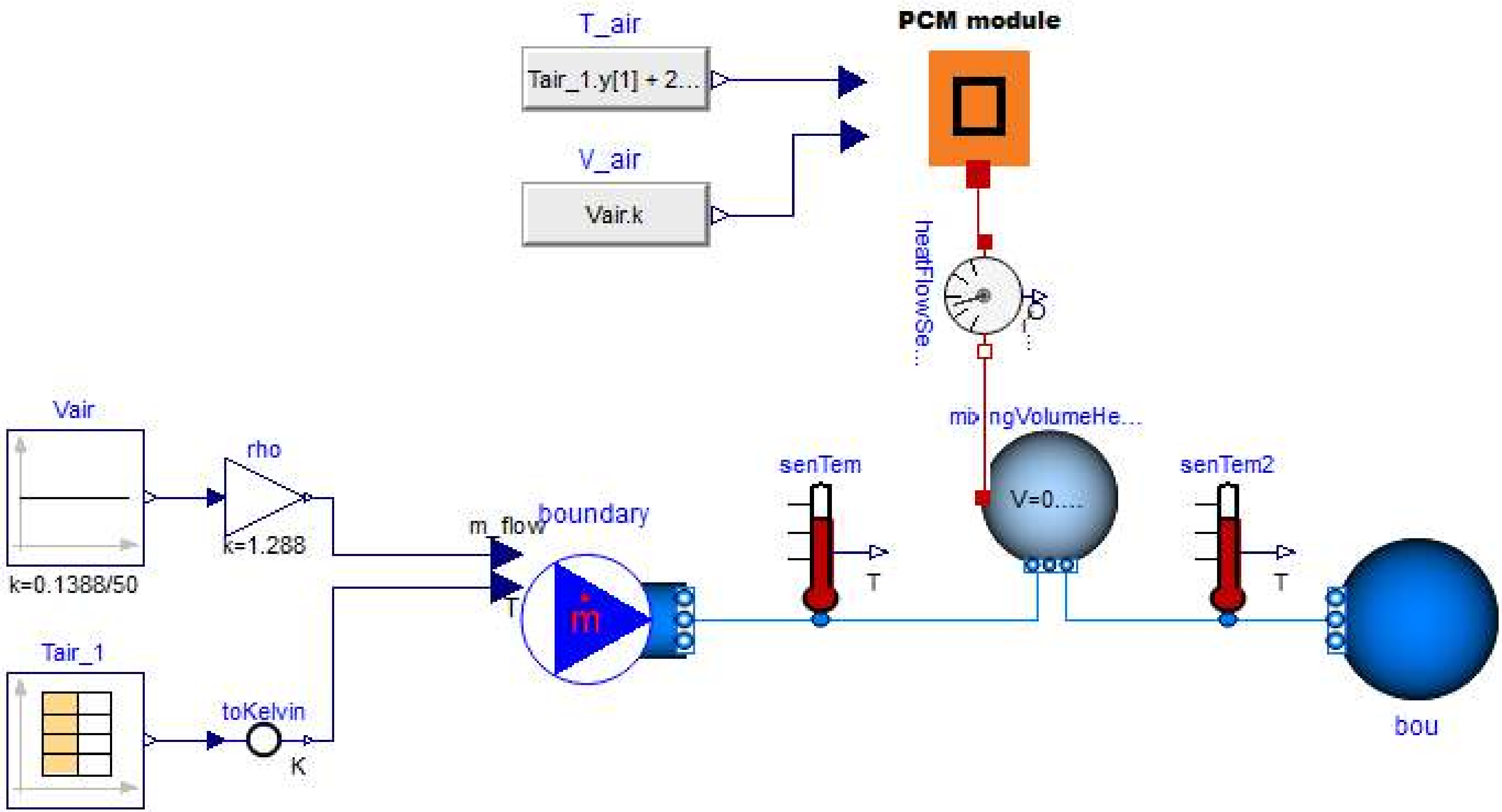
WP 1.2: PCM-based ventilation cooling

Convective heat exchanger consisting of parallel plate stacks



WP 1.2: PCM-based ventilation cooling

PCM heat exchanger (Buildings Library)



Konstantin Filonenko
kfi@mmmi.sdu.dk

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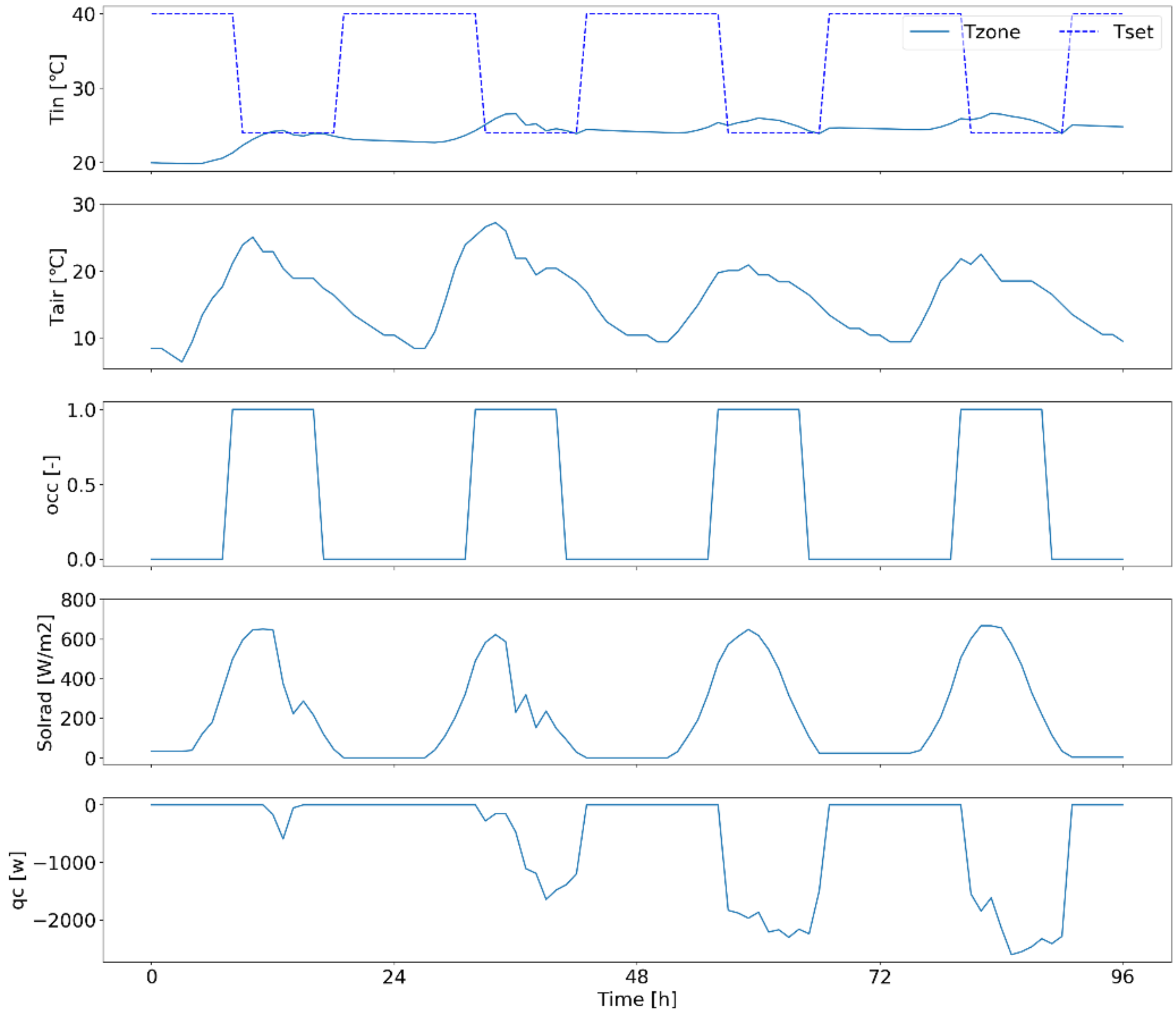
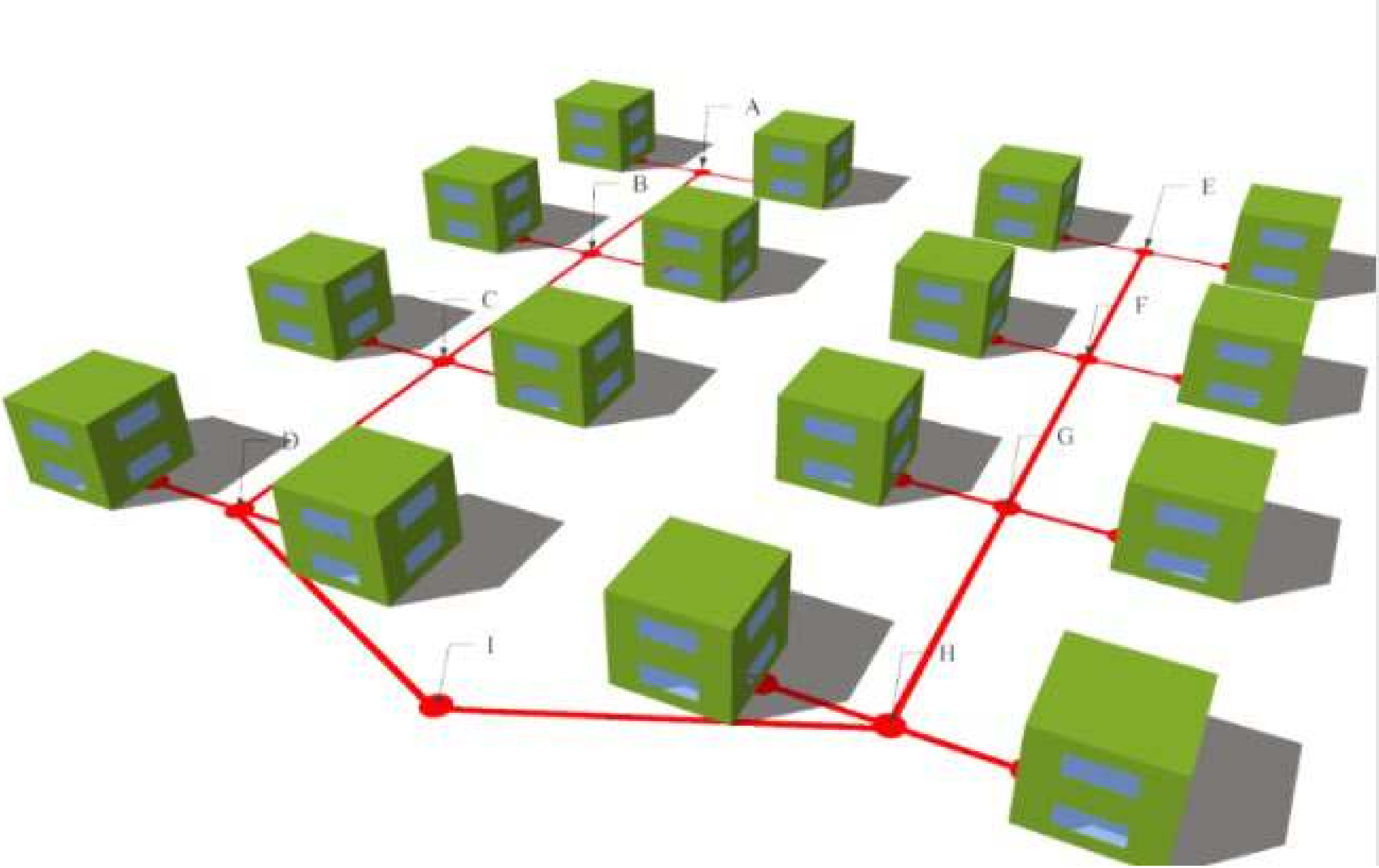
WP 1.2: PCM-based ventilation cooling

Office air cooling



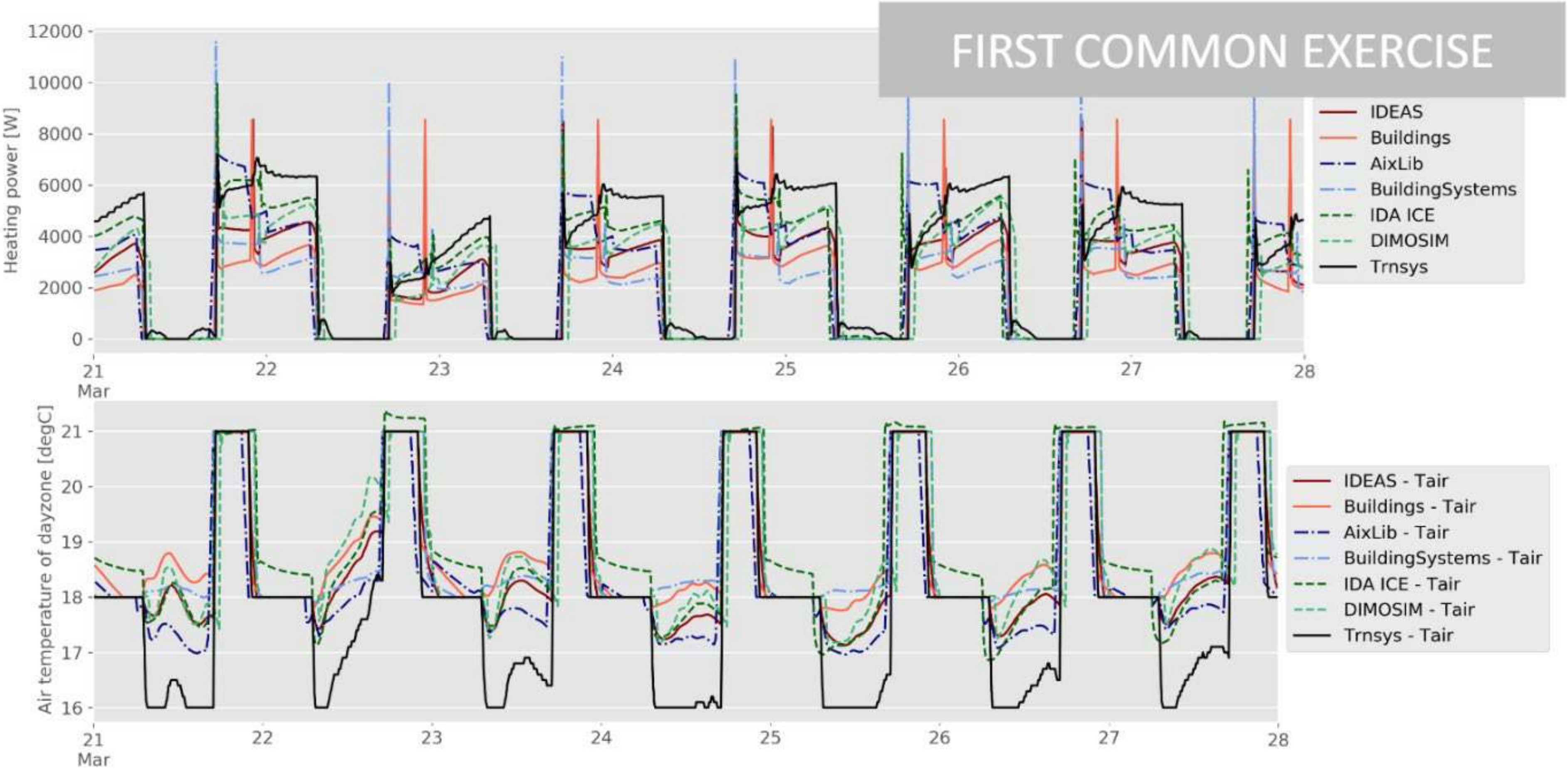
Konstantin Filonenko
kfi@mmmi.sdu.dk

WP 3.1: DESTEST



WP 3.1: DESTEST

Benchmarking district energy simulation tools



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kfi@mmmi.sdu.dk

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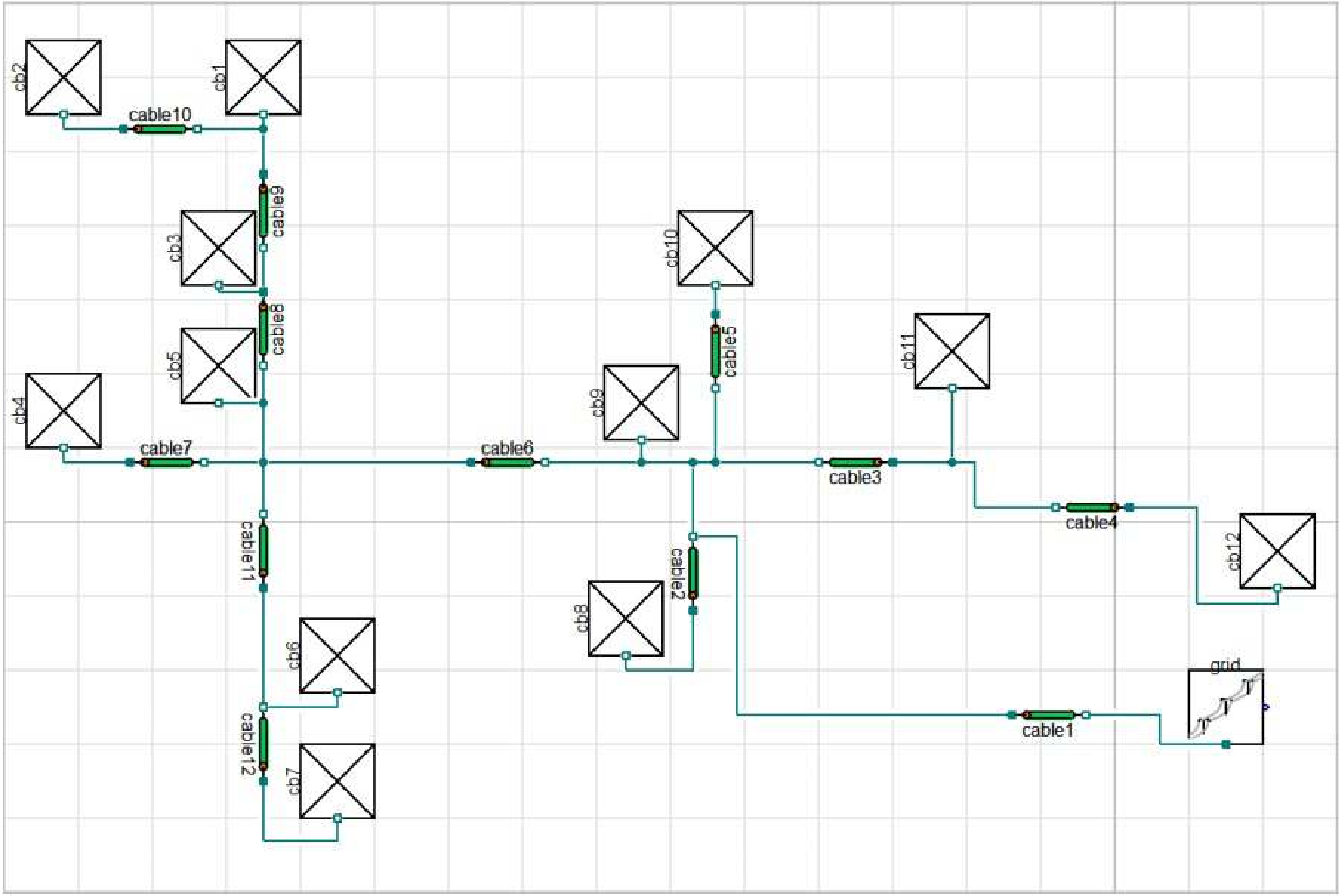
WP3.2: Industrial case studies

#1: Heat Pumps in 2030 grid (**EWII**)



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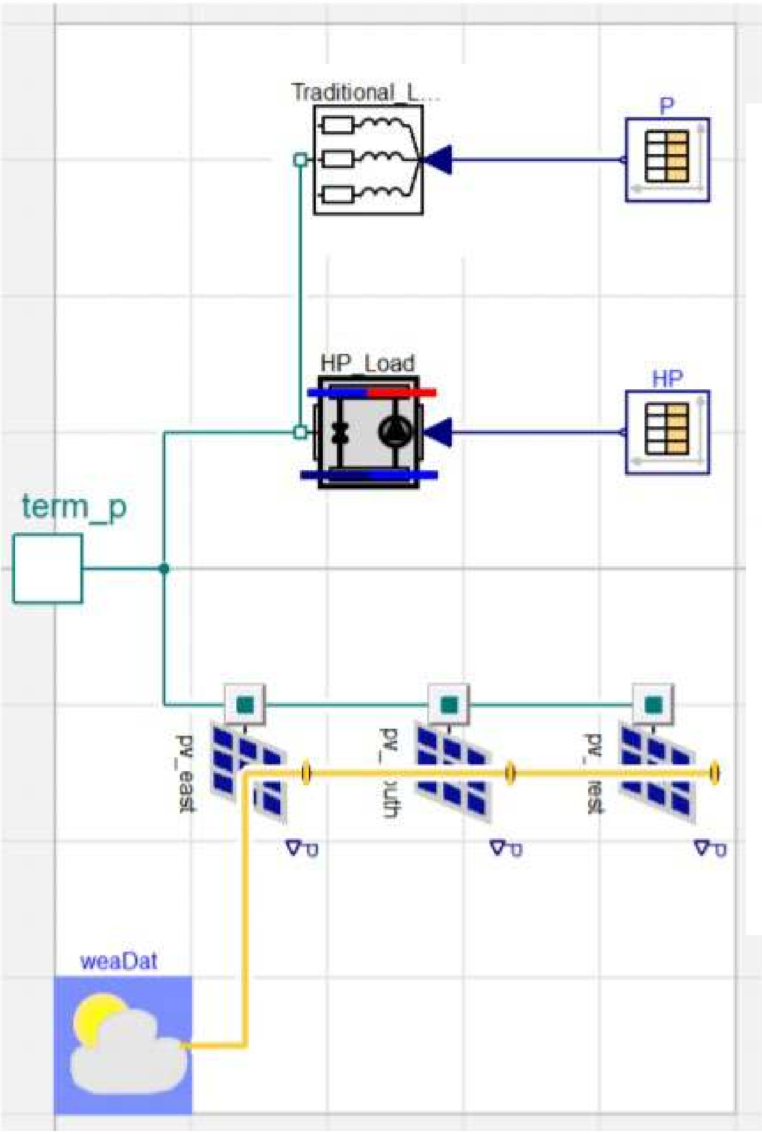
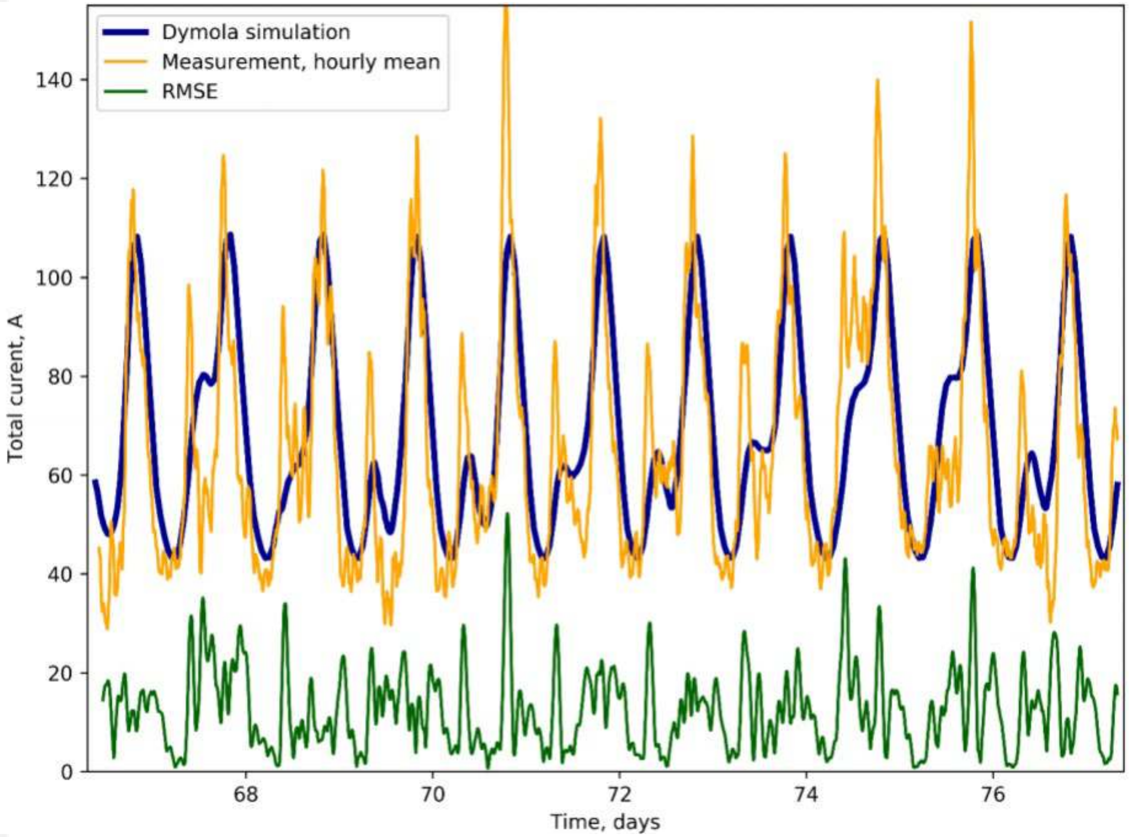
kfi@mmmi.sdu.dk

#1: Heat Pumps in 2030 grid (**EWII**)



- Simulated is close to measured (2019)

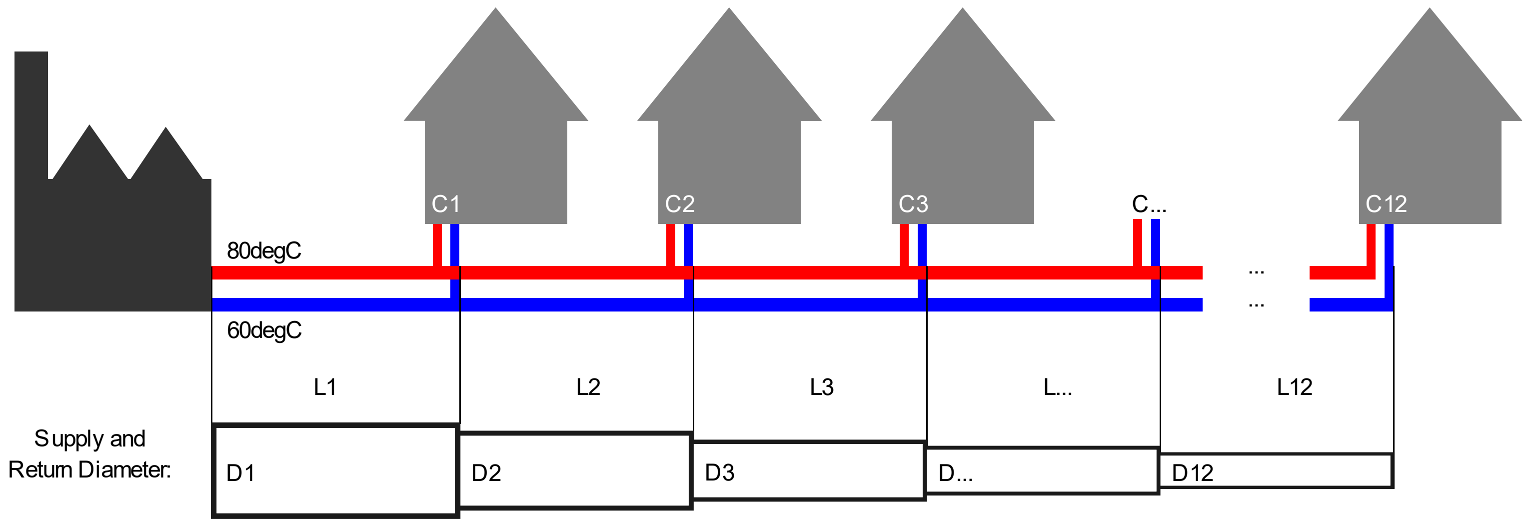


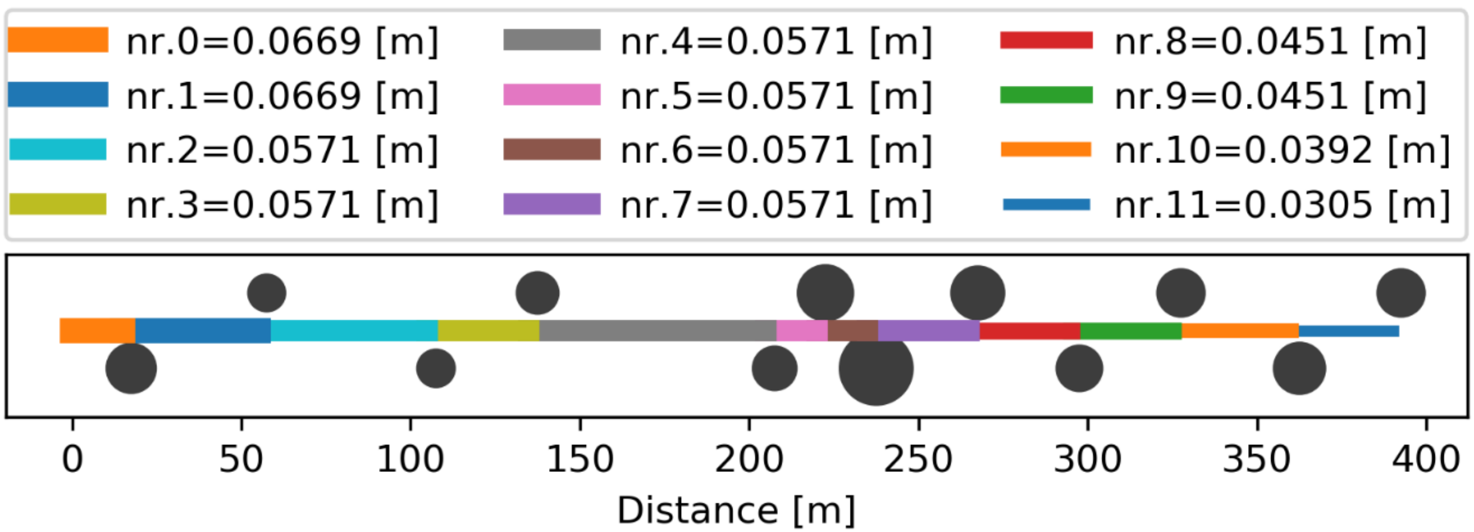
- Prediction of grid dynamics for 2030 and 2040 (from DEA projections)

#1: Heat Pumps in 2030 grid (**EWII**)

Scenario (HP/EV/PV)	Line capacity exceeded	i_max/i_capacity
23%/7.45%/0%	No	37%
100%/7.45%/0%	No	53%
23%/7.45%/50%	Short-term	44%
23%/24.7%/0%	No	42.8%
23%/65%/0%	Short-term	52.6%
100%/65%/0%	Long-term	67.8%

#2: Flexibility-based design/operation (**TREFOR**)

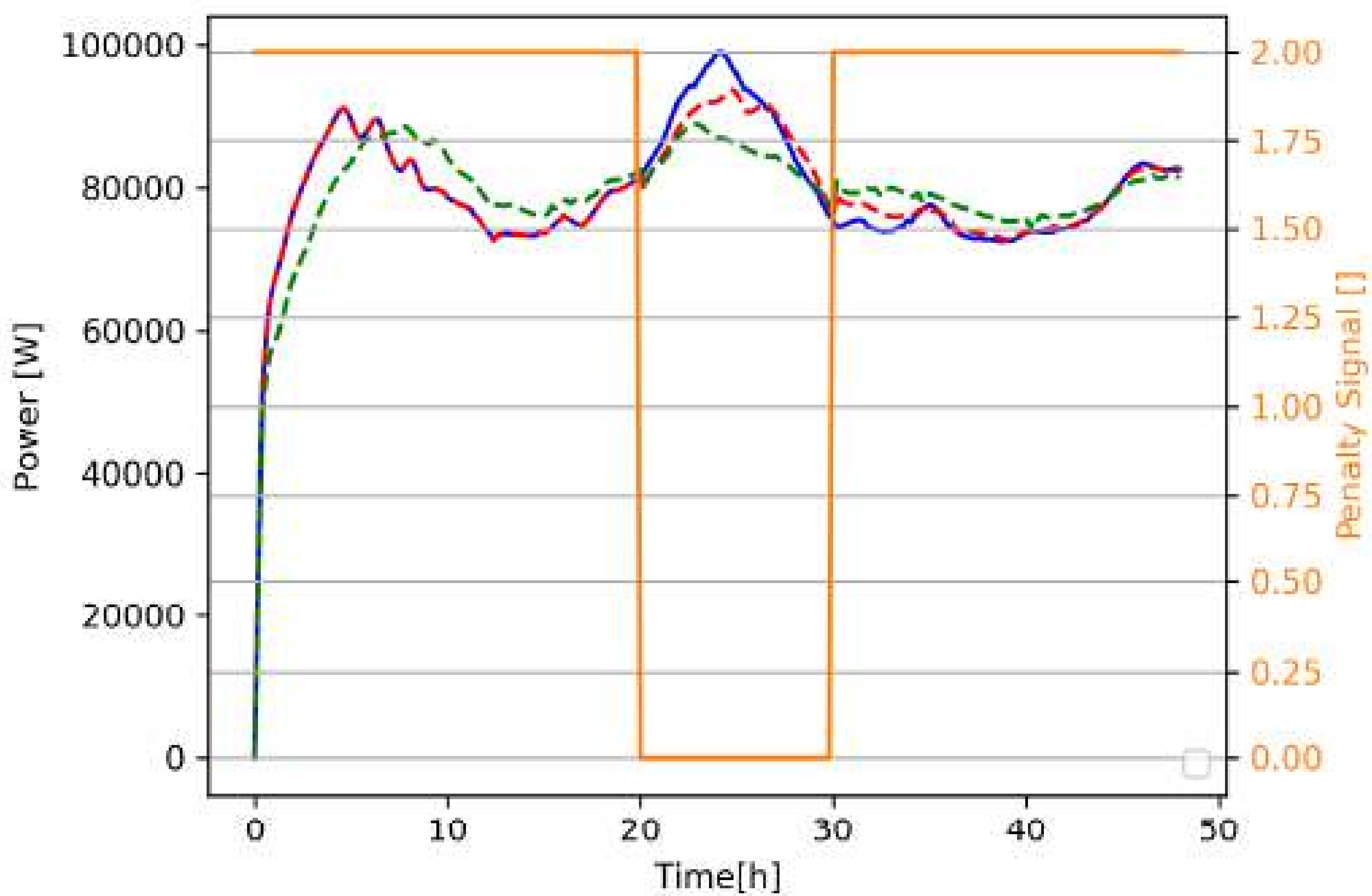




Konstantin Filonenko
kfi@mmmi.sdu.dk

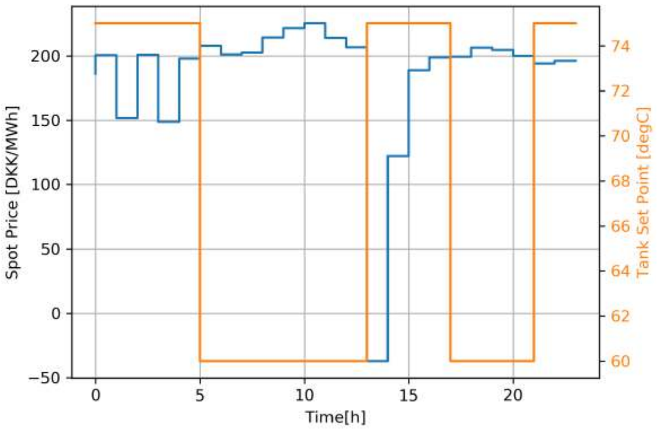
#2: Flexibility-based design/operation (**TREFOR**)

Peak shaving with the tank set point penalized (12 consumers)



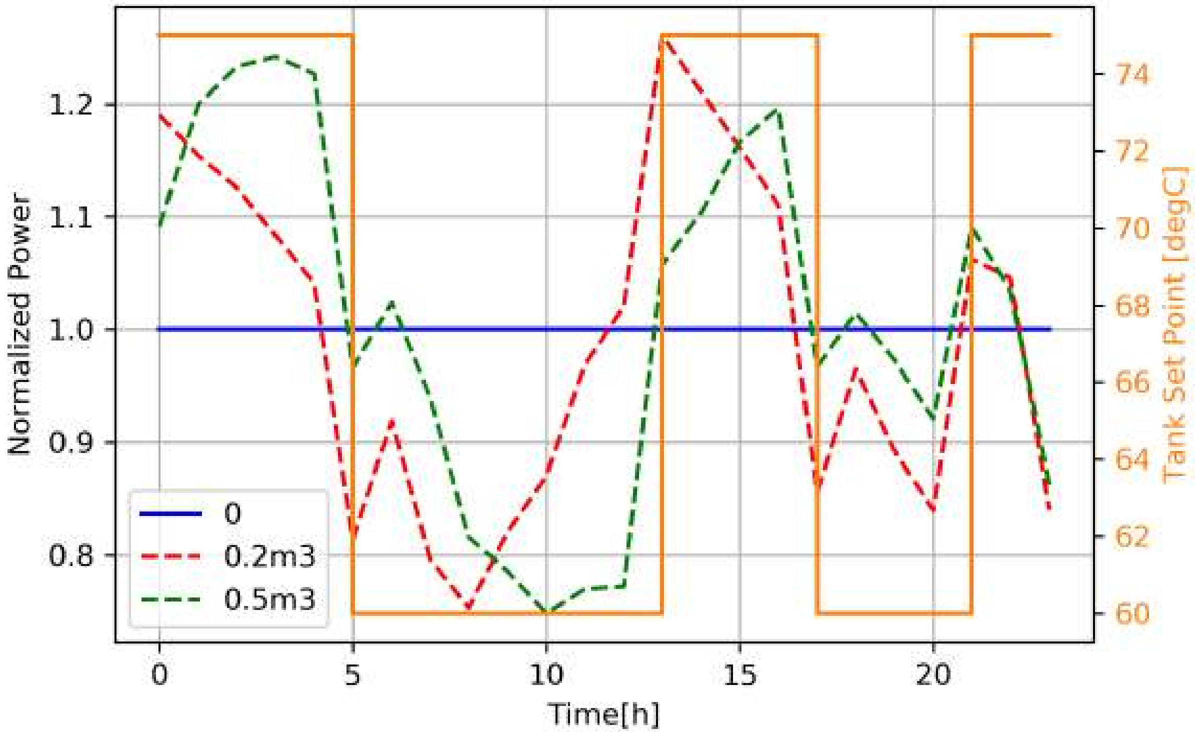
Konstantin Filonenko
kfi@mmmi.sdu.dk

#2: Flexibility-based design/operation (**TREFOR**)

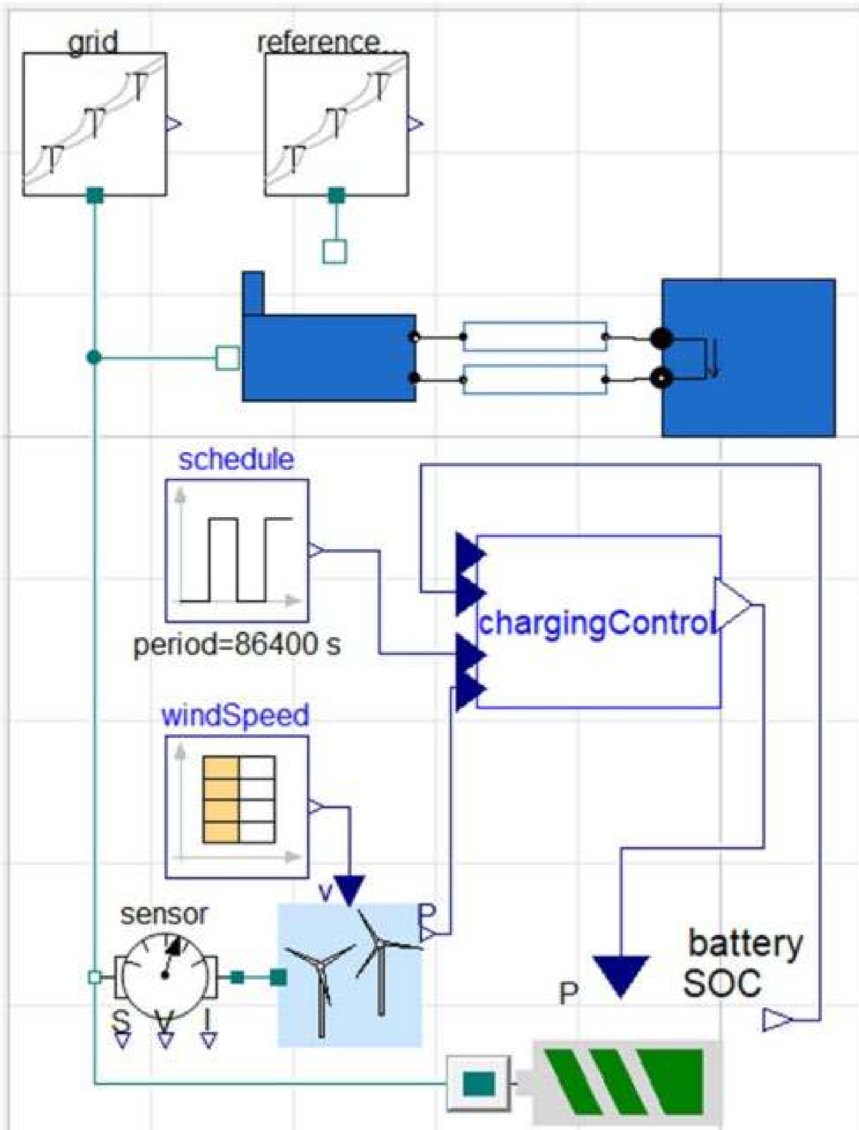


🡐 Price-based penalty

Plant power =>



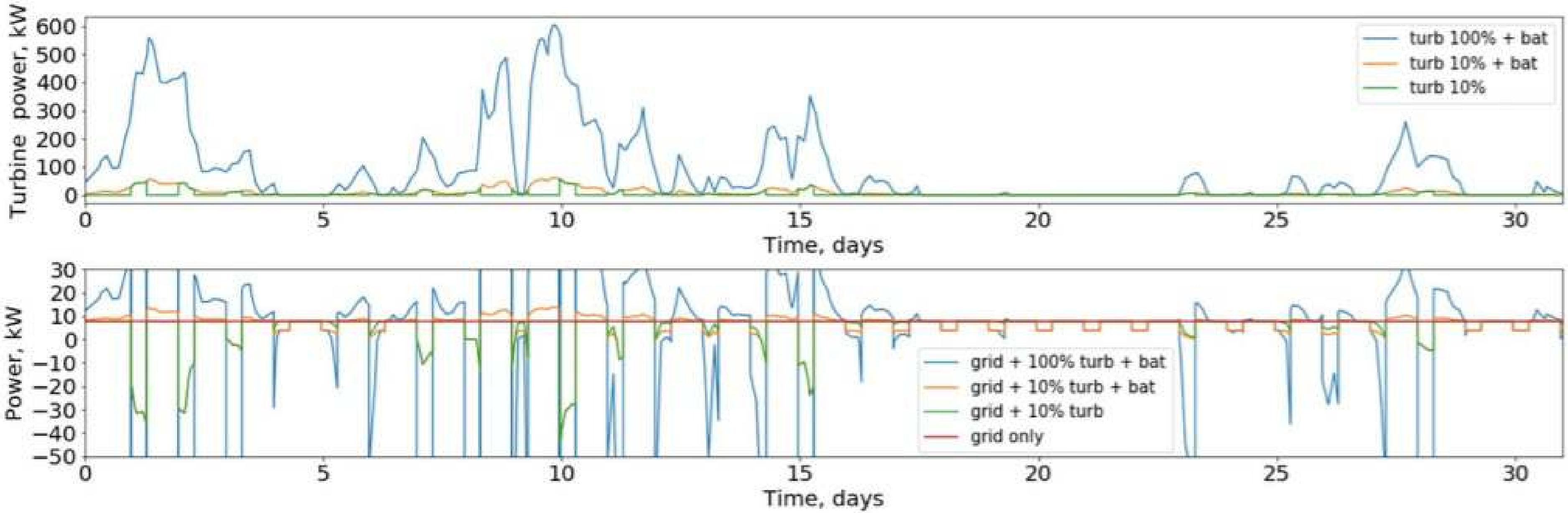
#3: Wind power-driven DH



- Wind-driven **pumps** at off-peak
- Small city DH – night
- Scenarios
  - - windpower, - storage
  - + windpower, - storage
  - + windpower, + storage
  - Full capacity vs 10%
- Tools: Buildings Library, SDU code

#3: Wind power-driven DH

- January simulation



- No storage: full coverage during 8 nights
- With storage: all nights are partially covered

Conclusions

- The developed Modelica-based tools are useful for District and Building Energy industrial research
- Functional Mock-Up Interface (FMI) is a powerful tool for companies to use Modelica with their internal routines
- Denmark contributes to the overall development progress of the energy modeling field through optimization algorithms and case studies

Contact info at Center for Energy Informatics

Konstantin Filonenko,
Adjunkt
kfi@mmmi.sdu.dk
65508975, 29992209
Campusvej 55
5230 Odense M

Christian Veje, professor
Vice sektionsleder
veje@mmmi.sdu.dk
65501607, 20585161
Campusvej 55,
5230 Odense M