A framework for zone model test within IBPSA project 1, WP3.1

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Presentation plan

1. A university teaching building—OU44, heating
2. A phase change material (PCM) based ventilation cooling system
3. Potential contribution to WP 3.1

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A university teaching building—OU44

Fig.1 University teaching building-OU44

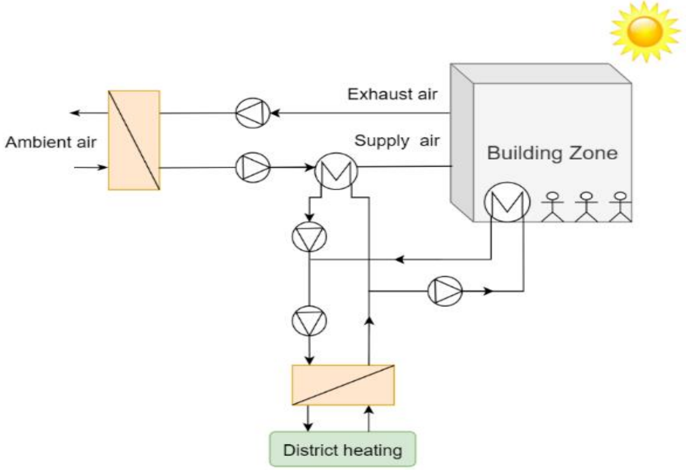


Fig.2 Schematics of the building energy system

Basic information

- Area: 8500m^2, can accommodate maximum 1350 people
- Three above-ground floors: classroom(40%), study zones(25%), common spaces (20%)
- A basement level containing main HVAC facilities and the main heat exchanger connected to district heating.

Ventilation

4 ventilation units, each with a rotary heat exchanger for reclaiming heat from exhaust air

Heating

Radiators and ventilation

Modeled as a single zone using Modelica Buildings Library

A university teaching building—OU44

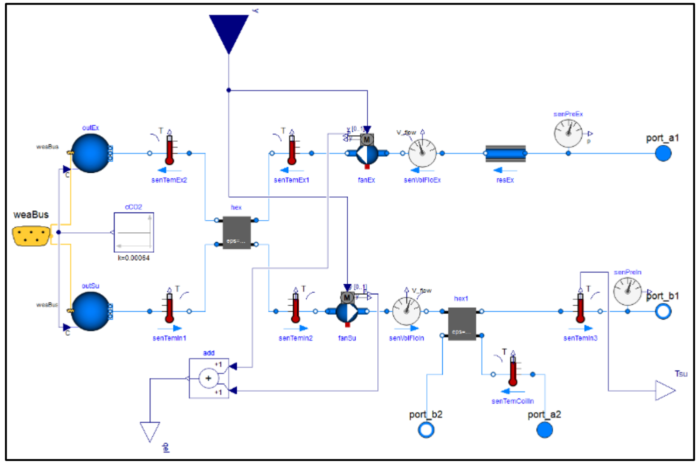


Fig.4 Air handling unit in Dymola

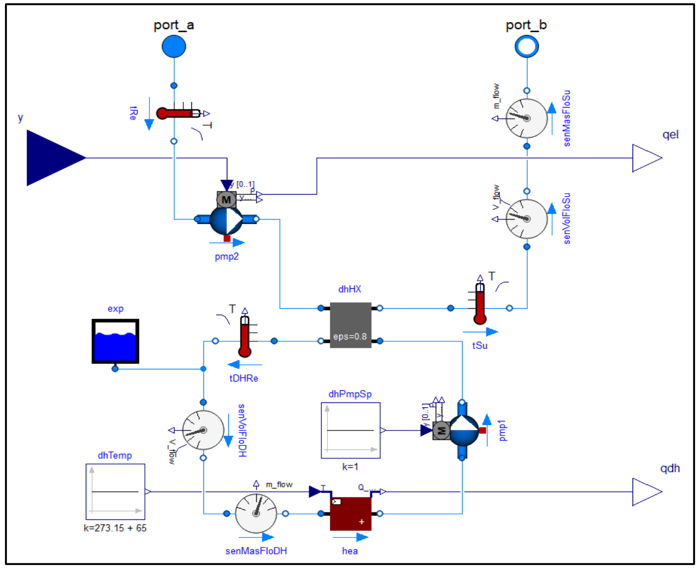
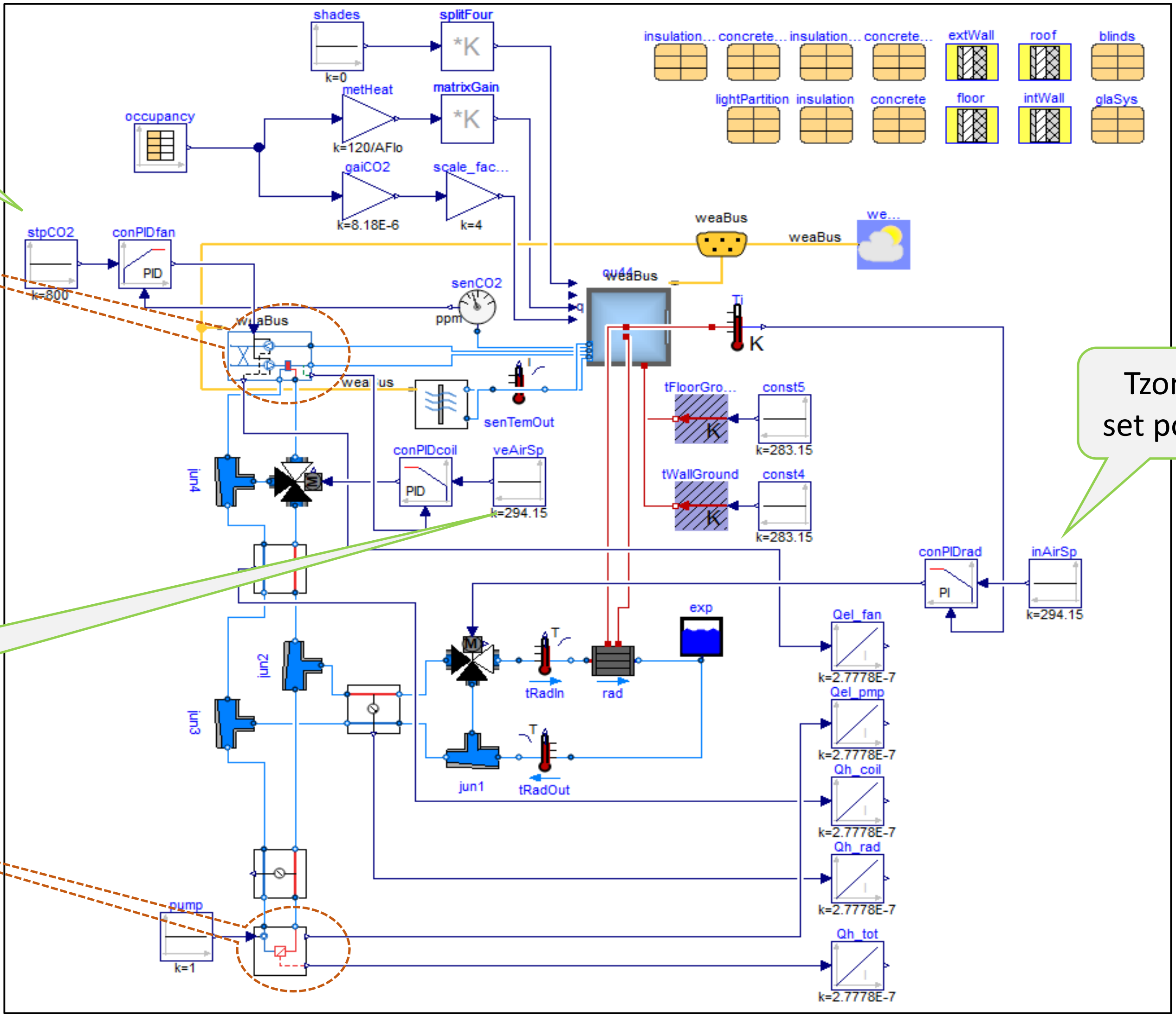


Fig.5 District heating system in Dymola

CO$_2$ set point

Buildings Library

Tsup set point



Tzone set point

Fig.3 Modelica implementation of OU44 teaching building

A university teaching building—OU44

Initial model for calibration: Tzone set point 21°C

Updated model for checking building thermal dynamics:

Tzone set point 21°C during the day, no heating supply during the night and weekends

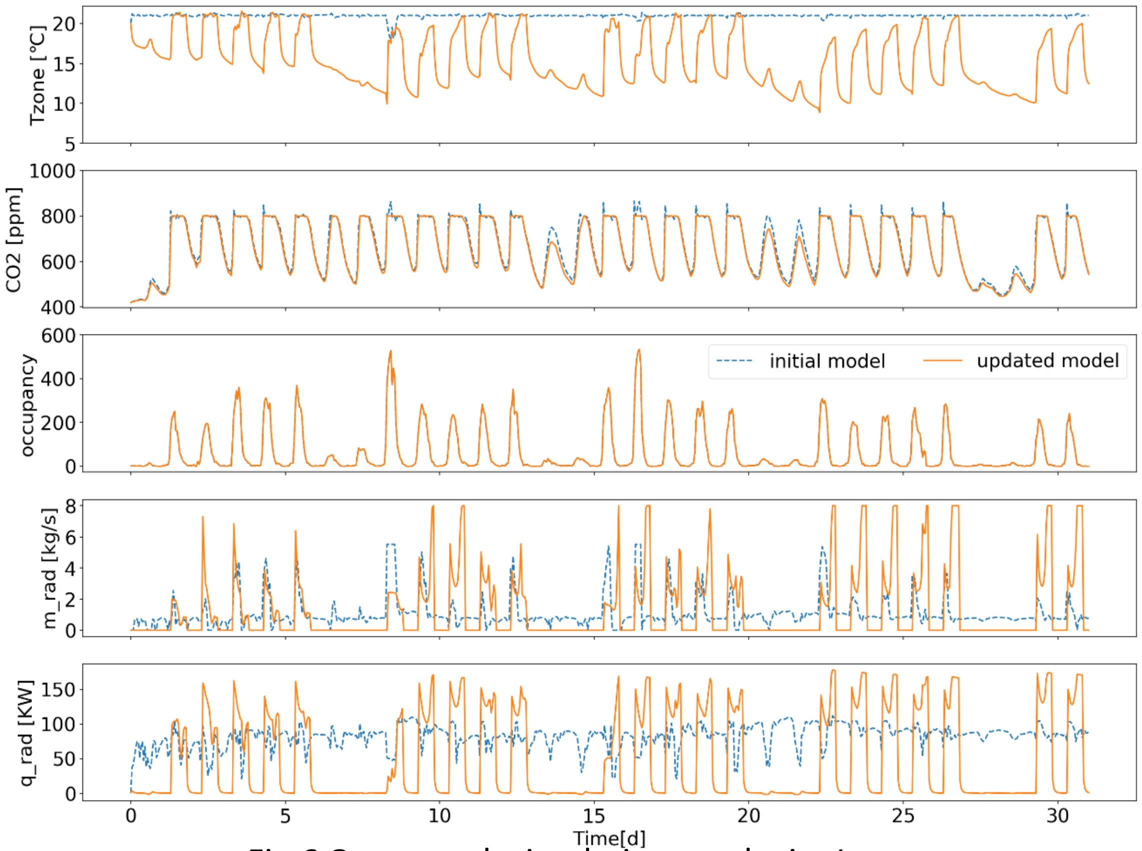


Fig.6 One-month simulation results in January

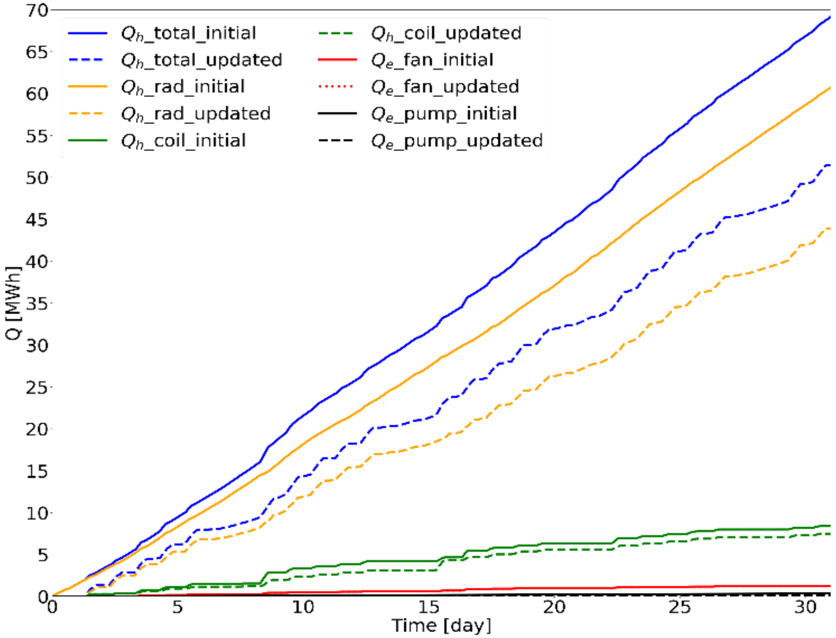


Fig.7 Energy flows in the initial and updated model

Table. 1 Energy consumption of the two setups

Energy consumption	Qh_total [MWh]	Qh_rad [MWh]	Qh_coil [MWh]	Qe_fan [MWh]	Qe_pump [MWh]
Initial model	69.15	60.74	8.41	1.27	0.37
Updated model	51.45	43.95	7.50	1.26	0.11

Source: Tao Yang, Konstantin Filonenko, Krzysztof Arendt, Christian Veje. "Implementation and performance analysis of the multi-energy building emulator". The 6th IEEE International Energy Conference, 2020 (Accepted).

A PCM-based ventilation cooling system

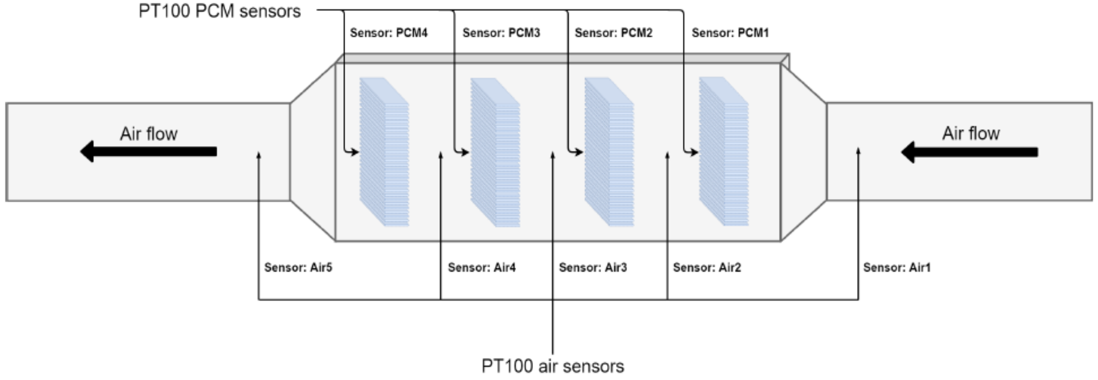


Fig. 8 Diagram of the PCM ventilation unit with sensors

- **Experimental setup**
- 4 stacks, each stack consists of 25 PCM panels with uniform vertical distribution
- Air flow rate 500 m^3/h
- Each PCM panel weights 2kg with properties shown in Table 2

Table. 2 PCM properties

	Density $[\mathrm{kg/m^3}]$	Conductivity $[\mathrm{W/(m \cdot }K)]$	Latent heat of fusion $[\mathrm{kJ/kg}]$	Specific heat capacity $[\mathrm{kJ/(kg \cdot }K)]$
Liquid	1400	0.6	140	2
Solid	1500	0.6	140	2

Modeling PCM control volume using Modelica

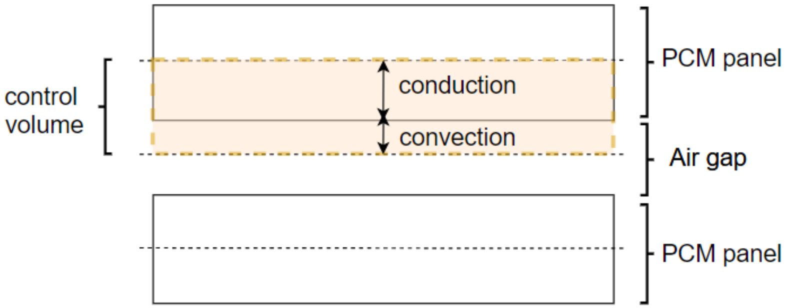


Fig. 9 Schematic diagram of control volume

A PCM-based ventilation cooling system

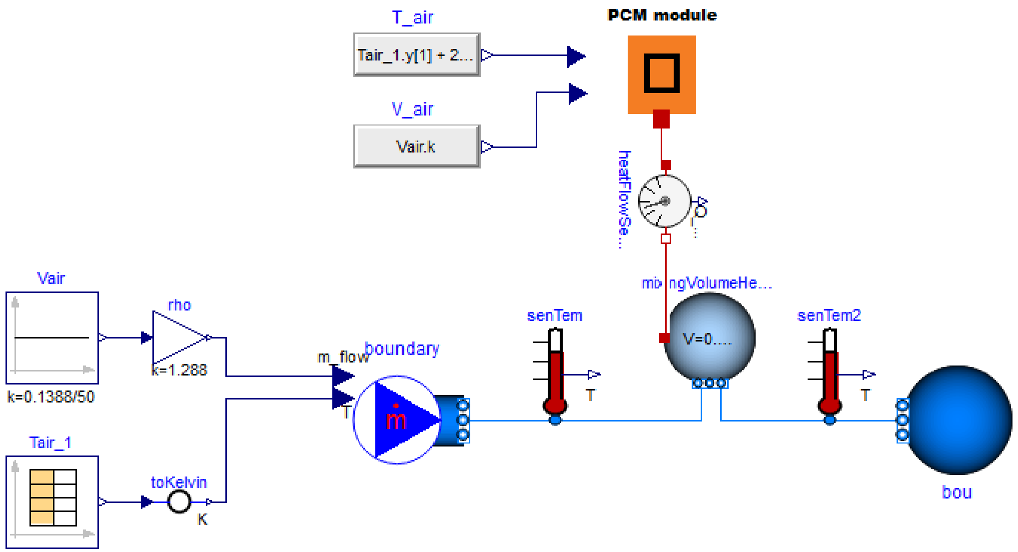


Fig.10 Configuration of PCM ventilation system in Dymola

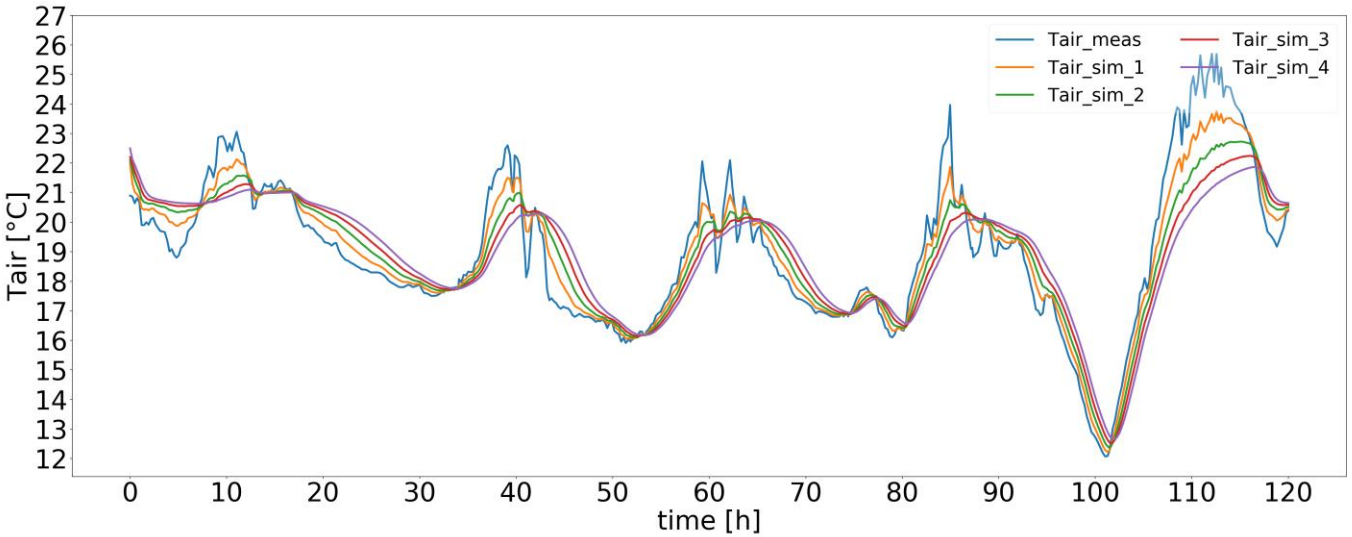


Fig.11 Simulation results of air temperature at each stack

Source: Tao Yang, Viktor Bue Ljungdahl, Muhyiddine Jradi, Konstantin Filonenko, Christian Veje. “Object-oriented modeling and performance evaluation of a PCM-based ventilation system”. The 33rd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, 2020 (Submitted).

A PCM-based ventilation cooling system

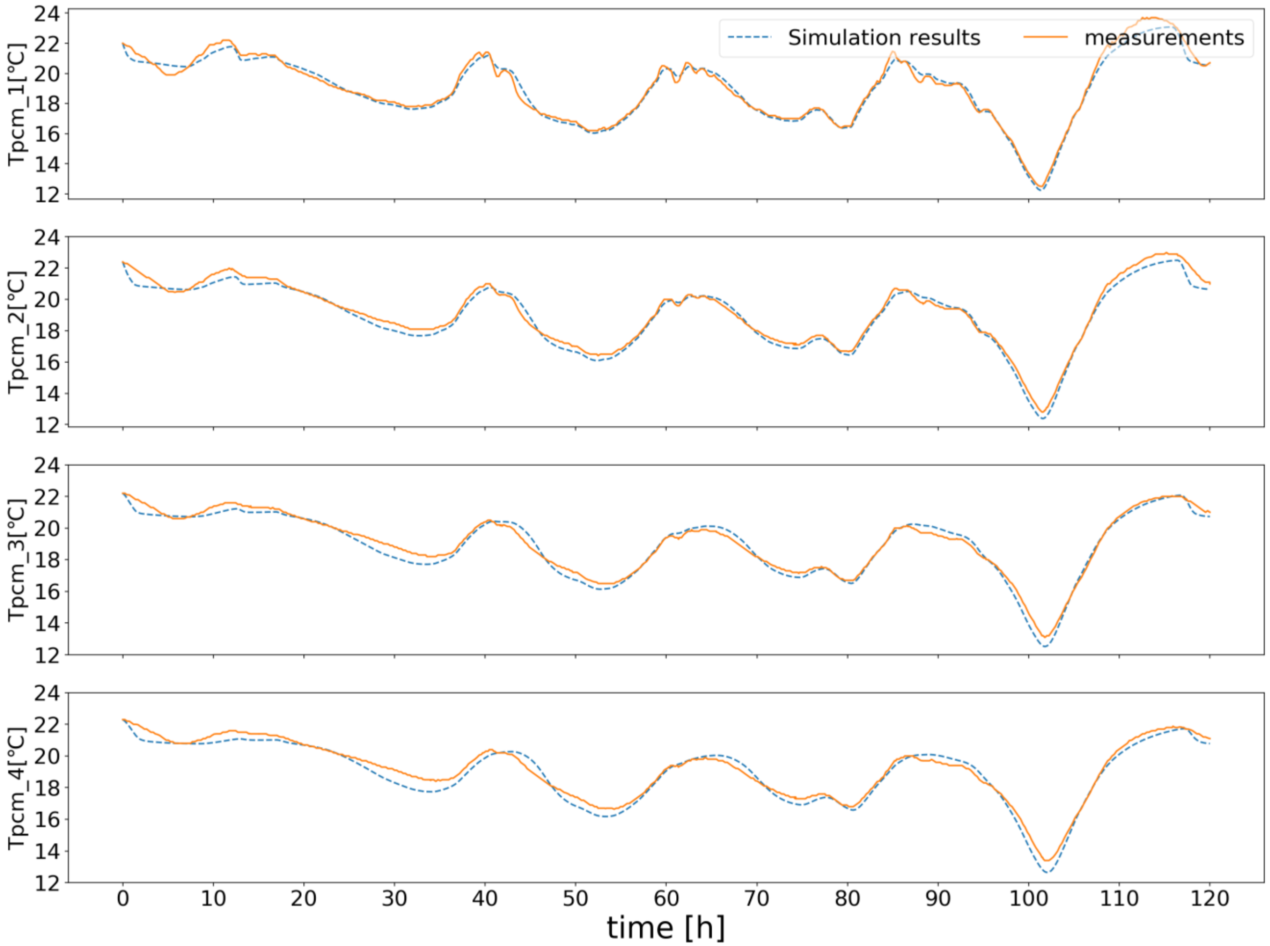


Fig.12 Validation of simulated PCM temperature against measurements at each stack

Table. 3 RMSE[° C] of each stack

	stack 1	stack 2	stack 3	stack 4
PCM	0.277	0.332	0.332	0.410
Air	0.477	0.336	0.414	0.489

Source: Tao Yang, Viktor Bue Ljungdahl, Muhyiddine Jradi, Konstantin Filonenko, Christian Veje. “Object-oriented modeling and performance evaluation of a PCM-based ventilation system”. The 33rd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, 2020 (Submitted).

A PCM-based ventilation cooling system

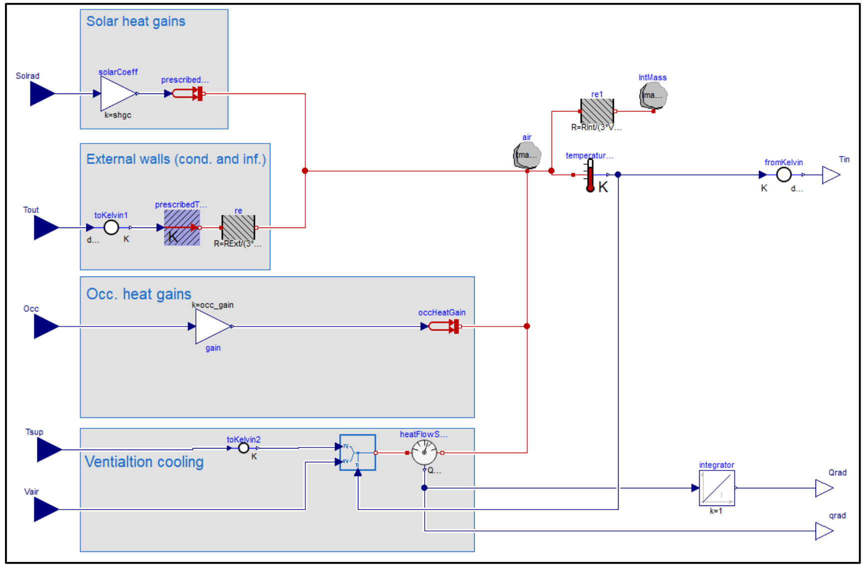


Fig.13 R2C2 zone model

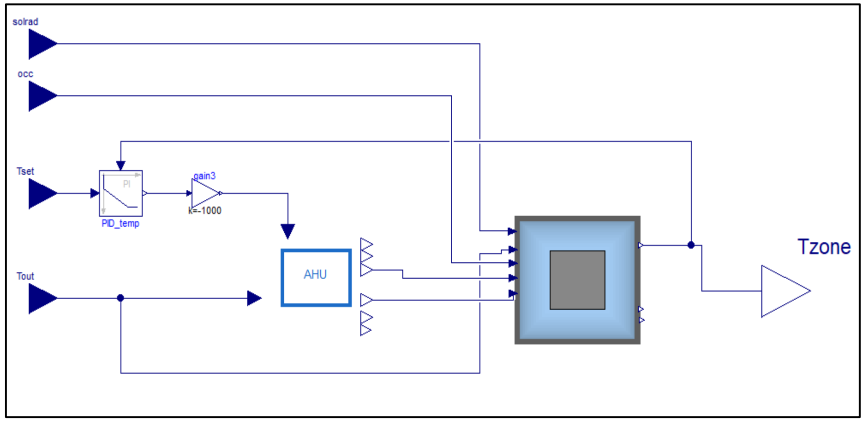


Fig. 14 PCM ventilation system integration with zone model

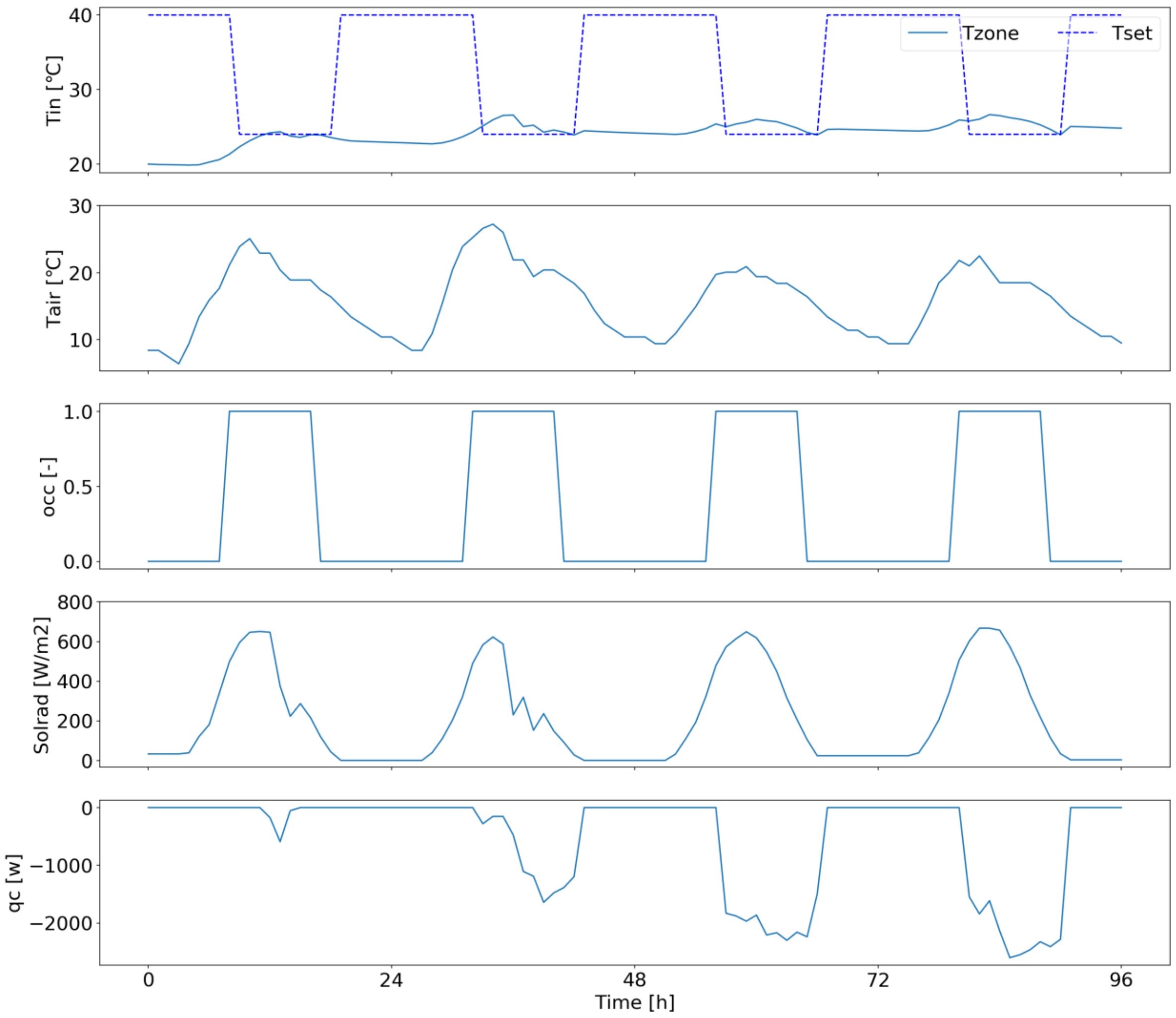
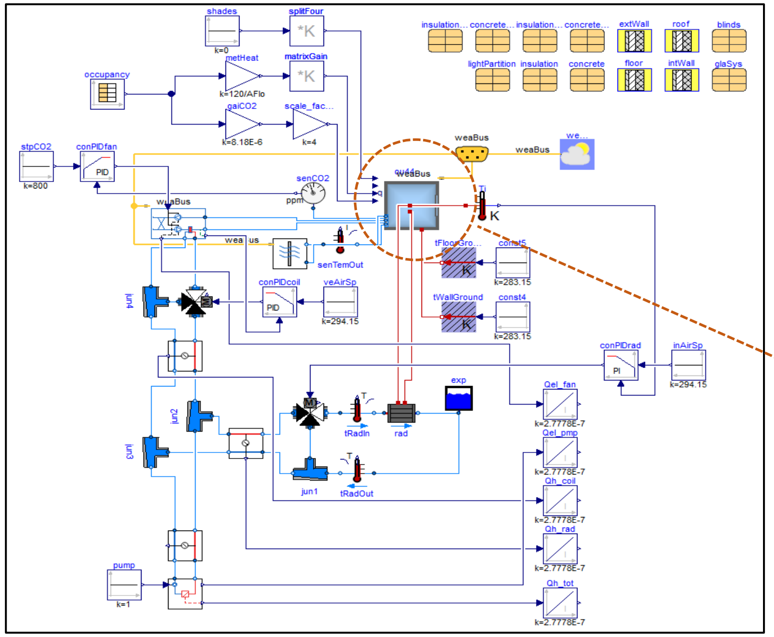


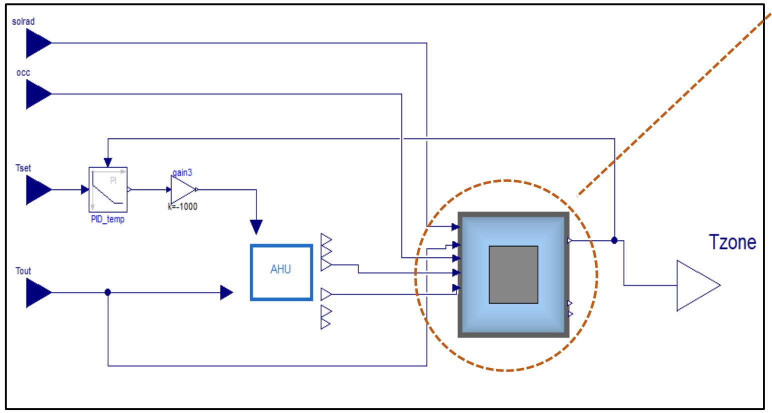
Fig. 15 Simulation results of Tzone under rule-based control

Potential contribution to WP3.1

Heating



Cooling

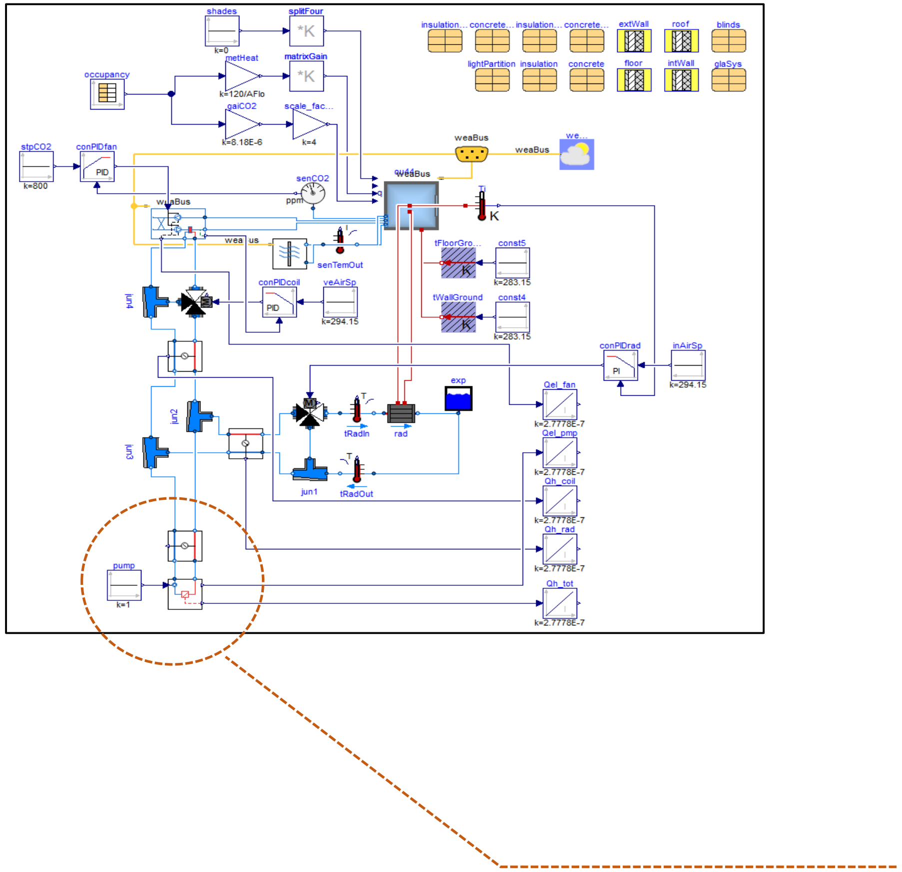


Proposal for common exercise (buildings):

- Replace zone model + radiator by the DESTEST building model
- Tune HVAC settings to fit each of the DESTEST demand curves
- Report heat production, electricity consumption in HVAC components, zone temperature vs previous DESTEST results
- Compare the tuned HVAC settings across models
- Report numerical and computational performance in each case

Potential contribution to WP3.1

Heating



Proposal for common exercise (network):

- Replace the district heating model with fluid ports + pump and the zone model with DESTEST consumer
- Use copies of the model in the DESTEST network
- Tune HVAC settings to make it work with the **network model**
- Compare results to previous DESTEST results for the network

Formulation of the common exercise

Heating model:

Step 1. Share the model: We send the model with full documentation and specification of the HVAC system

Step 2. Choose the scaling parameters: Model is connected to the HVAC system, temperature profile in the building is compared for several values of the scaling parameter, e.g. k=0.25, 0.5, 1 and 2, and district heating supply magnitude and temperature (60, 70, 80, 90 degC), to determine which overall HVAC size is suitable to cover the demand of the building.

Step 3. Fit the hydraulic parameters: pumps, valves of the HVAC system are tuned to match the reference electricity consumption of the HVAC system over an agreed period of time and demand is updated.

Step 4. The control parameters are tuned to get better match between curves and previous DESTEST results

Step 5. Comparison: chose best-fit results for HVAC parameters, room temperature, heat demand, heat production, electricity use for each implementation

Cooling model: The same steps, but the model will be sent in the form of FMU

Motivation of the common exercise and outcome

- Reliable interface for DESTEST buildings/network coupling (calibrated from measurements, reviewed by WP1.2 and tested with conventional control and MPC)
- DESTEST standards for HVAC models (model accuracy, validation, degree of detail)
- Tuned models can be easily customized by trying different controllers and serve as an input to WP1.2

Thanks for your attention!