



Energy in Buildings and
Communities Programme

Modelica Buildings library 2.0

Michael Wetter

October 17, 2016



Lawrence Berkeley National Laboratory

Overview

Overview

Major new additions

- Fast Fluid Flow Dynamics
- Electrical systems
- Load prediction
- FMI export containers

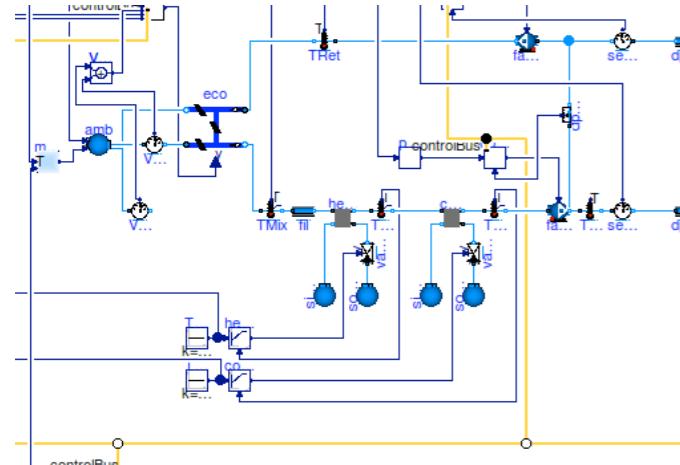
Various updates and next steps

The vision is to create a flexible computing infrastructure for

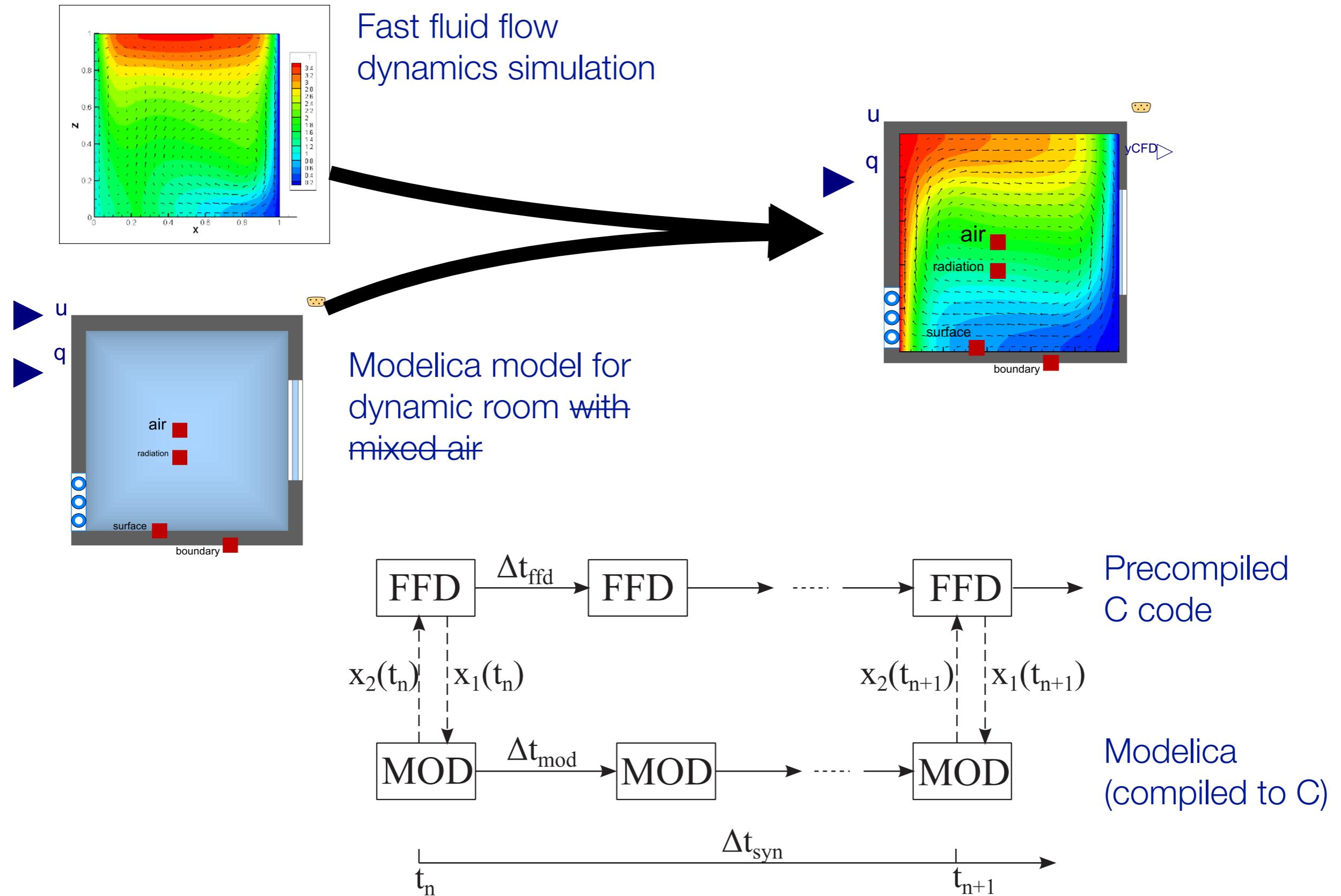
- a) the basis of the “Spawn of EnergyPlus”, and
- b) design, research, product development and operation of building and community energy systems.

500+ validated, free, open-source component models

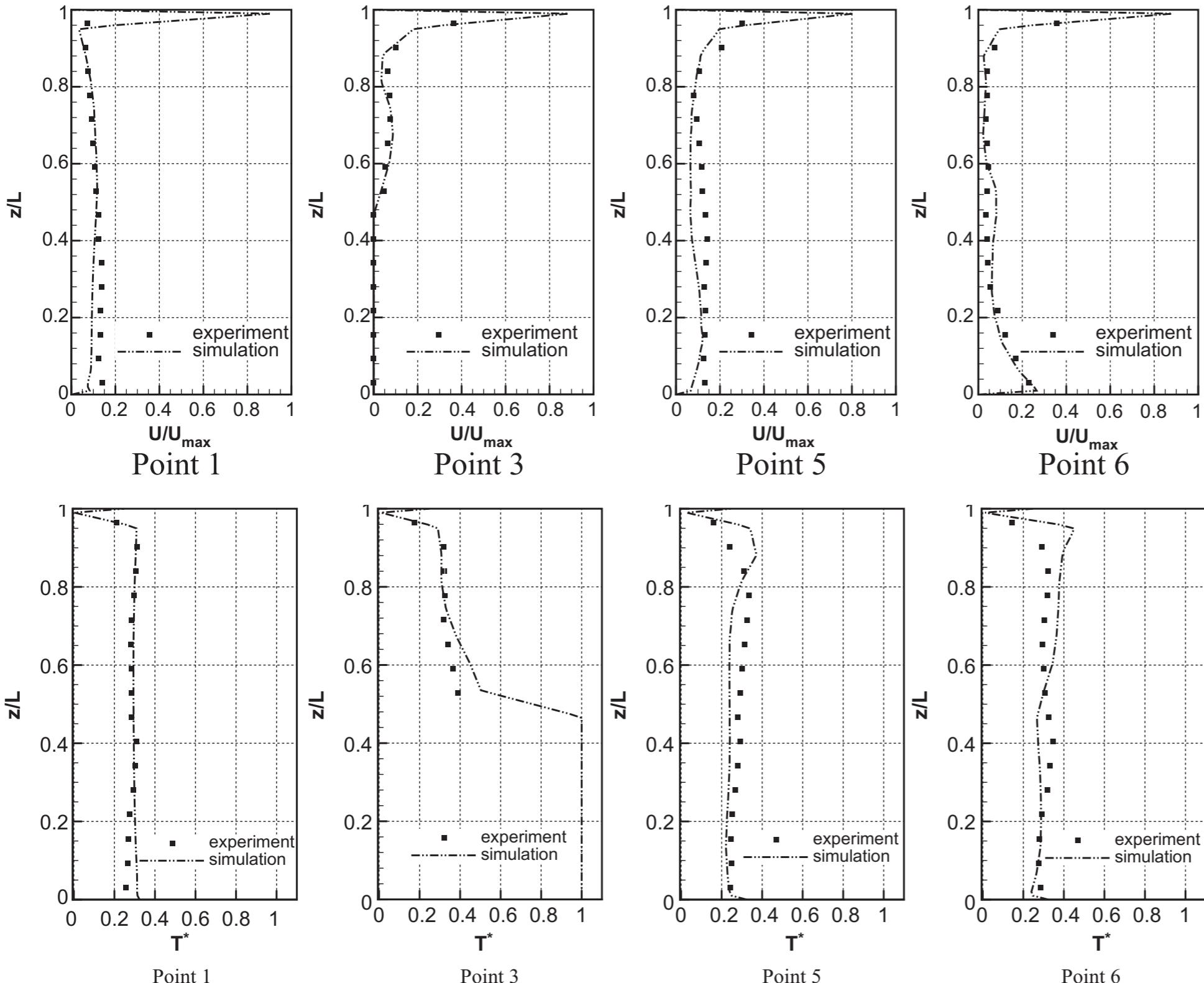
Air-based HVAC



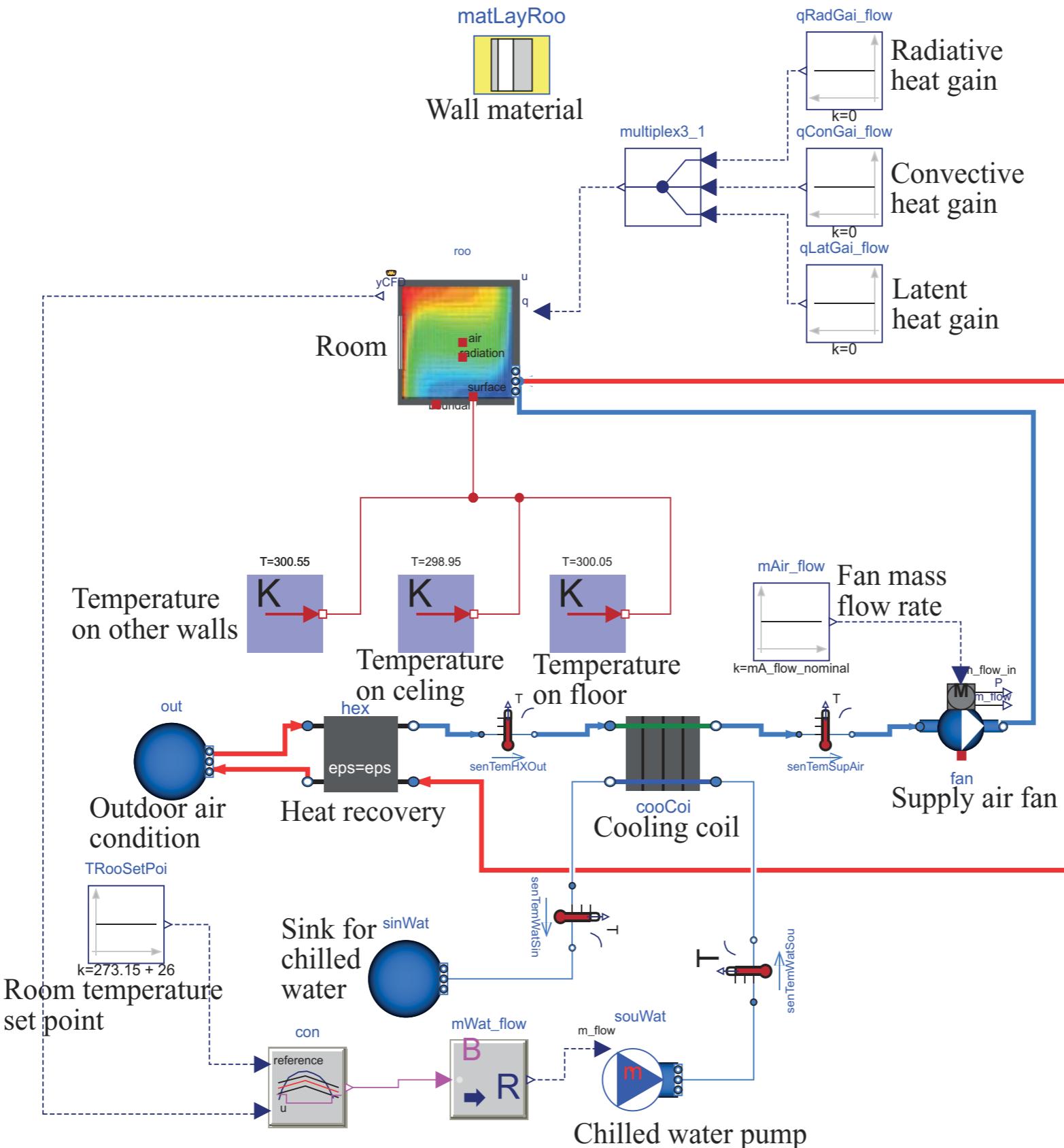
Room model with Fast Fluid Flow Dynamics



Validation of FFD with experimental data



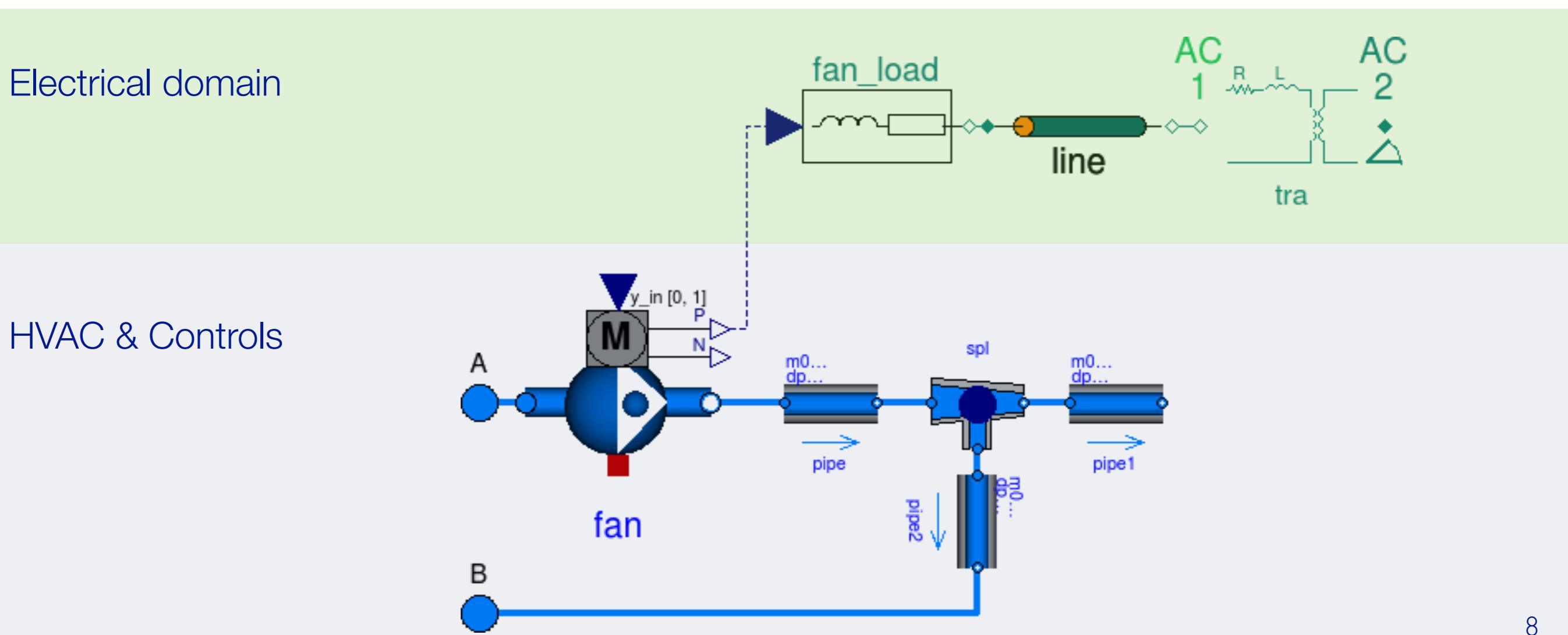
Feedback control with FFD in the loop



The Buildings.Electrical package adds 50+ models for AC and DC systems to the Modelica Buildings library

Typical applications include the analysis and design of

- integration of renewable energy systems
- building demand response (thermal mass, water tank or batteries)
- control algorithm that allow buildings to participate in stabilizing the electrical grid



The Buildings.Electrical package

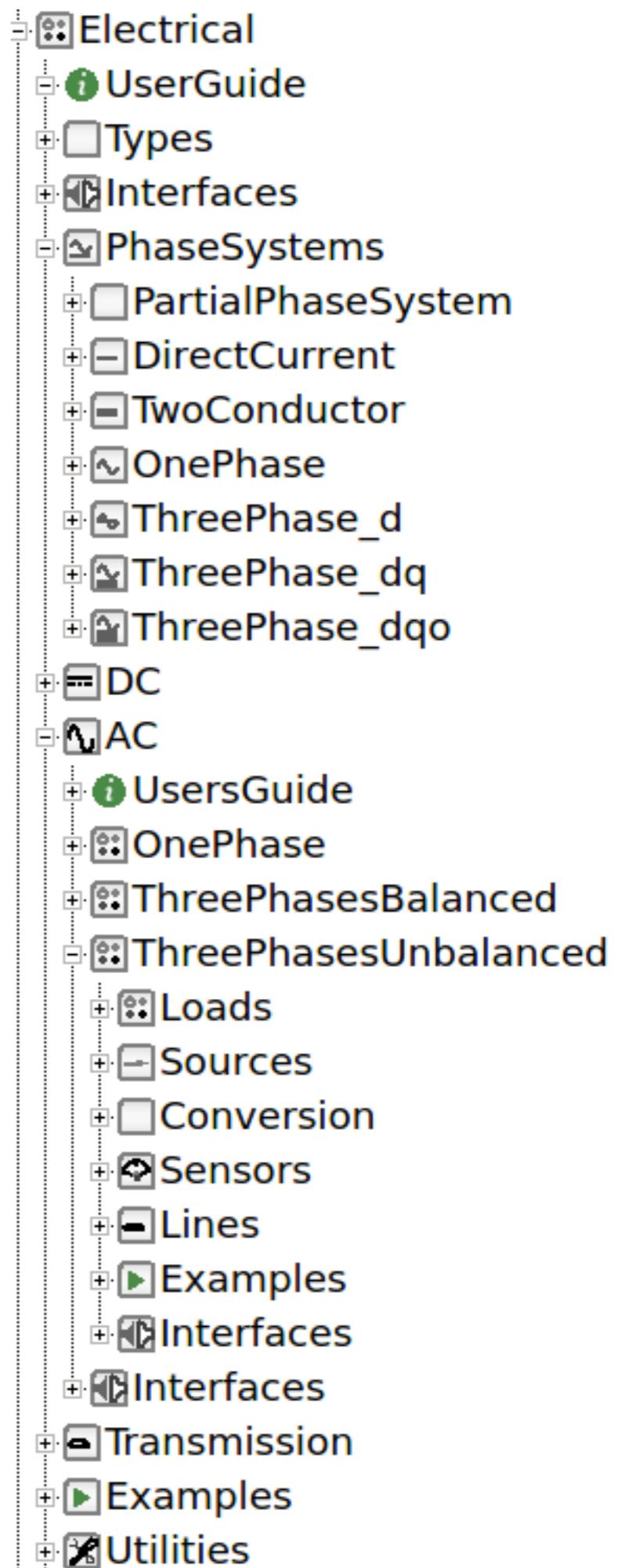
Code reuse through the use of interfaces and phase systems for

- DC
- AC 1-phase
- AC 3-phase balanced
- AC 3-phase unbalanced

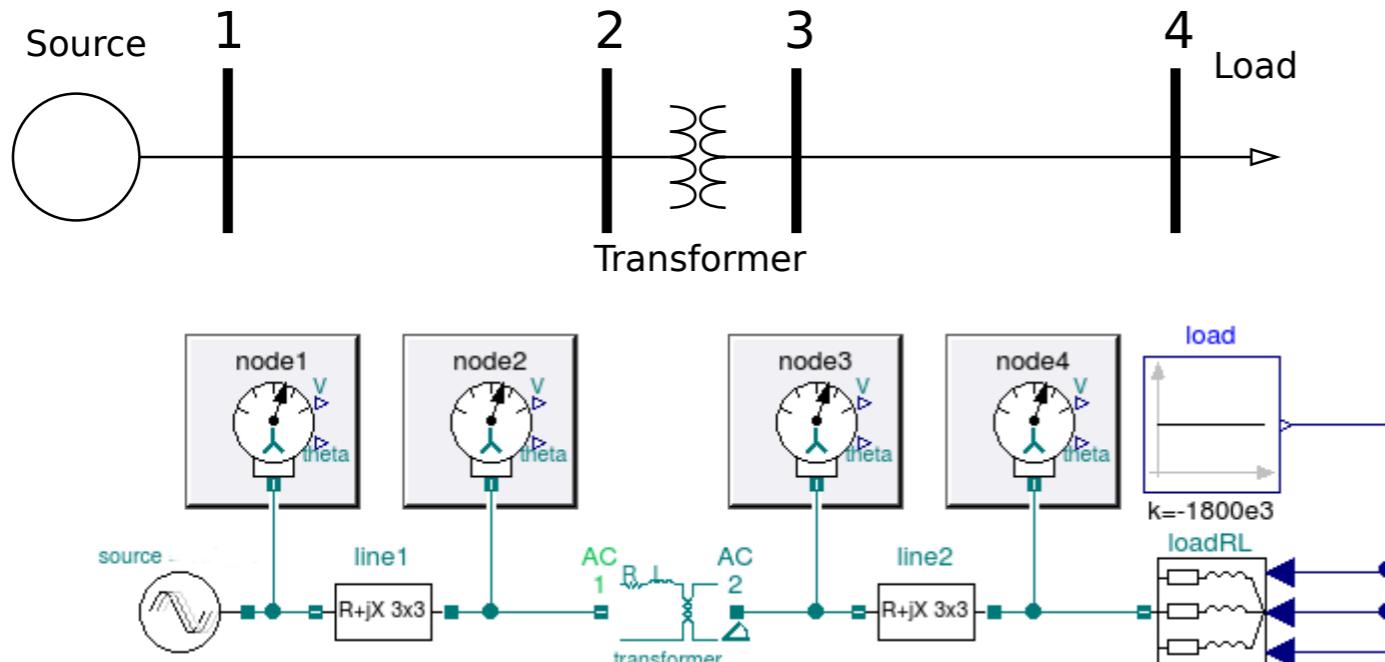
Fast computation through linearized models.

Robust initialization through the use of homotopy.

See also: Marco Bonvini, Michael Wetter and Thierry Stephane Nouidui.
[A Modelica package for building-to-electrical grid integration.](#)
Proc. of 5th BauSim Conference, p. 6--13, Aachen, Germany, September 2014.



IEEE validation tests are within accepted threshold of 0.05%



Transformer		Load
Gr Y - Gr Y	Step up	Balanced
Gr Y - D	Step up	Balanced
D - D	Step up	Balanced
Gr Y - Gr Y	Step down	Balanced
Gr Y - D	Step down	Balanced
D - D	Step down	Balanced
Gr Y - Gr Y	Step up	Unbalanced
Gr Y - D	Step up	Unbalanced
D - D	Step up	Unbalanced
Gr Y - Gr Y	Step down	Unbalanced
Gr Y - D	Step down	Unbalanced
D - D	Step down	Unbalanced

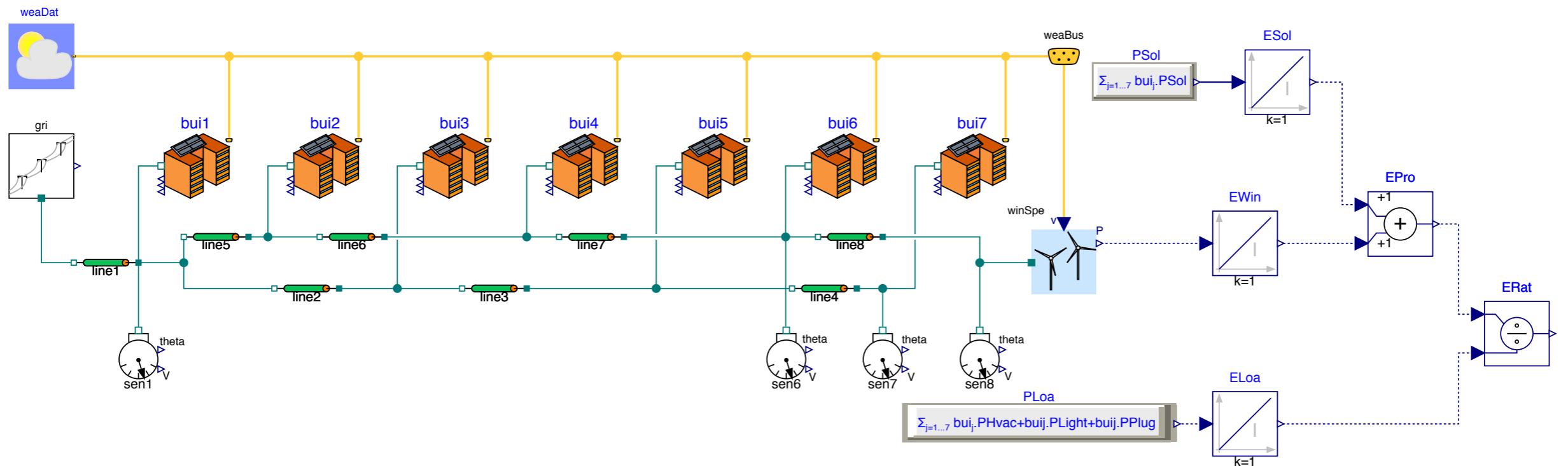
Control development for buildings-to-grid integration

Research questions:

1. How does large scale PV affect power quality?
2. How should voltage sags and swells be controlled?
3. What are implications on system design and operation?

Dynamic models of

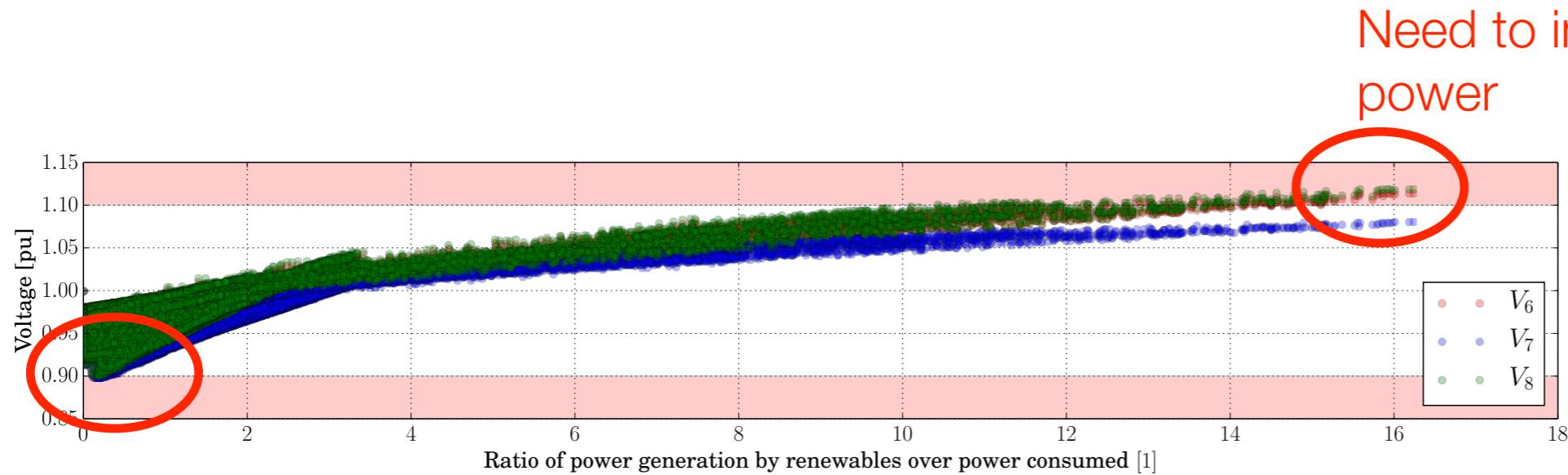
- building performance
(energy, peak power, comfort)
 - electrical grid
(real/reactive power, voltage, currents),
 - control,
- subject to weather, utility signals, user behavior etc.



Michael Wetter, Marco Bonvini and Thierry S. Nouidui.

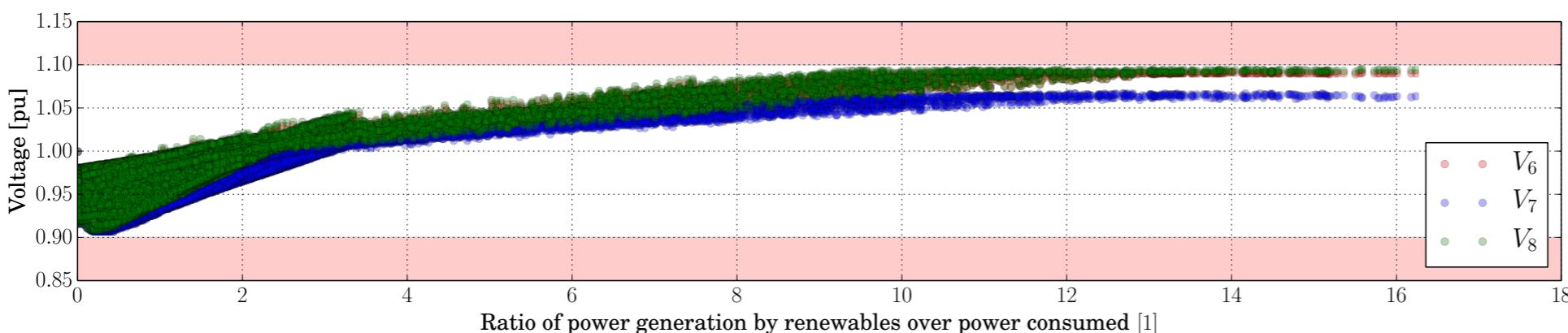
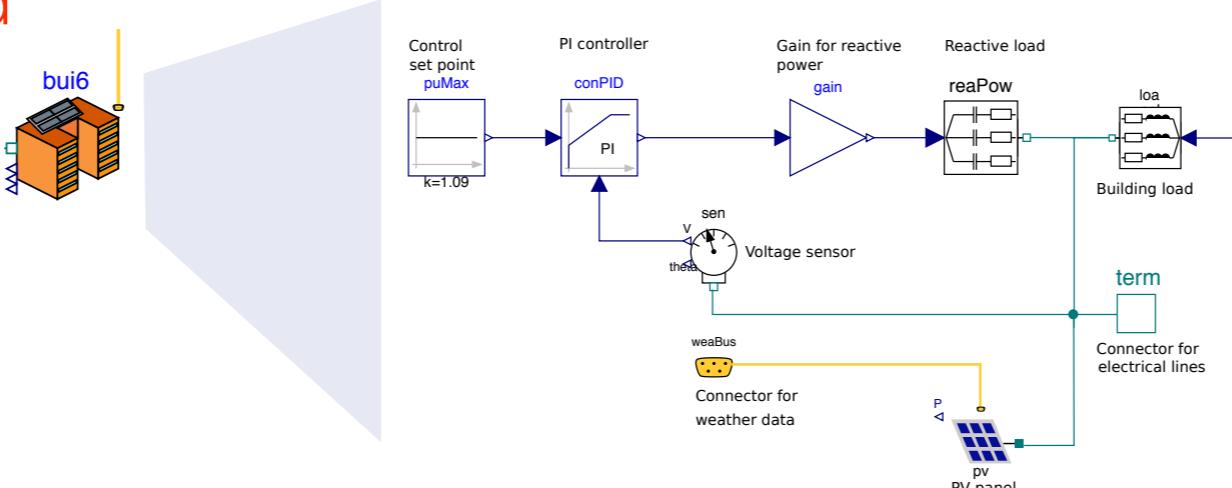
Equation-based languages - A new paradigm for building energy modeling, simulation and optimization.
Energy and Buildings, in press, 2015.

Control development for buildings-to-grid integration



Without control,
voltage is too high and
too low

Need building demand
response



Load prediction based on historical data

Prediction models

Load estimation for next k hours based on

- average, or
- weather regression

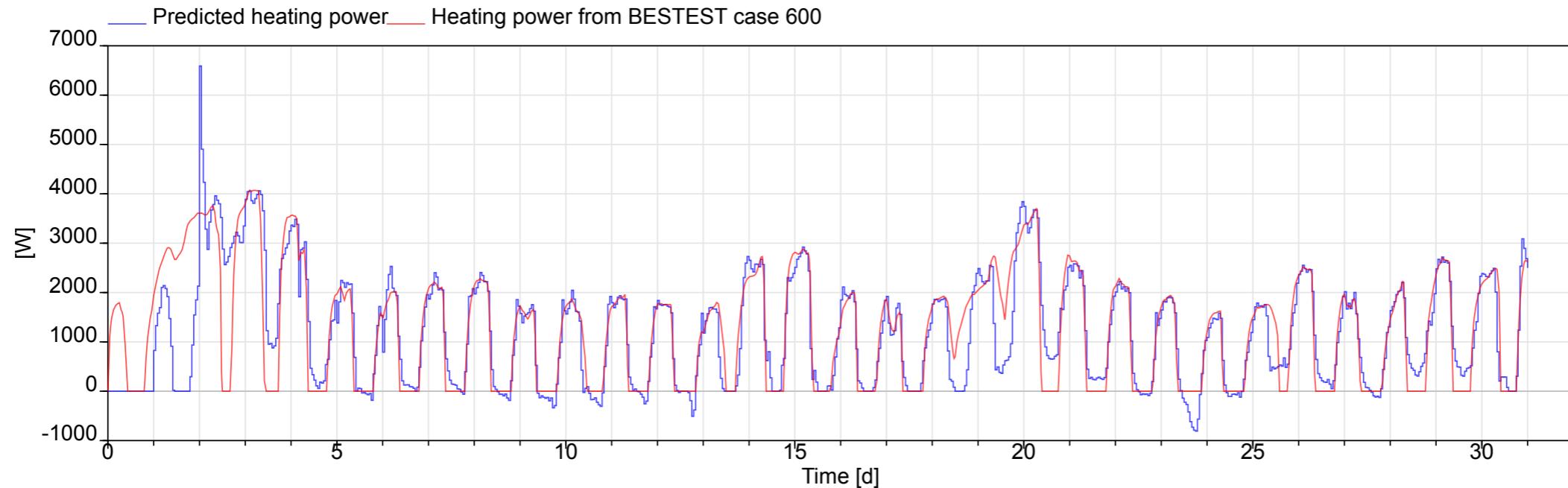
Prediction over past n days, split into m time intervals, optionally taking into account day-of-week.

Input can be discharged for the rest of the day when building is in demand response mode.

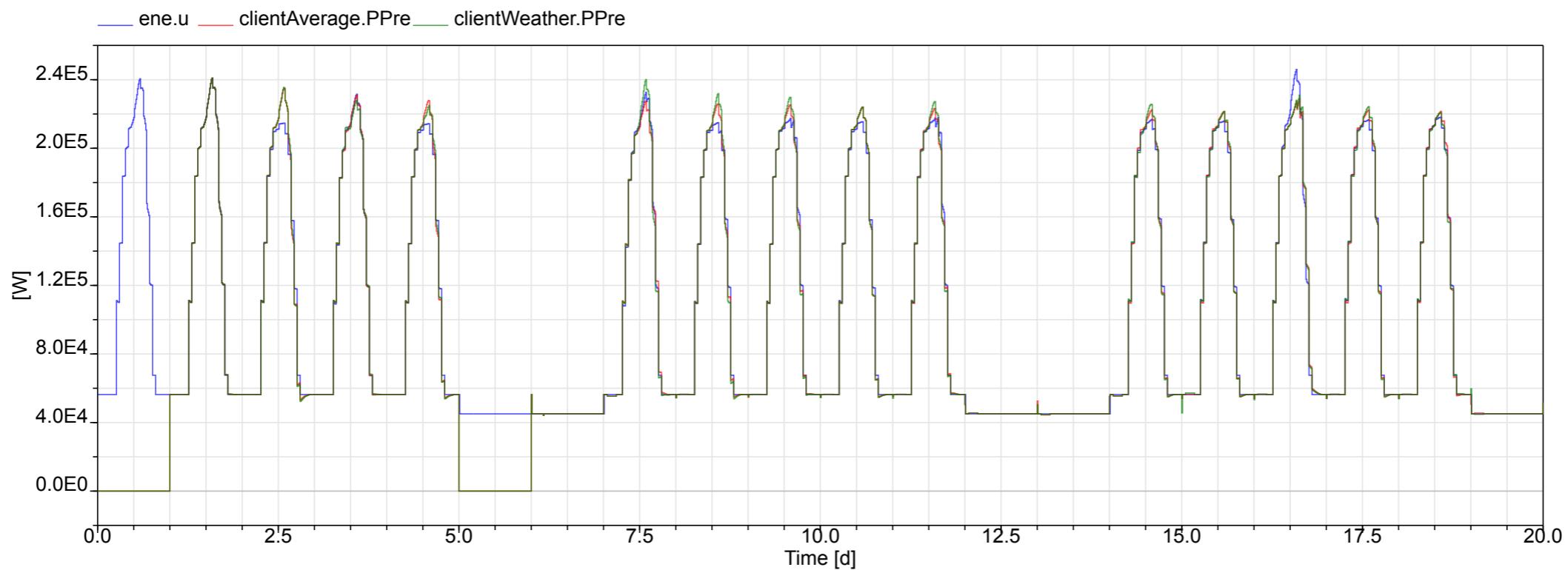
Typical applications:

Demand response.

Load prediction based on historical data



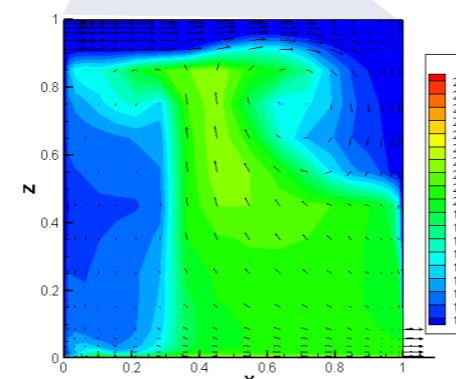
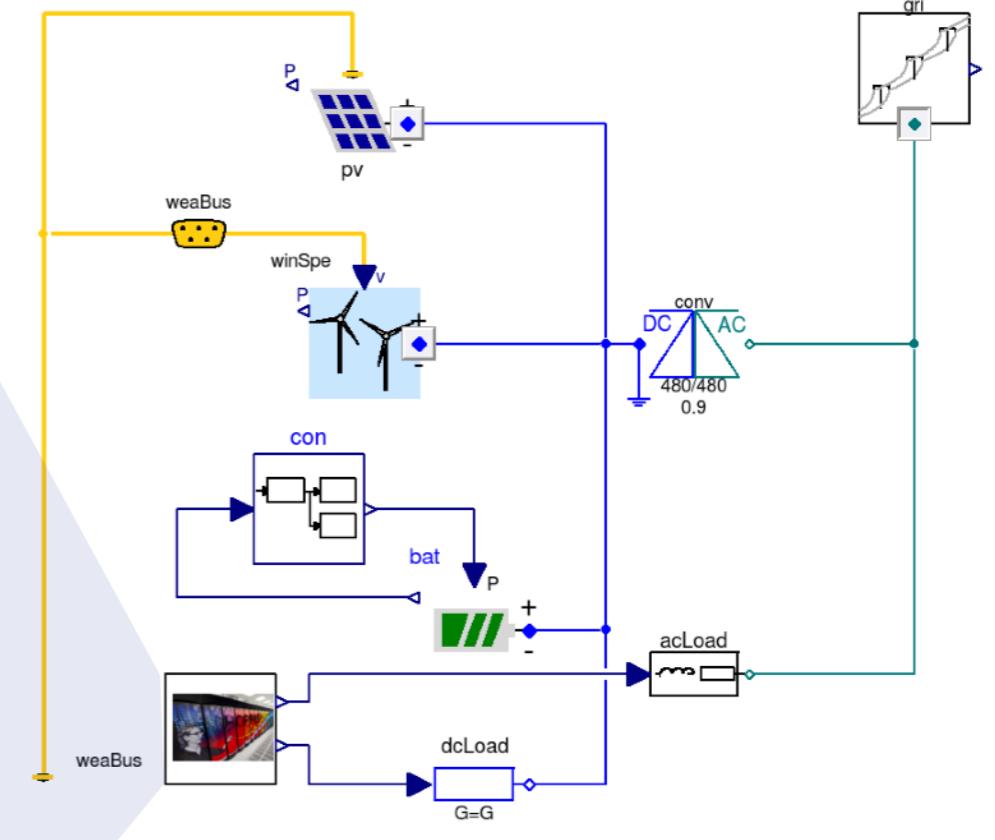
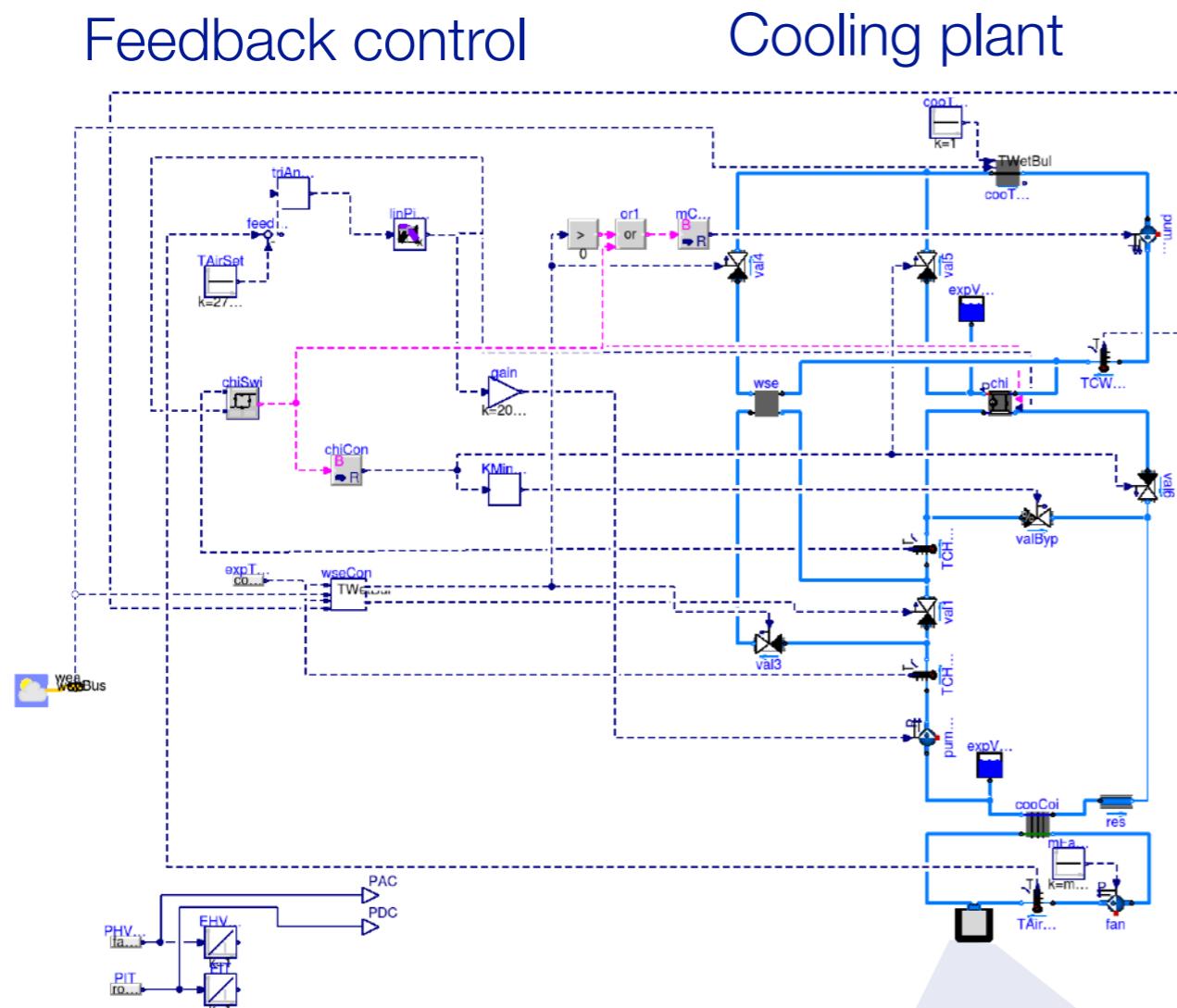
Prediction compared with BESTEST 600 heating power (weather-based regression)



Prediction compared with EnergyPlus load for LBNL building 90

Virtual rapid prototyping of dynamic multi-physics systems

MODELICA



Temperature
stratification
based on CFD

Current and upcoming projects

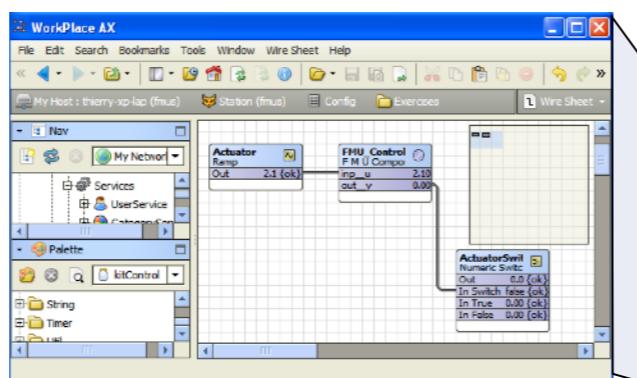
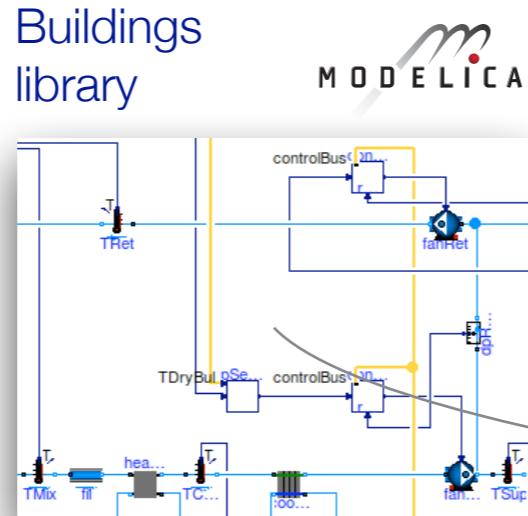
Design to operations

Spawn of EnergyPlus – Modularize EnergyPlus based on open standards to better address low energy systems and operation

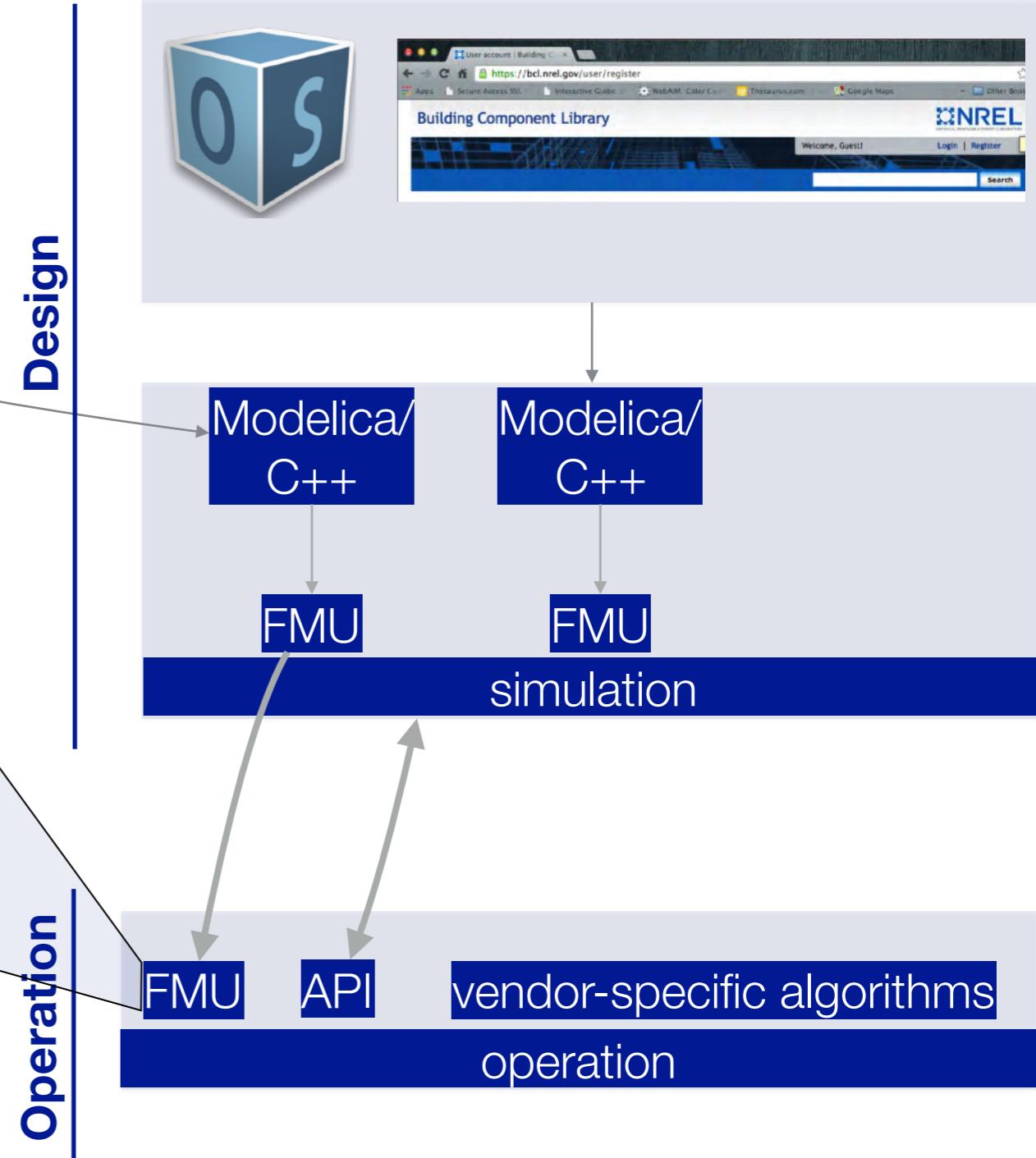


Spawn-of-EnergyPlus

- Inter-operability with control workflows and product development
- Support insertion of custom models and computing modules
- Standard interfaces (FMUs)
- Modular



Automatic code generation from Modelica to, e.g., Niagara

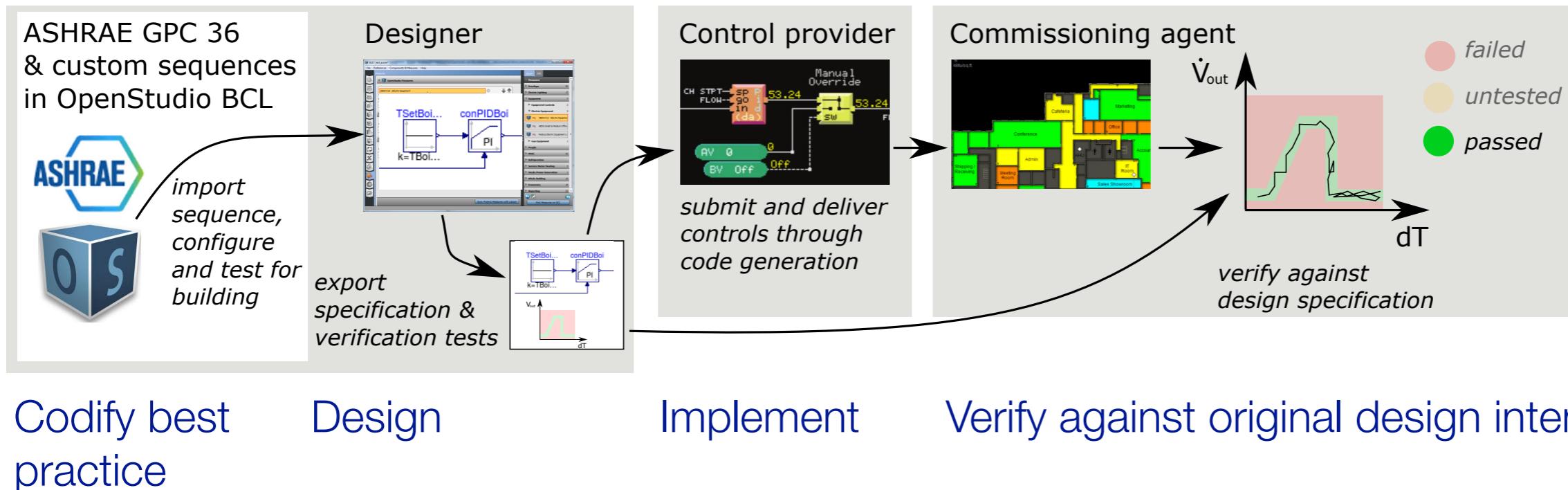


Michael Wetter, Thierry S. Nouidui, David Lorenzetti, Edward A. Lee and Amir Roth. [Prototyping the next generation EnergyPlus simulation engine](#). Proc. of the 14th IBPSA Conference, p. 403--410, Hyderabad, India, December 2015.

Michael Wetter, Wangda Zuo, Thierry S. Nouidui and Xiufeng Pang. [Modelica Buildings library](#). Journal of Building Performance Simulation, 7(4):253-270, 2014.

End-to-end quality control

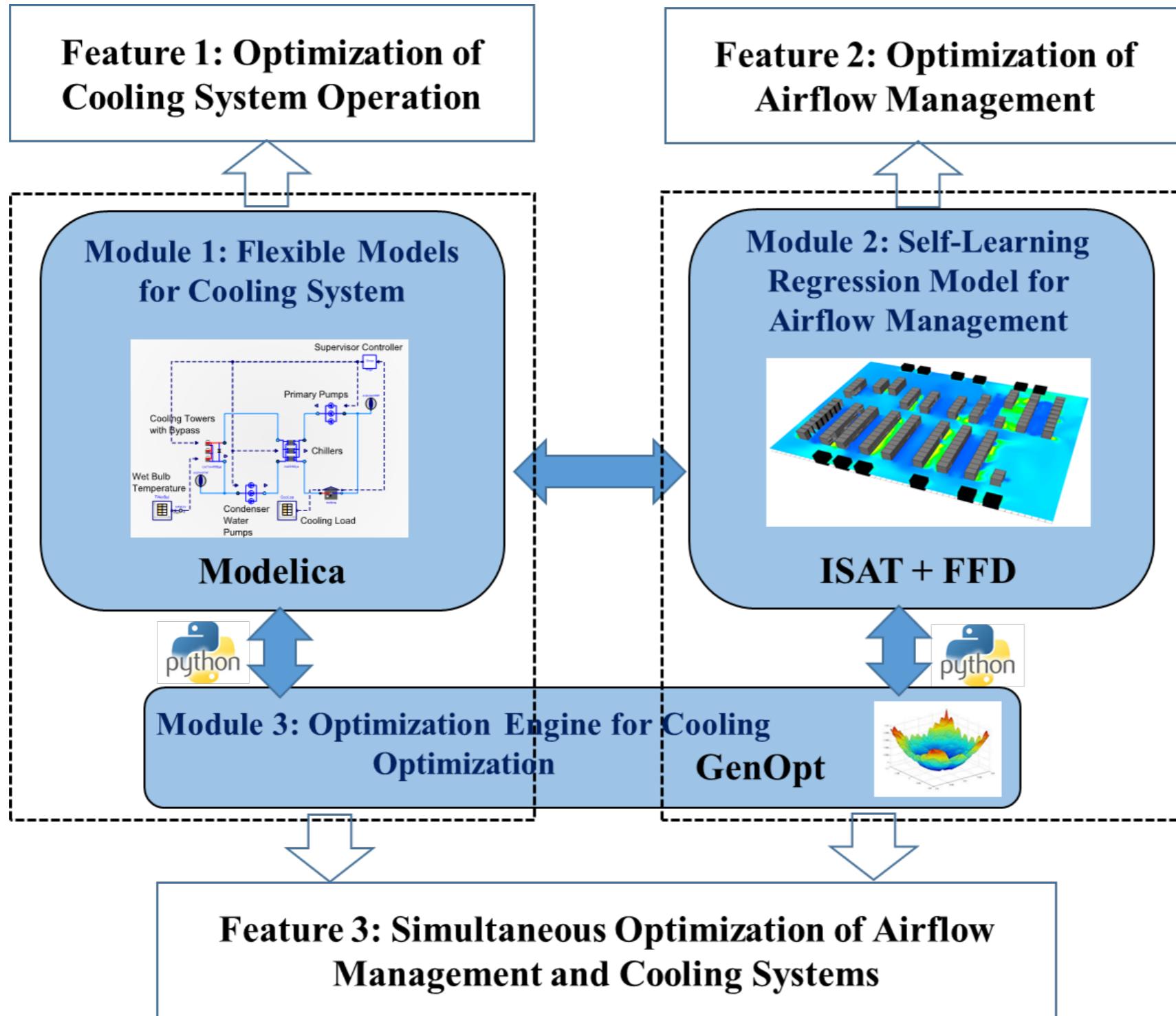
OpenBuildingControl: Design and implement control sequences error-free and at lower cost to owner (2016-19)



BACnet standardizes communication.

OpenBuildingControl will standardize expressing control sequences and functional tests for bidding, automatic implementation and automated functional testing.

Data center design and optimization tool (with University of Miami, 2016-19)

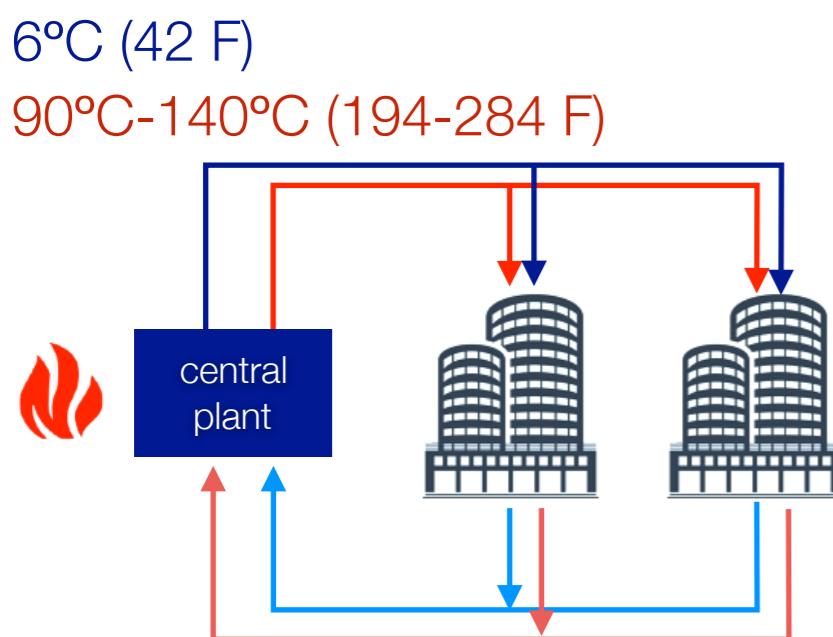


The smart electrical grid is bi-directional and modular; so should be shared energy systems for heating and cooling

Today

System temperatures are high because systems are designed for fossil fuels.

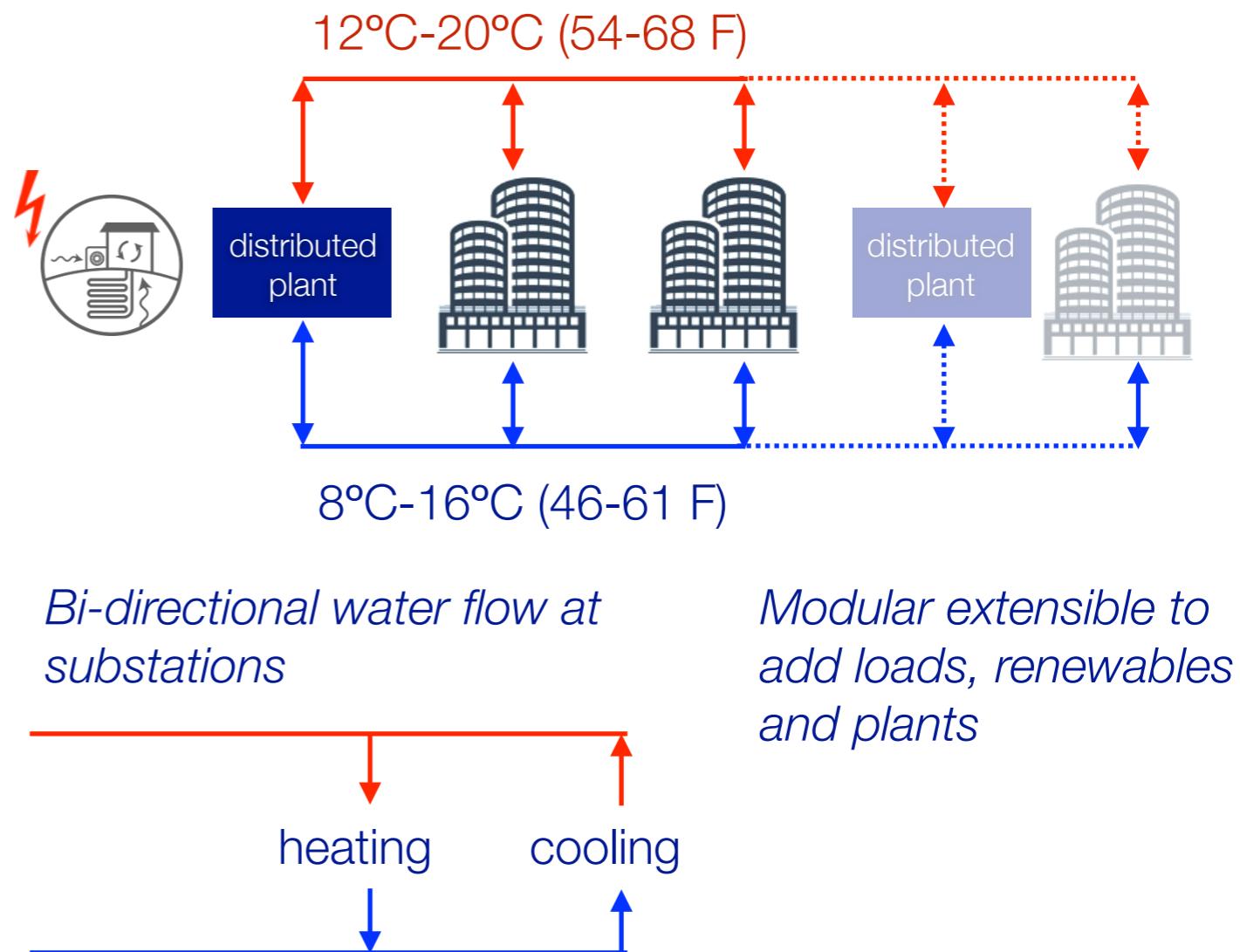
But for all electric vapor compression, solar thermal and waste heat recovery systems, these high temperatures penalize efficiency.



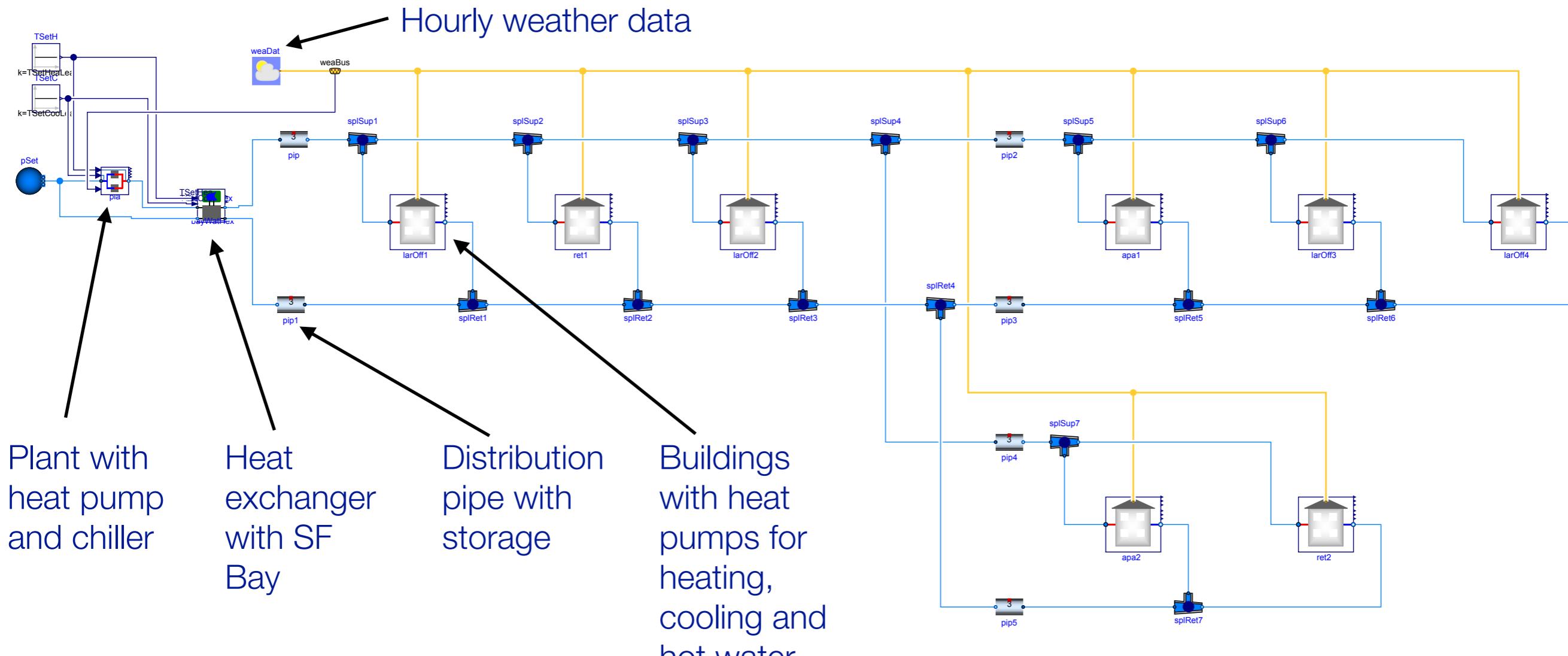
Future

Bi-directional energy flow to consumers and producers. Buildings boost the temperature to the level they need. When cooling, building dumps warm water into loop; when heating, building dumps cool water into loop.

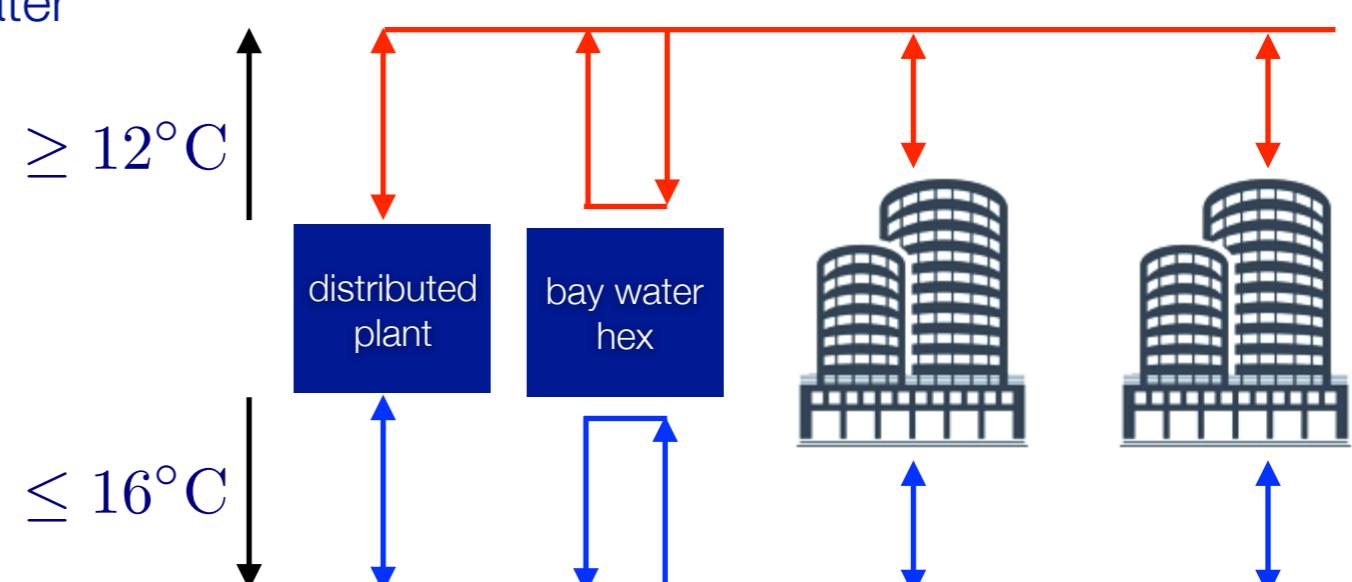
Loop temperature floats stable near ambient temperature.



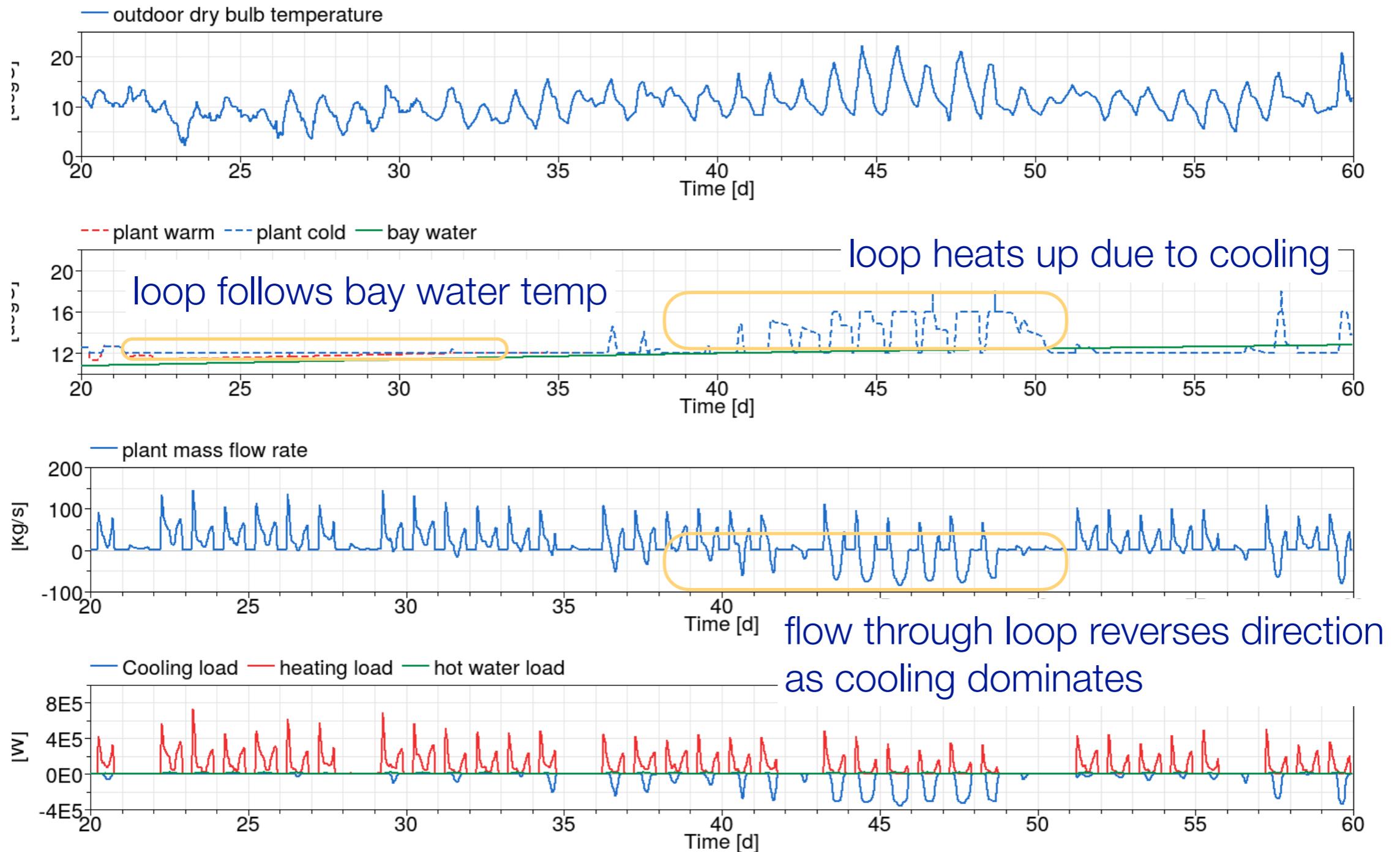
Built models for dynamic analysis of shared energy system with diversity of office, retail and apartment buildings



System model:
2,000 component models
26,000 variables
30 seconds for annual simulation with dassl



Can represent dynamic behavior including energy storage and bi-directional energy exchange



Next additions to support bi-directional DHC

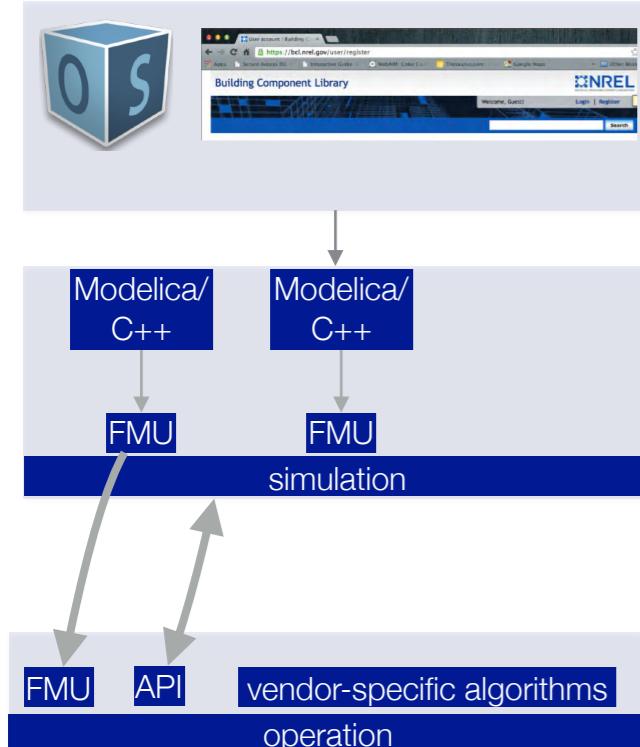
Pipe model (within Annex 60)

Low lift heat pump

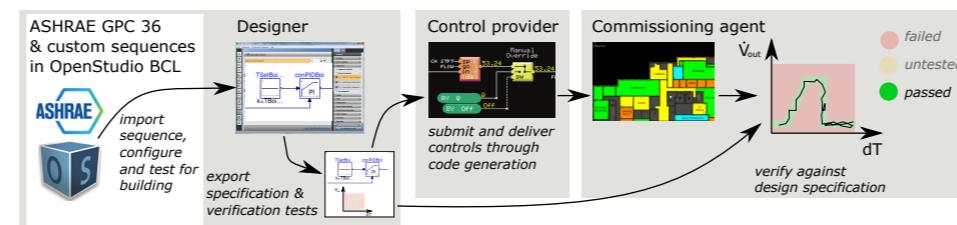
Borefield model (based on code of Damien Picard)

Next

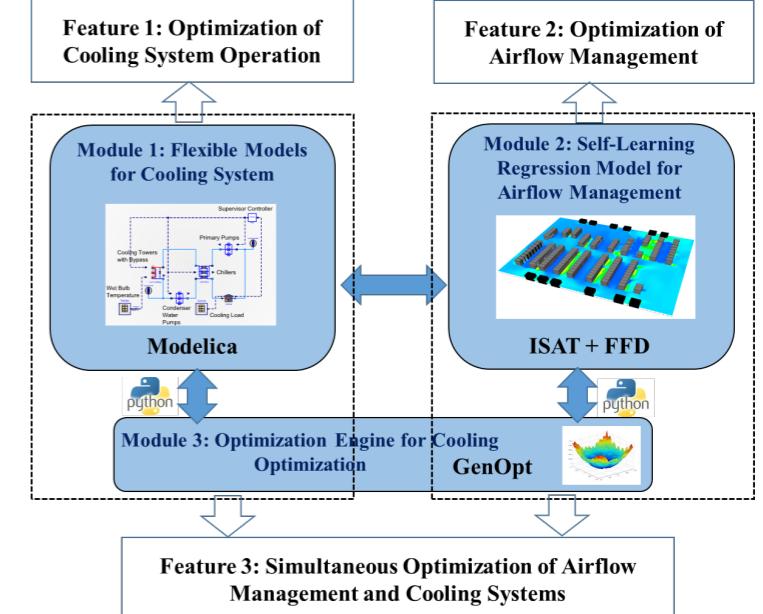
Spawn of EnergyPlus



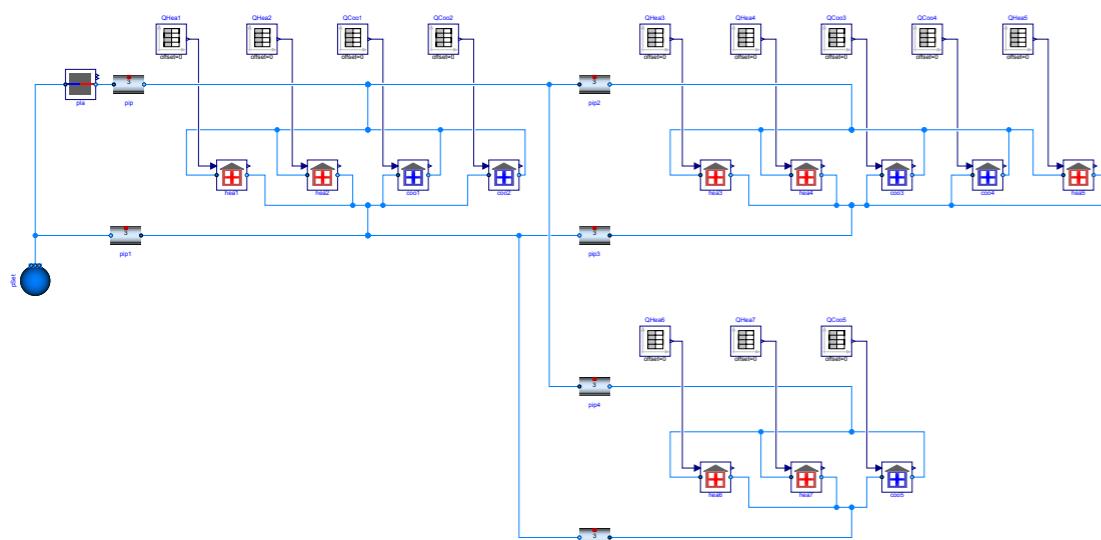
OpenBuildingControl



Data center design tool



Models for district energy systems
(pipes, reduced order building model)



IBPSA Project 1