

Modelica Buildings Library

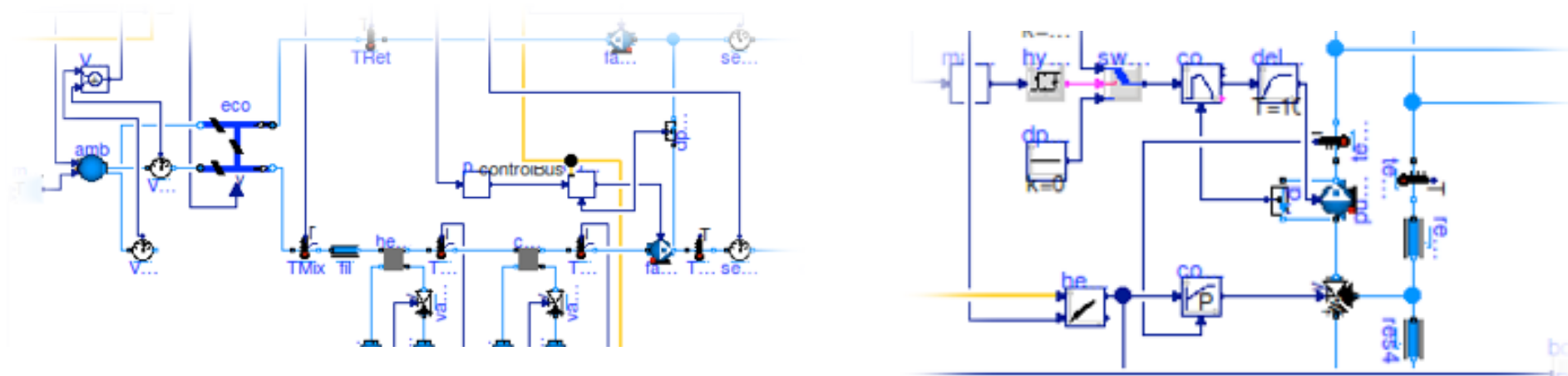
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Simulation Research Group

October 9, 2023

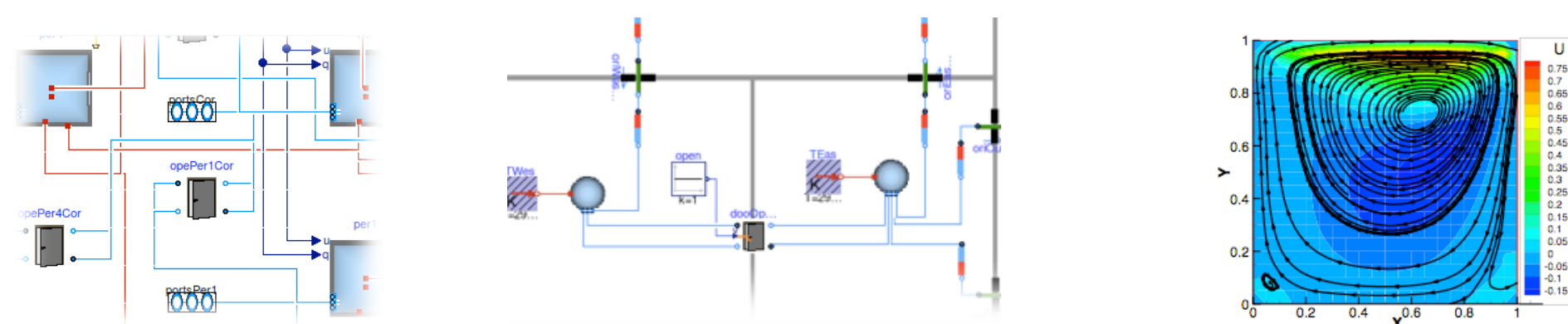
Modelica Buildings Library and Spawn for district energy modeling

Open-source repository of 2000+ models and functions, 45+ contributors, most cited paper in Journal of Building Performance Simulation since a few years. Co-develop with IBPSA Modelica Library.

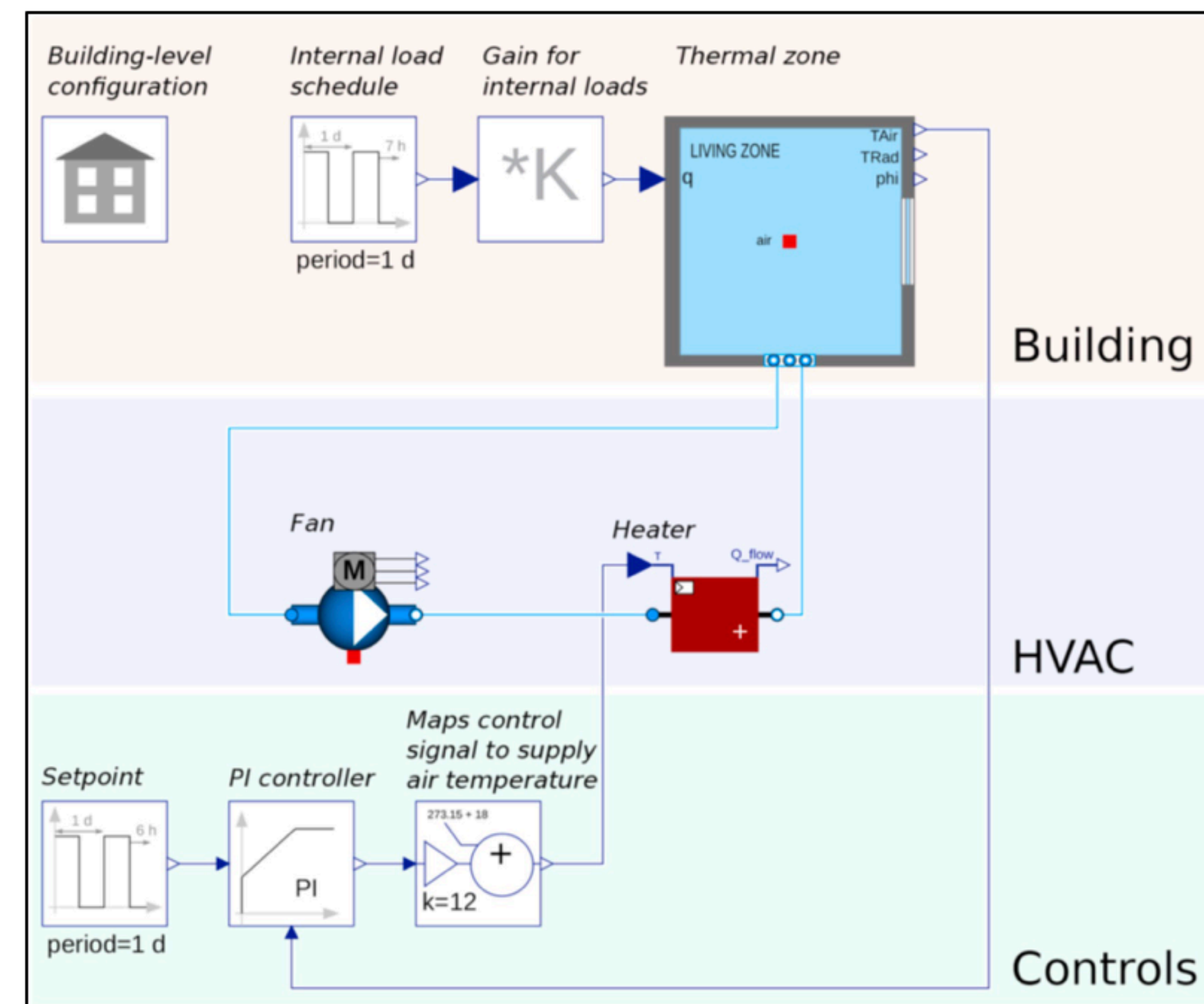
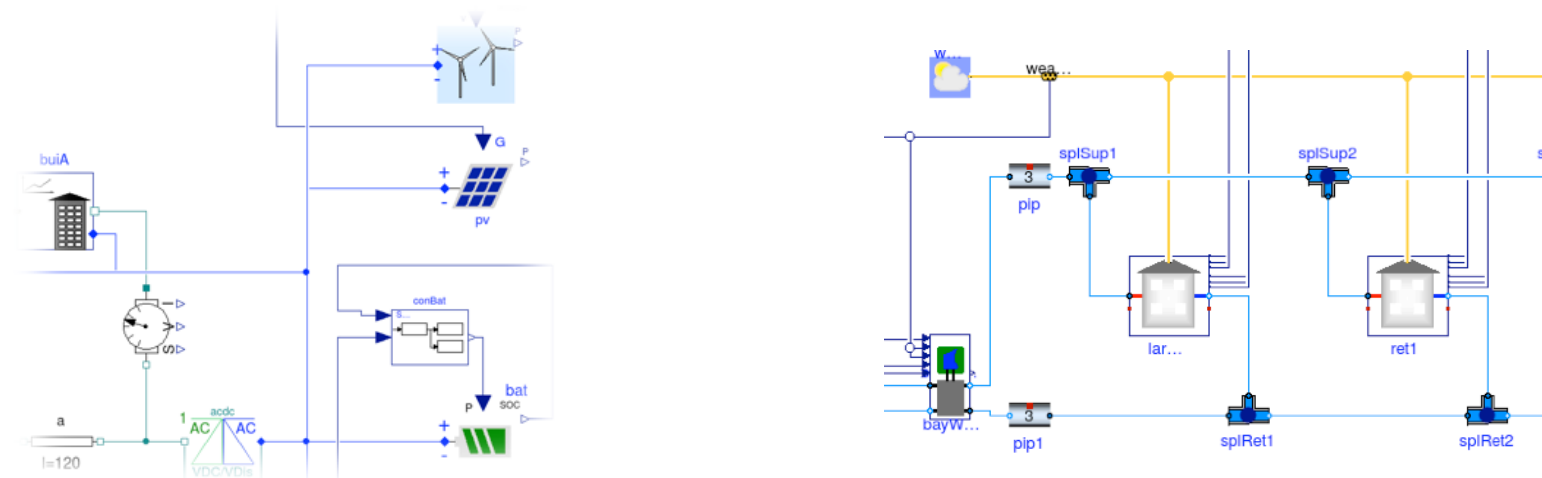
HVAC with realistic supervisory and local loop control



Building heat transfer, natural ventilation, and CFD



Fully coupled thermal, fluid flow, electrical and control simulation



Graphical run-time coupling with
Spawn of EnergyPlus

M. Wetter, W. Zuo, T.S. Noudui, and X. Pang (2014). Modelica Buildings library. *Journal of Building Performance Simulation*, 7(4):253-270.

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M. Wetter, K. Benne, A. Gautier, T.S. Noudui, A. Ramle, A. Roth, H. Tummescheit, S. Mentzer and C. Winther (2020). Lifting the Garage Door on Spawn, an Open-Source BEM-Controls Engine. *Proc. of Building Performance Modeling Conference and SimBuild*, p. 518–525, Chicago, IL, USA, Sep 2020.

Documentation and distribution

Documentation

- General user guide (getting started, best practice, developer instructions, ...).
- 26 user guides for individual packages.
- 3 tutorials with step-by-step instructions.
- All models contain an “info” section.
- Small test models for all classes, large test cases for “smoke tests,” and various validation cases.

Distribution

- For users:
<http://simulationresearch.lbl.gov/modelica>
- For developers:
<https://github.com/lbl-srg/modelica-buildings>

Buildings

UsersGuide

Air

Airflow

Applications

BoundaryConditions

Controls

Electrical

Fluid

UsersGuide

Actuators

UsersGuide

Dampers

Exponential

MixingBox

MixingBoxMinimumFlow

PressureIndependent

Examples

Validation

Motors

sta_a

sta_b

port_a

port_b

y

y_actual

y_filtered

filter

Information

Model for an air damper whose airflow is proportional to the input signal, assuming that at $y = 1$, $m_flow = m_flow_nominal$. This is unless the pressure difference dp is too low, in which case a $kDam = m_flow_nominal / \sqrt{dp_nominal}$ characteristic is used.

The model is similar to [Buildings.Fluid.Actuators.Valves.TwoWayPressureIndependent](#), except for adaptations for damper parameters. Please see that documentation for more information.

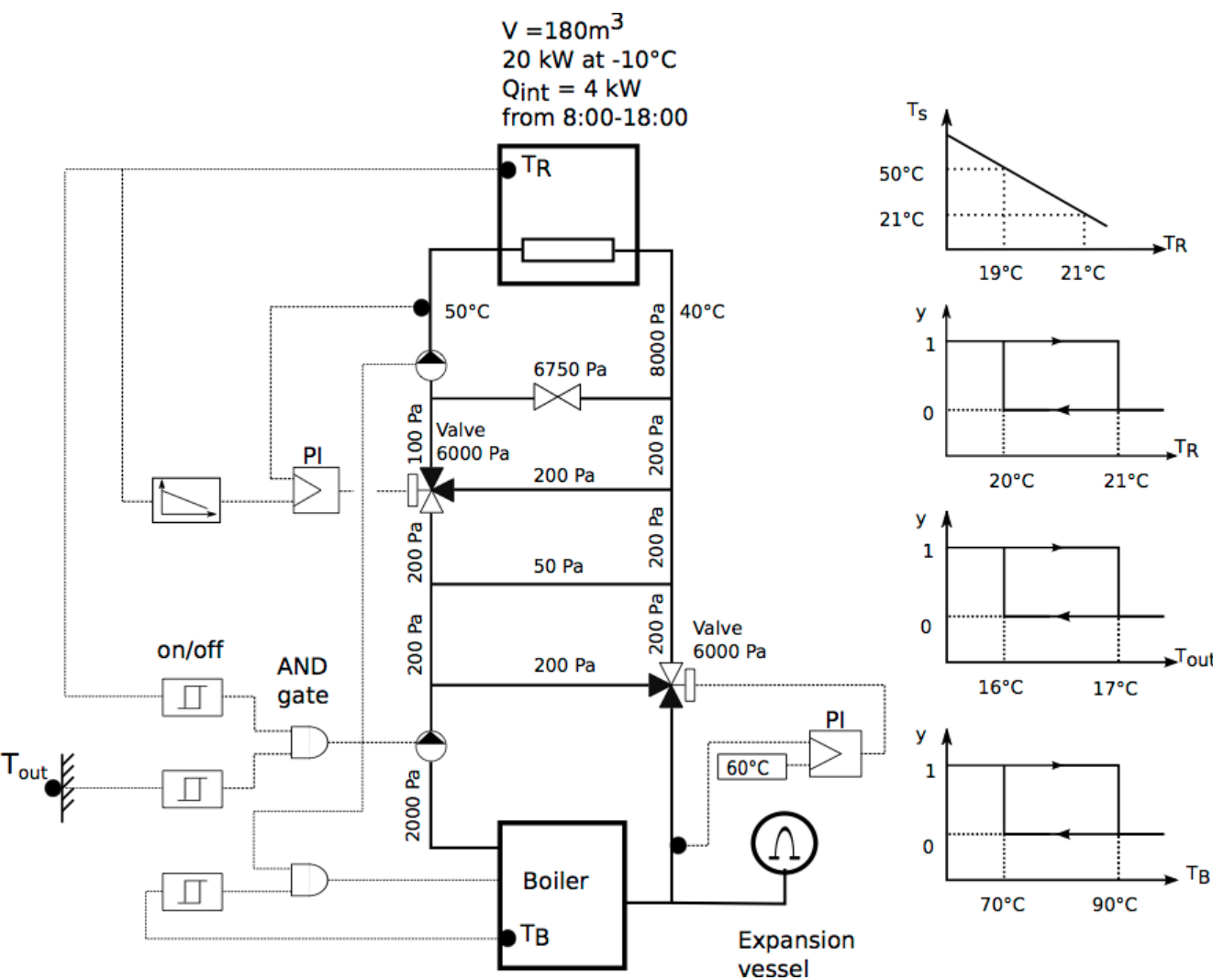
Computation of the damper opening

The fractional opening of the damper is computed by

- inverting the quadratic flow function to compute the flow coefficient from the flow rate and the pressure drop values (under the assumption of a turbulent flow regime);
- inverting the exponential characteristics to compute the fractional opening from the loss coefficient value (directly derived from the flow coefficient).

The quadratic interpolation used outside the exponential domain in the function [Buildings.Fluid.Actuators.BaseClasses.exponentialDamper](#) yields a local extremum. Therefore, the formal inversion of the function is not possible. A cubic spline is used instead to fit the inverse of the damper characteristics. The central domain of the characteristics having a monotonous exponential profile, its inverse can be properly approximated with three equidistant support points. However, the quadratic functions used outside of the exponential domain can have various profiles depending on the damper coefficients. Therefore, five linearly distributed support points are used on each side domain to ensure a good fit of the inverse.

Note that below a threshold value of the input control signal (fixed at 0.02), the fractional opening is forced to zero and no more related to the actual flow coefficient of the damper. This avoids steep transients of the



Modelica Buildings Library has comprehensive set of district energy models, enabling analysis of 1st to 5th generation systems

Large variety of thermal and electrical models exists

- 1st to 5th generation district heating and cooling
- AC and DC electrical models

Building Load

- Detailed EnergyPlus models
- Reduced order models
- Time series

Energy Transfer Stations

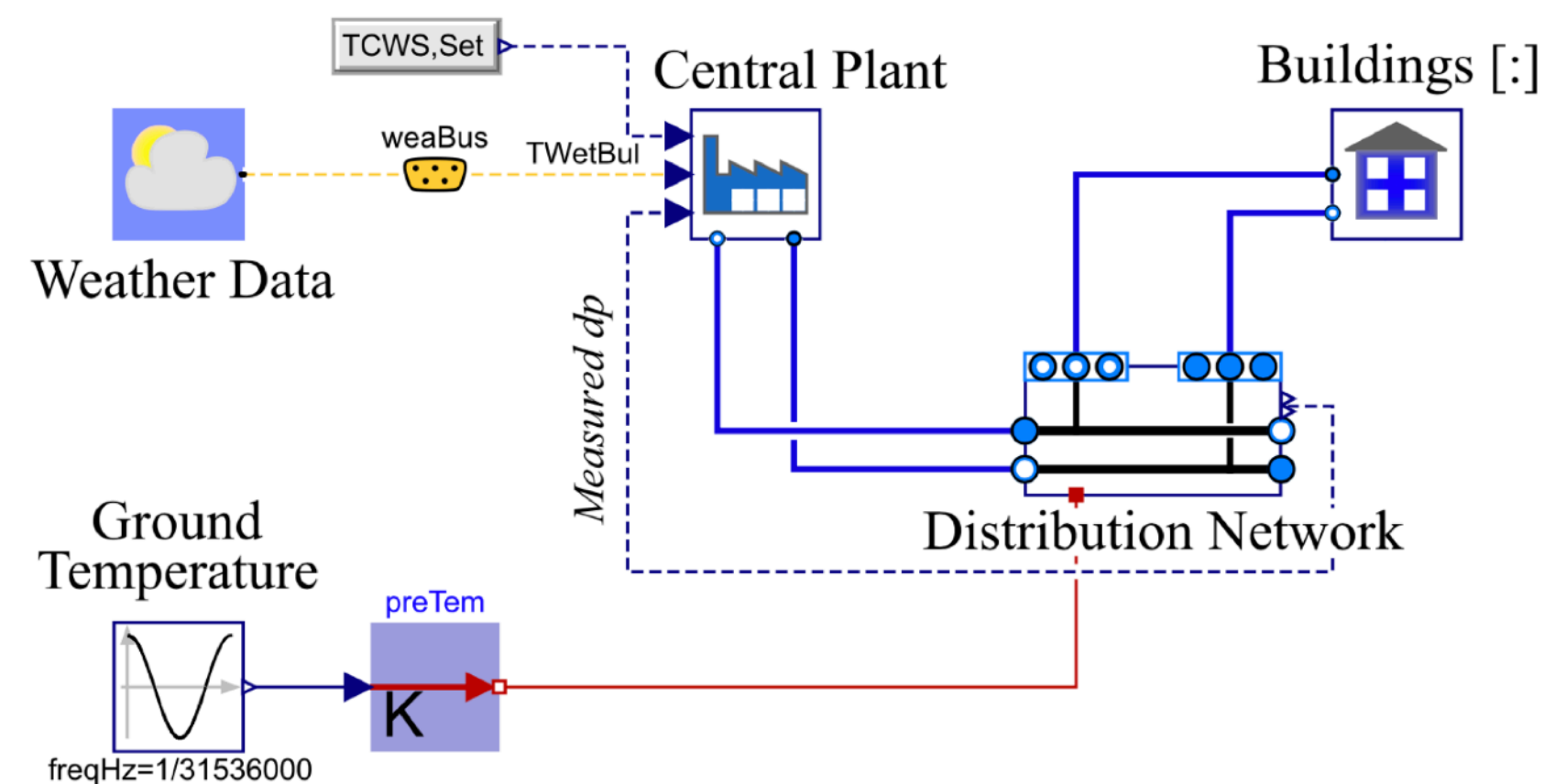
- Indirect connection
- Indirect connection with booster heat pump
- Direct connection

Network Topology

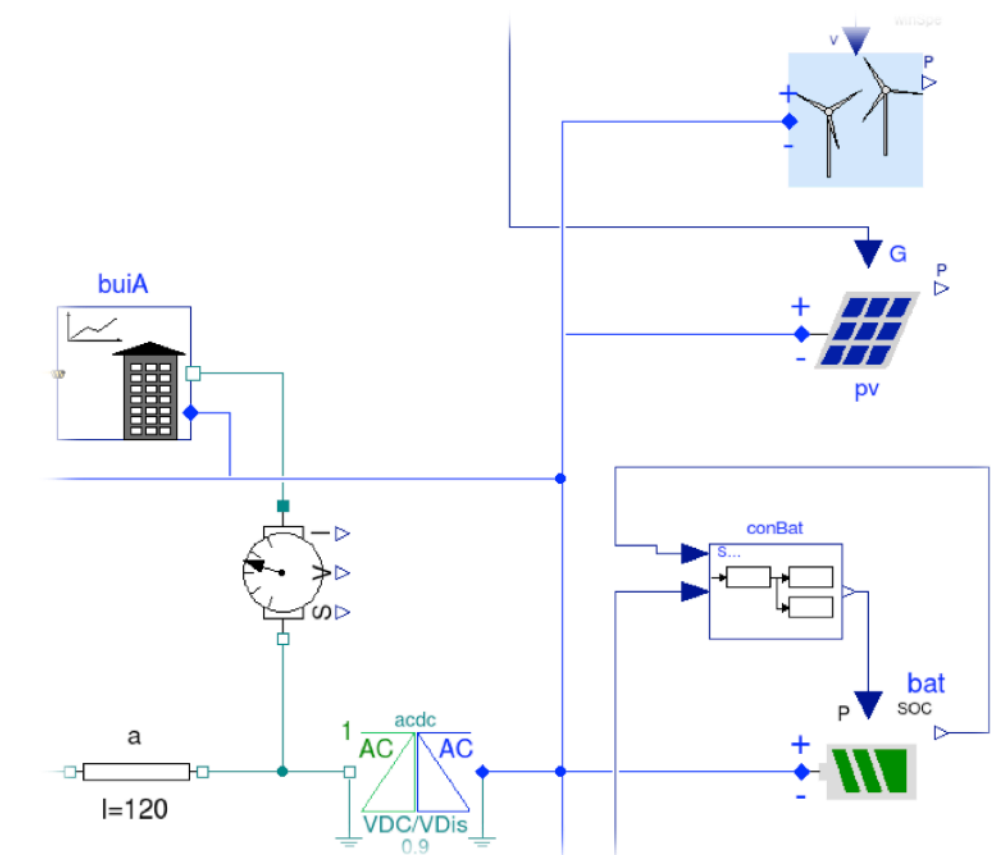
- 1-Pipe
- 2-Pipe
- 4-Pipe
- Steam heating

Various storage technologies

- Borefields
- PCM
- Water or ice tanks
- Coupling with detailed geothermal simulators (TOUGH)

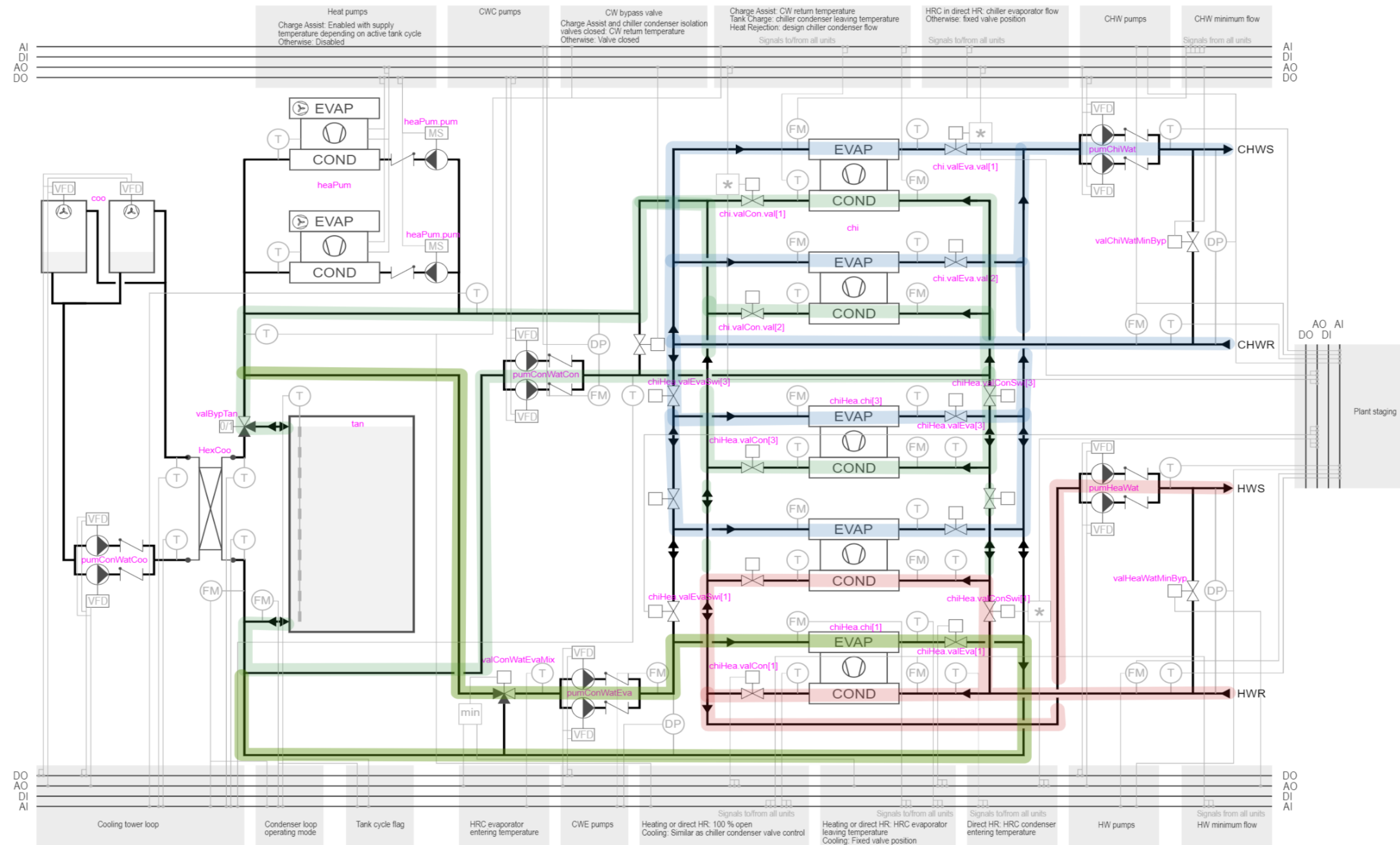


Library has preconfigured district energy systems.



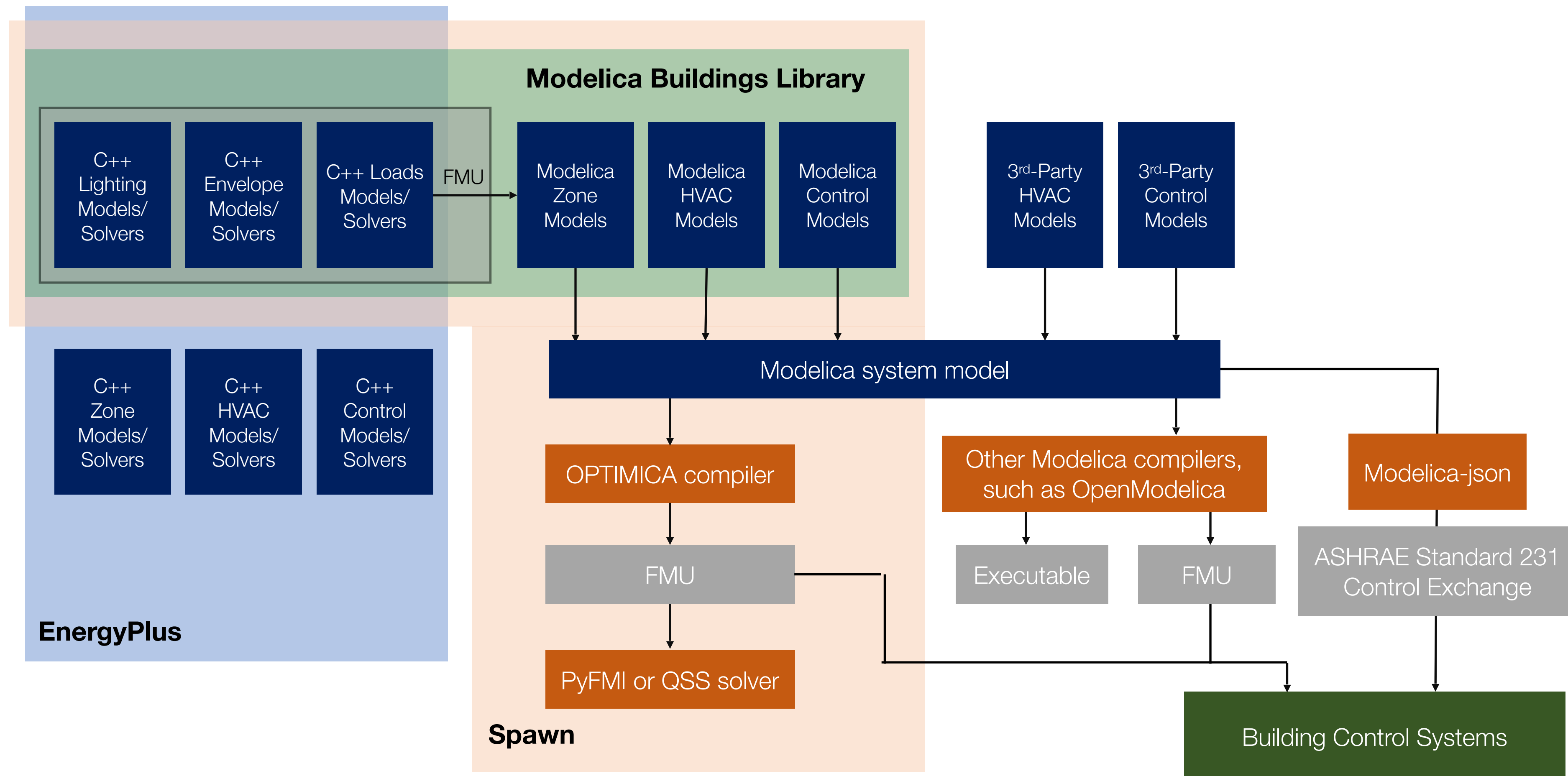
Models for electrical system simulation provide foundation for thermal, electrical, industrial and transportation sector integration.

Example of a energy transfer station

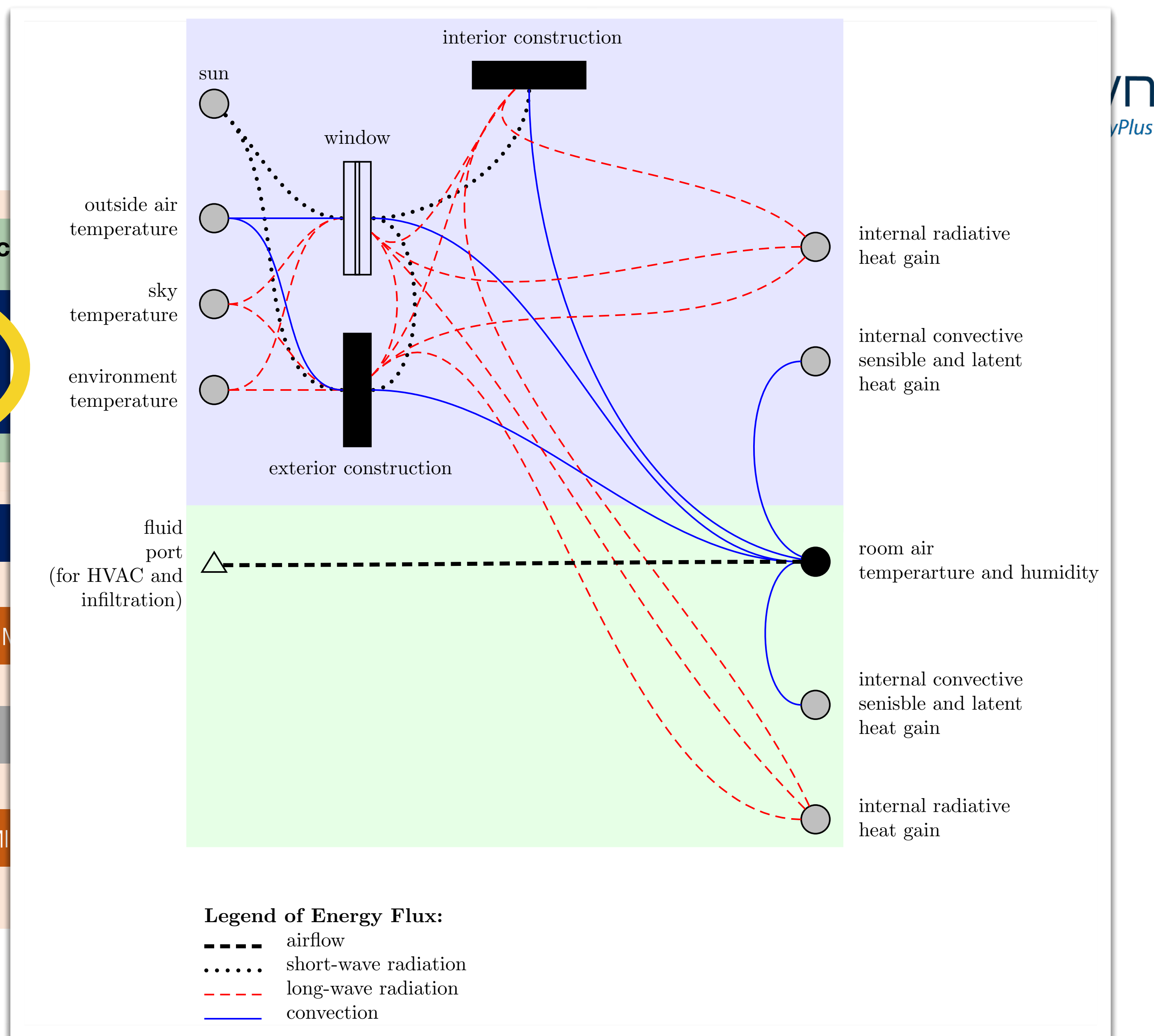
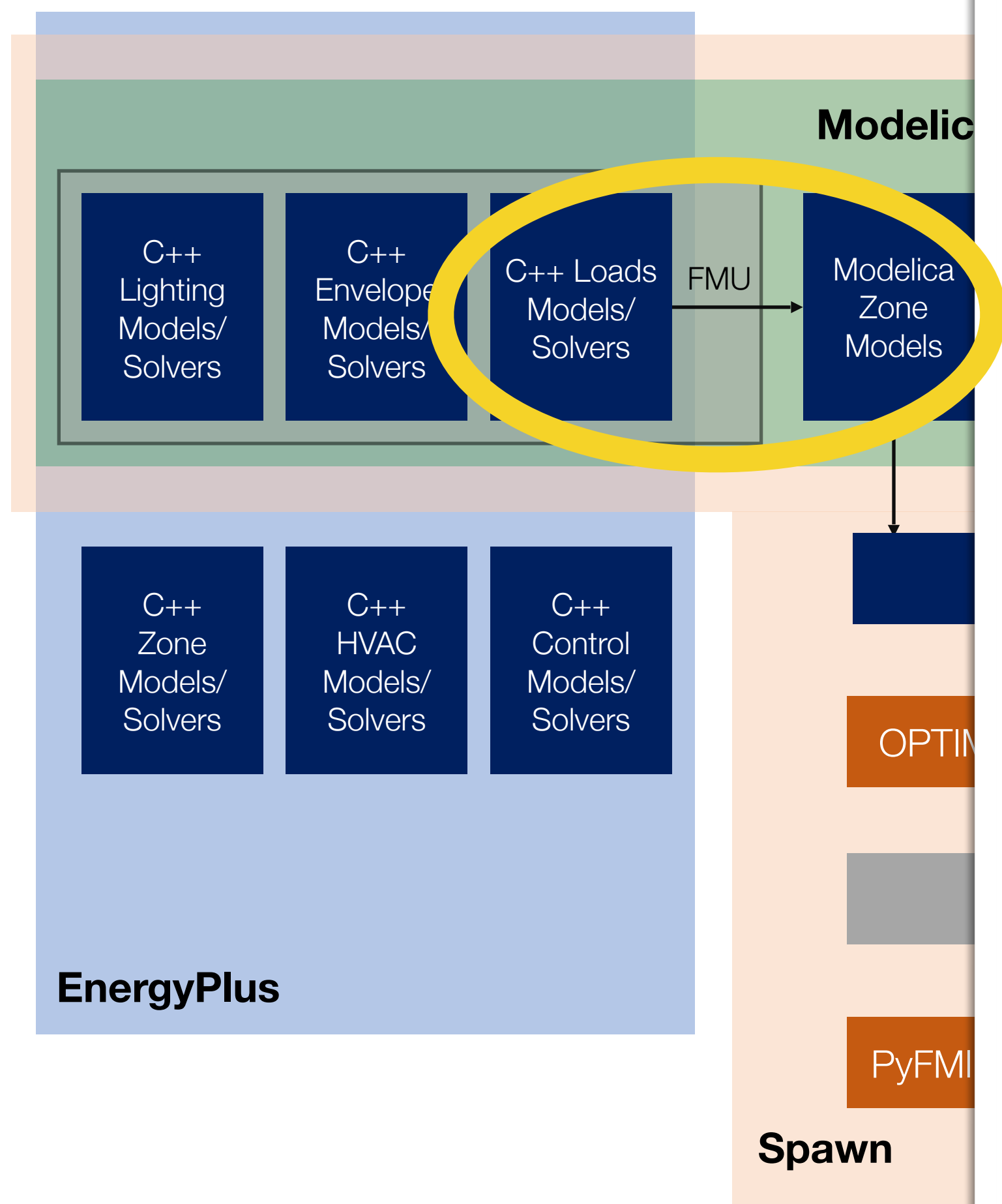


Example for an all-electric plant (model:
Buildings.Experimental.DHC.Plants.Combined.AllElectricCWStorage)

Spawn allows use of EnergyPlus envelope model with Modelica HVAC and controls via FMI Standard



Spawn allows use of EnergyPlus envelope model with Modelica HVAC and controls via FMI Standard

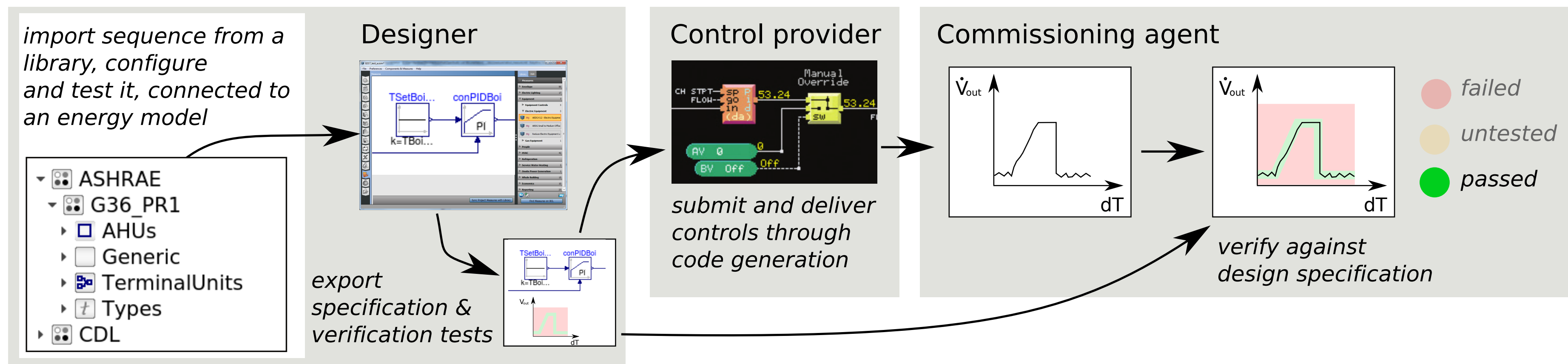


OpenBuildingControl digitizes the control delivery process based on the ASHRAE Standard 231P for which Buildings.Controls.OBC.CDL has the reference implementation

Sequence selection and performance assessment

Machine-to-machine translation

Formal end-to-end verification

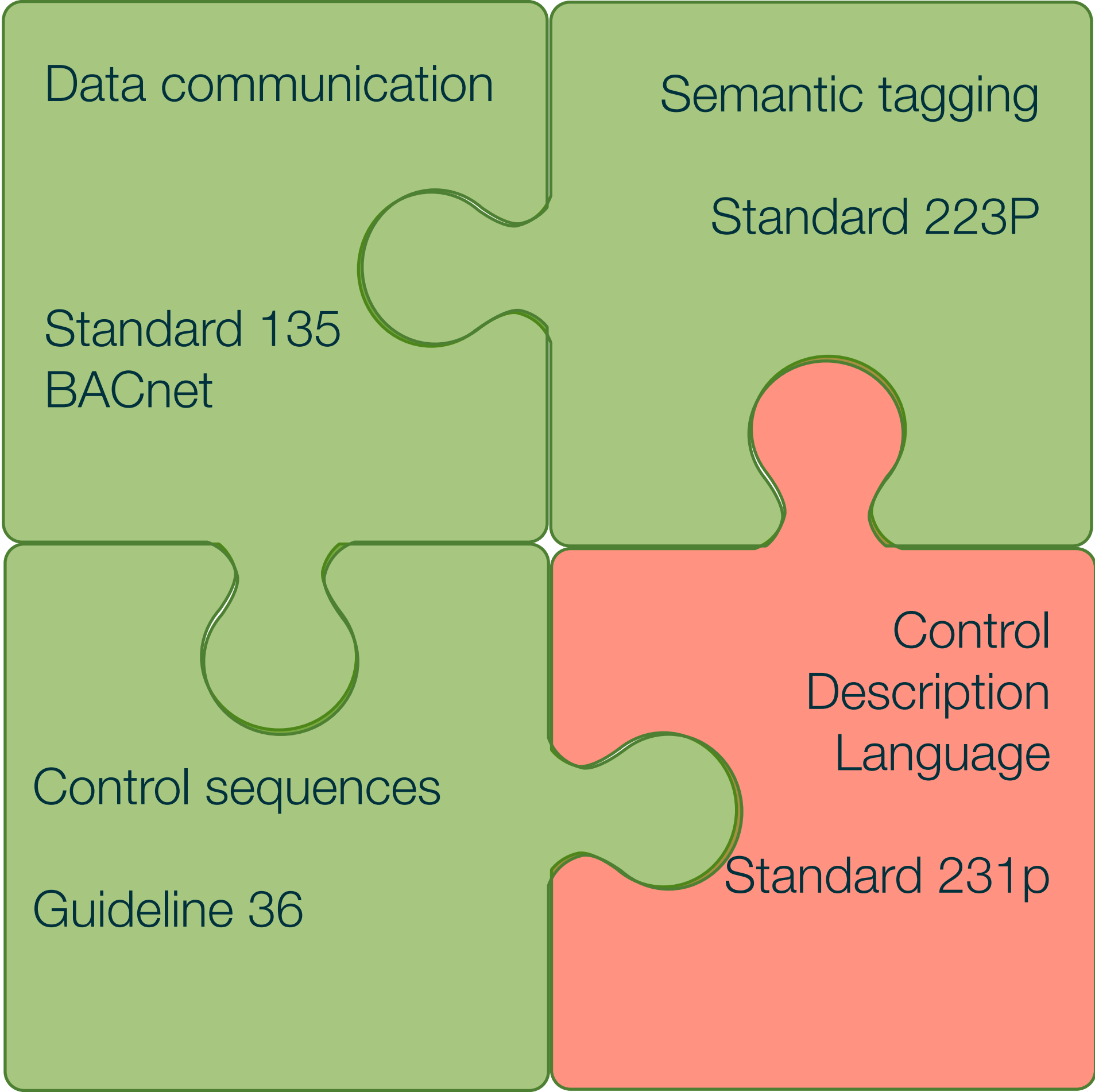


Michael Wetter, Paul Ehrlich, Antoine Gautier, Milica Grahovac, Philip Haves, Jianjun Hu, Anand Prakash, Dave Robin and Kun Zhang.

OpenBuildingControl: Digitizing the control delivery from building energy modeling to specification, implementation and formal verification.

Energy, Volume 238, Part A, January 2022.

What gap does CDL address?



Implementation

Name	Description
Constants	Package with constants
Conversions	Package with blocks for type conversion
Discrete	Package with discrete blocks
Integers	Package with blocks for integer variables
Logical	Package with logical blocks
Psychrometrics	Package with psychrometric blocks
Reals	Package with blocks for continuous variables
Routing	Package with blocks that combine and extract signals
Utilities	Package with utility functions
Types	Package with type definitions
Interfaces	Package with connectors for input and output signals

Elementary blocks



*Composition rules,
see <https://obc.lbl.gov/specification/cdl.html>*

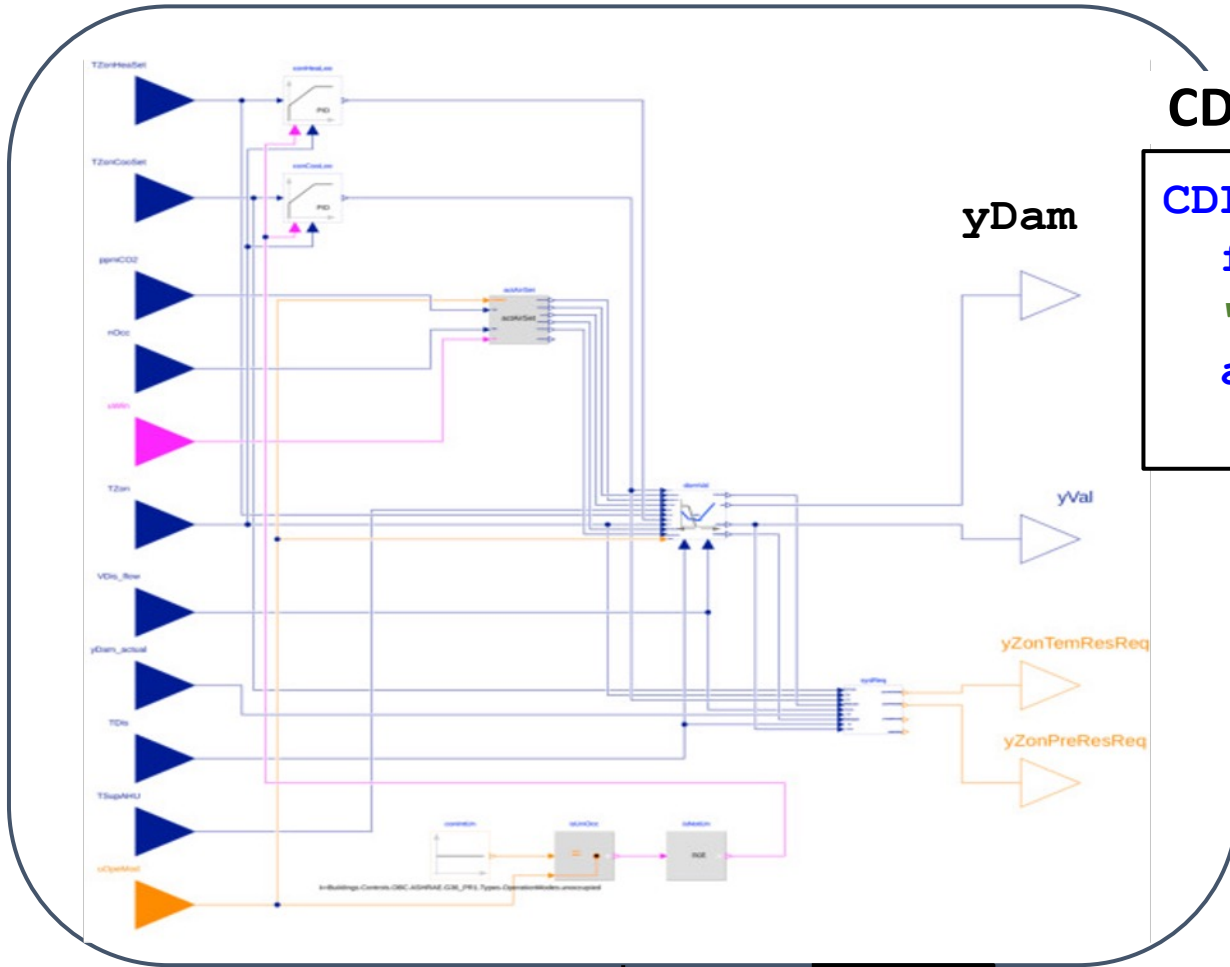
ASHRAE Standard 231P

Name	Description
UsersGuide	User's Guide
ASHRAE	Package with control sequences from ASHRAE projects
CDL	Package with blocks, examples and validation tests for control description language
OutdoorLights	Package with controllers for outdoor lights
RadiantSystems	Package with controllers for radiant heating and cooling systems
Shade	Package with controllers for shades
UnitConversions	Package with blocks for unit conversion
Utilities	Package with utility functions

Repository of pre-configured control logic

Combining control logic and semantic models to digitalized control delivery

Generic VAV terminal box control logic (CDL)



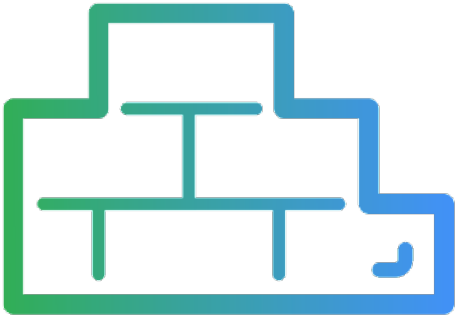
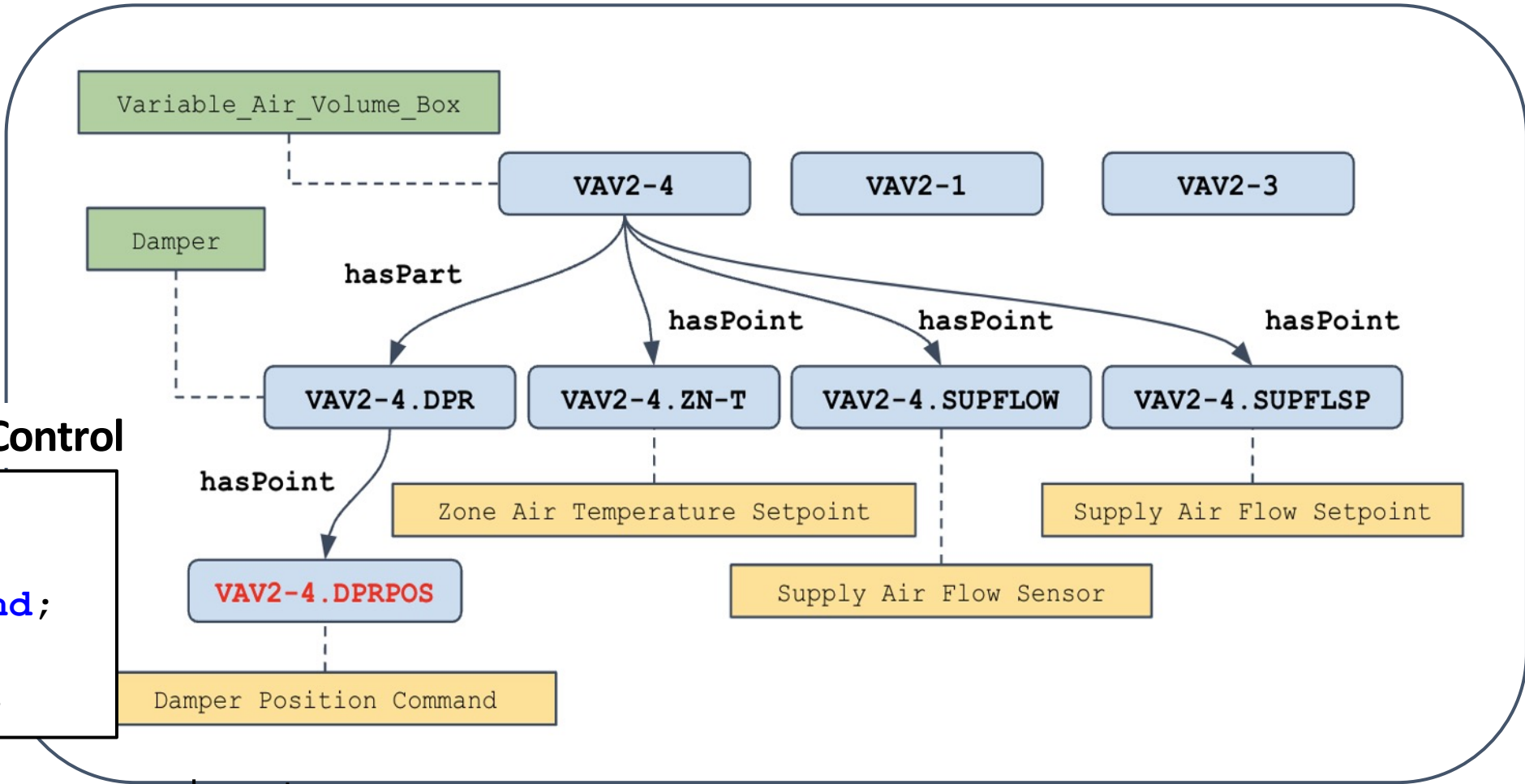
CDL for yDam VAV Damper Position Control

```
CDL.Interfaces.RealOutput yDam (  
  final min=0, final max=1, final unit="1")  
  "Signal for VAV damper"  
  annotation (__semantic(standard="brick"  
    "a brick:Damper_Command ."));
```

brick for VAV2-4.DPRPOS Damper Position Control

```
:VAV2-4 a brick:VAV;  
brick:hasPart :VAV2-4.DPR  
:VAV2-4.DPRPOS a brick:Damper_Command;  
brick:isPointOf :VAV2-4.DPR  
bacnet:object-name "DMP_CM_2-4" .
```

Building-specific semantic model (Brick)



Brick



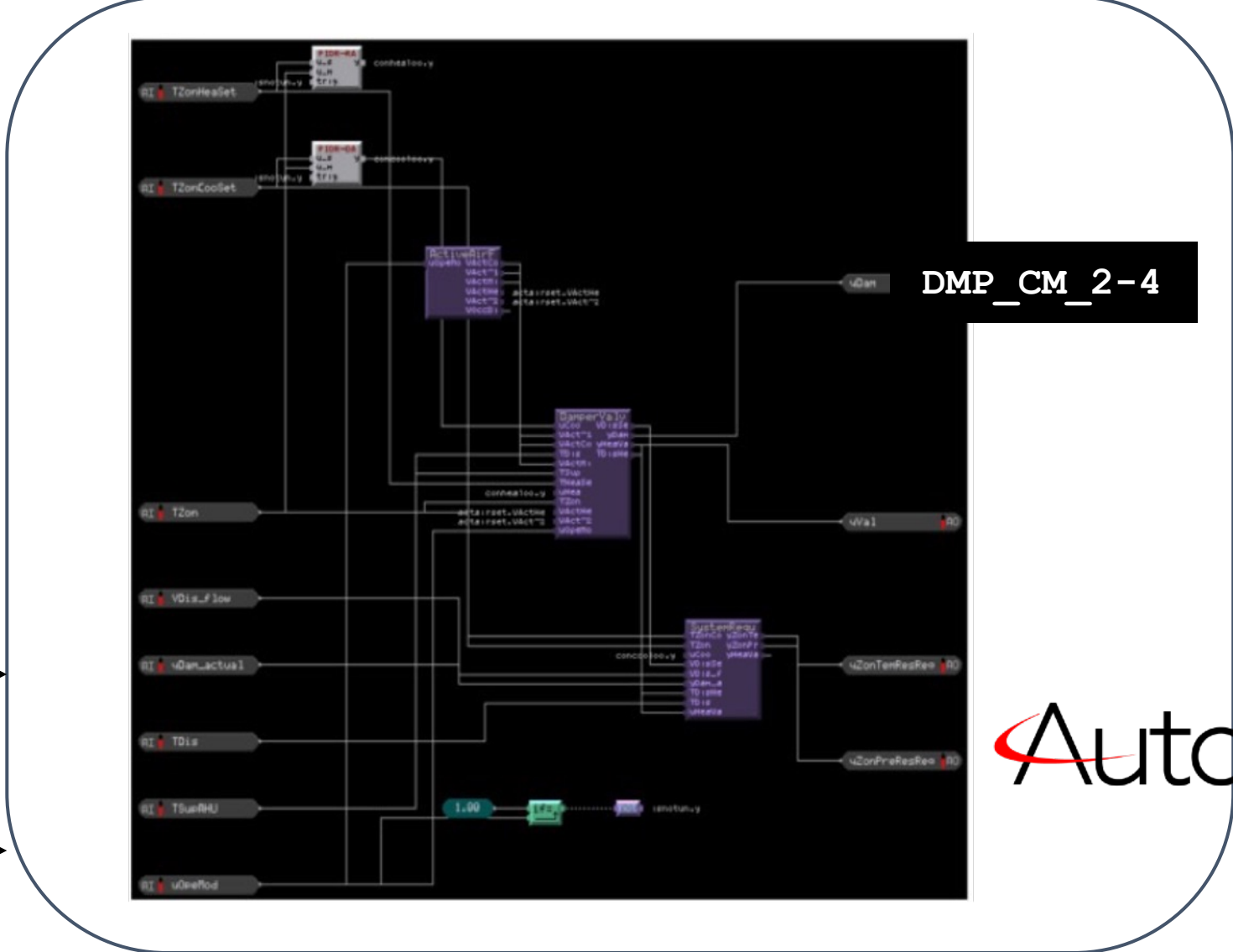
SPARQL query for finding VAV boxes in Brick model

```
SELECT ?vav WHERE {  
  ?vav a brick:VAV ;  
}  
Result: {"VAV2-4", "VAV2-1", "VAV2-3"}
```

SPARQL query for finding BACnet point name of VAV2-4 Damper Position control

```
SELECT ?dprpos ?point WHERE {  
  ?dprpos a brick:Damper_Command ;  
  brick:isPointOf+ :VAV2-4 ;  
  bacnet:object-name ?point .  
}  
Result: {"VAV2-4.DPRPOS", "DMP_CM_2-4"}
```

Building-specific VAV box control logic (ALC)



Discussion