

HVAC Library Buildings Library



Best of Both Worlds -
Integrating HVAC Library Heating and Cooling Systems with
Models from the Buildings Library

Annika Kuhlmann, M.Sc.
Jon Babst, M.Sc.

1. About XRG Simulation
2. HVACLibrary
3. BuildingsLibrary
4. Coupling Options
5. Example I: Coupling Spawn of Energy+
6. Example II: Coupling Component Models
7. Example III: Control with OBC/CDL
8. Summary

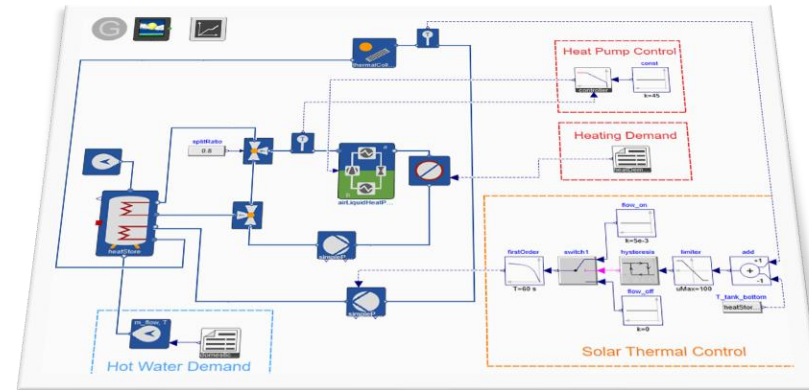
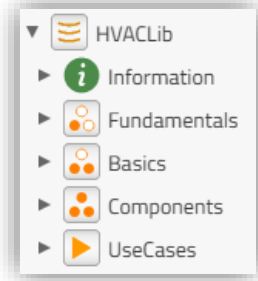
Who are we? What do we do?



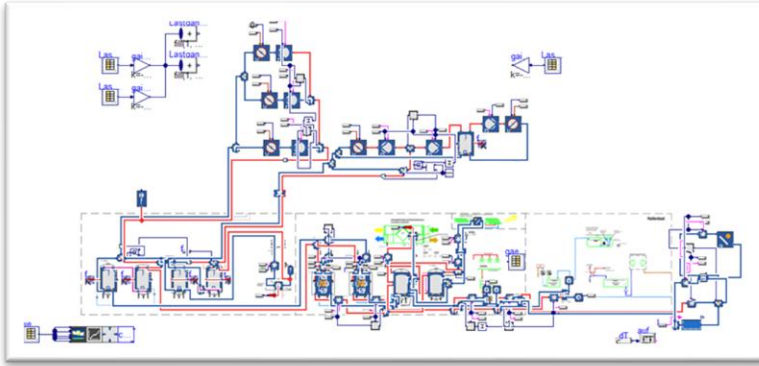
- Model-based system simulation with Modelica
- Main expertise in thermo-hydraulic energy systems in buildings, aviation & automotive and power generation
- Consulting and engineering services
- Development of simulation libraries and custom models in Dymola, Modelon Impact and OpenModelica



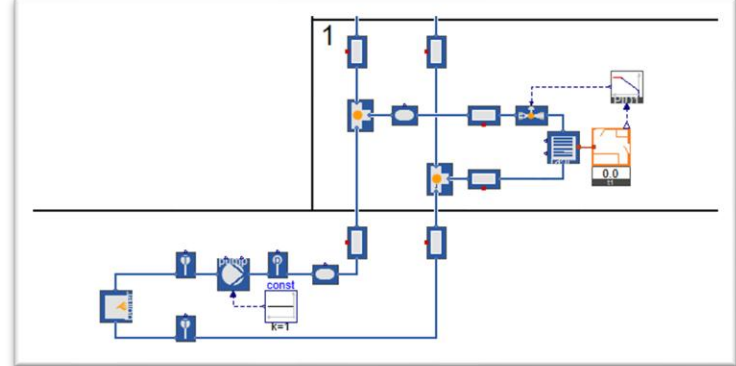
- Modelica library for HVAC and energy system simulation – air and liquid
- Used for simulation of annual energy consumption or control development
- Level of complexity in the model is kept low
- Mostly generic models that can be parameterized based on nominal data or data sheets
- Quickly build, parameterize and initialize system models



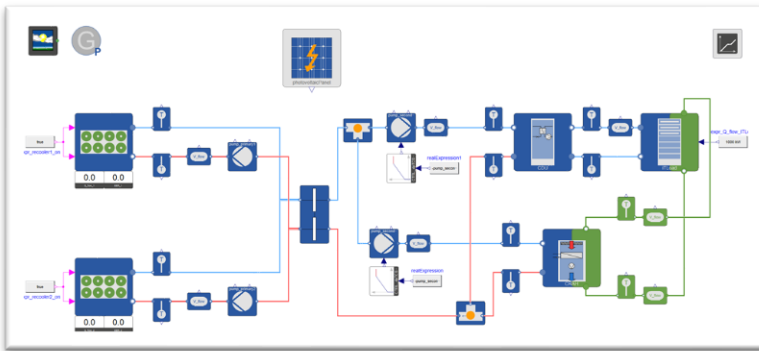
Complex hydraulic systems



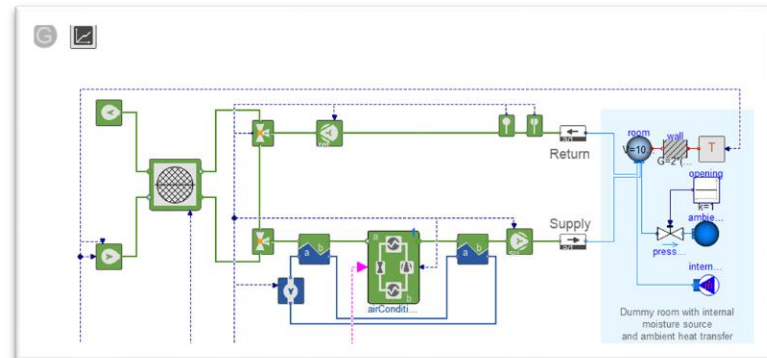
Feedback from thermal zone models



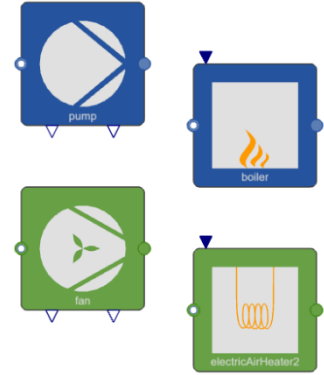
Datacenter



Air conditioning units/systems



- Different component models for **liquid** and **air**
- Flow connectors carry upstream temperature
→ reverse flow not calculated
- Media models based on MSL Media
 - Liquid media models with constant properties
 - Moist air medium model including condensation
- All volume models use a **steady-state mass balance** and a **dynamic energy balance** with temperature as state



$$0 = \dot{m}_{in} - \dot{m}_{out}$$

$T, \dot{m}, overPressure$

$T, \dot{m}, overPressure$

Xi, CO_2

$$der(M * u) = h_{in} * \dot{m}_{in} - h_{out} * \dot{m}_{out} + \dot{Q}$$





Pressure approach

- Simplified dynamic momentum balance to couple flow and pressure drop

$$\text{der}(\dot{m}) * \frac{L}{A} = dp_{in} - dp_{out} - dp$$

- Global pressure level – flow driven by “overPressure”
- Pressure drop calculated in components



Pressure-free approach

- Steady-state momentum balance

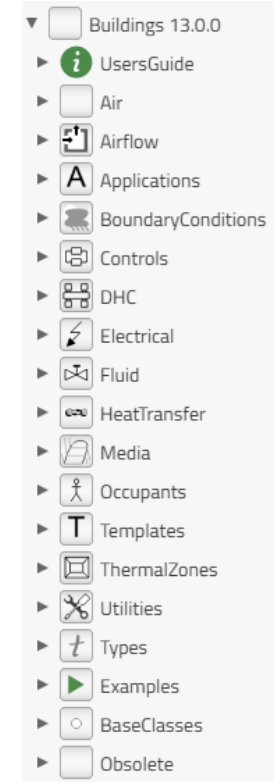
$$0 = dp_{in} - dp_{out} - dp$$

- No coupling between flow and pressure
- No pressure drop calculation in components
- Flow in each branch must be defined via pump or splits – input or controlled



Modelica Buildings Library

- Open-source Modelica library
- Developed and maintained by Lawrence Berkeley National Laboratory
- Widely adopted by academia and industry
- Comprehensive set of HVAC, control and building models
- Includes:
 - Detailed fluid systems
 - Building envelope models
 - Control sequences
 - Spawn of EnergyPlus integration



- Fluid connectors from MSL: carry specific enthalpy (stream), mass flow rate, pressure (and X_i , C)
- Classical MSL fluid approach: dynamic mass balance, dynamic energy balance, steady-state momentum balance

$$\text{der}(M) = \dot{m}_{in} - \dot{m}_{out}$$

$$\text{der}(M * u) = h_{in} * \dot{m}_{in} - h_{out} * \dot{m}_{out} + \dot{Q}$$

- Simple media models: liquids with constant properties, simplified moist air model (not saturated)
- States are usually U , m (and X_i)

Advantages of HVAC

- Fast and intuitive model development, even for engineers with limited Modelica experience
 - Component interconnections do not introduce nonlinear algebraic loops
- Robust initialization and improved simulation stability

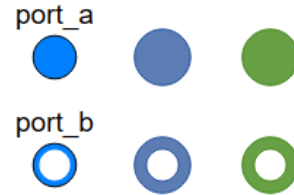
Advantages Buildings

- Open source
- Huge amount of specific components
- Building models

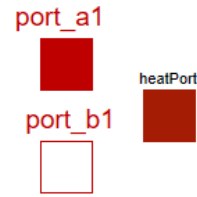
Customers requests:

- Use buildings libraries options for building modeling
- Simulate reverse flow in specific components
- Use buildings control automatization

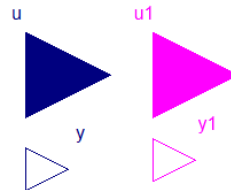
- **Flow coupling**



- **Heat coupling**



- **Control Coupling**



MediumHVAC

HVACLib
Liquid

$\dot{m}, T, p$

HVACLib
Air

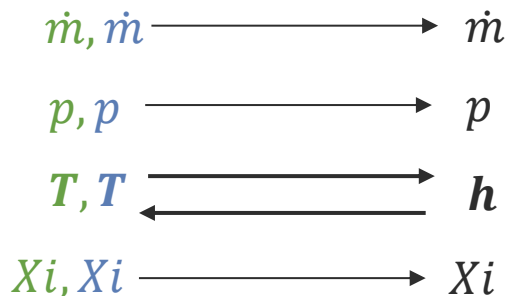
$\dot{m}, T, p, Xi$



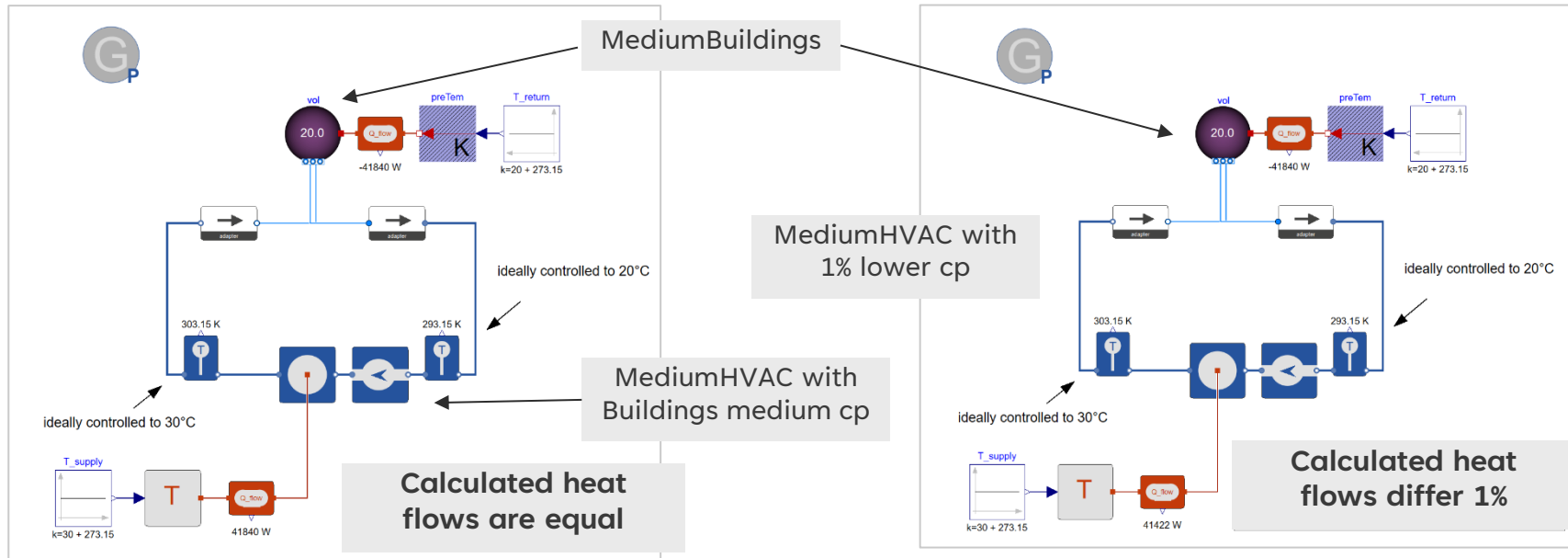
MediumMSL

MSL / Buildings

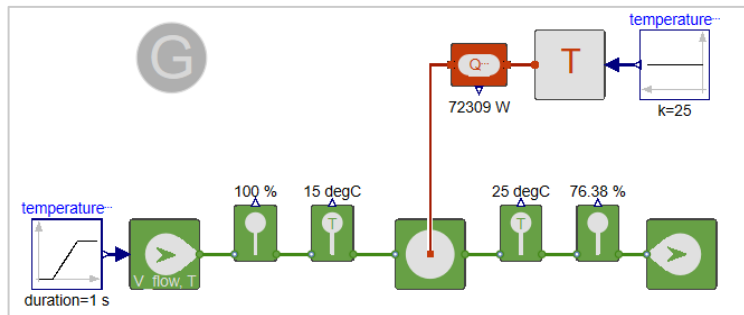
$\dot{m}, p, h, Xi$



Any media can be selected - BUT: the difference in cp will be the error in heat flow rates

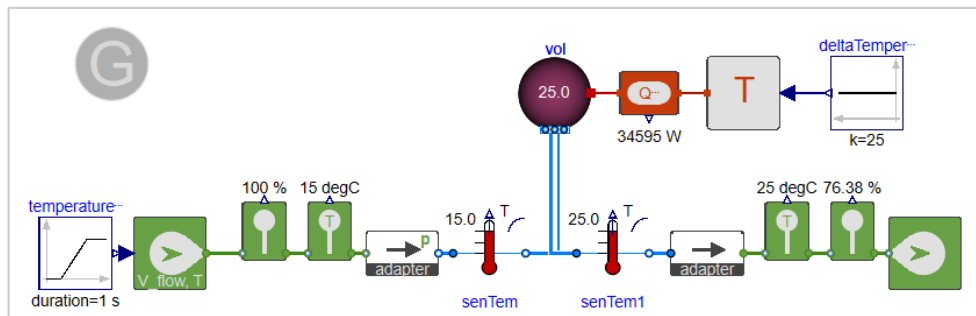


Simple tester: oversaturated moist air enters volume
– volume is heated to from 10°C to 25°C



1. HVACLib only:

- Liquid water is evaporated, then temperature increases
- Much energy is required for vaporization



2. Buildings volume:

- Heat of vaporization is neglected – less energy is required for heating the volume

HVACLib and Spawn of Energy+



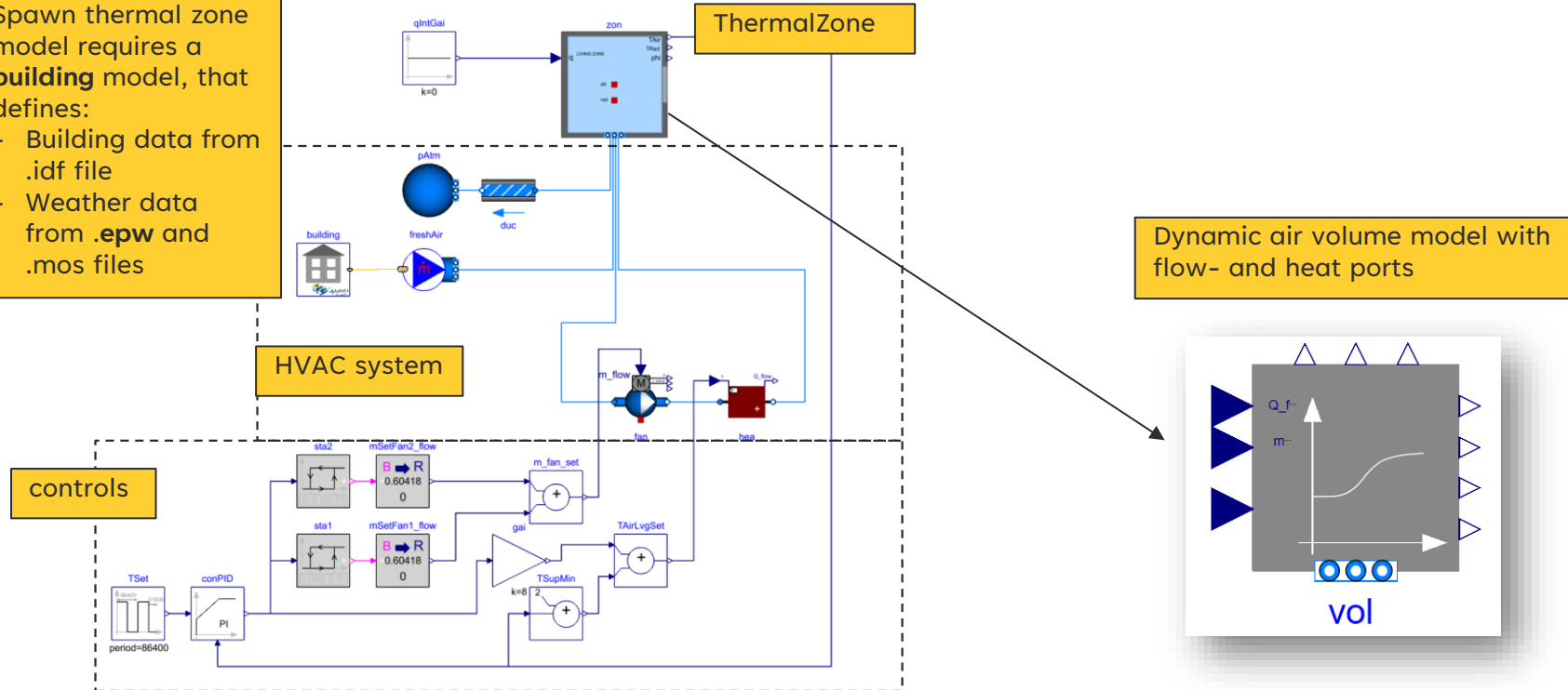
- Whole building energy-control **simulation tool chain** developed by DOE
- Bridges energy simulation and control implementation workflows
- Couples imperative **load-based envelope modelling** with new **equation-based modelling** of HVAC and controls for run-time data exchange



Buildings.ThermalZones.EnergyPlus_24_2_0.Examples.SingleFamilyHouse.AirHeating

Spawn thermal zone model requires a **building** model, that defines:

- Building data from .idf file
- Weather data from .epw and .mos files

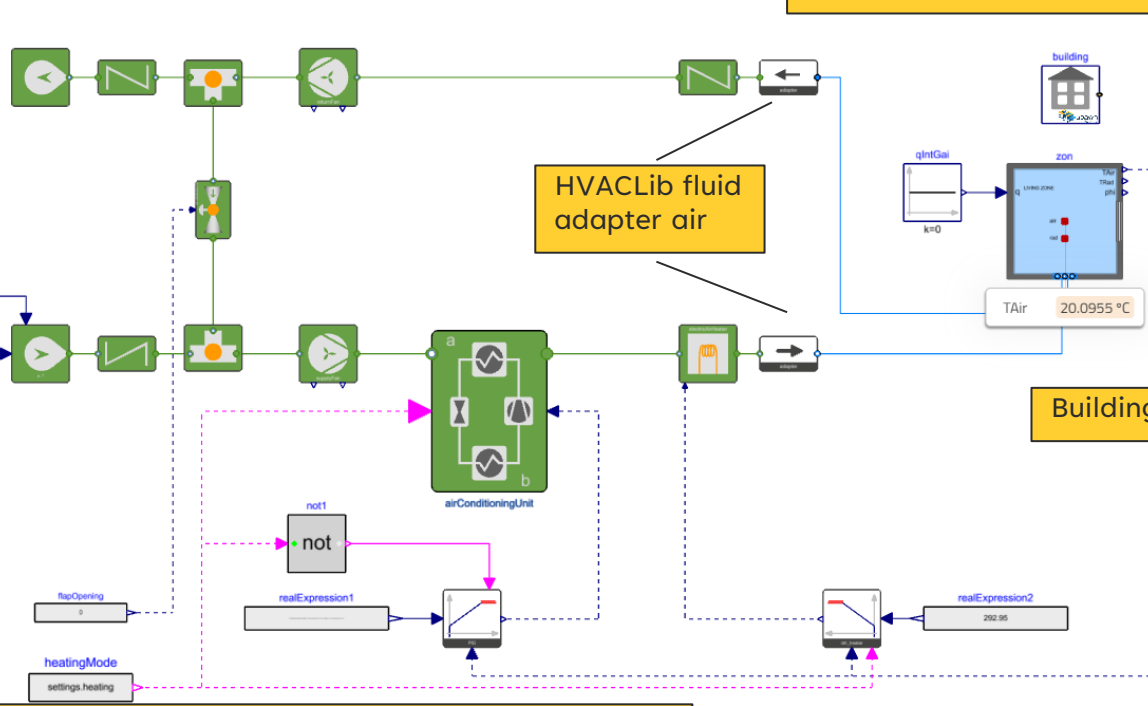
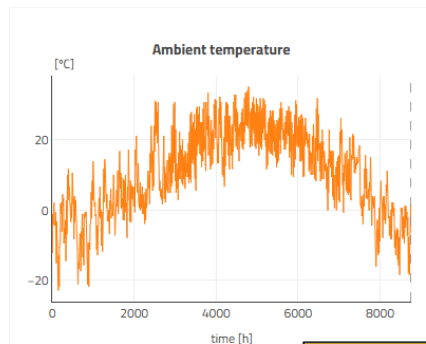


Example AirHandlingUnit

Simple air handling unit built with **HVACLib** air components

Thermal zone model from
BuildingsLibrary Spawn

HVACLib
weather
model
requires
.epw file



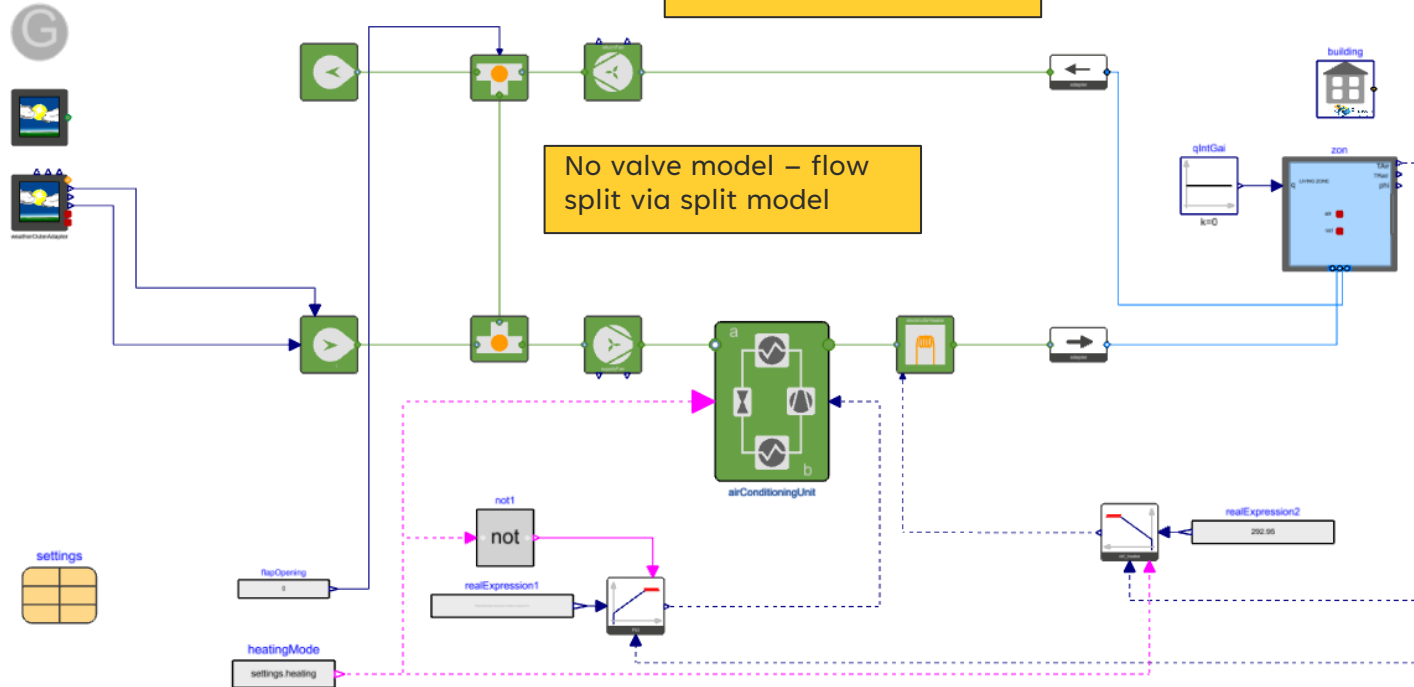
HVACLib.Fundamentals.Media.Gases.SimpleMoistAir

Example AirHandlingUnit

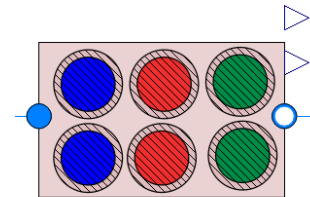
HVACLib pressure free approach

Fan models directly
define mass flow

No valve model – flow
split via split model

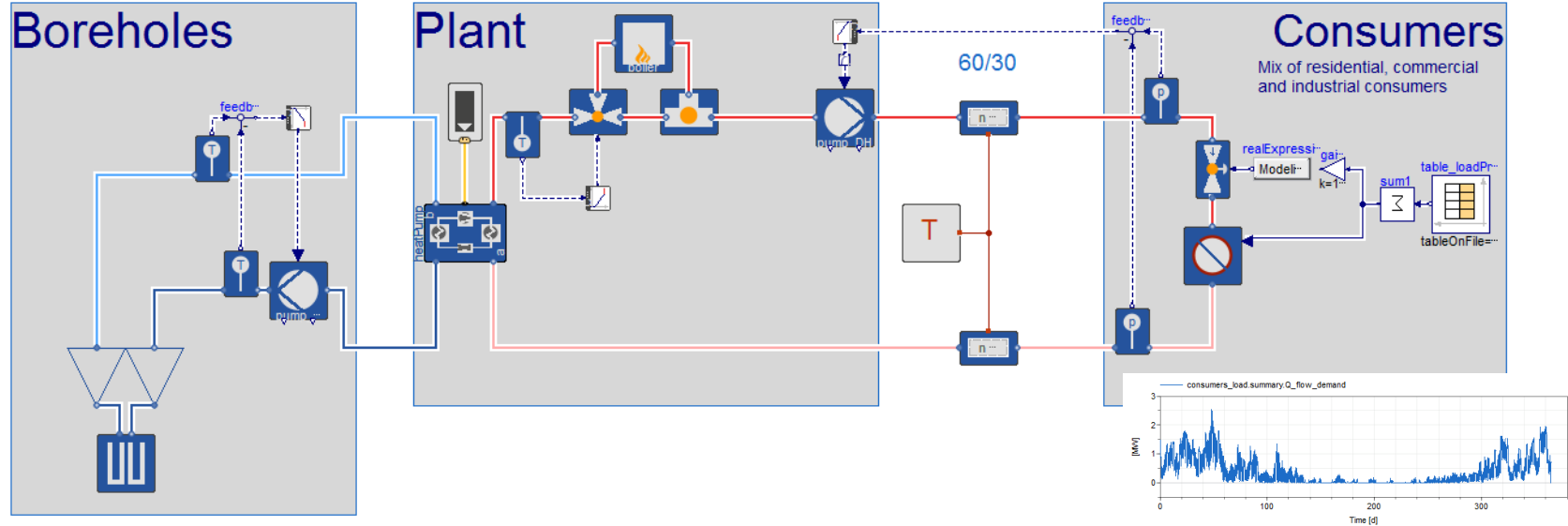


HVACLib and Buildings Components





Neighbourhood-scale district heating system



Geothermal borehole field with 175 probes

1.4MW heat pump + 1.2MW peak-load boiler
internal power control, external boiler bypass control.

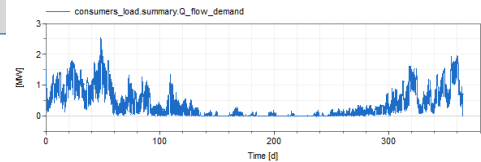
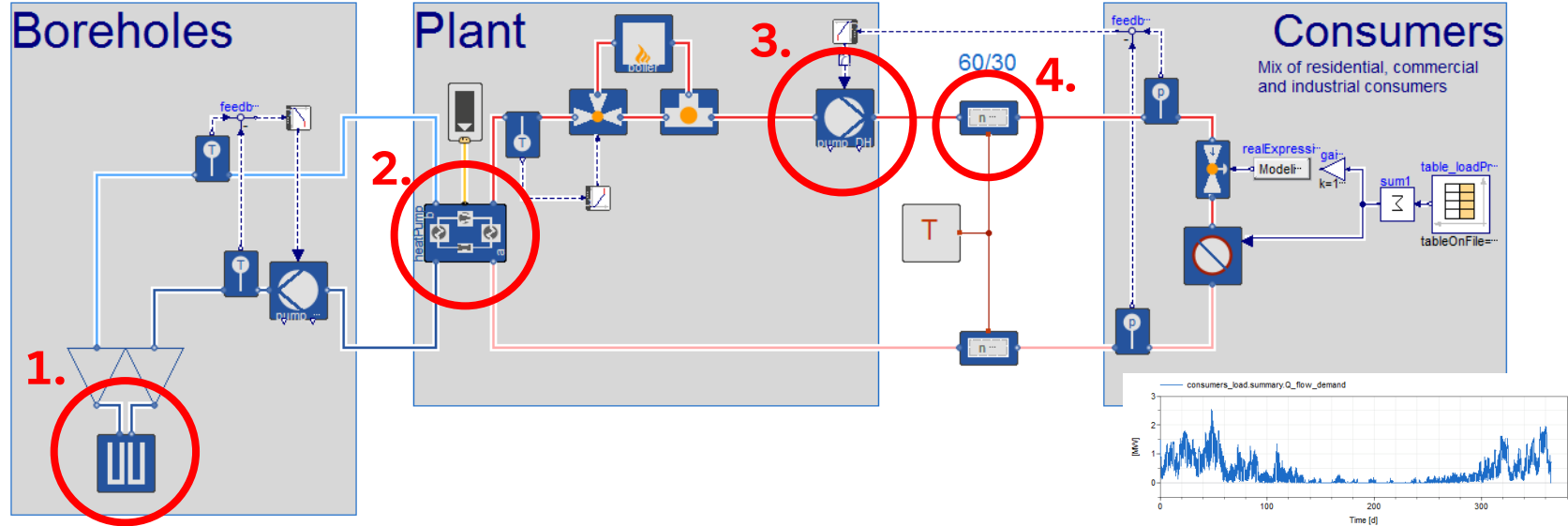
Constant pressure controlled pump

1km insulated pipe

Heating demand profile - 2.55MW
generated using HVAC's NominalThermalZone load mode using TMY weather data (Berlin)



Neighbourhood-scale district heating system



Geothermal borehole field with 175 probes

1.4MW heat pump + 1.2MW peak-load boiler
internal power control,
external boiler bypass control.

Constant pressure controlled pump

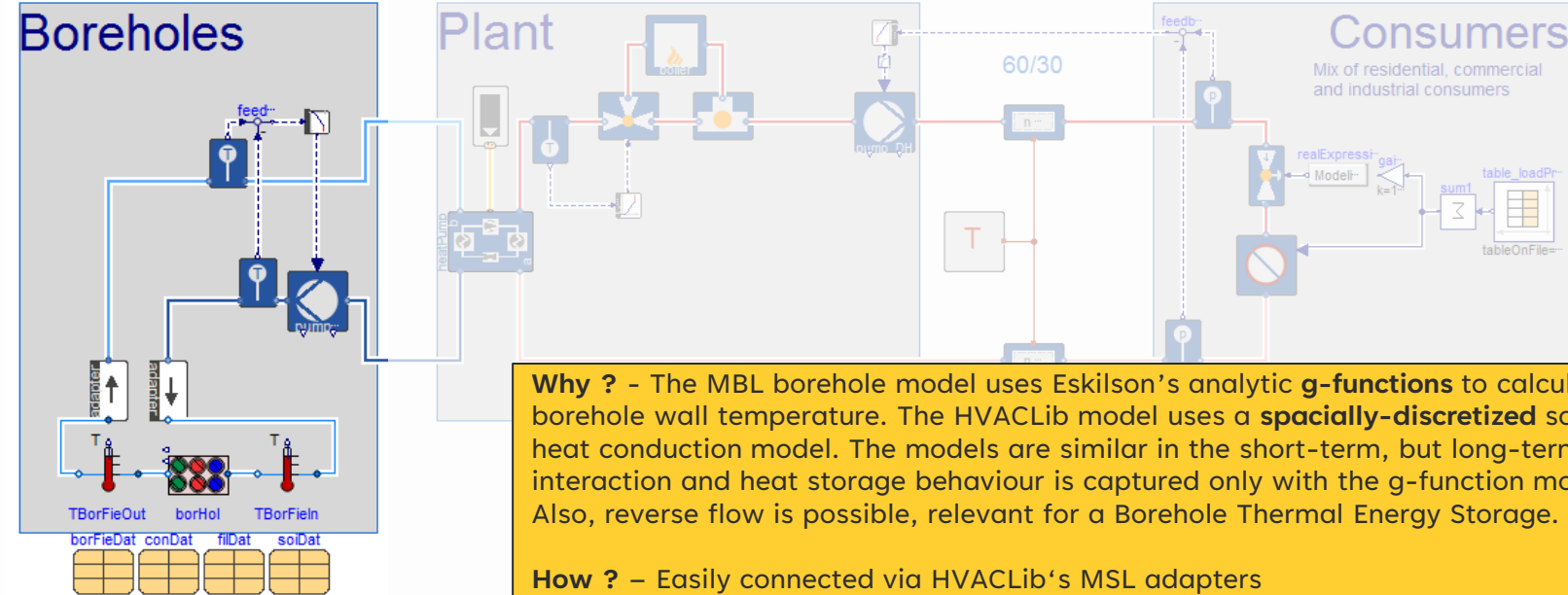
1km insulated pipe

Heating demand profile - 2.55MW

generated using HVAC's NominalThermalZone load mode using TMY weather data (Berlin)



Neighbourhood-scale district heating system



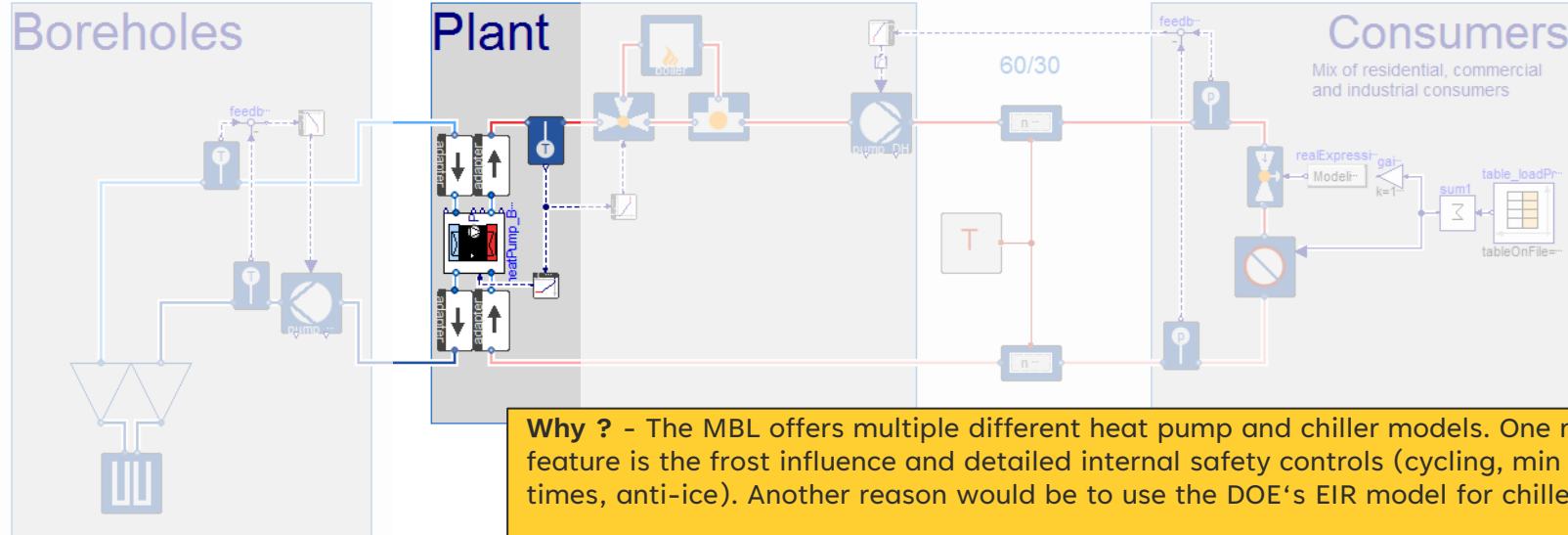
Why ? - The MBL borehole model uses Eskilson's analytic **g-functions** to calculate a borehole wall temperature. The HVACLib model uses a **spacially-discretized** soil heat conduction model. The models are similar in the short-term, but long-term interaction and heat storage behaviour is captured only with the g-function model. Also, reverse flow is possible, relevant for a Borehole Thermal Energy Storage.

How ? - Easily connected via HVACLib's MSL adapters

Consider ? - Parameter shank spacing (MBL: xC, HVACLib: s) is defined differently and needs to be converted.



Neighbourhood-scale district heating system



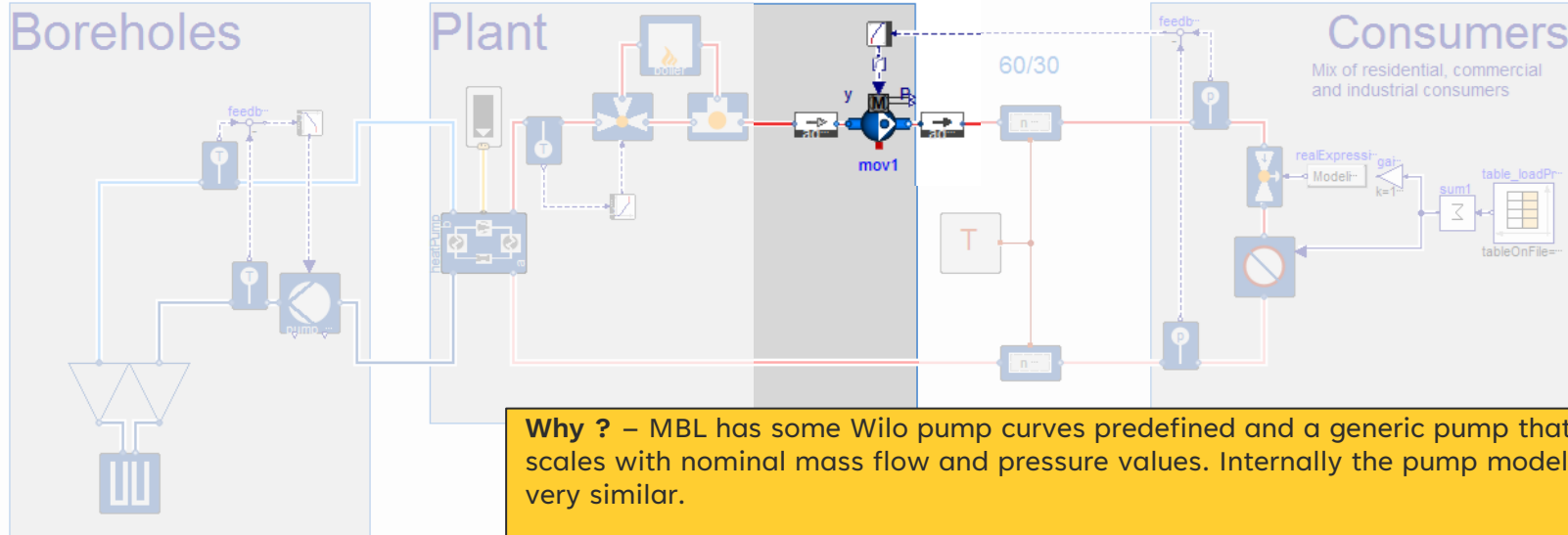
Why ? - The MBL offers multiple different heat pump and chiller models. One nice feature is the frost influence and detailed internal safety controls (cycling, min on/off times, anti-ice). Another reason would be to use the DOE's EIR model for chillers.

How ? - Easily connected via HVACLib's MSL adapters

Consider ? - The internal volume might have to be increased to prevent hitting the medium limits. An external power controller may be needed as this model in particular requires a relative power input.



Neighbourhood-scale district heating system



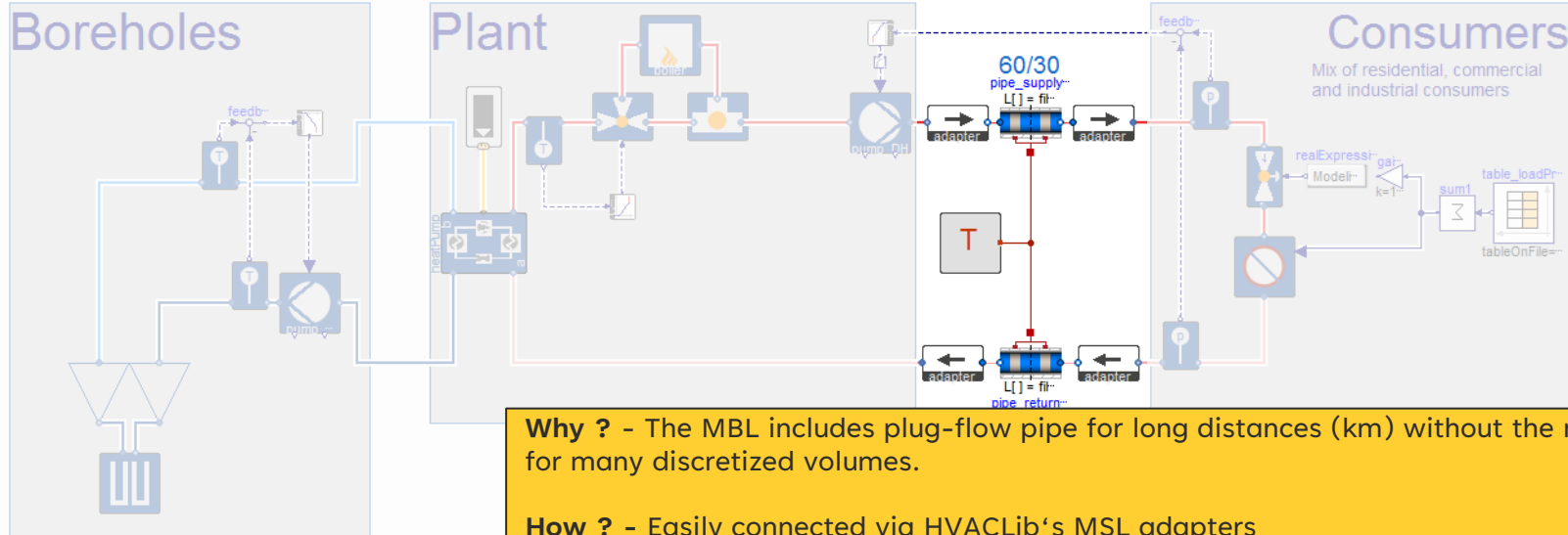
Why ? – MBL has some Wilo pump curves predefined and a generic pump that scales with nominal mass flow and pressure values. Internally the pump models are very similar.

How ? – via adapter. **Parameters „setPressure=true“ and „decoupleFlow=true“ have to be selected!**

Consider ? – The mass flow state variable will change position. Here: from pump to consumer valve.



Neighbourhood-scale district heating system



Why ? - The MBL includes plug-flow pipe for long distances (km) without the need for many discretized volumes.

How ? - Easily connected via HVACLib's MSL adapters

Consider ? - The heat transfer to ambient becomes nearly zero at low mass flows due to a regularization.

HVACLib and OBC/CDL



Problem:

“**Today’s control design**, implementation, and commissioning process is **manual**, labor-intensive, ambiguous and **error-prone**. It was not designed for high performance HVAC, much less for more complex decarbonized HVAC. “

Solution:

“Control Description Language (CDL),” does that by defining a portable representation of control logic that can be directly compiled for execution on commercial control platforms.

OBC: Open Buildings Control

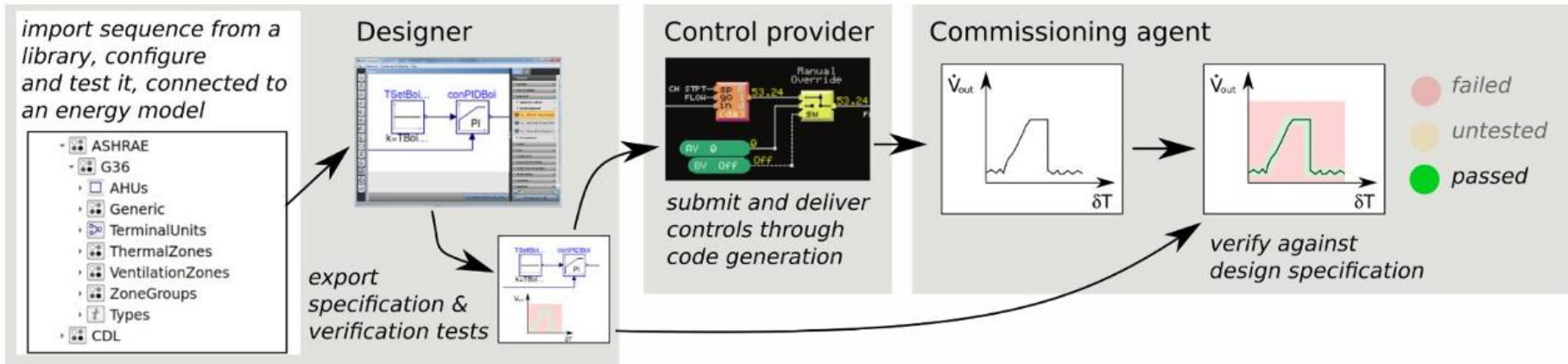


Research project

CDL: Control Description Language



“...a human-readable modeling language
for control logic...”
(ASHRAE Standard 231-2026)



Source: Michael Wetter, Lawrence Berkeley National Laboratory

- Idea is great: We had multiple cases of customers wanting to write controllers externally and interface with a HVACLib digital twin model via FMU
- Since subset of Modelica: Coupling with HVACLib possible

- Great idea and development!
- CDL is Modelica and therefore fully compatible with HVAC
- „...however, today's Building Automation Systems mostly do not support the direct execution...„
K. Walther, M. Wetter, A. Prakash, and J. Hu, "CDL-PLC Translator: From Modelica HVAC Control Design to IEC 61131 PLC Implementation," in Proceedings of the 16th International Modelica & FMI Conference, 2025.
- ->The complete workflow with direct execution is not yet possible in practice.

- Coupling of HVAC Library and Buildings Library is feasible using dedicated adapters
- Combining both libraries allows users to leverage the strengths of each modeling approach
- Pressure-based and pressure-free HVACLib approaches can both be coupled successfully
- Different medium models require careful consideration, especially for moist air applications
- Components like pumps in a closed loop require special adapter feature to decouple flow and set pressure level



XRG Simulation GmbH
Harburger Schlossstraße 6-12
21079 Hamburg
Germany
www.xrg-simulation.de