Energy in Buildings and Communities Programme

IEA EBC Annex 60

New Generation Computational Tools for Building and Community Energy Systems based on the Modelica and Functional Mockup Interface Standards

Co-operating agents:
Michael Wetter, LBNL, Berkeley, CA
Christoph van Treeck, RWTH Aachen, Germany

September 17, 2014

Lawrence Berkeley National Laboratory

The vision of Annex 60 is to create open-source software that builds the basis of next generation computing tools for the buildings industry

Allow engineers and scientists to

1) quickly assemble preconfigured, modifiable and scalable component models of

- buildings, district heating and cooling systems,
- electrical grids, and
- controls,

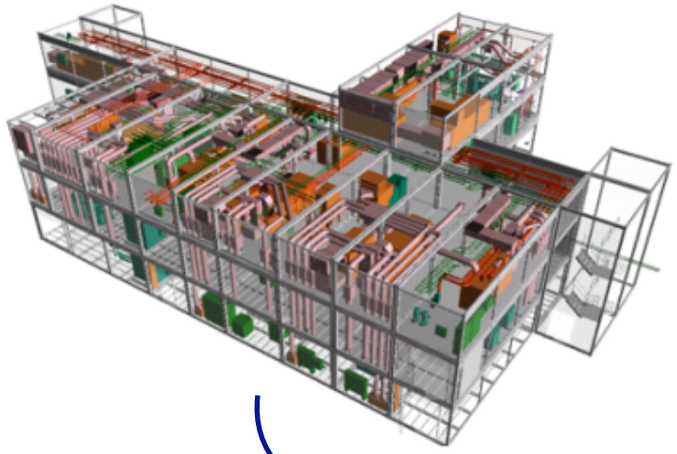
for design and analysis.

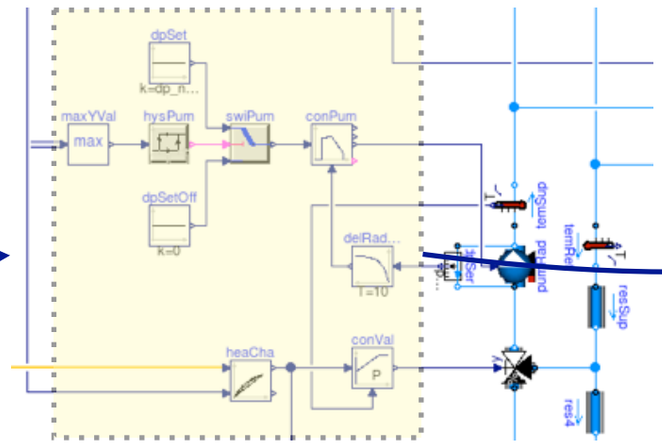
2) optimize the performance of technology options and control strategies in simulation, and

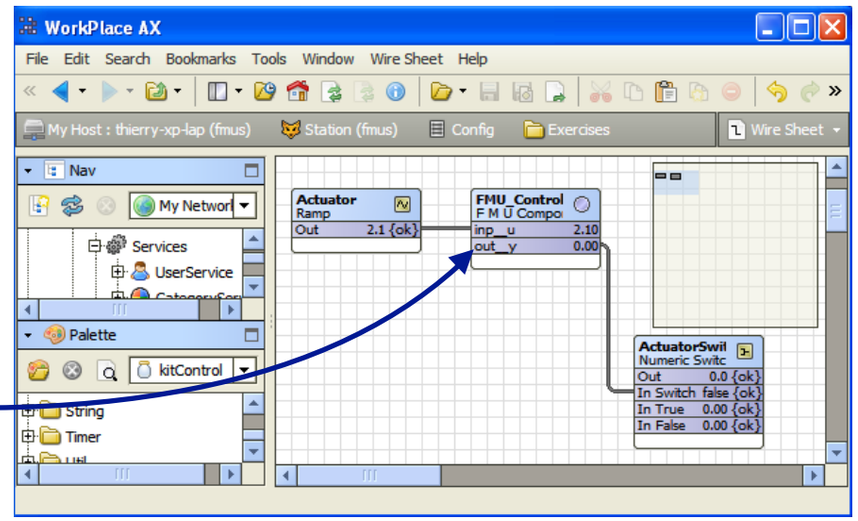
3) export models and control algorithms for

- hardware in the loop testing
- deployment to control systems and embedded hardware, and
- to run as a web service for real time operational support

Develop and distribute software open source.







Needs

Comprehensive, validated tools for

- design and operation of new buildings, energy grids and their control system
- model-based design, rapid virtual prototyping and hardware-in-the-loop

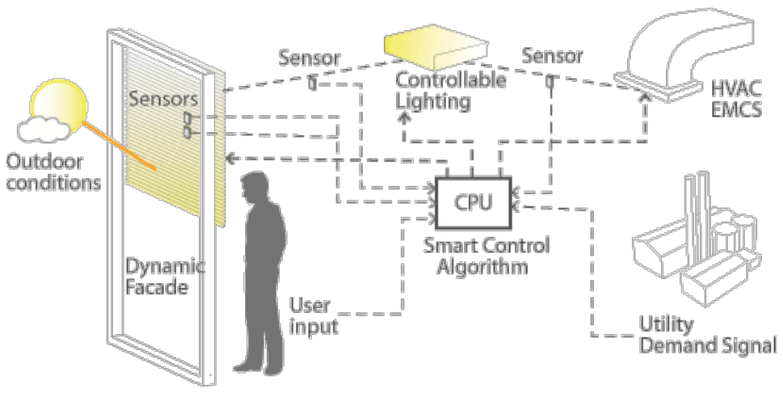
Scales from

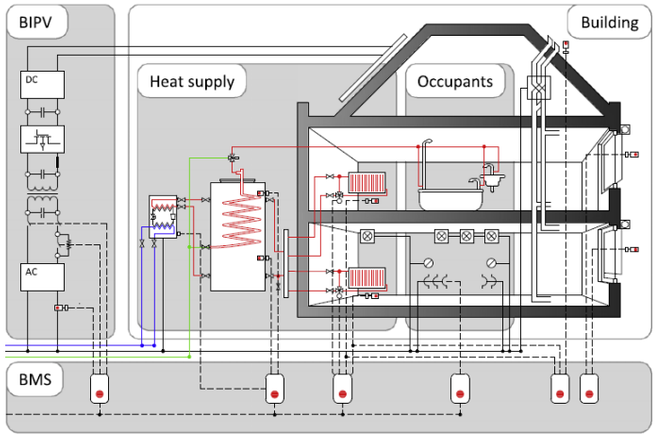
- local loop controller to supervisory controllers
- equipment to building systems
- buildings to community energy grids

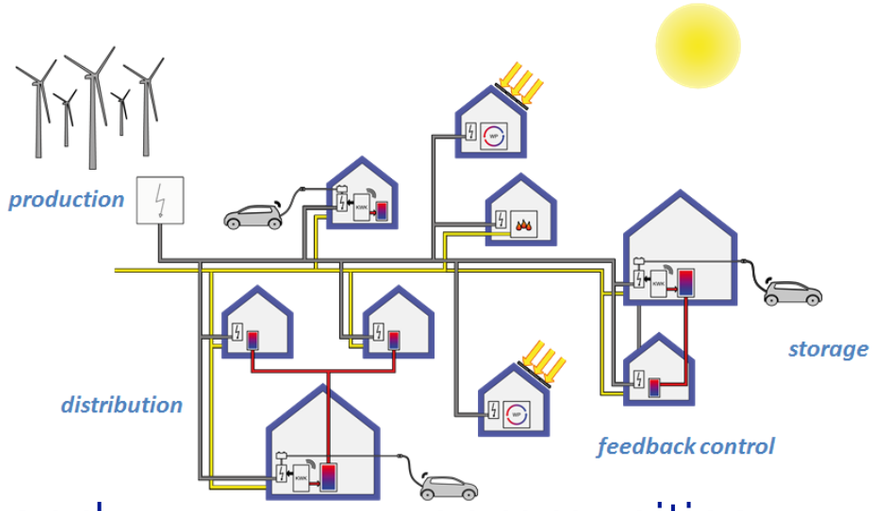
Multiple domains including thermal, air quality, electrical, control, lighting/daylighting and user behavior.

At the start of the Annex,

- 5 institutes developed their own Modelica libraries, leading to duplicative effort, limited scope and lack of interoperability.
- At least 5 different APIs for “interoperability between simulators” were in development.
- No BIM to Modelica translators.







From controls to buildings and communities

Objectives

For building designers and manufacturers

- open-source, free library of component and system models
- collection of case studies and demonstrations

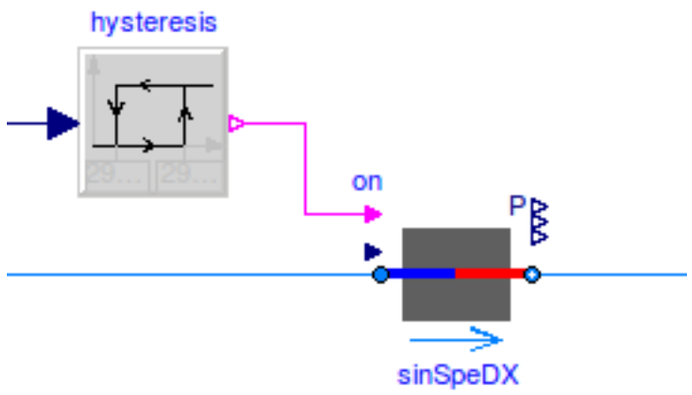
For researchers and manufacturers

- library and tools for rapid virtual prototyping and model-based design

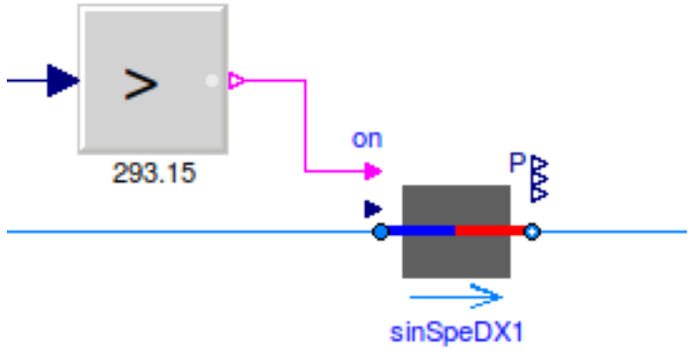
For simulation tool developers

- robust, validated software components with liberal open-source license, vetted by experts from around the world
- collaborative environment

Correct configuration

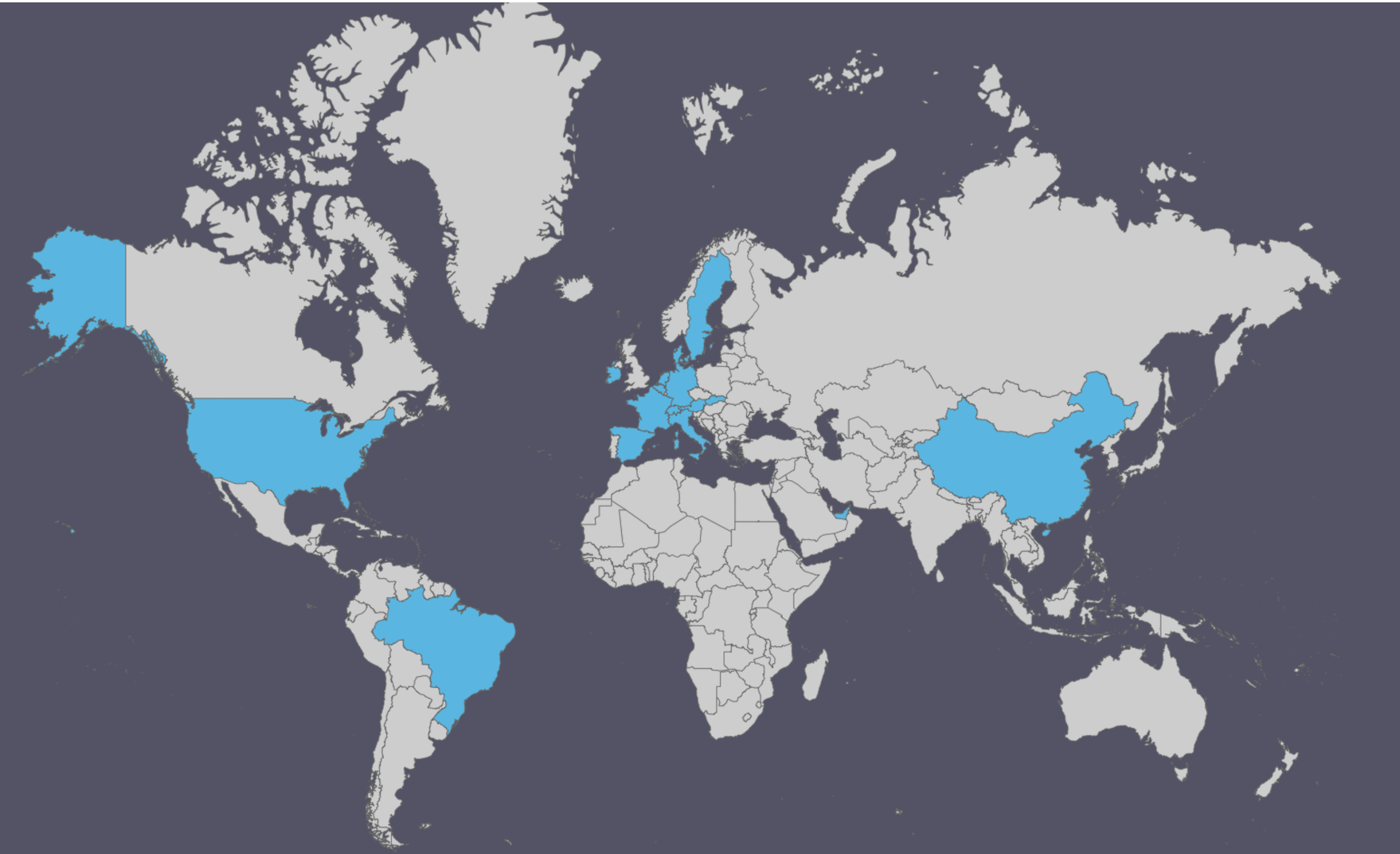


Avoid this configuration



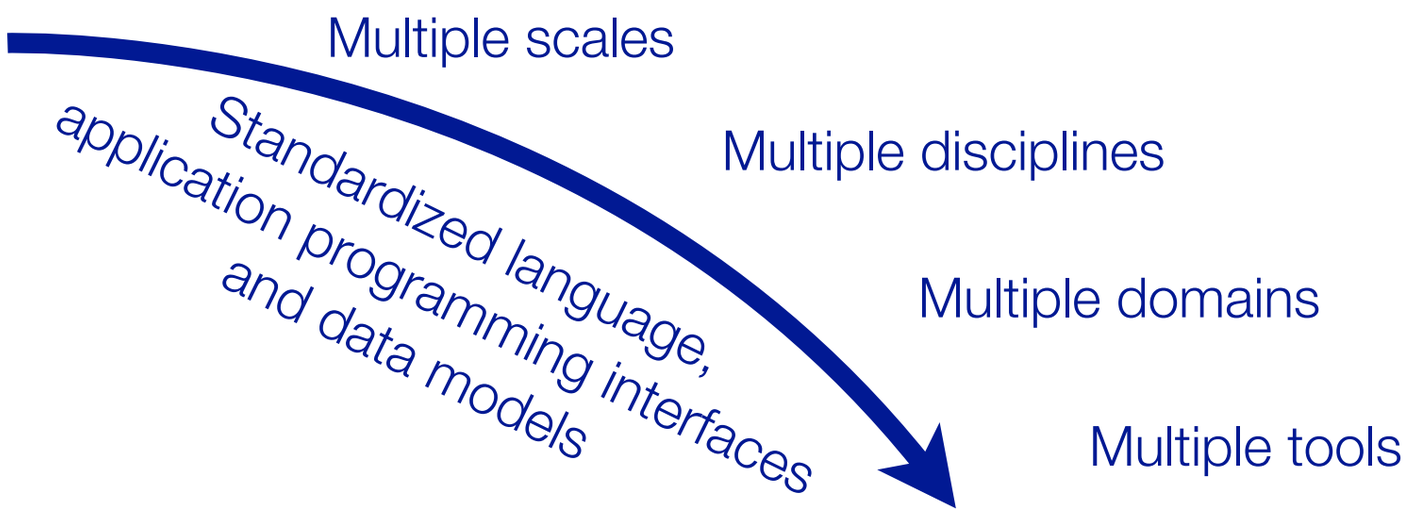
User guide with best practice.

38 institutes from 16 countries participate in Annex 60 between 2012 and 2017



Annex 60 structure

Energy in Buildings and Communities Programme



Objective

Building and community energy grids

designed & operated as integrated, robust, performance-based systems

Subtask 2

Applications on building design, district design, model-use during operation

Subtask 1

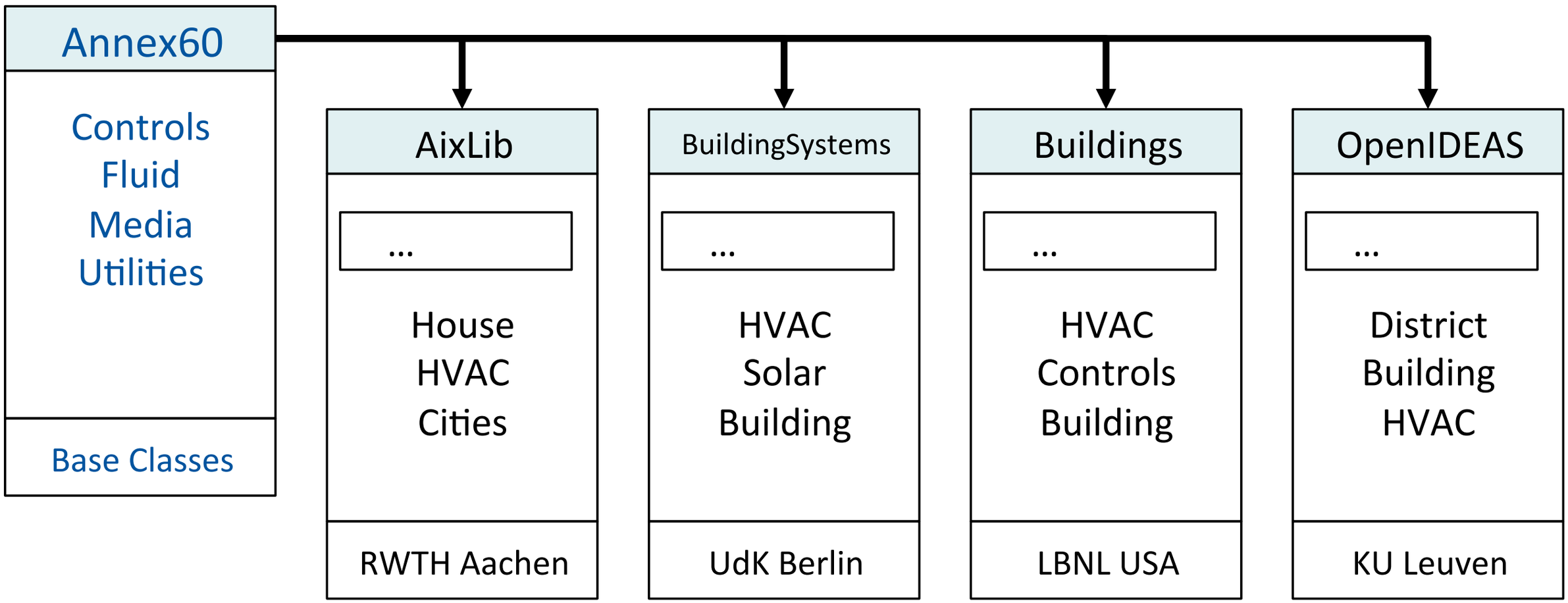
Technology development

Energy and control systems modeling libraries	**Co-simulation & model-exchange tools and interfaces**	**BIM translators**	**Automation**
Modelica. Free and open-source. Standardized interfaces. Buildings, districts, controls.	Functional Mockup Interface standard. FMI interfaces in existing simulators. Co-simulation algorithms.	Standardized model data exchange. Modelica/BIM interfaces.	Python modules for work-flow automation.

Activity 1.1- Modelica model libraries
Scope

Activity leader: Michael Wetter, LBNL, USA

Develop and distribute a well documented, vetted and validated open-source Modelica library that serves as the core of future building simulation programs.



Activity 1.1- Modelica model libraries Results up to date

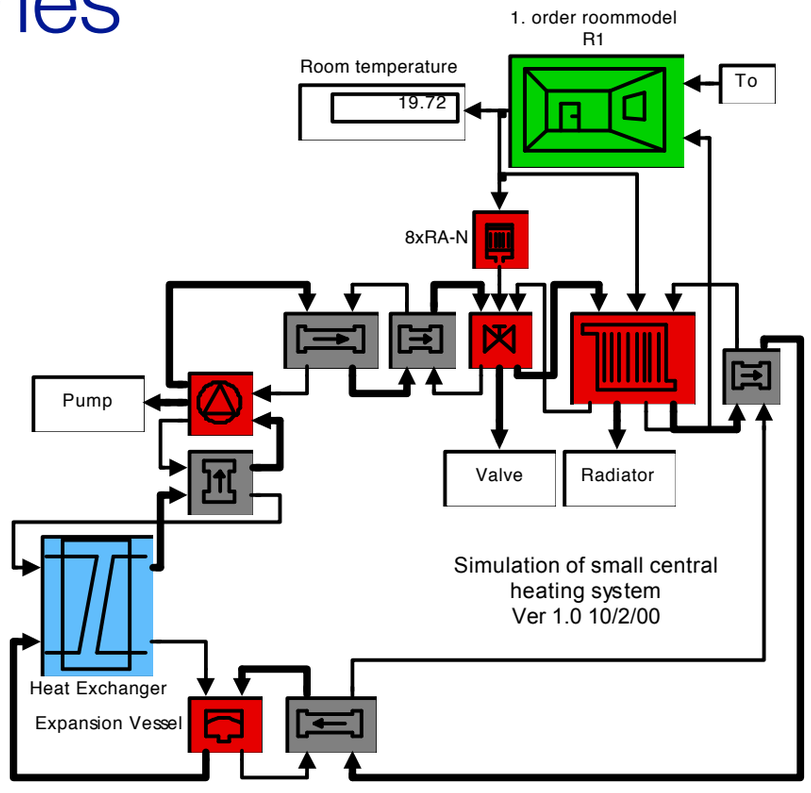
Activity leader: Michael Wetter, LBNL, USA

Developed core library with > 100 models, available at https://github.com/iea-annex60/modelica-annex60

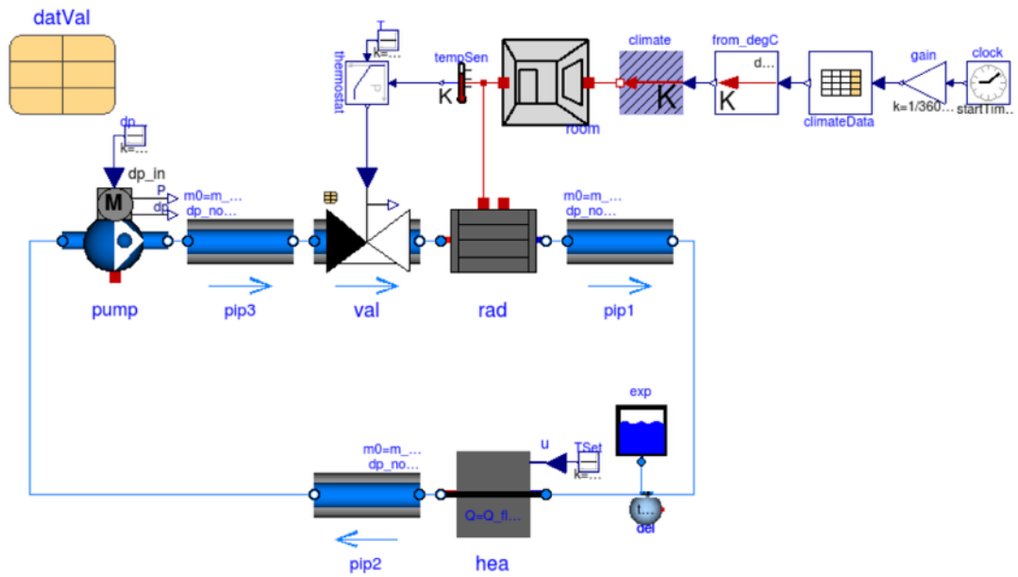
Successfully tested semi-automatic integration with LBNL and KU Leuven libraries.

Designed library to allow pre-compilation of models to make it applicable to IDA-ICE and the Spawn of EnergyPlus.

Ongoing: Benchmark numerical efficiency relative to IDA-ICE, MATLAB/Simulink, and IDEAS and AixLib Modelica libraries.



Simulink implementation using signal flow.



Modelica implementation using acausal models.

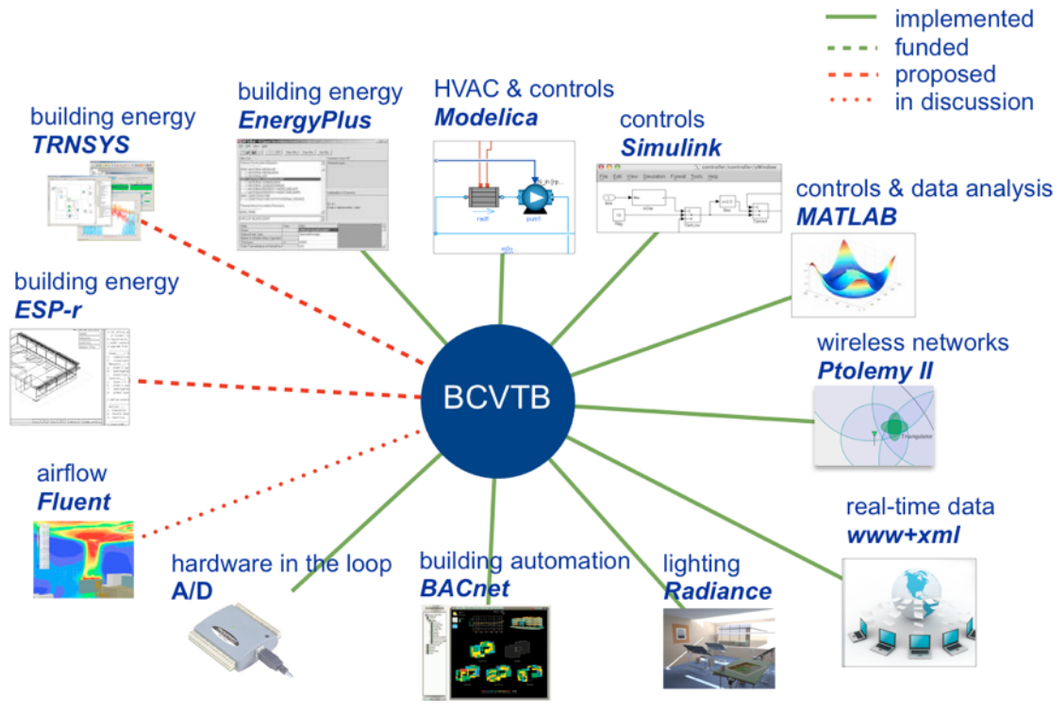
Activity 1.2- Co-simulation and model exchange Scope

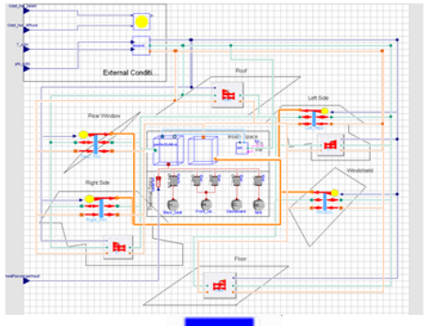
Activity leader: Frederic Wurtz, Grenoble University, France

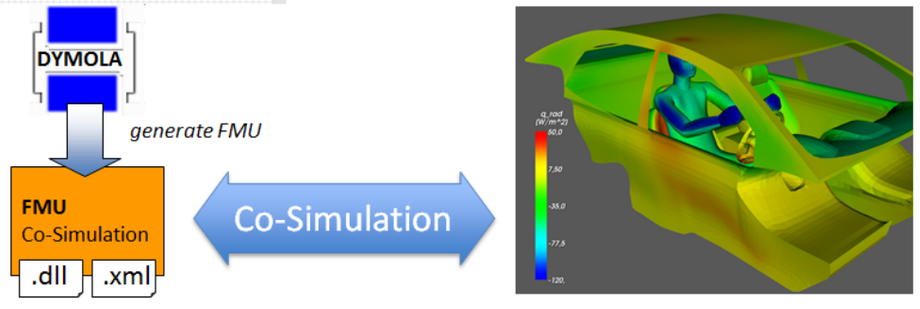
Implement FMI interfaces in building simulation programs.

Link domain-specific simulation programs with Modelica-based tools.

Exchange knowledge on development of co-simulation algorithms.

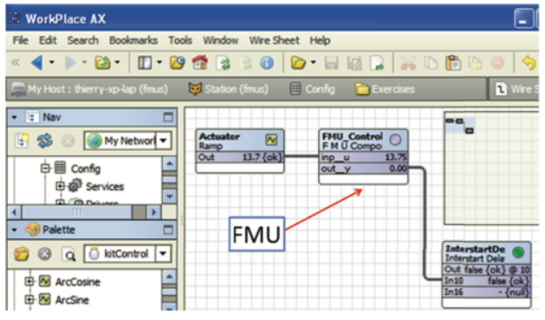




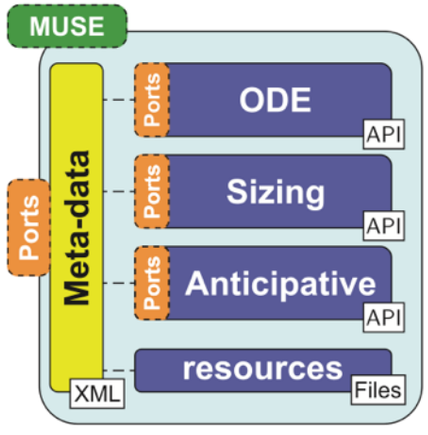


Activity 1.2- Co-simulation and model exchange
Results up to date

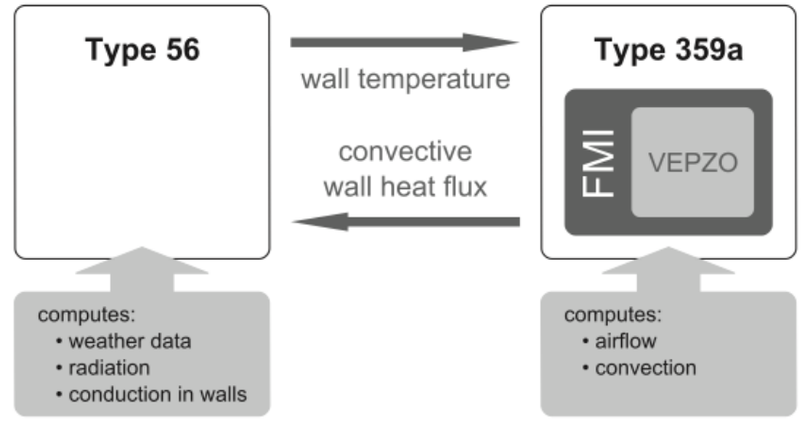
Joint paper about co-simulation in buildings, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6842396



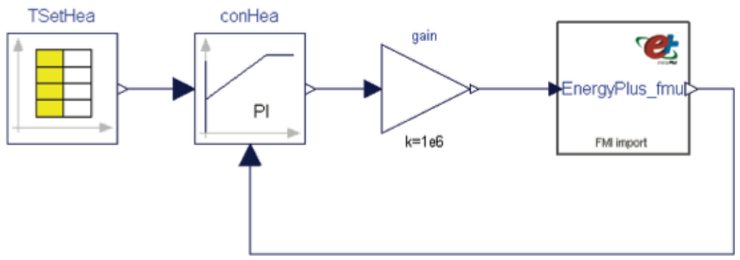
FMU import in Niagara
(LBNL, USA)



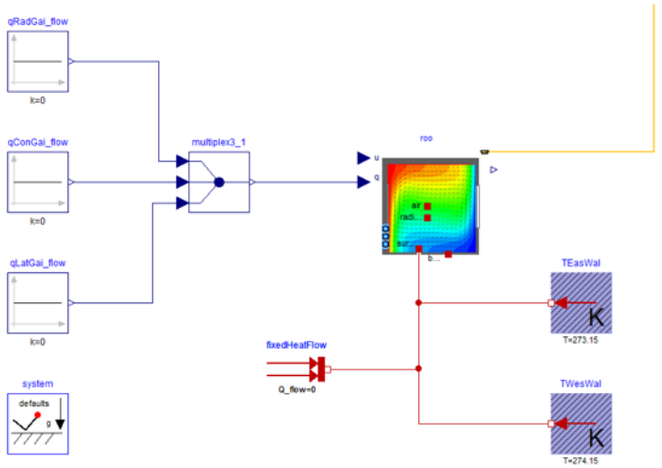
Model for unified energy systems
(Grenoble Uni., France)



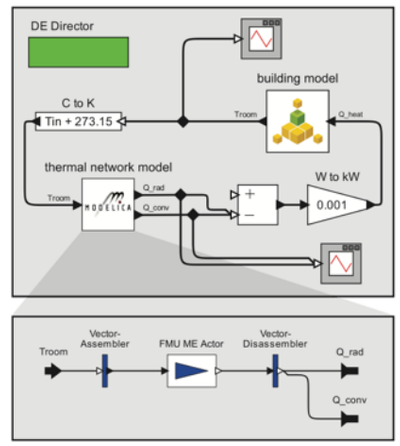
VElocity Propagating ZOnal model in TRNSYS
(Fraunhofer, Germany)



FMU export of EnergyPlus
(LBNL, USA)



CFD in Modelica Buildings library
(Univ. of Miami & LBNL, USA)

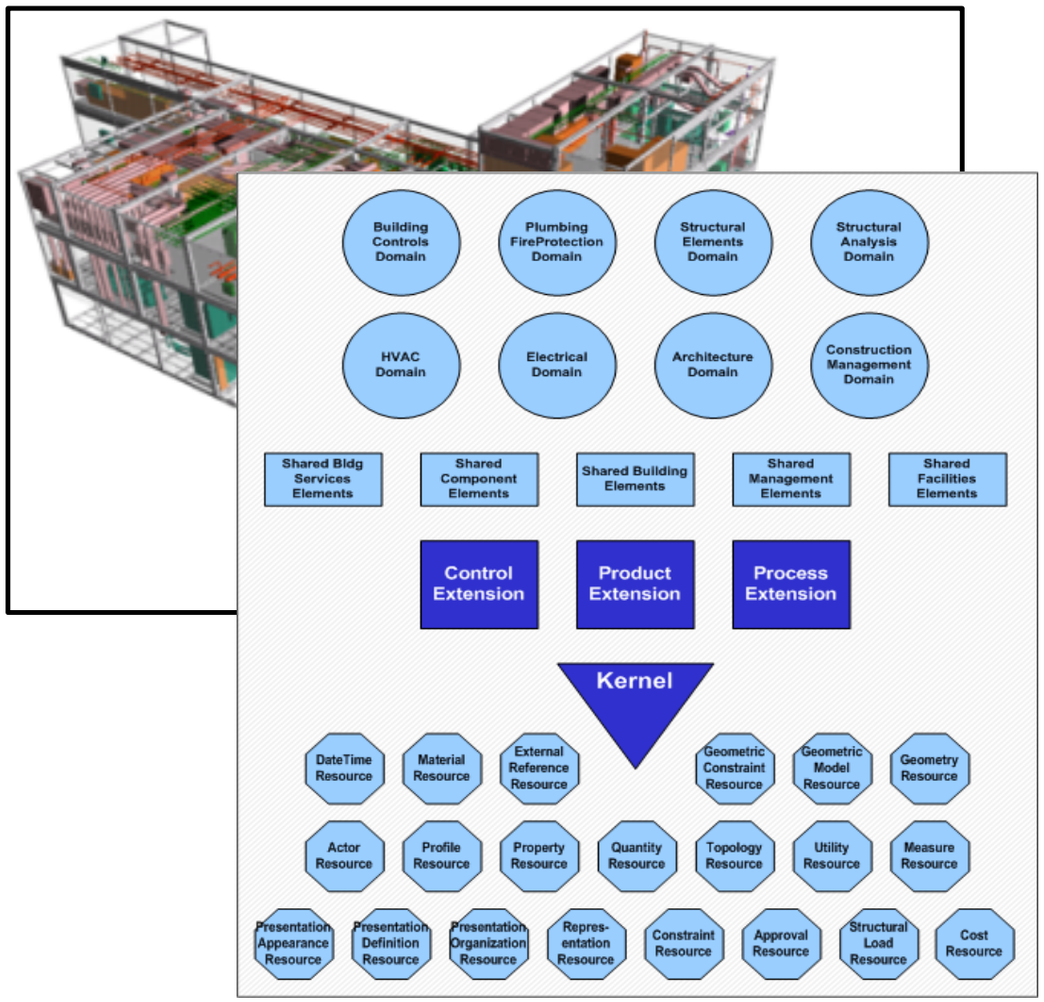


Co-simulation between TRNSYS & Modelica within Ptolemy II
(AIT, Austria)

Activity 1.3- Building Information Modeling Scope

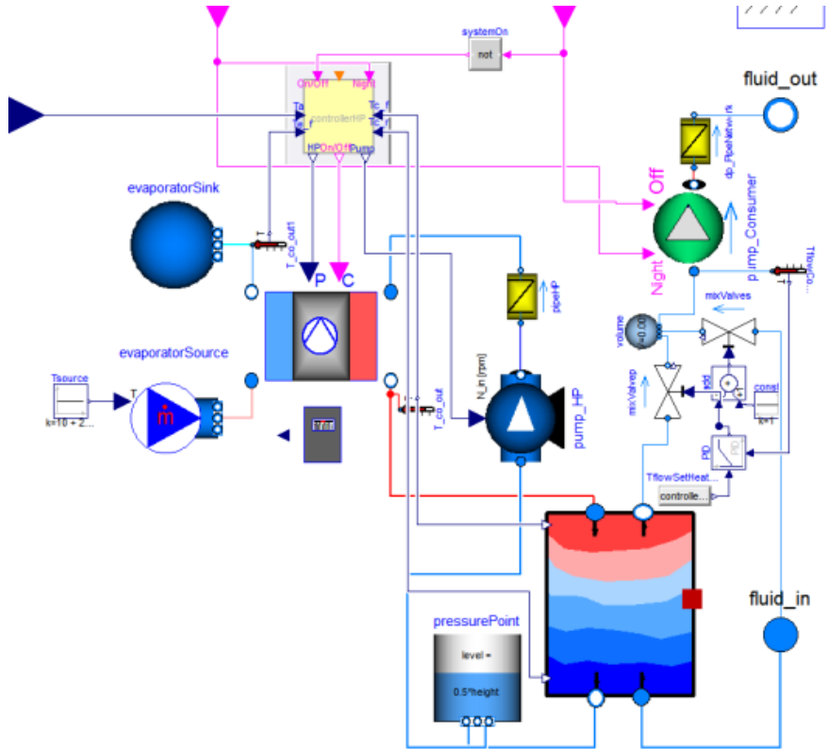
Activity leader: Christoph van Treeck, Germany

Develop BIM to BEM translation from Modelica.

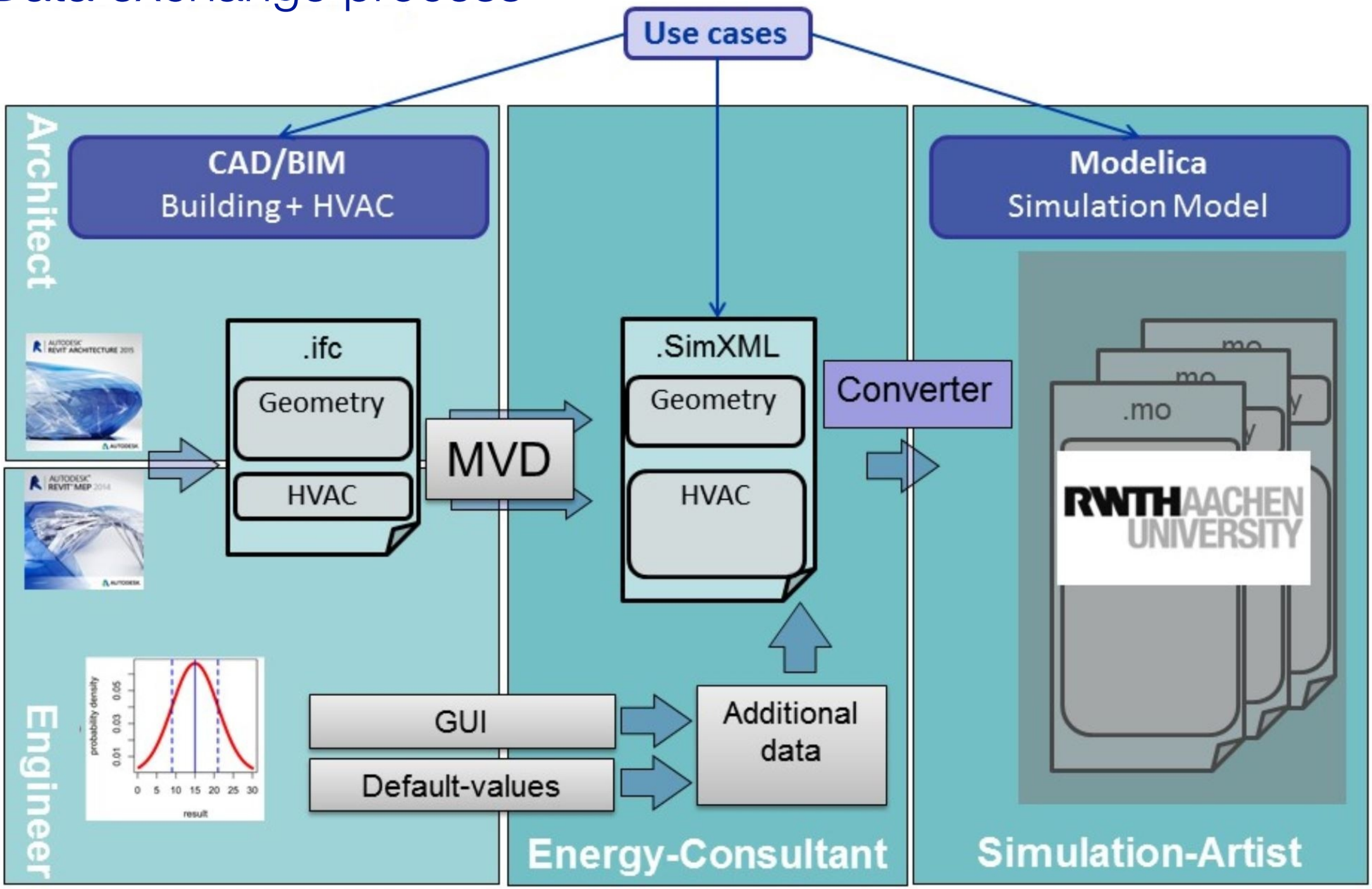


IFC model

eeBIM
xml representation

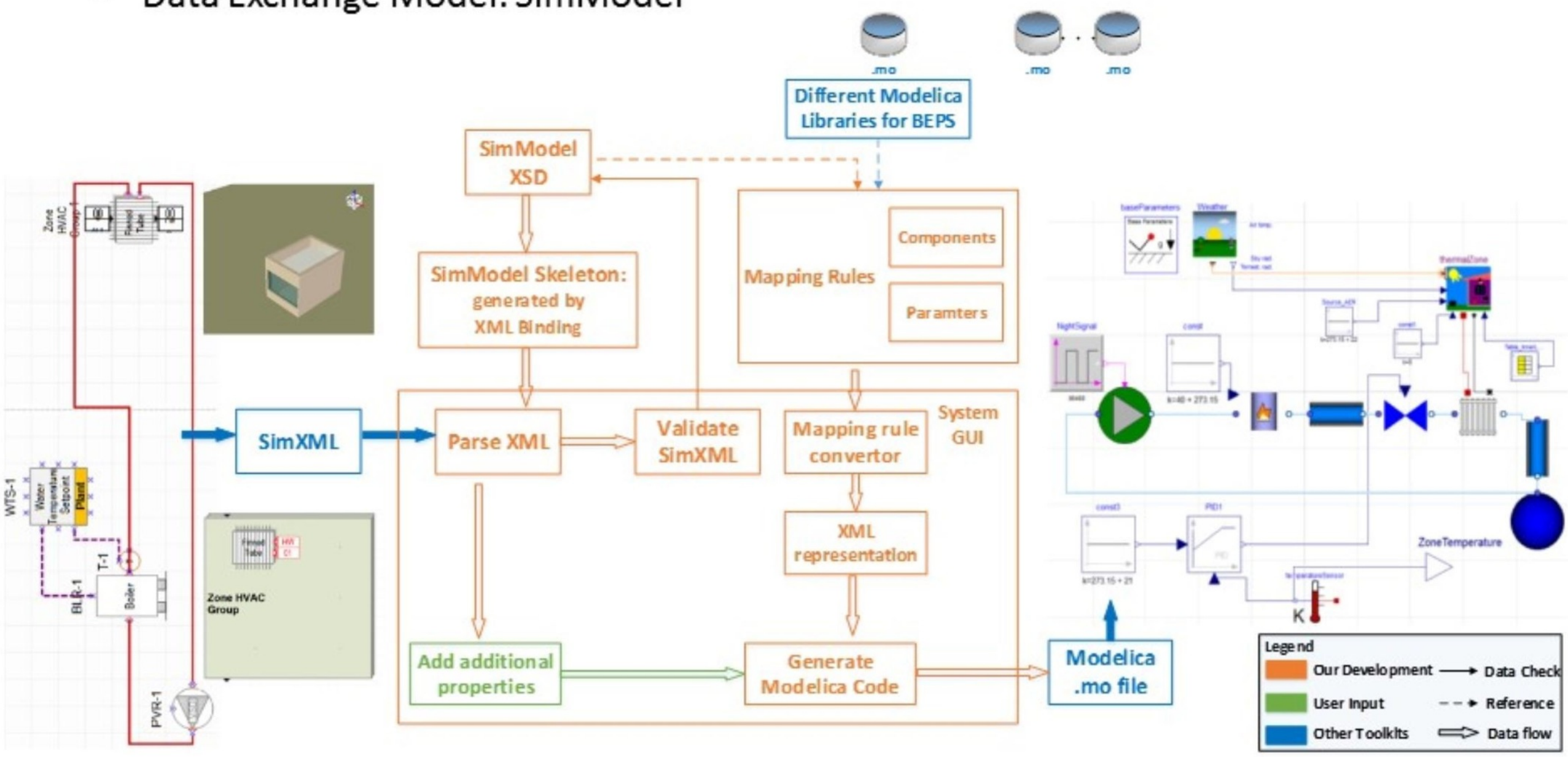


Activity 1.3- Building Information Modeling
Data exchange process



Activity 1.3- Building Information Modeling Transformation process

- Data Exchange Model: SimModel

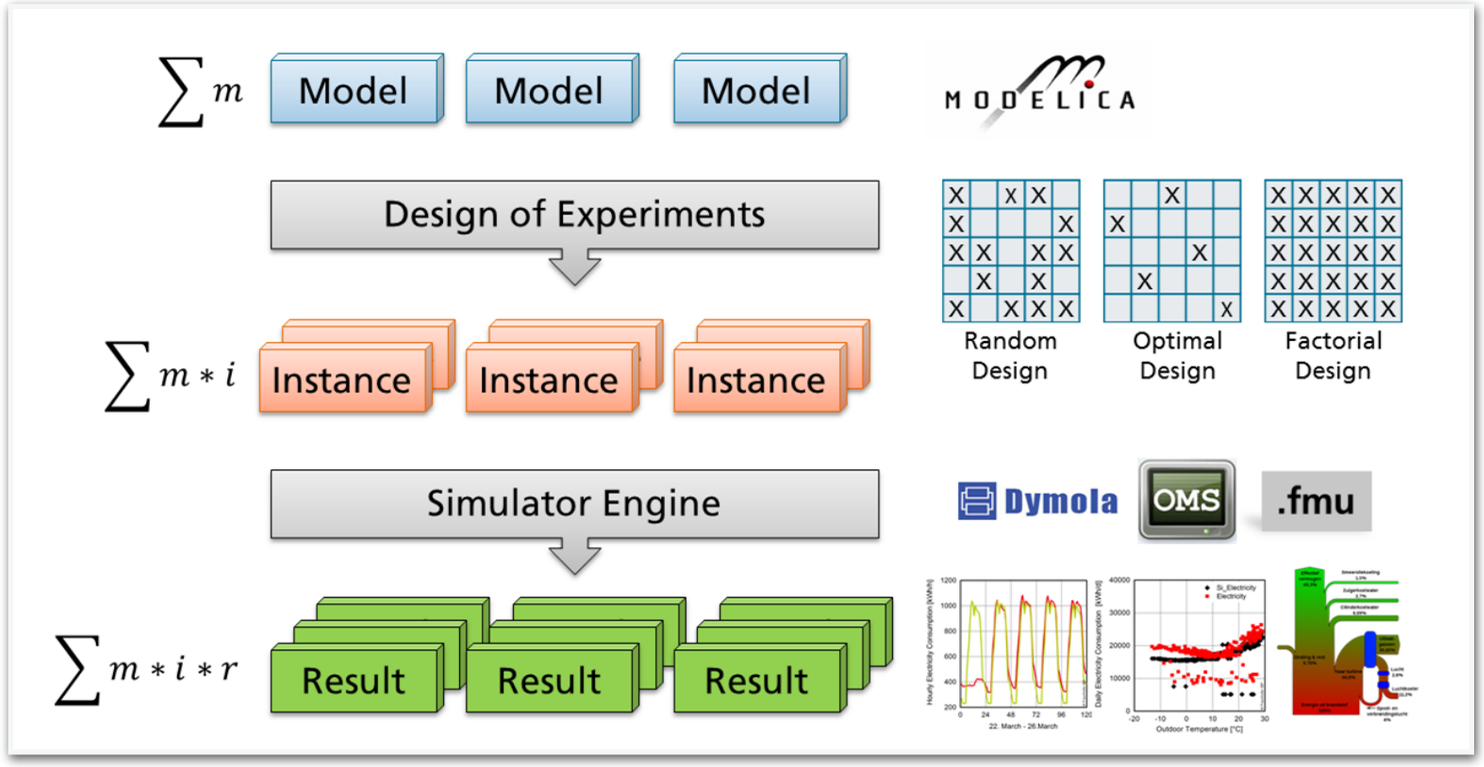


Activity 1.4- Workflow automation tools
Scope

Activity leader: Sebastian Stratbuecker, Germany

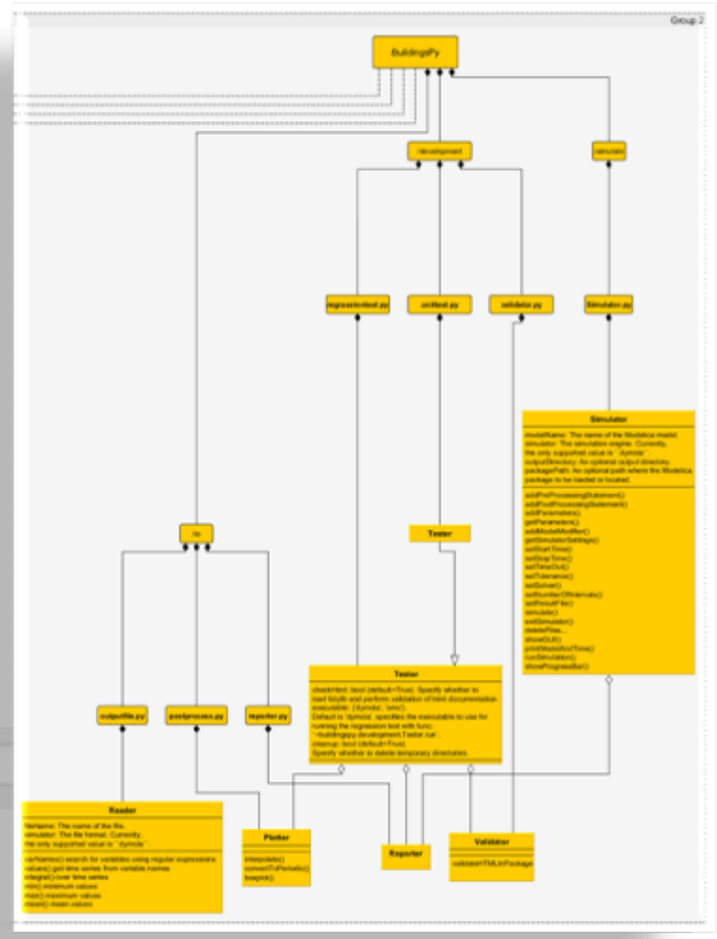
Collaborative development of Python packages for

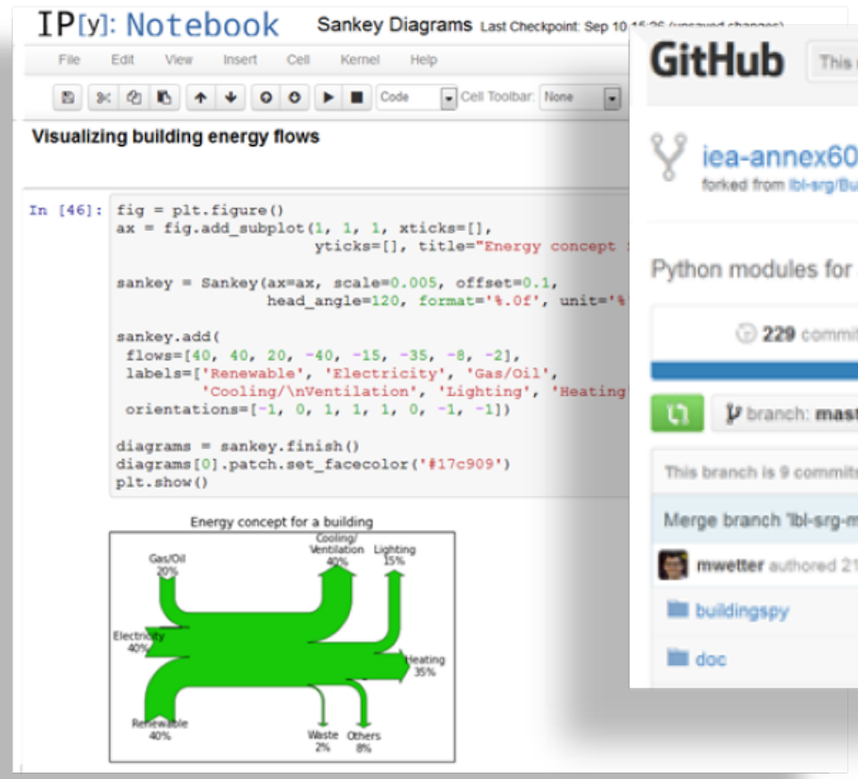
- pre-processing, running simulations, calling optimizers and post-processing.
- automating regression testing and quality control of Modelica libraries.



Activity 1.4- Workflow automation tools
Results up to date

- Definition of use cases for users and developers
  e.g. parametric studies, model calibration, regression testing
- Identification of state-of-the-art tools and packages
- Analysis of current implementations and missing functions
- Elaboration of comprehensive list of requirements
- Interactive Python workflow examples
- Setup of common code base using open source packages





Activity 2.1- Design of building systems
Scope

Activity leader: Christoph Nytsch-Geusen, Germany

Analysis of existing building and plant models for suitability of building design.

Demonstrate and document use of Modelica and FMI technologies applied in real projects.

Feedback of users to technology development.

Activity 2.1- Design of building systems
Results up to date

Activity leader: Christoph Nytsch-Geusen, Germany

7 case studies:

Development of PV-cooling systems for residential buildings in the MENA-region
(TU Berlin, UdK Berlin, Germany)

Control optimization of geothermal heat pump combined with thermally activated building systems (Fraunhofer ISE, Germany)

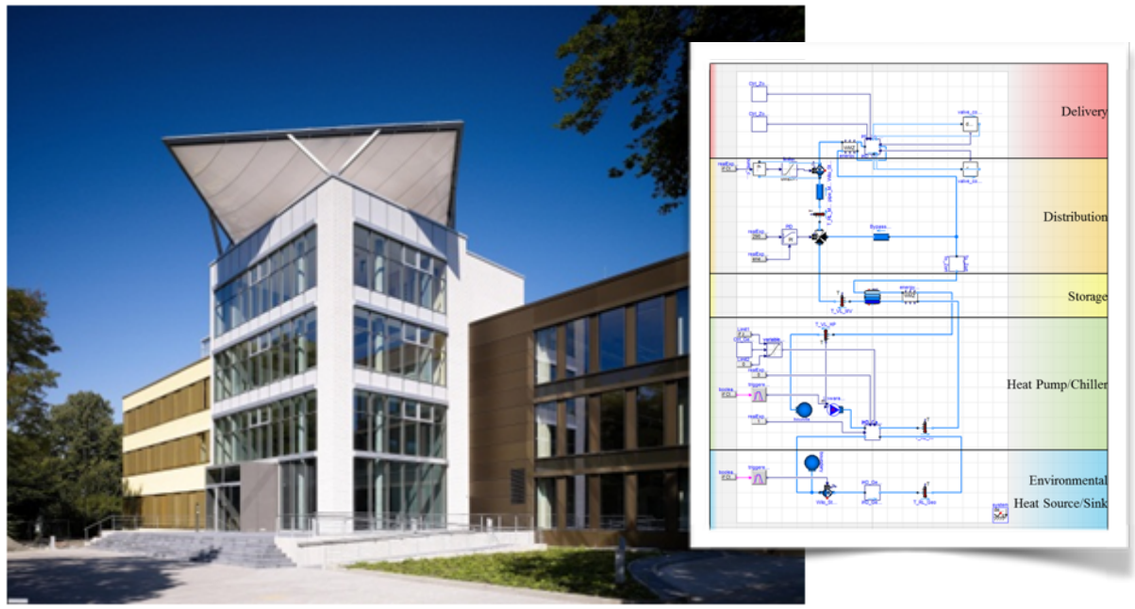
Investigation of the role of buildings in a European greenhouse gas emission free energy system
(KU Leuven, Belgium)

Implementation of Model Predictive Control for the HVAC system of a Belgian thermally activated office building (KU Leuven, Belgium)

Modeling for the design of an energy and water efficient hotel
(University of Miami, UCI Engineering, USA)

Design of an innovative two-pipe chilled beam system for both heating and cooling of office buildings
(Aalborg University, Denmark)

Integrated optimal design and control of office buildings using renewable energy sources
(KU Leuven, Belgium)



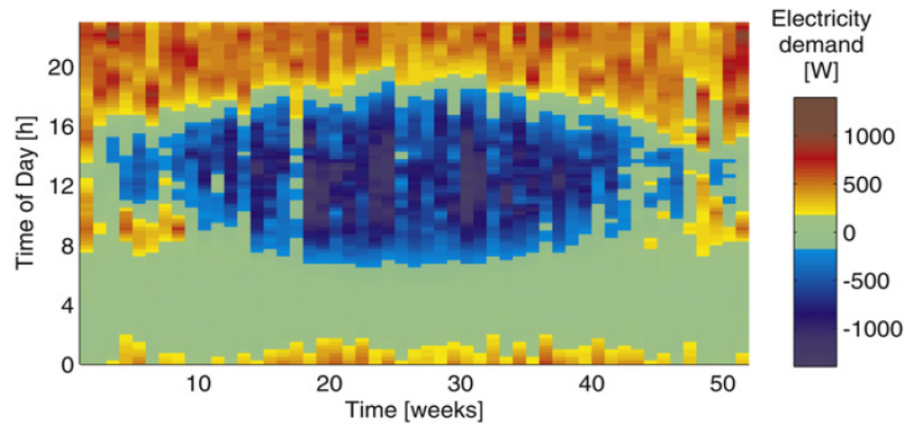
Activity 2.2- Design of district energy systems
Scope

Activity leader: Dirk Saelens, Belgium

How to scale simulation from buildings to thermal and electrical community energy grids?

Feedback of users to technology development.

Example: Mismatch between electricity generation from PVs and electricity demand



Net electricity demand ($P_{dom,net}$) with PV system sized to cover domestic load.

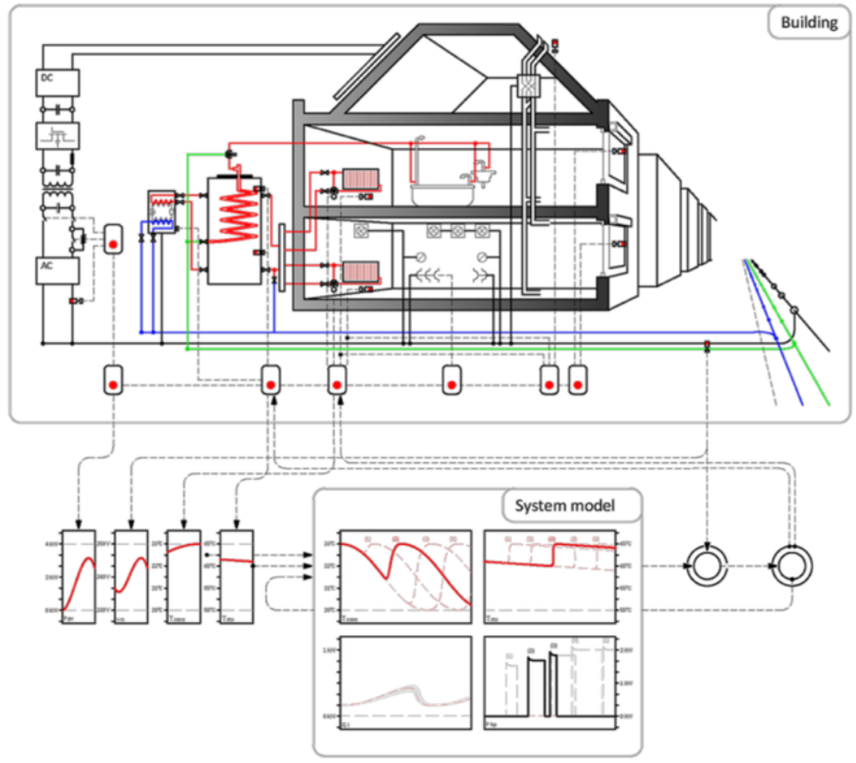
Reynders, G., Nuytten, T., Saelens, D. (2013). Potential of structural thermal mass for demand-side management in dwellings. Building and Environment.

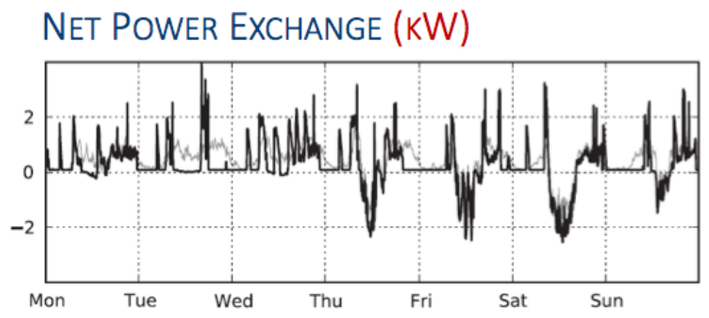
Activity 2.2- Design of district energy systems
Results up to date

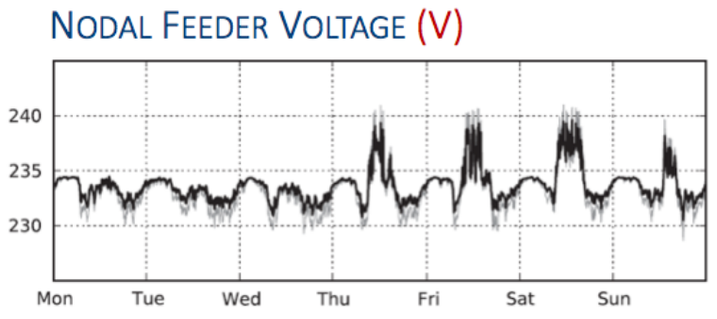
Activity leader: Dirk Saelens, Belgium

Ongoing case study: Definition of the "Annex 60 Neighborhood Case"

- modeling of different buildings and installations
- connection of models on district scale with distribution system to model interplay with centralized renewable energy systems and energy exchange
- application of control strategies







Activity 2.3- Model use during operation
Scope

Activity leader: Andrea Costa and Raymond Sterling, Ireland

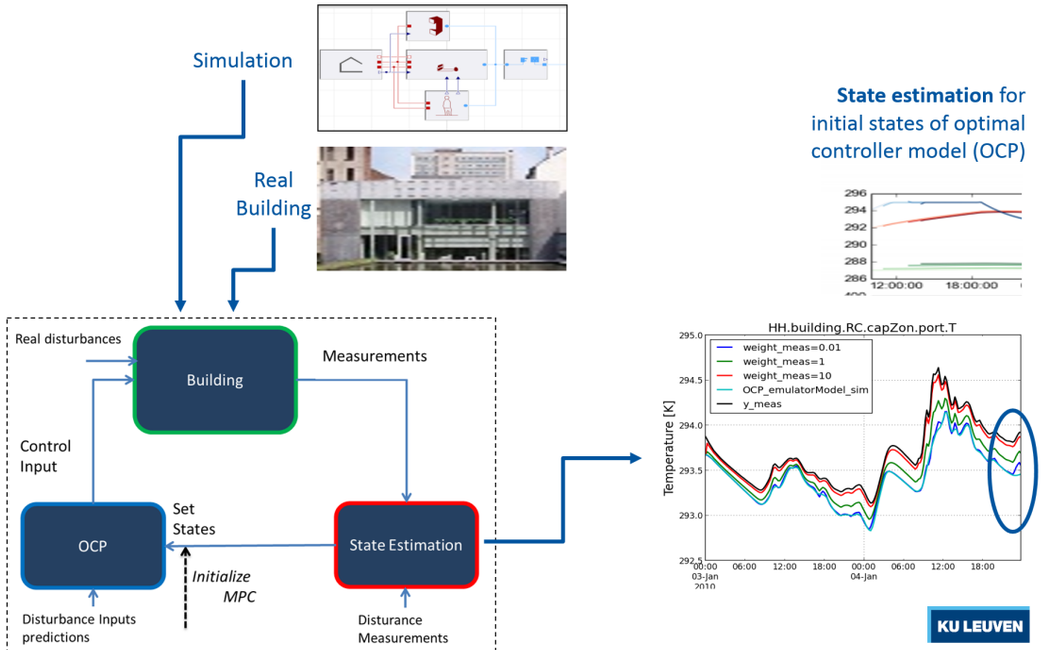
Demonstrate use of Modelica and FMI technologies for

- Model Based Control (MBC)
- Hardware in Loop (HiL)
- Fault Detection and Diagnosis (FDD)

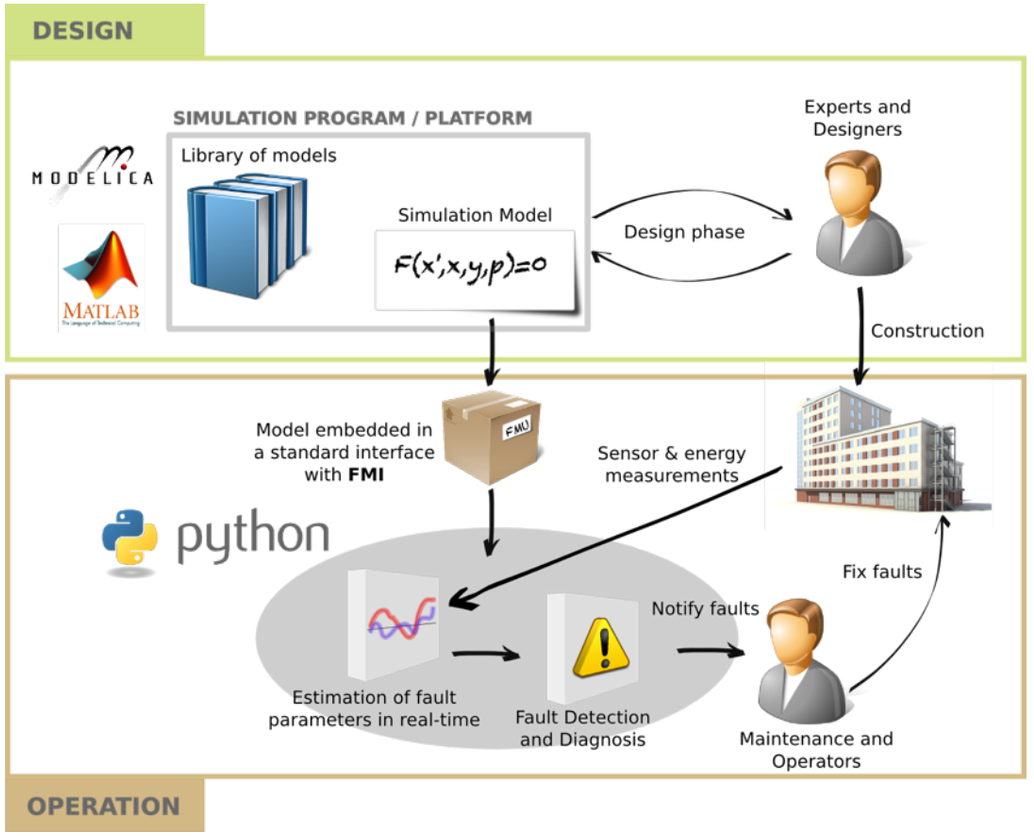
Real-time use of models for verification of design intent, monitoring and optimization of building operation.

How to accommodate the situation that control vendors typically use proprietary languages to implement control sequences.

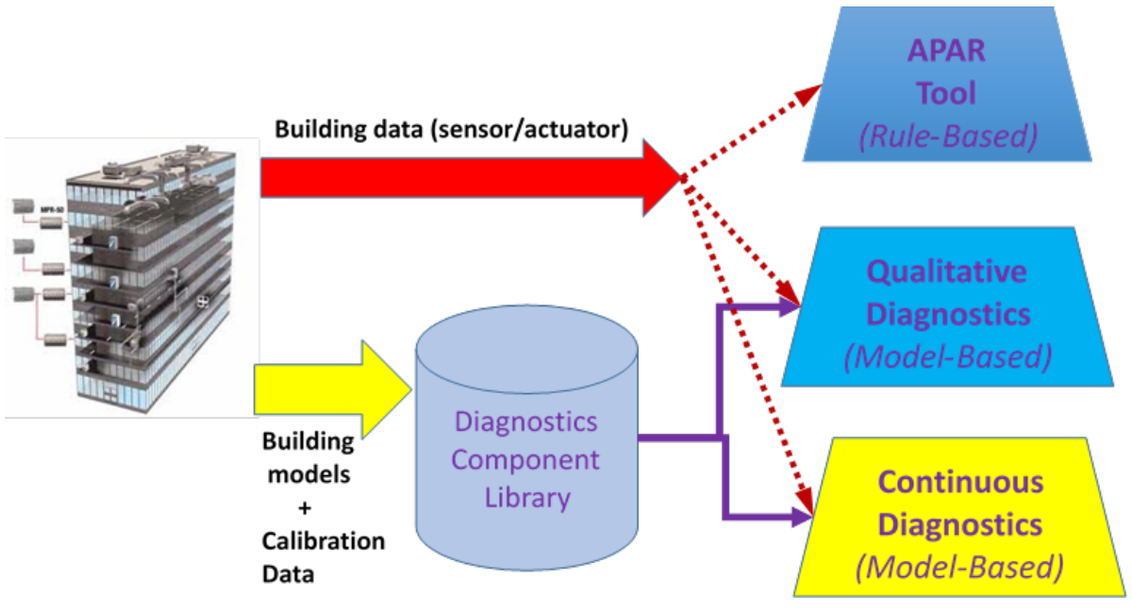
Activity 2.3- Model use during operation
Results up to date



MPC for building (KU Leuven, Belgium)



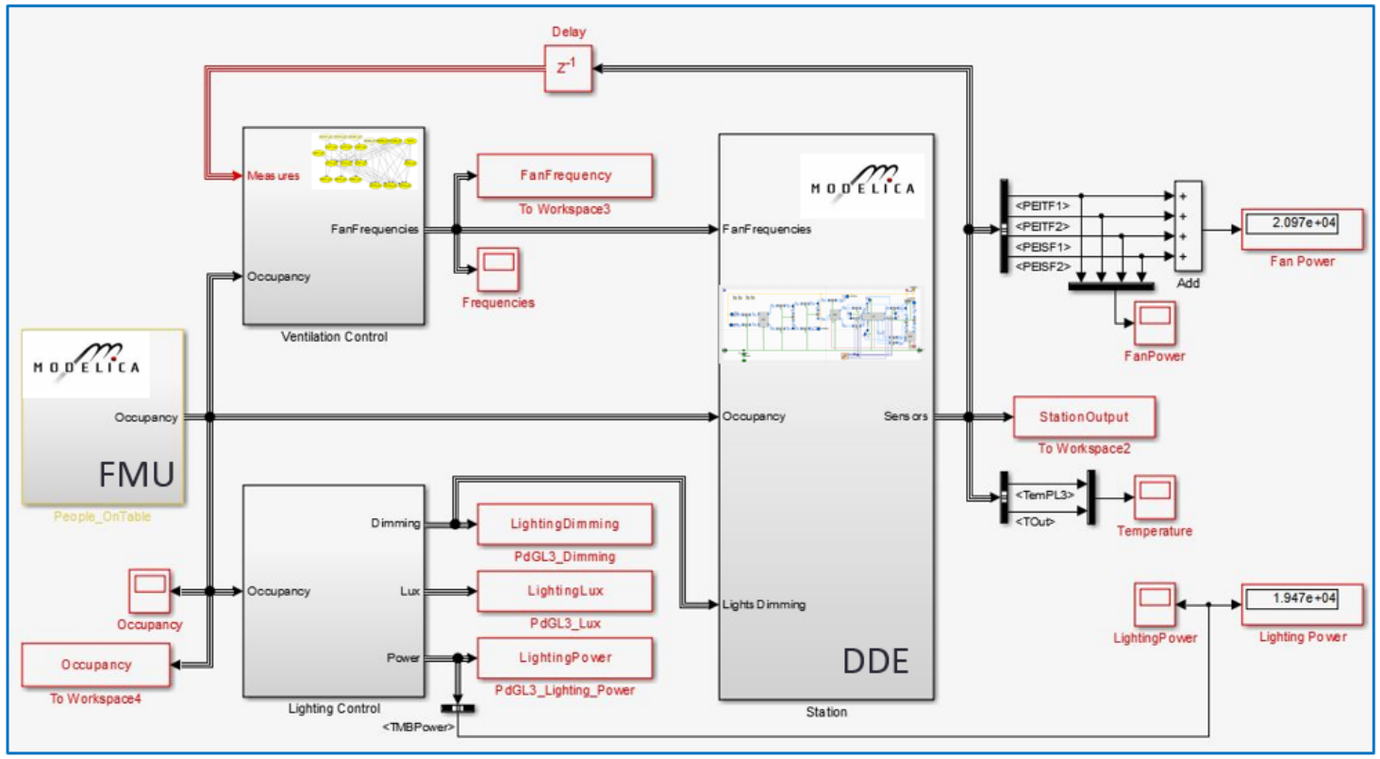
FDD based using a Modelica model and state estimation at a DoD chiller plant (LBNL, USA)

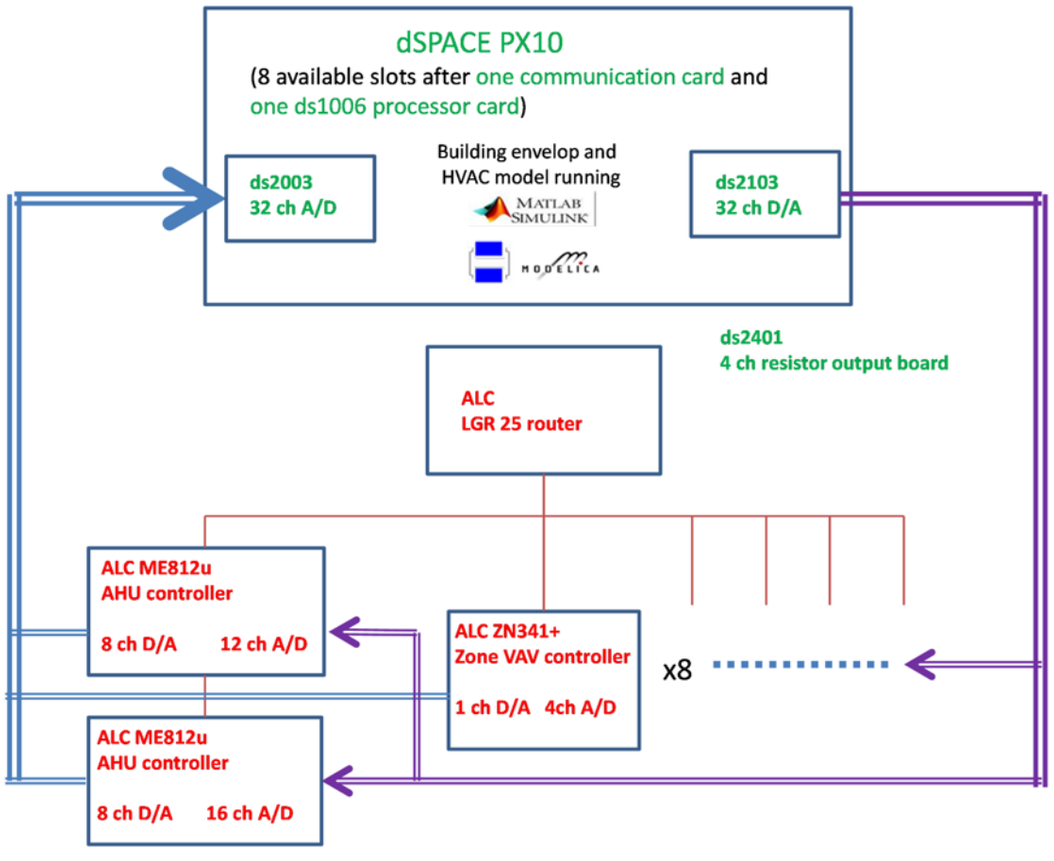


Qualitative FDD using a Modelica model of air handling units (NUIG, IE), (ISE, DE)

Activity 2.3- Model use during operation
Results up to date

Subway ventilation system optimization using Modelica models (UNIVPM, IT)





Control Loop Performance Assessment - develop, evaluate and field test an objective and quantitative metric and method to monitor and evaluate HVAC closed loop control performance (Univ of Alabama, USA)

Optimization Subcommittee
Goals

Within Annex 60 **optimization work** in different activities:

Subtask 2: Demonstration and Validation

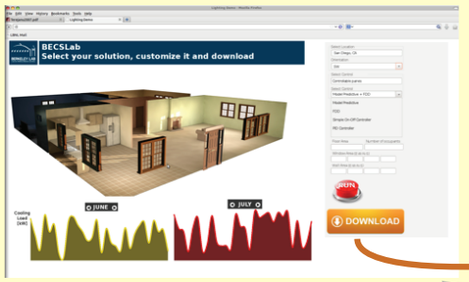
- Activity 2.1 Design of building systems
- Activity 2.2 Design of district energy systems
- Activity 2.3 Model use during operation

Goal of Optimization Subcommittee:

- What does Modelica enable from the optimization point of view?
- Where can Modelica give an added value?

  Gradient based optimization, Hessian, Jacobian directly from Modelica code, Dymola allows to linearize models, equations are available, JModelica, Casadi, OpenModelica, ...

DOE's interest in Annex 60 includes setting the technology basis for building simulation for the next 15 years and deploy it through the Spawn of EnergyPlus



automated production of FDD and MPC

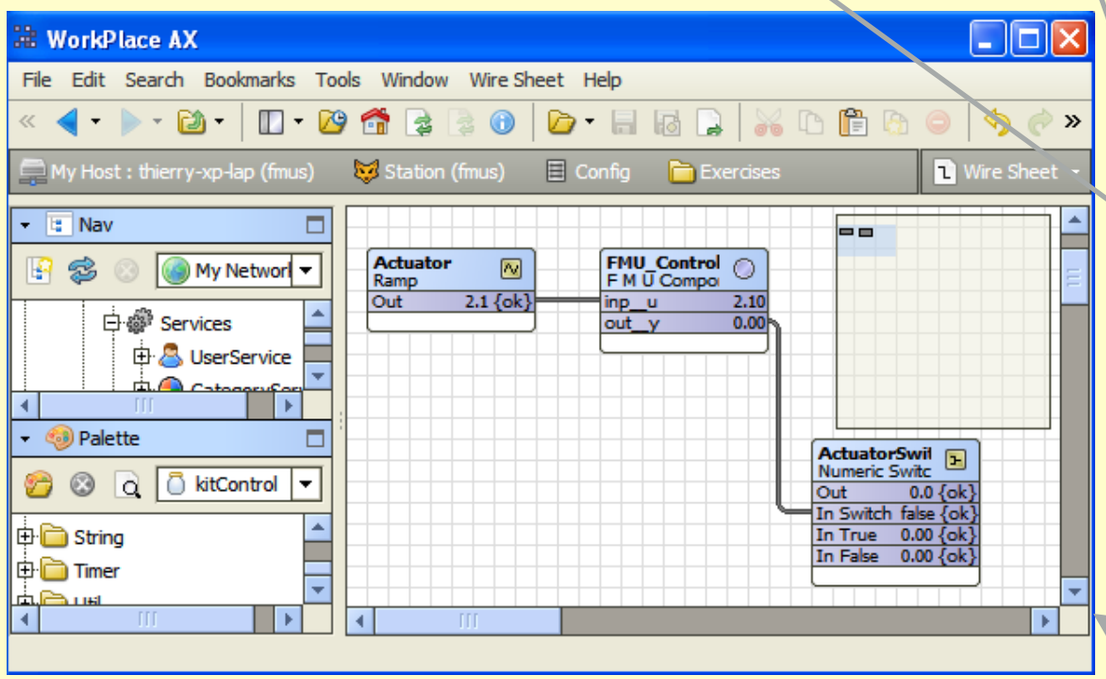
Design and deployment of energy-aware control sequences

Model Details	Description	Airflow (Cfm)	Key Document
42B	Belt-Drive	600 - 4,000	Product Catalog
42D	Ducted	600 - 2,000	Product Catalog
42C	Horizontal	200 - 1,200	Product Catalog
42S	Stack	300 - 1,200	Product Catalog
42V	Vertical	200 - 1,200	Product Catalog
42WKN	Hydronic Cassette	260 - 1,160	Product Catalog

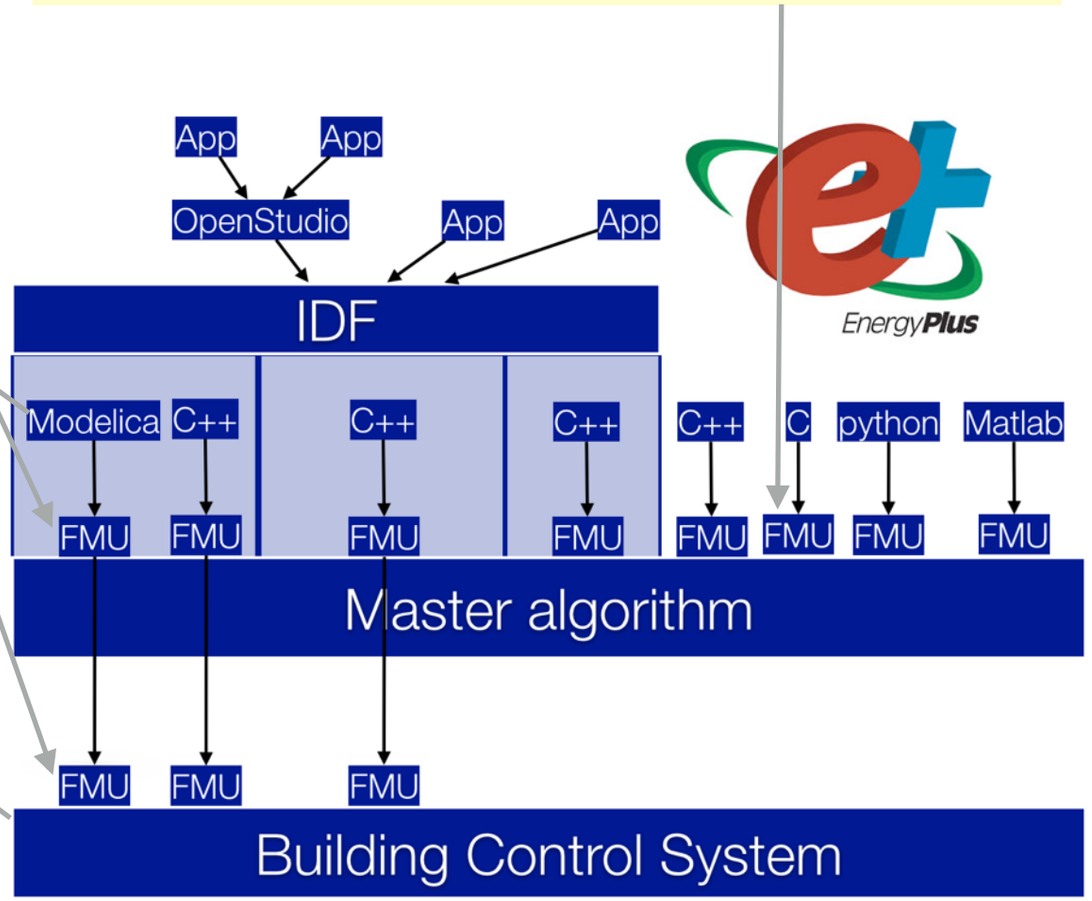
Learn about systems that use fan coils.

Download commercial fan coil equipment selection software.

Electronic product catalogues, e.g., ASHRAE SPC 205

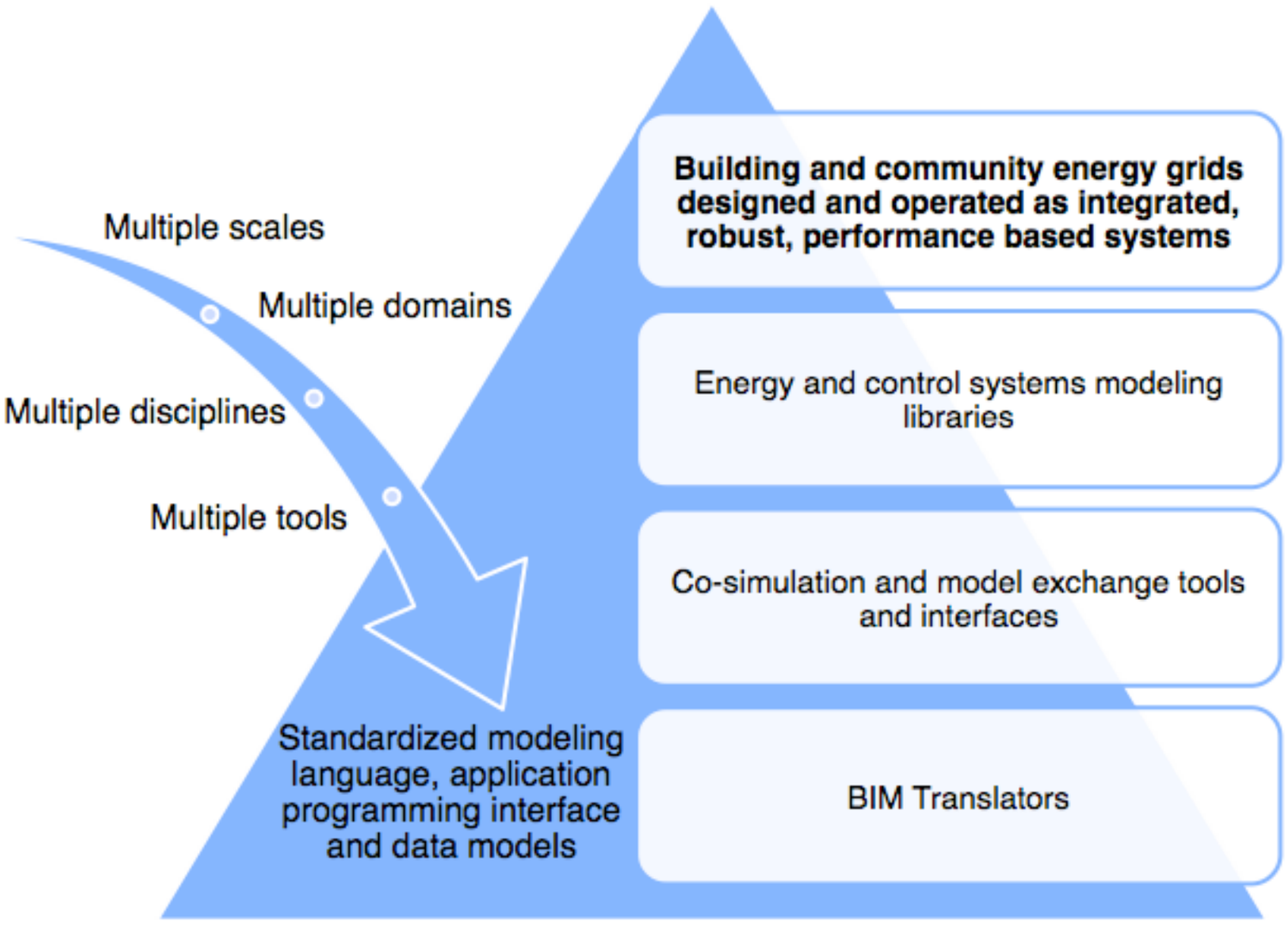


Model and control algorithm deployment, e.g., to Niagara control platform



EBC

Energy in Buildings and Communities Programme



http://www.iea-annex60.org

BERKELEY LAB Lawrence Berkeley National Laboratory

RWTH AACHEN UNIVERSITY