BIM/GIS and Modelica Framework
for
building and community energy system
design and operation

Co-operating agents:
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August 11, 2016

The vision of IBPSA Project 1 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) drag and drop preconfigured, modifiable and scalable component models of

- buildings,
- district heating and cooling,
- HVAC, and
- controls.

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
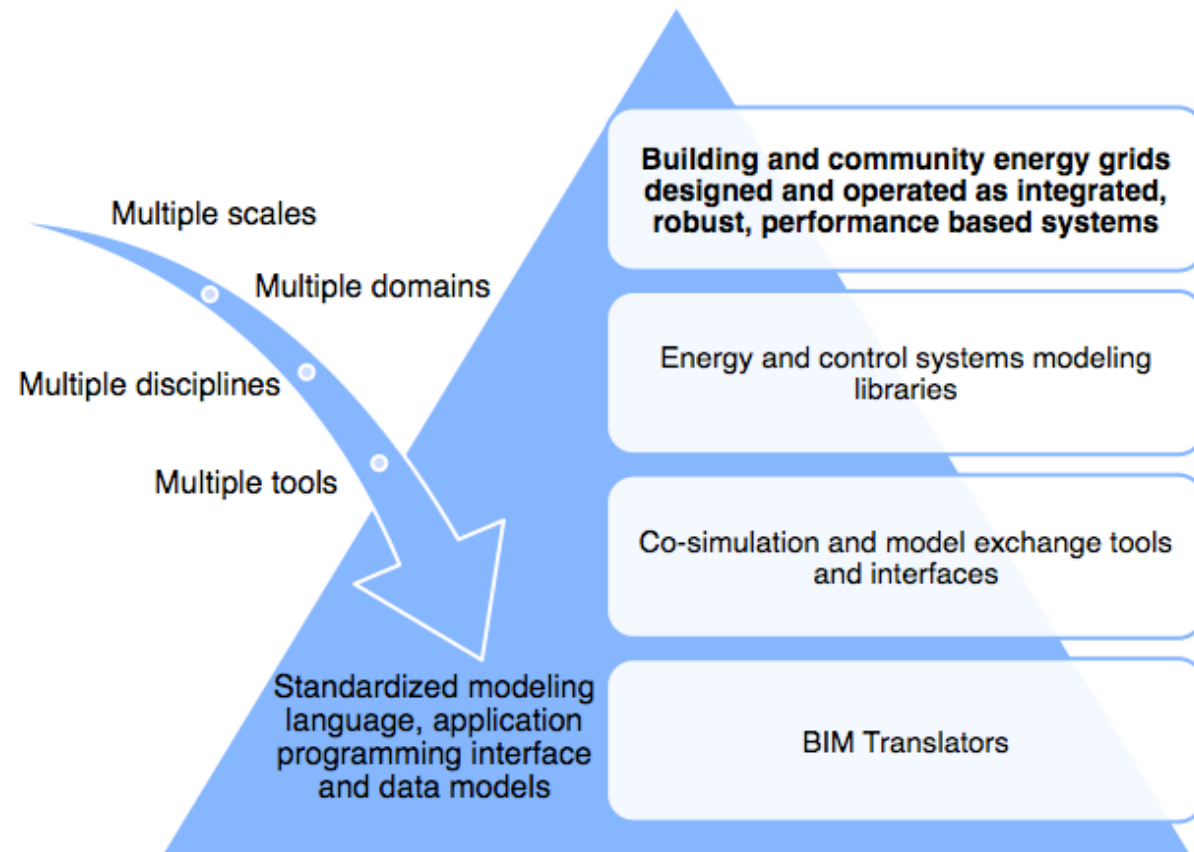- to run as a web service for real time operational support

All developed software is open source.
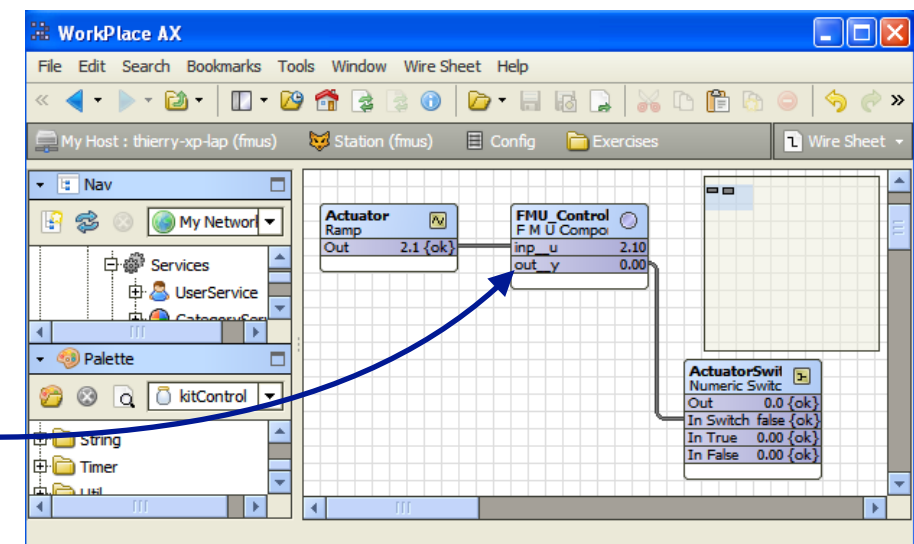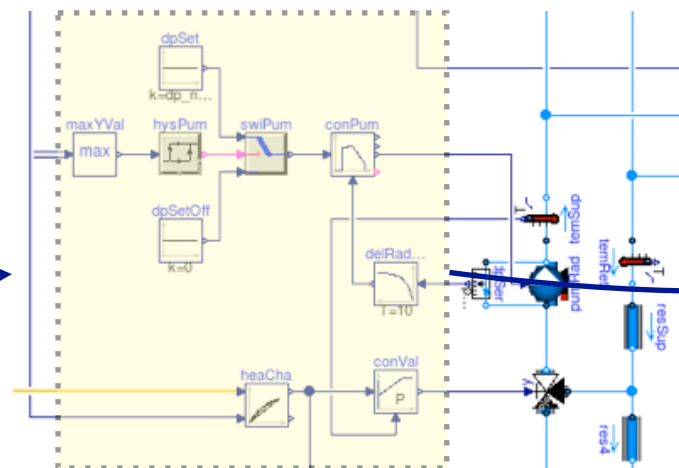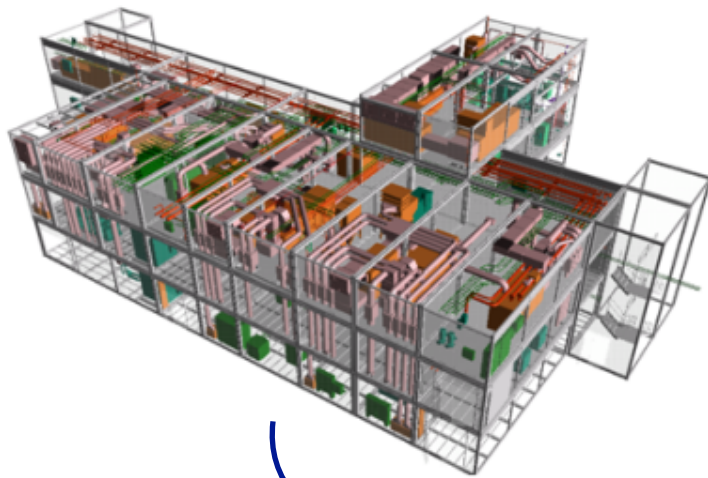
Introduction

2012-2017:
IEA EBC Annex 60 resulted in collaboration among 42 institutes from 16 countries

Multiple scales

Multiple domains

Multiple disciplines

Multiple tools

Standardized modeling language, application programming interface and data models

Building and community energy grids designed and operated as integrated, robust, performance based systems

Energy and control systems modeling libraries

Co-simulation and model exchange tools and interfaces

BIM Translators

EBC

Energy in Buildings and Communities Programme

BERKELEY LAB   Lawrence Berkeley National Laboratory

http://www.iea-annex60.org

RWTHAACHEN UNIVERSITY

2015: Joe Clarke's vision statement

Preview
Full text HTML
PDF
Access options
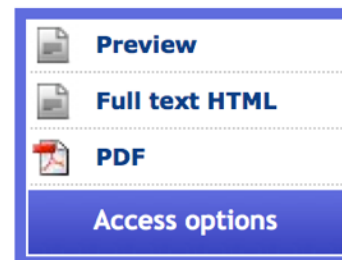
Joe Clarke's vision statement calls for a consolidation of models for HVAC and controls that can be used for testing, as a review framework and as a library (Propositions 1, 3, 4, 5, 6, 7, 9, 11 and 12).

The opportunity is

- to standardize the approach for how such component and system models are represented, both as data-model and as mathematical models that formalize the physics, dynamics and control algorithms,

- to agree upon the physics that should be included in such components for specific use cases, and

- to share resources for development, validation and distribution of such component and system models

IBPSA to conduct Project 1

December 2015: Board of IBPSA-World approved project.

May 2016: Planning meeting at University of Miami. Revision of proposal.

May 2016: Registration started at http://www.iea-annex60.org/news.html

October 2016: Planning session at Corsica, France.

Until July 2017: Planning and team building phase. Start of some of the research.

Aug. 2017-Aug. 2022: Research Phase.

IBPSA Project 1 goals

1. to consolidate the development of these technologies, ranging from equipment to system representations of the data (BIM/GIS) and their dynamic behavior (Modelica),

2. to share efforts for, and increase the range of, model validation, and

3. to provide to simulation tool providers stable, well-tested, validated and documented code that they can integrate in their software tools for deployment to design firms, energy service companies, equipment and control manufacturers.

4. to demonstrate through applications capabilities that are enabled through Modelica, and to identify and test through applications research needs and research results.

Needs addressed by Project 1

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.
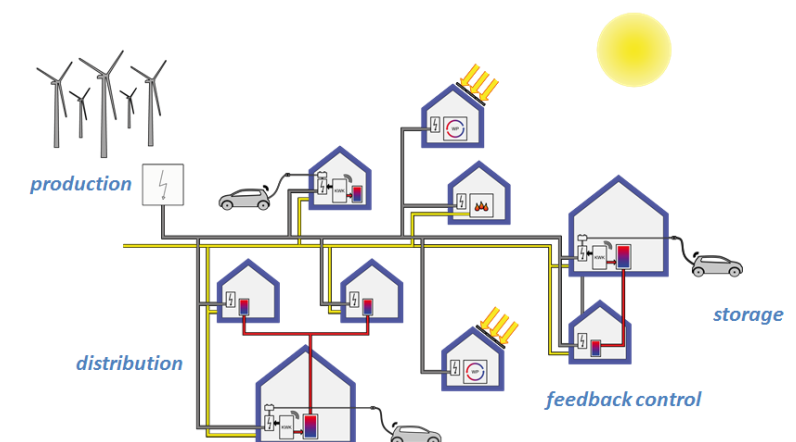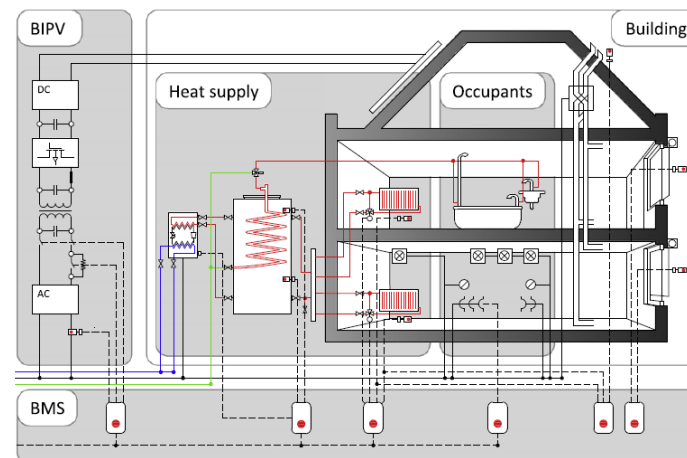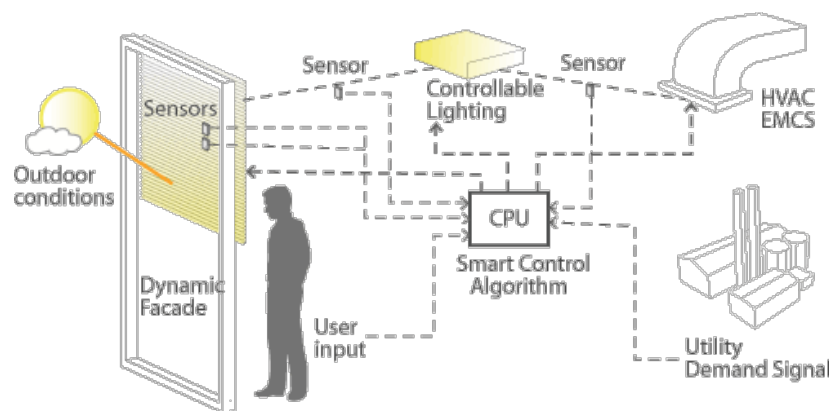
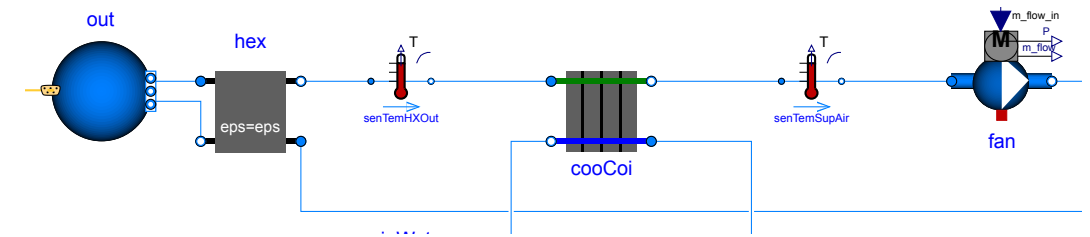From controls   to   buildings   and   communities

Structure

Tasks span from buildings to communities, and design to operation

Task 1: Modelica libraries for building and community energy systems

- WP 1.1: Library for design and operation
- WP 1.2: Library for Model Predictive Control
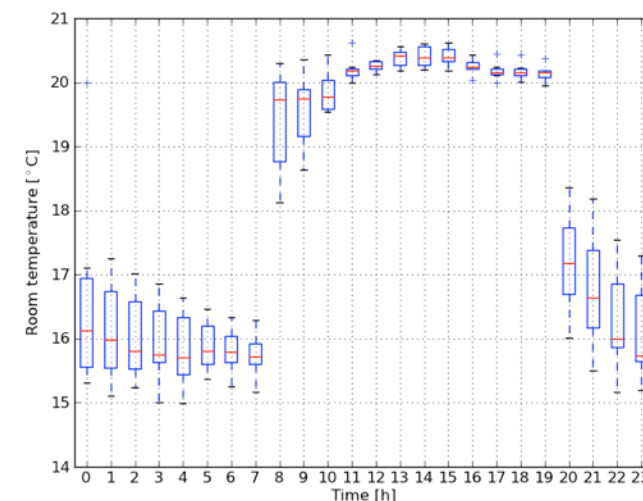

Task 2: Building and City Quarter Models

- WP 2.1: City Quarter Information Modeling
- WP 2.2: Building Information Modeling

Task 3: Application and Dissemination

- WP 3.1: Application
- WP 3.2: Dissemination

Levels of participation

Sponsoring participant

- Cash $5k per year.

Organizational participants

- minimum 0.5 full time employee per year, over the 5 year project

- contribute to 5 to 10 web-based coordination meetings annually

- attend semi-annual expert meeting, generally lasting 2 days

Individual participants

- no predetermined level of commitment, but needs to provide substantial contributions

Intellectual property

All workshops, software and documentation will be open accessible to anyone.

Modelica models will use a slightly modified version of the Modelica 2 license.

Code other than Modelica models will use the open-source BSD 3-Clause License.

IBPSA is the copyright and license holder.

See https://ibpsa.github.io/project1/license.html

Background technology and related activities in the US

Open standard as underlying technology:
Modelica, an open standard for equation-based, object-oriented modeling

Open, industry-driven standard for modeling multi-physics, engineered systems

Developed since 1996 because conventional approach for modeling was inadequate for integrated engineered systems.

Large eco-system of free and commercial libraries and environment for
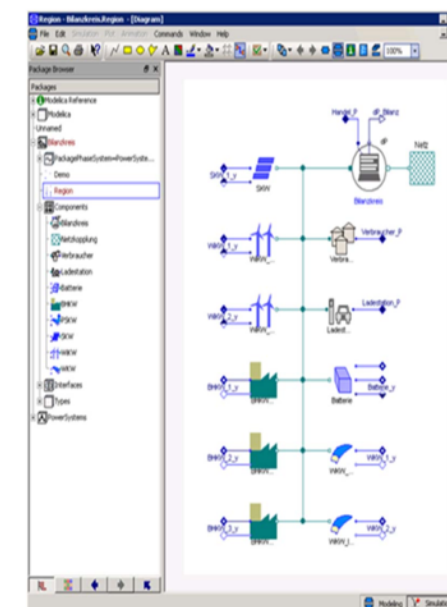
- modeling
- simulation
- optimization
- model-based design
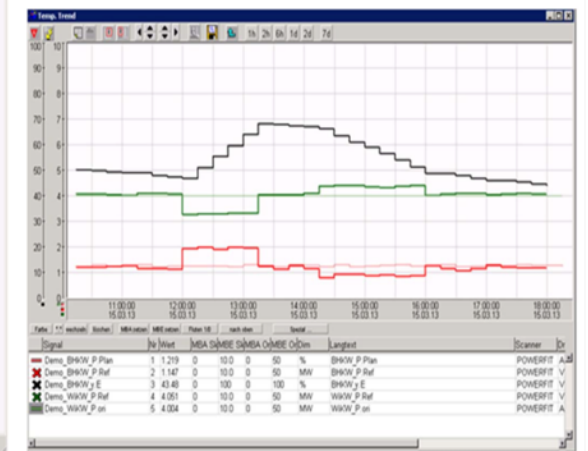- product life cycle management
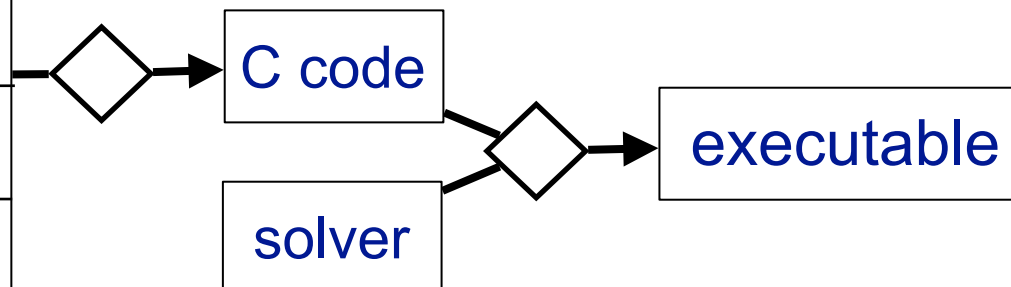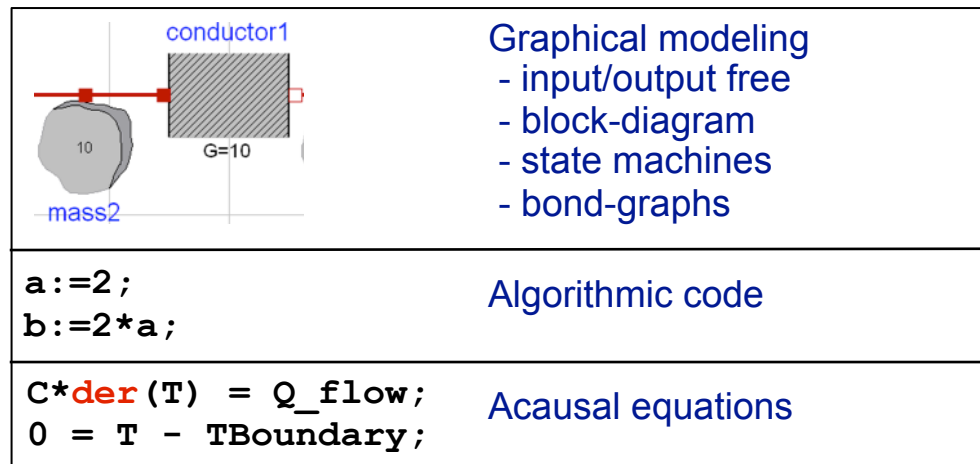
7% of German power production is optimized based on Modelica

Reference
Intraday optimization of municipal power

- Aim: balance production and load
- Exploit storage capacities, e.g. heat buffers, pump stores, electrical mobility

© ABB Group
May 8, 2014 | Slide 13

Source: http://new.abb.com/power-generation/power-plant-optimization

conductor1 G=10 10 mass2	Graphical modeling - input/output free - block-diagram - state machines - bond-graphs
`a:=2;` `b:=2*a;`	Algorithmic code
`C*der(T) = Q_flow;` `0 = T - TBoundary;`	Acausal equations

C code

solver

executable

Open standard as underlying technology:
The FMI Standard has been developed to encapsulate and link models and simulators for co-simula... mains

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first.last@edf.fr
EDF R&D - MIRE dept. & RISEGrid Clamart, France

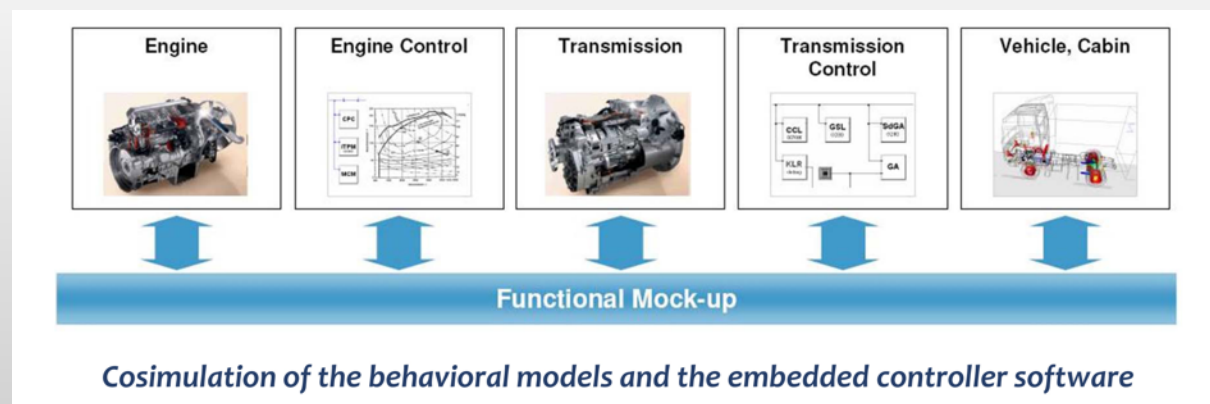Initially a 28 million € ITEA2 project with 29 partners, initia...

Standardizes C API and encapsulation for simulator and model interoperability.

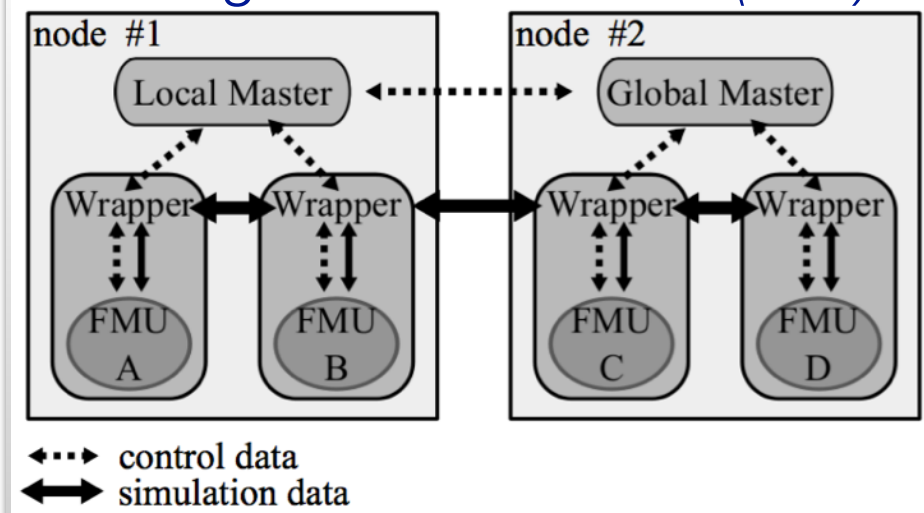Scales from embedded systems to high performance computers.

First version published in 2010. Second version published in 2014.

Supported by 72 tools.

Automotive co-simulation

Engine | Engine Control | Transmission | Transmission Control | Vehicle, Cabin

Functional Mock-up

Cosimulation of the behavioral models and the embedded controller software

Smart-grid co-simulation (EdF)
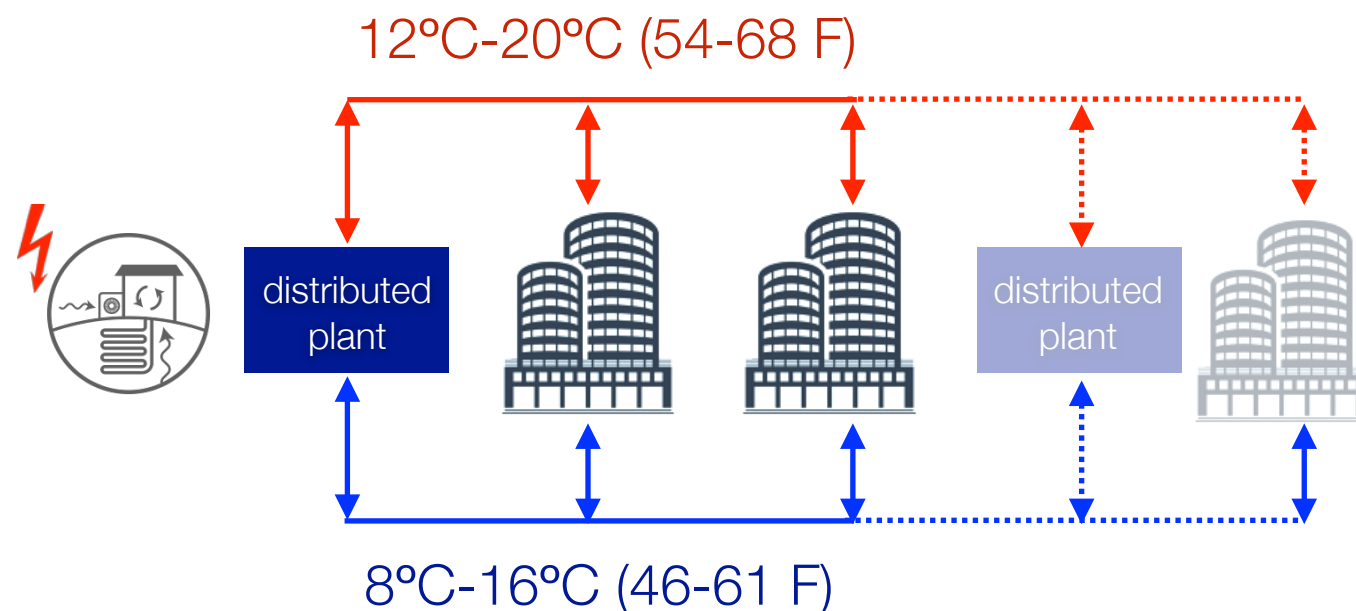

• • •▶ control data
◀━▶ simulation data

District energy systems — building tools needed by urban developers and cities to prioritize investment and policy decisions
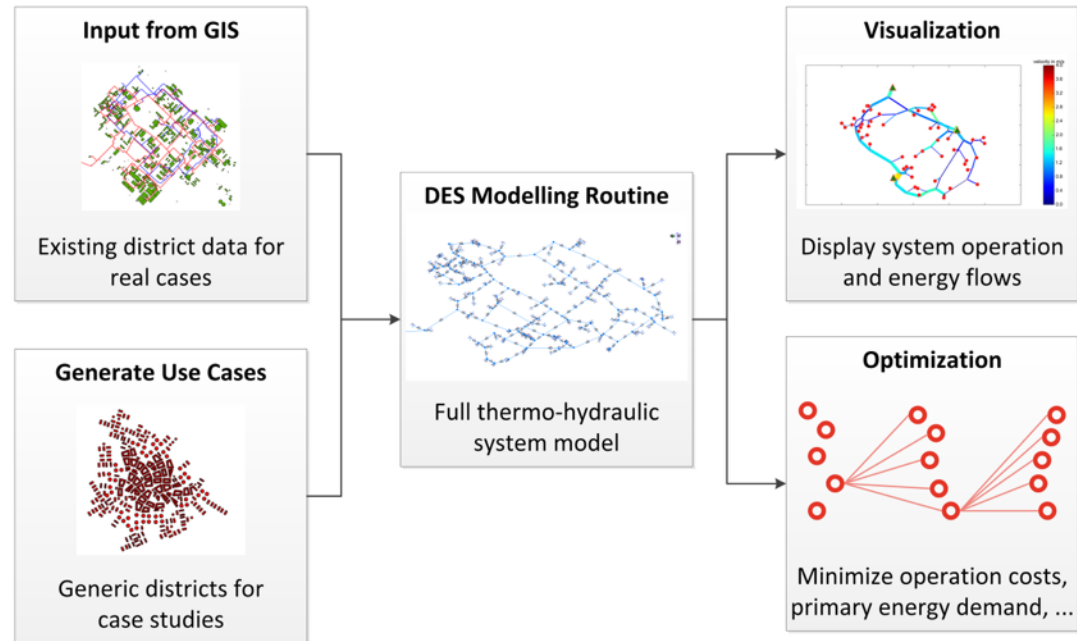
Source: RWTH Aachen

GIS to Modelica for performance analysis, visualization and optimization of district energy systems.

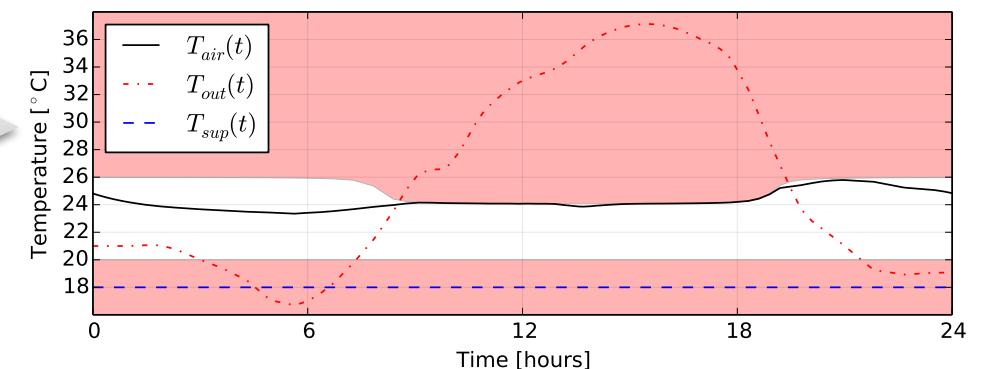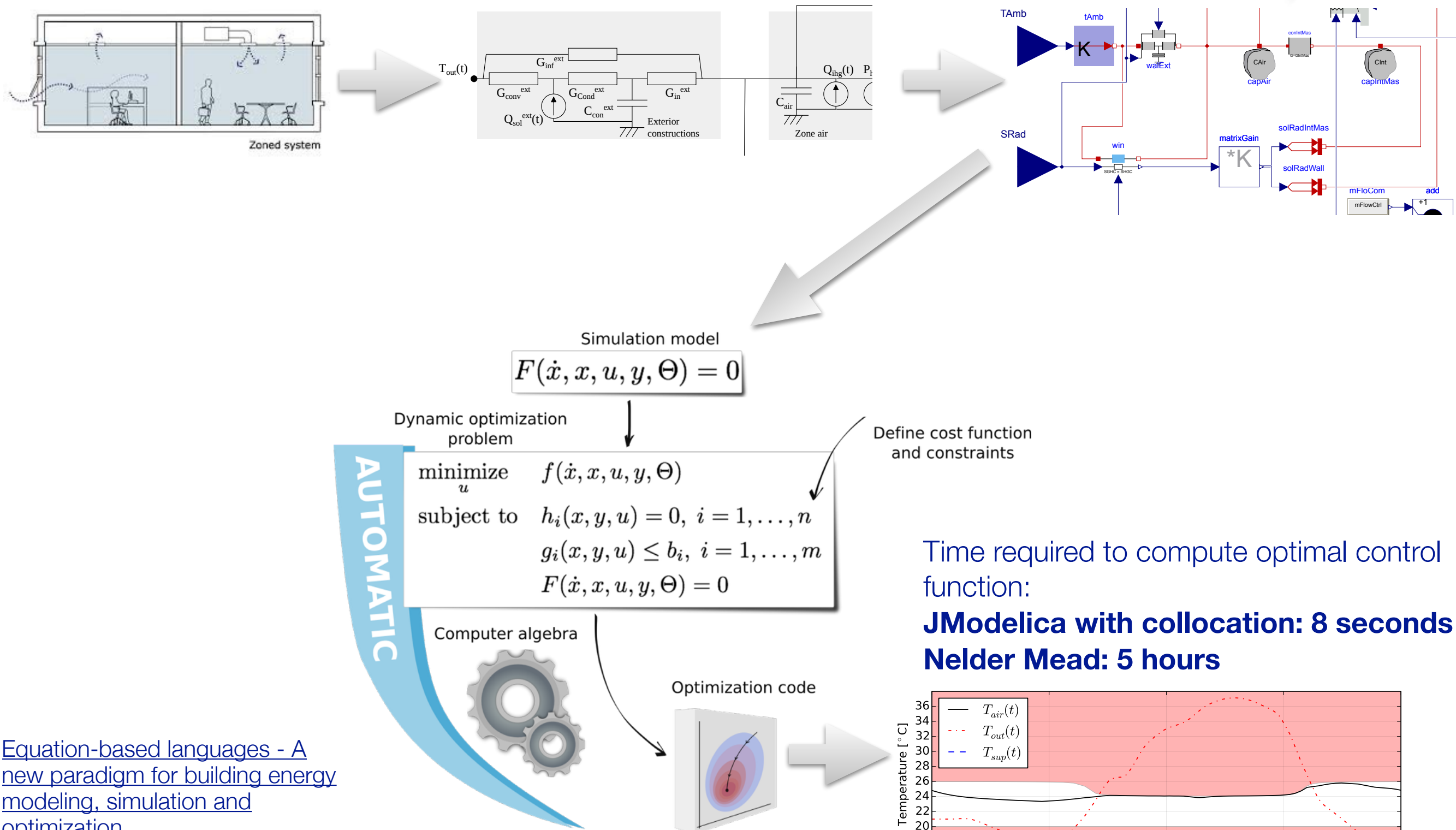12°C-20°C (54-68 F)

8°C-16°C (46-61 F)

Source: LBNL

Analysis of novel, modular extensible energy networks with decentralized energy hubs and bi-directional flow networks that share heating, cooling and waste heat among energy hubs and buildings.
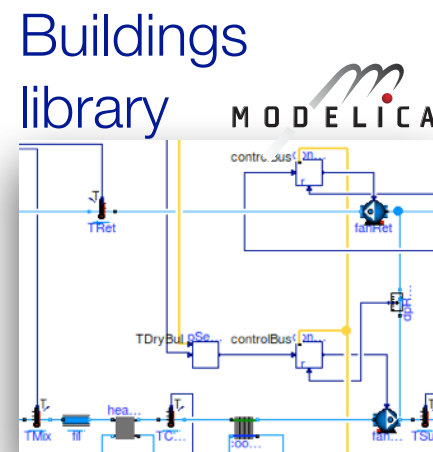
Optimization: 2200 times speed up for optimization through use of computer algebra

Zoned system

Exterior constructions

Zone air

$T_{out}(t)$ G_{inf}^{ext} G_{conv}^{ext} G_{Cond}^{ext} C_{con}^{ext} G_{in}^{ext} $Q_{sol}^{ext}(t)$ C_{air} $Q_{ihg}(t)$

Simulation model

$$F(\dot{x}, x, u, y, \Theta) = 0$$

Dynamic optimization problem

Define cost function and constraints

$$\begin{aligned}
\underset{u}{\text{minimize}} \quad & f(\dot{x}, x, u, y, \Theta) \\
\text{subject to} \quad & h_i(x, y, u) = 0, \; i = 1, \dots, n \\
& g_i(x, y, u) \leq b_i, \; i = 1, \dots, m \\
& F(\dot{x}, x, u, y, \Theta) = 0
\end{aligned}$$

AUTOMATIC

Computer algebra

Optimization code

Time required to compute optimal control function:
JModelica with collocation: 8 seconds
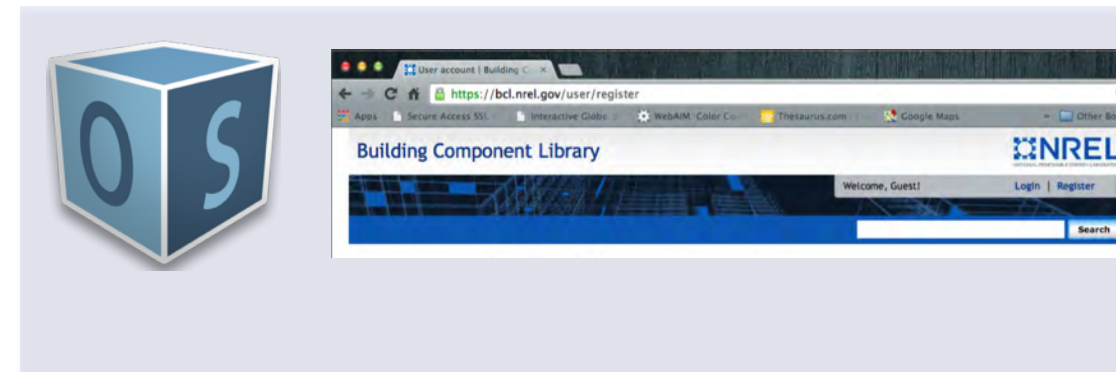**Nelder Mead: 5 hours**

Equation-based languages - A new paradigm for building energy modeling, simulation and optimization
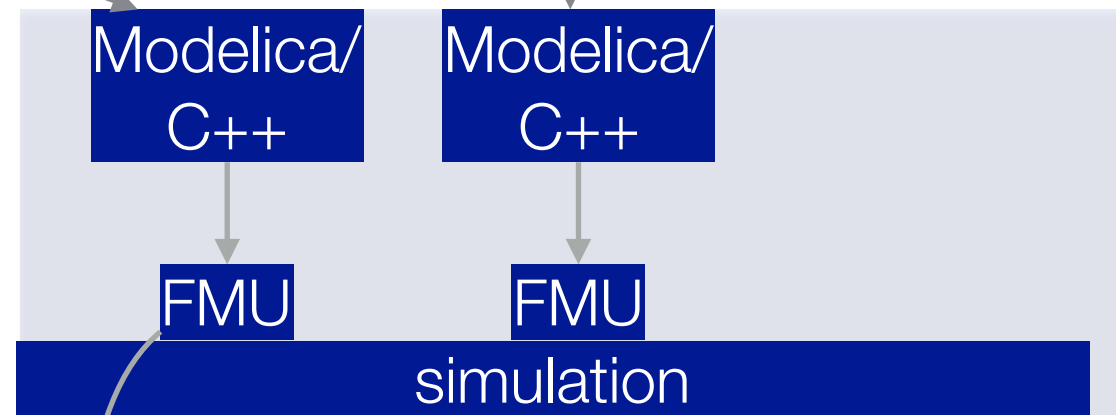Wetter M., Bonvini M., and Nouidui T. S. In press: Energy and Buildings

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Spawn of EnergyPlus — Modularize EnergyPlus, base it on standardized open technologies that better address very low energy systems and operation

Buildings library

User interface

simulation

logical

physical comm.

Modelica/ C++

Modelica/ C++

FMU

FMU

simulation

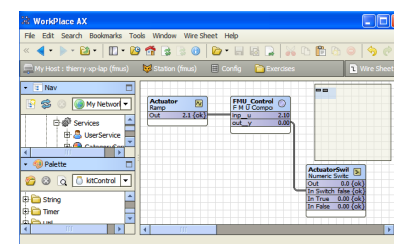FMU   API   vendor-specific algorithms

operation

communication layer

hardware   databases   web service

Spawn-of-EnergyPlus

- Modular
- Standard interfaces (FMUs)
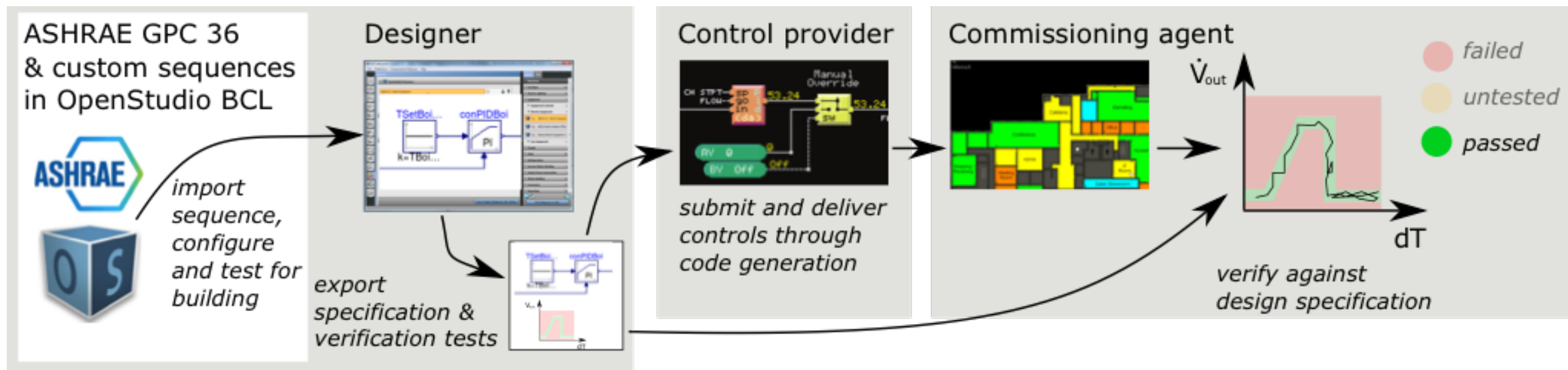- Inter-operability with control workflows and product development

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

OpenBuildingControl

Provide process and integrated set of tools for design, deployment and end-to-end quality assurance of control sequences.
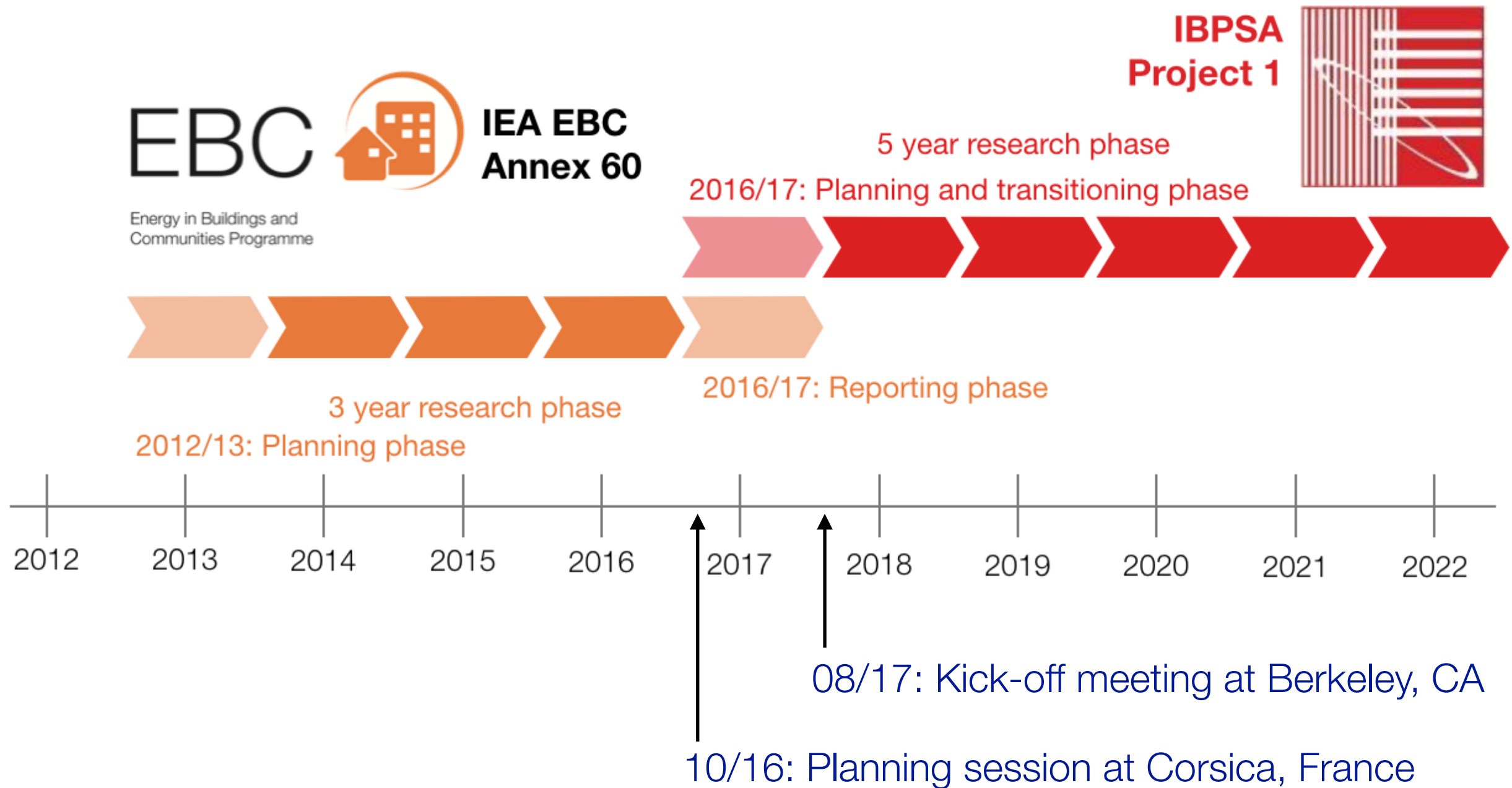
3 year DOE/CEC funded project.

Start in fall 2016.

Next steps

Next steps

How to participate

Registration

Full proposal and registration is at

https://ibpsa.github.io/project1/

IBPSA Project 1 Registration

This form is to register and express the anticipated level and type of contribution for the IBPSA Project 1. We are aware that making a 5 year prediction has significant uncertainty, but need to know your best guess in view of current or anticipated projects and plans.

Only enter information that you are willing to share publicly, as this information will be needed to communicate the scope and extend of the project to various others (IBPSA, funding agencies, prospective partners etc.).

The current proposal as approved by the IBPSA Board is accessible at http://www.iea-annex60.org/downloads/ibpsa_annex60_proposal.pdf

* Required

Type of membership *

○ Sponsoring participants. Valid 1 year, at $5k/year cash contribution, can be renewed annually.

○ Organizational participant. 6 months/year of a full time employee, plus participation at expert meetings.

○ Individual participant. Substantial contributions expected for name to be and remain listed.

Contact person first and last name *

Your answer

Email address *

Your answer

Affiliation *

Your answer

Description of project(s) that contribute to IBPSA Project 1 (around 100 words) *

Your answer

?