EBC

Energy in Buildings and Communities Programme

IEA EBC Annex 60 | Summary
New Generation Computational Tools for Building and Community Energy Systems

Michael Wetter[1], Christoph van Treeck[2] and the whole Annex 60 Team[3]
Co-operating agents

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[3] Full list of participants at http://www.iea-annex60.org/

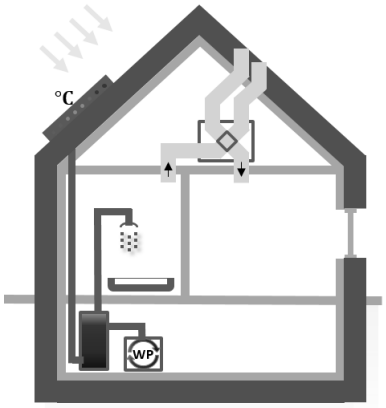
BERKELEY LAB Lawrence Berkeley National Laboratory

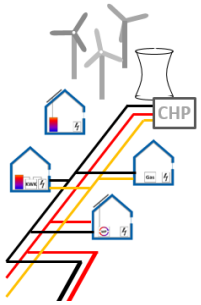
RWTH AACHEN UNIVERSITY

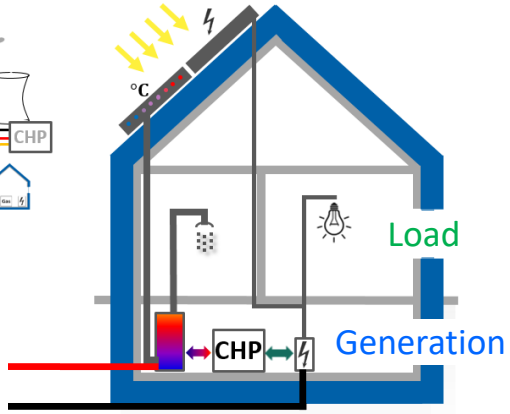
Annex 60 | Summary

- Conducted from 2012 to 2017
- Collaboration among 42 institutes from 16 countries
- Developed and demonstrated new generation computational tools for the design and operation of building and community energy systems
- Overcame Donald Trump's assumption of office
- Benefited from strong organizational framework (web/physical meetings and workshops, joint conference tracks) and common online collaboration environment
- Embracing standards was instrumental for the collaborative research and development

IEA Annex 60 | Key Drivers







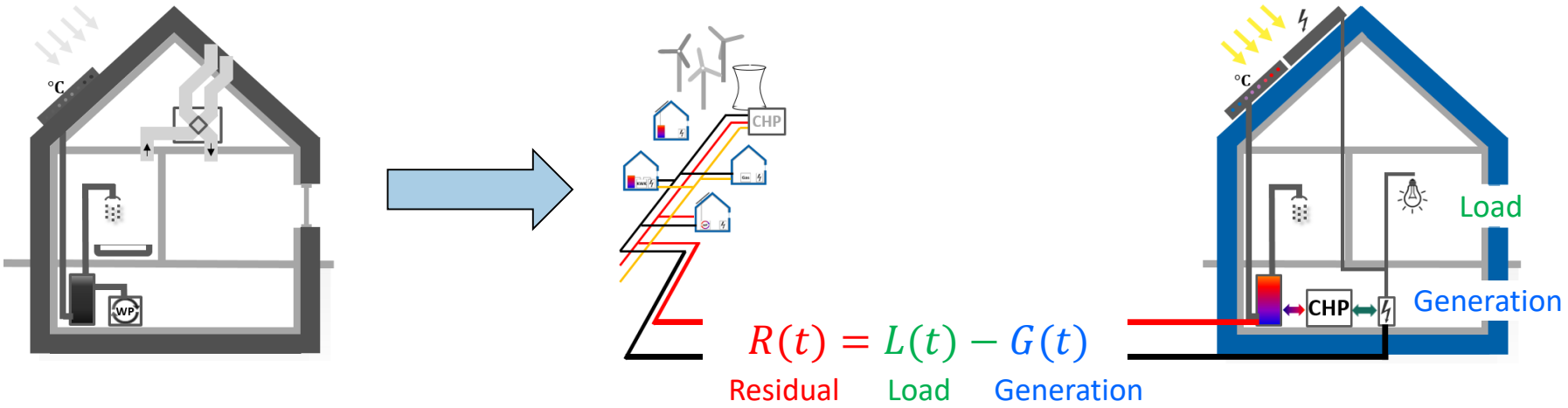
$$R(t) = L(t) - G(t)$$

Residual Load Generation

Trends towards zero energy and electrification of energy infrastructure

- that demand increasingly integrated buildings and district energy systems
- to reduce energy use, power density and to shift load.
- Measures include high-performance envelopes, renewable energy generation, energy storage, waste heat utilizationdistribution networks;
- advanced controls to orchestrate such operation while providing electrical load shifting and shedding capabilities, and bidding into dynamic electricity market.

IEA Annex 60 | Key Drivers



$$R(t) = L(t) - G(t)$$

Residual Load Generation

Consequences for 'new generation' digital planning tools…

- **Scalability** | building – user – energy system – distribution network
- **Multiple domains** | thermal – electric – hydraulic …
- **Advanced building operation and control** | commissioning, fault detection, predictive controls…
- **Interoperability** | interfaces btw. planning tools, manufacturer data, operation

Annex 60 | Summary

IEA Annex 60 created open-source software for system-level rapid prototyping, design and operation, that allows...

1) drag and drop preconfigured, modifiable and scalable component models of

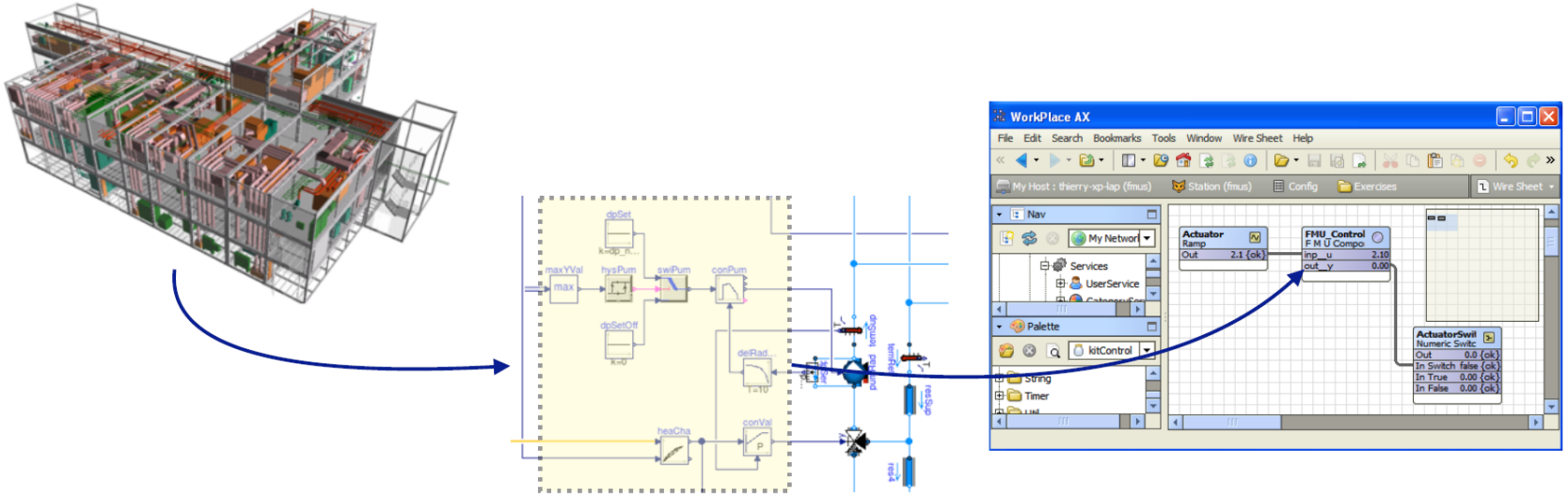
- buildings, district heating and cooling,
- electrical grids, and
- controls.

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.



What made such a collaboration and integration across design & operation possible?

Annex 60 | Open Standards

Building and district energy modeling, simulation and optimization based on open standards

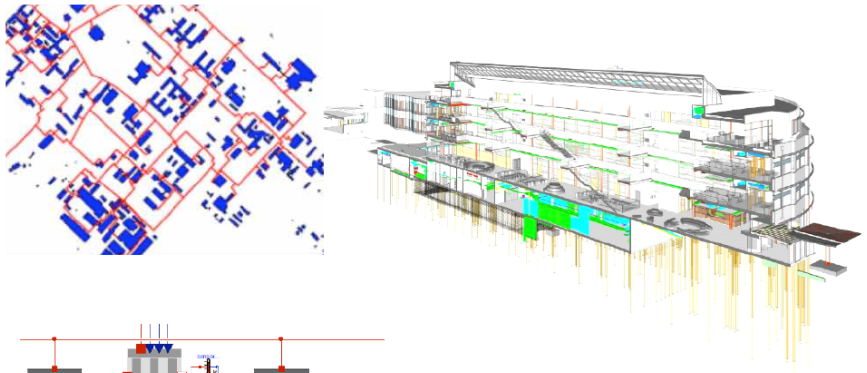
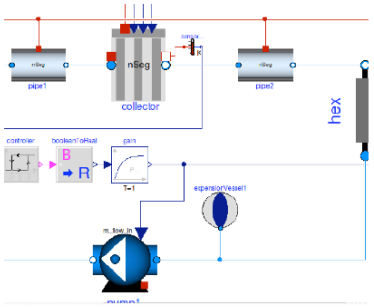
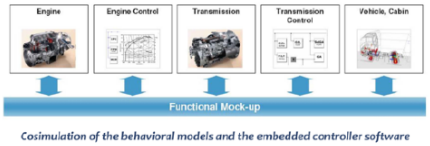
- the **Modelica modeling** language for implemeting models (https://www.modelica.org/),
- the **Functional Mockup Interface (FMI)** standards to couple simulators (https://www.fmi-standard.org/), and
- the **Industry Foundation Classes (IFC)** for building information modeling (http://www.buildingsmart-tech.org/)
  as well as other BIM-related standards such as Information Delivery Manual (IDM) and Model View Definitions (MVD).

Annex 60 committed to, leveraged and contributed to open standards that can be used with a variety of tools, rather than developed software technology that depends on the implementation of a single tool provider.

Avoids vendor lock-in and provides to industry a stable basis governed by standards.

Annex 60 | Open Standards

Building and district energy modeling, simulation and optimization based on open standards

Semantics	Standard	
static data	CityGML	
mathematics (behavioral models)	MODELICA	
computations (simulators)	fmi FUNCTIONAL MOCK-UP INTERFACE	 Cosimulation of the behavioral models and the embedded controller software

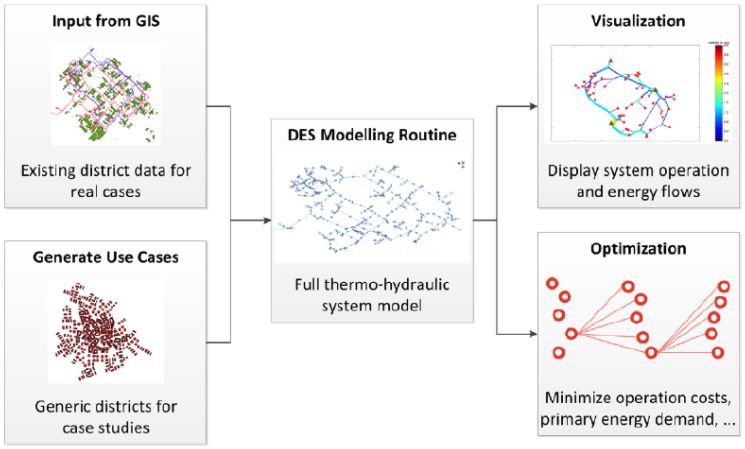
> 75M Euro investment during 2007-15

Supported by 90 tools

Outcome

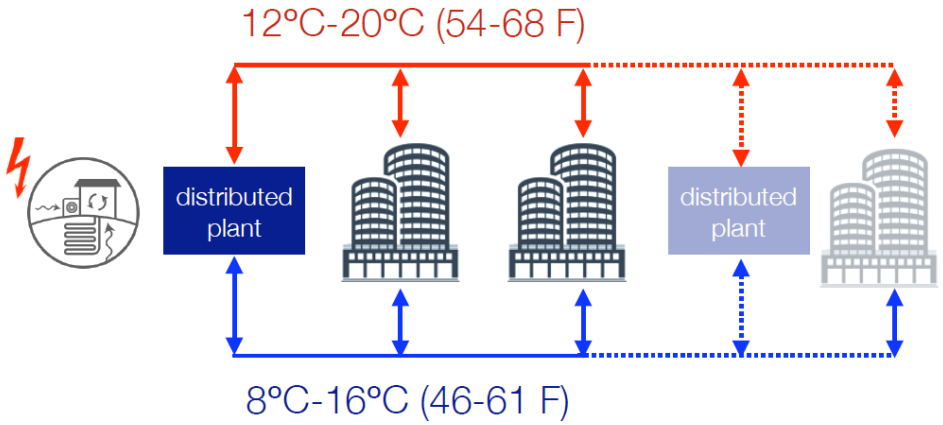
Annex 60 | Outcome

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.



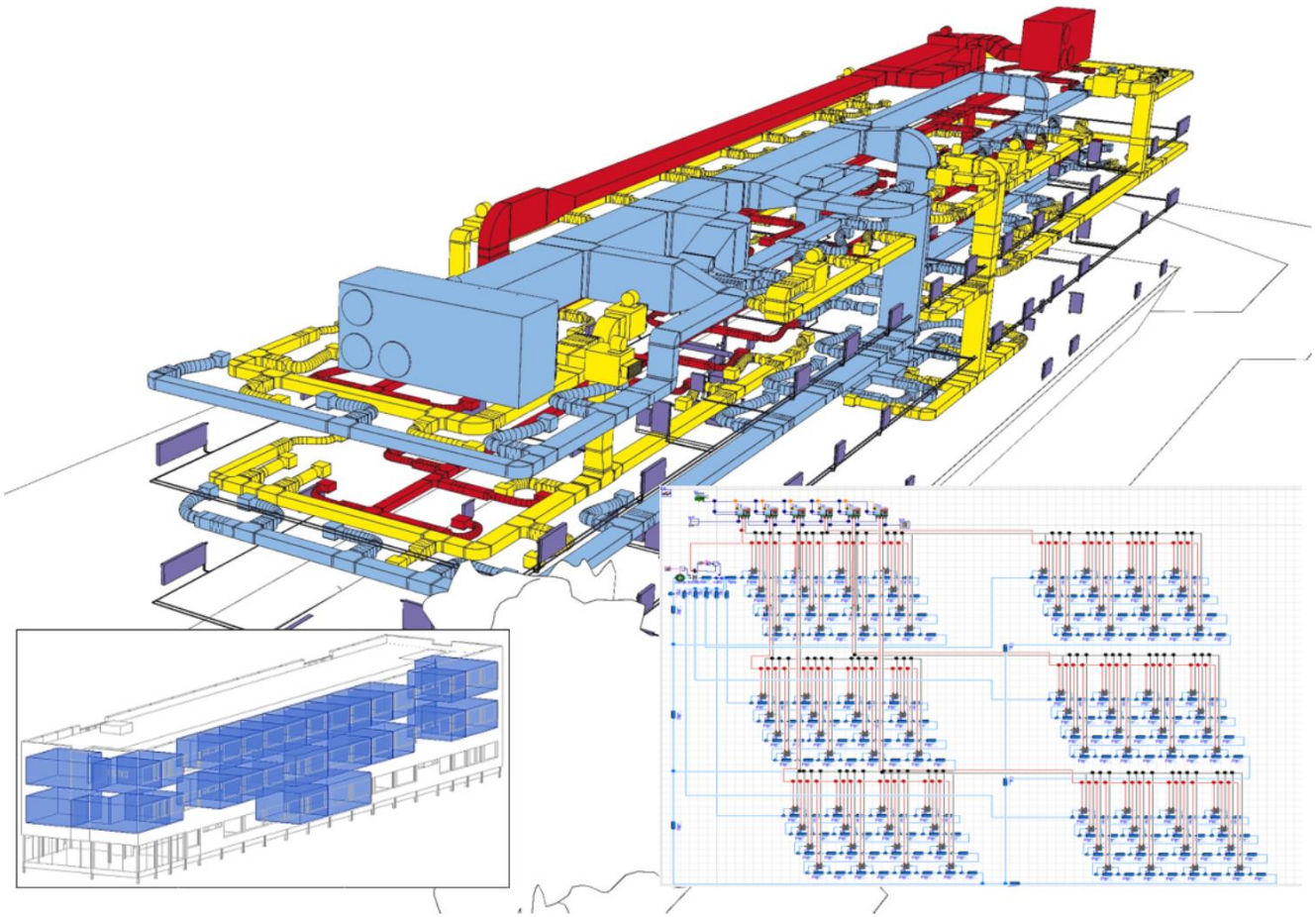
Source: LBNL

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.

Annex 60 | Outcome

GIS/BIM Transformation Process

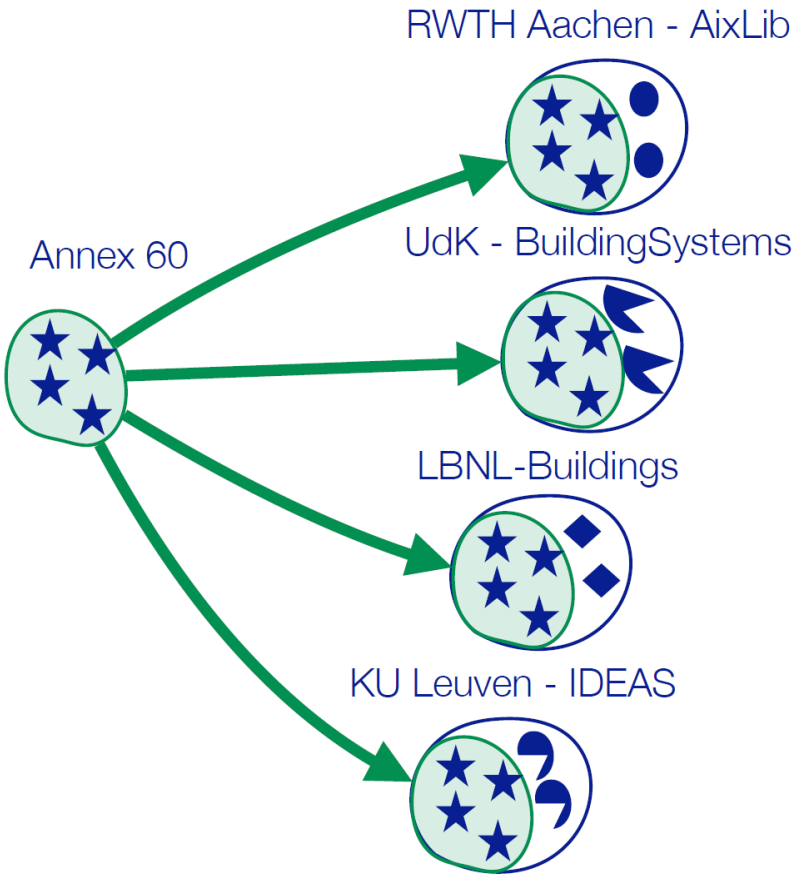
Support of multiple Modelica library branches by template-based transformation process



Sergio Pinheiro, Reinhard Wimmer, James O'Donnell, Sergej Muhic, Vladimir Bazjanac, Tobias Maile, Jérôme Frisch and Christoph van Treeck:
MVD based information exchange between BIM and building energy performance simulation,
Automation in construction, 90, 91-103, 2018, [DOI: 10.1016/j.autcon.2018.02.009]

Annex 60 | Outcome

Modelica library: In 2011, a joint effort started to avoid fragmentation, collaborate on development, implement best practices and share everything open-source and free



Annex 60 Modelica library is now used as the core of 4 major libraries for building and district energy systems.
https://github.com/iea-annex60/modelica-annex60

Michael Wetter, Marcus Fuchs, Pavel Grozman, Lieve Helsen, Filip Jorissen, Moritz Lauster, Dirk Müller, Christoph Nytsch-Geusen, Damien Picard, Per Sahlin and Matthis Thorade.
IEA EBC Annex 60 Modelica Library - An international collaboration to develop a free open-source model library for buildings and community energy systems.
Proc. of the 14th IBPSA Conference, p. 395--402, Hyderabad, India, December 2015.

Annex 60 | Outcome

Spawn of EnergyPlus – Modularize EnergyPlus based on open standards to address complexity of design & operation

Links design and operation

Allows specification & deployment of control sequences

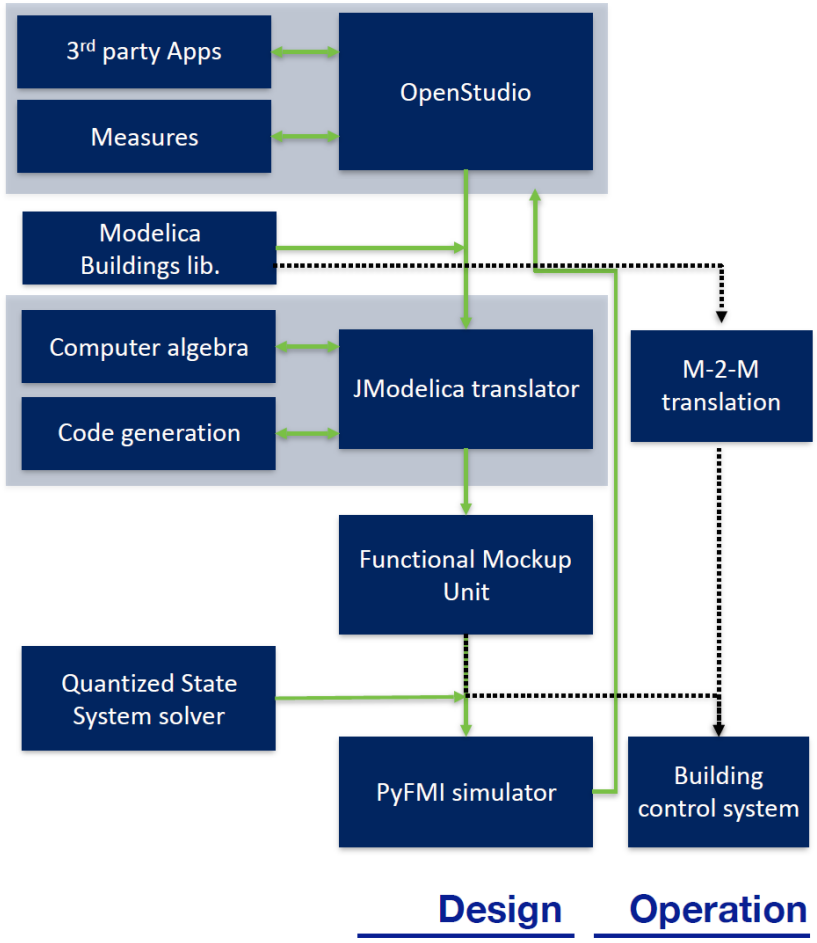
Inter-operability with control workflows and product development

Supports insertion of custom models and computing modules

Reduces technology lag

Built on open standards (Modelica and FMI)

Modular design allows component-wise upgrades



https://www.energy.gov/eere/buildings/downloads/spawn-energyplus-soep

Annex 60 | Outcome

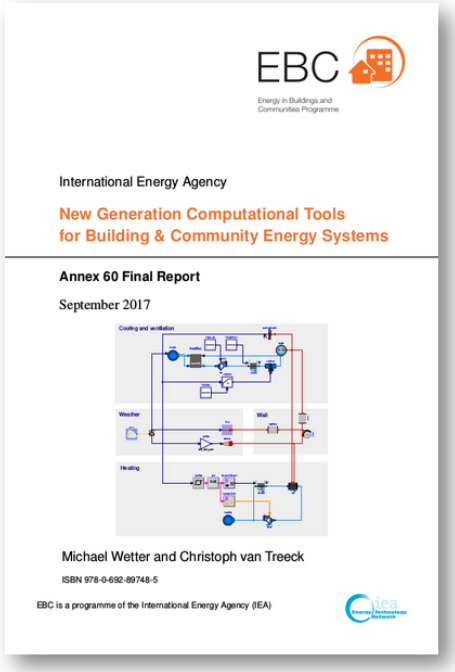
Model Predictive Control – combine modular modeling with computer algebra tools to obtain fast and robust code

Using computer algebra to recast optimization problem lead to 2,000 times faster optimization compare to a derivative free optimization method

Michael Wetter, Marco Bonvini and Thierry S. Nouidui. Equation-based languages - A new paradigm for building energy modeling, simulation and optimization. Energy and Buildings, 117(1), p. 290-300, 2016. doi: 10.1016/j.enbuild.2015.10.017

Publications

- Modelica: Annex 60 library
- BIM transformation toolchain and Annex 60 MVD
- Destest
- 14 Journal articles
- 38 Conference articles
- **Final report**, 500 pages



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Next

Continuation and dissemination framework

Non-coordinated
Modelica libraries

The Annex 60
Modelica library
open source, >300 objects

2013 | 2014 | 2015 | 2016 | 2017

EBC
Energy in Buildings and Communities Programme

EBC Annex 60
International Building
Performance Simulation
Association

IBPSA Project 1
International Building
Performance Simulation
Association

IBPSA

2017 | 2018 | 2019 | 2020 | 2021