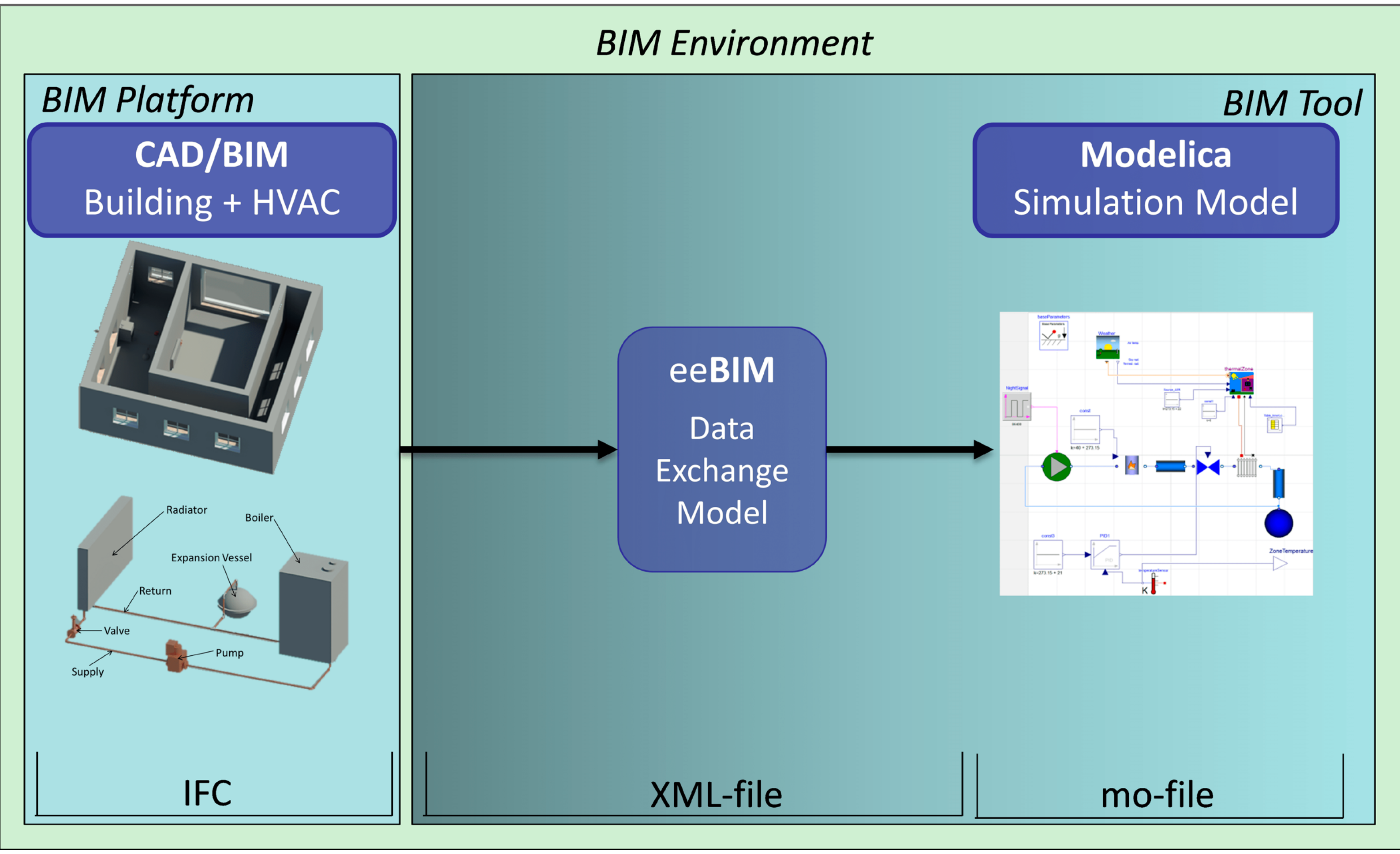
Energy in Buildings and
Communities Programme

International Energy Agency

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

Project Summary Report



EBC

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

Project Summary Report

Edited by
Michael Wetter and Christoph van Treeck

Participating countries in EBC: Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States of America

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Cover picture: Overview of the building information modelling transformation process
Source:RWTH Aachen University

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Project Summary

Building and district energy systems design and operation are subject to structural changes: First, building and district energy systems are becoming zero energy. Second, energy delivery is shifting from a mixture of fossil fuels to electricity with an increasingly large share of intermittent renewable sources. Third, the building delivery process is becoming increasingly integrated, based on digital planning tools such as Building Information Modeling (BIM). In consequence, a new generation of tools is required for planning, engineering, simulation and operation that can handle these issues.

The trends towards zero energy and electrification of the energy supply demand that buildings and district energy systems become increasingly integrated through active facades, energy storage, waste heat utilization within and among buildings through near ambient-temperature networks, and heat pumps that boost waste heat and renewable sources to usable temperatures. Advanced controls need to orchestrate this operation while providing electrical load shifting and load shedding capabilities, and bidding these capabilities into a dynamic electricity market.

This project successfully developed, demonstrated and disseminated new generation computational tools and tool chains for the design and operation of building and community energy systems. Receptors of the project outcomes are the building energy research community, Heating, Ventilation and Air Conditioning (HVAC) and urban energy system designers, design firms and energy service companies, equipment and control manufacturers and students in building science and controls.

With building performance modeling and simulation as a key technology, the project relates to all five Research and Development (R&D) focus areas of the EBC strategic plan, :integrated planning and building design, building energy systems, building envelope, community scale methods, and real building energy use for any type of building.

The project led to open-source, freely available, documented, validated and verified new generation computational tools. These tools allow buildings and community energy grids to be designed and operated as integrated, robust, performance based systems with low energy use and low peak power demand.

The developed tools are all based on three non-proprietary, open standards:

– the Modelica modeling language was used for modeling of building and district energy systems,
– the Functional Mockup Interface (FMI) standards was used to couple different simulation programs to prevent re-implementation and to facilitate re-use of program codes,
– the Industry Foundation Classes (IFC) were used as data exchange format to improve interoperability within the integrated building life cycle process.

The project committed to, leveraged and contributed to these 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. This provides a stable basis, governed by standards, to invest in for the industry as well as avoiding vendor lock-in.

Through this project, the technology readiness of existing building simulation was improved as world-wide, fragmented and duplicative activities were coordinated in modeling, simulation and optimization of building and community energy systems. Tool-chains were created, often by adapting and extending technologies from other industry sectors, to link BIM to energy modeling, building simulation to controls design tools, and design to operational tools. This project answered the research problem of how the structural changes of building and district energy systems design and operation are reflected by a new generation of computational tools. The developed tools were successfully disseminated and demonstrated in a series of associated national and international projects for building design, district energy system design, and for use of models during operation to support fault detection and diagnostics algorithms, model predictive control, and hardware-in-the-loop experimentation.

Although the project has delivered, as anticipated, a solid basis of tools and demonstrated its application, tool development is a continuous effort as it consecutively needs to provide support and to respond to new system technologies. Upcoming research and development issues that remain to be solved after completion of the project are therefore coordinated under the umbrella of the network of the International Building Performance Simulation Association (IBPSA) as a living and supporting dissemination framework.

Building energy modeling and simulation is an important implementation instrument of zero energy buildings and communities. Tools are quite complex, as dynamic systems need to be reflected between demand and supply sides and at different scales and levels, reaching from user behavior, over technical systems and buildings, via controls and distribution networks up to the issue of power generation. In order to facilitate the wide-spread use of such tools for design and operation, tools need to support open standards for (i) data representation, (ii) model implementation and (iii) simulator interoperability. Tools need to be further developed and advanced in terms of their user-friendliness and applicability as the application is currently limited to expert users. For BIM-based planning, uniform classification systems for product and manufacturer data as well as standards for function descriptions of technical systems are relevant. Policy needs to support such developments including the standards such as the International Organization for Standardization (ISO).

The future link between digital planning and Computer-Aided Facility Management (CAFM) will enhance the value chain from a building's owner or contractor's perspective. Linking design and operation through commissioning, fault detection and diagnosis will help to close the gap between predicted building energy performance and reality.

The project was conducted through a collaboration of 42 institutes from 16 countries. Among these institutes, researchers originated from universities, research institutions as well as from consultants and industry partners. Due to the close affinity of the project with open standards and the open dissemination strategy, the developed technology is accessible by the world-wide energy research community and not restricted to use in industrialized countries. As the project was dedicated to tool development for the energy sector, many interactions took place with members from other projects from the EBC and the Solar Heating and Cooling (SHC) implementing agreements of the International Energy Agency (IEA).

Project duration
2012 - 2017 (completed)

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Observers: Brazil, Slovakia, United Arab Emirates

Further information
www.iea-ebc.org

Project Outcomes

Background and Goals

To meet increasingly strict energy performance targets toward zero energy buildings and communities and challenges posed by distributed renewable energy generation on the electrical and thermal distribution grid, recent attention has been given to system-level integration, part-load operation and operational optimization of buildings. The intent is to design and operate a building or a neighborhood optimally as a performance-based, robust system. This requires taking into account system level interactions between building storage, Heating, Ventilation and Air Conditioning (HVAC) systems and electrical and thermal grid. Such a system-level analysis requires multi-physics simulation and optimization using coupled thermal, electrical and control models across multiple spatial and temporal scales as shown in Figure 1. Optimal operation also requires closing the gap between designed and actual performance through commissioning, energy monitoring and fault detection and diagnostics. All of these activities can benefit from using models that represent the design intent.

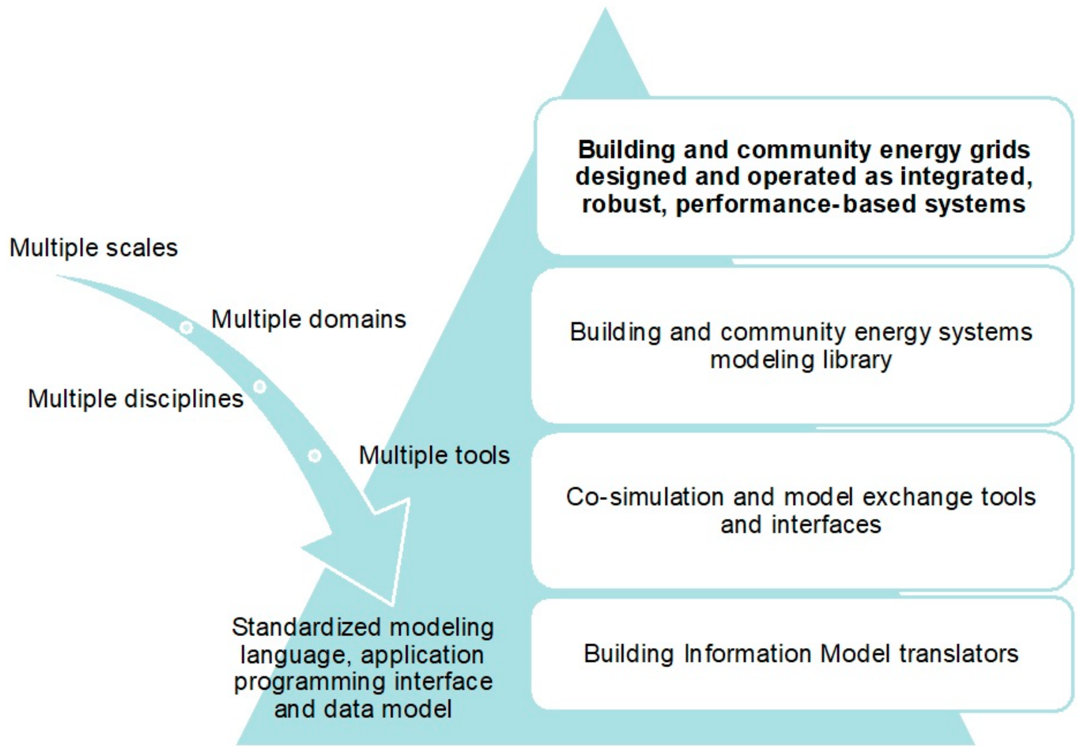

Figure 1: Overview of technical integration challenges that were addressed by this project

These models can then be used to verify responses of installed equipment and control sequences, and to compute optimal control sequences in a Model Predictive Controller (MPC), the latter of which possibly after simplifying the models.

Furthermore, in the Architecture, Engineering and Construction (AEC) domain, the processes of designing, constructing and commissioning buildings and energy systems are rapidly changing toward digitalization. Building Information Modeling (BIM) is an enabler as collaborative method and tool to consistently gather, manage and exchange building related data on a digital basis over the entire life cycle of a facility. BIM is not a specific software, it is rather a method as part of, but not limited to, the integral design. A truly added value is expected for the near future when design and commissioning in the sense of Computer-Aided Facility Management (CAFM) comes together. The above issues of commissioning, energy monitoring and fault detection and diagnostics can therefore highly benefit from a thorough digital planning when location and function of technical systems are together referenced in a digital model, when the as-built state is harmonized with and is well documented in a model, and when home and building automation becomes integrally linked with BIM.

In addition to the focus on closing the performance gap between design and operation, another recent focus is on system integration. Here, the challenge lies in the co-design and operation of building dynamics, HVAC, thermal and electrical storage, renewable energy generation, and grid responsive control in order to maintain the power quality of the electrical grid. Commonly, to support system integration, models from different engineering domains need to be coupled during run-time.

These issues impose structural changes to building and community energy modeling and simulation tools and processes.

- Modeling and simulation needs to tackle both demand and supply sides at multiple levels and multiple scales, reaching from user behavior, technical systems and buildings, controls and communication systems, and energy distribution networks up to power generation systems.
- Tools need to properly handle control sequences and hybrid systems in which the states evolve in time based on both continuous and discrete time semantics that arise from physics and digital control, respectively.
- Subsystem models need to be extractable in order to export and execute models in a self-contained form in the environment of a building automation system.
- Different physical domains and models of control systems need to be combined for a dynamic, multi-physics simulation that involves electrical systems, thermal systems, controls and possibly communication systems, which may evolve at vastly different time scales.

- Another issue is that model equations might become accessible in order to perform model order reduction and to solve optimal control problems.

In order to address these issues, this project developed and demonstrated new generation of computational tools for the design and operation of building and community energy systems. The project made use of the new and emerging technologies equation-based modeling, co-simulation and model exchange, optimization, and interoperability by means of building information modeling and data exchange.

Methodology and Scope

The EBC project: Annex 60 "New Generation Computational Tools for Building and Community Energy Systems" led to open-source, freely available, documented, validated and verified new generation computational tools. These tools allow to design and operate buildings and community energy grids as integrated, robust, performance based systems with low energy use and low peak power demand. The developed tools are all based on three non-proprietary, open standards:

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

The project 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. This avoids vendor lock-in and provides a stable basis, governed by standards, to invest in to the industry.

The target audience is the building energy research community, design firms and energy service companies, equipment and tool manufacturers, as well as students in building energy-related sciences. This project coordinated fragmented duplicative activities in modeling, simulation and optimization of building and community energy systems that are based on the Modelica and FMI standards. This project created tool-chains, often by adapting and extending technologies from other industry sectors, to link BIM to energy modeling, building simulation to controls design tools, and design tools to operational tools. WIt has been demonstrated these tools for building design, district energy system design, and for use of models during operation to support fault detection and diagnostics algorithms, model predictive control, and hardware-in-the-loop experimentation.

Results

Technology Development

The work was structured on technology development into the three areas "Modelica Model Library Development", "Co-simulation and Model Exchange Using the FMI Standard", "Building Performance Standards (BPS) Code Generation from BIM" and "Tools for Workflow Automation" and organized on the development around the three above mentioned standards IFC for data modeling, Modelica for multi-domain and multi-physics modeling, and FMI for run-time interoperability of simulators. Basing the work on these standards was critically important to enable a joint development, as many members brought into the project their existing code, further developed it within the project, and then integrated it back into this tool.

Modelica Model Libraries

Modelica, an object-oriented, equation-based, acausal modeling language, has been developed to support design and operation of complex engineered systems that are governed by differential equations, algebraic equations, time and state events. It is used in various industrial sectors such as automotive, aerospace, electrical engineering, power plants, robotics, buildings and district energy systems.

Models in Modelica are described by differential equations, algebraic equations and discrete equations. Using standardized interfaces, the mathematical relations of a problem between its interface variables are encapsulated in a model. The interface variables of multiple models can be connected with each other in a graphical model editor, without requiring any notion of what is input and what is output of a model, as shown in Figure 2. This encapsulation together with the standardized acausal model interface facilitates model reuse and model exchange. Since Modelica is a standardized language, models can be shared and exchanged by a large user community. To realize such a flexible modeling environment, the Modelica language embodies the object-oriented modeling paradigm in terms of supporting the encapsulation of knowledge and separation of concerns, offering topological interconnection capabilities, architecture-driven and hierarchical modeling, object instantiation, class inheritance and generalized networking capabilities.

A simulation environment then translates these Modelica models into a simulation program in a fully automated process. Since building system simulation problems lead to large, sparse differential algebraic equation systems, when translating a model, symbolic processing is used to reduce the dimension of the equation system. To exploit the sparsity of the model, the equations are simplified using computer-algebra and the coupled system of equations is converted for the solver to a block lower triangular form. After further manipulations, most equations are typically solved in an explicit manner, only small subsets of equations being subject to an iterative solution process. Furthermore, external code can be linked with Modelica

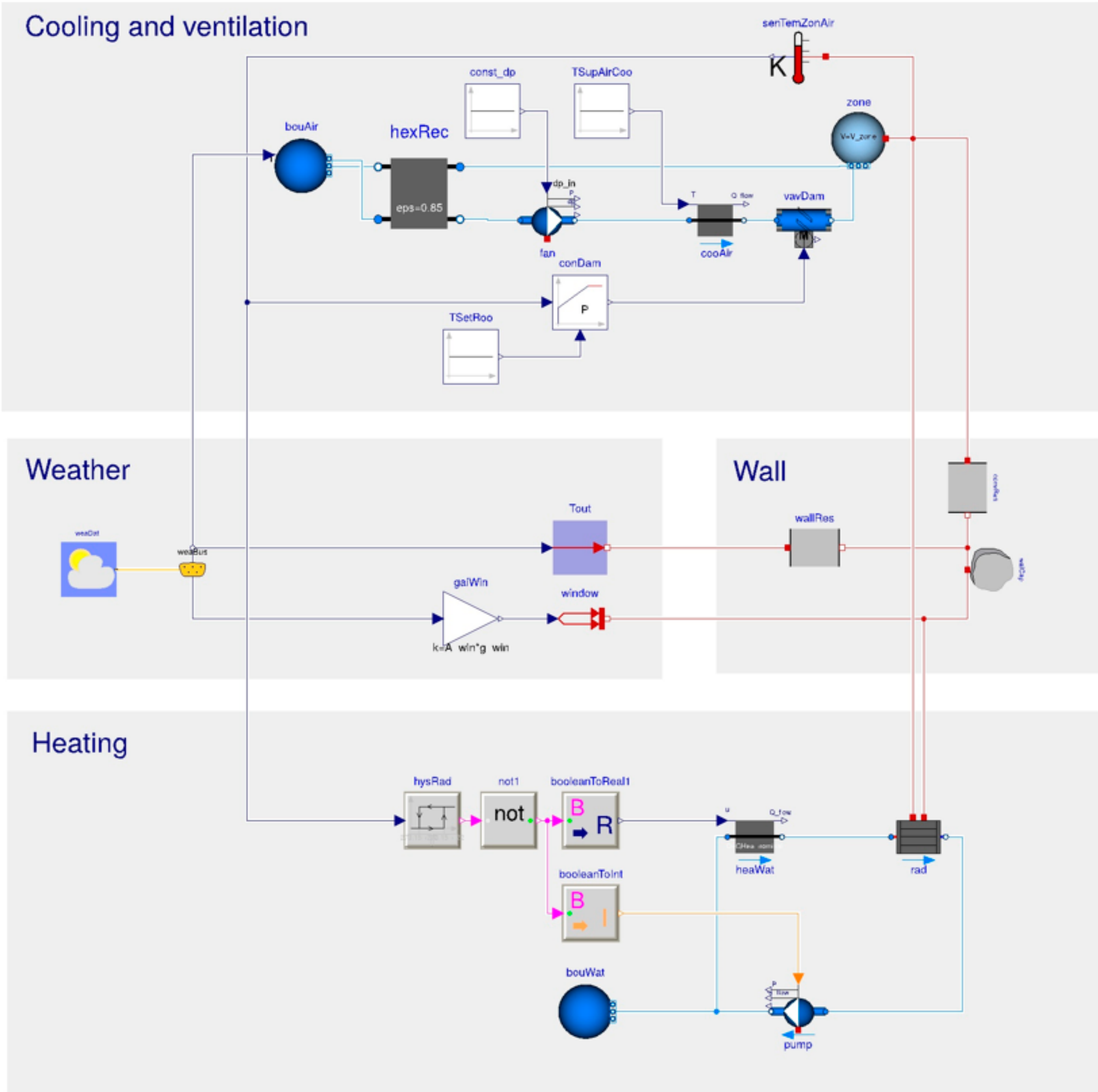

Figure 2: Modelica system model that shows a simple cooling and ventilation system (top), weather-driven heat gains, losses andstorage (middle) and an idealized heating system (bottom).

if parts of a computational problem shall be solved by another method, where other problem-related efficient solvers exist. This is the case when coupling a computational fluid dynamics program to a building envelope, HVAC and control simulation.

This project developed a free open-source library with more than 300 Modelica models for building and community energy systems (www.iea-annex60.org/pubs.html).This library became the core of the four Modelica libraries:

– AixLib, developed by RWTH Aachen, Germany,
– BuildingsSystems, developed by UdK Berlin, Germany,
– Buildings, developed by Lawrence Berkeley National Laboratory, Berkeley, CA, USA, and
– IDEAS, developed by KU Leuven, Belgium.

Prior to the project, theses libraries had limited scope, were mutually incompatible, and were in some cases not available to the public. In the project, these fragmented and duplicative activities were coordinated. As a result, the four major Modelica libraries for building and district energy systems now all share the same set of core models, they became more robust, better validated and compatible with each other. With this shared development, this project created a robust, open-source basis for a model library for the buildings performance simulation community. The approach of the library distribution can be compared to the distribution model of the operating system Linux, which offers a kernel that is used by different distributions. The project library comparably provides reliable base classes for building and HVAC component models. Developers of the different model libraries then integrate this library into their Modelica library and add additional models, provide documentation and support.

Co-simulation and Model Exchange Using the FMI Standard

Coupling simulation algorithms and tools is relevant, as a significant number of sophisticated simulation models and tools are available. Models and parametrization are provided by different specialists, with models being the outcome of many years of development. Hence, different programming languages and modeling approaches are used.

Many simulation tools implement only models for a specific domain, such as for thermal building simulation, electrical network simulation, or controls simulation. For many applications, it is desirable to use several simulation tools concurrently and make use of results generated by the different models at runtime and to transfer data automatically between codes. Pure integration of several existing models into a single simulation tool is technically very difficult and often unfeasible because

– tools include specialized numerical solvers,
– tools possess different and individual data structures and manage internal data differently,
– integration of code into a single tool may be restricted due to knowledge and copyright limitations, and
– maintenance and support of such integral models requires large investments of resources.

Translating existing models into Modelica is not always an alternative, as this may not be economically feasible, might be restricted due to intellectual property rights or might not even make sense as the built-in problem-related solver might be intrinsically advantageous for the problem subtype solved by the tool. Alternatively, code of complex systems can be decomposed into sub-systems, each subsystem being simulated with a domain-specific simulator taking advantage of numerical optimization and parallelization while data is exchanged during runtime via common interfaces.

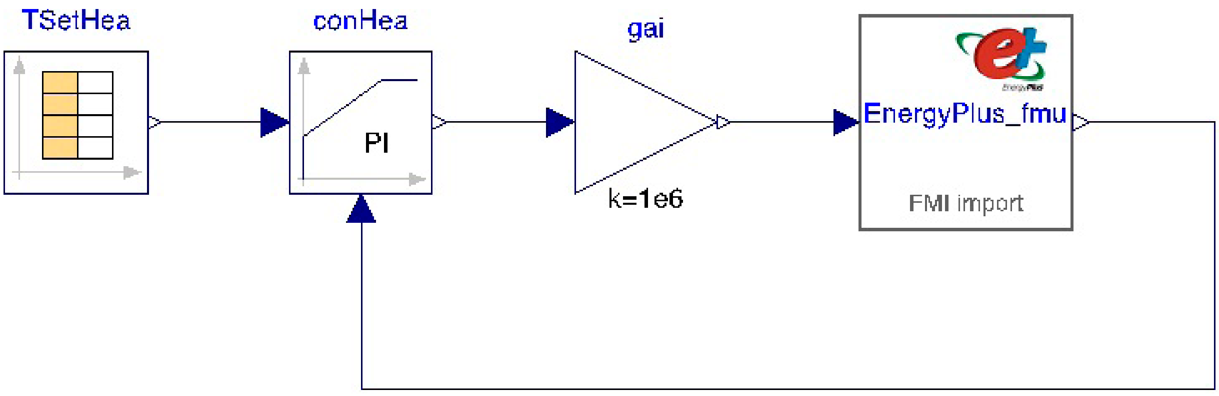

Figure 3: Modelica system model that connect a feedback controller with an EnergyPlus whole building model, which has been exported as an FMU.

This is the main idea of co-simulation through model coupling. Co-simulation is a technique in which simulators are executed simultaneously while exchanging data during runtime.

Options for tool coupling include interfacing directly by adopting code parts, leading to a one-to-one-approach where two tools exchange data via a specific protocol. Alternatively, a middleware can be used as a hub for interfacing a set of tools and synchronizing their data exchange and time evolution. To overcome limitations of existing tool coupling technologies, such as application-related restrictions, lack of functionalities or incompatibilities, the FMI standard has been developed.

The FMI standard allows two modes of encapsulating a model: model exchange and co-simulation. In FMI, a set of C-functions allows the exchange of data between Functional Mockup Units (FMU). The standard defines the signature of these functions, its semantics and a state-dependent sequencing of function calls during simulation. An metalanguage, XML data scheme defines meta-data of model and simulator for each FMU, such as the number and type of exchange variables, the simulator capabilities and the mathematical structure of the FMU. A zip file archive is used to package code with the implemented FMU functions as well as other resources.

In this project, we further developed co-simulation and model-exchange interfaces in legacy building energy simulation programs. We also further developed master algorithms and middle-ware for co-simulation and model exchange. All work was based on the non-proprietary FMI standard. For example, Figure 3 shows how an EnergyPlus model exported as an FMU and imported into a Modelica environment which to add a controller.

BPS Code Generation from Building Information Models

To support the transformation process from digital planning to simulation, in this project a mechanism was developed to transform a digital model of a building and its energy systems to Modelica code, as shown in Figure 4, that can be readily used for advanced building performance simulation. This was accomplished through the use and extension of the Open BIM data formats defined by the IFC and through the use of other BIM-standards such as IDM and MVD. This would thoroughly address the prevailing tedious, cumbersome and error-prone process of manual data conversion and model generation and to provide a methodology for automatically, or at least semi-automatically, transforming a digital model into an object-oriented acausal model. However, it was found that the transformation is hampered by several constraints such as

– data models contain inconsistencies and modeling errors and are typically not built by people skilled in energy performance simulation,
– data models may originate in the design process from other domains such as the architecture or structural domain,
– objects and parameters in a Computer Aided Design (CAD) model may significantly differ from the representation needed in Modelica,
– input models are typically lacking information relevant for BPS, and
– and a conversion process needs to support multiple Modelica libraries with different model topologies and varying syntax.

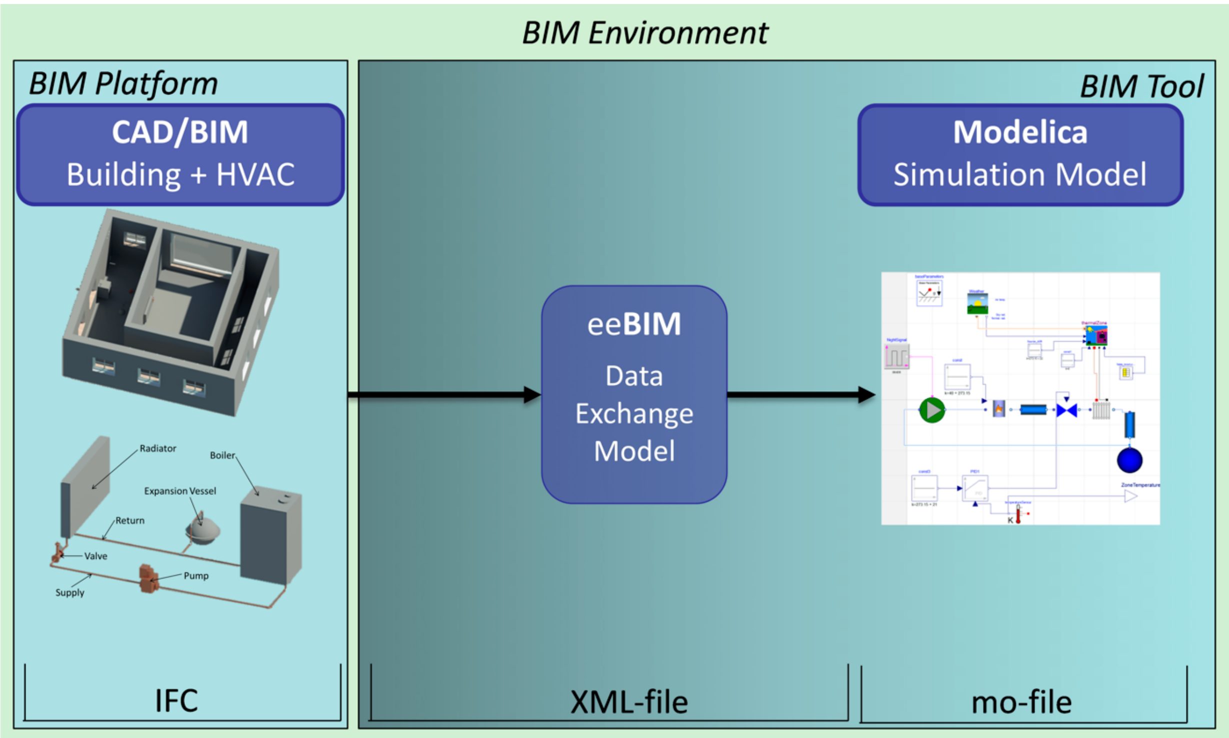

Figure 4: Overview of BIM transformation process from ifcXML to Modelica.

Consequently, these are several complex requirements for the specification of a software framework that is capable to deal with these constraints. Furthermore, a flexible methodology was required to take expert knowledge into account when it comes to object and parameter mapping. Asoftware framework was designed to provide interfaces to Open BIM data formats. These settings were considered by the following approach:

– As BIM data format, supporting on the Open BIM format IFC. Before processing BIM models, checking models for integrity concerning two aspects. First, accounting for the geometric consistency by an advanced model checking process which includes the definition of space boundaries. Second, checking the HVAC model by another model checking toolbox developed in this project.
– Transforming models into an intermediate data format called SimXML. Therefore, developing a flexible module for schema parsing. Relevant data which are missing in the BIM can be added to the SimXML data model.
– Managing these SimXML data by developing a dynamic schema parser in the C++ language. This offered flexibility to dynamically account for changes and updates of the SimXML schema (and, thus, for changes of the IFC data model as well). Then a Application Programming Interface (API) between C++ and Python to interact with the data model was implemented.
– Developing an object and parameter mapping mechanism as well as respective mapping rules to formulate engineering knowledge in a rule-based methodology. These rules are processed by the framework.
– Further developing and publishing an IFC MVD in order to specify the subset of IFC data relevant to BPS.
– To dynamically support multiple Modelica libraries at the same time, a template-based approach and implemented it in Python was selected.

The developed methodology was tested for a set of developed use cases. Thereby this followed a bottom-up approach which was based on these use cases. Therefore, the framework is currently limited to support these cases. This focused on a subset of IFC data, on the other hand, with the resources on hand it was possible to finalize the overall framework in the project and to provide a modular framework for further development and dissemination.

Tools for Workflow Automation

Workflow automation plays an important role in building and community energy performance simulation as models, tools and engineering tasks become increasingly complex. This project eveloped tools for workflow automation comprising free open-source Python packages to automate the workflow of developing and using Modelica models. For example, running a script to start tools in batch mode and to preprocess variables is common practice in simulation.

This is especially true if, for example, multiple domains are coupled, different scenarios shall be investigated, if input parameters are frequently varied, if multiple times a similar task shall be performed or if a conversion of input parameters or data formats becomes necessary.

Challenges for practitioners in the field of building energy simulations include the handling of huge amounts of both input and output data. Furthermore, in the case of sensitivity or uncertainty analyses of single or multiple parameters, many simulations will need to be run. In addition, the analysis of the resulting data or the conversion of the various data formats in simulation need a helping hand between the different codes applied. Tasks in simulation are time-consuming and error-prone if subject to manual procedures. Scripting languages and other automation environments help to gain efficiency, ensure a high quality of results and yield a reproducible workflow.

Functional requirements in terms of running simulations, pre- and post-processing results, data analysis and visualization, parametrization, data conversion, verification and optimization were summerized. WTHis project mapped requirements to existing tools and packages and identified missing functionalities. The project report contains a compilation of packages and several examples of workflow automation using BuildingsPy, awesim, ModelicaRes, PyFMI and Pandas. IPython Notebooks was used to present features of existing Python packages in order to assist engineers and researchers to increase the level of workflow automation.

Validation and Demonstration

Besides the technical development itself, in this project it has been demonstrated how these technologies can be horizontally integrated and applied to the design and operation of building and district energy systems. In many of these applications, Modelica models were combined with FMI-tools and workflow automation scripts, and with open-source and commercial software that has been developed outside of this project, to solve problems related to the design and operation of building and district energy systems. For a set of applications, the transformation from BIM-related data represented in the IFC standard was conducted to generate and execute Modelica simulation code. Had this work not been based on such standards, such a tight collaboration and integration of software would not have been possible. Moreover, analyzing multi-physics problems such as the integration of thermal and electrical systems, overlaid with controls that coordinates the two, would have been very difficult without Modelica's support for multi-physics modeling, and FMI's support for co-simulation using domain-specific tools.

In this project, the following has been delivered:

– for the design of building systems, how to design energy and control systems for buildings and how to size systems under consideration of diurnal weather patterns, energy storage and time-varying electricity prices of a smart grid has been demonstrated,

– for the design of district energy systems, validation and demonstration of the developed tools and the application of these tools to district energy systems and smart grid integration, and
– for model use during operation, control models and FMI export programs during the operation of building energy systems, and during hardware-in-the-loop experimentation have been used.

Governance and Dissemination

This project has benefited from a strong organizational framework to coordinate work between the various researchers world-wide. Over the course of this project, eight semi-annual international expert meetings have been conducted, most of them followed by technical workshops over multiple days. To synchronize work packages and activities, more than 120 online coordination meetings and web-conferences within the activities and among activity leaders have been conducted. Bitbucket repository system including a Wiki was used as key resource to organize collaboration and manage shared documents. Several special scientific tracks at national and international conferences were organized to disseminate and promote results of the entire project which helped us to gain a high international visibility. This project published a final report which is available as formatted document as well as dynamic web document. Other outputs of this project include 11 journal articles, 38 conference papers, a Modelica library and diverse source code packages, all managed through a Git code repository.

Continuation Framework

This project has delivered a solid basis of tools and demonstrated its application. However, tool development and dissemination management is a continuous effort as developers consecutively need to provide support and to respond to new system technologies. Upcoming research and development issues that remain to be solved after completion of the project are therefore coordinated under the umbrella of the IBPSA as living and supporting continuation and dissemination framework. During the projects working phase, already many interactions took place with members of several other projects from the EBC and the SHC implementing agreements of the IEA. The core of the team will continue key developments and disseminations of this project within the IBPSA Project 1 "BIM/GIS and Modelica Framework for building and community energy system design and operation".

Project Participants

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P.R. China	Chongqing University
Denmark	Aalborg University University of Southern Denmark
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Germany	RWTH Aachen University Maile Consulting TU Dresden KIT Karlsruher Institut of Technology Fraunhofer ISE Berlin University of the Arts (UDK) Fraunhofer IBP AEC3

Country	Organisation
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the Netherlands	Eindhoven University of Technology
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Sweden	Swegon AB EQUA Simulation AB
Switzerland	EMPA
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Project Publications

1. Michael Wetter, Christoph van Treeck New Generation Computational Tools for Building and Community Energy Systems Final Report, September 2017

EBC and the IEA

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 31 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the IEA Energy in Buildings and Communities (IEA EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)
The R&D strategies of the IEA EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. These R&D strategies aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five areas of focus for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*):

Annex 1:	Load Energy Determination of Buildings (*)
Annex 2:	Ekistics and Advanced Community Energy Systems (*)
Annex 3:	Energy Conservation in Residential Buildings (*)
Annex 4:	Glasgow Commercial Building Monitoring (*)
Annex 5:	Air Infiltration and Ventilation Centre
Annex 6:	Energy Systems and Design of Communities (*)
Annex 7:	Local Government Energy Planning (*)
Annex 8:	Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9:	Minimum Ventilation Rates (*)
Annex 10:	Building HVAC System Simulation (*)
Annex 11:	Energy Auditing (*)
Annex 12:	Windows and Fenestration (*)
Annex 13:	Energy Management in Hospitals (*)
Annex 14:	Condensation and Energy (*)
Annex 15:	Energy Efficiency in Schools (*)
Annex 16:	BEMS 1- User Interfaces and System Integration (*)
Annex 17:	BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18:	Demand Controlled Ventilation Systems (*)
Annex 19:	Low Slope Roof Systems (*)
Annex 20:	Air Flow Patterns within Buildings (*)
Annex 21:	Thermal Modelling (*)
Annex 22:	Energy Efficient Communities (*)
Annex 23:	Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24:	Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25:	Real time HVAC Simulation (*)
Annex 26:	Energy Efficient Ventilation of Large Enclosures (*)
Annex 27:	Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28:	Low Energy Cooling Systems (*)
Annex 29:	Daylight in Buildings (*)
Annex 30:	Bringing Simulation to Application (*)
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