Energy in Buildings and Communities Programme

New generation computational tools for building and community energy systems

Michael Wetter[1], Christoph van Treeck[2] and Jan Hensen[3]

[1]Lawrence Berkeley National Laboratory, Berkeley, CA, USA (Co-Operating agent)

[2]RWTH Aachen University (Co-Operating agent)

[3]Eindhoven University of Technology, Eindhoven, the Netherlands

September 30, 2013

1. Summary

Annex 60 will develop and demonstrate new generation computational tools for building and community energy systems based on the non-proprietary Modelica modeling language and Functional Mockup Interface (FMI) standards. The anticipated outcomes are open-source, freely available, documented, validated and verified computational tools that allow buildings, building systems 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 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. Currently fragmented duplicative activities in modeling, simulation and optimization of building and community energy systems that are based on the Modelica and Functional Mockup Interface standards will be coordinated. Tool-chains will be created and validated that link Building Information Models to energy modeling, building simulation to controls design tools, and design tools to operational tools. Invention and deployment of integrated energy-related systems and performance-based solutions for buildings and communities will be accelerated by extending, unifying and documenting existing Modelica libraries, and by providing technical capabilities to link existing building performance simulation tools with such libraries and with control systems through the Functional Mockup Interface standard. Demonstrations will include optimized design and operation of building and community energy systems.

2. Background and Target Audience

a) Description of Technical Sector

<u>Modeling and Simulation Needs for Very Low Energy Buildings and Community Systems</u>

As buildings become increasingly integrated to reduce energy and peak power and to increase occupant health and productivity, new challenges are posed to engineers when using building simulation programs to support decision making during product development, building design, commissioning and operation. New requirements that were not yet recognized 20 to 40 years ago when the development of current building simulation programs started include:

- Model-based design of integrated building systems by design firms and of products by equipment and controls providers to optimize energy-efficiency and peak load, and to reduce time-to-market for components, systems and advanced control systems.

- Design processes based on Building Information Models (BIM) which become increasingly used by design firms.
- Integrated design of building envelope, HVAC systems and control strategies by design firms.
- Model use to support operation, for control providers as part of an energy or smart-grid aware controller, for commissioning agents to provide a reference for the expected building operation, for fault detection and diagnostics providers to provide a reference model that can be used to classify fault signatures, and for urban planners and utility companies to develop design and operation strategies for energy grids with dispatchable distributed loads, generation and storage.

These applications require the integration of multiple domains (air-flow, thermodynamics, controls, indoor environmental quality, and electrical grid) and multiple disciplines (HVAC/energy consultant, architect, controls engineer, electrical engineer) that use a variety of tools that represent building systems across largely varying time scales from seconds to years and length scales from building components to urban districts. Next to the mentioned engineering consultancy services, the technology is as well important to the building simulation research community to build and deploy their R&D through standardized tools.

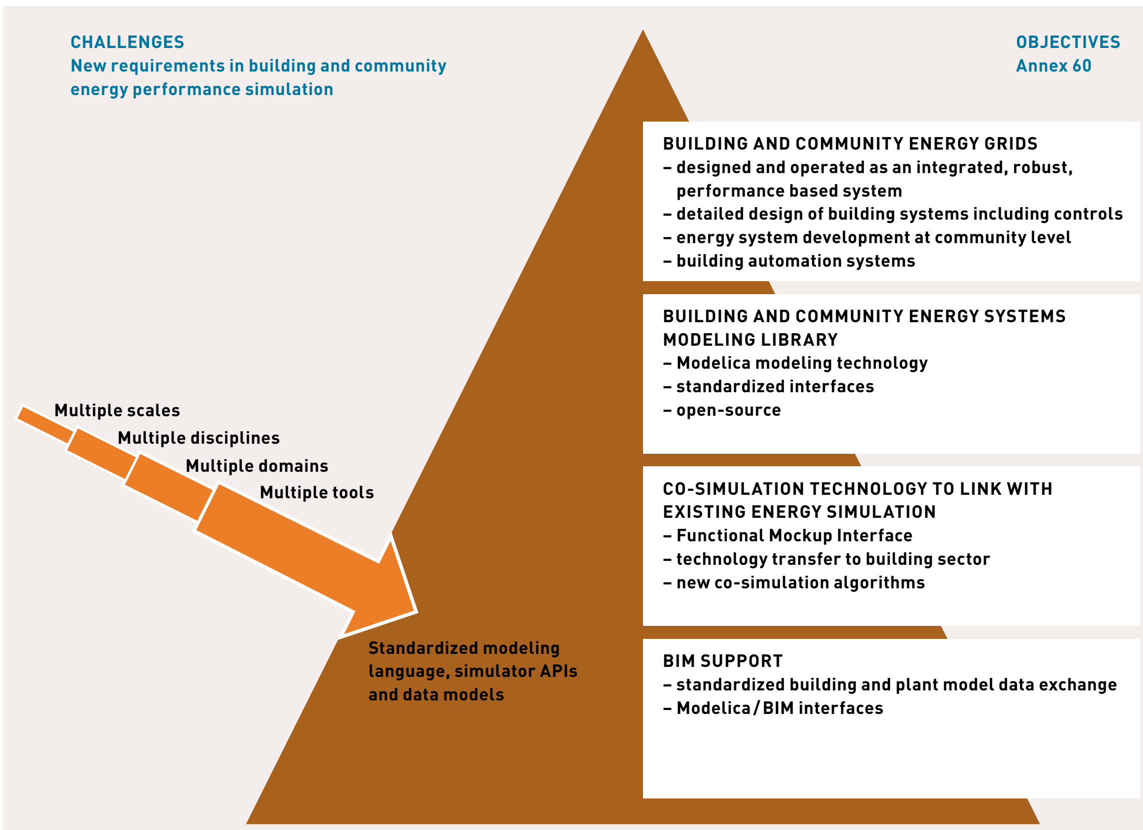

Figure 1: Overview of interrelation between technical challenges and anticipated outcomes of Annex 60.

Figure 1 shows these new challenges that will, in Annex 60, be addressed through the use of a standardized modeling language, standardized Application Programming Interfaces (API) and standardized data models. In contrast to these new computational technologies, today's building simulation programs were primarily designed as tools for energy analysis. Use of these programs during operation is cumbersome, as is their integration with models from other tools, or with models created by other team members or discipline experts. Furthermore, in today's building simulation programs, operational sequences are highly idealized. This prevents these tools from being used for the verification of the proper design and implementation of control sequences. It also makes it difficult to use the tools to analyze existing buildings which may have unconventional systems and control logic, because the original systems may have been retrofitted and buildings may have been re-purposed. Furthermore, current building energy performance simulation tools are not designed for the overall investigation of the interaction between buildings, district heating, cooling and electricity systems at the same time, which is required to evaluate new energy concepts that exploit dispatchable, distributed energy storage, generation and loads.

Modeling and Simulation Technologies that will be leveraged in this Annex

Modeling and simulation technologies that will be leveraged in this Annex are based on the object-oriented modeling language Modelica. The Modelica Standard Library contains more than 1300 models and functions that are open-source, freely available and well documented. However, the Modelica Standard Library does not have models for building energy systems, nor was the development of such models part of three European projects which were conducted with 54 million Euros investments in the automotive, aerospace and chemical industry. Moreover, current Modelica developments in the building sector are not coordinated. Consequently, model libraries lack common interfaces and typically cannot be linked with each other.

The need to couple legacy code to Modelica is clearly recognized. The Functional Mockup Interface standardizes the application programming interface for inclusion of simulation models into other simulation programs. It also standardizes how different simulation programs can communicate with each other during run-time. Modelica and the Functional Mockup Interface (FMI) standard have been selected as they are industrial-strength, non-proprietary, industry-driven standards that allow technology transfer between the building performance simulation community and much larger dynamic modeling communities from controls, automotive, power-plant, electrical system and chemical plant modeling.

Rather than reinventing the wheel, a major focus of this Annex will be how these investments, that are orders of magnitudes larger than what is invested in any single building simulation program, can be leveraged and extended where needed in a way that coordinates the activities of several countries. The Annex project therefore does not focus on the development of a single tool. At the same time, with the FMI technology, existing building energy simulation tools can be integrated.

Differences between Modelica and Legacy Simulators used in the Buildings Industry

An important difference between Modelica and related languages that have been used in the buildings industry, for example EES, NMF, Smile and MATLAB/Simulink, is that Modelica has orders of magnitude higher investments, it is an open-source language with both open-source as well as commercial modeling and simulation environments (https://www.modelica.org/tools), and it is well-posed to become a de-facto standard for modeling of dynamic, engineered systems. In Modelica, equations are typically encapsulated into models that are then used to schematically define the system architecture. From this high-level language, executable code is automatically generated.

b) Target Audience

The target audience for the results of this Annex will be the building energy research community (to build and deploy their R&D through standardized tools), leading-edge design firms and energy service companies (as the tool-chains become more mature and comprehensive), equipment and control manufacturers (as early adopters within their R&D process) and students in building science and controls.

Moreover, technology developed within this Annex will be incorporated in building performance simulation programs that are available to the buildings industry through open-source and commercial tools.

c) Explanation of Used Definitions

Acausal model: A model is called acausal if there is no causality specified between its variables. Acausal models are automatically reformulated during compilation time to form causal models based on what variables are known and unknown for the given application in which the model is used.

Application Programming Interface (API): Specification of a software interface that allows software components to communicate with each other.

Building Information Model (BIM): A Building Information Model is an instance of a data model that describes a building unambiguously, e.g. a digital footprint of a building and its properties, represented over its entire life cycle.

Co-simulation: By co-simulation, we mean the simultaneous coupled numerical solution of differential equations that share common variables but are implemented in two different computer programs. For example, building envelope heat transfer may be simulated in one program, and HVAC system operation may be simulated in another program, as neither of the two programs contains all required models.

Equation-based: Equation-based models are computational models that allow a model developer to declare the governing relations in terms of equations and not in terms of variable assignments, as C or Fortran does. Examples include Modelica, NMF, EES, gProms and Simscape.

Functional Mockup Interface (FMI) and Unit (FMU): The FMI standard defines an open interface to be implemented by an executable called Functional Mock-up Unit (FMU). The FMI functions are called by a simulator to create one or more instances of the FMU, called models, and to run these models, typically together with other models. An FMU may either be self-integrating (co-simulation) or require the simulator to perform numerical integration.

3. Objectives

The anticipated outcome of this Annex are open-source, freely available, documented, validated and verified computational tools that allow building and community energy grids to be designed and operated as integrated, robust, performance based systems with low energy use and low peak power demand. Targeting the building energy research community, design firms and energy service companies, equipment and tool manufacturers, as well as students in building energy-related sciences, currently fragmented duplicative activities in modeling and simulation of building and community energy systems will be coordinated taking advantage of Modelica and FMI standards.

Tools and libraries will be validated and their usability tested through their use in projects that support product development, building design, building integration in community energy grids, and through the real-time application of models. Validations will involve comparisons between simulations, analytical solutions and real-scale experiments (synergistic effects to existing Annex projects) and inter-model comparisons using existing standards such as ANSI/ASHRAE Standard 140 or VDI 6020 Standard, as well as process-related verifications.

In terms of the multi-domain approach, the scope is not restricted to specific building types. However, country-specific subtasks will restrict the scope, where appropriate, to specific building types, and/or to a specific modeling level such as a city quarter.

Multi-disciplinary challenges that will be addressed in this project include research and development of the following:

- A common open-source infrastructure of models that allow sharing and deploying to market the contributions of currently uncoordinated activities in Modelica-based building simulation.
- Tool-chains that link object-oriented CAD systems, building design tools and controls design tools with Modelica models, and that allow the deployment of these models to real-time systems in support of building commissioning, building controls and fault detection and diagnostics.

The ultimate goal of this Annex is to leverage, further develop as needed, deploy and demonstrate the use of modern modeling, simulation and analysis techniques that result in:

- Accelerated invention and deployment of integrated systems and performance-based solutions at the building and community level, at a reduced technical risk for early adopters, through a model-based design and performance verification process.
- Reuse of models across the whole building life cycle to ensure realization of design intent and persistence of energy savings, peak demand reduction and comfort through proper operation.
- Increase of system-level performance through more effective collaboration facilitated by interoperable models and simulators for the currently vertically separated disciplines: controls, thermal systems, daylighting, electrical systems and air quality.

Compared to conventional building simulation programs, the end-product will thus provide the means to reduce energy consumption and peak power demand. Specific objectives are:

- Rapid prototyping of new equipment, systems and controls to accelerate time-to-market for innovative low energy systems.
- Standardized APIs to enable simulator interoperability, allowing designers to link simulators for run-time data exchange with simulators of other domains and with building control systems.
- BIM to Modelica translators to reduce time and cost to create models for performance assessment and to ensure data integrity within the design process.
- Co-design of HVAC and control sequences to properly size systems that exploit thermal and electrical storage and to trade off investments between envelope, equipment and controls.
- Peak load reduction and load shifting at the community level to reduce the need for electrical reserve capacity generators, which typically have high CO2 emissions and large capital costs.
- Use of models to augment monitoring, control and fault detection and diagnostics methods.

The scope of the work includes applications in building energy systems and community energy grids during the design and operation phase, enabled through the modular design of models and interfaces to simulators and control systems.

4. Means and Technical Approach

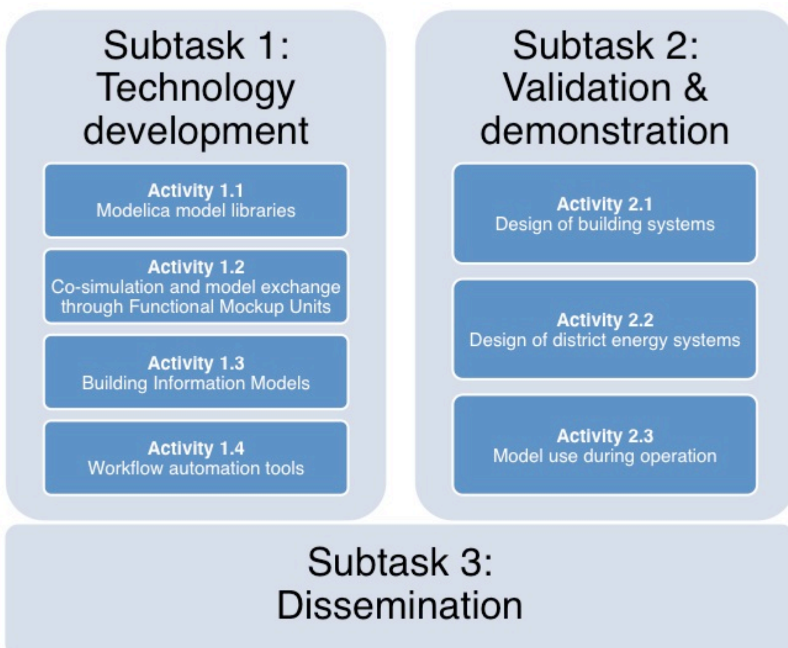

Figure 2: Structure and organization of the Subtasks of this Annex.

The Annex objectives shall be achieved by the participants collaboratively working on the Subtasks described below and as summarized in Figure 2. Subtasks 1 will develop the required software technology. Significant work already exists and will be leveraged. Subtask 2 is focused on validation, verification, demonstration and deployment of the developed software technology in the context of whole building and community energy performance design and operation. Subtask 3 will develop a guidebook, organize special tracks at professional conferences, and ensure effective collaboration with professional organizations. Due to the work that already exists for Subtasks 1, all Subtasks will start concurrently. Subtasks 1 and 2 are further organized into the following activities:

Activity 1.1 “Modelica model libraries” will develop free open-source libraries of Modelica models for building and community energy systems with associated documentation for new and experienced users. This will be accomplished through the further development and validation of existing libraries. An outcome will be comprehensive free open-source libraries that provide the modeling infrastructure for the overall Annex as well as for the buildings industry.

Activity 1.2 “Co-simulation and model exchange through Functional Mockup Units” will develop co-simulation and model-exchange interfaces in legacy building energy simulation programs and further develop middle-ware for co-simulation and model exchange. The non-proprietary Functional Mockup Interface standard will be leveraged. The outcome will be interfaces in legacy simulators and middleware that allow coupling Modelica models with legacy simulation programs, such as for computational fluid dynamics or daylighting for which equation-based models may not exist or may not be suited.

Activity 1.3 “Building Information Models” will develop BIM to Modelica translators for individual buildings, and through integration of geographical information systems, for community energy systems. This will be accomplished through the use of existing standards for exchanging energy calculation data, and through extending standards such as IFC as appropriate. This capability will facilitate the construction of whole building Modelica models, it will integrate energy performance simulation, especially with respect to Modelica, with the developments of BIM-based tools that are ongoing outside of this Annex, and provide a path for a next-generation BIM that also specifies control sequences.

Activity 1.4 “Workflow automation tools” will develop free open-source Python packages to automate the workflow of developing and using Modelica and FMI models and co-simulators. The Python packages will assist developers in unit tests and checking libraries with conformance to coding guidelines, users in pre-processing and post-processing batches of simulation, such as for parametric studies or for uncertainty propagation, and in the integration of Modelica or FMI models with optimization packages for design optimization and Model Predictive Control. This activity is meant to avoid duplication of work that would otherwise be conducted in the different activities of Subtask 2.

Activity 2.1 “Design of building systems” will demonstrate how to co-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. The approach is to formulate the problem as an optimal control problem, possibly with stochastic input, and solve the problem using existing nonlinear programming algorithms. This will demonstrate how new requirements of smart grids affect the design and operation of buildings, how state-of-the-art computer algorithms can help in designing very low energy buildings and ultimately lead to correctly-sized systems that operate efficiently across a larger range of part-load conditions.

Activity 2.2 “Design of district energy systems” will validate and use tools from Subtask 1 to design district energy systems and to develop control algorithms for smart grid integration of clusters of buildings, e.g., an office park, campus or residential neighborhood. This will be accomplished by integration of models for thermal, electrical and control systems at different levels of fidelity depending on the scale of the district energy system. This capability will assist utilities and control providers in the development of control strategies and rate structures for energy grids with a large share of distributed renewable energy generation.

Activity 2.3 “Model use during operation” will use control models from Activity 1.1 and FMI export programs from Activity 1.2 to deploy energy-aware control algorithms and models for monitoring to experimental facilities, building automation and energy management systems. The integration of these algorithms and models will be done through Functional Mockup Units which provide a simulator and control-system independent software interface. This will allow model use in hardware-in-the-loop experimentation, during building commissioning for functional testing, and during building operation to ensure energy-minimizing and smart-grid responsive control that continuously monitors performance relative to design intent.

5. General Provisions and Management Issues

Participants are encouraged to leverage, or to make their work compatible with, existing open-source environments such as OpenModelica or JModelica, as these tools already provide utilities such as graphical model editors, packages for optimization, interfaces for Functional Mockup Units and code generators for embedded systems.

All demonstrations will be documented and published in a user guide that demonstrates and explains the use of the developed products. The user guide will also serve as a reference to train new users in these technologies that are currently not well utilized in the buildings industry.

Annex 60 will not support or maintain the software following its termination. Individual participants may provide this service. It is therefore encouraged that any new software will be developed in the context of ongoing software development that already has established distribution channels and a track record of continued maintenance. See also the "Information and Intellectual Property" section.

Applications may also be performed in collaboration with participants from other IEA Annexes. Discussions have been held with

- The IEA EBC Annex 54 "Analysis of Micro-Generation & Related Energy Technologies in Buildings,"
- the IEA EBC Annex 58 "Reliable Building Energy Performance Characterisation based on Full Scale Dynamic Measurements," and
- The IEA EBC Annex 59 "High Temperature Cooling and Low Temperature Heating in Buildings."

a) Subtask Leaders

A Subtask Leader (the "Subtask Leader") for each of the foregoing Subtasks will:

(1) Co-ordinate the work performed under that Subtask;
(2) Assist the Operating Agent in preparing the detailed Program of Work and Budget;
(3) Direct technical workshops and provide the Operating Agent with written summaries of workshop results; and
(4) Edit technical reports resulting from the Subtask and organize their publication.

The Subtask Leader shall be a Participant who provides to the Subtask a high level of expertise and undertakes substantial research and development in the field of the Subtask. The Subtask Leaders shall be proposed by the Operating Agent, and designated by the Executive Committee acting by unanimity. Changes in the Subtask Leaders may be agreed to by the Executive Committee, acting by unanimity of the Participants.

b) Technical Advisory Committee.

The Participants shall establish a Technical Advisory Committee (the "Technical Advisory Committee") consisting of the Subtask and Activity Leaders and the Operating Agent or their respective designees. The Technical Advisory Committee shall assist the Operating Agent in the co-ordination of the Annex and advise the Operating Agent on the performance of the Annex.

6. Results and Deliverables

The outcome of this Annex will be libraries and tools for modeling, simulation, optimization, and embedded computing, built on open, industry-strength, extensible standards not owned by individual companies. This environment will allow a virtual representation of building equipment (provided in electronic catalogues of manufacturers), building systems and urban energy grids (created by design firms) and real-time models (created by controls providers) that accompany buildings throughout the life cycle for operational optimization and monitoring.

It is evident that the wide applicability of the Modelica modeling language is a strength of this Annex, because this will result in flexible tools that are applicable beyond narrow use cases and that integrate well with tools for model-based design and analysis of dynamic systems. The models and processes will be validated with respect to their usability and accuracy, and documented to allow wide adoption of the here developed tools by the buildings industry.

Research results will be published in peer-reviewed journals and conferences. Using a non-proprietary, open language opens a pathway for computational R&D in ongoing and future Annexes. There will also be periodic newsletters and a web site providing updates about activities and progress of the subtasks.

Specifically, the proposed end-products will be in Subtask 1 modeling libraries, tools for co-simulation and for Building Information Modeling, in Subtask 2 case study reports that illustrates and explains the use of these technologies and in Subtask 3 a guidebook. In particular, the deliverables will be:

- Subtask 1: Technology Development
  - Activity 1.1: Validated, with respect to accuracy and usability, documented models that can be used by designers, manufacturers, control providers, researchers and students with multiple open-source and commercial Modelica simulation environments that use a standardize model format, such as JModelica, OpenModelica, Dymola, SimulationX, MapleSim, Mosilab, MathModelica or AMESim.
  - Activity 1.2: New algorithms, implemented in existing building simulation programs and in co-simulation middleware, that allow efficient co-simulation and model-exchange through FMUs
  - Activity 1.3: Interfaces that allow designers to configure Modelica models from a Building Information Model compatible CAD system.
  - Activity 1.4: Python packages that automate the workflow of developing and using Modelica models and FMUs.
- Subtask 2: Validation and Demonstration:
  - Activity 2.1: Case studies that demonstrate to designers the co-design of building energy and control systems under consideration of system dynamics (energy storage and controls), uncertainty, and variability.
  - Activity 2.2: Case studies that demonstrate to urban planners and utilities the integration of buildings into a community-level energy grid.
  - Activity 2.3: Software and, for designers, control providers and for students, case studies that demonstrate how to use models to assist in the operation of buildings.
- Subtask 3: Dissemination: A guidebook that demonstrates how technologies of Annex 60 can be used in applications that are beyond the capabilities of traditional building simulation programs. Applications include rapid virtual prototyping, design of local and supervisory controls, and deployment of models in support of commissioning and operation. Dissemination will also include special tracks at conferences.

7. Relation to EBC Strategic Plan

The IEA EBC Strategic Plan 2007-2012, p.12ff., (http://www.ecbcs.org/docs/ECBCS_Strategic_Plan_2007-2012.pdf) includes as its strategic goals:

- G1, to support dissemination: “to develop and improve information mechanisms, methods and tools in order to create powerful, energy and environmentally aware end-users,” with a strategic focus on “influence reportive buildings...” so that “People ...know where they spend energy.”
- G2, to support decision-making “to develop methodologies, methods and validated tools for the life-cycle decision-making enabling process.”
- G3, to support building products and systems “to develop and demonstrate.... advanced operating systems for their use and control.”

Subtasks 1 “Technology development” addresses the strategic goals G1 and G3. This subtask advances the creation of virtualized built environments, which is a long-term goal of the IEA roadmap. Furthermore, Activity 2.3 “Model use during operation” directly addresses the development of advanced operating systems for building automation systems, which are energy-aware and can thus demonstrate to building operators where they use energy. Activity 2.1 “Detailed design of building systems” focuses on the co-design of energy-efficient buildings and advanced building automation algorithms. This will provide information technologies that advance the current design process from a component-based optimization to a system-level optimization where building envelope, mechanical systems and operational sequences are co-designed in order to leverage system-level opportunities for reducing energy load, exergy demand and increasing occupant comfort. Activity 1.1 “Modelica model libraries,” that addresses G2 through the development of validated tools, supports these applications. These new tools can be integrated with new design processes such as a BIM-based process by architectural engineering firms, which currently have no means to express advanced control sequences in a BIM, or model-based product development by manufacturers. Activity 1.2 “Co-simulation and model-exchange through Functional Mockup Units” provides the means to combine special purpose algorithms (e.g., computational fluid dynamics and ray-tracing for daylighting) with Modelica models of HVAC systems and controls, thereby allowing a system-level optimization. It also allows linking these tools to legacy programs that may contain prototypical models for the building stock in order to assess energy saving potentials across classes of buildings.

In summary, this Annex will leverage the rapid development of information technologies that happens in other industrial sectors with investments that are orders of magnitude higher than the investments in information technologies within the building sector. It will adapt these technologies to the buildings sector, and demonstrate new processes for product development, building design and building operations that are enabled through these advanced information technologies.

8. Time Schedule

The Annex will take a total of 5 years, starting from June 2012. Year 1 is the preparation phase, years 2, 3 and 4 are used to conduct the research, and year 5 is the reporting phase. Informal research collaboration is already going on during the preparation phase. The co-operating agents expect that results of it will be used and further developed in years 2, 3 and 4. Because substantial pre-work exists in modeling libraries and environments for co-simulation, the subtasks 1 and 2 can start in parallel, and will last over the whole duration of the project.

9. Specific Obligations and Responsibilities of the Participants

In addition to the obligations enumerated in Article 7 of the Implementing Agreement:

(1) Each Participant shall provide the Operating Agent with detailed reports on the results of the work carried out for each Subtask.
(2) Each Participant shall collect, assess and report to the Operating Agent data on a semi-annual basis.
(3) Each Participant shall participate in the editing and reviewing of draft reports of the Annex and Subtasks.

10. Specific Obligations and Responsibilities of the Operating Agent

In addition to the obligations enumerated in Articles 4 and 7 of the Implementing Agreement, the Operating Agent shall:

(1) Prepare and distribute the results mentioned in section 9 above.
(2) Prepare joint assessments of research, development and demonstration priorities for the above subtasks.
(3) As needed by the Annex, organize workshops, seminars, conferences and other meetings.
(4) Prepare the detailed Program of Work for the Annex in consultation with the Subtask Leaders and the Participants and submit the Program of Work for approval to the Executive Committee.

(5) Provide, at least semi-annually, periodic reports to the Executive Committee on the progress and the results of the work performed under the Program of Work.
(6) Provide to the Executive Committee, within six months after completion of all work under the Annex, a final summary report for its approval and transmittal to the Agency.
(7) In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the Agency or by other competent bodies.
(8) Provide the Participants with the necessary guidelines for the work they carry out with minimum duplication.
(9) Perform such additional services and actions as may be decided by the Executive Committee, acting by unanimity.

11. Funding

Each participant shall individually bear its own costs incurred in the Annex activities. Funding is expected to cover labour costs, consumables and investments associated with the execution of the subtasks. Also travelling costs should be covered to participate in at least two expert meetings per year during the four year preparation and working phases of the Annex. The working meetings shall be hosted by one of the participants. The costs of organizing and hosting the meeting shall be borne by the host participant.

Each participating country must designate at least one individual (an active researcher, scientist or engineer, here called the expert) for each activity in which they decide to participate. It is expected that the same expert attends all meetings and acts as technical contact regarding the national subtask contribution. A minimum commitment of six person months of labour for each year of the Annex term will be required for participation. For the subtask coordinators, funding shall allow for six person months and an extra two person months per year for Annex activities. For the operating agent funding shall allow for six person months and an extra four person months per year for Annex activities including the attendance at the two EXCO meetings per year.

12. Operating Agents

Co-operating agents are the United States, acting through the Lawrence Berkeley National Laboratory, and Germany, acting through RWTH Aachen University.

13. Information and Intellectual Property

All participating countries have access to the workshops and results of all subtasks.

To ensure open collaboration among the participants, Modelica models developed within this Annex will be open-source and freely available under the Modelica 2 license (or newer versions as applicable). An exception will be models of control algorithms and of HVAC equipment that contain proprietary information that result from industry funds. In this situation, models may, at the minimum, be made available as encrypted models if the work has been conducted under this Annex.

The use of the open-source BSD 3-Clause License (http://www.opensource.org/licenses/BSD-3-Clause) is encouraged for the development of elements of this tool-chain. However, if participants do not use this license, then they should at a minimum provide an open application programming interface that allows the integration of their tools with other software for design, optimization and operation of buildings.

14. Participants in this Annex

The participating countries are Austria, Belgium, China, France, Germany, Ireland, Italy, the Netherlands, Sweden and USA. Switzerland is requesting participation at a reduced level. Slovakia and Brazil request observer status.