BESMod - A Modelica Library providing Building Energy System Modules

Fabian Wüllhorst, Laura Maier, David Jansen, Larissa Kühn, Dominik Hering, Dirk Müller
**Motivation**

Domain-coupled building sector is a foundation for integration of renewable energy

**Climate Change** requires installation of renewables and a shift towards a more electrified energy system.

**Development** of new design and control methods is required.

**Simulation** can serve as a fast and economical option to analyze and optimize new methods.

**Consideration** of domain-coupling is vital in renewable building energy systems.

**Modelica** enables the modeling and coupling of different domains.

Are there libraries for the modeling of domain-coupled building energy systems?
Related work
Several libraries provide component models for all relevant domains

Rich pool of component models for all domains available in **twelve** libraries
Current gap
No library targets the domain-coupled simulation and analysis of build energy systems

- Rich pool of component models for all domains available in **twelve** libraries
- No single library provides the “best” models for all domains
- Lack of system models, uniform interfaces and consistent parameterization
- Use models from multiple libraries
- Provide systems using a modular structure and consistent parameterization

Develop **BESMod**, a library providing **Building Energy System Modules**
BESMod

General idea and scope of BESMod

- BESMod is built upon component libraries
  - Required Libraries
    - MSL
    - IBPSA
  - Optional Libraries
    - Buildings
    - AixLib
    - Building Systems

- BESMod is fully modular
  - A (sub)-system is a module
  - Modules/subsystems for all domains

Use models from multiple libraries

Provide systems using a modular structure and consistent parameterization
BESMod
Approach for a modular subsystem design

Bus connectors
- Color-coding
- No pre-defined variables
- No usage in the uppermost system

Vector sized ports
- Multiple zones
- Multiple generation systems

Interfaces
- BuiMeaBus
- HEMSBus
- OutputsBus
- UseProBus

Replaceability
- All modules are constrained by some PartialModule
- Usage of choicesAllMatching and modifiers

expandable connector UseProBus "Data bus with user profiles"
  extends BESMod.Utilities(Icons).UseProBus;
end UseProBus;

replaceable BESMod.Tutorial.BaseClasses.PartialModule module
  constrainedby BESMod.Tutorial.BaseClasses.PartialModule(
    final yMax=yMax
  )
  "Correct overwrite of top-down parameters"  2 ;
BESMod
Uniform parameterization approach based on four principles

1. Top-Down parameters
   - Given by the parent or adjacent systems
   - Always final

2. Bottom-Up parameters
   - Defined by remaining parameters
   - Not final, enables fine-tuning

3. Records for component data
   - Only component physics
   - Usage of top-down parameters

4. Component choices
   - E.g. use the bypass valve

---

Fabian Wüllhorst | American Modelica Conference | 25.10.2022 | BESMod - A Modelica Library providing Building Energy System Modules
BESMod
The building envelope is the core of the energy system

Layout
- Only building envelope
- User profiles are separated and depend on building model

Connectors
- Thermal
- Ventilation (moist air)
- Electrical

Parameterization
- Nominal $T$ and $\dot{Q}$ as bottom-up
- Geometry as bottom-up

Available Modules
- Thermal Zone
- High Order
- Mixed Air
- Energy Plus tbd.

Legend:
- Information signal
- Water
- Thermal
- Moist air
- Electrical
- Inflow
- Outflow
- (Design direction)

Building envelope
Supervisory Control
User

Ventilation

DHW

Layout

Connectors

Parameterization

Available Modules
BESMod
Description of the hydraulic subsystem

Layout
- According to EN 15316-1
- Similar setups in ASHRAE Standard 111

Connectors
- Fluid for DHW
- Heat for building

Parameterization
- Records as function of top-down parameters and constants
- Design rules presented in previous work

Available Modules
- Heat pump, boiler, storages, controls, radiators, UFH
- SolarThermal HeatPump

Legend:
- Information signal
- Water
- Thermal
- Moist air
- Electrical
- Inflow
- Outflow
- Design direction
- Building envelope
- Local Control
- Generation
- Distribution
- Transfer
- DHW

Parameterization
- According to EN 15316-1
- Similar setups in ASHRAE Standard 111

Connectors
- Fluid for DHW
- Heat for building

Available Modules
- Heat pump, boiler, storages, controls, radiators, UFH
- SolarThermal HeatPump
BESMod
Description of the electrical subsystem

Layout
■ According to EN 15316-1
■ Transfer system for e.g. infrared heating

Connectors
■ Component libraries use power
■ No domain-coupling, use of power (W)
■ No usage of voltage and current

Parameterization
■ PV sizing based on the roof area (top-down parameter)

Available Modules
PVAndBattery
DirectGridConnection

Legend:
- Information signal
- Water
- Thermal
- Moist air
- Electrical
- Inflow
- Outflow (Design direction)
**Ventilation**
- Similar to hydraulic system
- No transfer system required

**Weather**
- Not replaceable
- TMY3-Reader so far works for all cases

**Supervisory control**
- Connected to all local controls
- Type is defined in local control
- Internal supervisory control or external via e.g. BOPTEST

---

**Legend:**
- Information signal
- Water
- Thermal
- Moist air
- Electrical
- Inflow
- Outflow
  (Design direction)
**BESMod**

Steps to aggregate a coupled building energy system

**Simulation**
- Redecclare subsystems
  - Select component choices
  - Choose component records
  - Fine-tune bottom-up parameters
- Choose weather file
- Overwrite parameters to study
- Simulate

**Debugging**
- Disable single subsystems
- Test new subsystems in dedicated Tests package

**Available Systems**
- Bivalent heat pump, thermal storages, radiator, PV and battery, Ventilation with heat recovery, Supervisory control for DHW storage superheating
- Several other Examples
Proof of concept
Comparison of two building models with the same HVAC energy system

- Comparison of ThermalZone to MixedAir
- Model for PartialUseCase
- User and building modules not replaced

Highlights
- Only graphical interaction
- No additional connection on top-level
- Annual simulations take < 6 min

Results
- Different Building physics
- PV sizes with roof area
- MixedAir with higher solar gains
Conclusion
Several areas for future development exist:

**Library Development**
- Electrical connectors update in IBPSA
- Validation of coupled systems
- Compatibility to OpenModelica
- Extension of Continuous Integration

**Future Use-Cases**
- Control development and testing
  - Development of cases for BOPTEST?
  - Coupling to Ontologies such as Brick
- Simulation based design optimizations

Future Use-Cases:
- Control development and testing
  - Development of cases for BOPTEST?
  - Coupling to Ontologies such as Brick
- Simulation based design optimizations
Conclusion
Already active developer community in Aachen hopes for international support

- BESMod is only as good as the component libraries and the community!
- Active user community in Aachen
  - 20 Students and 10 Ph.D. candidates
  - Currently, we perform personal workshops to explain the usage
  - Better documentation and YouTube tutorials to follow
- Invitation to use and further develop BESMod

Visit and use BESMod:

https://github.com/RWTH-EBC/BESMod

Promotional reference 03ET1495A.

This work emerged from the IBPSA Project 1.
**BESMod**

**Approach for a modular subsystem design**

**Bus connectors**
- Color-coding
- No pre-defined variables
- No usage in the uppermost system

**Interfaces**
- BuiMeaBus
- HEMSBus
- OutputsBus
- UseProBus

**Vector sized ports**
- Multiple zones
- Multiple generation systems

**Replaceability**
- All modules are *constrained by* some `PartialModule`
- Usage of `choicesAllMatching` and `modifiers`

**Compatibility to OpenModelica**
- Arrays in expandable connectors
- Expandable in expandable
- Replaceable arrays

```modelica
expandable connector UseProBus "Data bus with user profiles"
    extends BESMod.Utilities.Icons.UseProBus;
end UseProBus;
```