Model Library

Green Building

The sub-libraries

- AmbientConditions
- Building
- CombinedHeatAndPowerUnit
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enable the user to simulate and analyze building systems including renewable energy suppliers, storage systems and even new eMobility concepts.

The library comprises system components that are common in building systems engineering, and it uses standardized terms and parameters in calculations of heat and electrical power for each component. This allows for analyses of system interactions throughout various physical domains on a single platform.

The modeling technique is intuitive and easy to understand. Neither is it necessary to create further differential equations or complex control strategies, nor would real systems have to be abstracted as mathematical calculation models.

Model libraries for a wide range of building system components

Intuitive modeling with common connectors and parameters

Innovation: Integration of eMobility

Many degrees of freedom for system configuration and parameterization

Simulation of physical behavior and control strategies on one platform

Expandable control algorithms and strategies

Flexible choice of model parameters

Picture of a luxury lakeside mansion with integrated micro wind turbines and photovoltaic systems on the roof (small picture) and the derived building system model consisting of five thermal zones and the corresponding system configuration (large picture).
Ambient Conditions
This library comes with calculation algorithms for ambient conditions of the intended building location. It contains basic elements for each simulation model. The ambience model also takes care of importing the required weather data.

Ambience
- calculates the current local time (time of day, season) and the sun’s angle of incidence on the plane ground surface
- defines the time base for the input of weather and energy consumption data
- imports all relevant weather data (solar radiation, wind speed, outdoor temperature)

Ambience Measurement
- makes a single connection available for each variable of the ambience bus

AmbienceOutput

Building
This library offers the possibility to simulate the heating and cooling demand of a building depending on internal and external characteristics like ambient temperature as well as heat losses of electric devices. The building zone model is used to calculate heat losses and gains of internal heat sources and through the building envelope. The required heat can be provided by an internal heating system model or by an external heating system library component.

HeatedZone
- simulates the internal temperature depending on internal masses (walls and ceilings) as well as room volume
- calculates heat losses and gains through the building envelope with respect to heat transmission, ventilation, solar yields etc.
- considers further internal heat sources (electric devices etc.)
- internal simulation of the heating system

BuildingZone
- simulates the internal temperature depending on internal masses (walls and ceilings) as well as room volume
- calculates heat losses and gains through the building envelope with respect to heat transmission, ventilation, solar yields etc.
- considers further internal heat sources (electric devices etc.)
- external simulation of the heating system allows for variable analysis of different heat supply systems

VolumeFlowControllerBuilding
- controls the volume flow inlet to the heating system with respect to target temperature and current zone temperature
TemperaturDistribution

- used to exchange zone temperatures of building zones
- allows heat to be exchanged between connected building zone boundaries

Combined Heat and Power Unit

This library contains a variable simulation model for combined heat and power units (CHP) which can be used in modern building energy systems to produce electrical energy from a generator powered by a combustion engine. Occurring heat losses are used for heating at the same time. The system operation can be controlled depending on either the heat or the electrical power demand.

- simulates heating of a heat medium with losses occurring from cooling the CHP’s combustion engine
- simulates the electrical power production of a CHP generator feeding the local grid
- simulates heat supply to the heating system through a circulation pump model controlled by external control algorithms
- simulates fuel combustion

CHPControlHeatLed

- controls the CHP’s operating times depending on the heat demand
- includes thermal shut-off limits like maximum flow temperature
- regulates circulation pumps with respect to target volume flow
- modulates the thermal energy output for CHP systems depending on temperature distribution

CHPControlCurrentRegulated

- controls the CHP’s operating times depending on the electrical power demand
- includes thermal shut-off limits like maximum flow temperature
- regulates circulation pumps with respect to target volume flow
- modulates the thermal energy output for CHP systems depending on temperature distribution

Condensing Boiler

The model components in this library can be used to simulate the behavior of highly efficient heating systems. Depending on the chosen fuel, the heat output of these systems can be controlled continuously or discretely using different burner stages. These efficient heating systems have now been combined with highly efficient motor-generator systems. Thus, heat losses from the electricity production can now also be used for heating, which can be simulated with a dedicated element from this library.

- simulates heating of a heat medium with respect to fuel combustion and heat recovery from emissions
- heat supply continuously adjustable by external control algorithms
- simulates heat supply to the heating system through a circulation pump model controlled by external control algorithms
**Domestic Water Supply**

The models for domestic water supply extend the Combined Heat Storage model with respect to heat supply and heat extraction in a domestic water tank. Both can be achieved through heat exchangers or through volume flow inlets directly. Another structure allows for domestic water tanks to be heated via electrical power provided by either a heat pump or an electric heater.

All models in this library calculate the necessary energy for domestic water heat supply. The amount of consumed hot water in a building must be added to the simulation model as additional input data.

**CondensingBoilerDiscrete**
- simulates heating of a heat medium with respect to fuel combustion and heat recovery from emissions
- heat supply discretely adjustable by external control algorithms (burner stage)
- simulates heat supply to the heating system through a circulation pump model controlled by external control algorithms

**CondensingBoilerStirling**
- simulates heating of a heat medium with respect to fuel combustion and heat recovery from emissions and heat losses from electricity production
- heat supply continuously adjustable by external control algorithms
- simulates heat supply to the heating system through a circulation pump model controlled by external control algorithms
- simulates electrical power supply (linear generator) to the local grid

**CBControlHeatLedContinuous**
- controls CB operating times depending on heat demand
- includes thermal shut-off limits like maximum flow temperature
- regulates circulation pumps with respect to target volume flow
- modulates thermal energy output depending on temperature distribution
- usable for CB systems continuously modulating heat

**CBControlCurrentRegulated**
- controls CB operating times depending on electrical power demand
- includes thermal shut-off limits like maximum flow temperature
- regulates circulation pumps with respect to target volume flow
- modulates thermal energy output depending on temperature distribution
- usable for CB systems with electric generators

**CBControlHeatLedDiscrete**
- controls CB operating times depending on heat demand
- includes thermal shut-off limits like maximum flow temperature
- regulates circulation pumps with respect to target volume flow
- modulates thermal energy output depending on temperature distribution
- usable for CB systems discretely adjusting heat

**ThermallyHeatedBoiler**
- simulates the temperature behavior in a boiler with a defined number of heat medium layers, one upon another
- heat supply and extraction via internal heat exchangers or directly via volume flow inlet
- simulates heat losses through the boiler insulation
- maximum of three heat inputs and three hot water outputs
### ElectricallyHeatedBoiler
- simulates the temperature behavior in a boiler with a defined number of heat medium layers, one upon another
- heat extraction via internal heat exchangers or directly via volume flow inlet
- simulates heat losses through the boiler insulation
- maximum of three hot water outputs
- electrically heated through heat pump or electric heater

### VolumeFlowControllerBoiler
- controls the volume flow inlet of the heat medium depending on the target temperature and the current temperature of the boiler
- usable for controlled heating of thermally heated boiler

### StaticPowerController
- controls heat supply via electric heating systems depending on the target temperature and the current temperature of the boiler
- usable for controlled heating of electrically heated boiler
- constant heat supply, controlled through pulse width modulation

### DynamicPowerController
- controls heat supply via electric heating systems depending on the target temperature and the current temperature of the boiler
- usable for controlled heating of electrically heated boiler
- modulated heat supply

### HotWaterSupply
- used to model the domestic water demand in buildings
- includes an internal circulation pump
- determines cold water temperature, desired flow temperature and volume flow
- can be connected to a boiler

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### Heating System
This library allows comprehensive analyses of different heat supply systems for buildings, such as floor heating and radiators. The Heating System model can be connected to multiple building zones. This allows for heating and cooling load calculations to be detached from the heat supply system simulation. Just like in real buildings, the heat required for several building zones can be supplied by one heating system or vice versa which means the heat for one building zone can also be supplied by several heating systems. This approach increases the extensibility and variability of the Green Building simulation libraries significantly.

### HeatingSystem
- simulates heat supply of various heating systems (floor heating, radiator) depending on flow, return and ambient temperature
- includes the ratio of heat radiation to heat convection for different heating systems
<table>
<thead>
<tr>
<th>Component</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>VolumeFlowController-HeatingSystem</td>
<td>- controls the volume flow inlet for heating systems with respect to current and target temperatures of the heated building zone(s)</td>
</tr>
<tr>
<td>HeatingUnitSeries</td>
<td>- connects several heating system models with one heat supply system in series</td>
</tr>
<tr>
<td></td>
<td>- the volume flow to the connected heating system is controlled by an external heat controller</td>
</tr>
<tr>
<td></td>
<td>- the remaining volume flow of the heating medium bypasses the heating system</td>
</tr>
<tr>
<td>HeatingUnitParallel</td>
<td>- connects several heating system models with one heat supply system in parallel</td>
</tr>
<tr>
<td></td>
<td>- the volume flow to the connected heating system is controlled by an external heat controller</td>
</tr>
<tr>
<td></td>
<td>- the remaining volume flow of the heating medium bypasses the heating system</td>
</tr>
<tr>
<td>HeatingUnitFlowTemperature</td>
<td>- controls the flow temperature to the heat sink</td>
</tr>
<tr>
<td></td>
<td>- contains an internal circulation pump</td>
</tr>
</tbody>
</table>

**Heat Pump**

These electrical systems extract energy from environmental media like air, soil and ground water. The heat pump model in this library uses pre-defined data for the electrical energy demand and the heat output depending on the temperature of the heating system flow and the environmental medium’s temperature. This makes it easy to simulate various types of heat pump systems.

<table>
<thead>
<tr>
<th>Component</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>HeatPump</td>
<td>- simulates heating of a heat medium with respect to compressor efficiency which depends on the medium’s environmental temperature</td>
</tr>
<tr>
<td></td>
<td>- operating times regulated by external control algorithms</td>
</tr>
<tr>
<td></td>
<td>- heat supply to heating system simulated by a circulation pump model controlled by external control algorithms</td>
</tr>
<tr>
<td></td>
<td>- simulates the compressor’s electrical power demand from the local grid</td>
</tr>
<tr>
<td>HPControlHeatLed</td>
<td>- controls the HP’s operating times depending on the heat demand</td>
</tr>
<tr>
<td></td>
<td>- includes thermal shut-off limits like maximum flow temperature</td>
</tr>
<tr>
<td></td>
<td>- regulates circulation pumps with respect to target volume flow</td>
</tr>
<tr>
<td></td>
<td>- accounts for controlling inner processes like de-icing</td>
</tr>
</tbody>
</table>
**Heat Storage**

The heat storage model library contains model elements for different kinds of structures using a liquid medium for storing heat. It also includes specialized heat control algorithms.

<table>
<thead>
<tr>
<th>Model</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>HeatStorageStratified</td>
<td>- simulates the temperature behavior in the heat storage consisting of a defined number of heat medium layers, one upon another</td>
</tr>
<tr>
<td></td>
<td>- direct heat supply and extraction via volume flow inlet</td>
</tr>
<tr>
<td></td>
<td>- simulates heat losses through the heat storage insulation</td>
</tr>
<tr>
<td></td>
<td>- maximum of three heat inputs and three heat outputs are simulated for a defined height of the heat storage</td>
</tr>
<tr>
<td>HeatStorageMixed</td>
<td>- simulates the temperature behavior in the heat storage consisting of a defined number of heat medium layers, one upon another</td>
</tr>
<tr>
<td></td>
<td>- heat supply and extraction via internal heat exchangers</td>
</tr>
<tr>
<td></td>
<td>- simulates heat losses through the heat storage insulation</td>
</tr>
<tr>
<td></td>
<td>- maximum of three heat inputs and three heat outputs are simulated for a defined height of the heat storage</td>
</tr>
<tr>
<td>HeatStorageCombined</td>
<td>- simulates the temperature behavior in the heat storage consisting of a defined number of heat medium layers, one upon another</td>
</tr>
<tr>
<td></td>
<td>- heat supply and extraction via internal heat exchangers or direct volume flow inlet</td>
</tr>
<tr>
<td></td>
<td>- simulates heat losses through the heat storage insulation</td>
</tr>
<tr>
<td></td>
<td>- maximum of three heat inputs and three heat outputs are simulated for a defined height of the heat storage</td>
</tr>
</tbody>
</table>

| VolumeFlowControllerHeatStorage | - controls the volume flow inlet of the heat medium depending on the heat storage’s current and target temperatures |

**Micro Wind**

The micro wind model can be used to simulate the electrical power supply of micro wind turbines integrated into a building. Their housing enhances the airflow through the wind turbine increasing the usable wind energy for electrical power generation. The integrated generator model is controlled by an external controller which regulates the electrical torque and thus the generator’s efficiency.

<table>
<thead>
<tr>
<th>Model</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroWindTurbine</td>
<td>- simulates the wind energy generated by a micro-wind turbine depending on rotor and housing characteristics as well as wind speed and direction</td>
</tr>
<tr>
<td></td>
<td>- calculates energy losses for the transmission and the generator</td>
</tr>
<tr>
<td></td>
<td>- generator torque regulated by an external controller</td>
</tr>
<tr>
<td></td>
<td>- generator supplies energy to the local grid directly</td>
</tr>
<tr>
<td>MicroWindControl</td>
<td>- controls electrical torque of the generator and thus its efficiency</td>
</tr>
</tbody>
</table>
**Photovoltaics**
The photovoltaics model in this library simulates the electrical power output of a scalable photovoltaic system depending on solar radiation, collector temperature and module efficiency. Characteristics for voltage and current are derived from the real electrical behavior of photovoltaic modules. Using a maximum power point controller ensures the highest efficiency possible.

| Photovoltaics | • simulates the electrical power output of a photovoltaic system depending on solar radiation, angle of incidence and collector temperature  
| | • calculates the collector's temperature with respect to current solar radiation, ambient temperature and nominal module coefficients  
| | • connected to the local grid via DC/AC converter systems (analogous to electrical plugs)  
| PVConverter | • controls electrical power output to the local grid via DC/AC converter systems  
| | • calculates the control angle for DC/AC converter systems depending on current maximum power voltage characteristics  

**Solar Thermal**
This library contains a model for solar thermal systems calculating the temperature behavior of different types of solar collectors with respect to ambient temperature and solar radiation. It enables simulations of solar heat output to various types of heat storage facilities and other heating systems.

| SolarThermal | • simulates heating of a solar collector depending on direct solar radiation, angle of incidence and ambient temperature  
| | • heat emission to ambience and heat dissipation to the internal heating system are used for the simulation of the collector's temperature behavior  
| | • heat supply to the connected heating systems is regulated by external control algorithms  
| SolarThermalControl | • controls solar thermal heat supply to the connected heating systems  
| | • includes thermal shut-off limits like maximum flow temperature  
| | • regulates the circulation pump with respect to target temperature distribution  
| | • includes return temperature of the heating system for switch-on/off control  

**Stationary Battery**
This library contains a highly dynamic battery model and a controllable battery converter model. The battery model can be parameterized for different battery types like li-ion or lead-acid batteries. The library provides a common set of reliable input parameters for different types of batteries. The data was derived from standardized measurement procedures for different types of batteries. It is also possible to conduct analyses on battery aging.

| StationaryBattery | • simulates battery voltage behavior depending on the battery charge, impedance, current, battery health and temperature  
| | • calculates the battery charge and battery health with respect to battery aging and temperature  
| | • includes a battery aging algorithm incorporating influences from temperature, current and battery charge  

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BatteryCharger

- variable battery connection to AC components (single-phase, three-phase)
- simulates battery current depending on the desired charge or discharge power
- charge or discharge power can be controlled by external algorithms (charging strategies) depending on the battery charge

Vehicle
This library contains simulation models for the calculation of the electrical energy and fuel demand of electric vehicles. These models extend the stationary battery model using pre-calculated data for the electrical power and fuel demand of vehicles. Algorithms simulating the power demand for heating and cooling depending on the outdoor temperature are also included. A charging station model is used to control the charge and discharge of the vehicle battery when the vehicle is connected to the local grid.

BEV
- simulates the charge and discharge behavior of an electric vehicle’s battery depending on the driving cycle and the charging strategy
- electrical power demand as pre-calculated input data with respect to driving cycle and vehicle characteristics
- simulates the demand for heating and cooling depending on outdoor temperature

PHEV
- simulates the charge and discharge behavior of a plug-in hybrid-electric vehicle’s battery depending on the driving cycle and the charging strategy
- electrical power and fuel demand as pre-calculated input data with respect to driving cycle and vehicle characteristics
- simulates the demand for heating and cooling depending on outdoor temperature

ICEV
- simulates the fuel demand of a conventional vehicle with internal combustion engine using pre-calculated input data for driving cycle and vehicle characteristics
- simulates the demand for heating and cooling depending on outdoor temperature

ChargingStation
- variable vehicle connection to the local grid (AC single-phase, AC three-phase)
- controls charging strategies for eVehicle batteries
- allows for discharging eVehicle batteries in Vehicle2Grid-Mode when connected to the local grid as an additional electrical storage depending on the operating strategy
**Interfaces.Electrical**

This library contains models and connectors for connecting various electrical components.

<table>
<thead>
<tr>
<th>Connector</th>
<th>Description</th>
</tr>
</thead>
</table>
| DC Connector    | • direct current (DC) connector  
                    • defines a DC-system's current values for voltage and current |
| Single-Phase Connector | • single-phase connector for alternating current (AC) systems  
                              • defines an AC-system's current values for voltage and current as well as the power factor |
| Three-Phase Connector | • three-phase connector for alternating current (AC) systems  
                                     • defines an AC-system's current values for voltage and current as well as the power factor of each phase |
| Define Electrical | • defining element for electric connectors  
                                     • variable input of effective voltage, current and delay angle  
                                     • defines the output connector’s properties through internal simulation results for voltage, current and delay angle of models for electric devices |
| Extract Electrical | • extracting element for electric connectors  
                                      • variable output of effective voltage, current and delay angle  
                                      • extracts the input connector’s properties voltage, current and delay angle for internal differential-algebraic calculations in models for electric devices |
| Define Current | • defines the electrical output and delay angle of an electric device depending on its grid voltage and electrical power output |
| Extract Current | • extracts the electrical current input and delay angle for internal differential-algebraic calculations in models for electric devices depending on grid voltage |
Interfaces.Thermal
This library contains models and connectors for hydraulic connections between different components of a heating system.

<table>
<thead>
<tr>
<th>Thermal Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>- input connector for heating systems (flow or return port)</td>
</tr>
<tr>
<td>- defines volume flow and temperature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thermal Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>- output connector for heating systems (flow or return port)</td>
</tr>
<tr>
<td>- defines volume flow and temperature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Define Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>- defining element for thermal connectors</td>
</tr>
<tr>
<td>- variable input of volume flow and temperature</td>
</tr>
<tr>
<td>- defines the output connector properties with inner simulation results for volume flow output and output temperature of models for heating devices</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Extract Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>- extracting element for thermal connectors</td>
</tr>
<tr>
<td>- variable output of volume flow and temperature</td>
</tr>
<tr>
<td>- extracts the input connector's properties volume flow input and input temperature for internal differential-algebraic calculations in models for heating devices</td>
</tr>
</tbody>
</table>

Utilities.Electrical
This library contains various electrical models derived from real electric systems and electronic circuits. They are, however, only meant for distributing energy between different electric systems in a rather symbolic way. The library components allow for calculating the total electrical energy demand of a simulated building also with respect to feeding electrical energy into the local grid including the effective and reactive electrical power ratio.

<table>
<thead>
<tr>
<th>Voltage Tap-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>- connects a single-phase AC component with a defined phase of a three-phase AC component</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>- enables the input of external electrical power data into the local grid as well as the connection of different local grids</td>
</tr>
<tr>
<td>- calculates the effective current and power factor per phase depending on the grid voltage and input data for effective and reactive electrical power</td>
</tr>
<tr>
<td><strong>Measure Electrical</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
</tbody>
</table>
| **Grid**               | • calculates the total electrical power demand and supply of the local grid  
                          • includes the total ratio of effective and reactive electrical power  
                          • defines the effective local grid voltage  
                          • calculates the total power factor of the local grid |
| **Cable**              | • simulates the voltage drop in a cable between two electric components |
| **B6C Converter**      | • simulates a three-phase AC/DC voltage converter  
                          • connects three-phase AC components with DC components  
                          • calculates the reactive power demand depending on the component’s effective power and the DC/AC voltage ratio  
                          • calculates the input’s/output’s current ratio with respect to converter efficiency |
| **B6C Controller**     | • controls the control angle of a B6C Converter depending on electrical power demand and the DC voltage of a connected DC component |
| **B2C Converter**      | • simulates a single-phase AC/DC voltage converter  
                          • connects single-phase AC components with DC components  
                          • calculates the reactive power demand depending on the component’s effective power and the DC/AC voltage ratio  
                          • calculates the input’s/output’s current ratio with respect to converter efficiency |
| **B2C Controller**     | • analyses the control angle of a B2C Converter depending on electrical power demand and the DC voltage of a connected DC component |
Utilities.Thermal
This library contains auxiliary models for hydraulic connections between different components of a heating system. They are derived from real hydraulic system components. They are, however, only meant for distributing thermal energy between various components of a heating system in a rather symbolic way.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measure Thermal</strong></td>
<td>• auxiliary device for measuring the simulated temperature and the volume flow in a hydraulic pipe between two heating system components</td>
</tr>
<tr>
<td><strong>Pipe</strong></td>
<td>• simulates heat losses in a hydraulic pipe between two heating components</td>
</tr>
</tbody>
</table>
| **Pump**            | • defines a variable volume flow in a hydraulic pipe between two heating components  
                     | • calculates the energy demand of a hydraulic pump depending on volume flow and pump type (input data) |
| **Hydraulic Shunt** | • separates the heat supply from the heat sink system                       
                     | • the heat sink flow temperature depends on the shunt temperature which can be controlled through the ratio between heat supply and the heat sink |
| **Distribution Valve** | • distributes the input volume flow across two hydraulic pipes           
                         | • variable distribution ratio can be controlled by an external control algorithm |
| **Merging Valve**   | • combines two input volume flows into one                                 
                     | • calculates the resulting output temperature depending on the input volume flow ratio |
| **Flow Temperature Mixing Valve** | • calculates the heat supply’s return volume flow depending on the heat sink’s regulated flow temperature 
                                         | • the heat sink’s flow temperature can be controlled by an external control algorithm |
| **Return Temperature Mixing Valve** | • calculates the heat sink’s volume flow depending on the heat supply’s regulated return temperature  
| | • the heat supply’s return temperature can be controlled by an external control algorithm |
| **Volume Flow Controller** | • controls the volume flow inlet to heating systems with respect to current and target temperatures |
| **Heat Controller** | • controls the heat output of heating systems depending on the actual system temperature |
| **District Heating Grid** | • calculates the total thermal power demand and supply of the local district’s heating grid  
| | • includes the flow temperature of the district heating grid  
| | • defines the volume flow from the district heating grid |

**Utilities.InputData**

This library contains samples of weather data for 10 locations worldwide. Different types (e.g. windy summer day or sunny winter day) as well as reference years are included. It is also possible to define further locations with custom weather data.

| **Weather Data** | • base type for all specific weather data records  
| | • contains information about geographic locations and time series for ambient temperature, solar radiation and wind |