Universität der Künste Berlin

Modelica library BuildingSystems

User guide

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June 23, 2023

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CHAPTER

ONE

INTRODUCTION

This user guide explains the use of the Modelica library BuildingSystems (http://www.modelica-buildingsystems.de), which is being developed for the dynamic simulation of the energetic behavior of single rooms, buildings and whole districts.

One important part of the library consists of an adaptive building model, which is able to adapt its spatial resolution (0D, 1D, 3D modelling approach) and also its physical model (e.g. pure thermal or a hygro-thermal calculation) to the respective problem of the simulation analysis.

0D modelling approach: The adaptive building model works in a strongly simplified and abstracted configuration (low-order or gray box model), which leads to numerically fast calculations. A typical case study is the simultaneous calculation of the thermal energy demand of a large number of single buildings of a district in combination with a district heating network (compare with Figure 1.1).

1D modelling approach: In this case the adaptive building model uses more spatially resolved algorithms and models and also more simulation time for a single building. A typical application is multi-zone-building models, which calculate the heating and cooling energy demand, the air temperatures and air moistures for each thermal zone as well as the air exchange between the single thermal zones of a complex building. The Rooftop building in Figure 1.2, for example, has two air-conditioned and two not air-conditioned rooms, so it could be modelled with four thermal zones.

3D modelling approach: The most advanced configuration consists of a spatially resolved room model, which describes the three-dimensional air flow within a room volume, the geometrical long-wave and short-wave radiation distribution and also the multidimensional heat transport within the building construction. For example, this model is able to calculate the location-dependent thermal comfort within a room (compare with Figure 1.3).

The BuildingSystems library supports pure thermal or also hygro-thermal calculations for all three modelling approaches. Mixed thermal and hygro-thermal simulation analysis and different spatial resolutions for different zones of a building model are also supported.

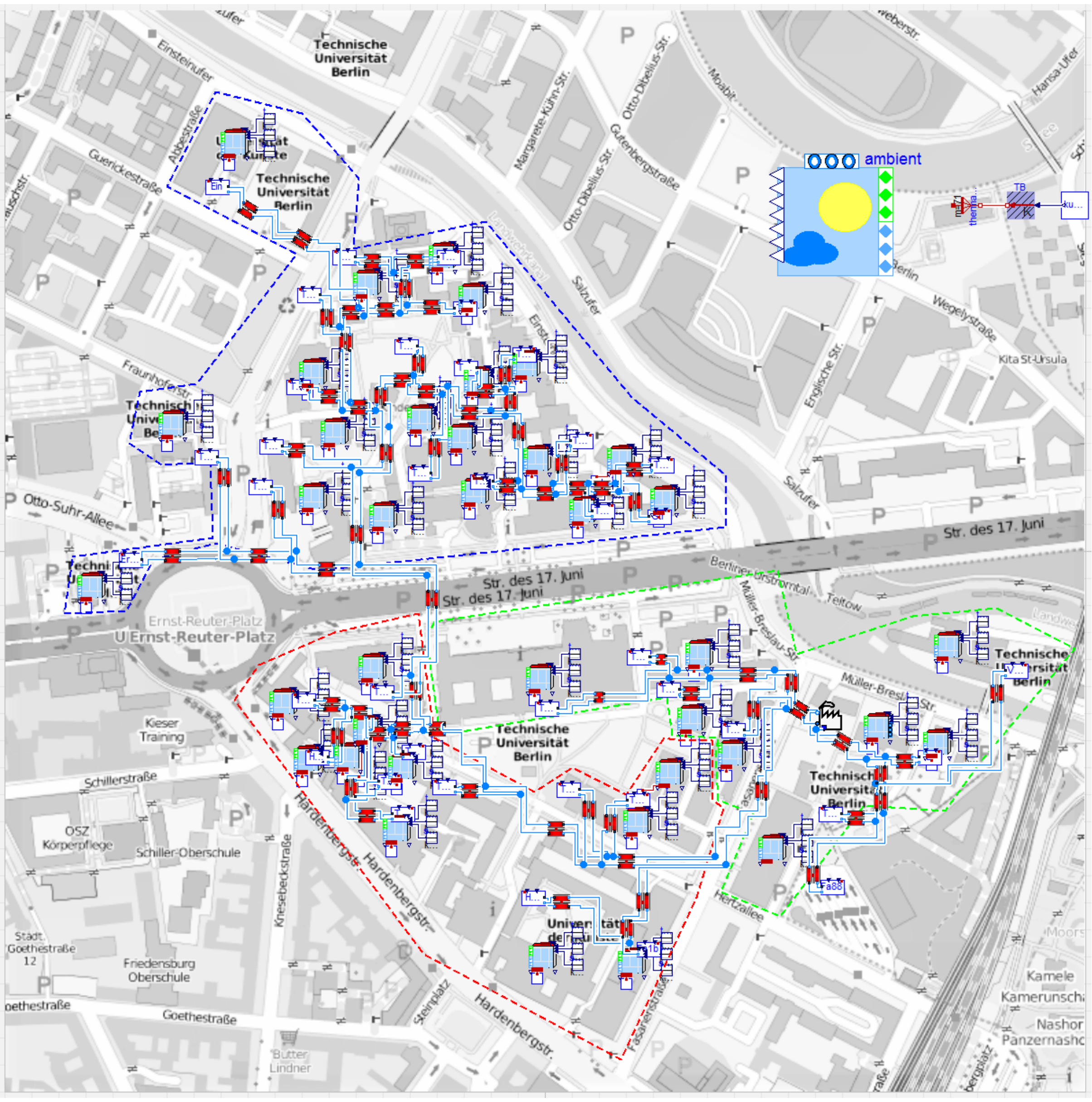


Fig. 1: Application of the simplified building model (0D modelling approach) for district modeling: 39 buildings of the Campus Berlin-Charlottenburg are connected by a district heating grid (ATES project).

Fig. 2: The Rooftop building, which was designed for placement on the roof of a Gründerzeit building in Berlin (UdK Berlin/TU Berlin contribution to the competition Solar Decathlon Europe 2014)

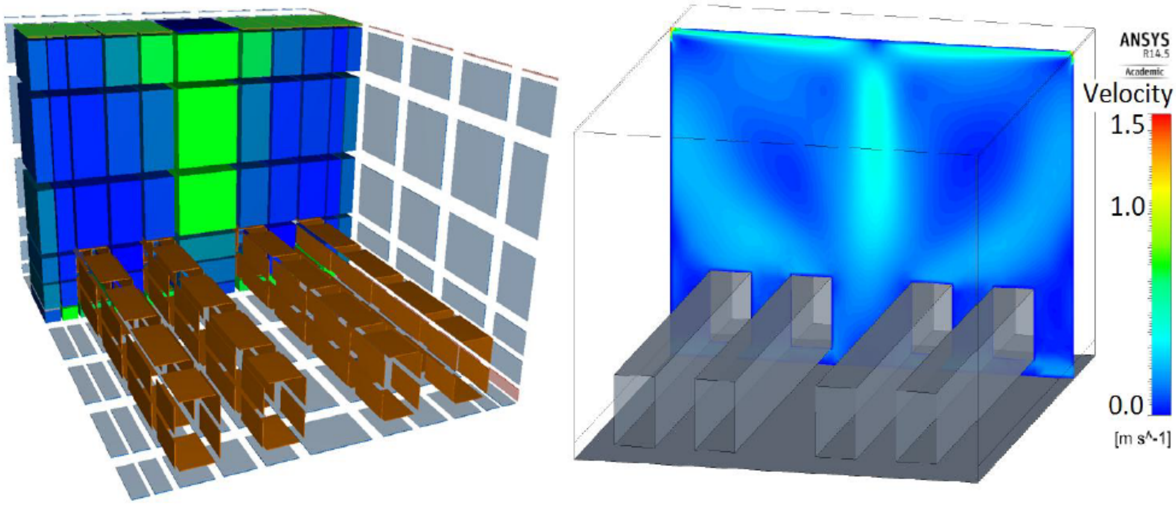


Fig. 3: Spatially resolved room model of the Aachen Model Room AMoR modelled with the 3D zonal approach of the BuildingSystems library (left) and with ANSYS CFD (right) (project UCaHS)

CHAPTER TWO

SIMPLE BUILDING MODEL

In the first example a simplified building model is connected to an ambient model which supplies the building model with the climate data of a given location (Berlin, Germany). Here you will find the explanations for several fundamental working steps for the application of the BuildingSystems library (together with Dymola 2016 or higher) such as

- the configuration of a system model structure,
- the definition of the building model parameters,
- the definition of the boundary conditions of the building model and
- the performance of a simulation experiment.

The selected building model *BuildingSystems.Buildings.BuildingTemplates.Building1Zone1DBox* uses a thermal 1D-modeling approach, which means all models of the building constructions (walls, roof, ground plate, etc.) are discretized regarding energy balancing in one dimension and the air space within the zone is modeled with one aggregated thermal node.

2.1 Set up the system model structure

Download the BuildingSystems library from https://github.com/UdK-VPT/BuildingSystems. Open the library with Dymola and perform the following steps:

1. Open dialog: *File* -> *New* -> *Model* and fill in the field *Name:* “SimpleBuilding”.
2. Extend the new model from *Modelica.Icons.Example* (see Fig. 1) and click OK.
3. Mark the new example *SimpleBuilding* in the package browser and save it with *File* -> *Save* in the file *SimpleBuilding.mo* in a folder of your choice.
4. Ensuring that Dymola is in “Diagram” mode (in the menu *Window* -> *View* -> *Diagram* or by clicking on the icon at the top of the Dymola window), find *BuildingSystems.Buildings.BuildingTemplates.Building1Zone1DBox* in the package browser in the upper left part of the Dymola window, and drag and drop a component model from the Dymola package browser onto the grid. Rename it *building*. This component is able to calculate the thermal energy balance of a one-zone thermal building model. It is suited to our first example, because a simulation analysis can be carried out after defining only a few parameters.
5. Drag and drop an ambient model *BuildingsSystems.Buildings.Ambience* from the package browser onto the grid. Double-click on the model, and choose the climate data for *Germany_Berlin_Meteonorm_NetCDF* from the drop-down menu in the parameter *weatherDataFile*. Now, pre-calculated hourly weather data for Berlin provided by Meteonorm (http://www.meteonorm.com/en/) will be used to support the building model with ambient values for air temperature, moisture, direct and diffuse radiation, wind speed and wind direction.
6. Connect the blue connectors *ambience.toAirPorts* and *building.toAmbienceAirPorts* of the two models. Click on OK in the window that opens to connect all ports of the selected type. Now the climate boundary conditions which are caused by the ambient air of the building will be considered (convective heat transfer and optionally also the moisture transport).

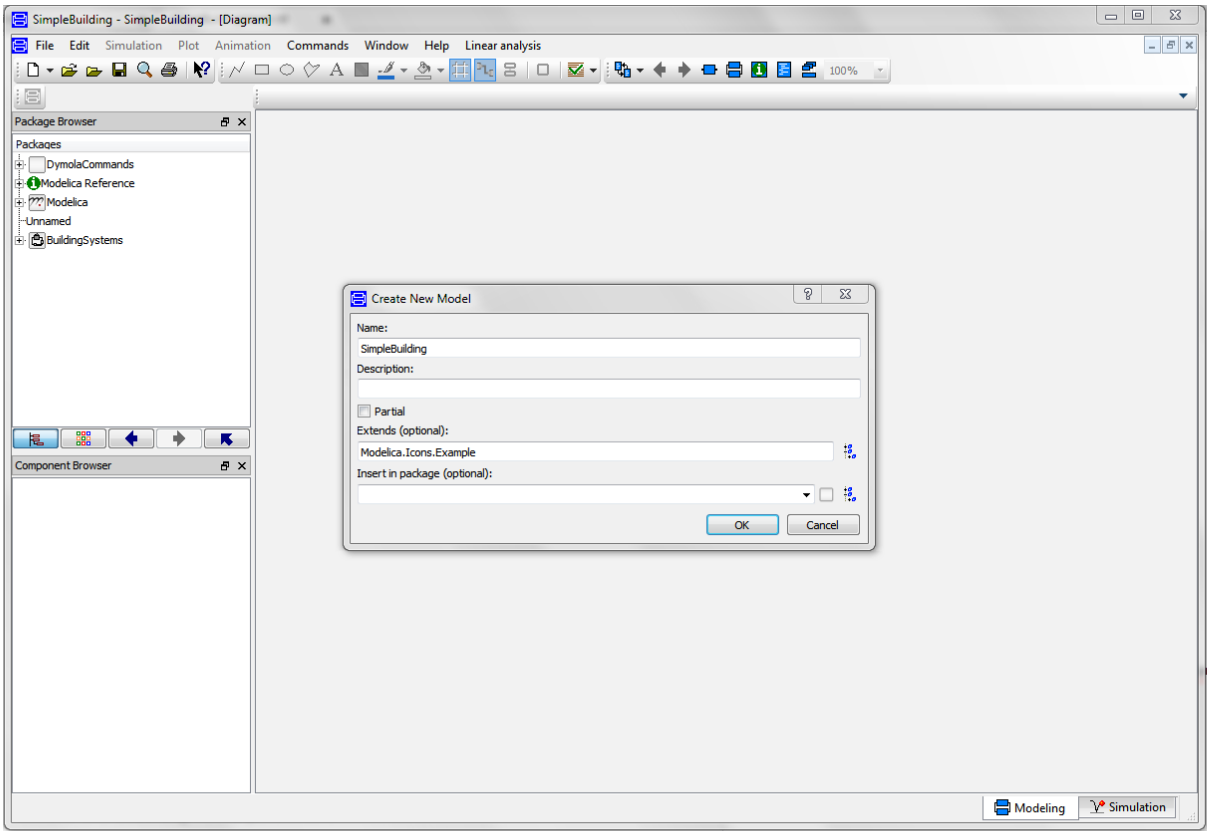


Fig. 1: Definition of a new system model in Dymola

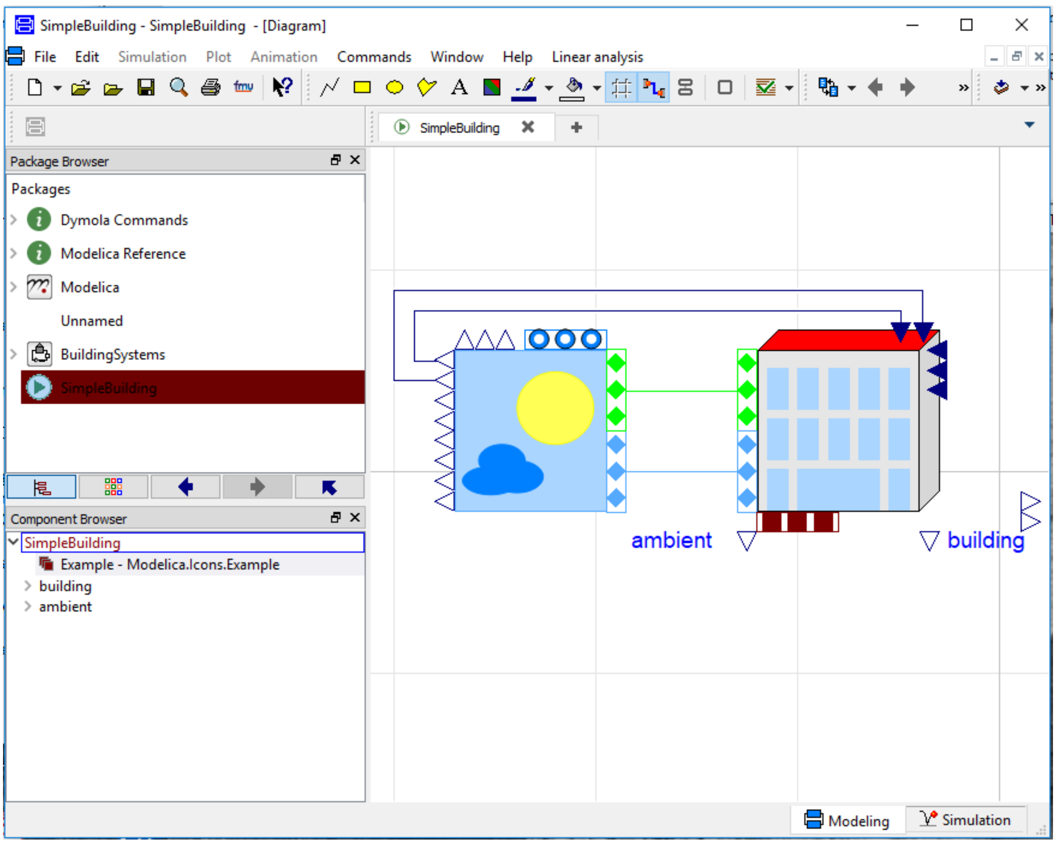


Fig. 2: The simulation model, which consists of a building model and an ambient model

7. Next, connect the green connectors *ambience.toSurfacePorts* and *building.toAmbienceSurfacePorts* of the ambience and the building model. This enables the ambient model to deliver the boundary conditions for short-wave radiation from the sun and the long-wave radiation exchange with the sky.

8. The ambient model needs to know the number of surfaces of the building model which are in contact with the ambient air. For this purpose double-click on the ambient component and add this information to the parameter *ambience.nSurfaces* by clicking on the small arrow/triangle to the right of the text field and selecting Insert Component Reference: building -> extends BuildingSystems.Buildings.BaseClasses.BuildingTemplate -> nSurfacesAmbience.

9. Connect the output variable *ambience.TAirRef* and the input variable *building.TAirAmb* (ambient temperature at a reference height of 10 m) and also *ambience.xAirRef* and *building.xAirAmb* (ambient absolute moisture). Both variables are necessary for the calculation of the energy loss caused by the air exchange of the building. Your model should now look like Figure 2.

2.2 Define the building model parameters

1. **Define the building dimensions**. The inner space of the example building is 9 m wide, 9 m long, and 3 m high. These dimensions are equal to the enclosed air space; the outer dimensions of the building model depend on the thickness of the selected wall, roof, and base plate constructions. Double-click on the building and fill in these values under Geometry within the tab *General* of the parameter dialog (see Fig. 3).

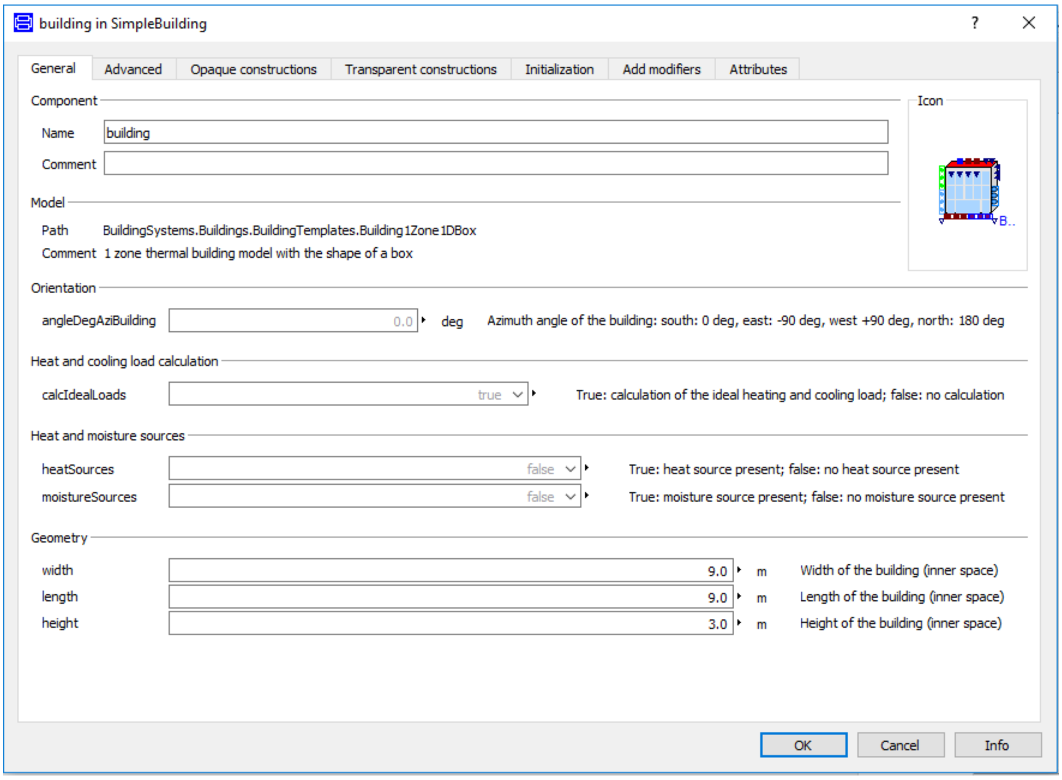


Fig. 3: Definition of the geometry of the building model

2. **Define the type of opaque construction** in the building model component. For this purpose open the tab *Opaque constructions* (see Fig.4), and, in the group *Exterior constructions*, select

   - the type *Outer wall construction for single-family house EnEV 2014* for all exterior walls (constructionWall1 to constructionWall4),
   - the type *Roof construction for single-family house EnEV 2014* for the roof (constructionCeiling), and
   - the type *BasePlate construction for single-family house EnEV 2014 for the base plate (constructionBottom).*

Set the parameters *InteriorWalls* and *InteriorCeilings* to "false" (group Interior constructions on the same tab), because, for this example, interior constructions will be neglected.

It is worth noting that the walls and windows are numbered 1 = West, 2 = North, 3 = East, and 4 = South, as shown in Figure 5.

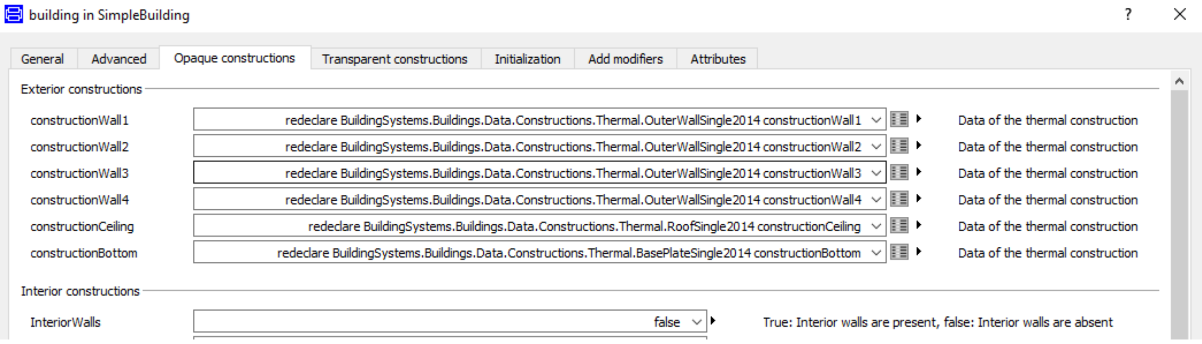


Fig. 4: Definition of the opaque constructions

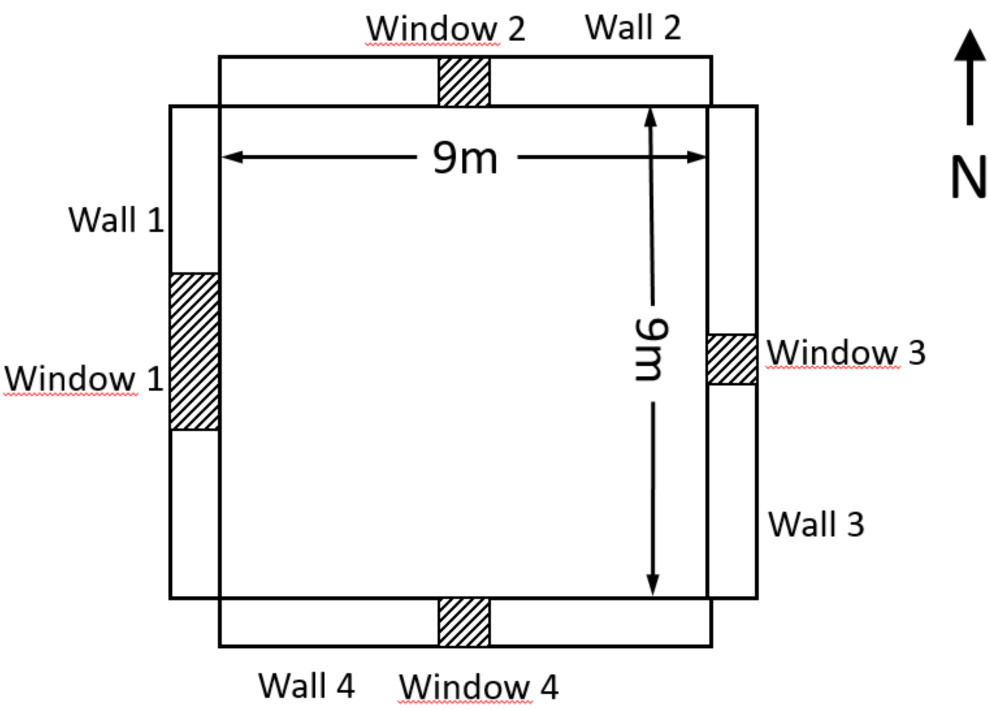


Fig. 5: Cardinal directions as defined in Modelica

3. **Define the type of transparent constructions** in the building model. In the tab *Transparent constructions* (see Fig. 6), select the construction type *Heat protection double glazing with UValGla=1.4W/(m2.K) and g=0.58* for all windows (window1 to window4) . Define the size of *window1* to 3 m width by 1 m height and *window2*, *window3*, and *window4* to 1 m width by 1 m height. Set the frame portion of all of the windows to 0.3.

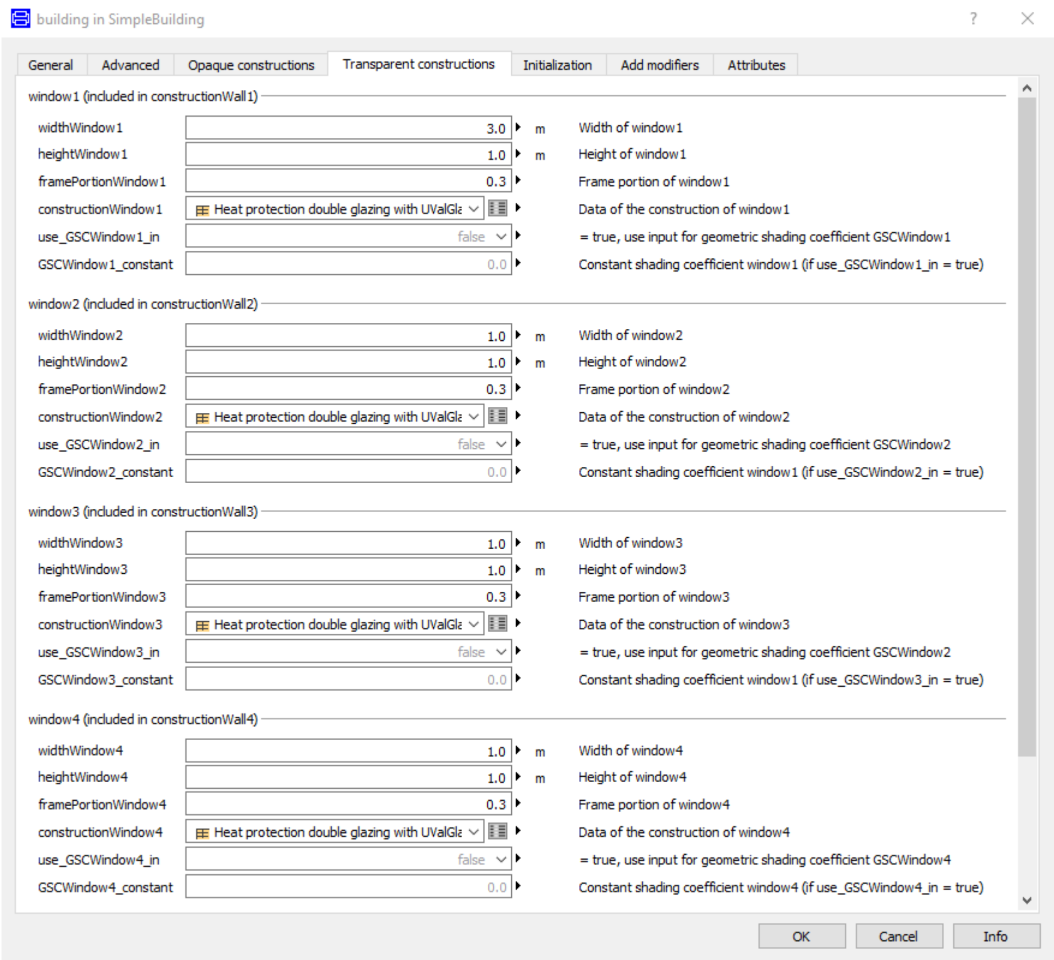


Fig. 6: Definition of the transparent constructions

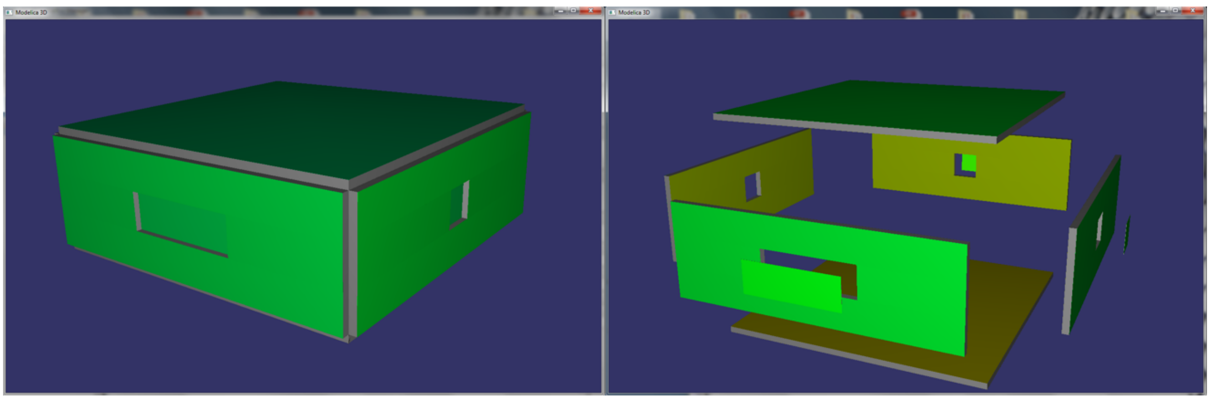


Fig. 7: Left: Visualization of the building model with the color illustrating the surface temperatures of the building constructions. Right: Exploded visualization of the building model.

2.3 Set the boundary conditions of the building model

1. **Define the set temperatures for heating and cooling** and the **air change rate**. To define the set temperatures and the air change rate, find the MSL model class *Modelica.Blocks.Sources.Constant* in the package browser menu and drag and drop three instances of it into the system model. Rename them to *TSetHeating*, *TSetCooling* and *airchange* and parametrize them with 273.15 + 20.0 (20 degrees Celsius) 273.15 + 24.0 (24 degrees Celsius) and 0.5 (half an air change per hour) respectively. Connect the output of the three blocks with the corresponding input variables *building.TSetHeating*, *building.TSetCooling* and *building.airchange* on the upper right corner of the building model. For a smoother connection, you can right-click on the blocks and flip them horizontally.

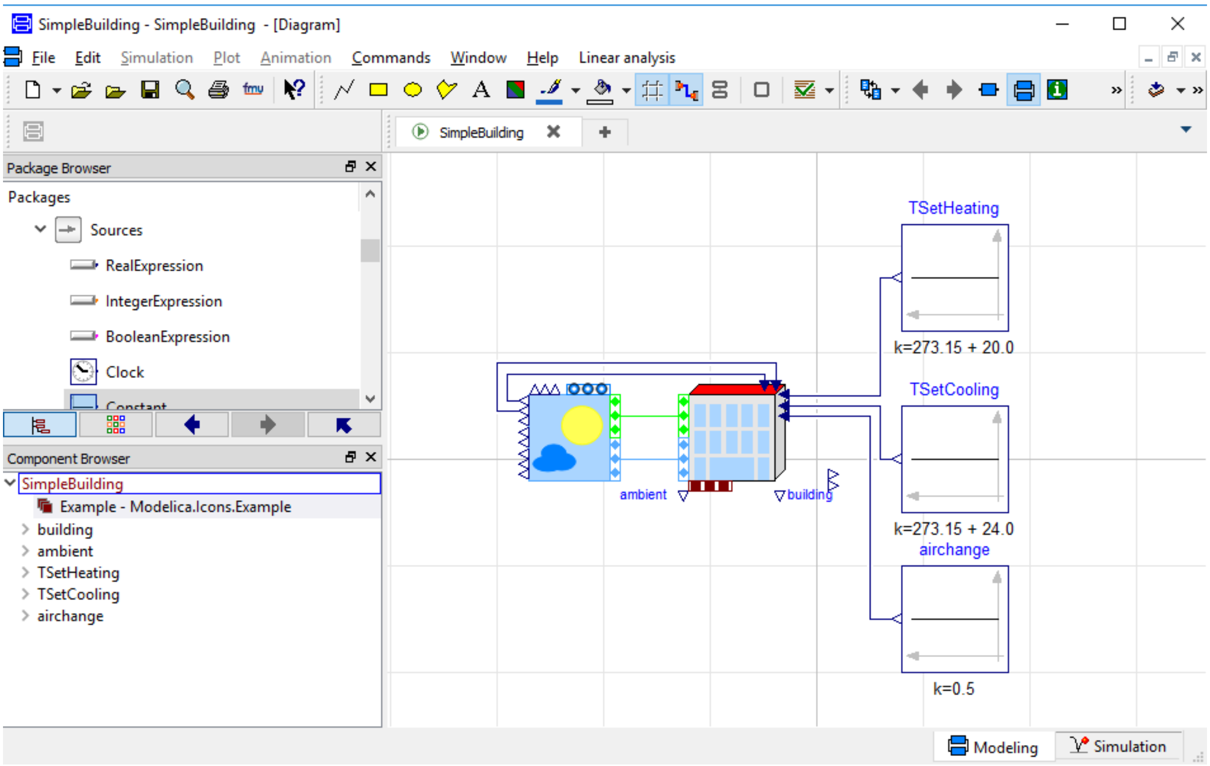


Fig. 8: Completed system model with boundary condition (set temperatures, air change rate)

The Modelica code of the described example of this chapter can be found under

https://github.com/UdK-VPT/BuildingSystems/blob/master/BuildingSystems/Resources/Documentation/ExamplesUserGuide/SimpleBuilding.mo .

2.4 Simulate the system model

Now the model is 100 percent prepared for a simulation analysis. Simulate the model over a time period of one year. To do this, select the experiment *SimpleBuilding* in the package browser of Dymola and switch to the simulation mode.

1. Open the *Simulation Setup* dialog and fill in 31536000 (3600 seconds/hour x 24 hours/day x 365 days/year = 31536000 seconds) into the *Stop time* entry field and perform the simulation experiment.
2. Study the simulation results: the next two diagrams (Fig. 10 and 11) show the main important temperatures (outside and inside air temperature, operative temperature) and the ideal heating and cooling power for the building, which guarantees that the indoor air temperature remain in the desired area between 20 and 24 degrees Celsius.

The first diagram illustrates that the indoor air temperature and the operative temperature (the mean value of the indoor air temperature and the mean surface temperature within the zone) are close together. The reason is the insulated construction of the walls, the ceiling and the base plate in accordance with the current German energy code (EnEV 2014). The indoor air temperature only reaches maximum values of 24 degrees Celsius during some summer days.

In the location Berlin, close to 100 percent of the thermal energy demand is made up of heating energy. A small amount of cooling energy is only needed during some of the hot summer days.

2.5 Change the climate location

In the next step, change the location of the building to study the impact of a hot and dry climate on the thermal energy demand of the building model in comparison to the moderate climate of Berlin. Double-click on the ambient component and change the parameter weatherDataFile within the component to *Iran_Hashtgerd_Meteonorm_NetCDF*. Hashtgerd is a city in northern Iran, 100 km west of Tehran.

The outside temperature in Hashtgerd is close to 40 degrees Celsius during the summer (compare to Berlin 32 degrees Celsius). This leads to a significant cooling demand in summer, but there is still a relevant heating demand in winter.

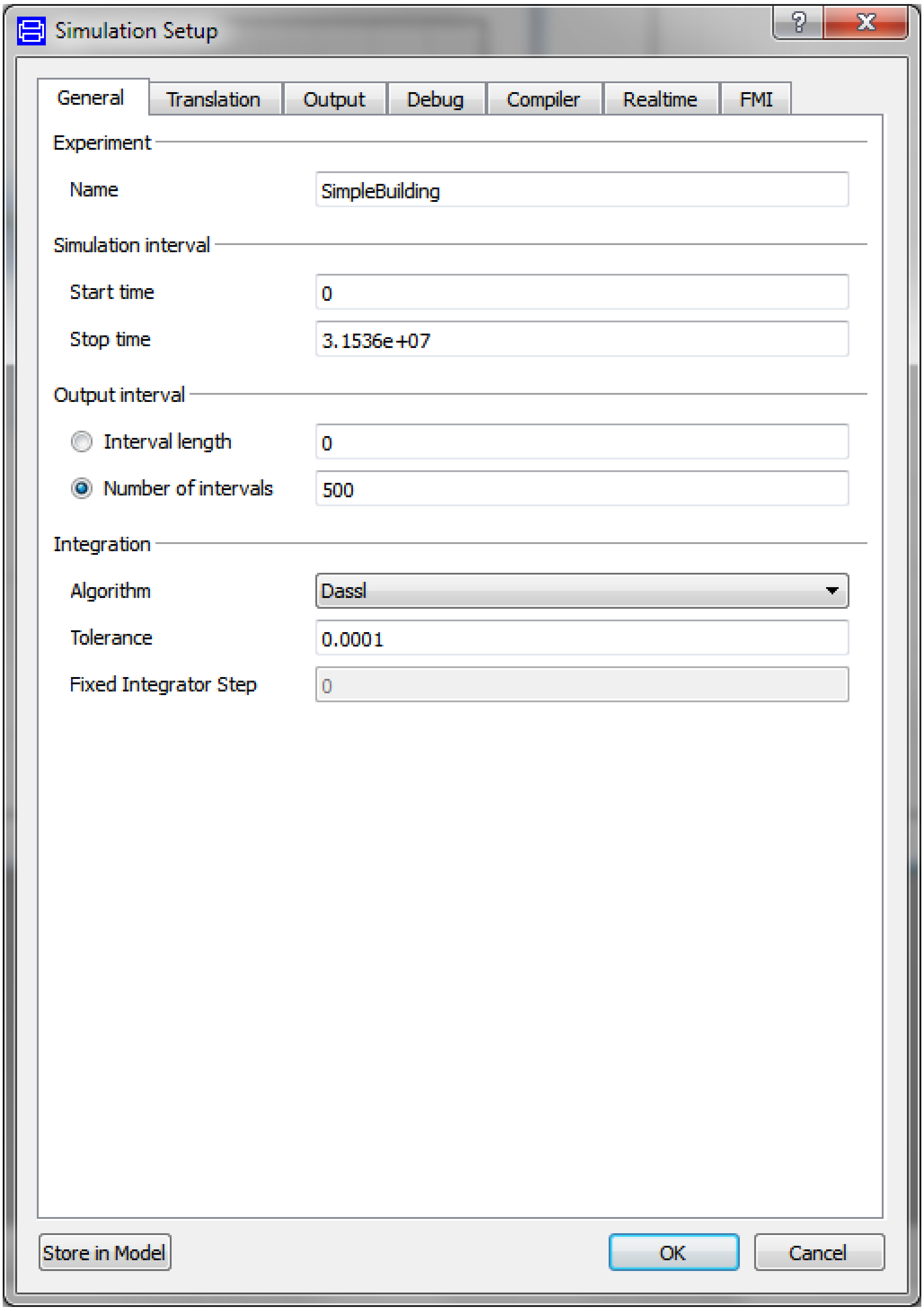


Fig. 9: Simulation set-up window

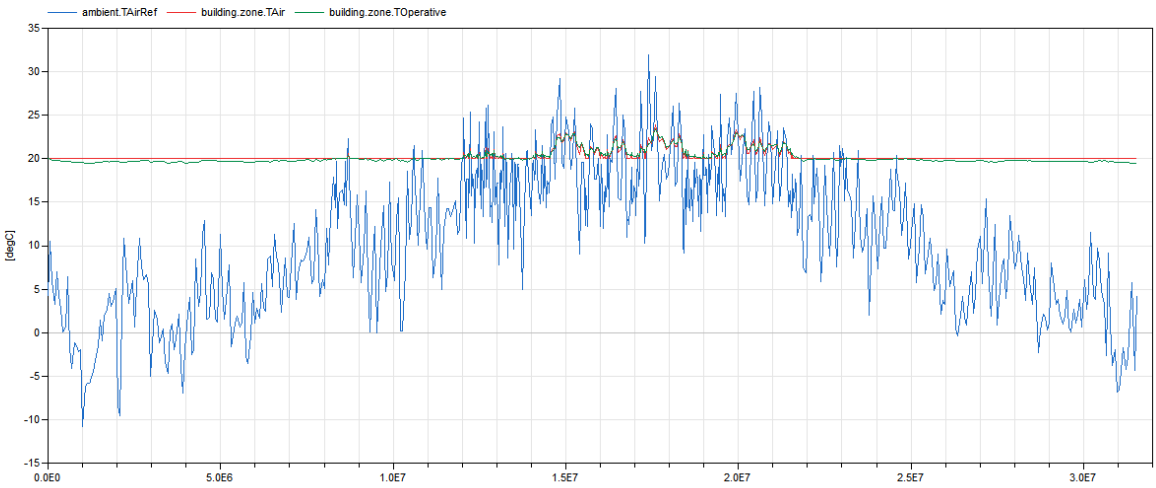


Fig. 10: Air temperature, operative temperature and ambient air temperature during the yearly simulation (location Berlin, Germany)

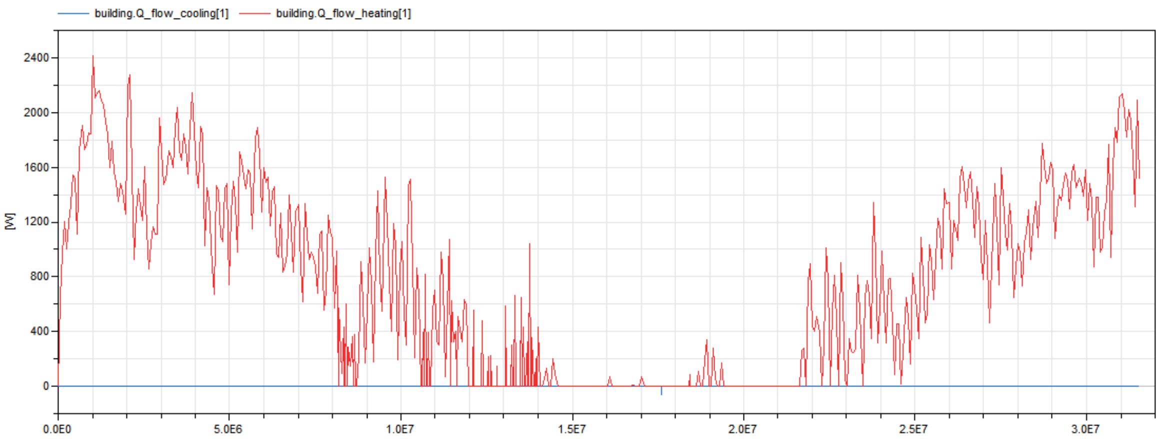


Fig. 11: Thermal energy demand for heating and cooling during the yearly simulation (location Berlin, Germany)

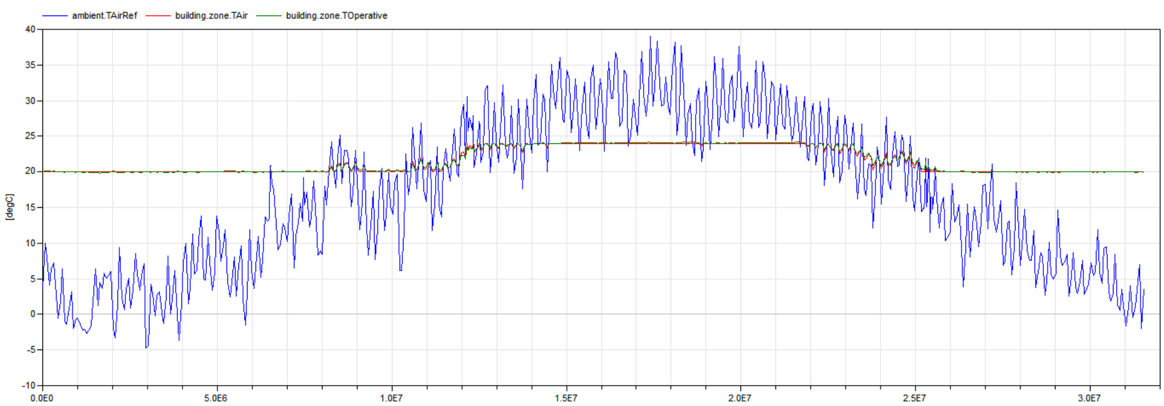


Fig. 12: Air temperature, operative temperature and ambient air temperature during the yearly simulation (location Hashtgerd, Iran)

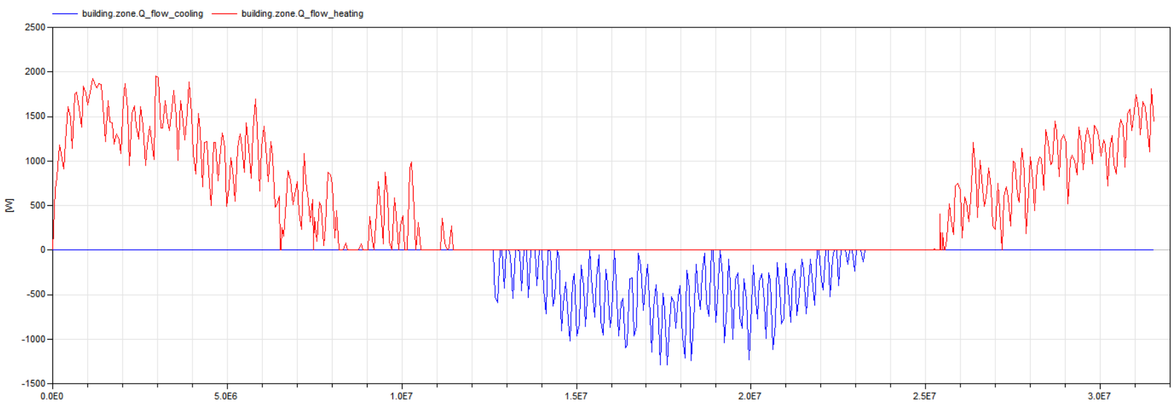


Fig. 13: Thermal energy demand for heating and cooling during the yearly simulation (location Hashtgerd, Iran)

CHAPTER

THREE

MULTI-ZONE BUILDING MODELING

In this chapter the application of the BuildingSystems library for multi-zone building modeling is demonstrated.

For this purpose, a thermal building model of the *Thermal Model House* (http://www.thermisches-modellhaus.de) with two thermal zones shall be created:

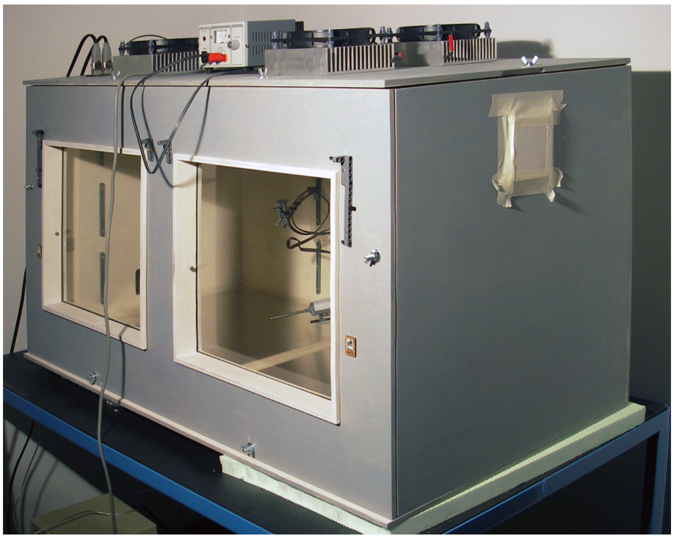


Fig. 1: Thermal Model house: A portable experimental test facility for building physics studies, developed by UdK Berlin.

The *Thermal Model House* (TMH) is a portable experimental test facility with a simple geometry and a compact size of approximately 1 m length, 0.5 m depth and 0.5 m height. This small thermal box is able to reproduce different phenomena of building climatization within physical experiments. Due to its manifold configuration options, it is possible to do experiments about the energy balance of rooms, about the heat and air transport processes within rooms, about ventilation, heating and cooling of buildings as well as about building control. The TMH is being developed at the Institute of Architecture and Urban Planning at UdK Berlin. It is used for the education of architecture and engineering students and also for research.

One configuration of the TMH works with a inner partition wall, which divides the air volume of the box into two different thermal zones. These zones can be separately heated or cooled using individual heating surfaces on the bottom and cooling surfaces on the ceiling. Exactly this configuration shall be modelled in the present case.

The modelling and simulation process is described using the Modelica simulation environment, Dymola (version Dymola 2018 FD01). First of all the Modelica library *BuildingSystems* has to be loaded into Dymola. After that, the library will occur in the library tree in addition to the other present Modelica libraries.

The creation and configuration of a new thermal building model takes place in the following steps:

- Configuration of the building model structure (topology of the construction of the buildings model)
- Definition of the building model parameters (building geometry and physical parameters of the construction elements)

- Definition of the boundary conditions of the system model (climate conditions of the building ambience, set temperatures for heating and cooling for each thermal zone)

3.1 Set up the building model structure

1. **Create a new package** for your simulation experiment.

- Open dialog: *File -> New -> Package* and fill in the field *Name of new package:* “ThermalModelHouse” and click OK
- Mark the new package *ThermalModelHouse* in the package browser and save it with *File -> Save* in the file *ThermalModelHouse.mo* in a folder of your choice.

2. **Create a new building model** based on the template model class *BuildingTemplate*. That means you insert a new building model into the previously defined package as follows:

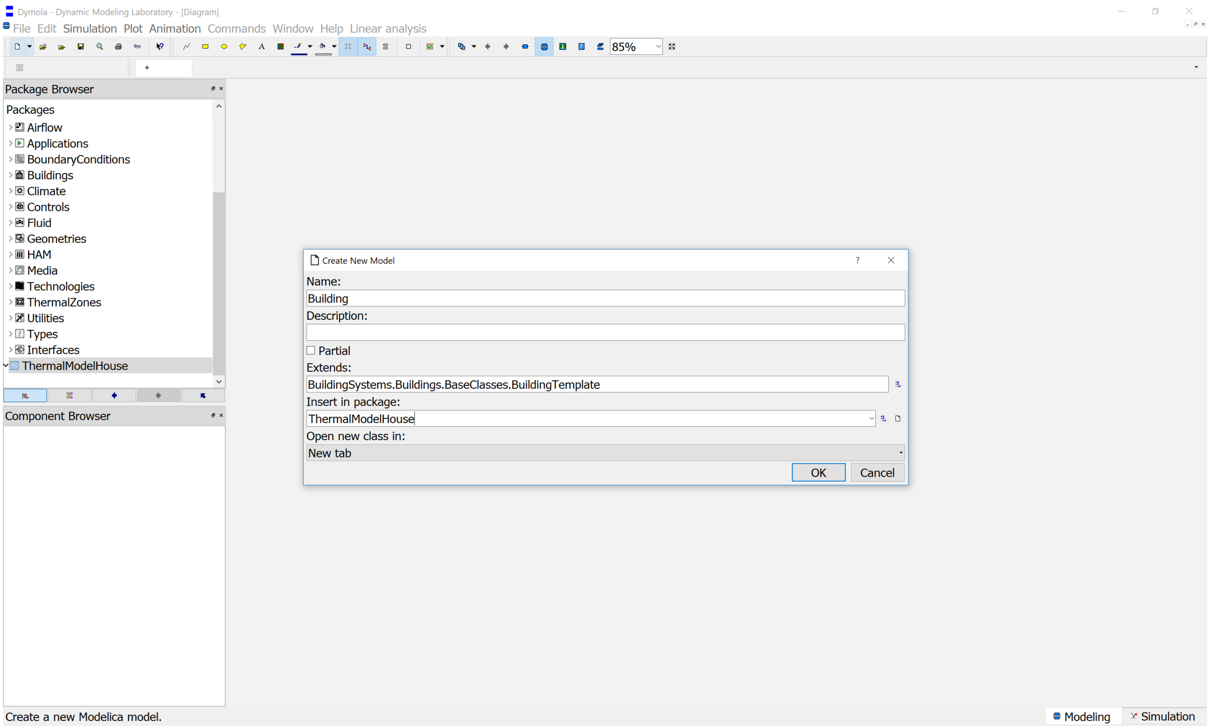


Fig. 2: Definition of a building model based on a building template

- Open dialog: *File -> New -> Model* and fill in the field *Name of new model:* “Building”. Then click on the button to the right of the field *Extends (optional):* and navigate to the model class *BuildingSystems.Buildings.BaseClasses.BuildingTemplate* and click OK. Further click on the button right of the field *Insert in Package (optional):* and navigate to the package *ThermalModelHouse* on the top level and click OK (compare the Dymola screenshoot above).

As a result you can see now the inner structure (the *Diagram view* in Dymola) of the empty building model. On the left side you see the interfaces to the building ambience, below the interfaces to the ground of the building and on the right side the input signals for the set temperatures for heating and cooling of each zone and the interfaces of the air paths to the ambience.

3. **Instantiate two thermal zones**, which shall represent the left and right part of the TMH.

   For this purpose drag and drop a component model from the class *BuildingSystems.Buildings.Zones.ZoneTemplateAirvolumeMixed* into the building model and rename it to *zone1*. Add *zone2* in the same manner:

4. **Instantiate construction elements**.

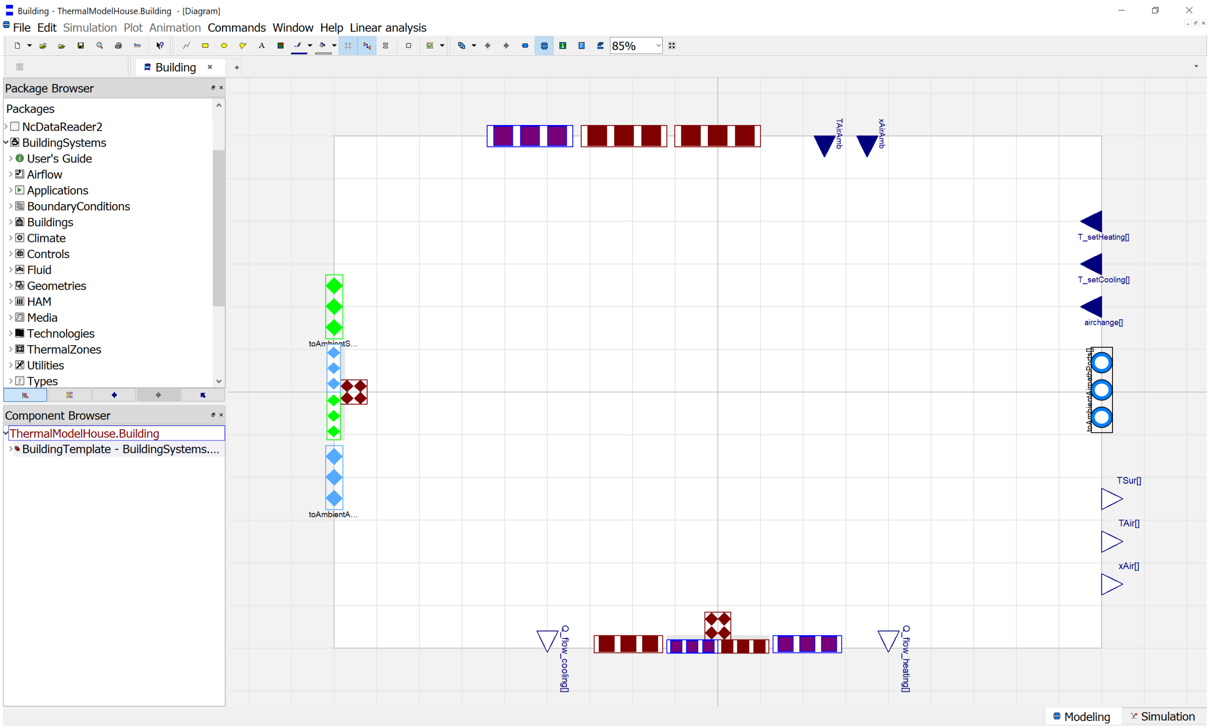


Fig. 3: View on the empty building model

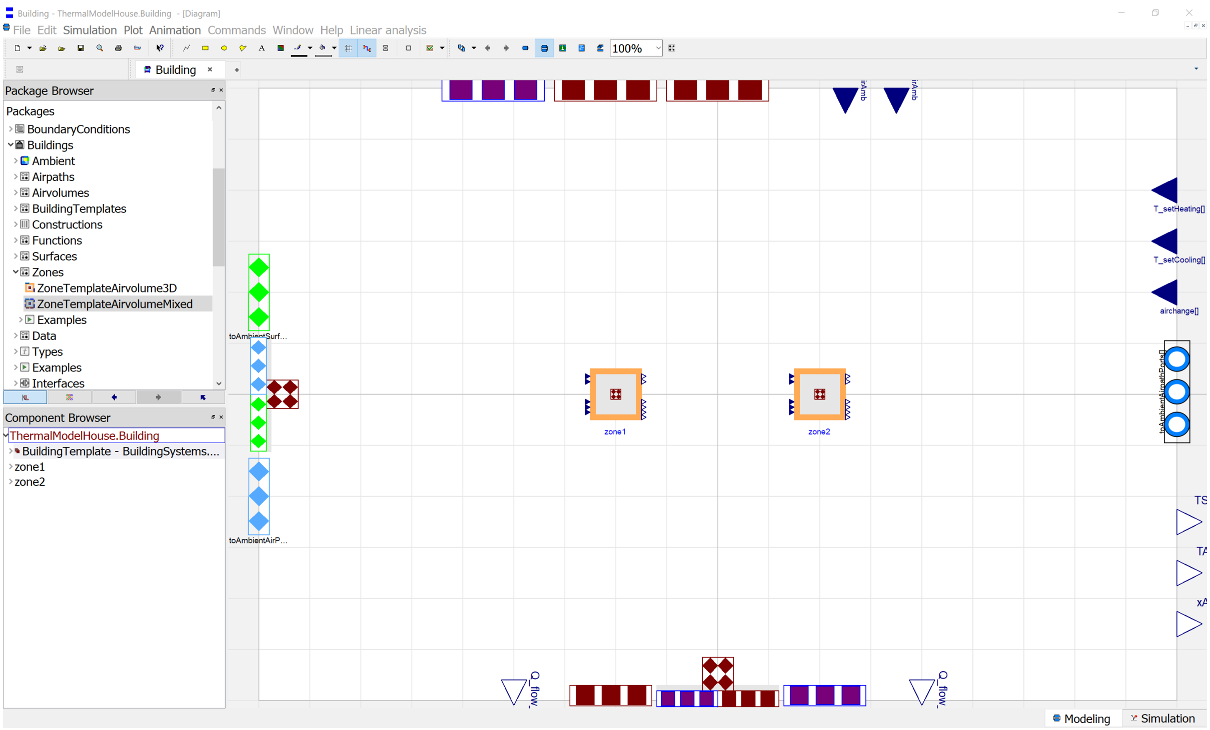


Fig. 4: Building model with two thermal zones

For the opaque constructions (walls, bottoms, ceilings etc.) use the model class *BuildingSystems.Buildings.Constructions.Walls.WallThermal1DNodes* and for the transparent constructions (windows) the model class *BuildingSystems.Buildings.Constructions.Windows.Window*.

Notice, that each component comes with a blue line (which indicates side 1) and has the connector *toSurfacePort_1*. The other unmarked side 2 owns the connector *toSurfacePort_2*. The blue line helps you to distinguish both component sides, e.g. if you want to define single layers of a construction in a certain order. In our case we bring all component models in a position, that all blue lines show to the zones respectively in the case of the partition wall to *zone1* and to the adjacent *zone2*.

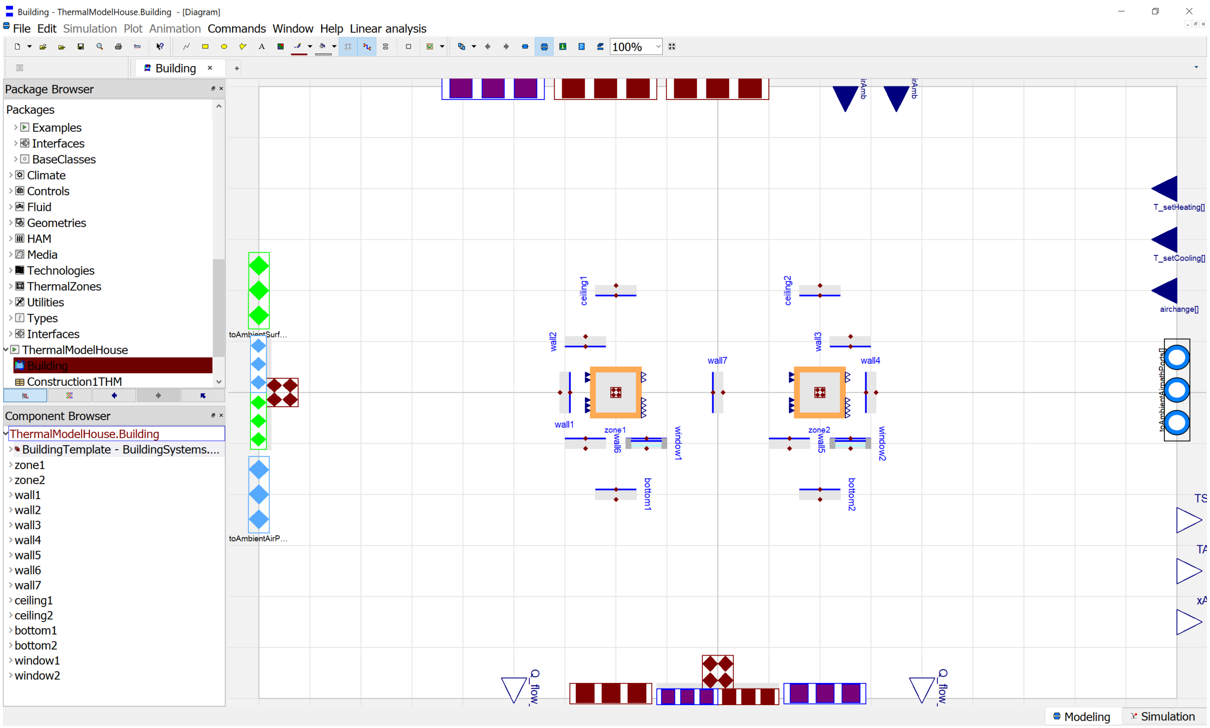


Fig. 5: Building model with zone and construction models

In our case we have to instantiate seven walls (*wall1* to *wall7*), two bottoms (*bottom1* and *bottom2*), two ceilings (*ceiling1* and *ceiling2*) and two windows models (*window1* and *window2*).

5. **Connect construction elements**.

   Now connect the connectors of all "blue sides" with the zone models as in the following picture:

   Here each zone model offers you six different positions for connections to the construction elements (*toConstructionPorts1* to *toConstructionPorts6*) to enable a simplification of the graphical diagram.

   In a further step connect the connectors of the other sides of all construction elements to the construction connector of the building model (*toConstructionPorts* on the left side).

   Finally connect the input values of *T_setHeating* and *T_setCooling* (four connections) and the output values *Q_flow_heating* and *Q_flow_cooling* (again four connections) from the building model to both zone models. Now your topology of your building model is completely specified:

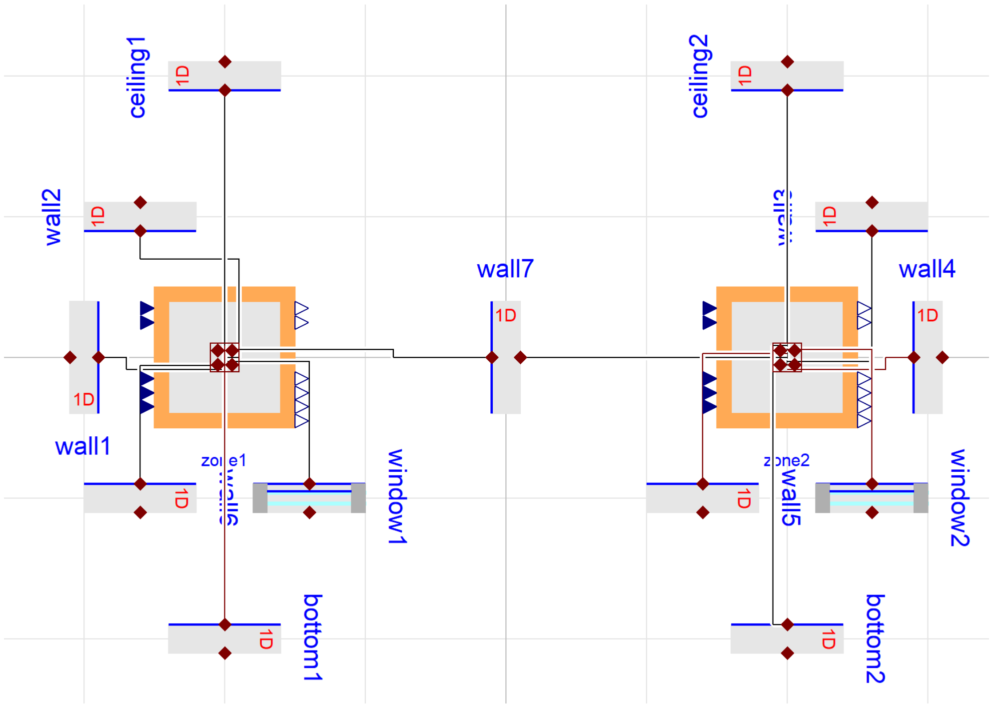


Fig. 6: Building model with connected construction elements

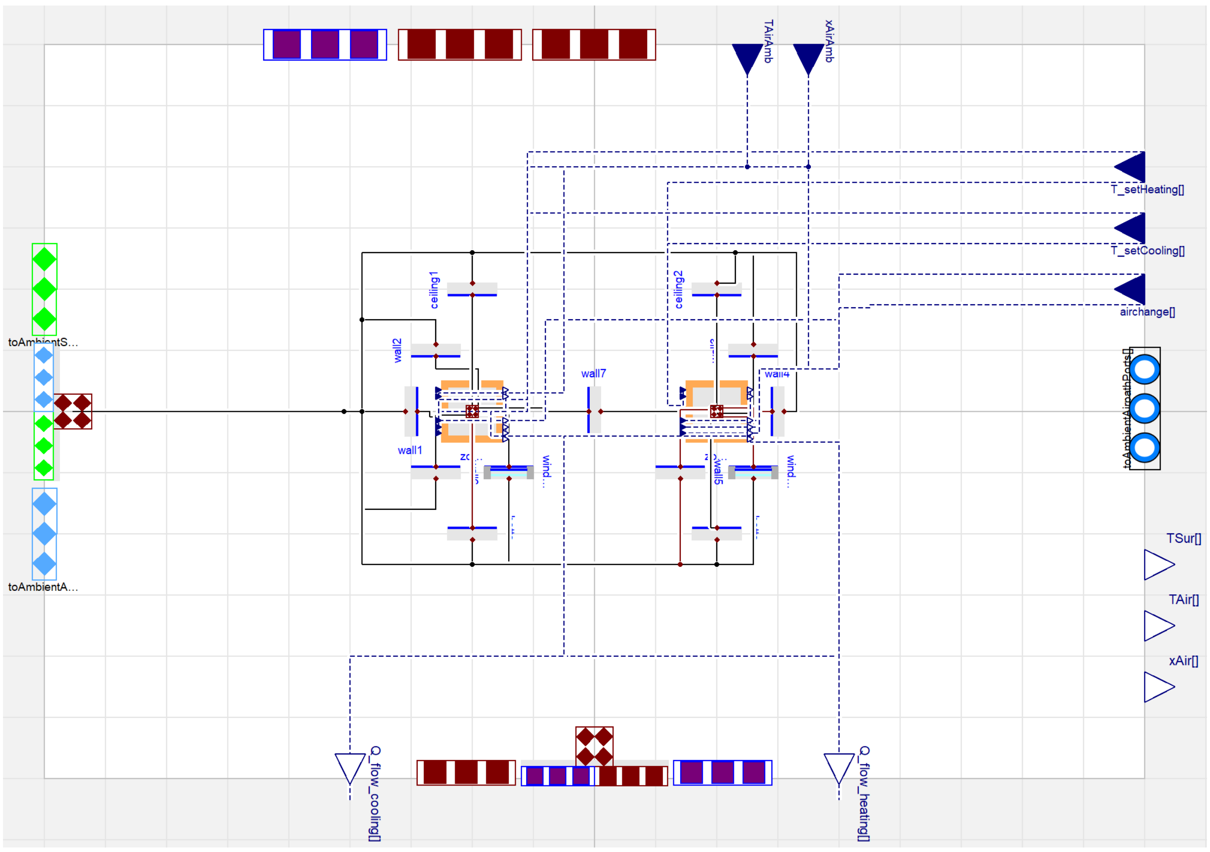


Fig. 7: Completed topology of the building model with two thermal zones

3.2 Define the building model parameters

Now the building model has to be completed with parameters, which exactly describe the problem. The first type are geometrical parameters, e.g. the size of the construction elements or the volumes of the zones. The second type are physical parameters which define the building constructions (e.g. the heat conductivity or specific heat capacity of the used materials).

1. Geometrical parameters

   The TMH has a strongly simplified geometry. In our problem each thermal zone describes one half of the TMH, which has in total an inner dimension of 1.0 m x 0.5 m x 0.5 m. So each opaque construction element (walls, bottoms and ceilings) has a height of 0.5 m and a width of 0.5 m. Double-click on each component and fill in these values in the *General tab* in the *Geometry* group.

   Both thermal zones have an air volume of 0.5 m x 0.5 m x 0.5 m = 0.125 m3. The height of the zone is 0.5 m. Fill in these values into the zone model's *zone1* and *zone2*.

   Each of the windows of the TMH has a width of 0.378 m and a height of 0.33 m, which leads to a window area of approx. 0.125 m2. The thickness of the window pane is 0.003 m. Assign these three values to both window models.

   Because *window1* is enclosed in *wall6* and *window2* in *wall5* the area of the window models has to be communicated from the window to the wall models. Double-click on *wall6* and fill in the parameter field *nInnSur* 1 and in the field *AInnSur* using the *Edit Text* option

   ```
   AInnSur=window1.width*window1.height
   ```

   Do the same with *wall5* and *window2*.

   Finally add the parameter values for the orientation of each construction elements, which face to the ambience by setting the azimuth angle and the tilt angle. The default values for each construction element (walls and windows are 90.0 degree for the tilt angle and 0.0 degree for the azimuth angle. North is defined by an azimuth angle of 180 degree, east by -90 degree and west by + 90 degree:

element	angleAzi	angleTil	element	angleAzi	angleTil
wall1	90.0	90.0	bottom1	0.0	180.0
wall2	180.0	90.0	bottom2	0.0	180.0
wall3	180.0	90.0	ceiling1	0.0	0.0
wall4	-90.0	90.0	ceiling2	0.0	0.0
wall5	0.0	90.0	window1	0.0	90.0
wall6	0.0	90.0	window2	0.0	90.0
wall7	default	default			

2. Construction parameters

   All the opaque construction elements except the partition *element wall7* share the same construction. For this reason a common construction type shall be configured, which will be later assigned to each individual construction.

   - Definition of a construction type

     Extend a child record from the general parent record for opaque constructions *BuildingSystems.Buildings.Data.Constructions.OpaqueThermalConstruction* and rename it to *Construction1TMH*. Then include it in the package *ThermalModelHouse*.

     The *Construction1TMH* shall have three layers. The materials of the three layers are 0.006 m wood, 0.030 m insulation and again 0.009 m wood. The layer order is counted from inside (zone) to outside (building ambience). The BuildingSystems library contains in the package *BuildingSystems.HAM.Data.MaterialProperties* a database with pre-defined thermal and hygro-thermal material property sets.

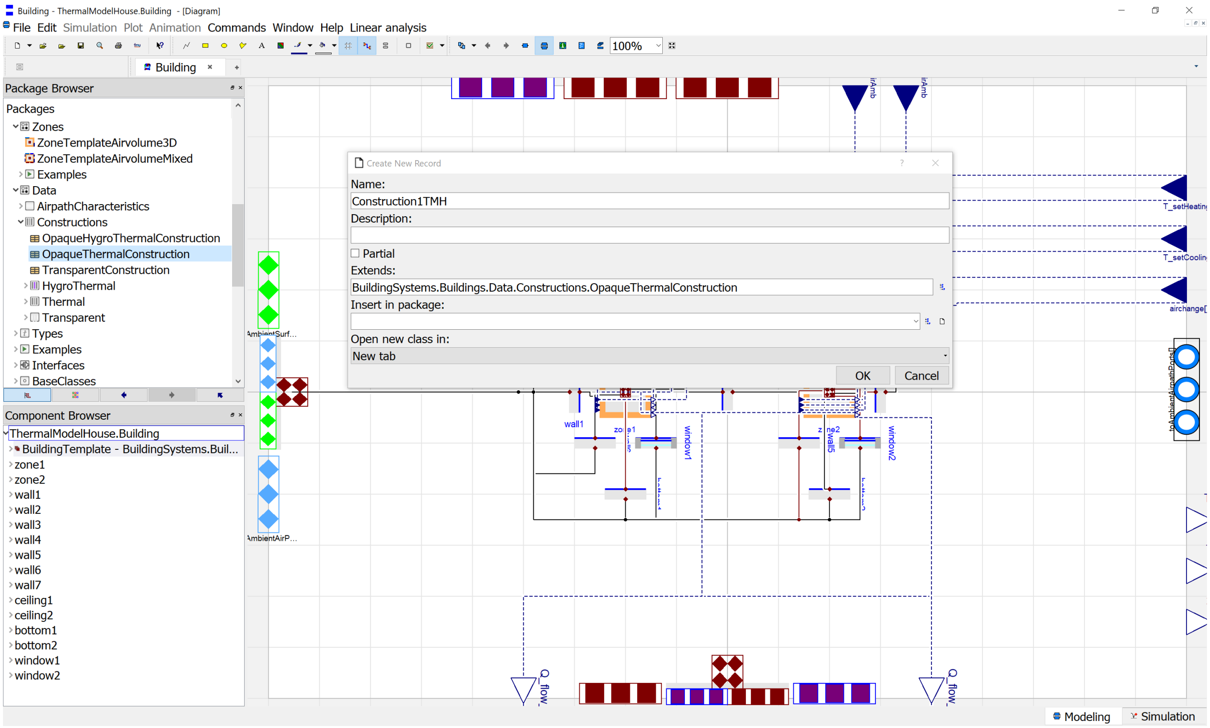


Fig. 8: Definition of a construction type based on template for opaque constructions

Now double-click on the construction type record *Construction1TMH* left in the package browser and adapt the parameterization of the construction direct in the Modelica source code editor of Dymola with the help of the pre-defined materials:

```
record Construction1TMH
  "Outer constructions of the TMH"
  extends BuildingSystems.Buildings.Data.Constructions.
↪OpaqueThermalConstruction(
    nLayers=3,
    thickness={0.006,0.030,0.009},
    material={BuildingSystems.HAM.Data.MaterialProperties.Thermal.Wood(),
    BuildingSystems.HAM.Data.MaterialProperties.Thermal.Insulation(),
    BuildingSystems.HAM.Data.MaterialProperties.Thermal.Wood()});
end Construction1TMH;
```

- Assignment of an construction type

  Now you can assign this common construction type to all the opaque construction elements by inserting component references using the component parameter dialog of Dymola:

  The generated code, for example for *wall1* shall look now like:

```
BuildingSystems.Buildings.Constructions.Walls.WallThermal1DNodes wall1(
  redeclare Construction1TMH constructionData,
  width=0.5,
  height=0.5,
  angleDegAzi=90.0,
  angleDegTil=90.0);
```

- Create in the same manner for the partition wall a second *construction2TMH*, which only consists in one layer of wood with a thickness of 0.009 m and assign it afterwards to *wall7*.

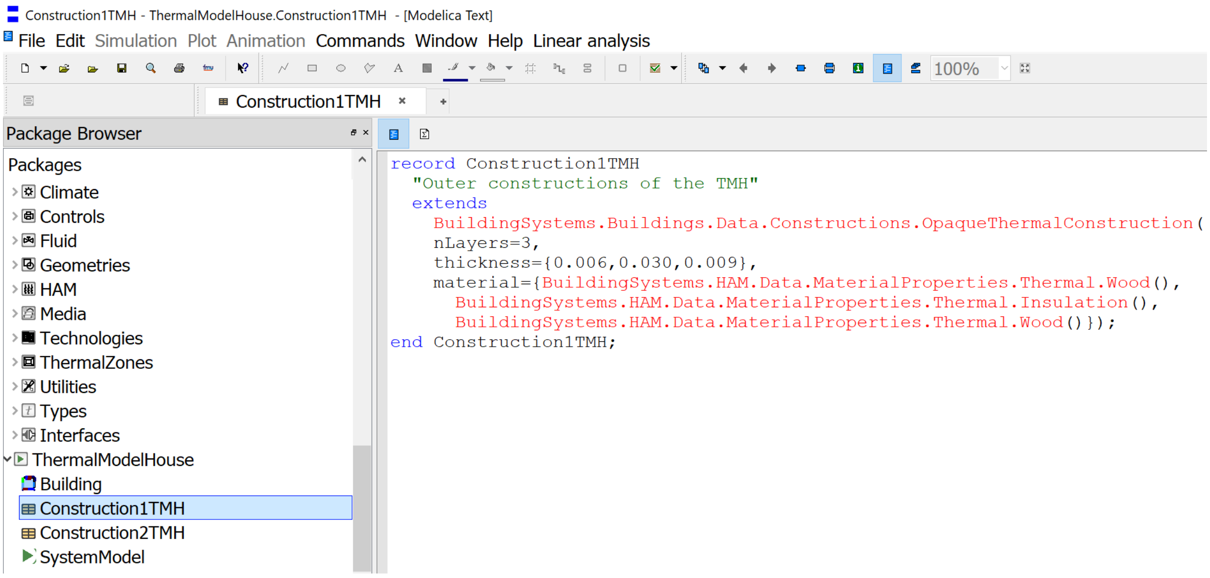
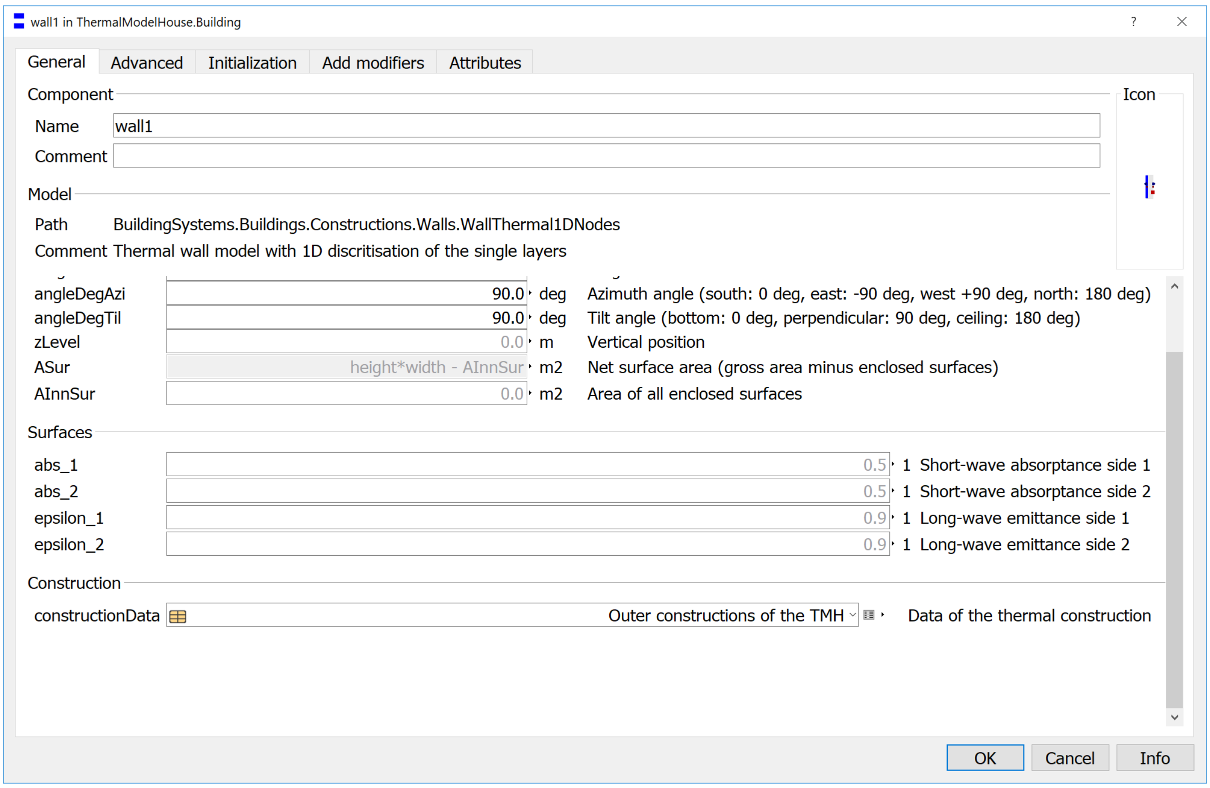


Fig. 9: Adapted record type of the first construction



3.3 Configure the system model and set its boundary conditions

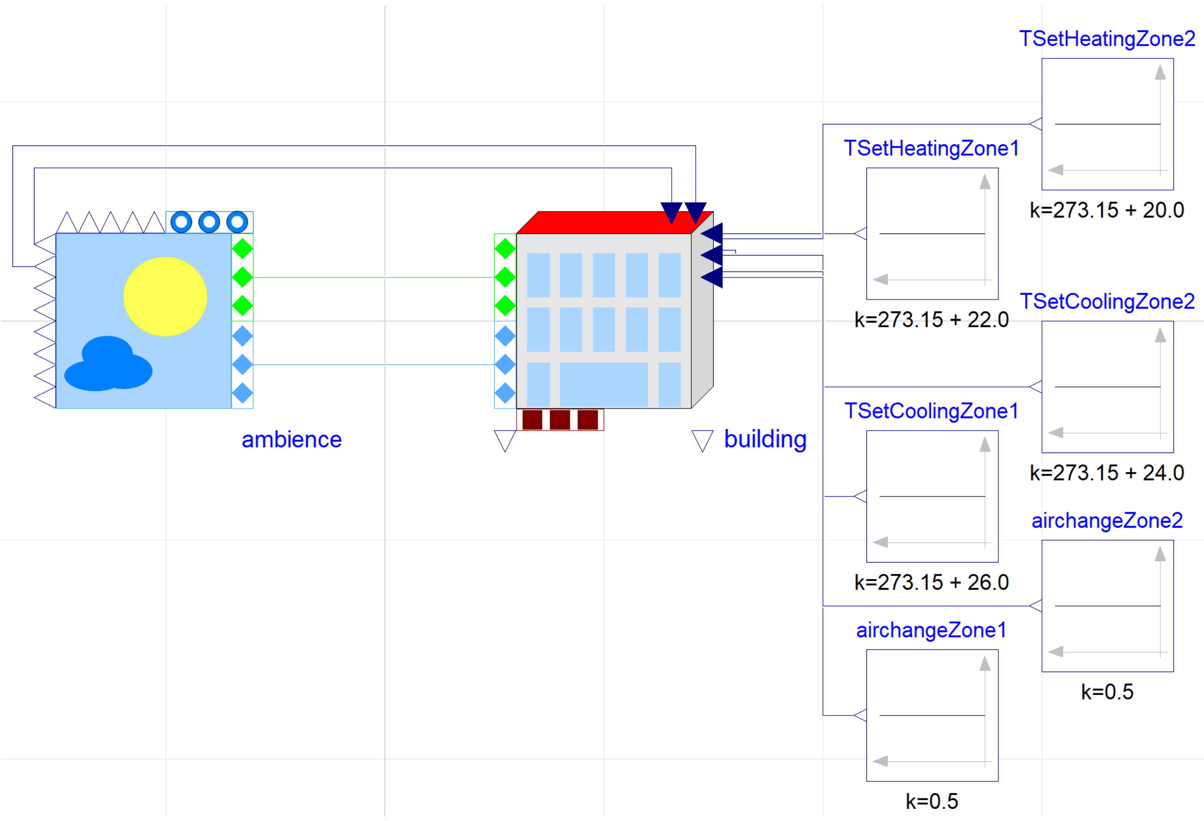


Fig. 10: System model of the TMH

1. Create a new model with the name *SystemModel* and insert it into the package *ThermalModelHouse*.
2. Instantiate the previous defined building model within the system model and rename it to *building*.
3. Instantiate an ambient model *BuildingSystems.Buildings.Ambience* within the system model and set the climate data (parameter weatherDataFile) to *USA_SanFrancisco_Meteonorm_ASCII*.
4. Assign the parameter *nSurfaces* of the ambient model to the number of surfaces of the building, which are in contact with the building environment:

```
nSurfaces={building.nSurfacesAmbience)
```

5. Connect the ambient model and the building model regarding to their blue interfaces (boundary conditions of the facade surfaces to the air) and their green interfaces (boundary conditions of the facade surfaces to the solar irradiation and other enclosing surfaces)
6. Connect the output variable *ambience.TAirRef* and the input variable *building.TAirAmb* (ambient temperature at a reference height of 10 m) and also *ambience.xAirRef* and *building.xAirAmb* (ambient absolute moisture).
7. Add six constant sources of the type *Modelica.Blocks.Sources.Constant* for the definition of the set temperatures for heating and cooling as well as the air change for both thermal zones:

```
..
Modelica.Blocks.Sources.Constant TSetHeatingZone1(k=273.15 + 22.0);
Modelica.Blocks.Sources.Constant TSetCoolingZone2(k=273.15 + 20.0);
Modelica.Blocks.Sources.Constant TSetHeatingZone1(k=273.15 + 26.0);
Modelica.Blocks.Sources.Constant TSetCoolingZone2(k=273.15 + 24.0);
```

(continues on next page)

(continued from previous page)

```
Modelica.Blocks.Sources.Constant airchangeZone1(k=0.5);
Modelica.Blocks.Sources.Constant airchangeZone2(k=0.5);
```

and connect them to the input signals of the building model.

Caused by this definition of the set temperatures *zone1* will have a higher temperature level than *zone2* during the simulation experiment.

The Modelica code of the described example of this chapter can be found under

https://github.com/UdK-VPT/BuildingSystems/blob/master/BuildingSystems/Resources/Documentation/ExamplesUserGuide/ThermalModelHouse.mo .

3.4 Simulate the system model

- Perform a simulation with the system model over 10 days (start time = 0.0 s end time = 60 s/h x 24 h/d * 10 d = 864000 s).

  The following diagrams illustrate selected results of the simulation experiment:

  1. The yearly air temperature for *zone1* and *zone2* and the outside air temperature (1st to 3rd line).
  2. The corresponding ideal heating and cooling load for zone 1 (4th and 5th line).
  3. The corresponding ideal heating and cooling load for zone 2 (6th and 7th line).
  4. The heat flow by heat transmittance through both surfaces of *wall7* between both zones (8th and 9th line).

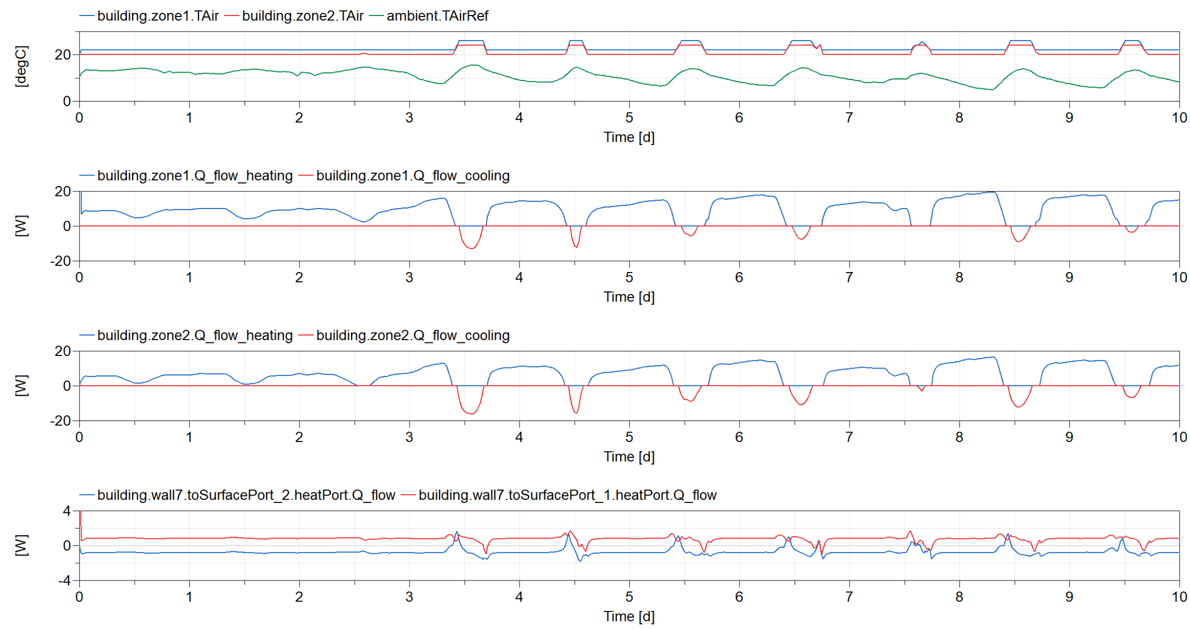


Fig. 11: Simulation results of both the TMH over 10 days, location San Francisco (USA)

CHAPTER FOUR

BUILDING COMPONENT MODELS

This chapter describes the component models of the building model of the BuildingSystems library and their exemplary application.

4.1 Partial models

1. *AirElementGeneral*
2. *AirvolumeGeneral*
3. *BuildingElement*
4. *BuildingTemplate*
5. *ConstructionGeneral*
6. *HeatConduction3DWithTube*
7. *PartialMixingVolume*
8. *RadiationDistribution*
9. *RelationRadiationConvection*
10. *ShadowingElementGeneral*
11. *SurfaceGeneral*
12. *TriangularConstructionGeneral*
13. *WallGeneral*
14. *WallHygroThermalGeneral*
15. *WallThermalGeneral*
16. *WallThermalTriangularGeneral*
17. *WallTriangularGeneral*
18. *WindowGeneral*
19. *ZoneTemplateGeneral*
20. *OpaqueConstruction*

4.2 Ambience model

Ambience

4.3 Wall models

1. *WallHygroThermal1DNodes*
2. *WallThermal1DNodes*
3. *WallThermalTriangular1DNodes*

4.4 Window models

1. *SlidingWindow*
2. *Window*

4.5 Shadowing models

1. *Embrasure*
2. *Overhang*
3. *OverhangElement*

4.6 Door models

Door

4.7 Air volume models

1. *Airvolume3DTemplate*
2. *AirvolumeMixed*
3. *MixingVolumeMoistAir*

4.8 Zone models

1. *ZoneTemplateAirvolume3D*
2. *ZoneTemplateAirvolumeMixed*

4.9 Comfort model

ThermalComfort_DIN_EN_ISO_7730

4.10 Geometry models

tbd

4.11 Interface models

tbd

CHAPTER

FIVE

ENERGY SYSTEMS SIMULATION

has to be added …

References

BIBLIOGRAPHY

[NGHLRadler12] Christoph Nytsch-Geusen, Jörg Huber, Manuel Ljubijankic, and Jörg Rädler. Modelica BuildingSystems - Eine Modellbibliothek zur Simulation komplexer energietechnischer Gebäudessysteme. In *BAUSIM 2012*. 2012.

[NGMIRadler14] Christoph Nytsch-Geusen, Katharina Mucha, Alexander Inderfurth, and Jörg Rädler. Entwicklung eines räumlich und physikalisch adaptiven energetischen Gebäudemodells in Modelica. In *BAUSIM 2014*. 2014.