Modeling Solar Thermal Systems with DesignBuilder-EnergyPlus

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What is simulation?

1. The act or process of simulating.

2. Act or object made in **imitation** of something else with intent to **deceive**.

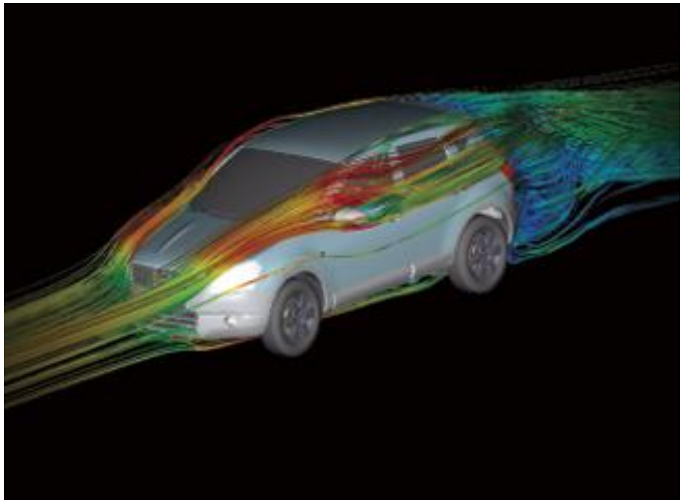
3.a. **Representation** of the functioning of **one system** by means of the functioning of another **(simplified)** system.

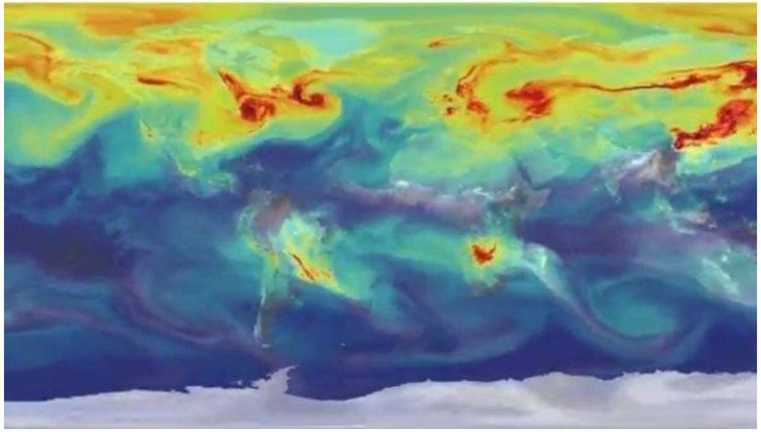
3.b. **Examination** of a **problem** (often not subject to direct experimentation) by means of a **simulation device**.

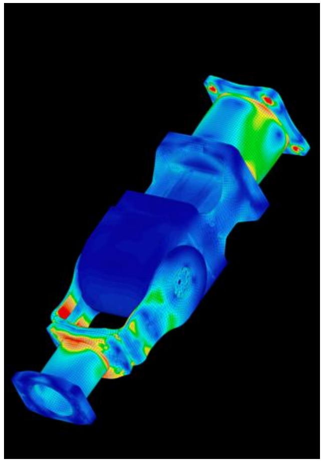
Based on *www.merriam-webster.com*

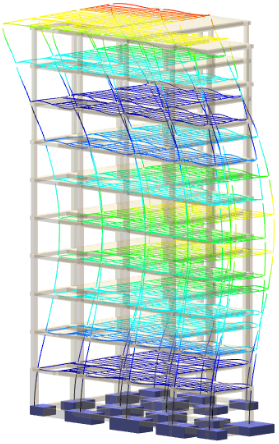
Horse simulation (Wikipedia)

Examples of simulation applications









Product design

Engineering

Weather prediction

Training and education

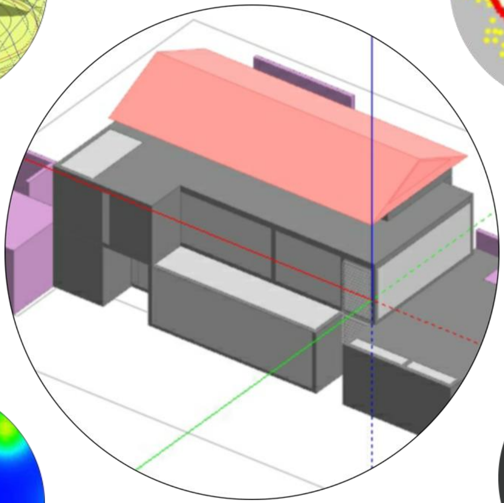
Video games

And of course:

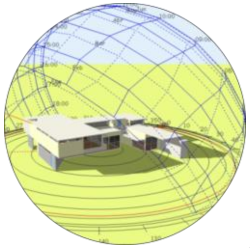
Building and **HVAC** design

DesignBuilder, a modular approach

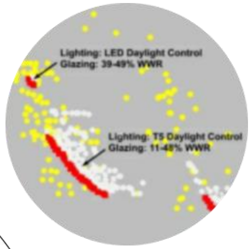
3d modeler



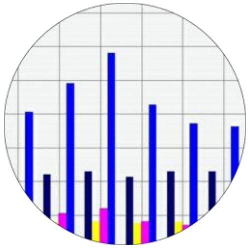
Visualization



Optimization (Genetic Algorithms)

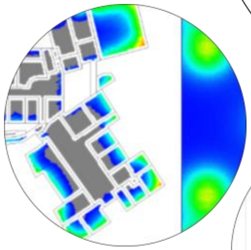


Simulation (EnergyPlus)



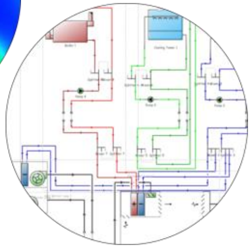
LEED

Daylighting (Radiance)

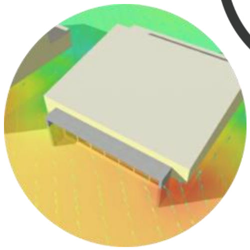


Costing

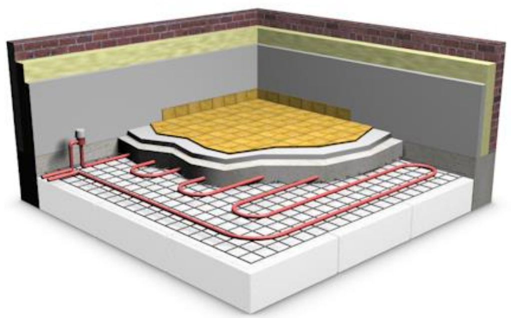
Detailed HVAC (EnergyPlus)



CFD (Computational Fluids Dynamics)

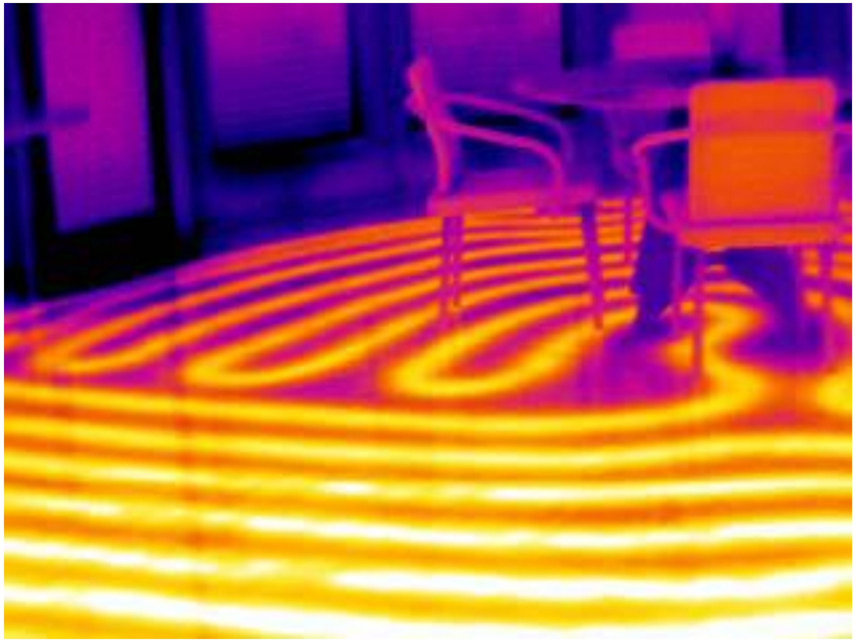


Case study: **STS** applied to a heated floor system



A dwelling in Boise, Idaho, USA
(Lat. **43.57**, Long. **-116.22**)

DesignBuilder-EnergyPlus heated floor model

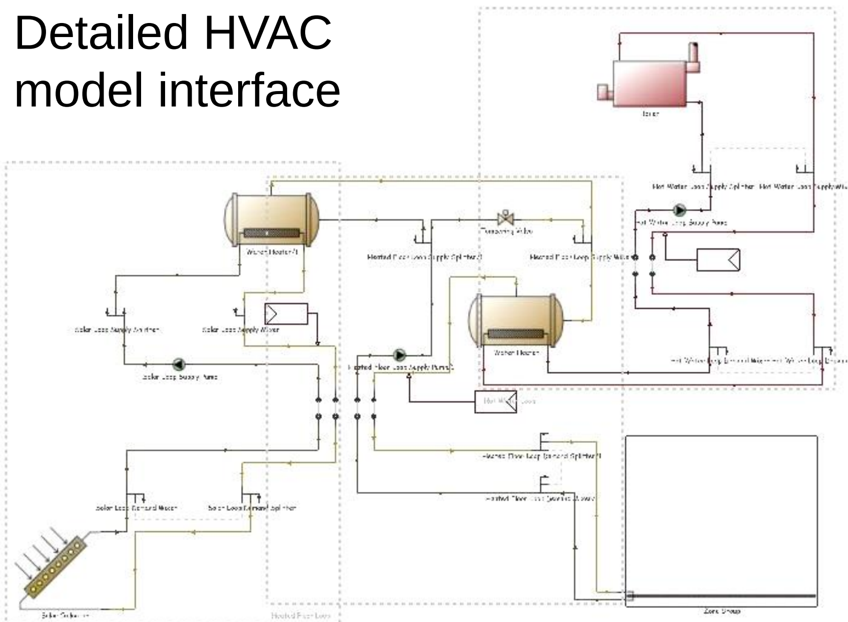


Low temperature radiant systems with **hot water pipes** embedded in **floor constructions**.

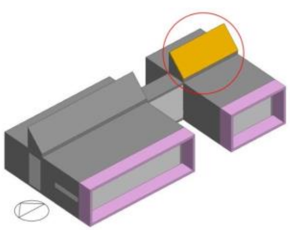
- Large heating surface area and relatively low fluid temperature (40-55 ºC).
- Two types of heated floor: **Constant flow** and **Variable flow**. Variable flow heated floor is fully autosizable.
- Heated floors can be connected to hot water loops fed by boiler, Ground Source Heat Pumps and/or **Solar Thermal Systems**.

General modelling approach

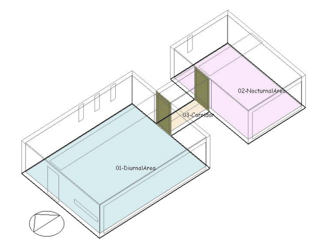
Detailed HVAC model interface

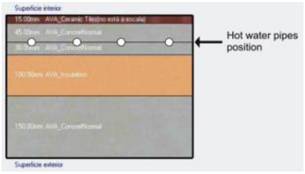


Solar collector surface



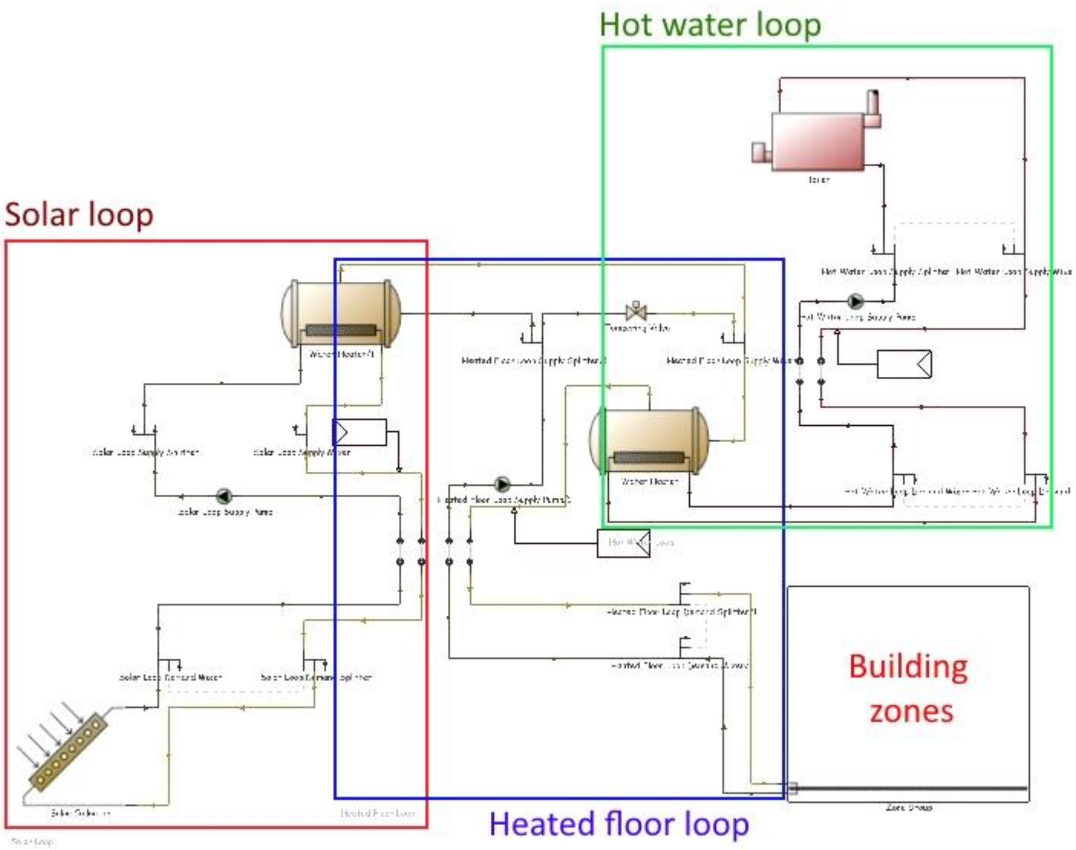
Building thermal zones





Ground floor construction

Detailed HVAC model: general scheme

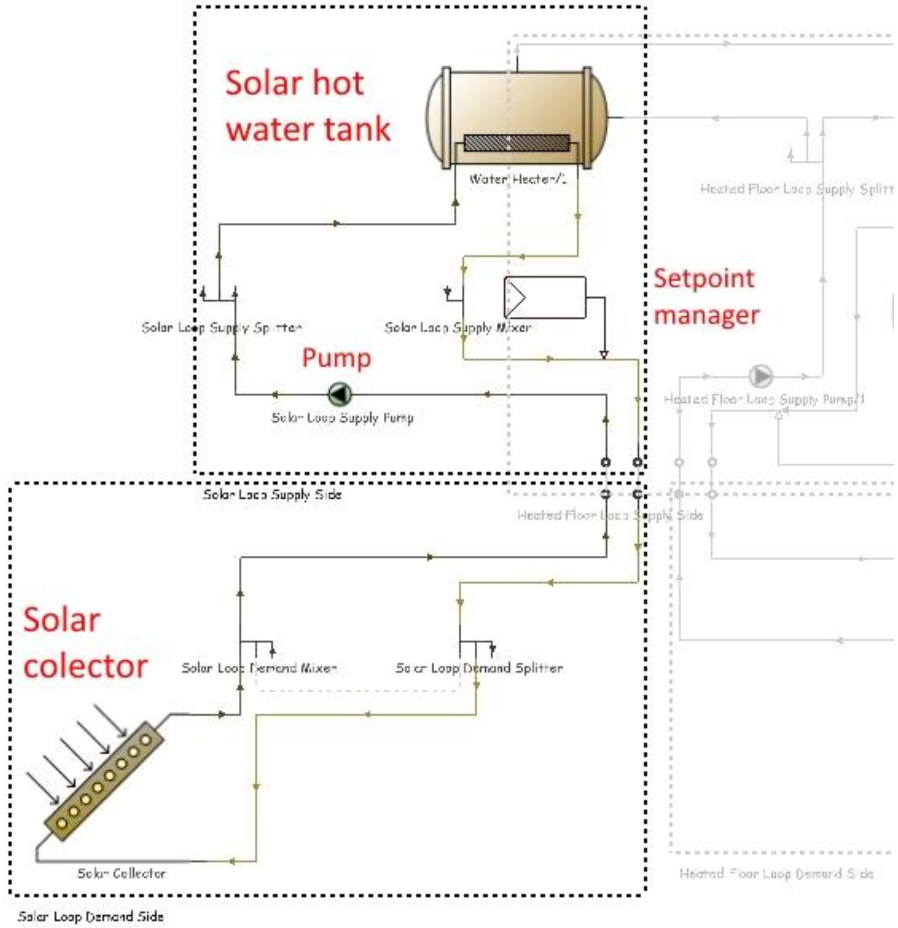


The system consists of three main loops:

- Solar loop
- Heated floor loop
- Hot water loop

The heated floor loop connects the systems with the building zones.

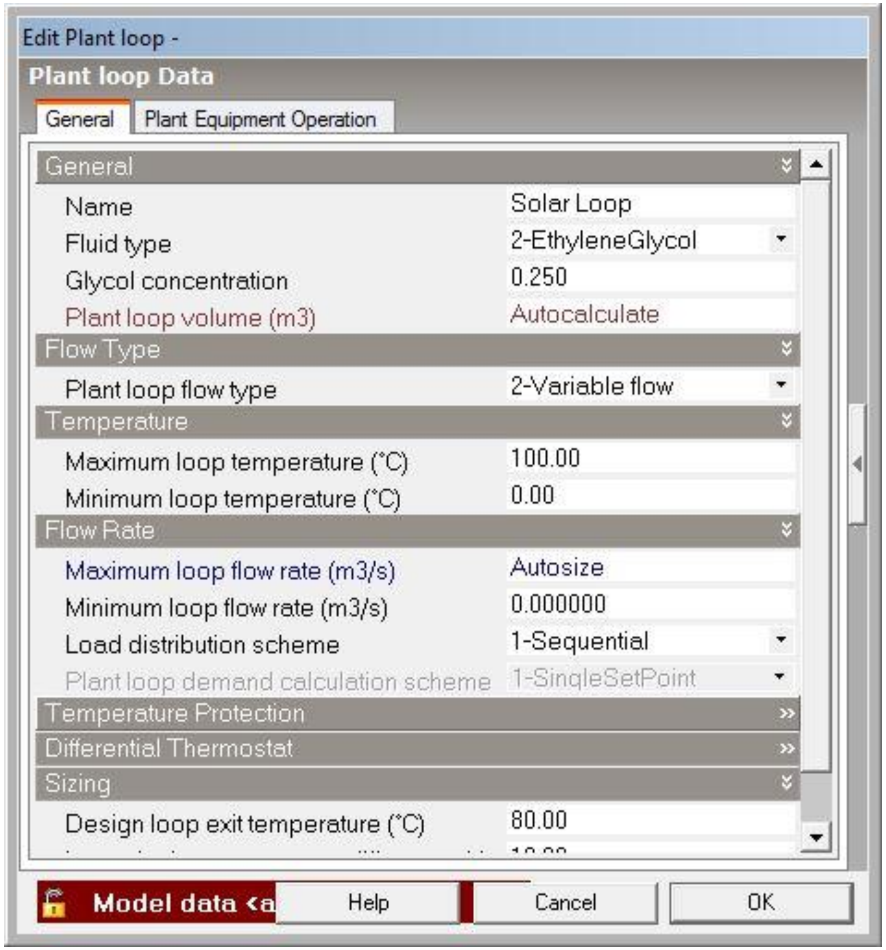
Detailed HVAC model: solar loop



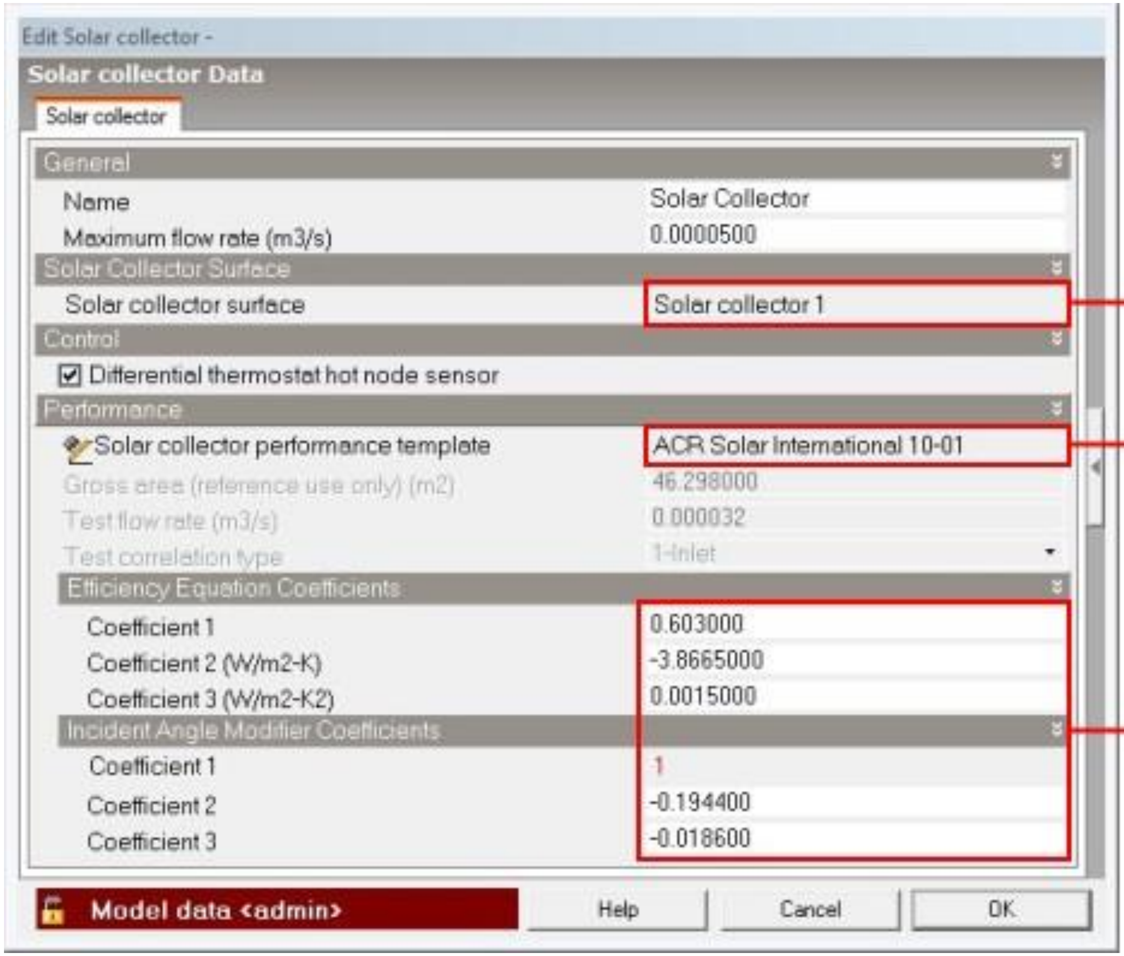
Solar loop with storage water tank.

- The solar collector heats the working fluid, which is sent to a heat exchanger into the solar hot water tank.
- The solar water tank heats the water and stores it for later use.

Solar loop data



Solar collector data



Link to the solar collector surface in the 3d model

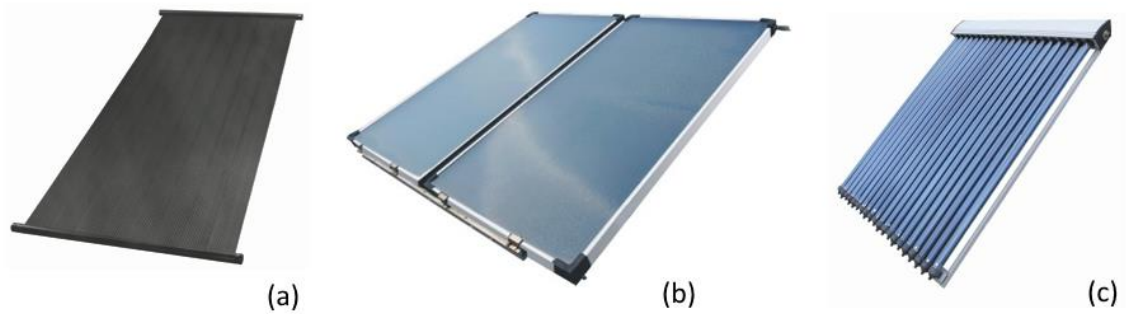
Selection of solar collector type

Solar colector performance data (from template)

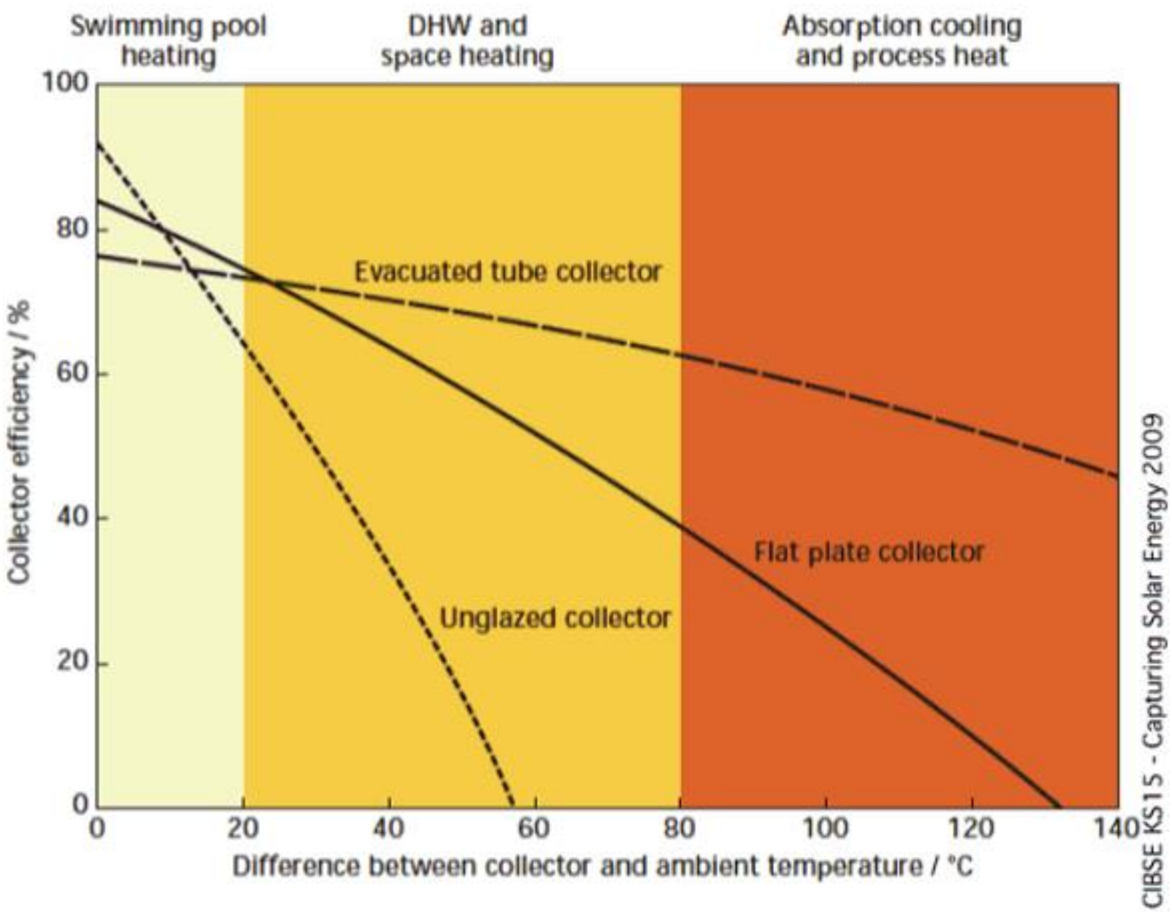
Solar collector object

The **EnergyPlus** solar collector model is based on the equations of the ASHRAE standards, as well as Duffie and Beckman (1991).

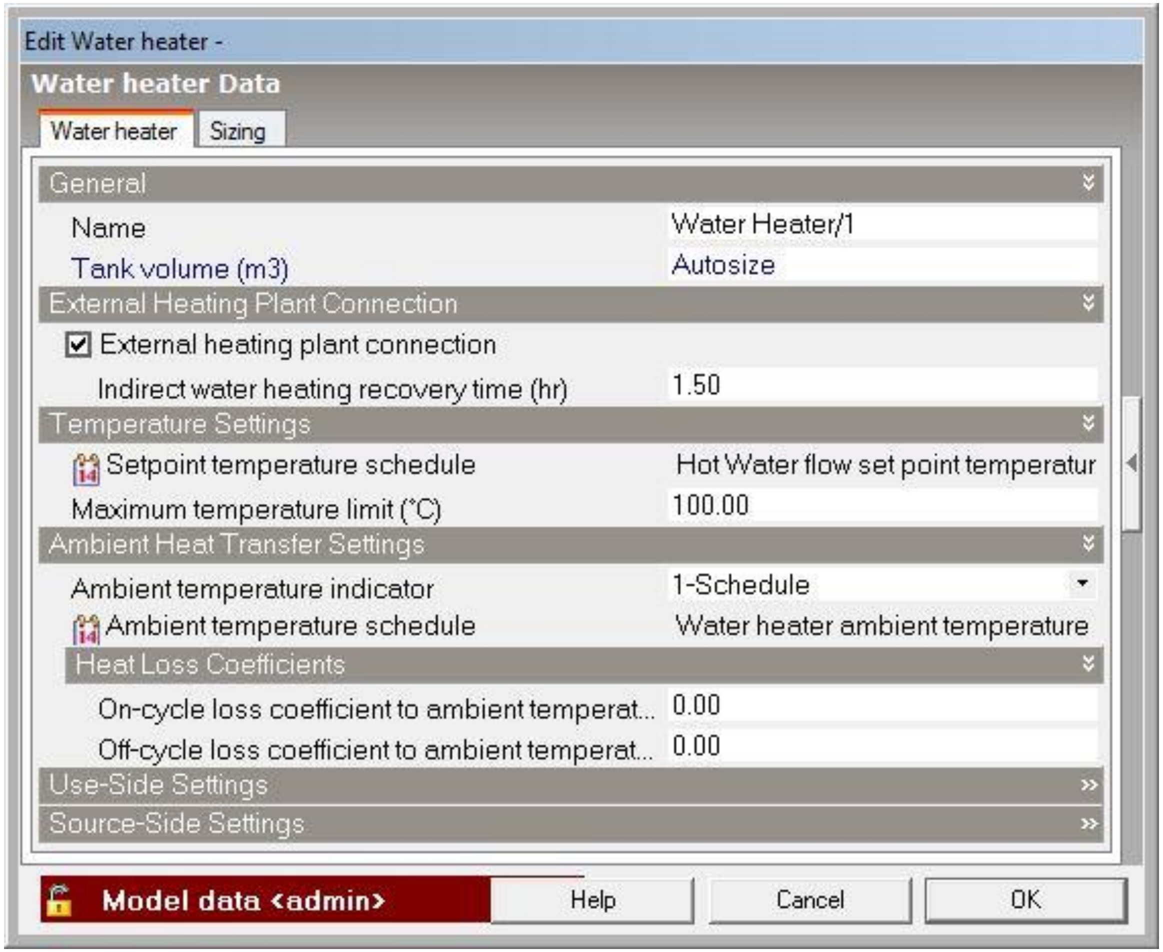
- This model applies to **unglazed** (a) and **glazed** (b) flat-plate collectors, as well as banks of **tubular** (c) evacuated collectors.
- The model uses coefficients for the **energy conversion efficiency** and **incident angle modifier**, based on testing methodologies described in ASHRAE Standards 93 and 96.
- **DesignBuilder** offers a dataset of templates containing performance coefficients for near 170 commercial solar collectors (unglazed, glazed, and tubular).



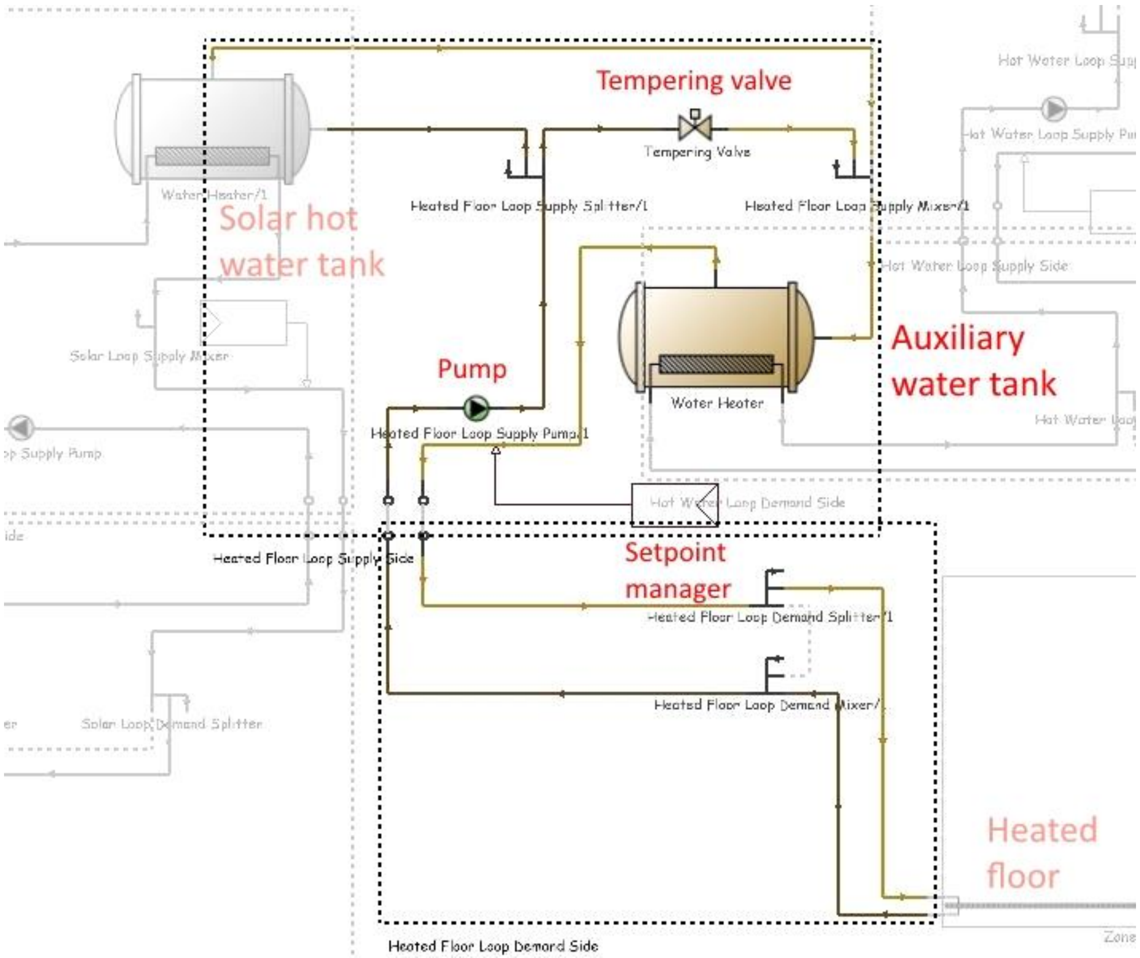
Efficiency and applications of solar collector types



Solar hot water tank data



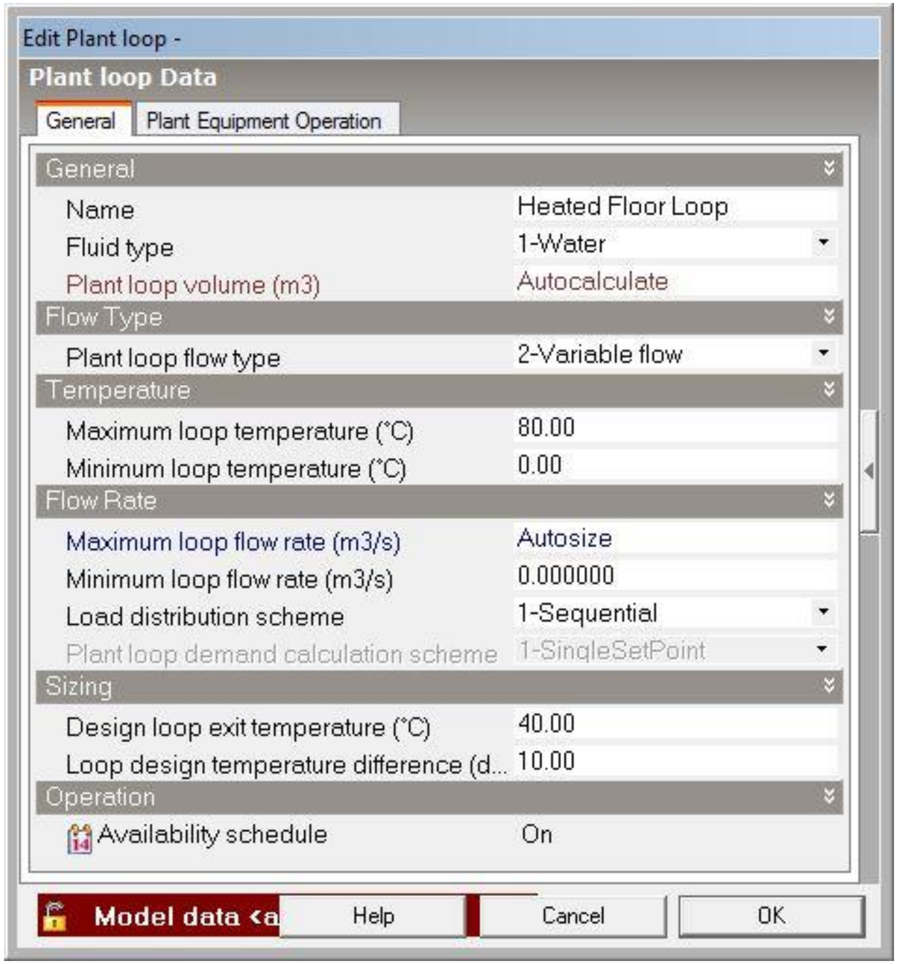
Detailed HVAC model: heated floor loop



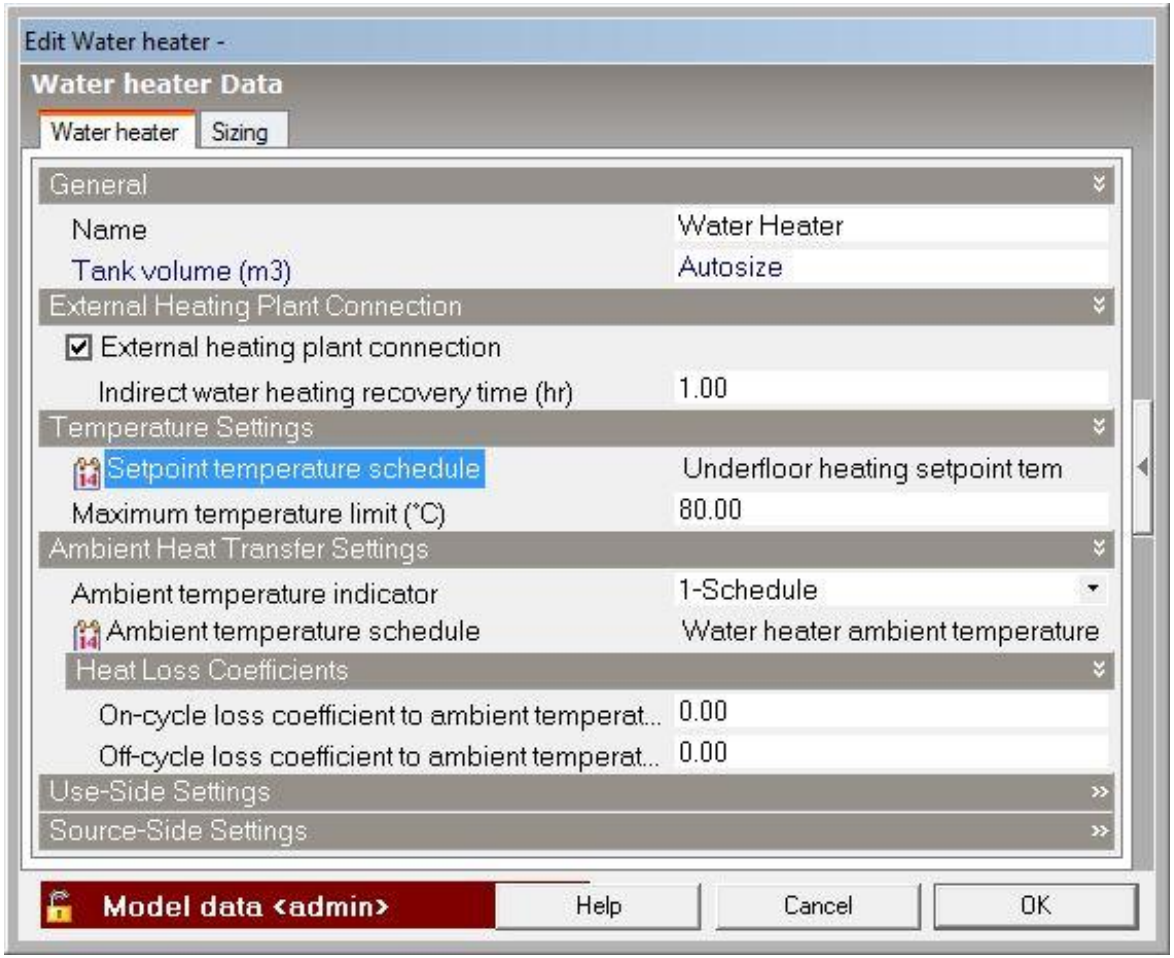
The auxiliary water heater provides additional heat if the solar tank water is not hot enough.

- Can be modelled as an instantaneous-tankless water heater, but in this case it is modeled as a standard tank with external heating source.
- The hot water leaving the storage tank can be tempered using a three-way valve (tempering valve) to achieve the target temperature.

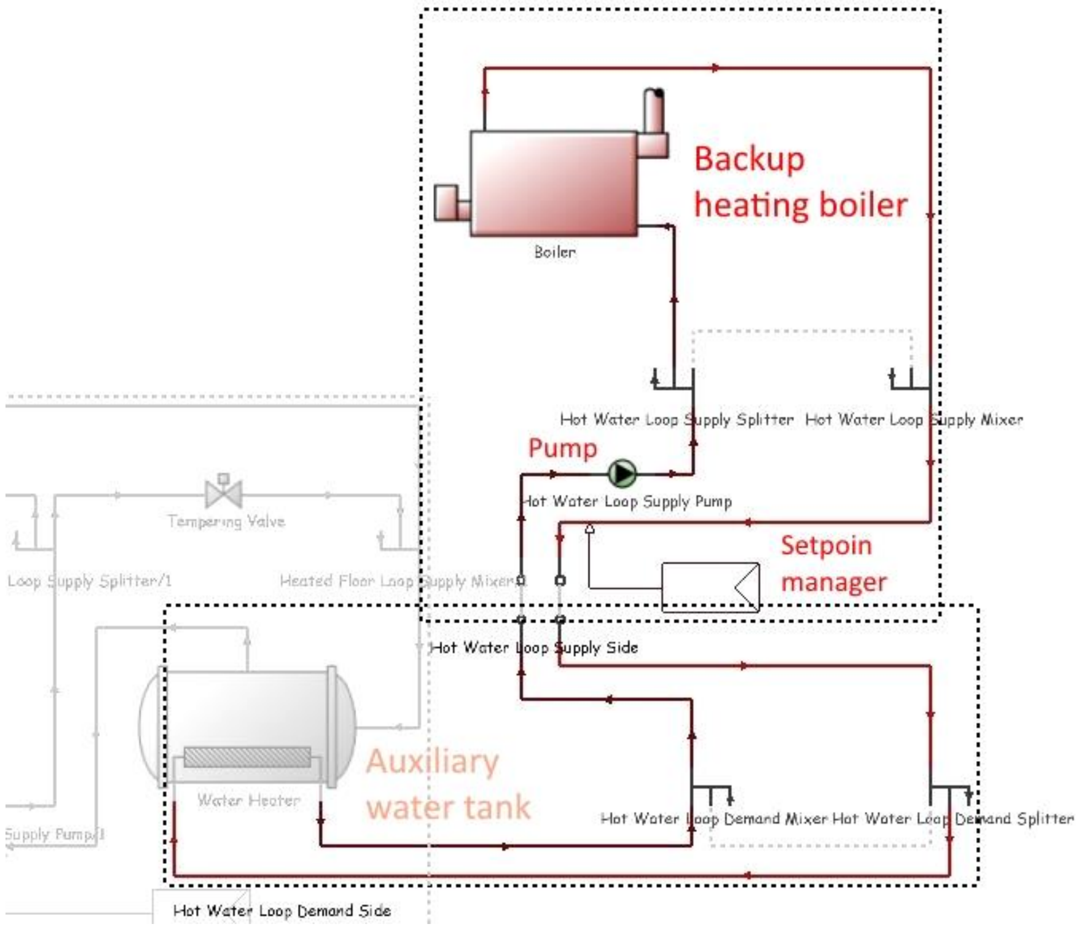
Heated floor loop data



Auxiliary water tank data

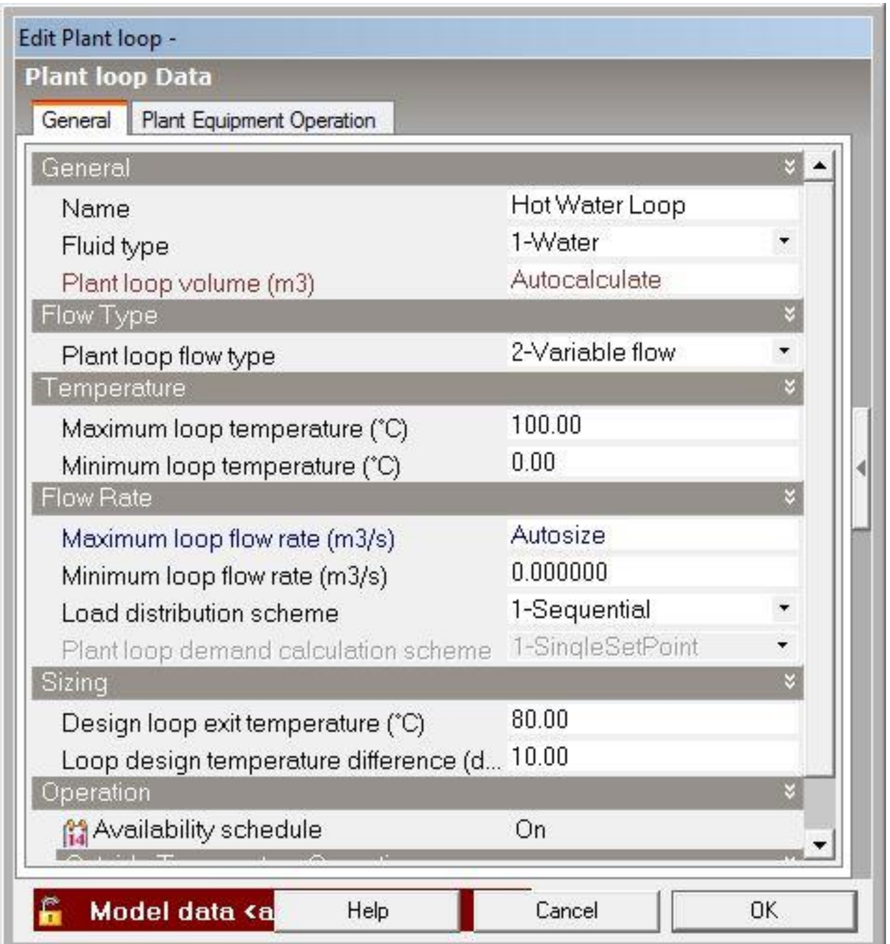


Detailed HVAC model: hot water loop

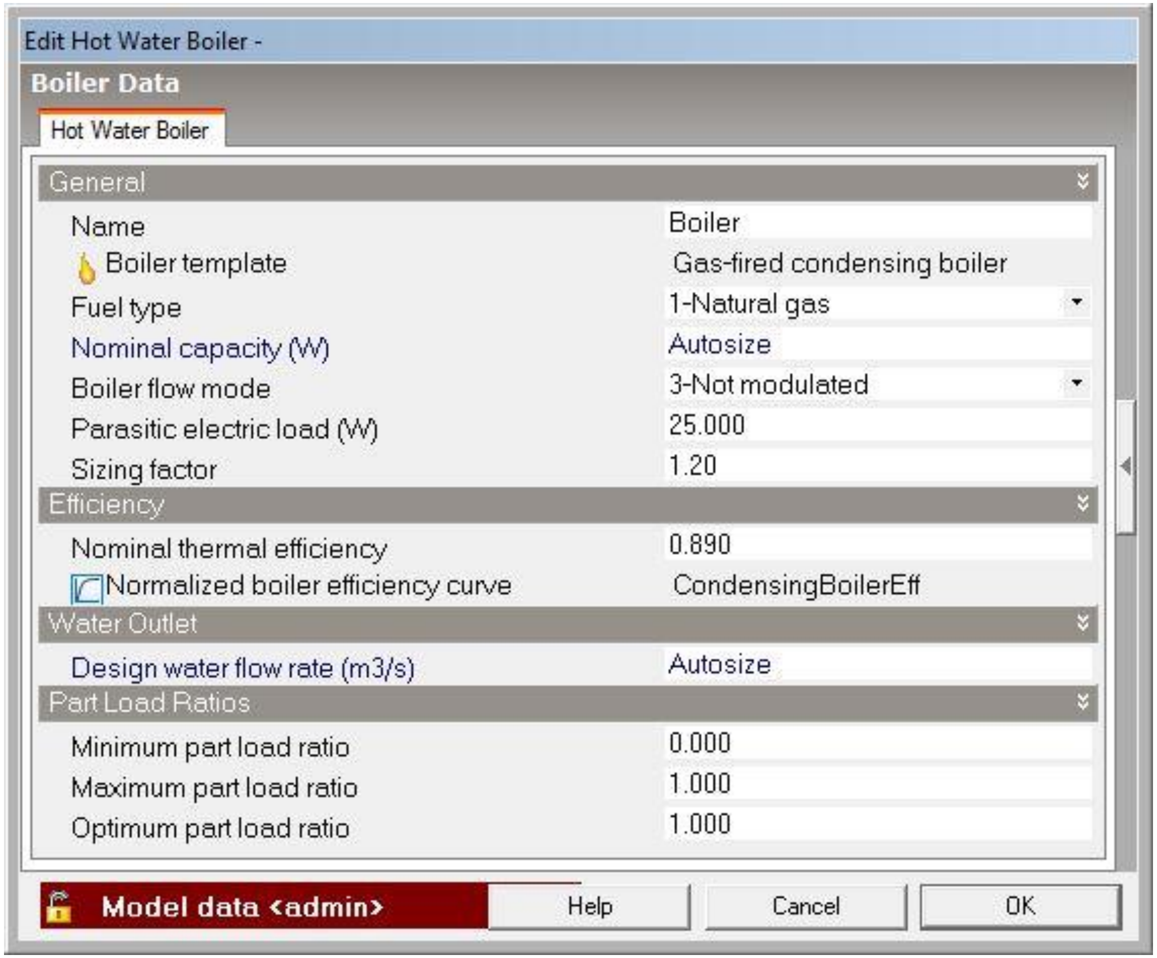


The backup heating boiler provides heat to the auxiliary water tank, generating a specific hot water loop.

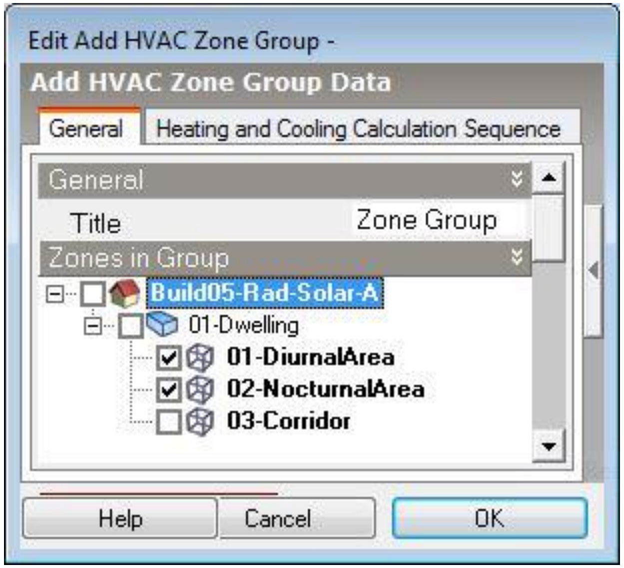
Hot water loop data

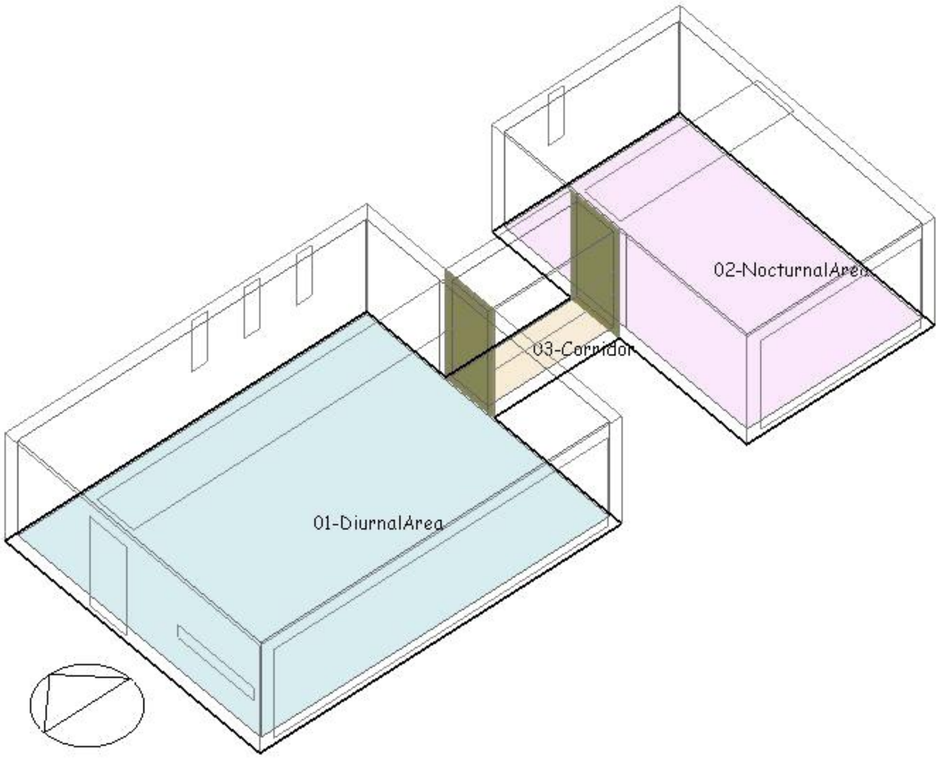


Backup heating boiler data



Link to the 3d model: thermal zones

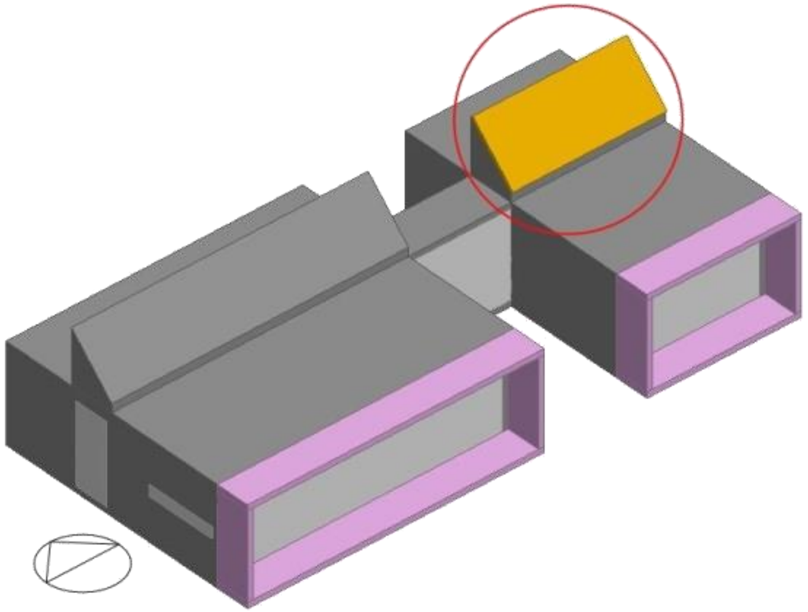




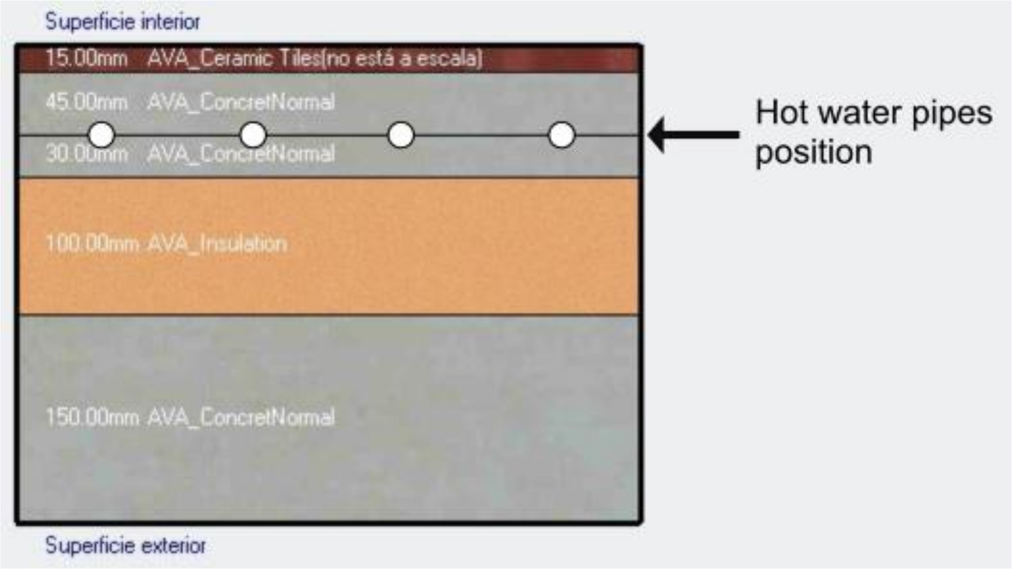
Link to the 3d model: solar collector **surface**

The **solar collector surface** object defines the **gross area**, **position**, **orientation** and **tilt** of the collector. It is included in the detailed solar and shading calculations:

- Incident solar radiation includes **beam** and **diffuse radiation**, as well as radiation reflected from adjacent surfaces.
- **Shading** of the collector by other surfaces, such as nearby buildings.
- Collector surface shading other surfaces (i.e. reducing the incident radiation on the roof).



Link to the 3d model: ground floor constructions



The floor of the zones served by the heated floor system may be defined as an “internal source”.

- It allows to define the position of hot water pipes embedded in the construction.
- It is possible to select from **one-dimensional** or **two-dimensional** heat transfer solution.
- 2-D solution method allows the return water temperature to be accurately calculated.

Considerations about heated floor configuration

Configuration of the heated floor construction has a significant affect on the whole system performance. Some points to take care about:

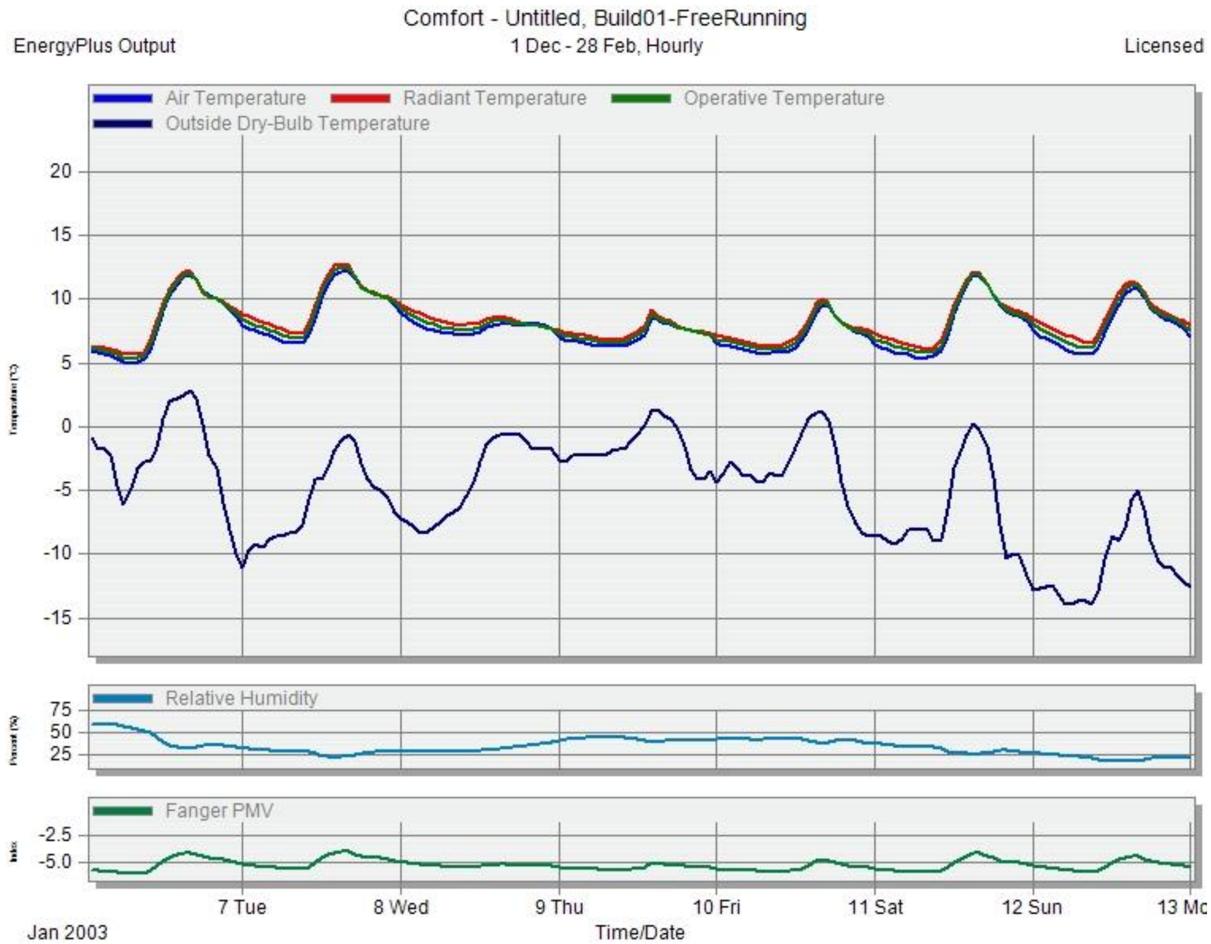
- In order to achieve all its potential, the system requires that heated water pipes are embedded into a **high thermal mass layer**.
- The thermal mass layer should be in contact with the zone.
- The quantity of thermal mass must be carefully calibrated, in order to avoid a excessively **slow response** and high **deviation** from zone setpoint temperature.
- Without good **insulation** below the heated floor source, much of the heat will not find its way into the intended zone.
- If the **floor finishing** has low conductivity (i.e. a thick pile carpet) then the heated floor will struggle to provide adequate heating to the room.

Simulation results

Besides the previously described heated floor with solar thermal system, other options have been simulated for comparison. This is the list of all the simulated options:

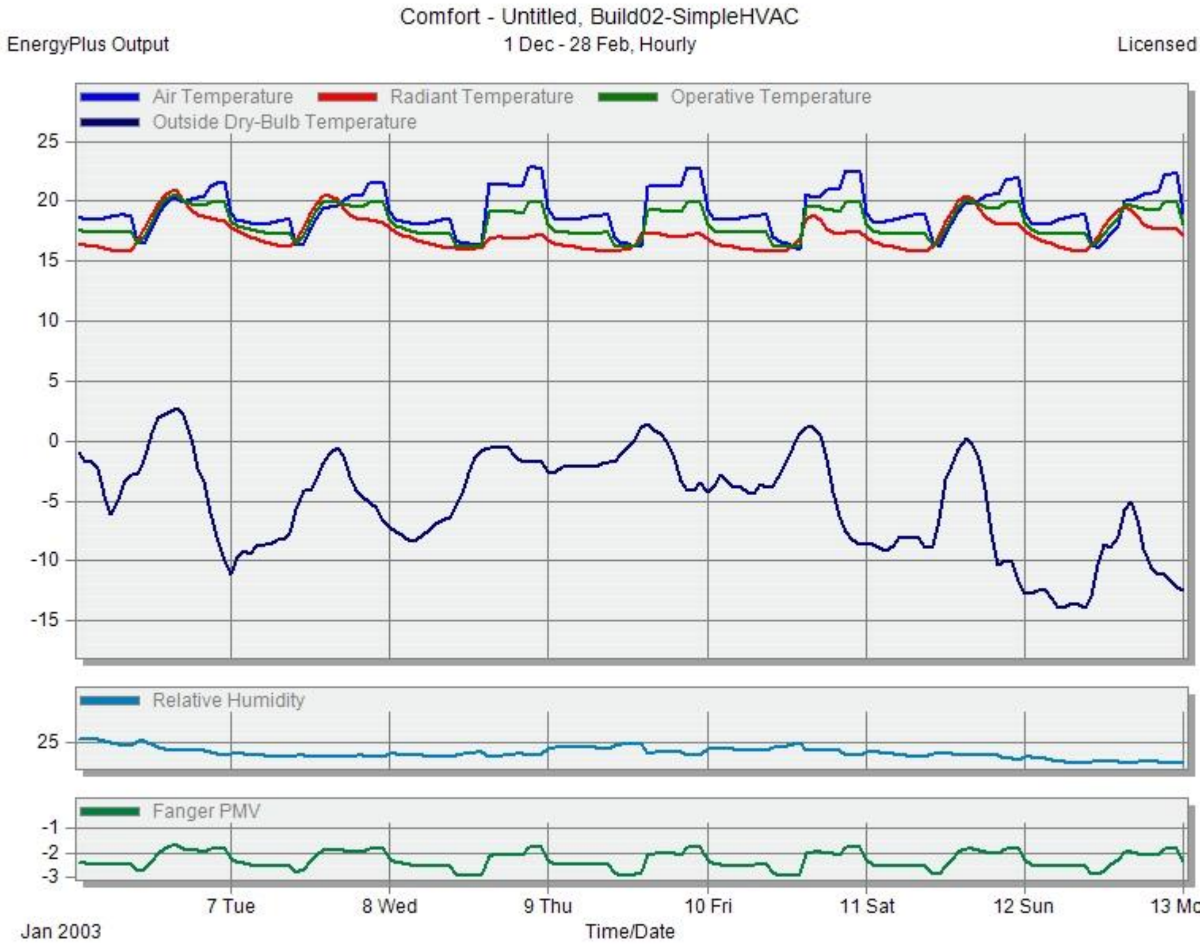
- **Free running building**. No HVAC system.
- **Simple HVAC system** (convective ideal system).
- **Heated floor A**: Without solar thermal system. Boiler and water storage tank.
- **Heated floor B**: Solar thermal system. Glazed flat plate collector, 12.22 m^2 surface area.
- **Heated floor C**: Solar thermal system. Glazed flat plate collector, 23.53 m^2 surface area.
- **Heated floor D**: Solar thermal system. Evacuated tubes collector, 23.53 m^2 surface area.

Simulation results



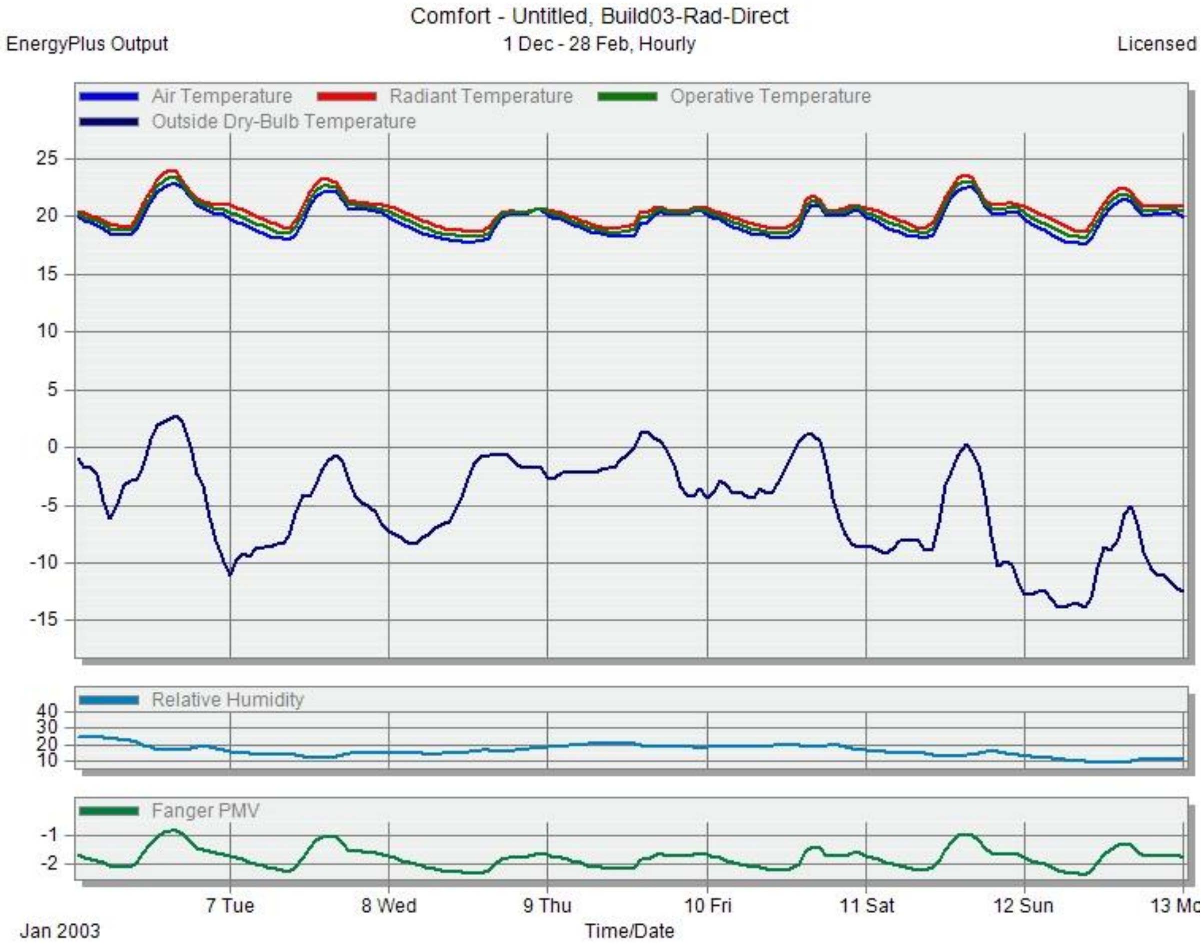
Zone temperatures, free running.

Simulation results



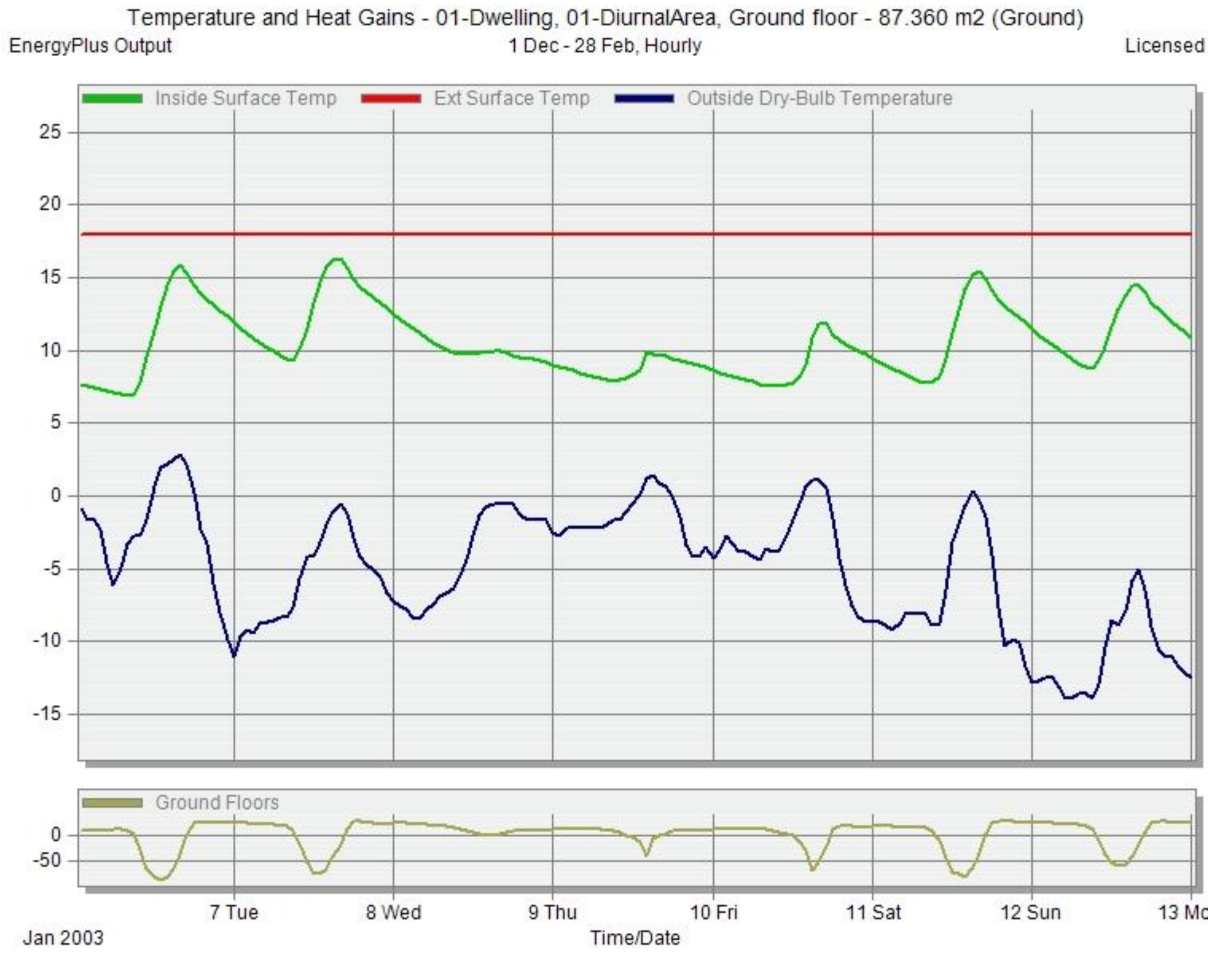
Zone temperatures, simple HVAC.

Simulation results



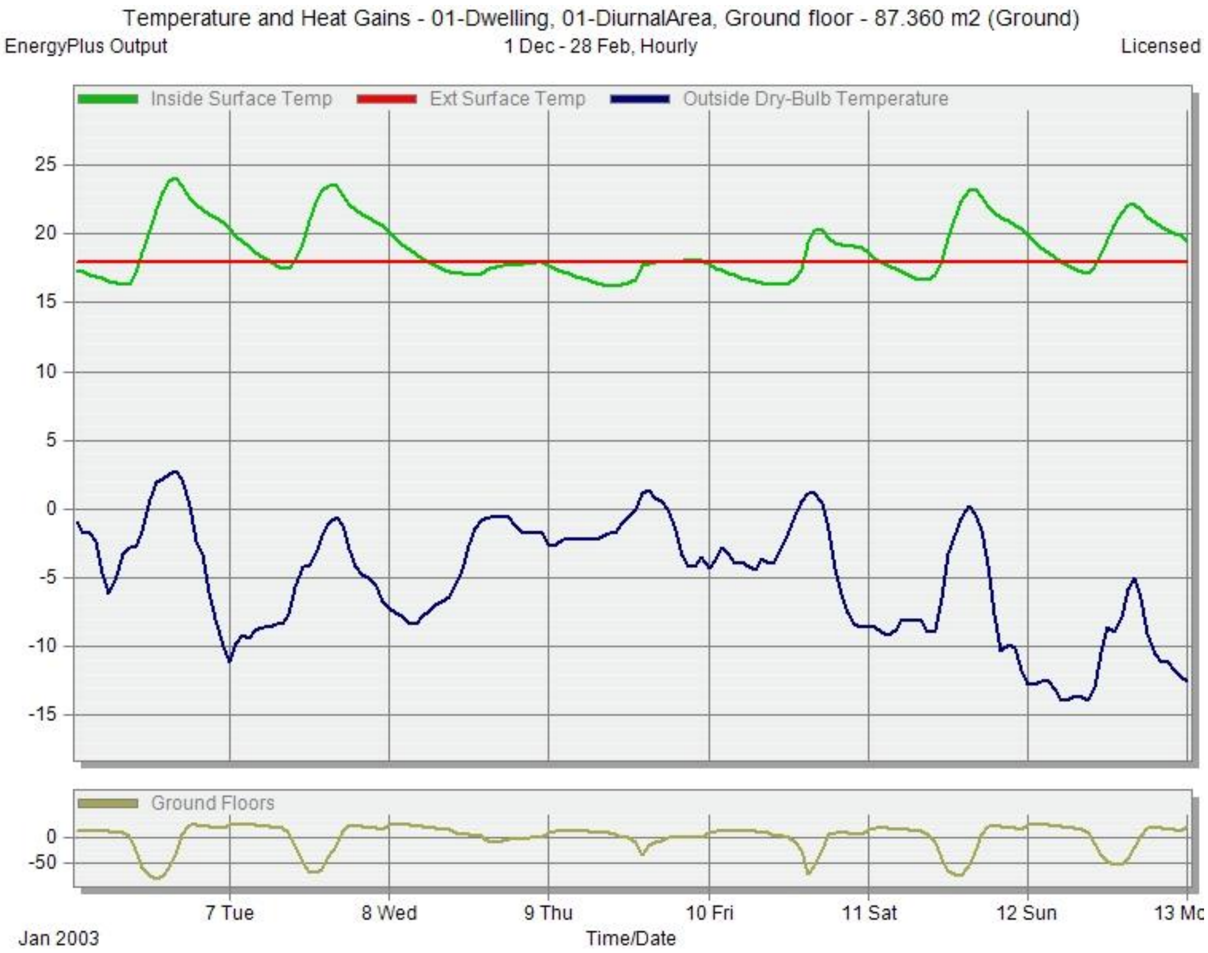
Zone temperatures, heated floor.

Simulation results



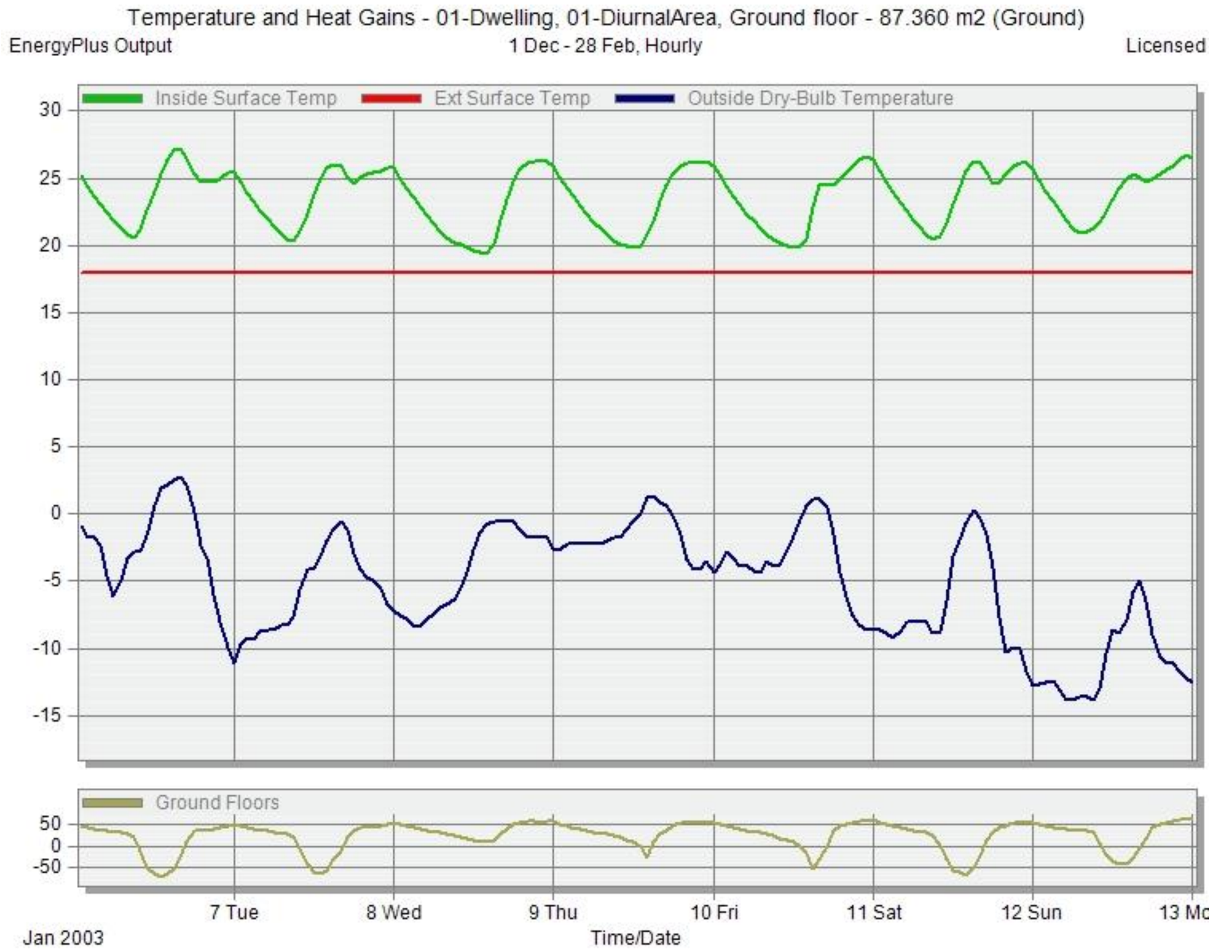
Floor surface temperature, Free running.

Simulation results



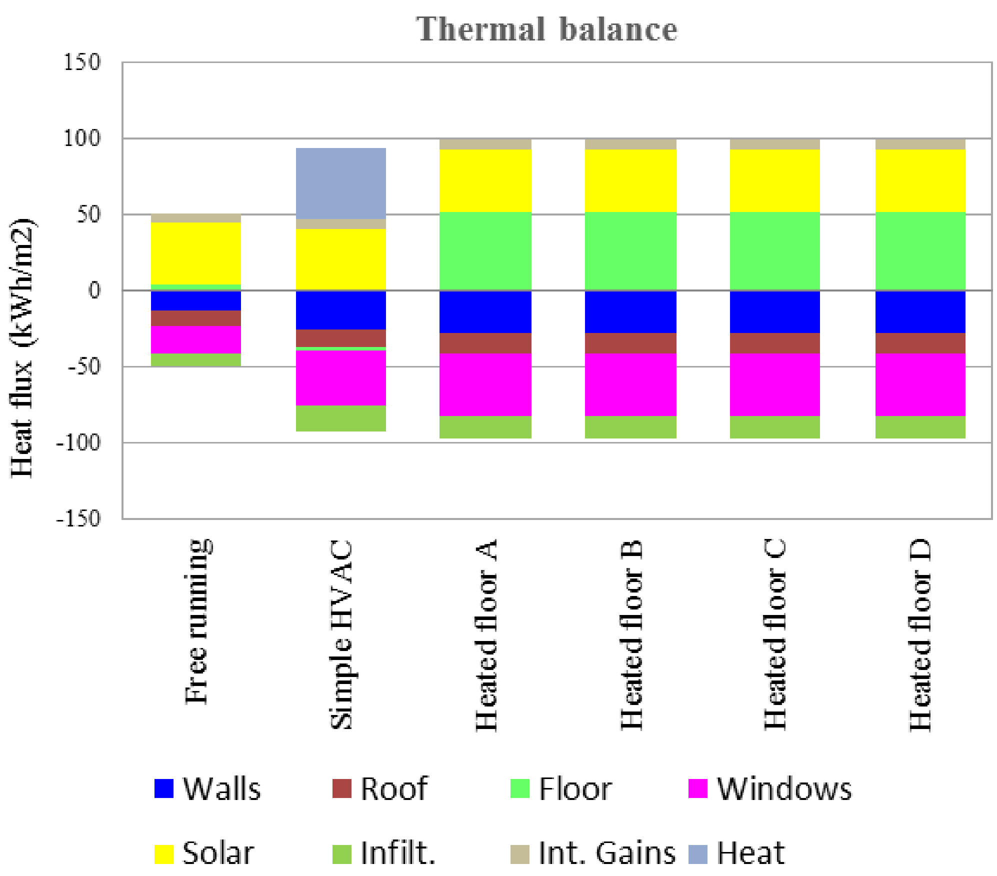
Floor surface temperature, Simple HVAC.

Simulation results



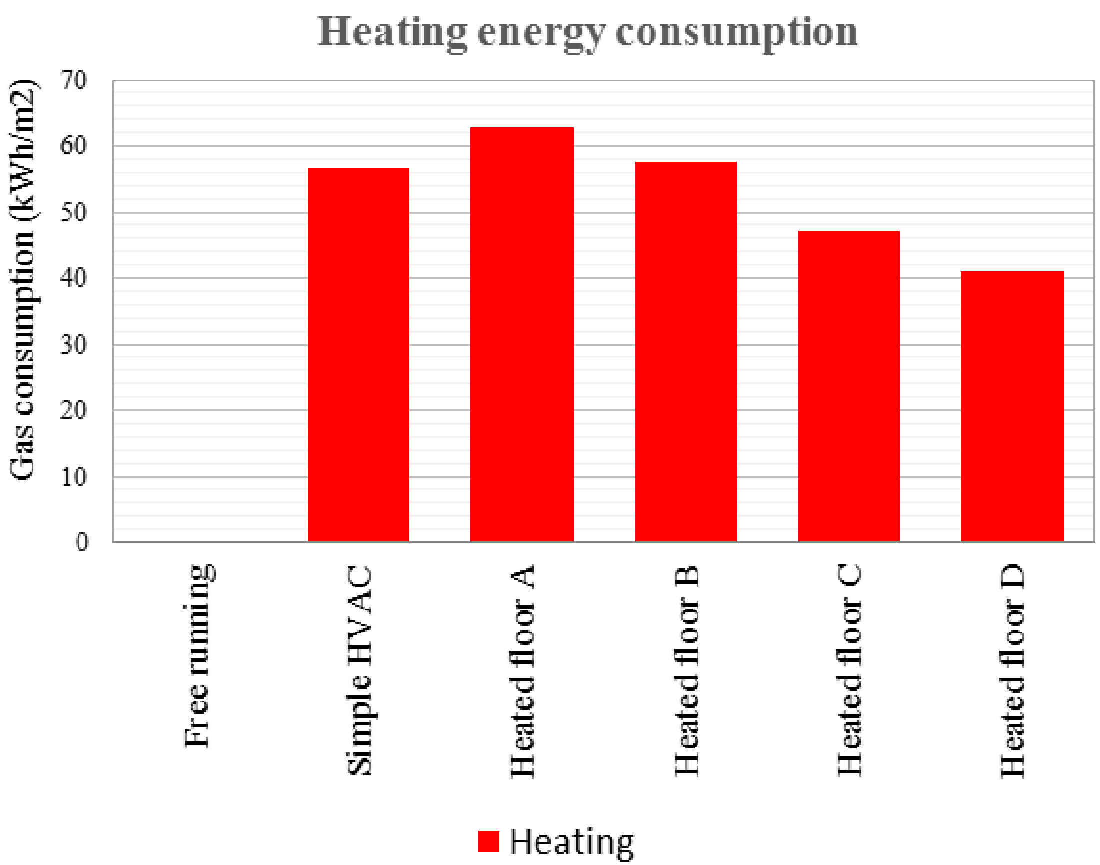
Floor surface temperature, Heated floor.

Simulation results



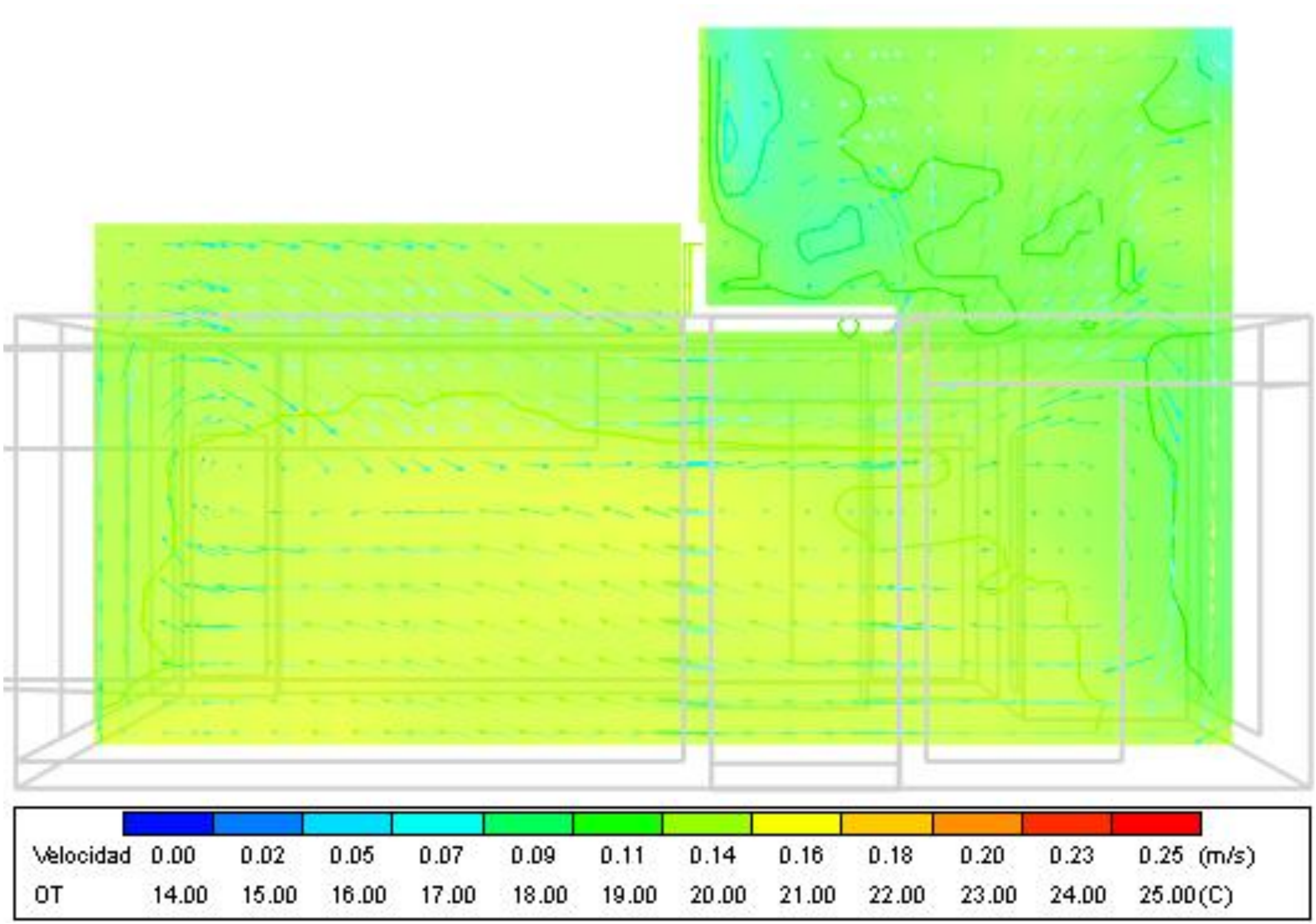
Building thermal balance during the simulation period.

Simulation results

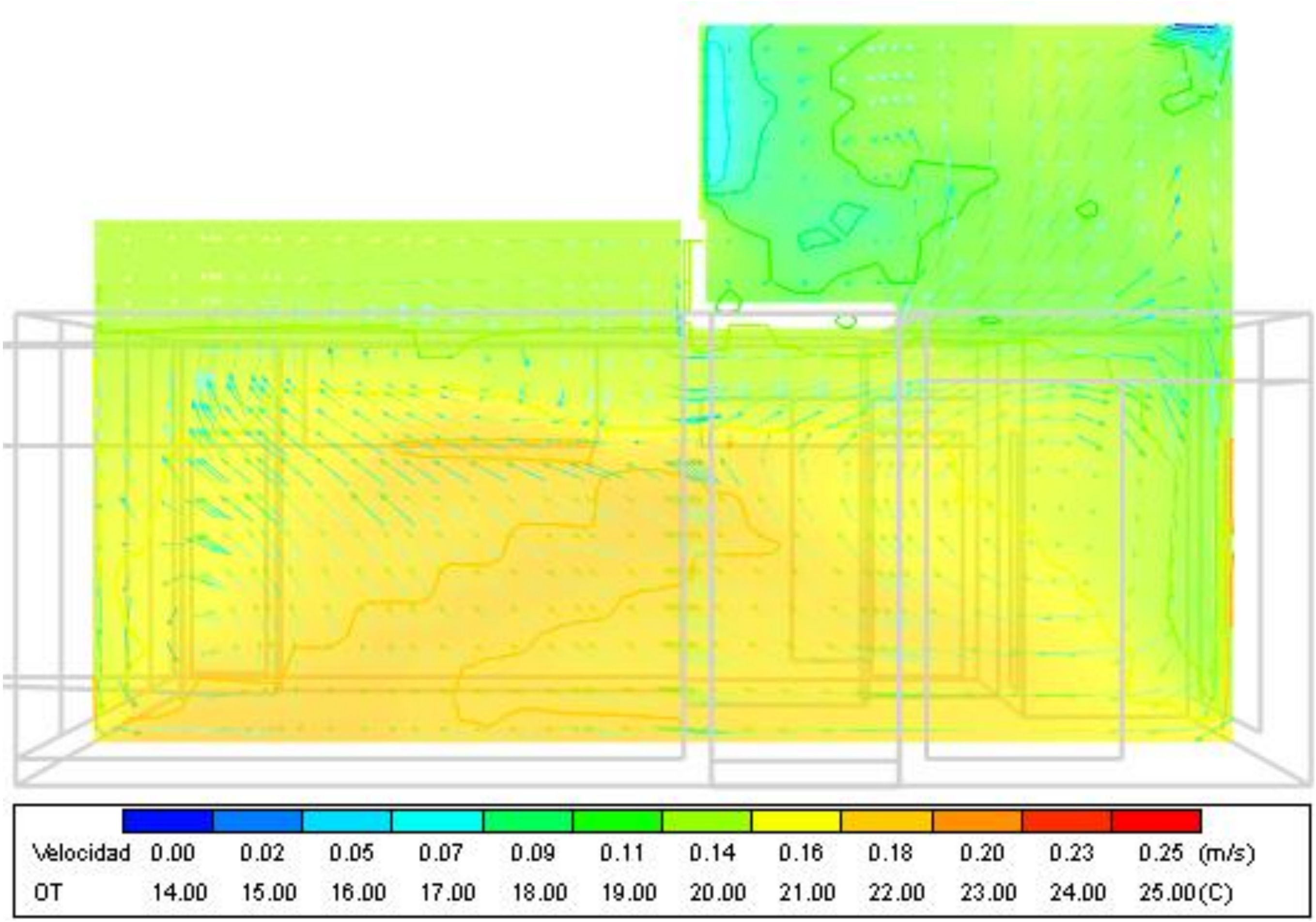


Building heating energy consumption during the simulation period.

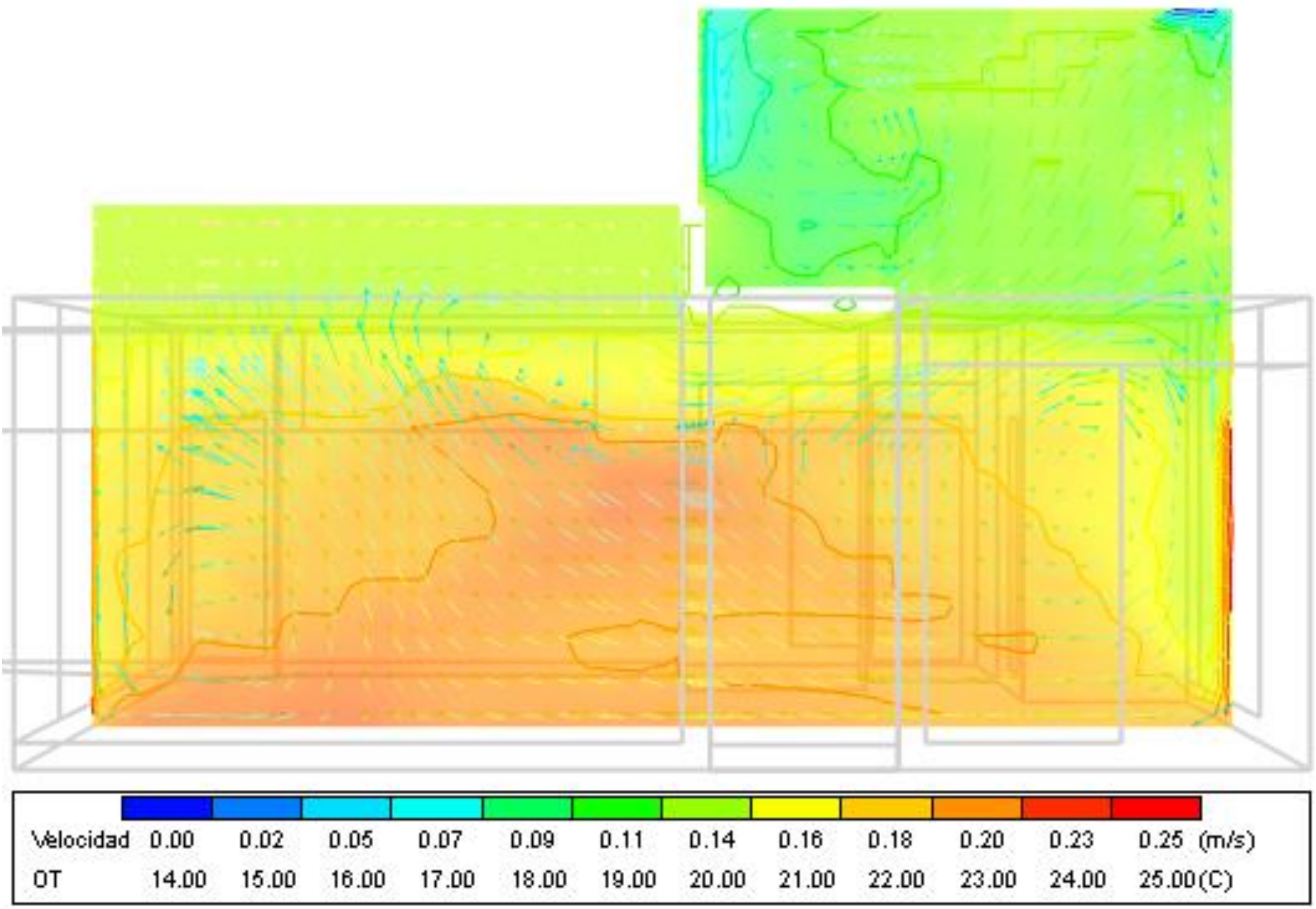
CFD analysis: Floor at **20** ºC



CFD analysis: Floor at **25** ºC



CFD analysis: Floor at **30** ºC



Conclusions

DesignBuilder allows to model, simulate and evaluate solar thermal systems coupled with DWH and/or HVAC systems. Its main advantages are:

- Latest **EnergyPlus** version as simulation engine.
- Relatively **easy configuration** of **detailed HVAC** Systems (user friendly interface).
- Easy and reliable link between **HVAC system** and **3d model**, which allows to explore strategies to optimize both together.

Some limitations:

- Uses performance coefficients to describe solar collectors. It's not possible to model this devices in a very detailed way.
- Just tubular and glazed/unglazed flat plate collectors available at the moment.

Practical session

Download and install the latest **Release** version of DesignBuilder from:

www.designbuilder.co.uk

(You have to register in order to download and use the free 30 day trial license).

Bring your computer with DesignBuilder installed and functioning!

Thanks for your attention!