Modeling Solar Thermal Systems with DesignBuilder

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August 01 2014

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What is DesignBuilder?

DesignBuilder is a software focused on buildings energy and environmental analysis. It comprises a core **3-D modeler** and 9 analysis modules:

- **Visualization** - Rendered images and site shading analysis.
- **Certification** - EPCs and Part-L2 calculations in UK and Ireland.
- **Simulation** - **EnergyPlus** simulations for energy and environmental analyses.
- **Daylighting** - Reports daylight factors and iluminance using **Radiance**.
- **HVAC** - A graphical interface to model detailed **EnergyPlus** HVAC systems.
- **Cost** - Early stage building cost estimation.
- **LEED** - LEED EAp2 and ASHRAE 90.1 calculations.
- **Optimization** - Multi-criteria optimization based on evolutional algorithms.
- **CFD** - Computational Fluid Dynamics for detailed environmental analysis.

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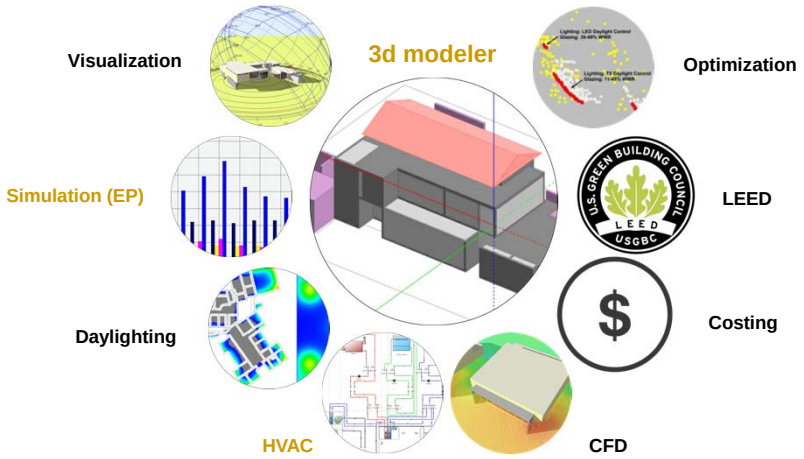
Modular approach of DesignBuilder



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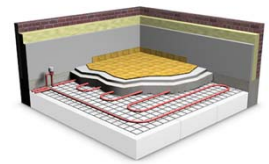
Case of study: STS applied to a heated floor system



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

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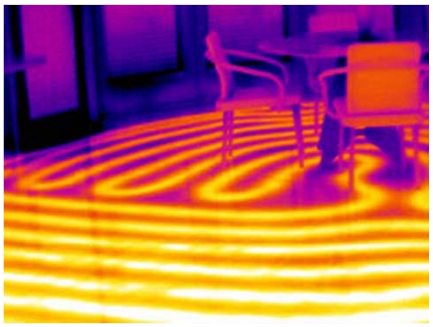
DesignBuilder-EnergyPlus heated floor model



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

- 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, GSHP and/or solar thermal systems.

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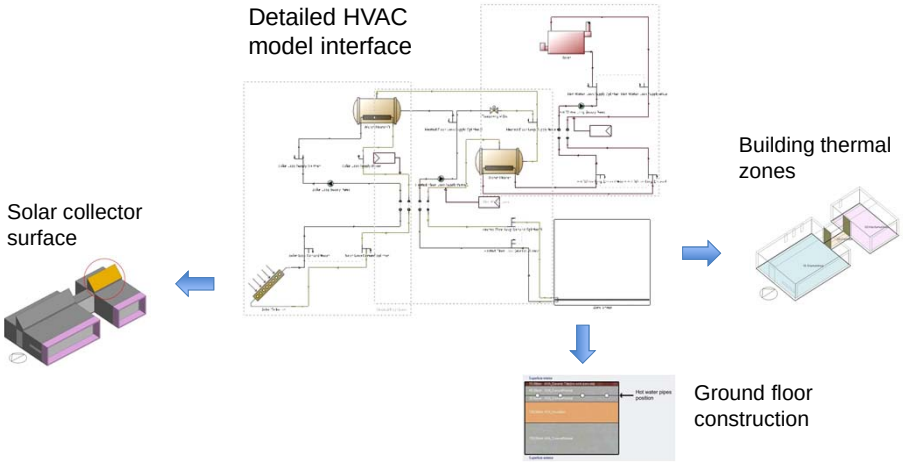
General modelling approach



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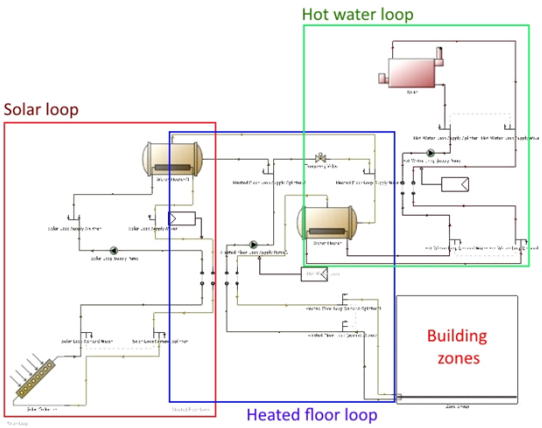
Detailed HVAC model: general scheme



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.

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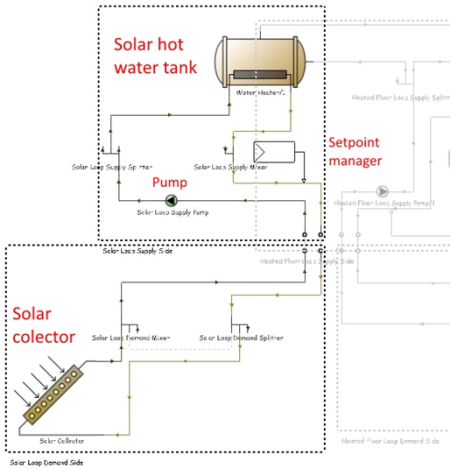
Detailed HVAC model: solar loop



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.

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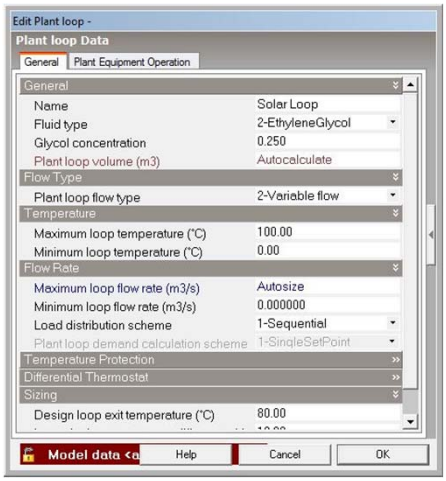
Solar loop data



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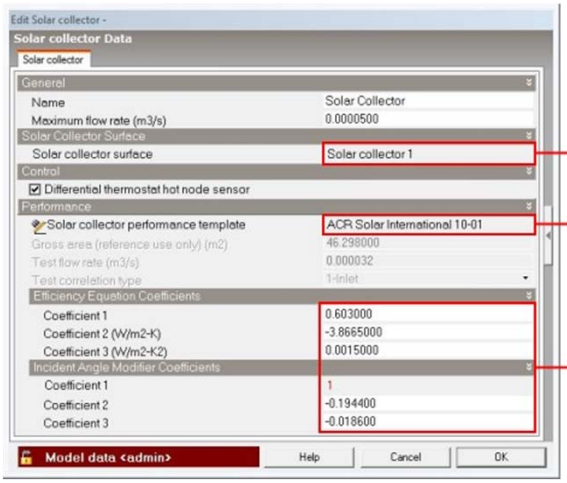
Solar collector data



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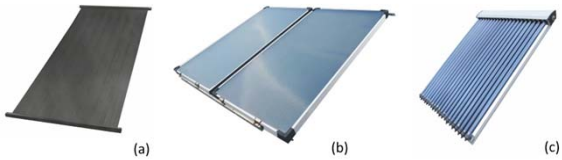
Solar collector object

The **EnergyPlus** solar collector model is based on the equations found in the ASHRAE standards and 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 the 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).



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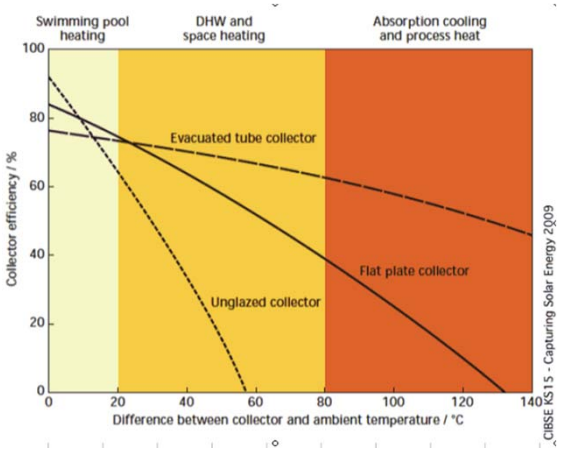
Efficiency and applications of solar collector types



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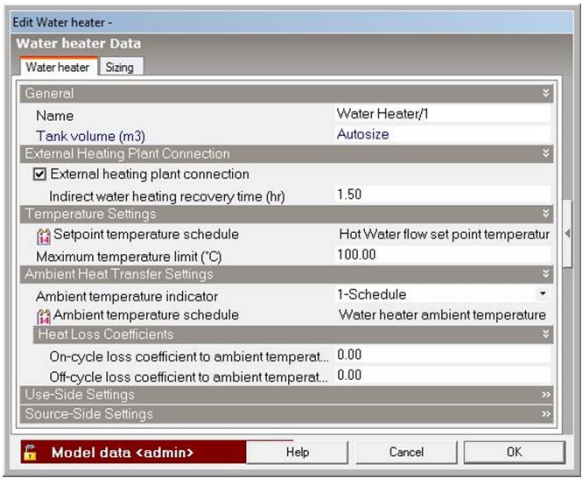
Solar hot water tank data



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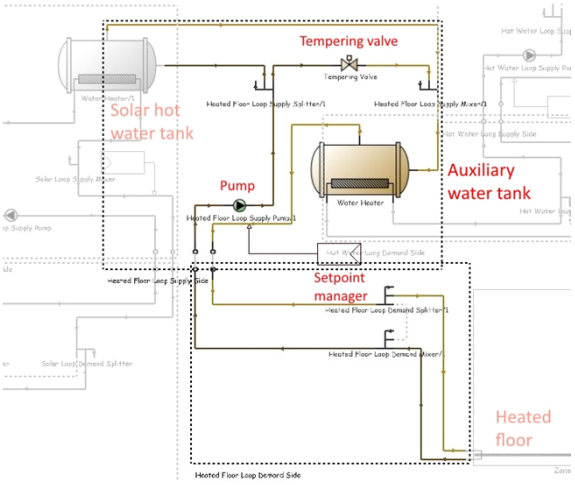
Detailed HVAC model: heated floor loop



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. In this case it is modeled as a standard tanked water heater 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.

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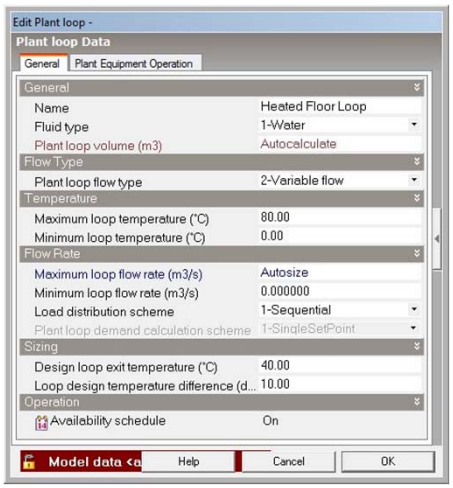
Heated floor loop data



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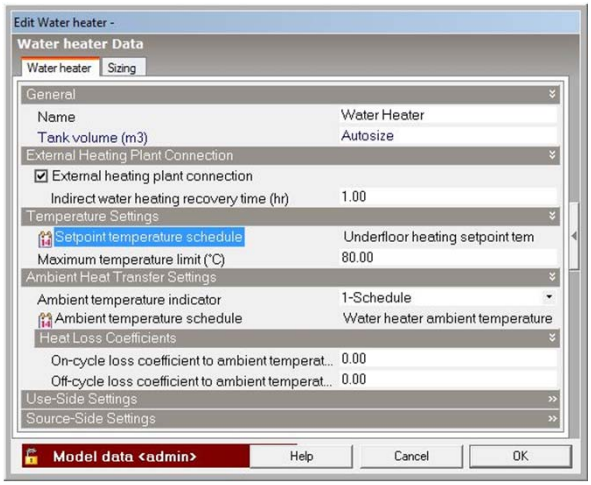
Auxiliary water tank data



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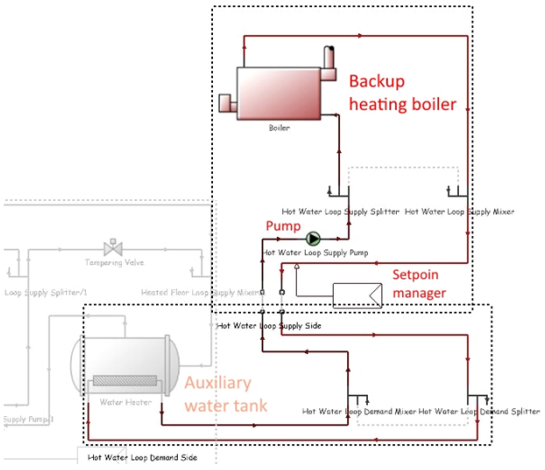
Detailed HVAC model: hot water loop



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

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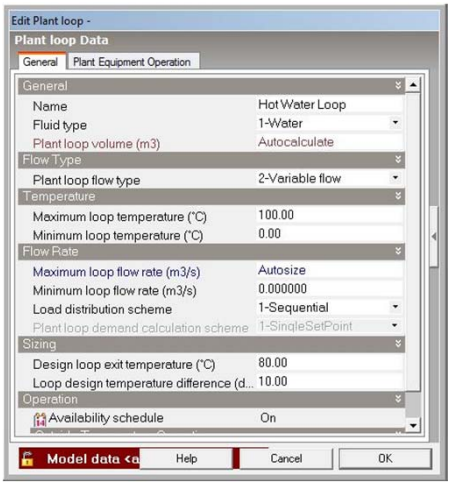
Hot water loop data



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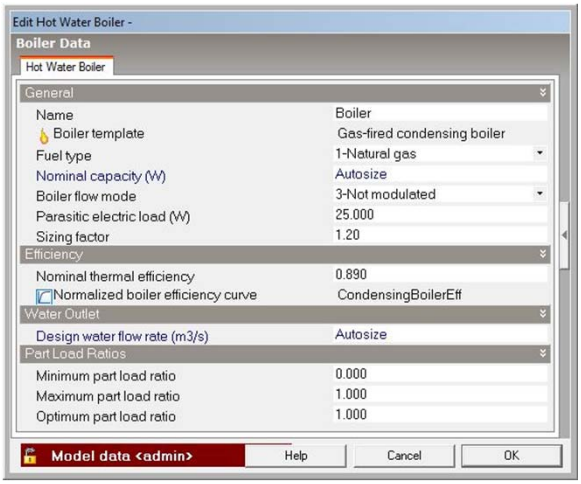
Backup heating boiler data



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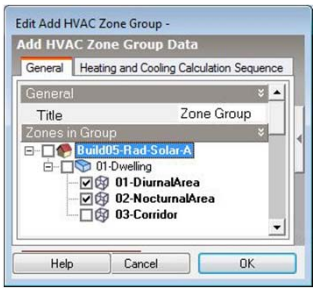
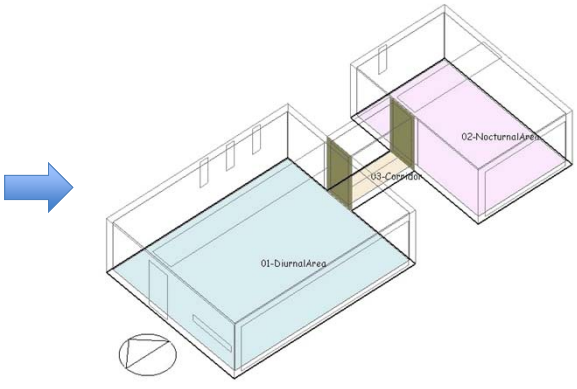
Link to the 3d model: thermal zones





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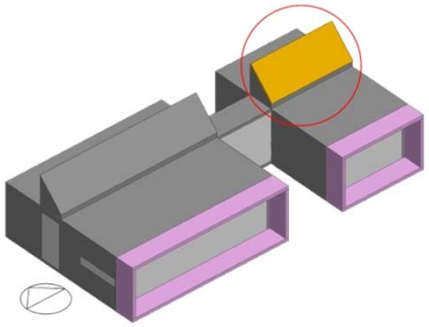
Link to the 3d model: solar collector **surface**

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:

- Solar radiation incident includes **beam** and **diffuse radiation**, as well as radiation reflected from adjacent surfaces.
- **Shading** of the collector by other surfaces, such as nearby buildings, is also taken into account.
- Likewise, the collector surface can shade other surfaces (i.e. reducing the incident radiation on the roof).



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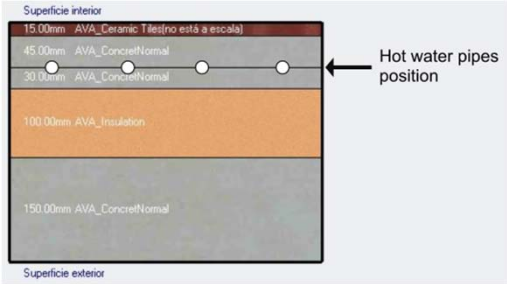
Link to the 3d model: ground floor constructions



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

- In 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.

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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**, which 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.

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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**.
- **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.

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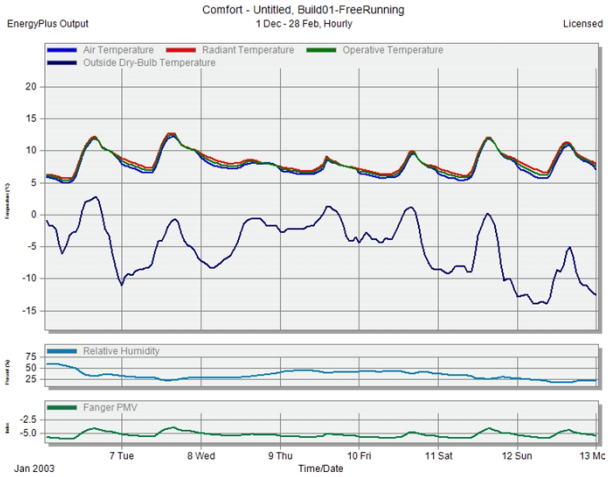
Simulation results



Zone temperatures, free running.

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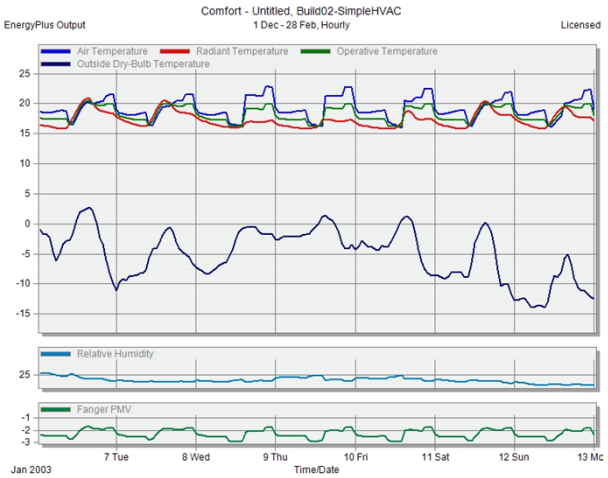
Simulation results



Zone temperatures, simple HVAC.

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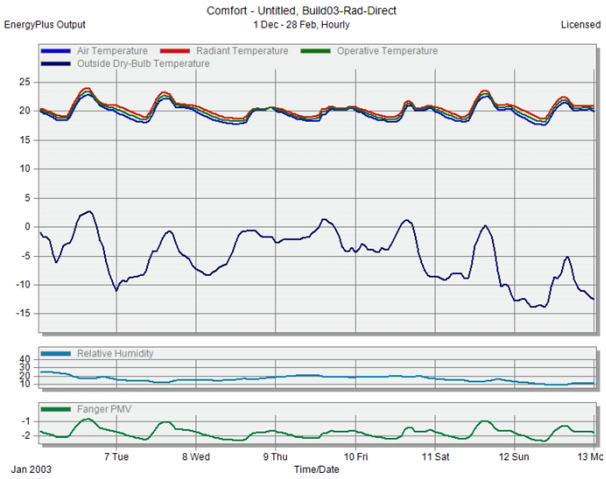
Simulation results



Zone temperatures, heated floor.

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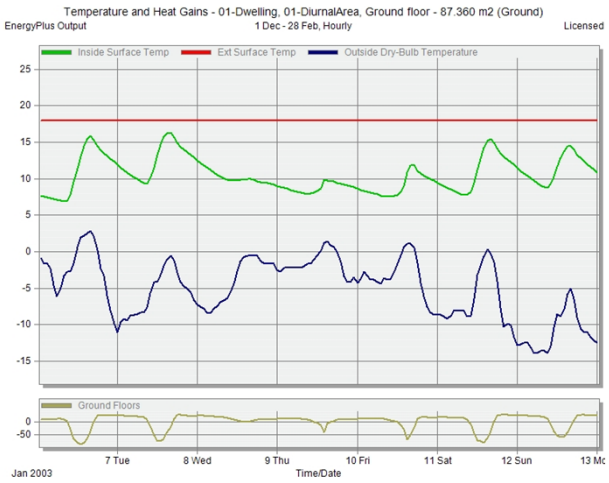
Simulation results



Floor surface temperature, Free running.

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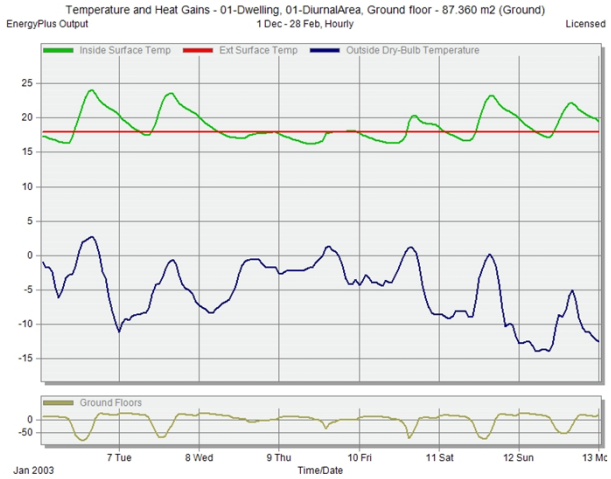
Simulation results



Floor surface temperature, Simple HVAC.

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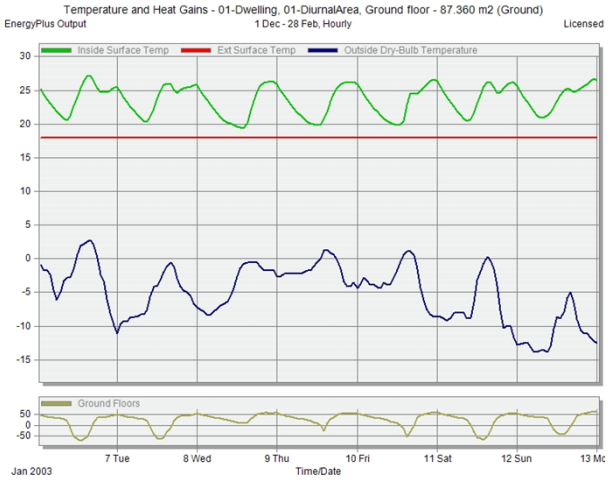
Simulation results



Floor surface temperature, Heated floor.

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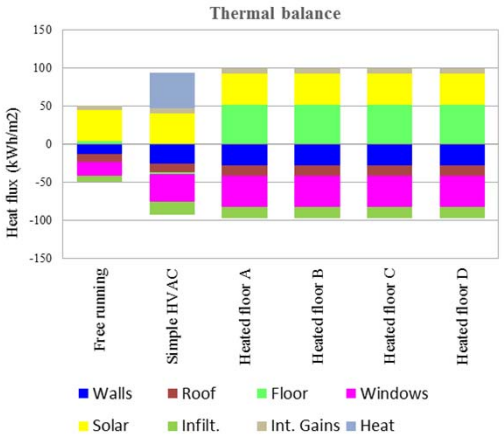
Simulation results



Building thermal balance during the simulation period.

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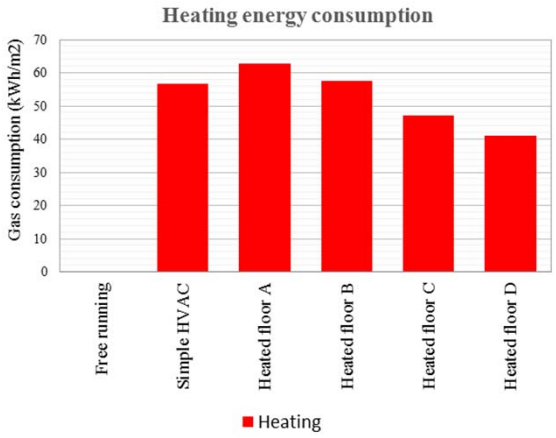
Simulation results



Building heating energy consumption during the simulation period.

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Conclusions

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

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

Some limitations of the software:

- Not suitable for modeling innovative, non-standard, solar thermal systems.
- 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.

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