



European Cooperation in the field of Scientific and Technical Research



Building Integration of Solar Thermal Systems – TU1205 – BISTS

Modeling Solar Thermal Systems with DesignBuilder

Ms. Arch. Arturo Ordóñez García

Universidad Rovira i Virgili, Tarragona, Spain

August 01 2014



COST is supported by
the EU RTD Framework Programme

ESF provides the COST Office
through an EC contract



European Cooperation in the field of Scientific and Technical Research

Building Integration of Solar Thermal Systems – TU1205 – BISTS



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 illuminance 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 evolutionary algorithms.
- **CFD** - Computational Fluid Dynamics for detailed environmental analysis.

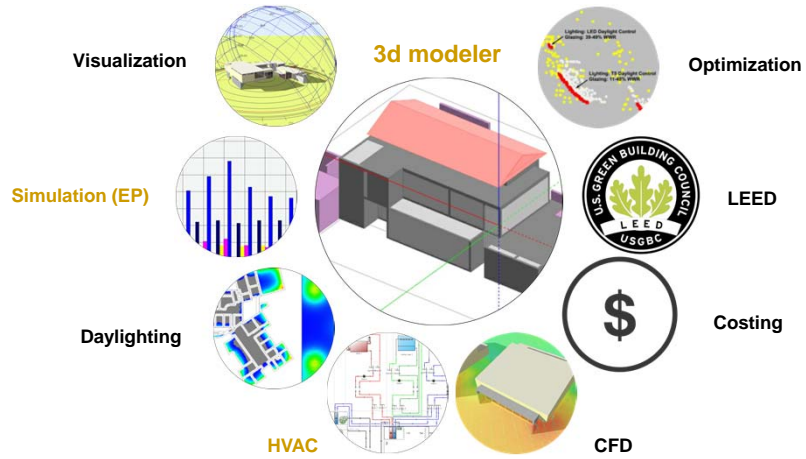


COST is supported by
the EU RTD Framework Programme

ESF provides the COST Office
through an EC contract



Modular approach of DesignBuilder

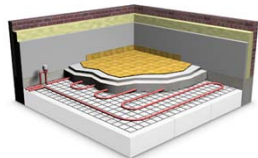


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Case of study: STS applied to a heated floor system



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

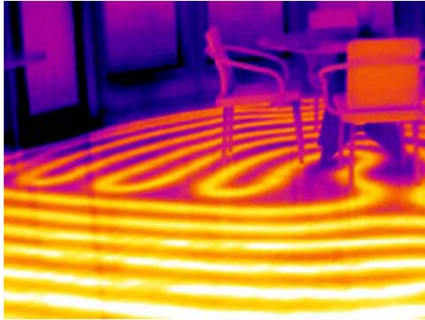


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



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 °C).
- 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.

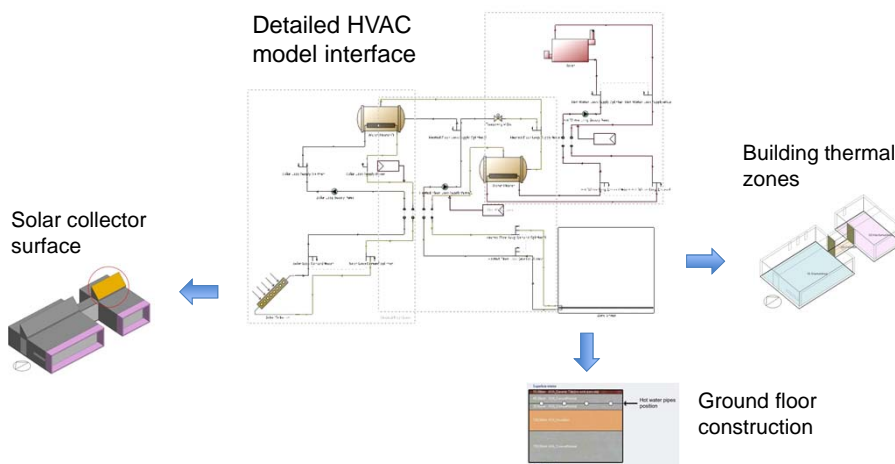


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



General modelling approach

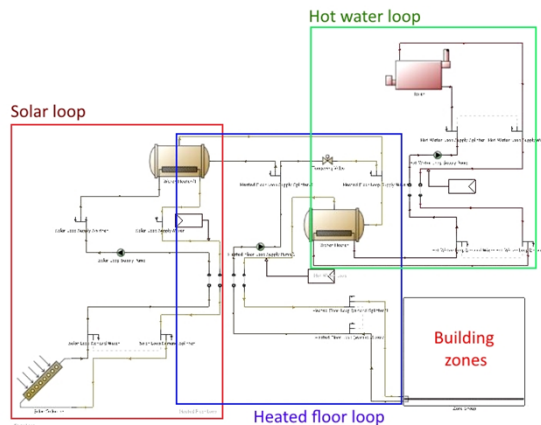


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



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.

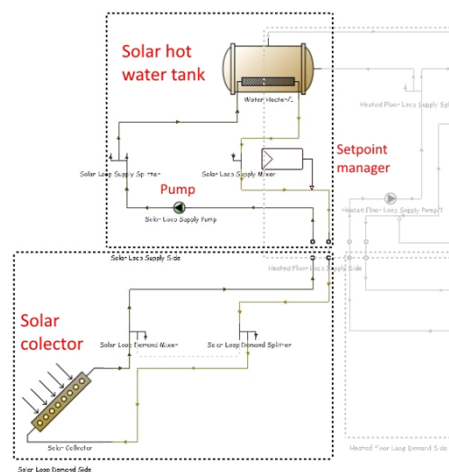


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



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.



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Solar loop data

Field	Value
Name	Solar Loop
Fluid type	2-EthyleneGlycol
Glycol concentration	0.250
Plant loop volume (m3)	Autocalculate
Plant loop flow type	2-Variable flow
Maximum loop temperature (°C)	100.00
Minimum loop temperature (°C)	0.00
Maximum loop flow rate (m3/s)	Autosize
Minimum loop flow rate (m3/s)	0.000000
Load distribution scheme	1-Sequential
Plant loop demand calculation scheme	1-SingleSetPoint
Design loop exit temperature (°C)	80.00

Solar collector data

Field	Value
Name	Solar Collector
Maximum flow rate (m3/s)	0.0000500
Solar collector surface	Solar collector 1
Solar collector performance template	ACR Solar International 10-01
Gross area (m2)	46.298000
Test flow rate (m3/s)	0.000032
Efficiency Equation Coefficients	
Coefficient 1	0.603000
Coefficient 2 (W/m2-K)	-3.8665000
Coefficient 3 (W/m2-K2)	0.0015000
Incident Angle Modifier Coefficients	
Coefficient 1	1
Coefficient 2	-0.194400
Coefficient 3	-0.018600

Link to the solar collector surface in the 3d model

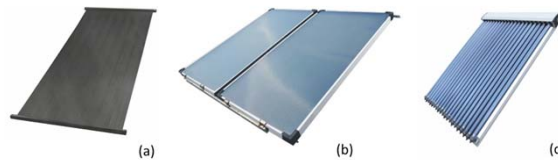
Selection of solar collector type

Solar collector performance data (from template)

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).

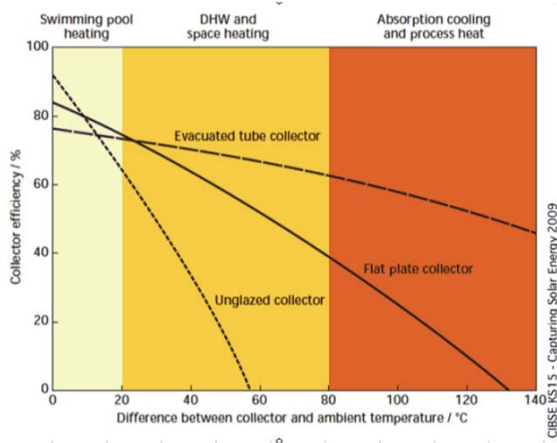


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Efficiency and applications of solar collector types



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Solar hot water tank data

Edit Water heater -

Water heater Data

Water heater | Sizing

General	
Name	Water Heater/1
Tank volume (m3)	Autosize
External Heating Plant Connection	
<input checked="" type="checkbox"/> External heating plant connection	
Indirect water heating recovery time (hr)	1.50
Temperature Settings	
Setpoint temperature schedule	Hot Water flow set point temperatur
Maximum temperature limit (°C)	100.00
Ambient Heat Transfer Settings	
Ambient temperature indicator	1-Schedule
Ambient temperature schedule	Water heater ambient temperature
Heat Loss Coefficients	
On-cycle loss coefficient to ambient temperat...	0.00
Off-cycle loss coefficient to ambient temperat...	0.00
Use-Side Settings	
Source-Side Settings	

Model data <admin> Help Cancel OK

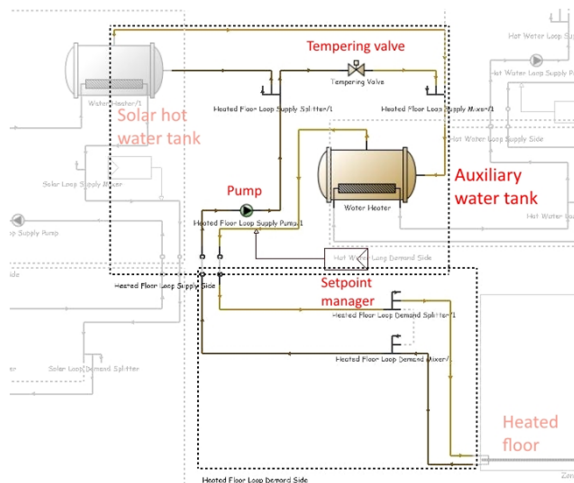


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



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.



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Heated floor loop data

Edit Plant loop -

Plant loop Data

General Plant Equipment Operation

General

Name	Heated Floor Loop
Fluid type	1-Water
Plant loop volume (m3)	Autocalculate
Flow Type	
Plant loop flow type	2-Variable flow
Temperature	
Maximum loop temperature (°C)	80.00
Minimum loop temperature (°C)	0.00
Flow Rate	
Maximum loop flow rate (m3/s)	Autosize
Minimum loop flow rate (m3/s)	0.000000
Load distribution scheme	1-Sequential
Plant loop demand calculation scheme	1-SingleSetPoint
Sizing	
Design loop exit temperature (°C)	40.00
Loop design temperature difference (d...)	10.00
Operation	
Availability schedule	On

Model data <admin> Help Cancel OK



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Auxiliary water tank data

Edit Water heater -

Water heater Data

Water heater Sizing

General

Name	Water Heater
Tank volume (m3)	Autosize
External Heating Plant Connection	
<input checked="" type="checkbox"/> External heating plant connection	
Indirect water heating recovery time (hr)	1.00
Temperature Settings	
<input checked="" type="checkbox"/> Setpoint temperature schedule	Underfloor heating setpoint tem
Maximum temperature limit (°C)	80.00
Ambient Heat Transfer Settings	
Ambient temperature indicator	1-Schedule
<input checked="" type="checkbox"/> Ambient temperature schedule	Water heater ambient temperature
Heat Loss Coefficients	
On-cycle loss coefficient to ambient temperat...	0.00
Off-cycle loss coefficient to ambient temperat...	0.00
Use-Side Settings	
Source-Side Settings	

Model data <admin> Help Cancel OK

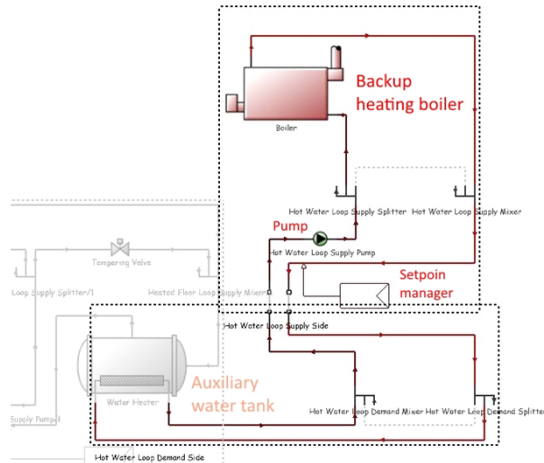


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Detailed HVAC model: hot water loop



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



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Hot water loop data



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Backup heating boiler data

Edit Hot Water Boiler -
Boiler Data

Hot Water Boiler

General	
Name	Boiler
Boiler template	Gas-fired condensing boiler
Fuel type	1-Natural gas
Nominal capacity (W)	Autosize
Boiler flow mode	3-Not modulated
Parasitic electric load (W)	25.000
Sizing factor	1.20

Efficiency	
Nominal thermal efficiency	0.890
<input checked="" type="checkbox"/> Normalized boiler efficiency curve	CondensingBoilerEff

Water Outlet	
Design water flow rate (m3/s)	Autosize

Part Load Ratios	
Minimum part load ratio	0.000
Maximum part load ratio	1.000
Optimum part load ratio	1.000

Model data <admin> Help Cancel OK

Link to the 3d model: thermal zones

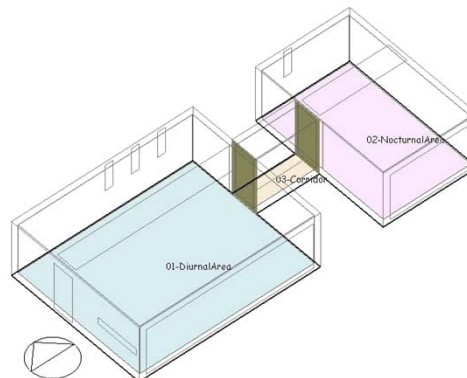
Edit Add HVAC Zone Group -
Add HVAC Zone Group Data

General Heating and Cooling Calculation Sequence

General	
Title	Zone Group

Zones in Group

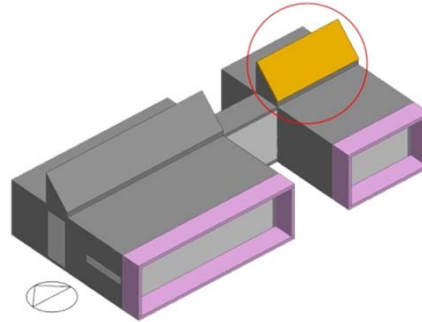
- Build05-Rad-Solar-A
 - 01-Dwelling
 - 01-DiurnalArea
 - 02-NocturnalArea
 - 03-Corridor



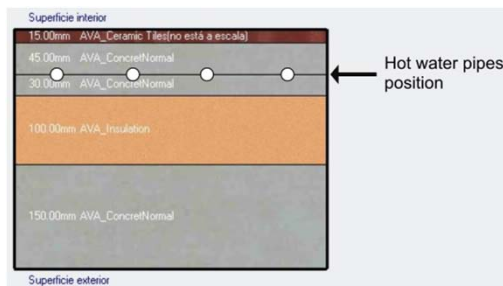
Link to the 3d model: solar collector **surface**

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).



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”.

- 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**, 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.



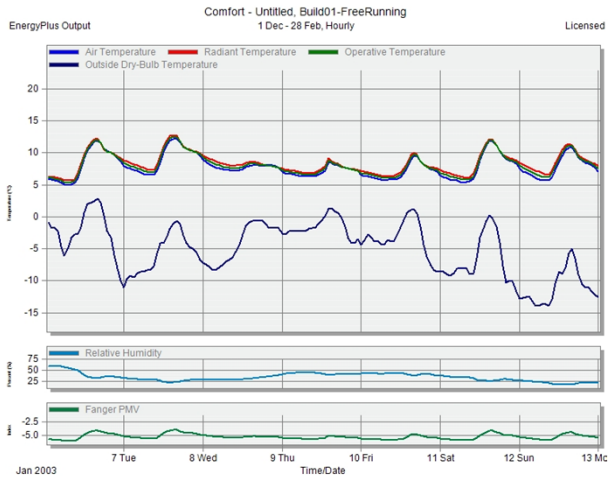
Simulation results

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 m² surface area.
- **Heated floor C:** Solar thermal system. Glazed flat plate collector, 23.53 m² surface area.
- **Heated floor D:** Solar thermal system. Evacuated tubes collector, 23.53 m² surface area.



Simulation results



Zone temperatures, free running.

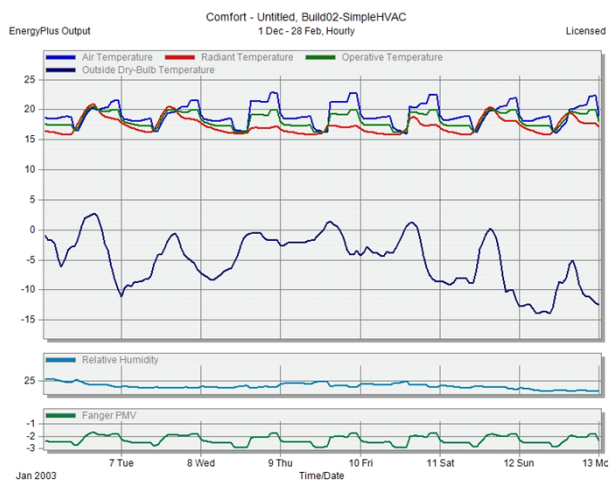


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Simulation results



Zone temperatures, simple HVAC.

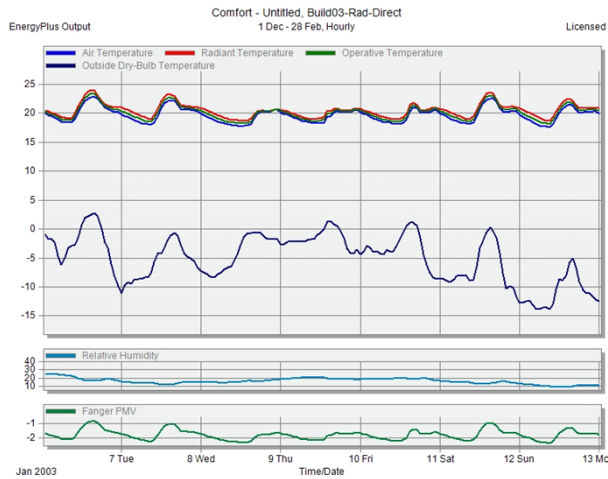


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Simulation results



Zone temperatures,
heated floor.

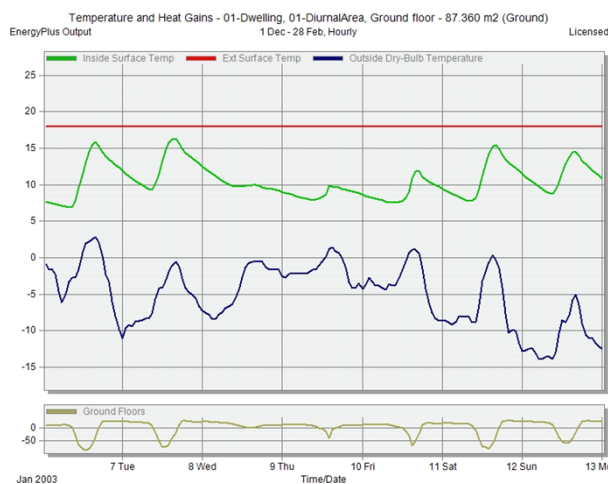


COST is supported by
the EU RTD Framework Programme

ESF provides the COST Office
through an EC contract



Simulation results



Floor surface
temperature, Free
running.

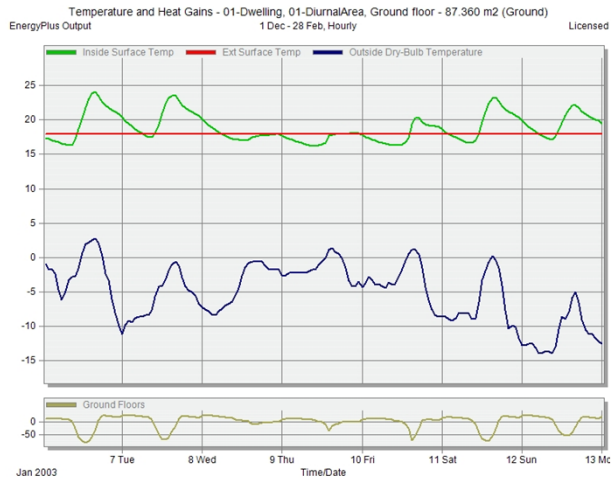


COST is supported by
the EU RTD Framework Programme

ESF provides the COST Office
through an EC contract



Simulation results



Floor surface temperature, Simple HVAC.

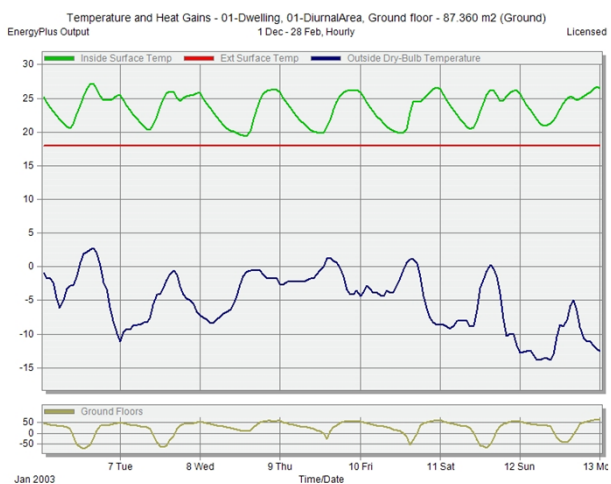


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Simulation results



Floor surface temperature, Heated floor.

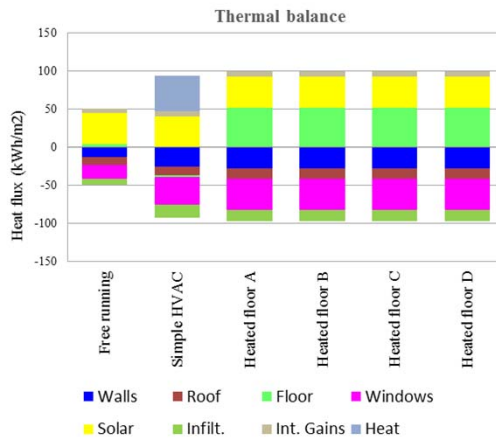


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Simulation results



Building thermal balance during the simulation period.

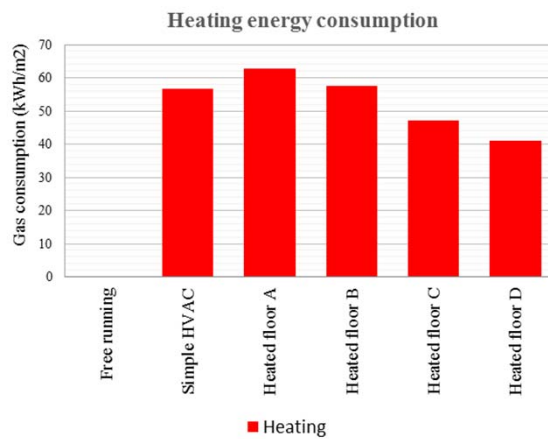


COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract



Simulation results



Building heating energy consumption during the simulation period.



COST is supported by the EU RTD Framework Programme

ESF provides the COST Office through an EC contract





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.



Thanks for your attention!

