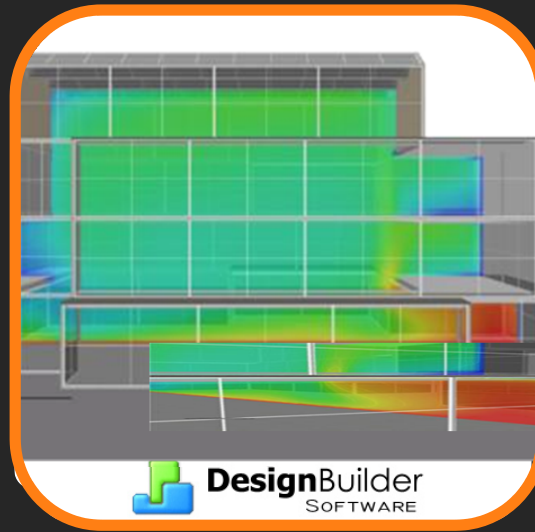




Building Performance Simulation for Designers - Energy
DesignBuilder // EnergyPlus
‘Tutorial #2’
Load Schedules



GEOMETRY



LOADS



RESULTS





OVERVIEW

- This document is the second document of a series of tutorials created as a guide for building energy performance simulation beginners. Its focus audience are designers interested in studying the effect of early design decisions such as orientation, shape and façade layout on the energy efficiency of their projects. Throughout the document we will be using DesignBuilder/ EnergyPlus as our simulation tool.



OVERVIEW

This specific document, 'Tutorial #2 – Load Schedules', will help you to develop and quantitative understanding of:

- The impact of occupants and other internal loads on indoor environmental conditions in a non-air conditioned space;
- The impact of occupants and other internal loads on the energy demand of a fully conditioned space;
- The value of the “shoe-box” modeling approach to compare basic energy conservation measures (ECM's).



SET - UP

In case you do not have DesignBuilder already installed on your computer, please refer to the first document of this tutorial series. In that document you will find all the instructions required to set-up DesignBuilder on your computer. Make sure to pay close attention to all the steps and execute them carefully.



| **DesignBuilder™** |

You may download a FREE 30-day evaluation version of the latest DesignBuilder version from the 'DesignBuilder Software' website. This document is based on **DesignBuilder v.1.6.9.0003 BETA** (release date: 09/26/08).

<http://www.designbuilder.co.uk>

INFO

DesignBuilder Software requires you to provide some general information about yourself before you can download the evaluation version. You must be logged in before attempting to download. If you do not have a login and password, you will have to register first.



INDEX

- THE SHOW-BOX MODEL
- SETTING INTERNAL LOADS
- SIMULATIONS
- ANALYZE RESULTS

INFO

It is recommended that you work through the four sections in the order provided. Further information can be accessed through **// links /**distributed throughout the text.



SHOEBOX MODEL

- Establishing an appropriate base case building is the first step in evaluating low-energy design and other sustainability strategies during the design process. Furthermore, goals for resource use and costs are set relative to the base case.
- This task can be difficult, because there is no universal approach. At the early stages of design, detailed knowledge of the building's energy systems is not available (nor is necessary to carry out exploratory energy performance studies). Early in the programming phase, the base case is often a building in the shape of a 'shoebox' with the same assumptions as those called for in the actual building program.



SHOEBOX MODEL

- A "Shoebox" energy model is an initial, oversimplified energy model of a building in which the actual building (or part of the building) is represented as a rectangular box. At this early point one should already work with actual climate data, building type, usage patterns, and utility rates for the projects (if known).
- The shoebox energy model especially valuable during the schematic design phase before the building form has been determined. It can be build very quickly and can therefore be used to inform early design decisions to optimize building energy performance.



SHOEBOX MODEL

- In this tutorial you will be working with a building model which was created according to the shoebox approach. This approach will allow us to quickly quantify the impact of load schedules for occupancy and other internal loads on the interior environmental conditions of a space.
- We will be using the same shoebox model in later tutorials while exploring the impact of other ECMs on the energy balance of a space. The assumption is that if (for example) evaporative cooling is effective for the shoebox model, it is likely to be effective for the actual building as well. Again, the intention is to be able to do a quick sensitivity study early on in the design when key design decisions are made.

INFO

The exact efficacy of measures in a shoe box model compared to a real-design depends on certain assumptions, such as, floor area, envelope surface, etc.



SHOEBOX MODEL

- Note that DesignBuilder has some useful preset building types ('Single Zone' and 'Parametric Building') to carry out quick 'shoebox' type energy studies in early stages of design. These building types can be found when selecting "insert new building".
- However, in this document we will not be using these templates as we intend to further build on the same model in future tutorials in order to better understand the interdependency of different design variable on the overall energy performance and indoor environmental conditions of a building.

INFO

The current version of DesignBuilder v1.6903 does not have the 'Parametric Building' modelling option fully operational.



SHOEBOX MODEL

We will be working with a file template especially set-up for this tutorial. You can download the template from the course website (follow the instructions detailed further in this document to start working using this template).

At the end of this section you should be able to:

- Understand the basis of a 'shoe-box' modeling approach.
- Understand the different indoor environmental conditions of a free-floating space and a fully conditioned space.

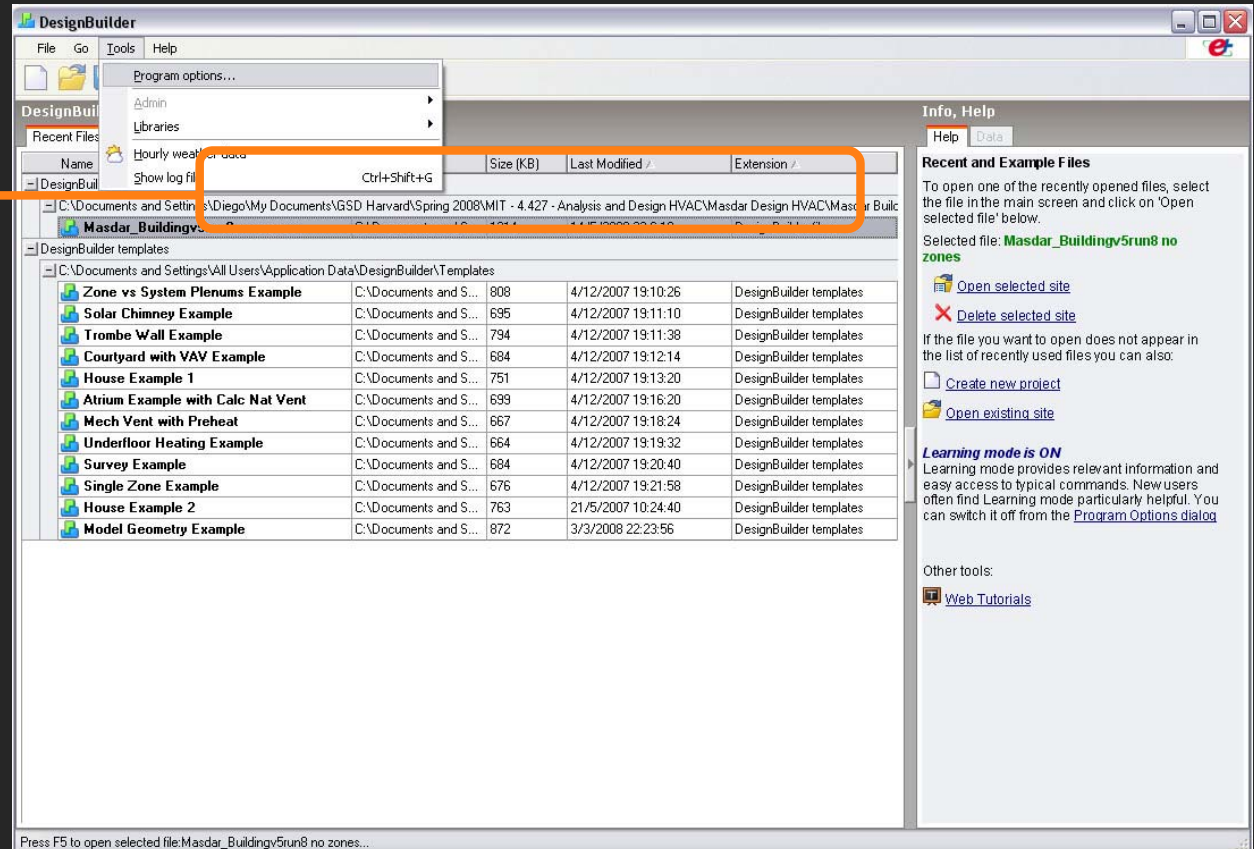


SHOEBOX MODEL

Selecting a Template

1.

From the course website, download the template named 'Energy.2.LoadSchedules' and save it to a folder of your choice on your PC (see INFO note). To open the file just start DB and you will find the template in the home screen.



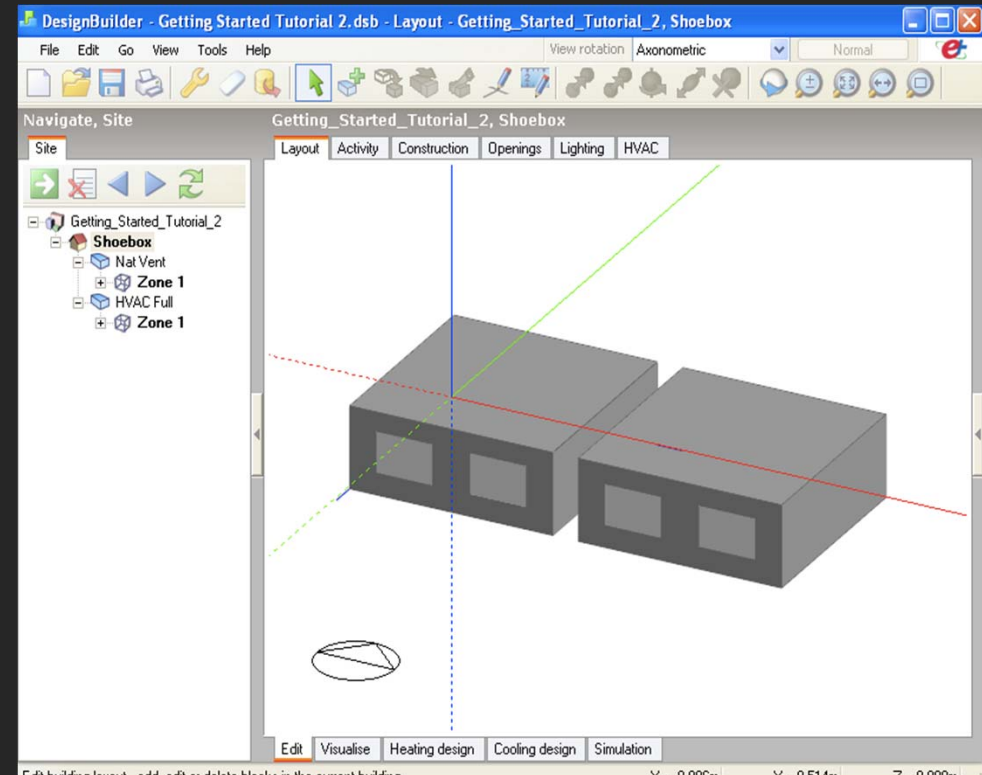
INFO

DesignBuilder will automatically search your machine for all .csb files. You may want to save the file to the default DB folder for templates c:/program files/designbuilder/data/templates



SHOEBOX MODEL

The template is composed by two shoebox-like spaces built as separate blocks under separate building type. (This is necessary to be able to later compare Fuel Breakdowns). Both spaces are 8.0m x 8.0m x 3.0m with all surfaces set as “adiabatic” (no heat transfer occurs), except for the south façade and ceiling. I.e. the model represents a top floor, south-facing perimeter space in a mid-sized building. No external obstructions are considered.



INFO

The roof was not set as an adiabatic surface to increase the impact of the envelope on the thermal behavior of the space. This way, when the optimization of the building envelope is investigated in ‘Tutorial 3 – Building Envelope’, the improvements of the thermal performance will be more noticeable.

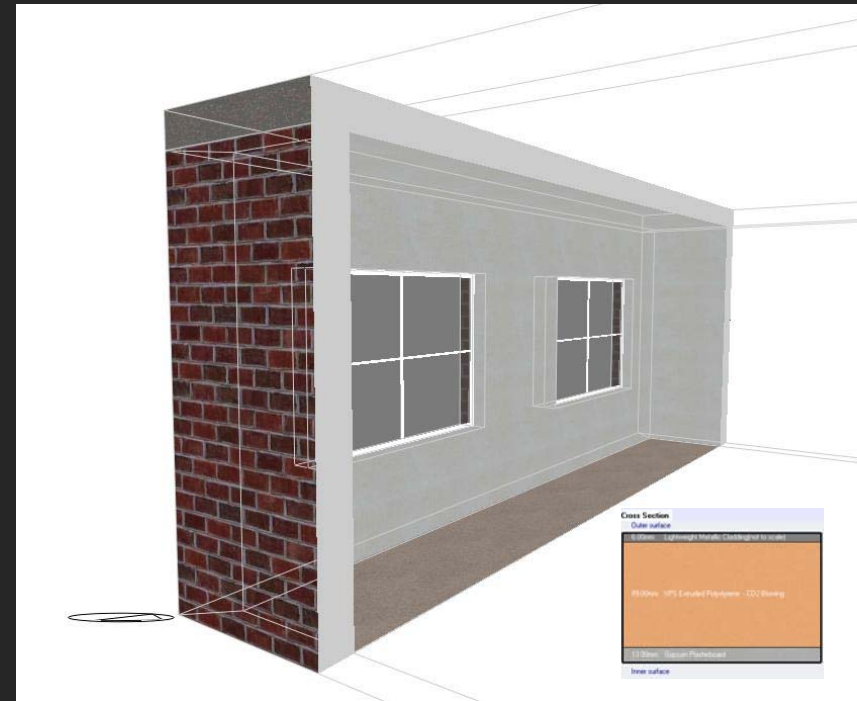


SHOEBOX MODEL

The construction properties in both spaces are set to 'IECC 1998'.

External Wall: 3 layers (13mm gypsum plasterboard, 89mm XPS extruded polystyrene and 6mm lightweight metallic cladding, U-value: 0,350 (W/m²K).

Exterior Glazing: generic single clear 6mm glazing, U-value: 6.121 (W/m²K)



INFO

Thermal properties of the construction are set to a 'low-market' standard for Boston's current construction practices to benefit the later understanding of the impact of envelope optimization. The envelope optimization will be carried out in 'Tutorial #3 – Building Envelope'.

For more information on the International Energy Conservation Code (IECC) go to <http://www.energycodes.gov>.



SHOEBOX MODEL

One shoebox space is set to be naturally ventilated and the other one is set to be fully conditioned (mechanically cooled and heated).

- The naturally ventilated space is set up so that the natural ventilation is activated (windows are opened) when the outside temperature is below the 'natural ventilation cooling point' of 24C.
- The fully conditioned space is set up so that the environmental set points (HVAC thermostat) is set to 20C for heating and 24C for cooling

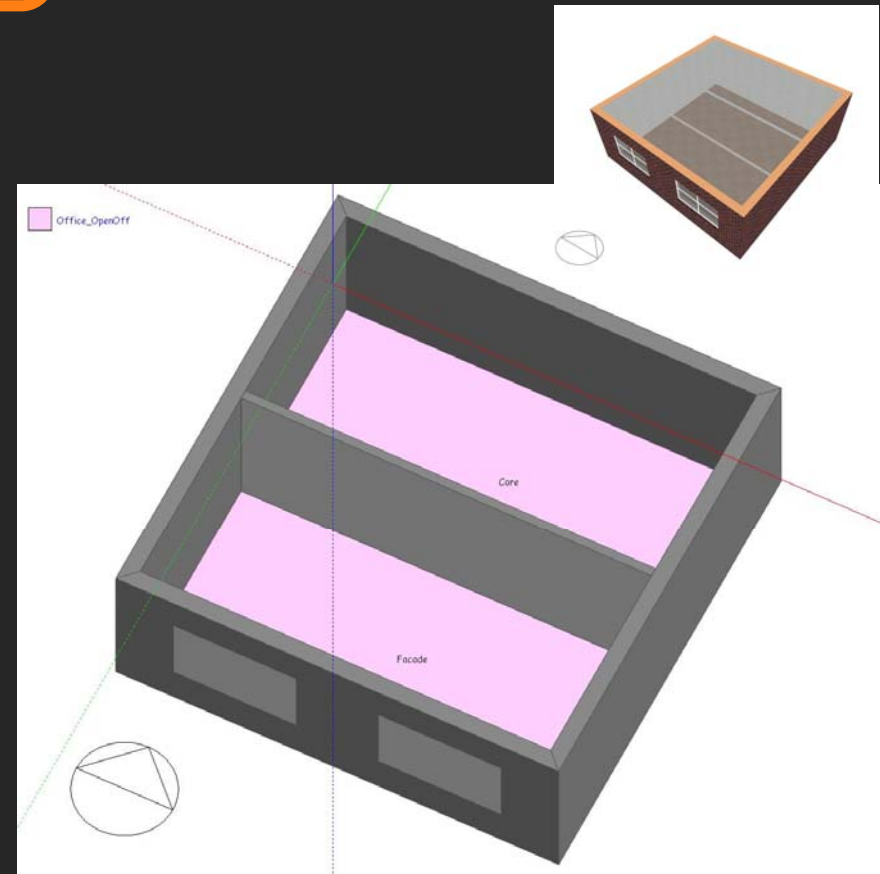
INFO

Note that when using the calculated natural ventilation model option windows and vents are only opened when: The inside air temperature is above this cooling set point temperature AND the inside air temperature is greater than the outside air temperature AND the operation schedule allows for ventilation.



SHOEBOX MODEL

Each space is ‘virtually’ subdivided in 2 symmetrical zones, a core zone and a façade zone. A virtual partition is used so that the local effect of the solar gain in the perimeter zone may be calculated. In the absence of virtual partitions, the risk of overheating could be underestimated due to the distribution of solar gain throughout the open plan space.



INFO

A virtual partition is an ‘air wall’ between 2 zones which is introduced to mathematically sub-divide the space, i.e. to tell EnergyPlus to solve the energy and mass equations for two separate areas within a larger open space. Virtual partitions are commonly used for separating perimeter zones from core zones, when there are to be different HVAC provisions within a space or when carrying out daylighting, solar overheating or comfort studies.



SIMULATIONS

Workflow:

1. First, you will run an annual simulation to review the thermal behavior and energy consumption of both structures without internal loads.
2. Then you will set-up the corresponding internal loads for both spaces and run an annual simulation again, this time to review how the thermal and energy profiles are affected.
3. Finally, you will run a cooling simulation for a design week period to review the internal environmental conditions of both conditioned and unconditioned spaces under extreme conditions



SIMULATIONS

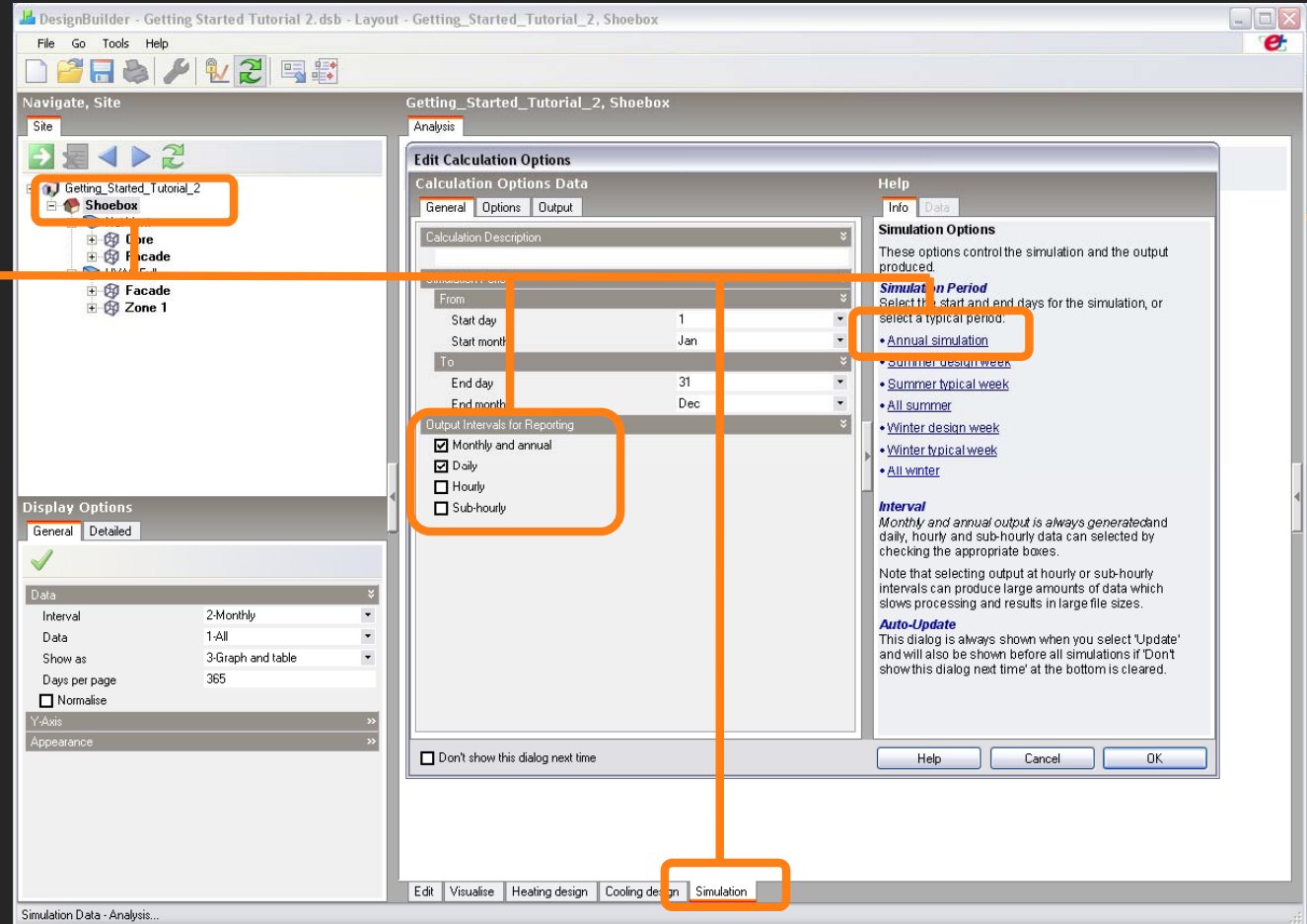
Running an annual simulation

2.

Run an annual simulation at the building level to compare the indoor environmental conditions and energy demand of both, unconditioned and fully conditioned spaces.

Note that at this point no internal loads are set up.

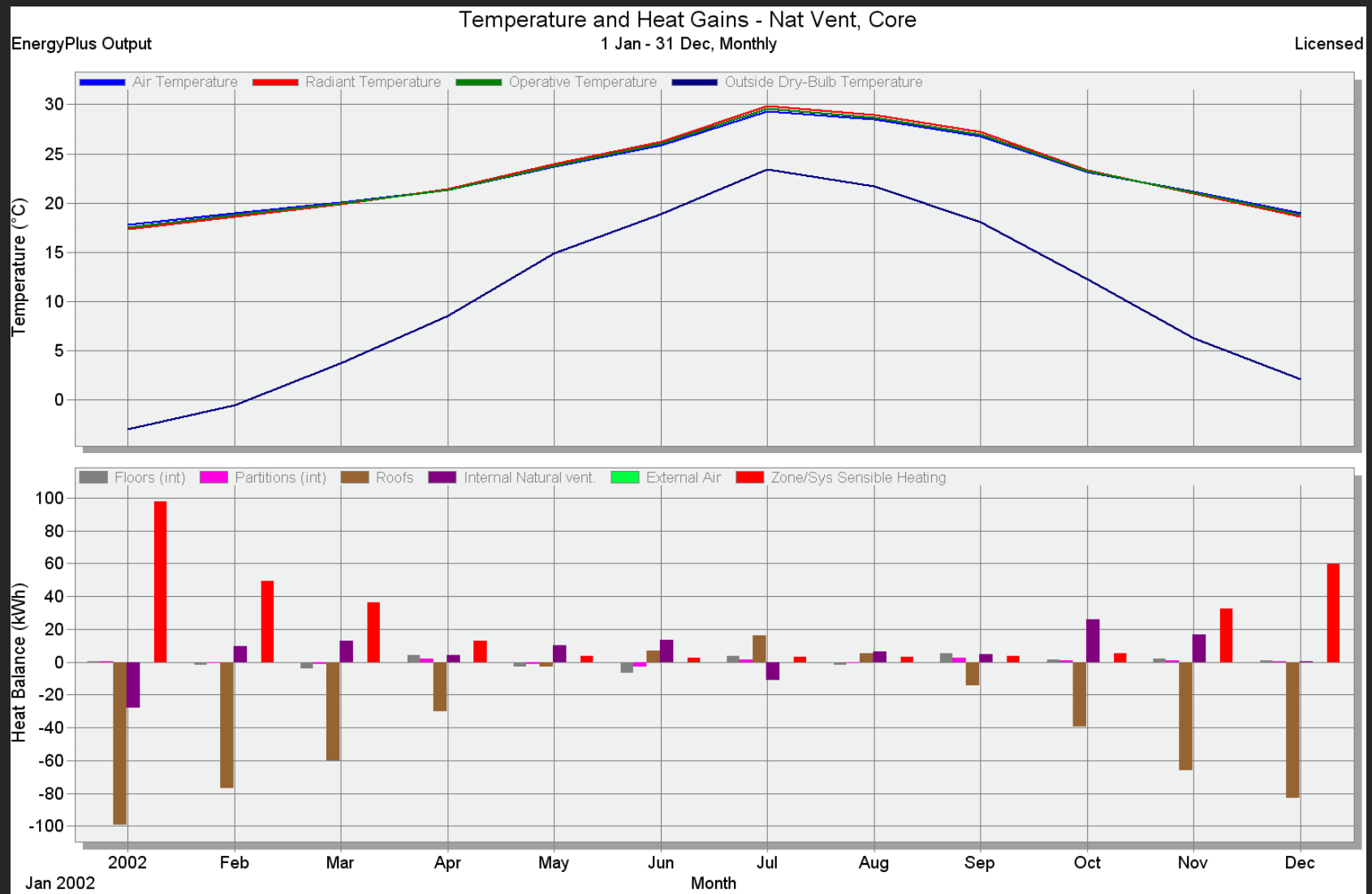
- No occupancy
- No artificial lighting
- No plug loads (computer, faxes, photocopy machines, task lights, etc)
- No natural ventilation (due to no occupants)





SHOEBOX MODEL

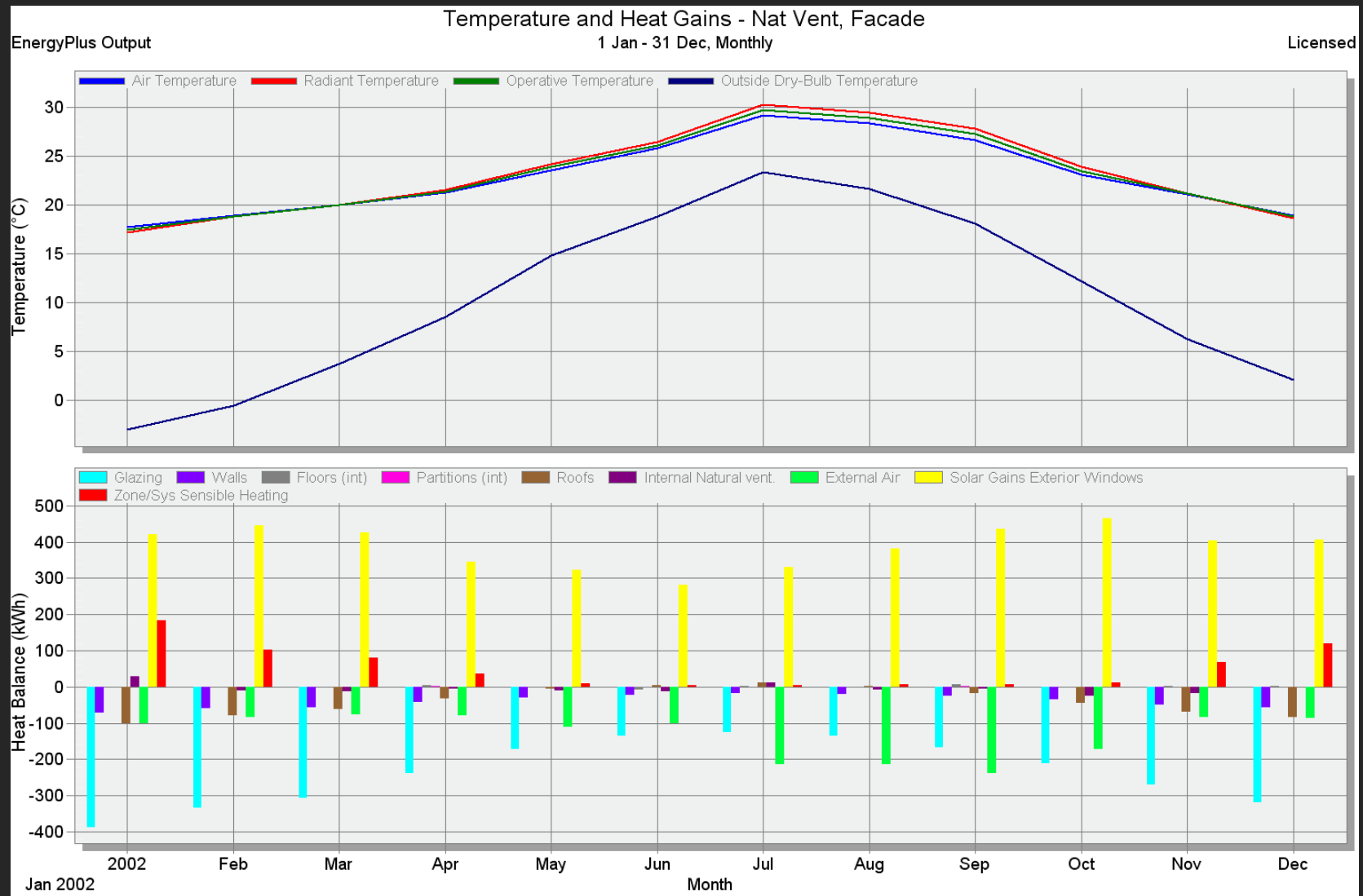
Results annual simulation – Naturally Ventilated Space: Core Zone





SHOEBOX MODEL

Results annual simulation – Naturally Ventilated Space: Perimeter Zone



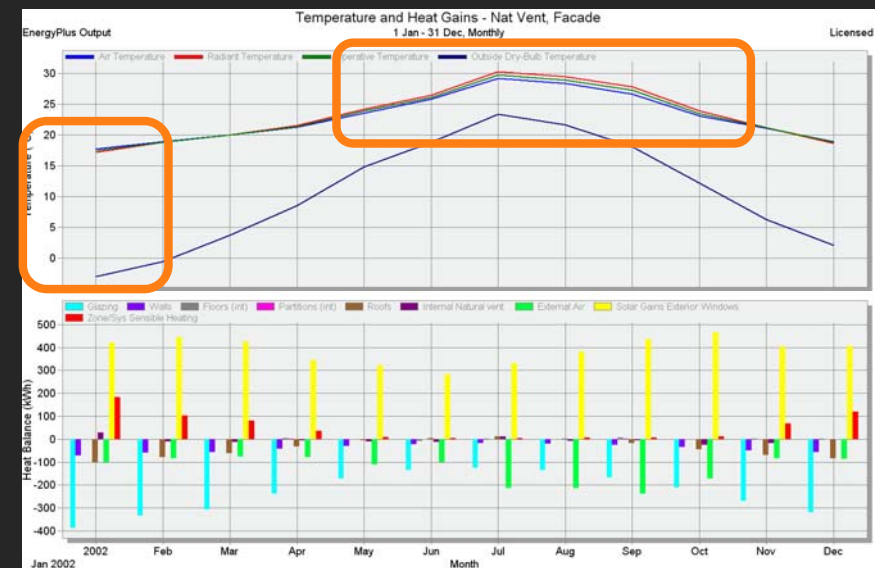


SHOEBOX MODEL

Results annual simulation – Naturally Ventilated Space

When comparing the internal environmental conditions of the ‘naturally ventilated’ core zone and façade zone:

- One can see that ‘free floating summer’ characteristic of the space (both zones), where the temperature rises over 35C. One can also see that this condition does not prevail in winter due to the intervention of heating. As a result the inside air temperature doesn’t drop below 18C. (The considered heating system is hot water radiator based.)
- In addition, one can see that both zones have almost the same comfort conditions (as expected since a virtual partition assumes air flow). One must note that this temperature is not in the comfort range with maximum temperature of 35C in the core and the façade zones.

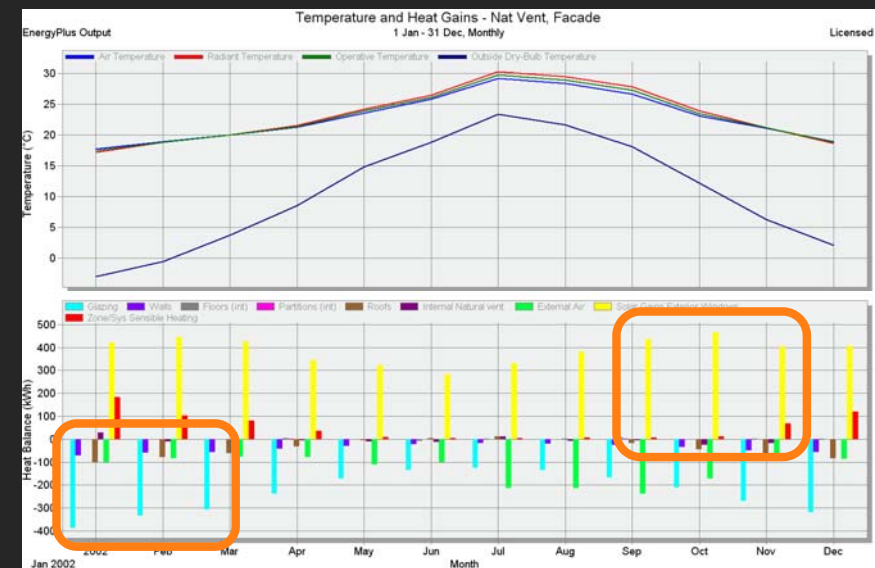




SHOEBOX MODEL

Results annual simulation – Naturally Ventilated Space

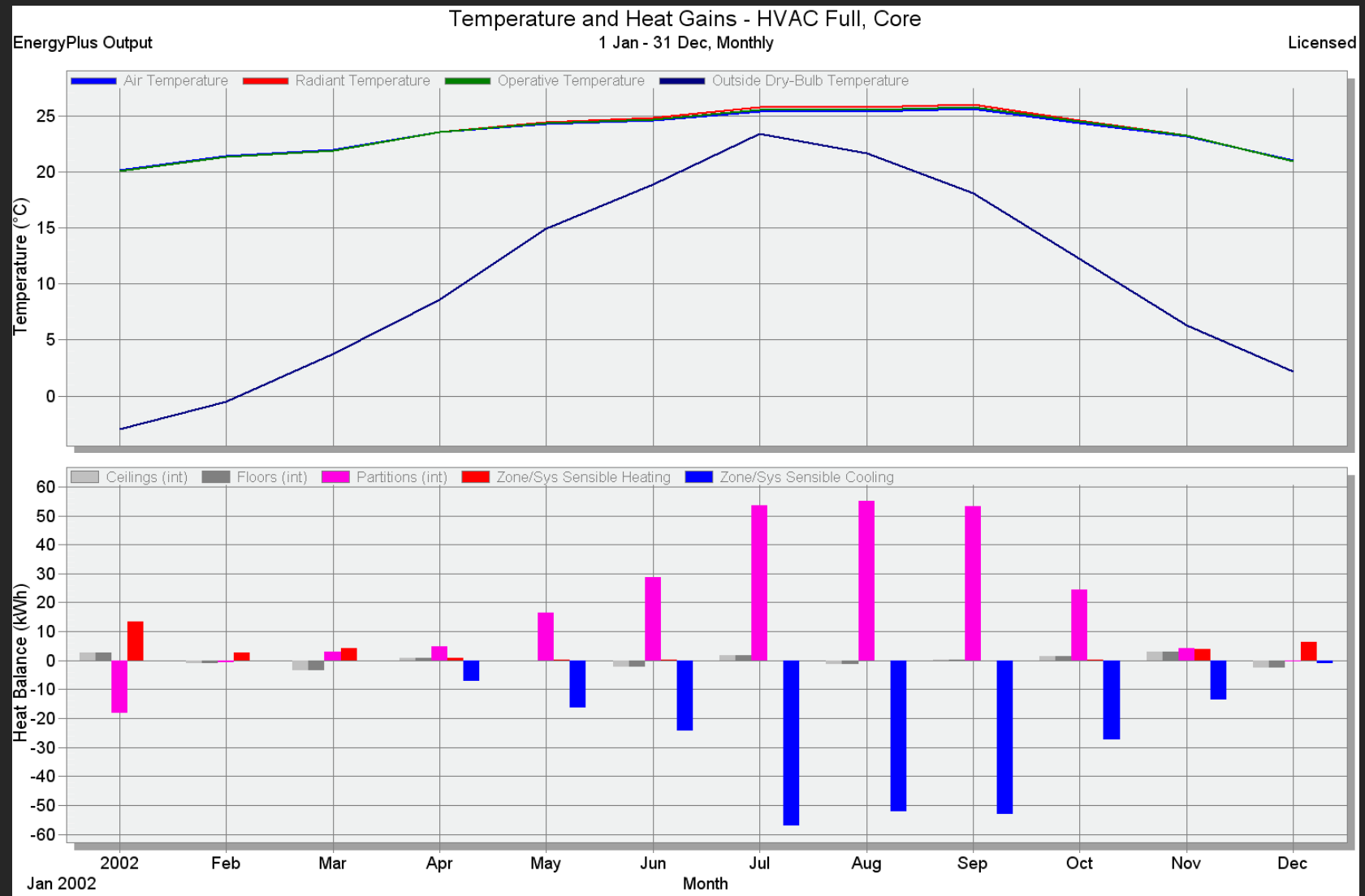
- In the heat balance, the core zone losses, as expected, occur mainly through the ceiling (-100kWh). The sum of the heat losses (roof and internal natural ventilation with the façade zone) are balanced by the heating system input. Some negligible energy gain/losses are observed due to the thermal mass of the floor and walls.
- The heat balance of the façade zones shows that the main energy gains are due to solar heat gains, with 281-465kWh. This gains are distributed along the whole year, with a small decrease during the summer due to the higher solar angle. At the same time, the window glazing is responsible for most of the heat losses, with a monthly peak of -387kWh in January.





SHOEBOX MODEL

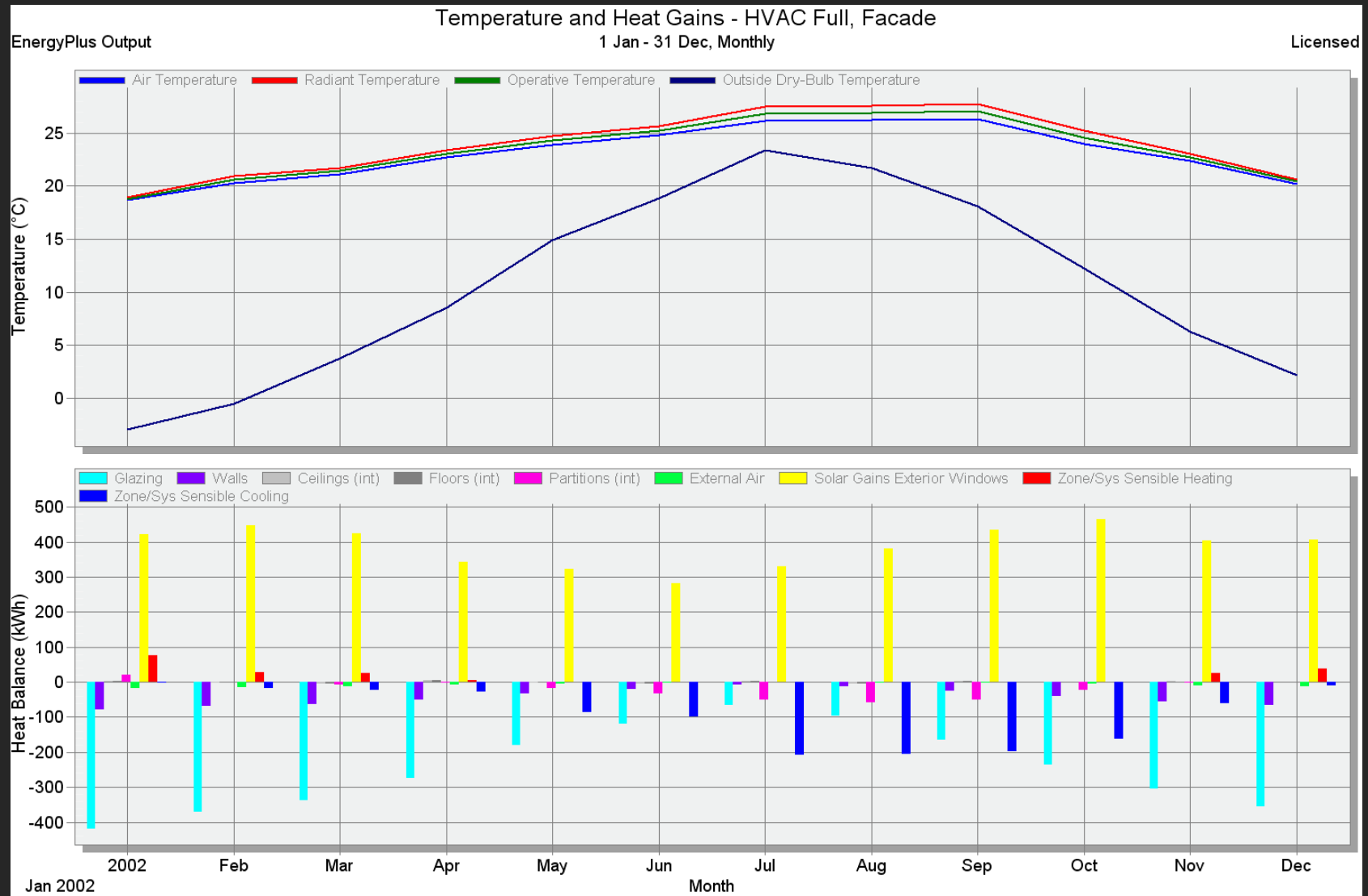
Results annual simulation – Fully Conditioned Space: Core zone





SHOEBOX MODEL

Results annual simulation – Fully Conditioned Space: Perimeter zone



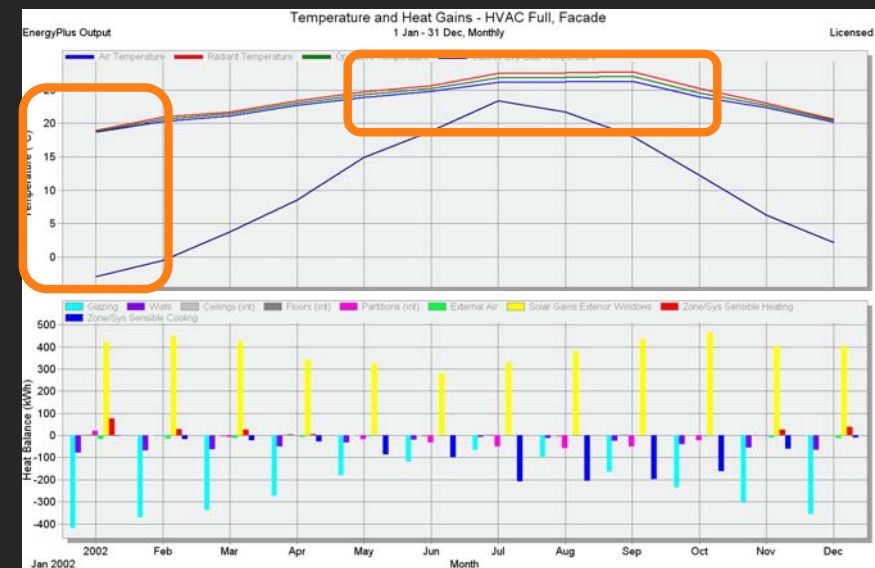


SHOEBOX MODEL

Results annual simulation – Fully Conditioned Space

When comparing the internal environmental conditions of fully conditioned core zone and façade zone:

- The ‘fully conditioned’ characteristic of the space (in both zone), is evident since the dry bulb air temperatures don’t rise over the 26C during the summer months and don’t drop down below 19C in winter.
- As in the naturally ventilated space, both zones, the core and façade, have almost the same comfort conditions (1.4C difference in winter). However, due to the cooler air temperatures (26C) one can see that the high surface temperature of the glazing in the south façade has a bigger impact in the operative temperature of the façade zone. In this space the operative temperature rises 0.76C compared to a rise of only 0.17C in the Nat Vent façade zone.

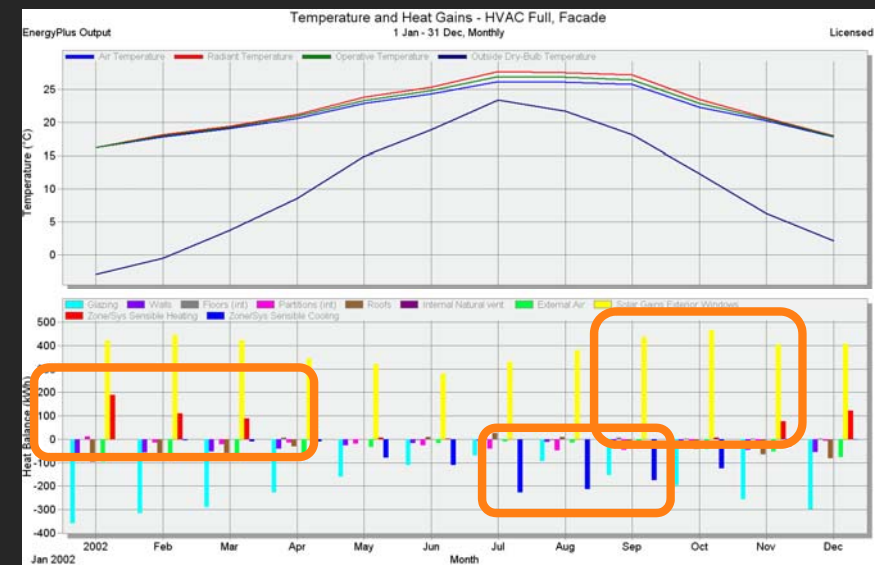




SHOEBOX MODEL

Results annual simulation – Fully Conditioned Space

- In the heat balance of the core zone, one can clearly see the energy required for heating and cooling the core to the temperatures set in the thermostat (heating and cooling setpoint temperatures) These values are expressed by the Zone/Sys Sensible Heating 115 kWh and Zone/Sys Sensible Cooling -84 kWh.
- On the other hand, in the façade zone, the high solar heat gains (281-465kWh) and the high energy losses through window glazing (-418kWh in January), make the energy required for heating and cooling the core to the setpoint temperatures differ drastically: Zone/Sys Sensible Heating 188 kWh and Zone/Sys Sensible Cooling -228 kWh. This demonstrates why HVAC systems are designed using 'thermal zones' to sub-divide spaces with different heat gains/losses.





INTERNAL LOADS

In this section you will now set up internal loads for both spaces, run an annual simulation again, and the thermal and energy profiles are affected.



The internal loads to be added to the spaces are:

- Occupants
- Turn on Natural Ventilation according to occupants schedules (model operable windows as if occupants will operate them manually)
- Artificial Lighting
- Plug Loads (Computers, screens, task lights, etc)



INTERNAL LOADS

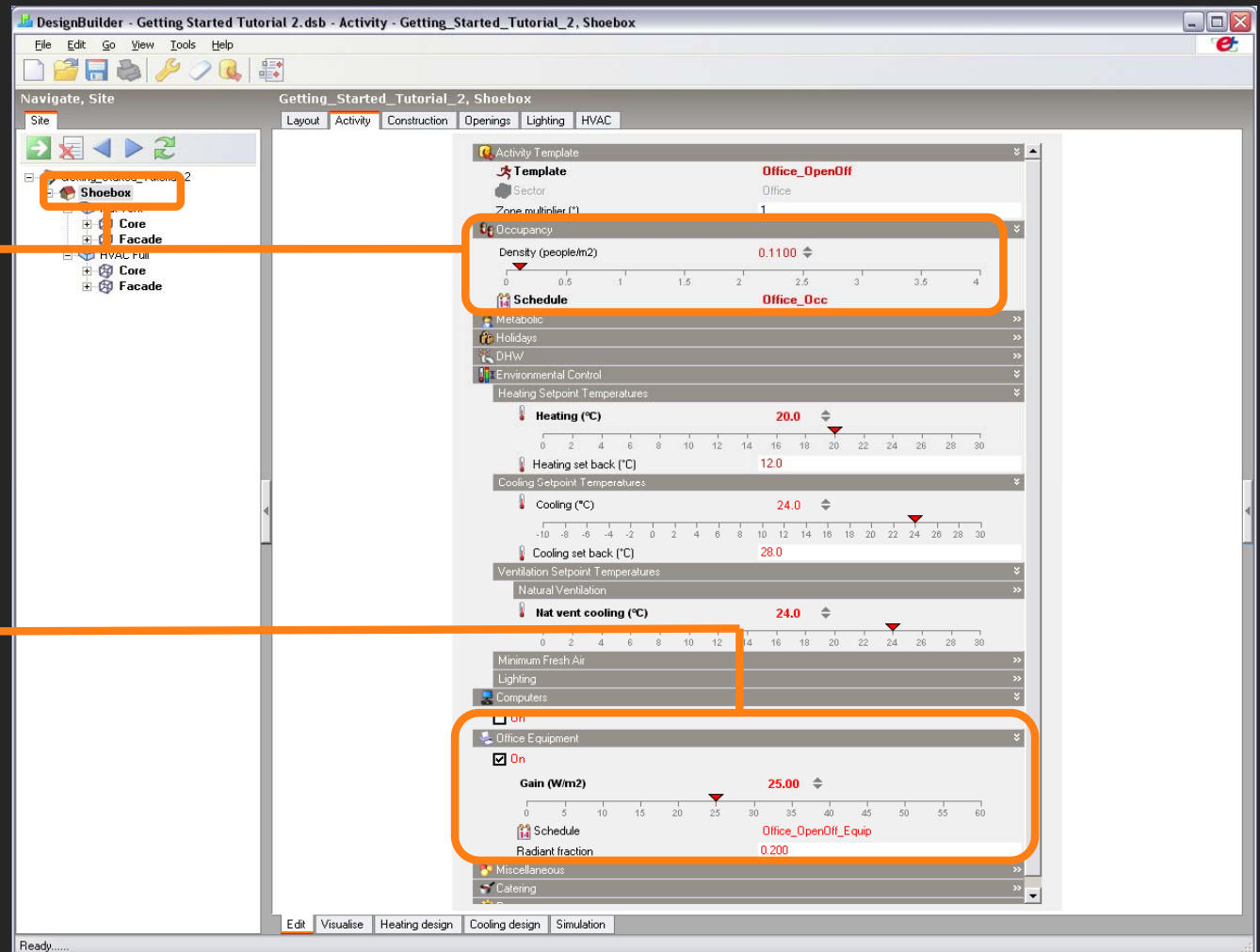
Setting Activities and Occupancy

3.

At the building level go to the “activity” tab > “Occupancy” and set the occupancy to 0.11 people/m².

4.

Turn the ‘Office equipment’ tab ON and choose 25 w/m². All plug loads will be lumped in this value (Computers, screens, task lights, etc)



INFO

You should not modify the assigned schedules for ‘Occupancy’ or ‘Office equipment’.



INTERNAL LOADS

Setting Lighting Loads

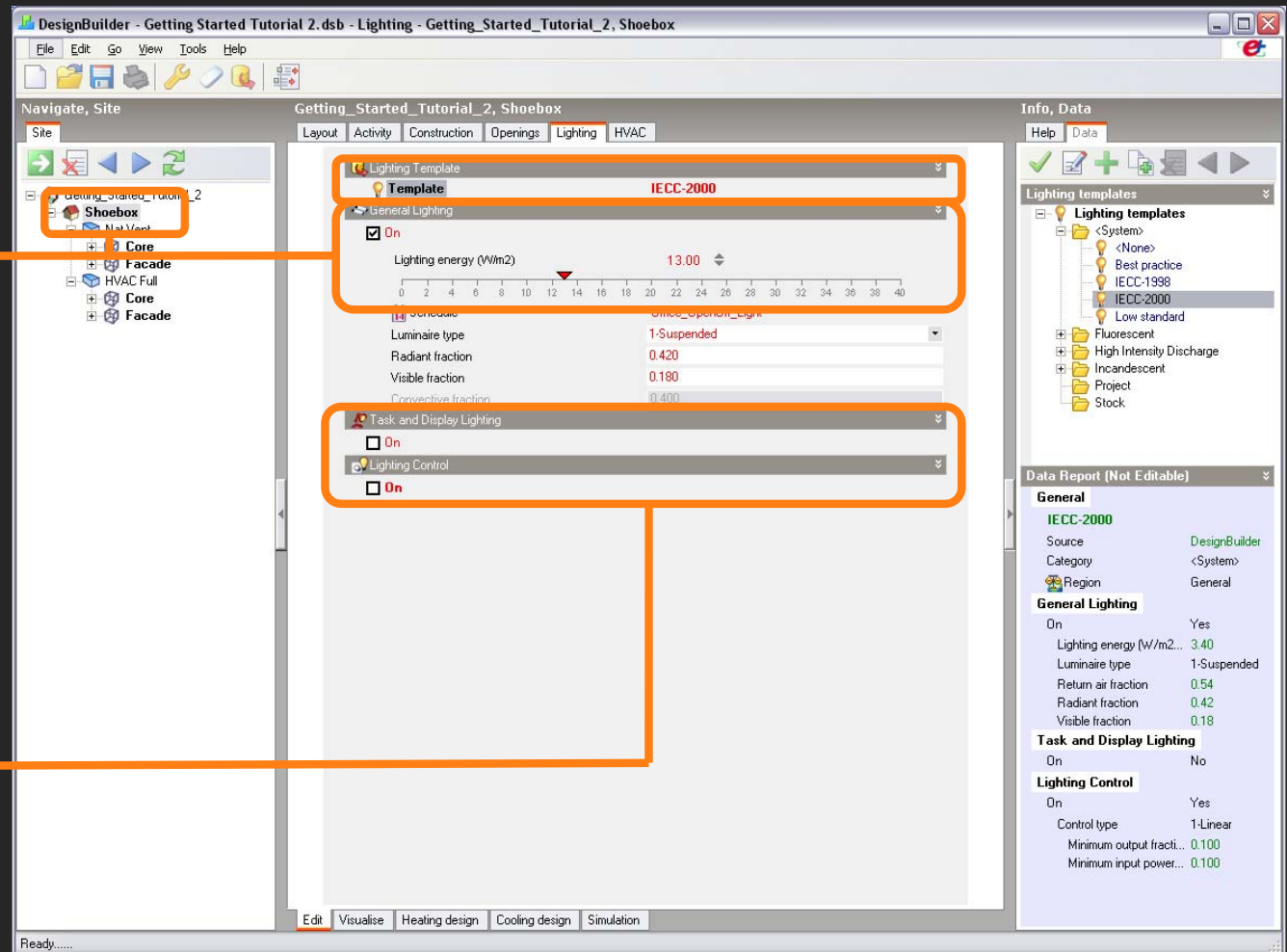
5.

At the building level go to the 'Lighting' tab > 'Lighting Template' and select 'IECC-2000'.

Then, go to the 'general lighting' tab and select 13W/m².

6.

Turn off the 'Task and Display lighting' tab and the 'Lighting Control'.



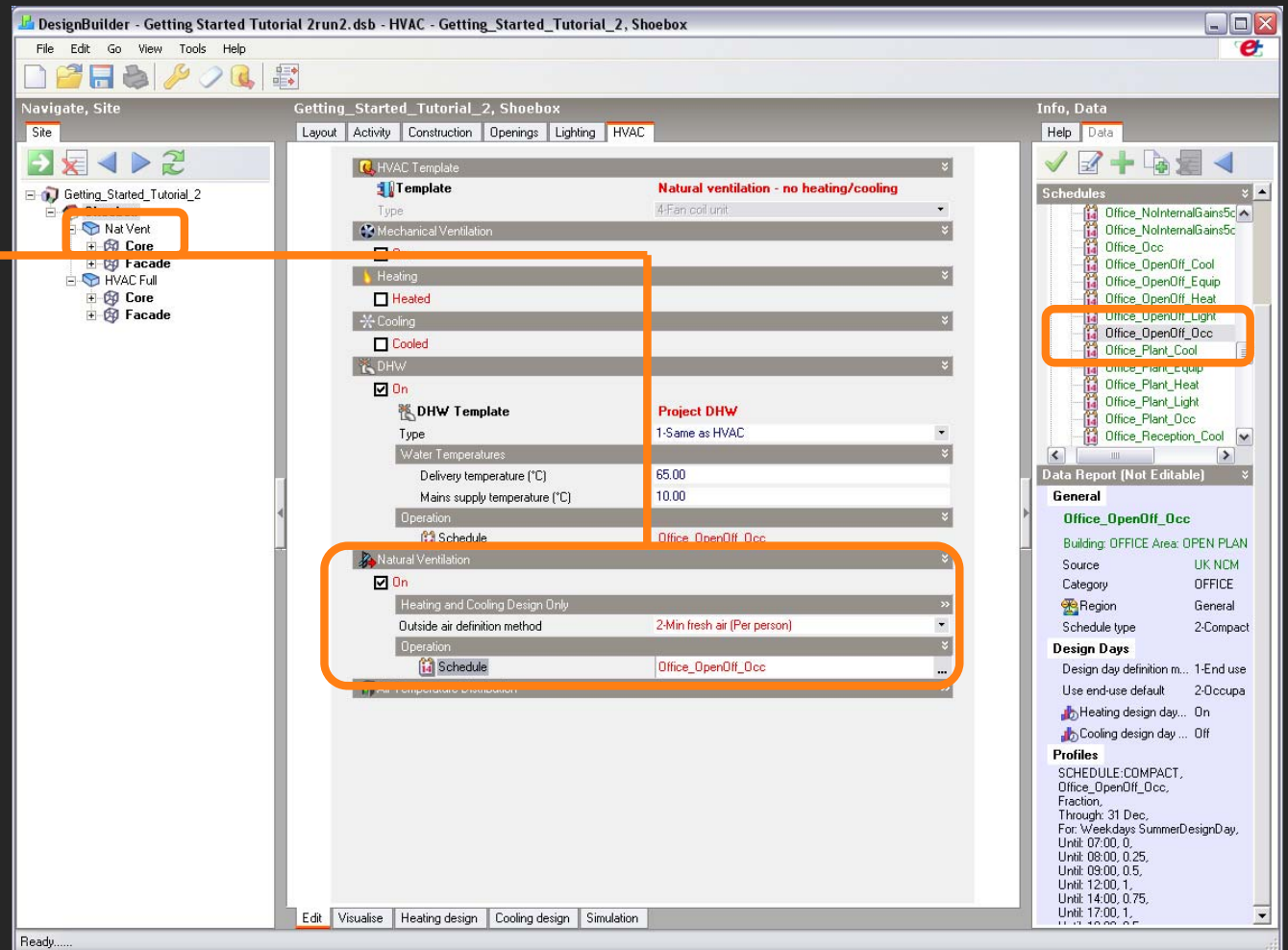


INTERNAL LOADS

Setting HVAC Controls

7.

At the 'Nat Vent' (block) level go to the 'HVAC' tab > 'Natural Ventilation' > 'Schedule' and change the current schedule to 'Office_Open_Occ'. You can find it in the right hand menu under the 'Office' folder.





INTERNAL LOADS

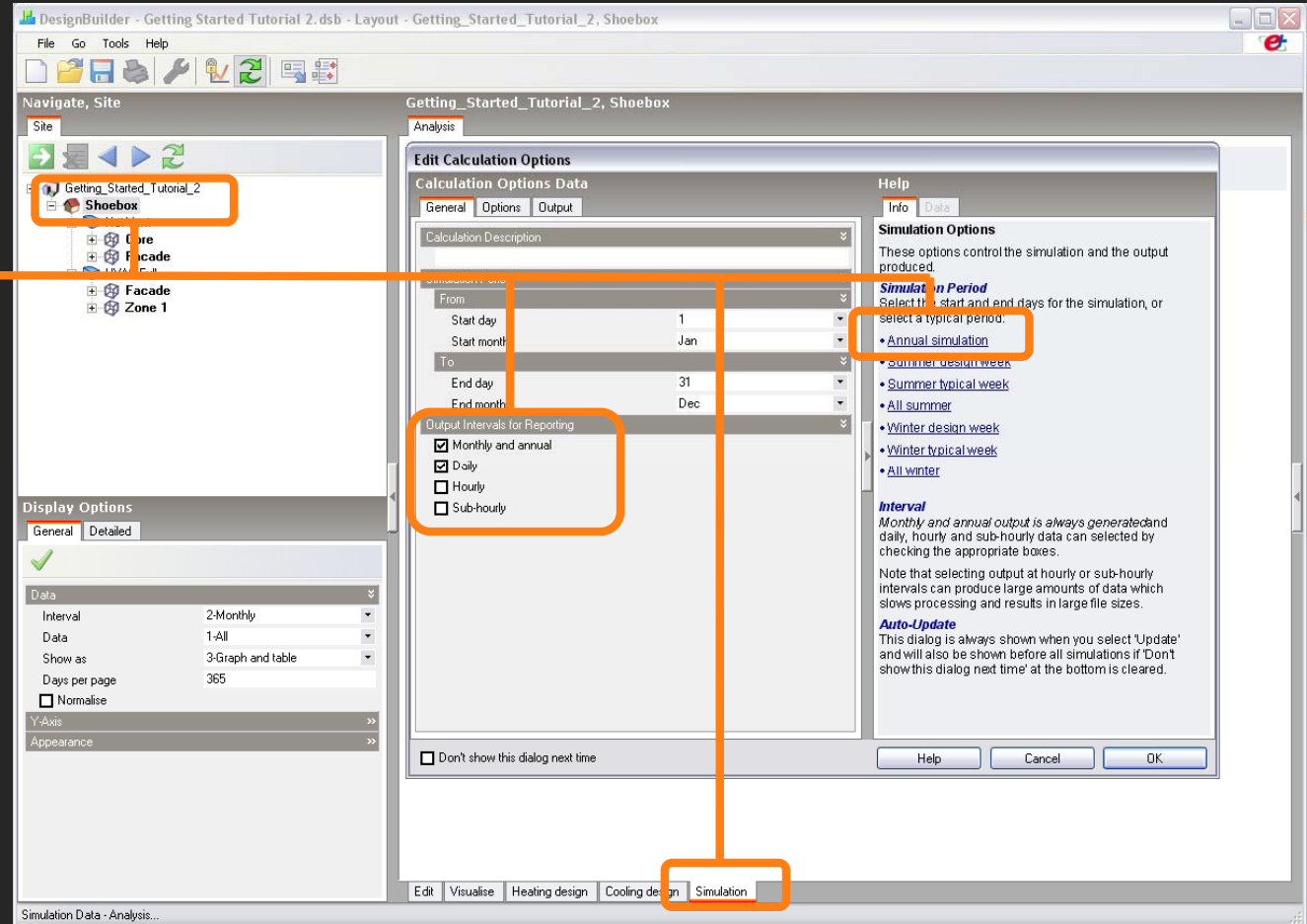
Running an annual simulation with loads

8.

Run an annual simulation at the building level to compare the indoor environmental conditions and energy demand of both, unconditioned and fully conditioned spaces.

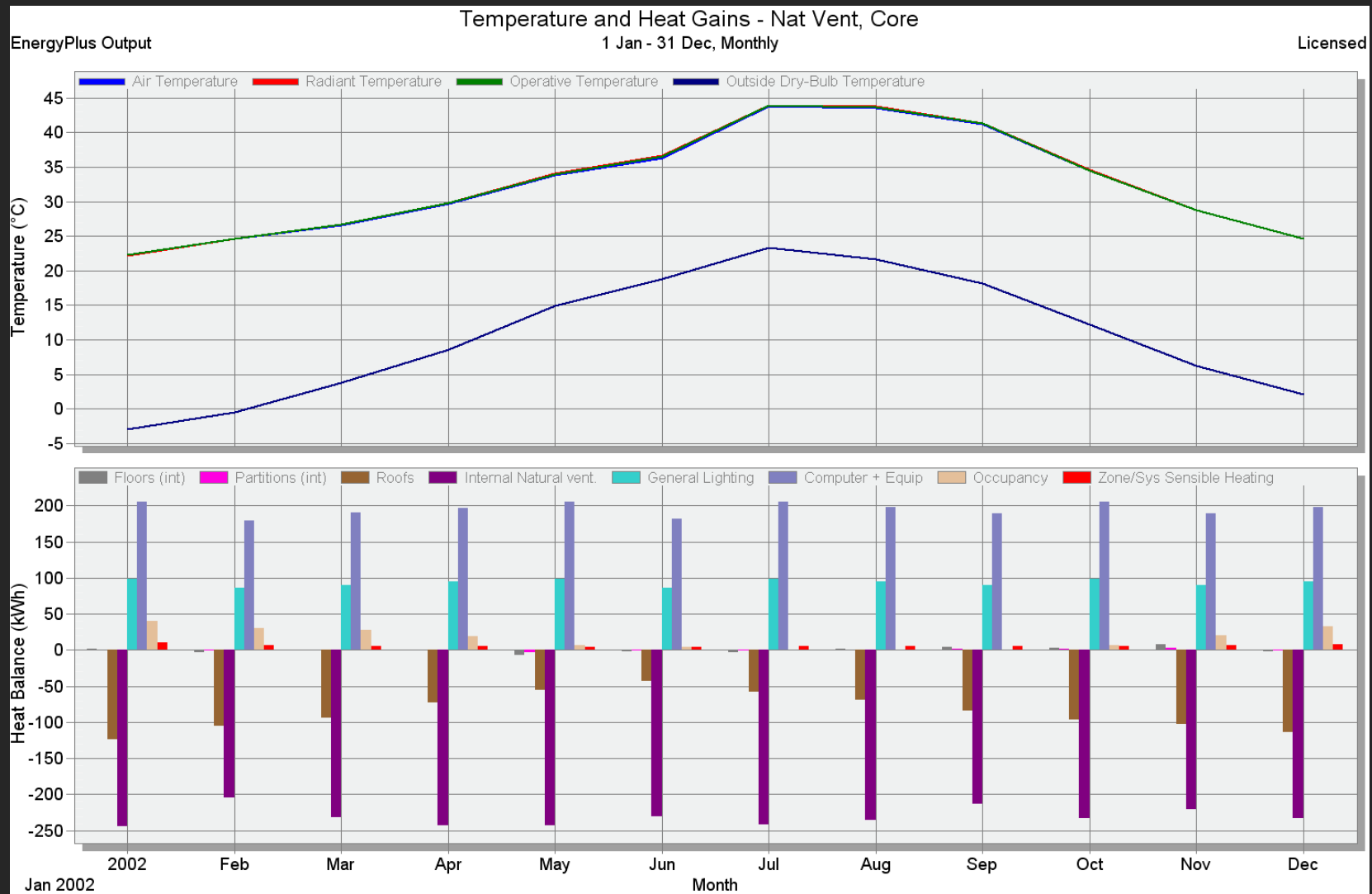
Note that at this point internal loads have been set up.

- Occupancy: 0.11 per/m²
- Artificial lighting: 13 W/m²
- Plug loads (computer, faxes, photocopy machines, task lights, etc): 25 W/m²
- Natural ventilation has been scheduled with: Open Office Occupancy profiles



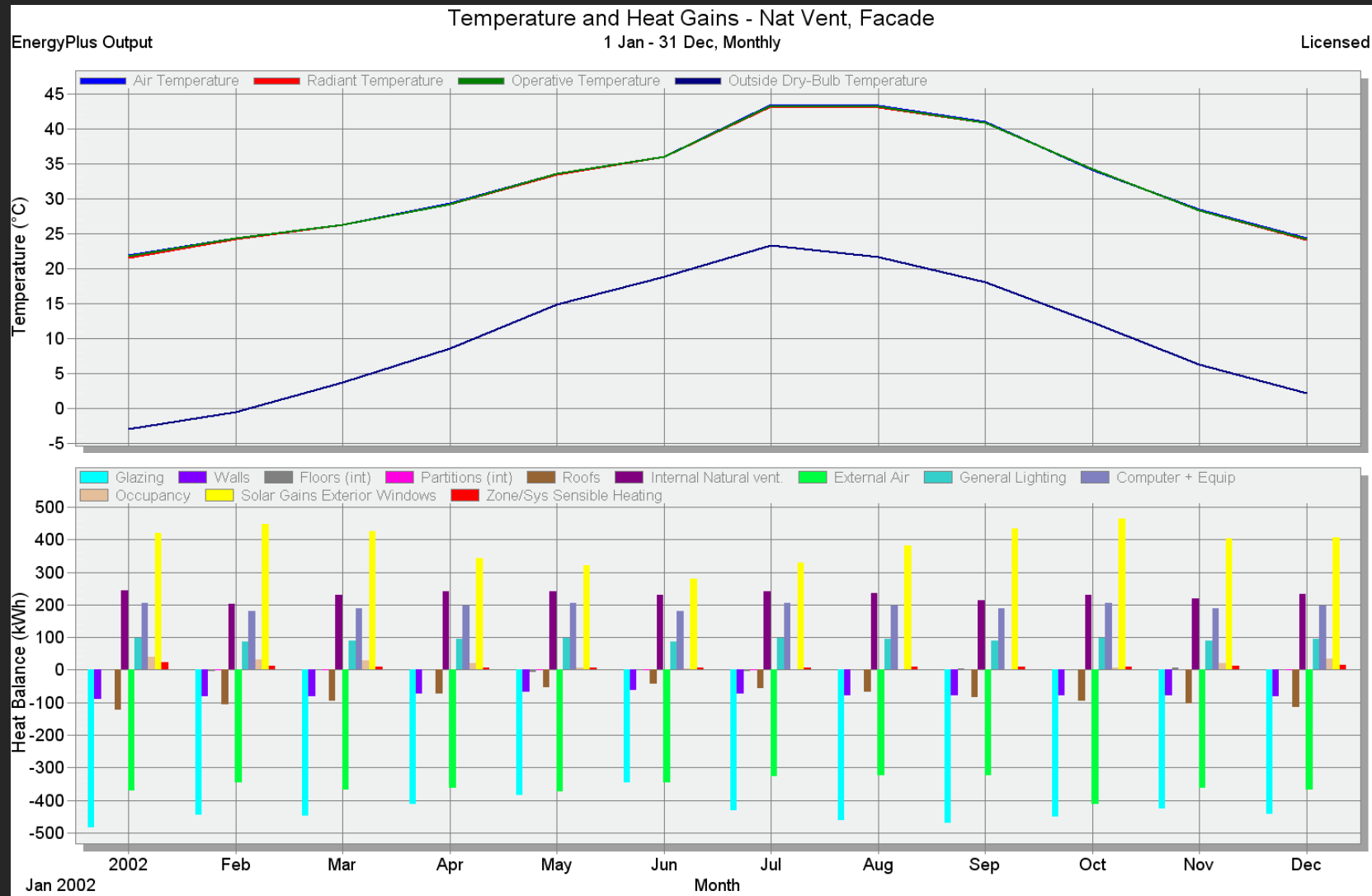
SIMULATIONS

Annual Simulation Results – Naturally Ventilated Space: Core Zone. With Internal Loads



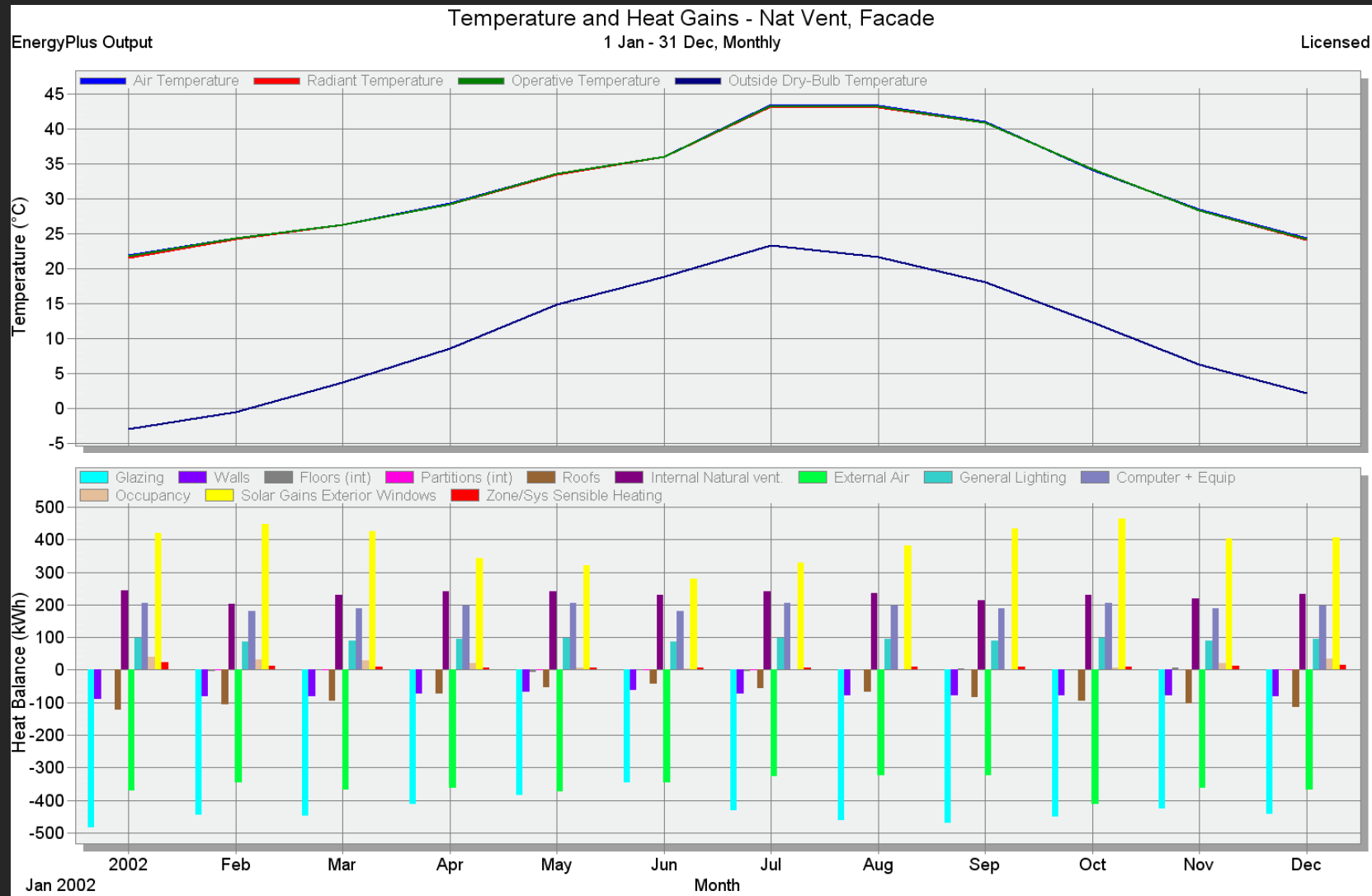
SIMULATIONS

Annual Simulation Results – Naturally Ventilated Space: Perimeter Zone. With Internal Loads



SIMULATIONS

Annual Simulation Results – Naturally Ventilated Space: Perimeter Zone. With Internal Loads



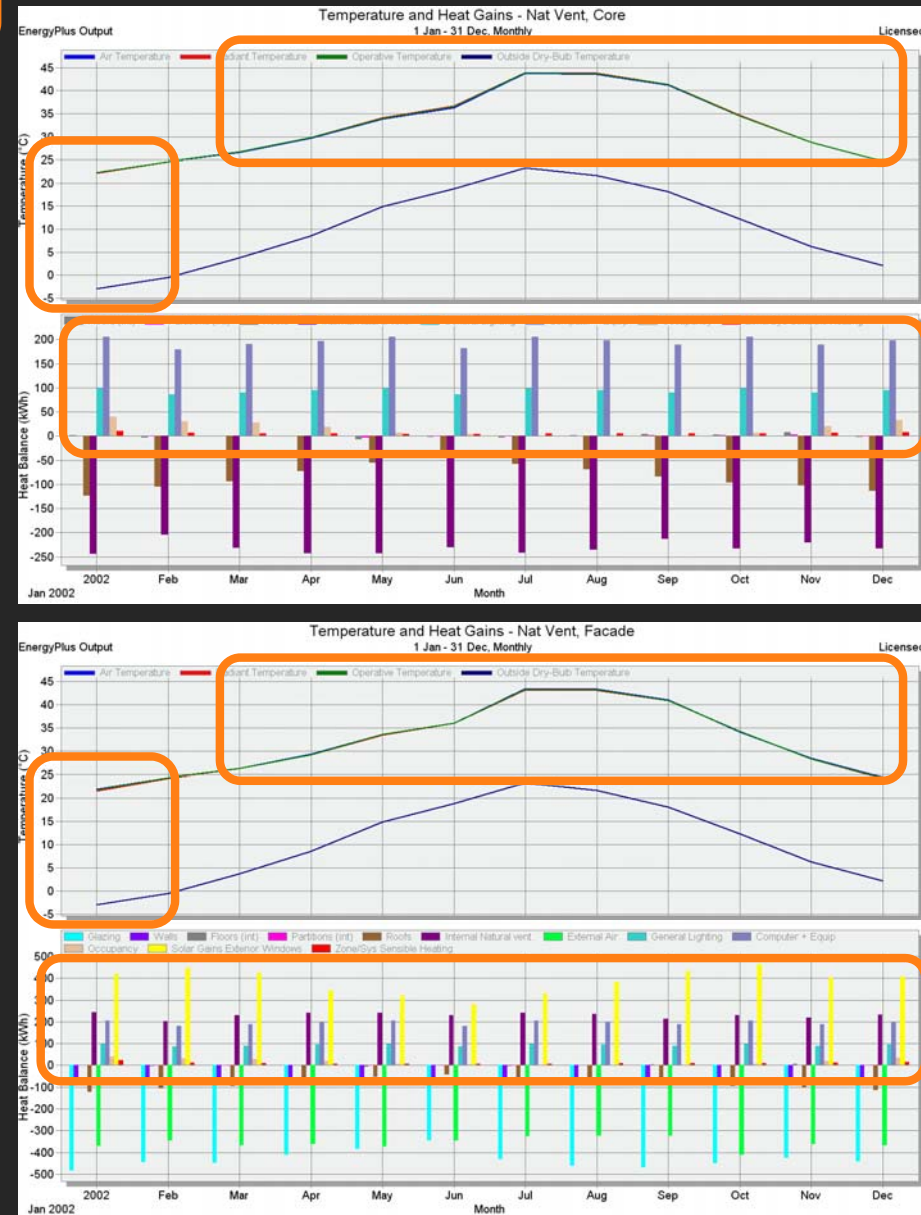


SIMULATIONS

Annual Simulation Results – Naturally Ventilated Space With Internal Loads

When comparing the internal environmental conditions of the naturally ventilated core zone and the façade zone, this time with internal loads:

- One can see the clear impact of having internal loads in the interior environmental conditions of the space. Even when occupants can activate Natural Ventilation (by opening 50% of the windows), the interior air temperature rises up to 44C in summer and 23C in winter (outside temp. -3C), due to the high internal loads.

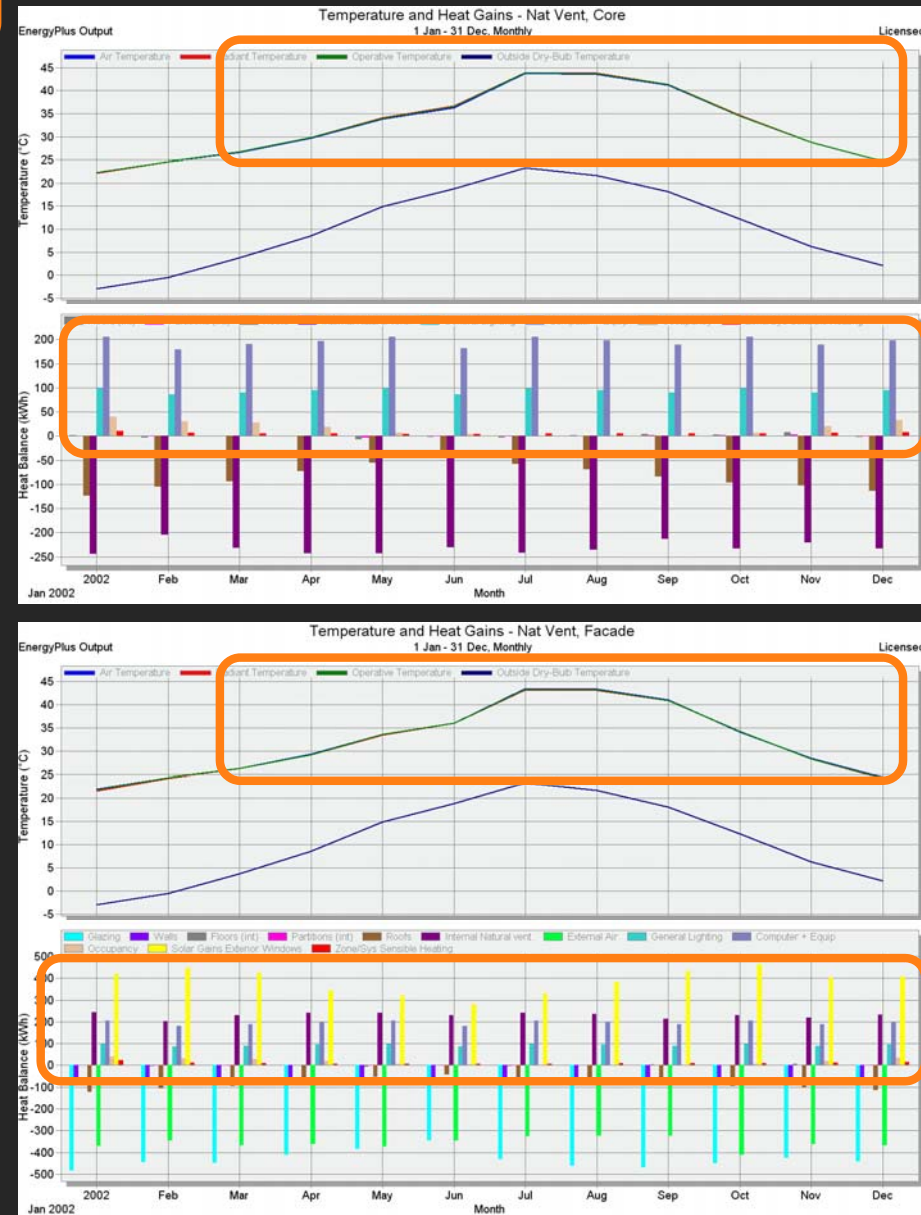




SIMULATIONS

Annual Simulation Results – Naturally Ventilated Space With Internal Loads

- At this point we are not trying to determine possible strategies to improve the natural ventilation performance of the space, but rather understand the impact of internal loads on a naturally ventilated space. As one can see, the internal loads now cause the space to require mainly cooling strategies over 10 months of the year.
- Is important to remember that cooling design and heating design simulations are required to further study the daily thermal behavior of the space. By carrying out those simulations one can determine whether heating strategies will be at all required in the space, as well as what are the maximum comfort conditions expected to occur in the space under extreme conditions.





SIMULATIONS

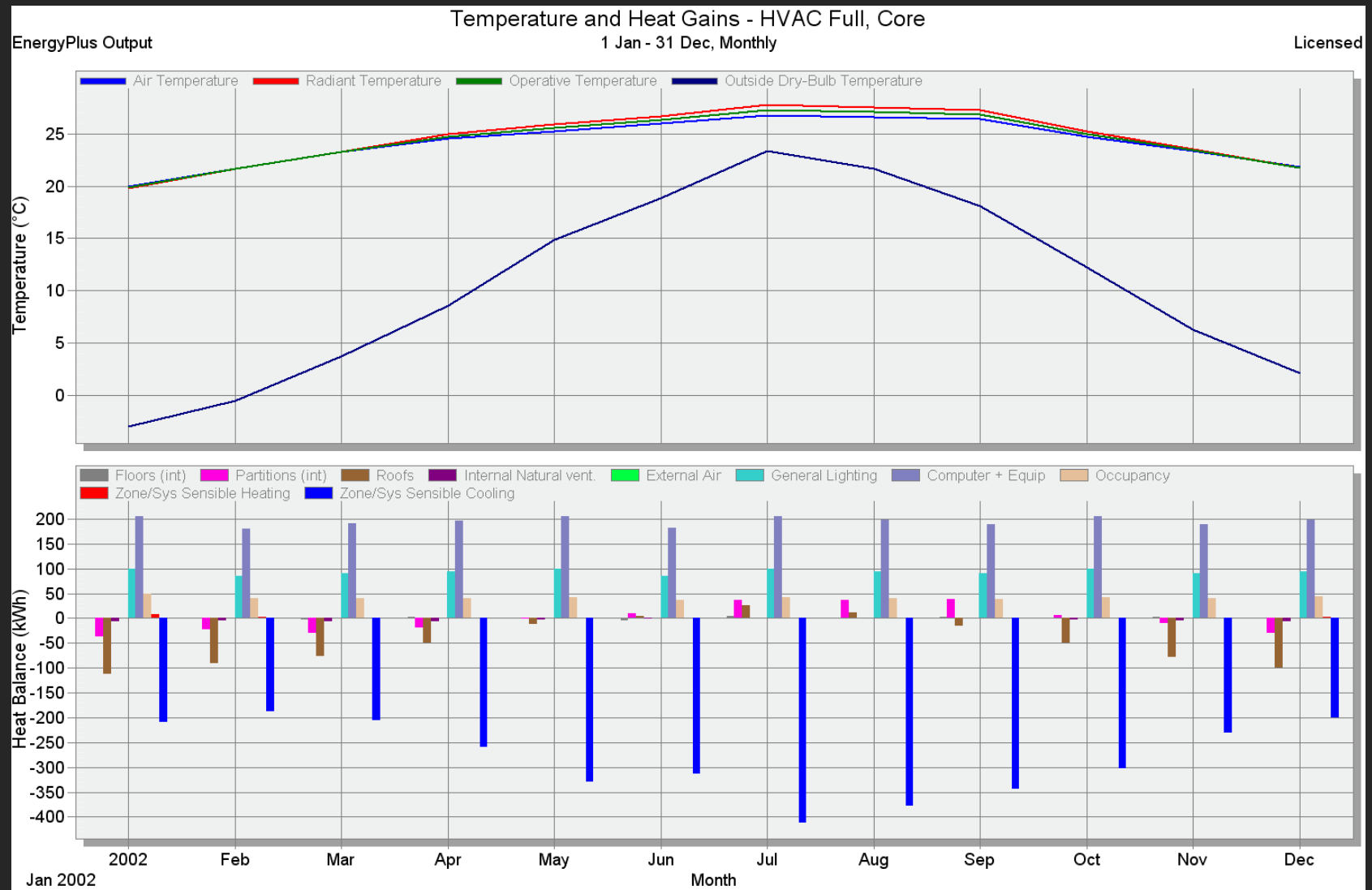
Results annual simulation – Naturally Ventilated Space

- In the heat balance, now the main heat gains in the core zone are the 'office equipment' with 200 kWh, followed by 'General lighting' with 100 kWh.
- The heat losses by interior convection to the façade zone and by conduction through the ceiling are fairly constant. This is to be expected since heat transfer is driven by the temperature difference between interior/exterior or one zone with another, and as the temperature difference between interior and exterior is maintained fairly constant throughout the year. This, along with the fact that the interior temperature is always above the heating set point, which causes the heat flux to be maintained in one direction during the year (monthly totals).



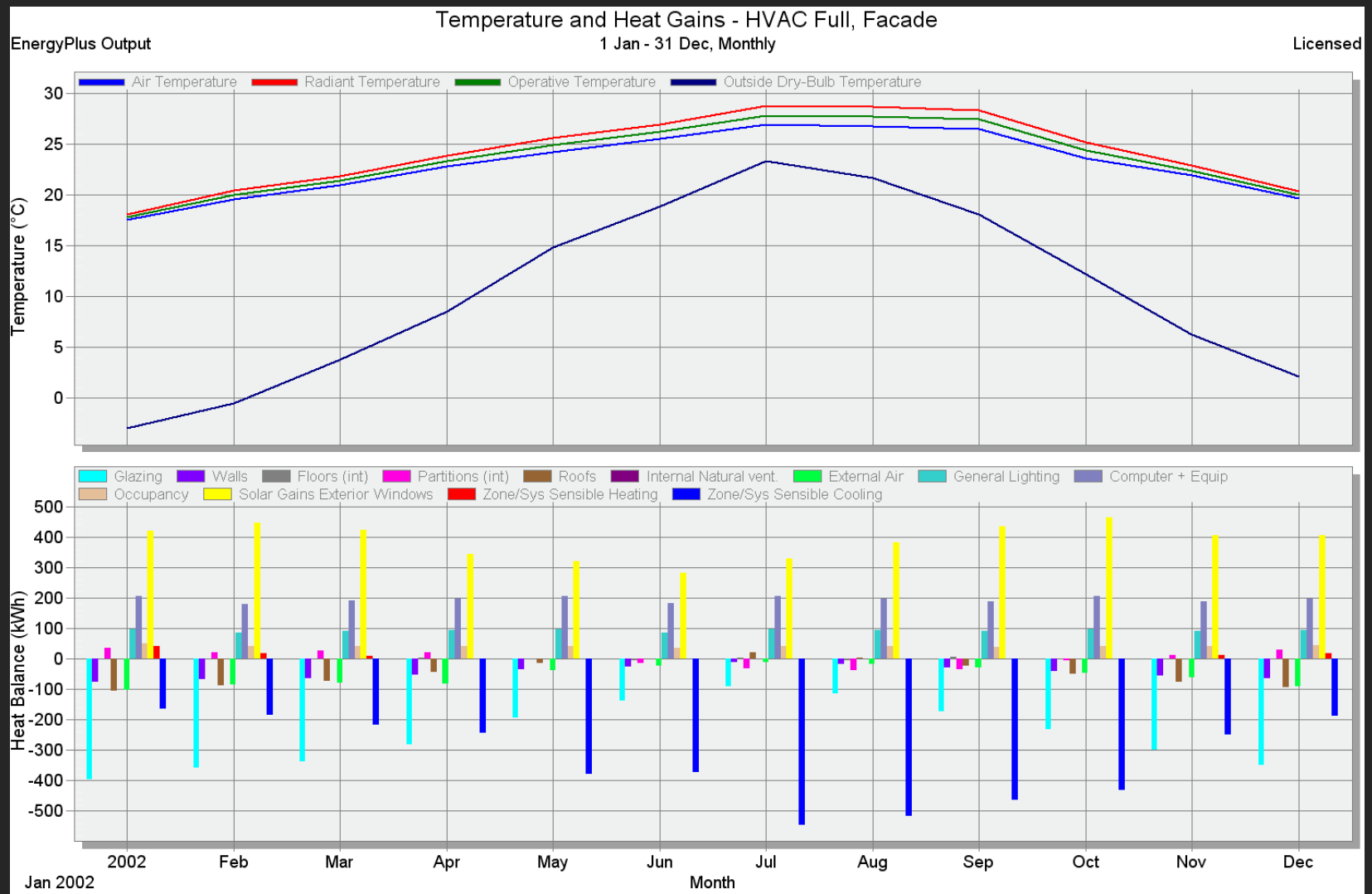
SIMULATIONS

Annual Simulation Results – Fully Conditioned Space: Core Zone. With Internal Loads



SIMULATIONS

Annual Simulation Results – Fully Conditioned Space: Perimeter Zone. With Internal Loads



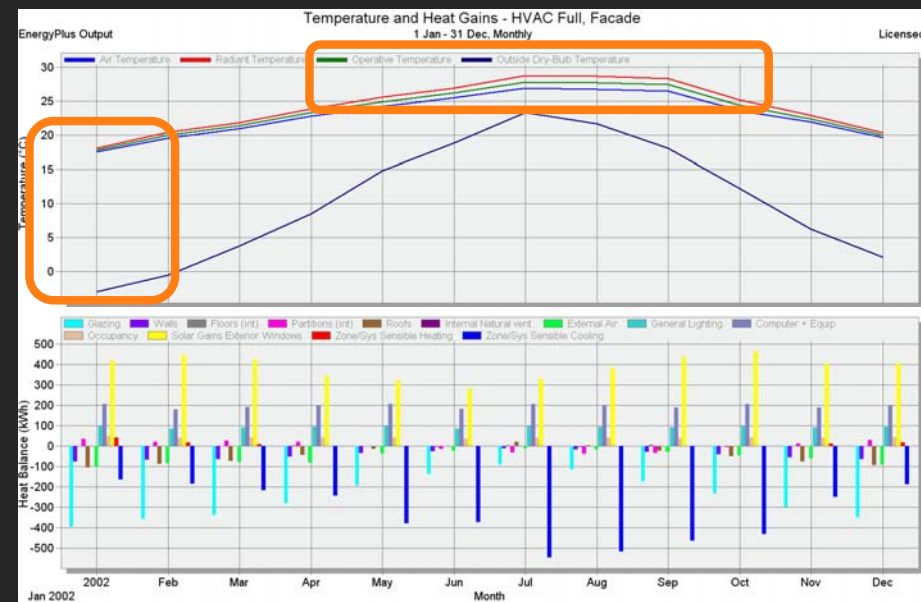
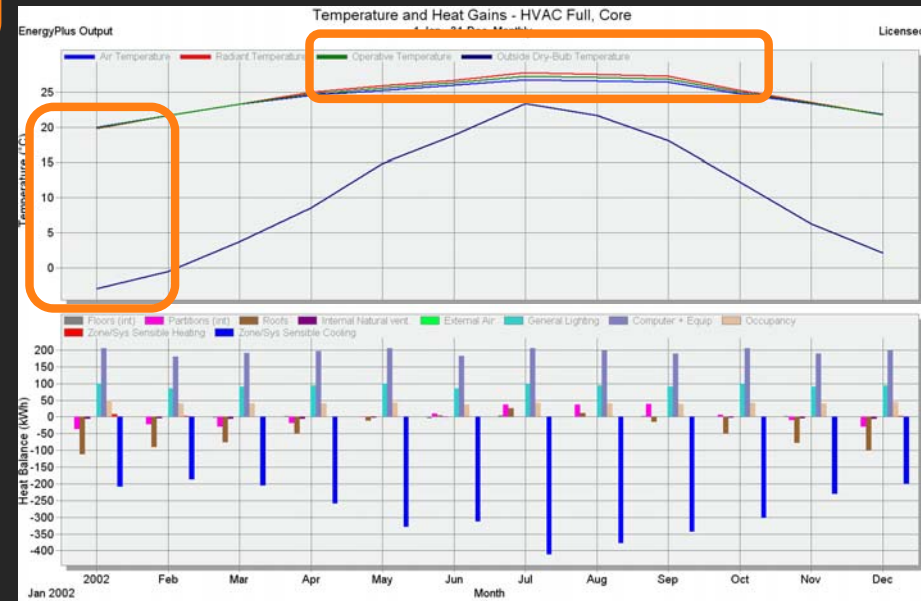


SIMULATIONS

Results annual simulation – Fully Conditioned Space

When comparing the internal environmental conditions of fully conditioned core and façade zones:

- The ‘fully conditioned’ characteristic of the space (in both zones), is evident since the dry bulb air temperatures don’t rise over the 26C during the summer months and don’t drop down below 18C in winter.
- As in the naturally ventilated space, both zones, the core and façade, have almost the same comfort conditions (1.4C difference in winter). However, due to the cooler air temperatures (26C) one can see that the high surface temperature of the glazing in the south façade has a bigger impact in the operative temperature of the façade zone. In this space the operative temperature rises 0.76C compared to a rise of only 0.17C in the Nat Vent façade zone.

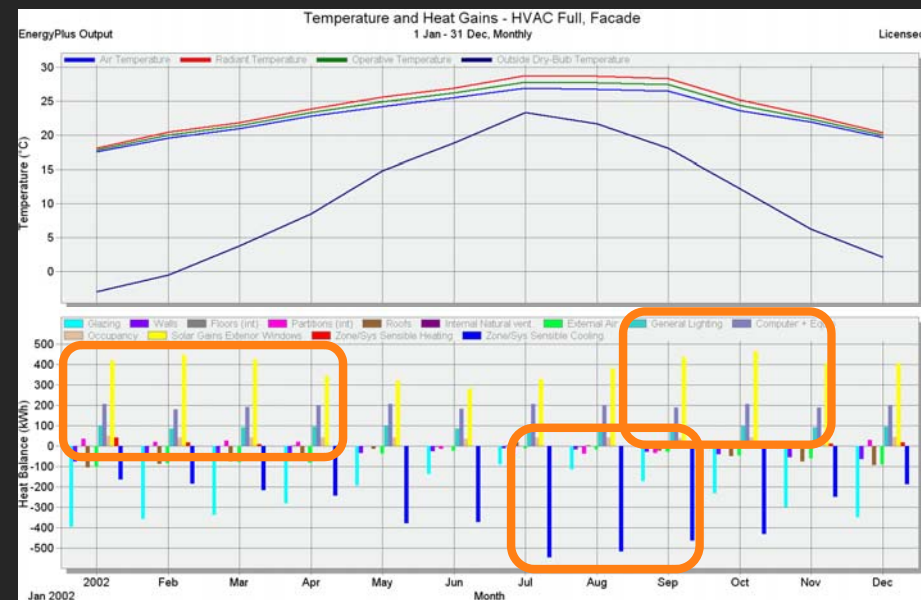
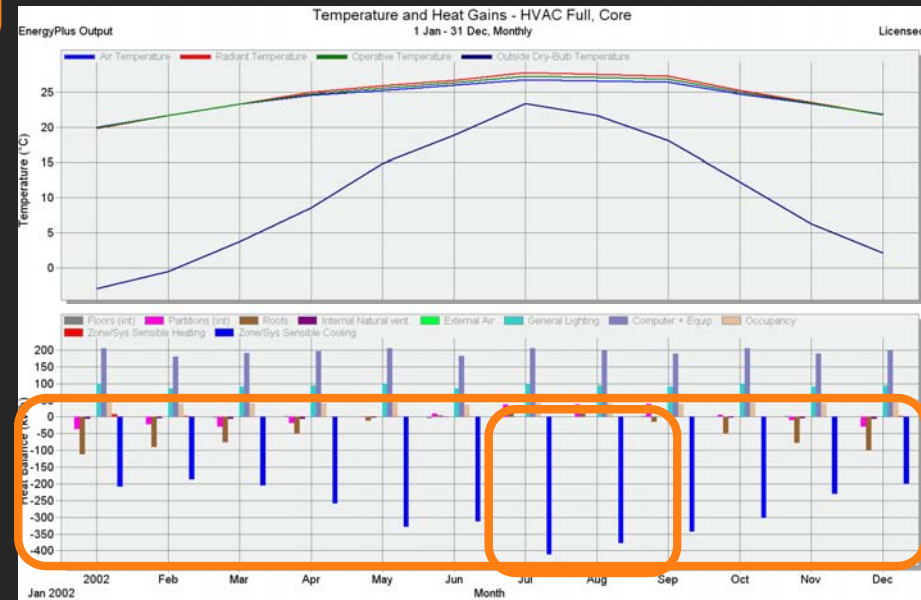




SIMULATIONS

Results annual simulation – Fully Conditioned Space

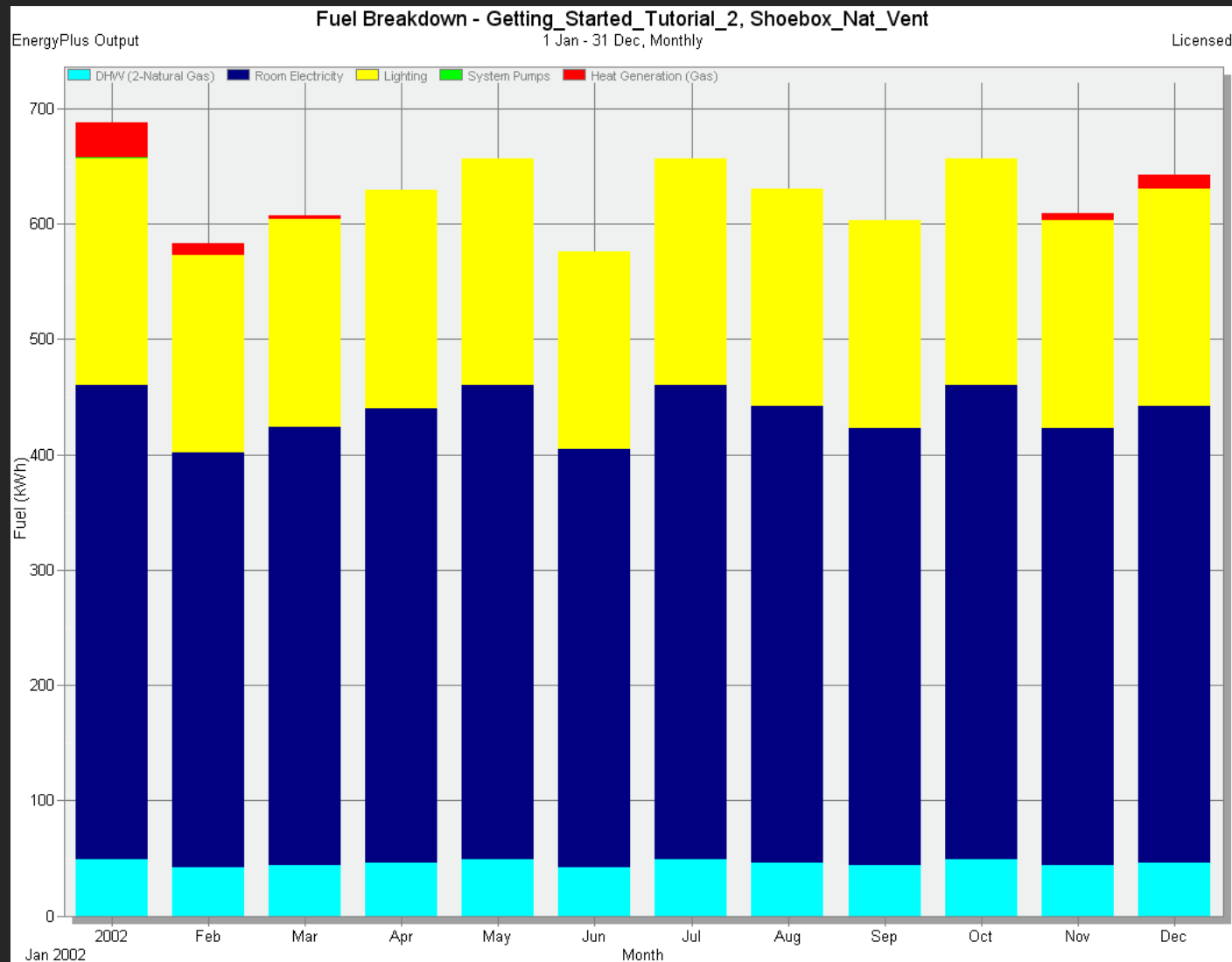
- In the heat balance of the core zone, one can clearly see the energy required for heating and cooling the core to the temperatures set in the thermostat (heating and cooling set point temperatures) With internal loads the space turns clearly into a cooling dominated all year long .
- On the other hand, in the façade zone, the high solar heat gains (281-465kWh) and the high energy losses through window glazing (-418kWh in January), make the energy required for cooling the core to the set point temperatures differ drastically: Core Sensible Cooling load - 413 kWh and Façade Sensible Cooling load - 545 kWh. This is a 32% higher cooling load for the façade than the core, which proves why HVAC systems are designed using 'thermal zones' to sub-divide spaces with different heat gains/losses.





SIMULATIONS

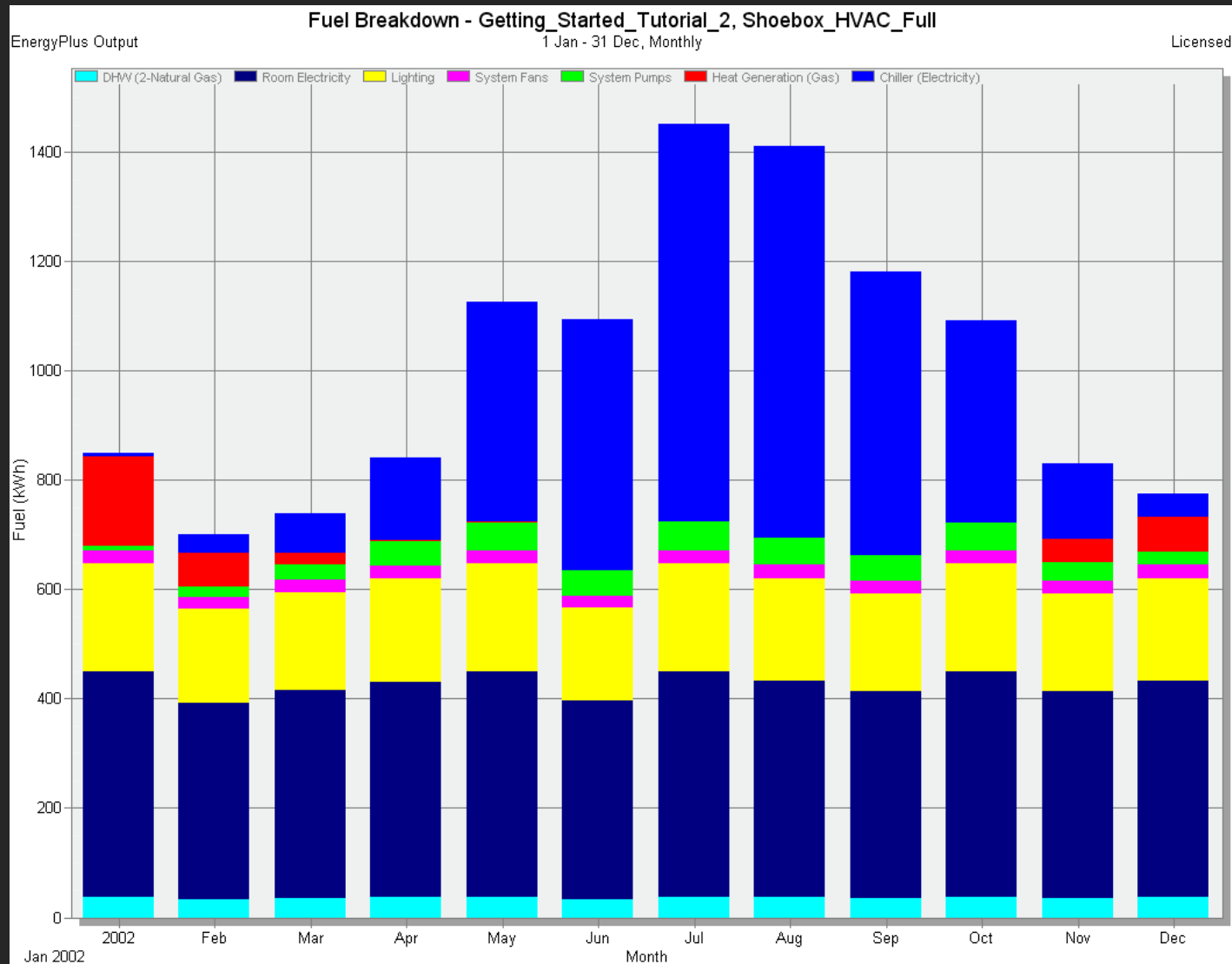
Results annual simulation – Naturally Ventilated Space: Monthly Fuel Breakdowns





SIMULATIONS

Results annual simulation – Fully Conditioned Space: Monthly Fuel Breakdowns

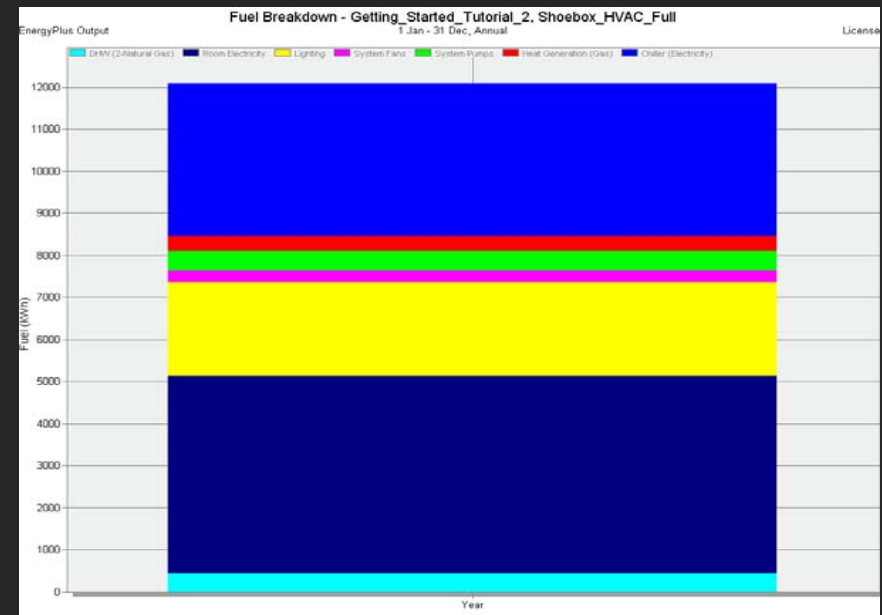
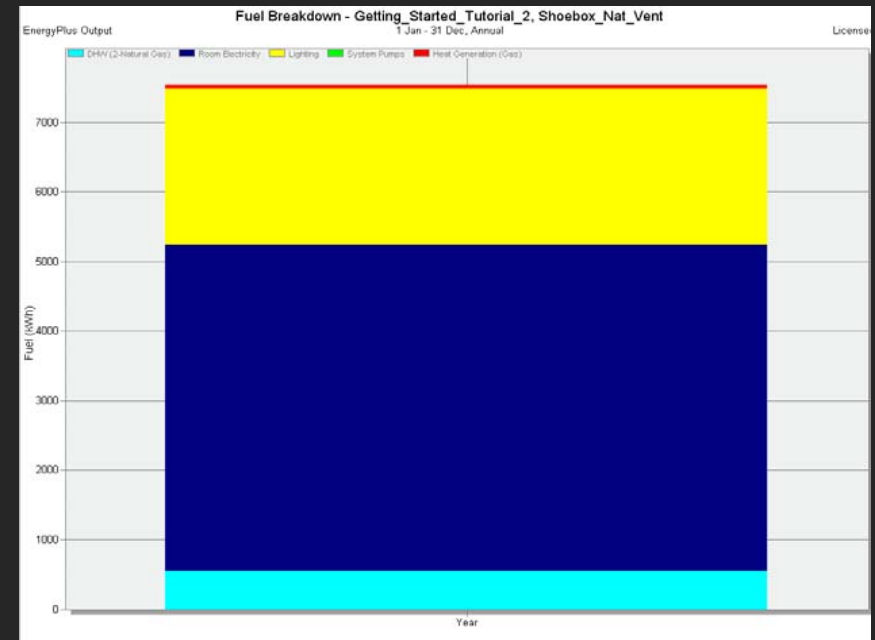




SIMULATIONS

Compare the Annual Energy Consumption of the both spaces with Internal Loads.

- The fuel breakdown comparison between the naturally ventilated space and the fully conditioned space show the energy demand by end use. One can see the proportion of energy use for cooling/heating the space versus the energy demand of internal loads.
- Through the brief analysis sequence provided in this document you should be able to relate the annual energy demands with the internal environmental conditions of each space. For example, the naturally ventilated space has an annual energy demand of 7,500 kWh, compared to the about 12,100 kWh of the fully conditioned space, however, as shown in previous slides, it is not able to meet comfort conditions.





EXERCISE

Cooling Design Simulation – Naturally Ventilated Space and Fully Conditioned Space

Now that have run annual energy simulation for both spaces, with and without internal loads, you are encouraged to repeat the analysis for both spaces with internal loads for a Summer Typical Week. Review the simulations interpret the results regarding:

- The impact of occupancy profiles and their related internal loads schedules on the internal comfort conditions of both spaces.
- The impact of occupancy profiles and their related internal loads schedules on the energy demand of both spaces.
- Predominant heat gains and losses in each space and for the different thermal zones.



CONCLUSION

- In this document you have used DesignBuilder to run annual and weekly simulations of two spaces with different heating and cooling strategies. You were able to verify the impact of internal loads on the interior environmental conditions of a space and its energy demand.



CONCLUSION

This document provided a quick, non-exhaustive overview of the building energy performance simulation capabilities offered by DesignBuilder/EnergyPlus. Should you decide to use this tool in the future consult the REFERENCE section for further reading. Remember:

- It is your responsibility to **learn the assumptions and limitations** of the programs you are using.
- Preparing and running a simulation take time. Before rushing into doing a simulation you should **have a clear idea of how the simulations results can help you resolve a specific design question** that you could not answer otherwise.



NEXT STEP

- Now you should continue with tutorial #3 in which you will learn how to customize data templates and components (glazing, constructions, schedules, shading devices, etc).
- Remembers, 'an energy model can be no more accurate than the assumptions that lie behind both the proposed building and the baseline building model. Even though the model performs complex calculations accurately on this assumptions, the result will be misleading if the assumptions are faulty'.



ACKNOWLEDGEMENT

The development of this document has been supported by the following organizations.

Harvard Graduate School of Design: The GSD has been putting special attention to the advancement of environmental building performance, supporting a number of researches in the matter. (www.gsd.harvard.com).

The Presidential Instructional Technology Fellows : The Presidential Instructional Technology Fellows (PITFs) program was established to recruit and train fellows in conjunction with the Schools to work with faculty to develop digital course materials with immediate educational benefits. PITFs leverage existing software tools developed here at Harvard and provide outreach(<http://isites.harvard.edu/icb/icb.do?keyword=k2526&pageid=icb.page12917>).