HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #7

CHAPTER 2: BUILDING ENERGY SIMULATION

Co-funded by the Erasmus+ Programme of the European Union

7.2.1 DETAILED METHODS AND DYNAMIC SIMULATION - WHEN TO APPLY?

Simplified methods take into account the time-varying effects in the energy balance by using average value. The easiest solution is to calculate with seasonal (annual) values. Comparatively, the monthly methods take into account seasonal changes. At the same time, the hourly methods and dynamic simulation reflect the effect of day-night and temporary fluctuations too. There are several factors which change dynamically within a day, such as:

- Operation of shadings
- Temperature settings (night and weekend set back)
- Needs
- Occupancy
- Daily operation of mechanical ventilation
- Night ventilation
- Temperature of distribution network and storages
- Energy consumption of equipment utilizing environmental energy
- Outages (weekend).

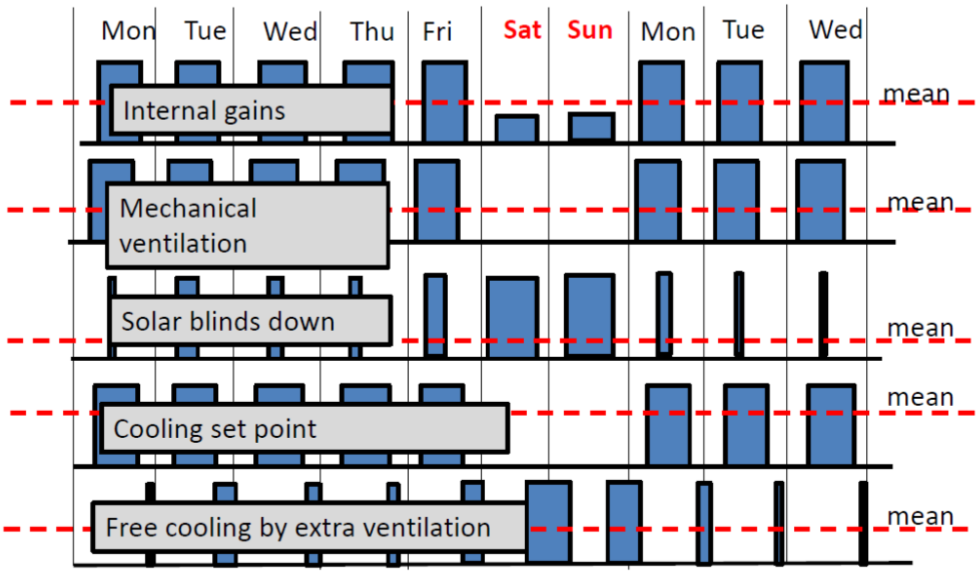

Fig. 7.2.1. Dynamic effects in a building: intermittent effects and their mean values (Dick van Dijk BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

Figure 7.2.1. illustrates the temporal changes of some dynamically changing parameters. It is visible that the calculation with mean value can have a distorting effect. For example, the mean low utilization of shadings may lead to the incorrect conclusion that there is hardly any

defense against solar load. Although in reality, the use of shadings is likely adapted to the radiation load.

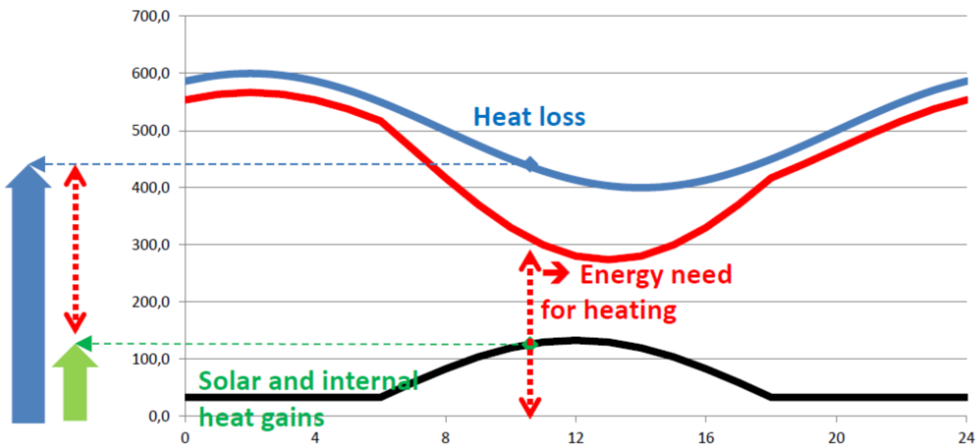

Fig. 7.2.2. The change of losses and gains over time in one day (old building) (Dick van Dijk BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

The more heat-insulated a building is, the more significant the problem is. Figure 7.2.2. shows the daily losses and gains of an old, poorly insulated building. The difference is the current heat demand, which is always positive. It means that there is a heating demand during the whole day. Because the gains are fully utilized, the demand can be calculated with the average values accurately.

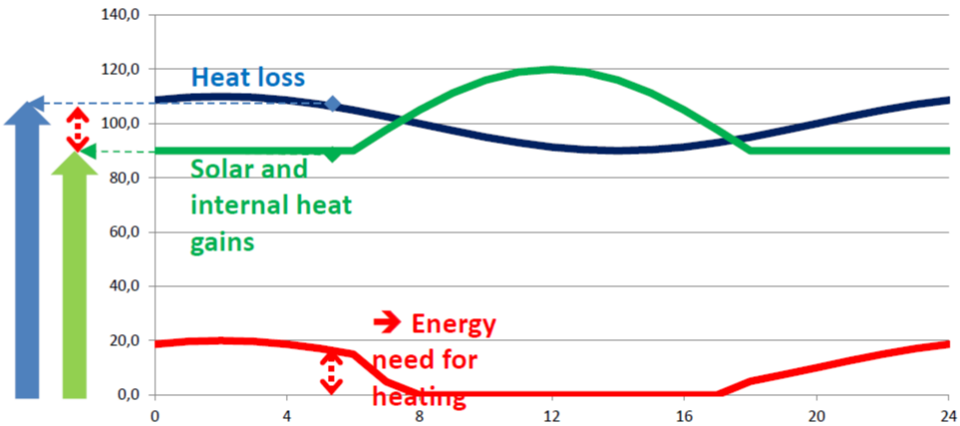

Fig. 7.2.3. The change of losses and gains over time in one day (low energy building)(Dick van Dijk BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

Contrary, in the case of a well-insulated building (Figure 7.2.3.): the gains around noon exceed the losses, which means that the heating demand is zero. Calculated with average value, the results are incorrect because some of the gains are not utilized in these hours, but this is not reflected in the average values. Thus, the determined heating demand is less for the whole day than if the hourly method or simulation would be used. The monthly and seasonal methods therefore lead to bias, which is handled by using correction factors (in this case: utilization factor).

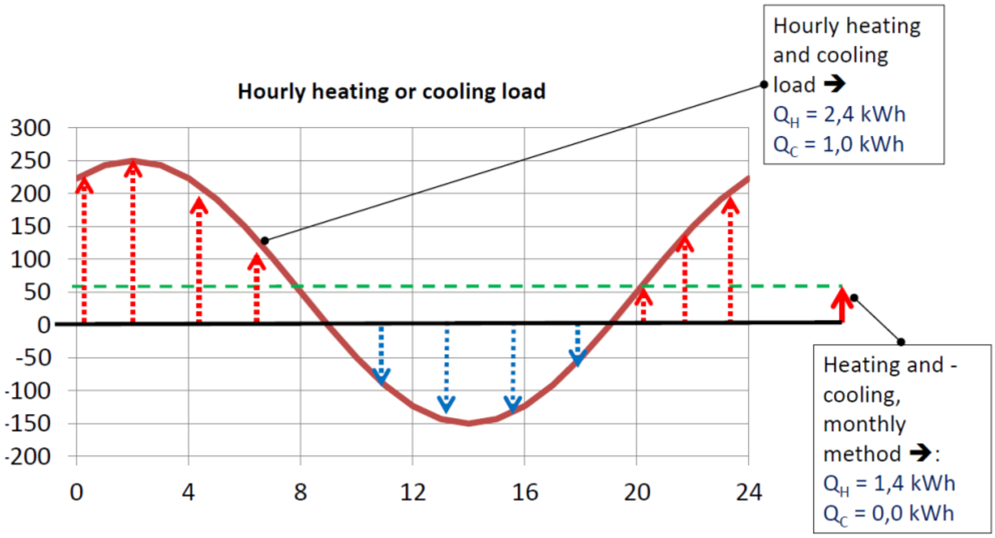

Fig. 7.2.4. Daily changes of heating or cooling demand during transitional period (Dick van Dijk BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

There may be heating and cooling demand in different time periods within one day (Figure 7.2.4.). The areas under the curve show the daily heating demand in the positive space and the daily cooling demand in the negative space. Their values are 2.4 kWh and 1.0 kWh. Calculate the daily average of the heat demand: the heating demand is the difference between the two values, which is 1.4 kWh; and the cooling demand is zero. This problem can be handled by applying hourly or simulation methods because even the daily scale calculation is inaccurate without correction.

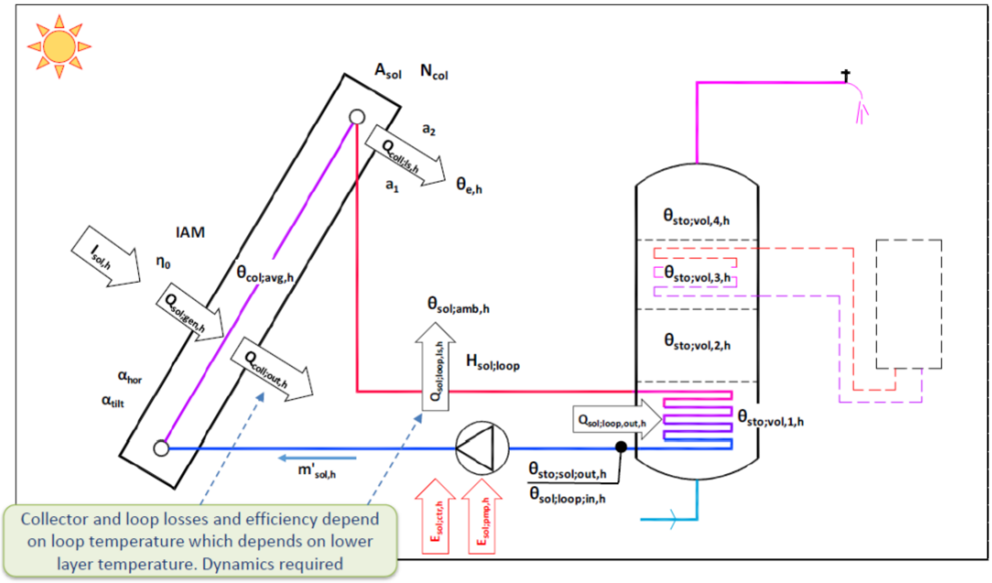

Fig. 7.2.5. Circuit diagram and energy flows of solar DHW production (Laurent Socal BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

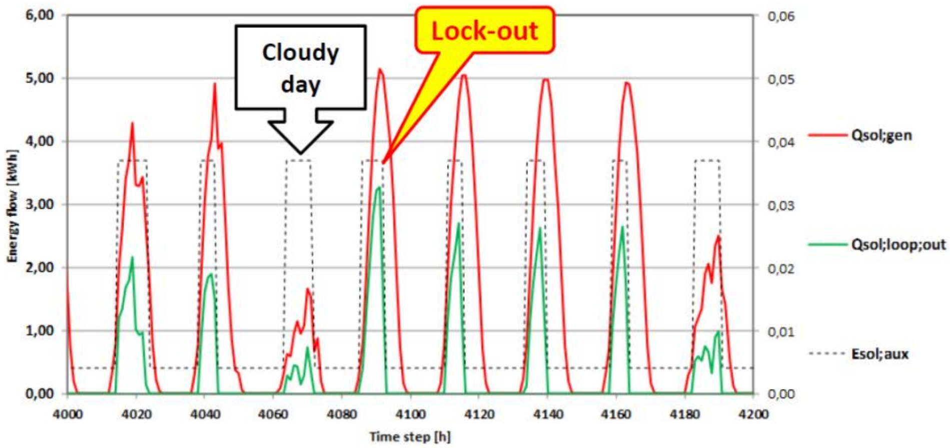

Fig. 7.2.6. The changes of the solar radiation reaching the solar collector (Qsol;gen), the heat transferred through the heat exchanger of the storage (Qsol;loop;off) and the pump power consumption (Esol;sol;aux) (Laurent Socal BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

There are also several examples of building technology systems. In the case of a solar collector system, the collector can be overheated and the pump stops until it cools down again (the pump control works based on the temperature in the lower zone of the storage tank). This situation is not typical in less sunny weather when the total radiant energy which reaches the collector can be utilized. However, in the case of intense radiation, only partial utilization occurs. This case is illustrated in Figure 7.2.6. The third and last days are overcast.

Then the pump runs all day and as long as there is a solar energy yield, the utilization is full. On the other days, the pump must be stopped earlier because the lower zone of the storage tank overheats. This lock-out significantly reduces utilization. An even more important factor is the daily DHW demand. It is also generally out of sync with production. In the case of the seasonal or monthly method, the problem is treated with correction factors (coverage ratios), but such factors are only available for certain typical cases.

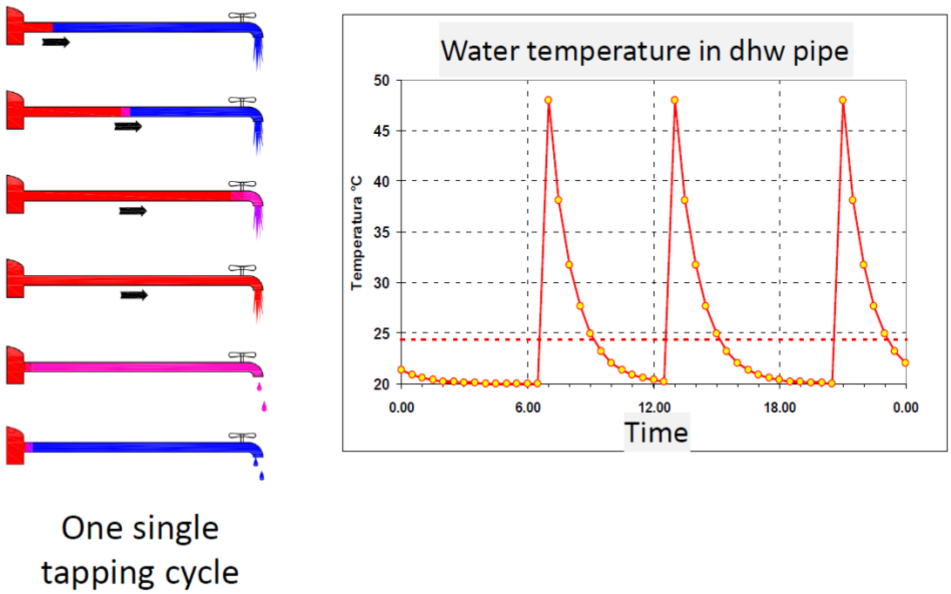

Fig. 7.2.7. Dynamic behavior of DHW pipes outside the circulation circuit (Laurent Socal BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

The heat supply network also has dynamic properties. Figure 7.2.7. shows the heating and cooling process of a pipe section outside the circulation circuit for one tapping cycle. The diagram illustrates well that the determination of the daily average temperature (dashed red horizontal line) - from which the monthly and seasonal averages are calculated if the simplified calculation method is used - is not an easy task. The results are incorrect if the calculation is done with the design hot water temperature values. The problem can be modeled well with simulation and the hourly method, provided that we know the temporal and quantitative characteristics of the tapping cycles accurately.

Fig. 7.2.8. Daily values of carbon dioxide concentration in an apartment (Laurent Socal BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

The role of dynamic effects is also significant in the case of comfort parameter based control solutions. An example is the CO_2 concentration-controlled ventilation. The concentration of carbon dioxide depends on the occupancy and usage. Figure 7.2.8. shows the results of a CO_2 measurement in an apartment. The highest concentration appears at night when everyone is at home. The concentration gradually decreases during the day when they leave home, and it begins to increase again in the evening, as they return home. If a fresh air mechanical ventilation is located, it will switch on at higher concentrations based on the settings. This concentration may be higher than the daily average concentration. It may even result that there is no need for mechanical ventilation in the case of the seasonal method, while the demand may be significant in the case of the hourly method.

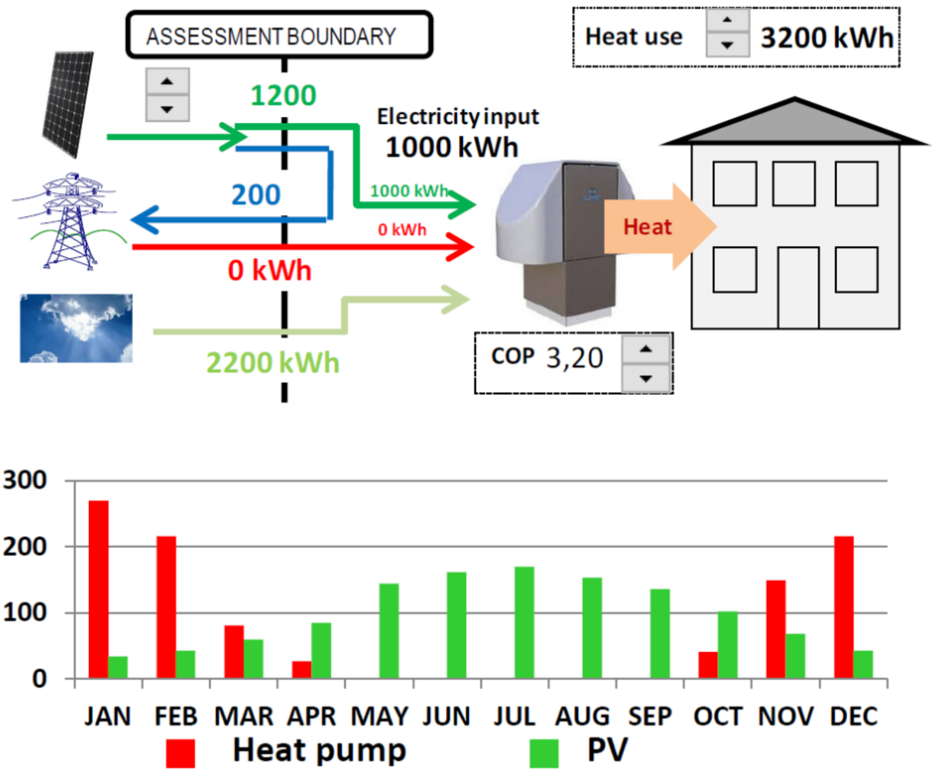

Fig. 7.2.9. Production (PV power generation) and demand (heat pump power consumption) of a solar-assisted heat pump system (Laurent Socal BUILD UP Webinar series Webinar 4: EPB standards hourly vs monthly methods 26 May 2020)

Finally, there is an example of solar power generation. Figure 7.2.9. shows the monthly energy demand and PV power generation of a solar-assisted heat pump system. The electricity generated by the solar cell can cover the electricity demand of the heat pump on an annual average. However, if the monthly production is examined, this is no longer the case at all. It means that the calculation with the annual average leads to incorrect results if there is no correction according to the utilization. The figure does not show, but the problem also occurs in a daily cycle: there are heating demand peaks at night, while the solar cell does not produce energy. So the problem can be modeled really well with hourly method or simulation.

It was visible that calculation with the smallest possible scale gives more accurate results in many cases, especially in the case of low-energy buildings and buildings served by renewable energy systems. However, it should also be mentioned that the detailed calculation method gives more accurate results only if the input data are available with sufficient detail and reliability. In the case of examples mentioned above: if the daily values of internal heat loads, tapping demands, or carbon dioxide concentration are not known and only assumptions could be given, the detailed methods will not provide more accurate results either. Detailed methods are more time and resource-intensive than simplified methods. Because of the more complicated calculations process, there is a higher probability of an error and their control is also more difficult.

7.2.2 INTRODUCTION: HISTORY OF BUILDING ENERGY SIMULATION

Buildings are one of the most significant energy consumers as they consume about 30% of the global energy. Thus, buildings emit a huge amount of greenhouse gases, such as CO_2. CO_2 gas emission is one of the most acute problems nowadays and there are several efforts to decrease the pollution. To reduce the energy demand and the harmful emission of the buildings, the exact knowledge of energy consumption and the influencing factors are necessary. The demands and loads of the buildings could be determined among others, with the help of building energy simulation tools. [1][2]

The history of building energy simulation started in the middle of the XX: century. The first study in ASHREA Journal about using computers to solve HVAC simulation tasks was published in 1959. This paper was about the calculation of the gas pressure in compressor cylinders using a Bendix G-15 computer. [1][3]

In the '50s an IBM 7094 computer was also applied to solve building simulation problems at the National Bureau of Standards (NBS) but this computer worked with FORTRAN programming language. In 1964, this computer was used to determine the thermal conditions in fallout shelters. [1][3]

In 1967 the Task Group on Energy Requirements (TGER) was founded by ASHREA. The aim of this task group was to create a building energy simulation software with public domain. In the same year, the Automated Procedure for Engineering Consultants brought on a calculation tool appropriate for the limited memory computers. [1]

The engineers and programmers started to use computers for solving different kinds of simulation problems and develop their own programs. In the second half of '60s engineers worked a lot on cooling and heating load calculation problems. In 1970, the first symposium addressed computer building energy simulation - "Use of Computers for Environmental Engineering Related to Buildings" – took place in Gaithersburg, Maryland with great success. [1][3]

In the '70s several building energy simulation programs existed but they stood on very different stages of development. Some of them were very detailed and were able to calculate hourly results but the others could only handle steady-state conditions. Because of the differences in the elaboration of programs and in financial support, many of the existing simulation programs disappeared. [1]

The ASHRAE Task Group on Energy Requirements (TGER) brought out a 2 volume book in 1975 to support the work of the researchers and developers. The books summarized the calculation and modelling methods of the existing simulation programs. [1]

In 1979 in the Electric Power Research Institute (EPRI) report 31 solar heating and cooling simulation computer programs were presented and compared. This report provided detailed information about the presented simulation programs and it also gave a great summary of them. [1]

In 1985 the Building Energy Simulation Conference was held in Seattle, Washington. This conference was not only remarkable from an engineering viewpoint but the history and the actual state of building simulation program development in different parts of the world was also an important topic. [1]

Experienced the advantages of the building simulation programs several simulation tools were developed until the ‘90s using different kinds of calculation methods but most of these simulation programs disappeared. Many firms did not publicize the working method of their simulation programs and that is the reason why they couldn’t be developed in an appropriate way. On the contrary, the public domain simulation programs were used by several researchers and could be evolved rapidly. [1]

The government started to support the development of some public domain simulation programs, which brought the private companies into a hard financial situation. Until this time, several reliable calculation methods and simulation tools were developed and therefore the emphasis started to place on the creation of new interfaces for the existing simulation programs too. [1]

The public domain programs commonly use the weighting factor method (for example DOE-2) and heat balance method (for example BLAST) to determine the heating and cooling loads of the building. The weighting factor method applies pre-calculated/custom weighting factors to transform the heat gains through the surfaces to heating and cooling loads. The heat balance method calculates with conductive, convective and radiative heat balance in every surfaces. [1]

The topic building energy simulation is still in the middle of attention. Several researches are addressed to the examination of different simulation programs: their usability for building modelling. The benefits of cooperation were realized and there have been a number of initiatives to motivate professionals to work together. Such an initiative was the first Building Energy Modelling Innovation Summit, held in 2011, inBoulder, Colorado. [1]

7.2.3 TYPES OF SIMULATION PROGRAMS

Using building energy simulation programs, the energy consumption of an existing or planned building can be quickly calculated with different conditions, the results can be compared and therefore it could help to reduce their energy needs. With the help of the simulation programs the process of planning is getting easier: designers can easily make decisions because they can examine how the modifications influence the behaviour of the building. These programs are not only able to calculate the energy loads but they support the job of engineers in the process of HVAC system selection, cost of building and operation determination and comfort parameters calculation. [4]

Numerous building energy simulation programs are in use. These programs use different calculation methods, have different complexity, different possibilities for usage and the determination of the input data could also be different in each program. More complex a software is, the more user experience is needed. The choice of which software should be used depends on the personal preference and the aim of the research. Several articles are about the comparison of the building energy simulation tools. The most complex building energy simulation programs commonly used nowadays are for example Energy Plus, ESP-r (Energy Simulation Software tool), IDA ICE (Indoor Climate Energy), IES-VE (Integrated Environmental Solutions - Virtual Environment) and TRNSYS. [4][5]

The first generation of detailed building energy simulation programs, such as DOE-e, Blast and ESP-r were developed in time of oil embargo in the 1970's. The price of energy increased and thus the energy consumption needed to be decrease. The more complex next generation of energy simulation programs arrived in the middle of the 1990's, such as Energy Plus and DeST. To help them widely spread, third-party modules and interfaces were also created, such as eQuest, OpenStudio and DesignBuilder. These detailed simulation programs uses different methods and models to determine the simulation results. Conduction transfer function (CTF) and thermal response factor methods could be applied to transient heat transfer calculation, radiant time series method is suitable for determine the cooling loads and lumped parameter models could be used to calculate the energy consumption of a building. [1][2]

The simulation results of simplified building energy and load evaluation models are not as accurate as the detailed simulation programs because they calculate with steady-state conditions. These models are ideal to give quick result and provide assistance in decision-making and help to find the most appropriate model options. As simplified methods, degree-day method could be used to determine the heating demand of buildings and bin method could be applied to calculate the energy performance of them. [2]

To analyse the energy usage of buildings statistical and regression methods could also be used. Multiple linear regression (MLR) and artificial neutral network (ANN) methods calculate the energy loads and consumption of buildings on the basis of historical data. Support vector machine (SVM) models could also be applied to examine the energy usage of buildings. The behaviour of occupants influences largely the energy demand of buildings, therefore the analysation of their actions and the development of behaviour models are important. Faults models point the faults of HVAC and control systems, which could cause huge energy losses. [2]

Building energy simulation tools represent the thermal zones with uniformed data which method does not lead to accurate results mainly in the case of large zones. But computational fluid dynamics (CFD) can handle the distribution of the air properties and some building simulation software, like DesignBuilder contain it. Coupling building energy and environment simulation tools is favourable for both cases: with the help of building energy simulation more accurate boundary conditions could be served for CFD calculations and with the help of CFD more accurate input data could be determined for building energy simulations. [2]

7.2.4 STEPS OF SIMULATION (USING A WORKING EXAMPLE)

There are three main steps in the process of building energy simulation. First of all the examined building has to be determined: the structure and construction materials have to be specified in the used software or it could be imported from another program. The energy consumption is largely influenced by the occupants' behaviour and that is the reason why the details of the usage have to be given (for example the personal activities, existing equipment, comfort parameters, different kind of schedules, etc.) in the second step. After giving these information, the building energy simulation could be run and the results should be checked in the third step. This check is necessary in every cases: the programs can indicate running errors but wrong input data can also cause false simulation results as well. [4]

To learn the steps of simulation a working example was developed in DesignBuilder, which is one of the most known building energy simulation software. The engine of this software is EnergyPlus. The full text of the exercises is in the annex, containing practising tasks for:

- Geometry
- Constructions, openings
- Lighting, shading
- Schedules, templates
- Load calculations, simple HVAC
- Detailed HVAC, renewable integration. [6]

The history of Energy Plus started in 1996 in the United States of America. In the United States two building energy simulation programs were developed before: DOE-2 and BLAST. DOE-2 was sponsored by the US Department of Energy (DOE) and BLAST was sponsored by the US Department of Defence (DOD). These programs have become too expensive to maintain and develop and therefore a new simulation software, the EnergyPlus was created based on the two existing and well-functioning programs. Energy Plus is sponsored by the Department of Energy (DOE). It has modular, structure code and it has heat balance engine like BLAST. EnergyPlus does not have a visual interface and therefore the user-friendly usage requires a third-party software tool, like DesignBuilder. The time step of the calculation could be modified so simulation results could be determined with different accuracy. The program calculate different kind of loads and consumptions such as the electricity consumption of different parts of the system or the heat gains of the simulated zones.[4][5][7]

The three main parts of the EnergyPlus are the simulation manager, the heat and mass balance simulation module and the building systems simulation module. The simulation manager colligates the whole simulation process. For example, it ensures communication and data flow between different parts of the program and coordinates their operation. The heat and mass balance simulation module and the building systems simulation modules have a great influence on each other. The heat and mass balance simulation module calculates the loads in every time steps and provides information about the simulated zone conditions for the building systems simulation module. The building systems simulation module determines the building systems related simulation results and give feedback to the heat and mass balance simulation module, which calculates therefore with potentially modified space temperatures in the next time step. [7]

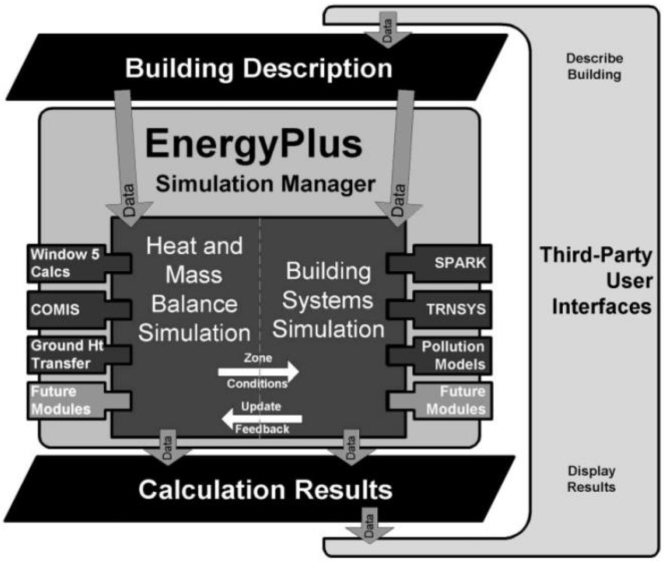

Figure. 7.2.10. Energy Plus structure [7]

During the process of building modelling, the characteristics of the building environment have to be specified. It covers not only the exact location: for example the orientation and weather conditions should to be set as well. The energy consumption of the building depends on the environmental conditions significantly: the same building in Norway or in Italy has a very different energy need. DesignBuilder has a large database in all areas of the program and not only these default data could be applied. The available data sets could be modified or own database could be imported into the program as well.

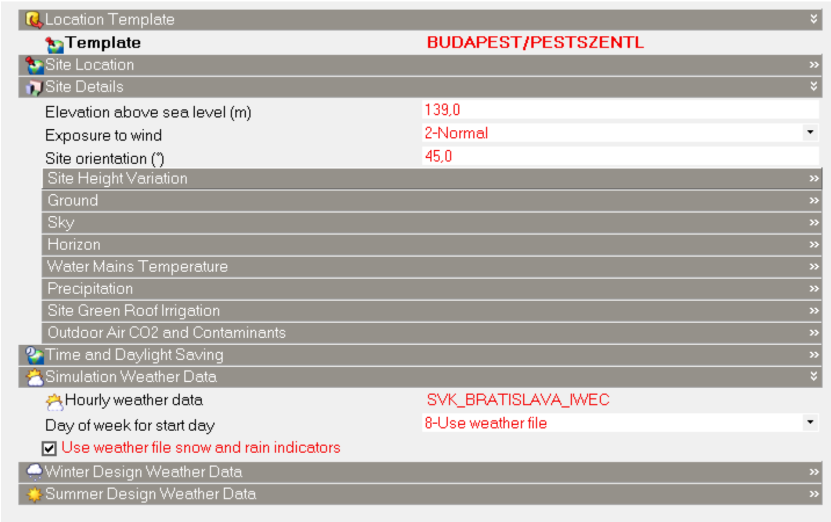

Figure 7.2.11. DesignBuilder – Location tab

Modelling the geometry of a building, not only the external surfaces but the internal structure could also be given. Each floor is typically specified as one block. In some cases the geometry of the building could be so complex, that multiple blocks should be created to model the same floor. The blocks could be divided into zones, which zones do not necessarily correspond to the rooms of the building. The rooms could be represented by one zone or they could be divided into separate zones according to their properties. For example in the case of an office building, some office rooms could be merged into one zone under certain conditions to shorten the simulation time. Another example could be a huge office room, which should be divided into several virtual zones according to the required comfort parameters and activities in different parts of the room. Standard component blocks could be created in DesignBuilder (pink on the figure) too. These blocks do not participate in the energy calculations, but their shading effects are taken into account during the simulation. If a room or part of it is under the ground level, the heat losses and gains are differ from the ones above this level. The reason given is that their outer surface contact with the ground floor and not with the outside air. In such cases, ground component blocks could be used (green on the figure) to represent this effect.

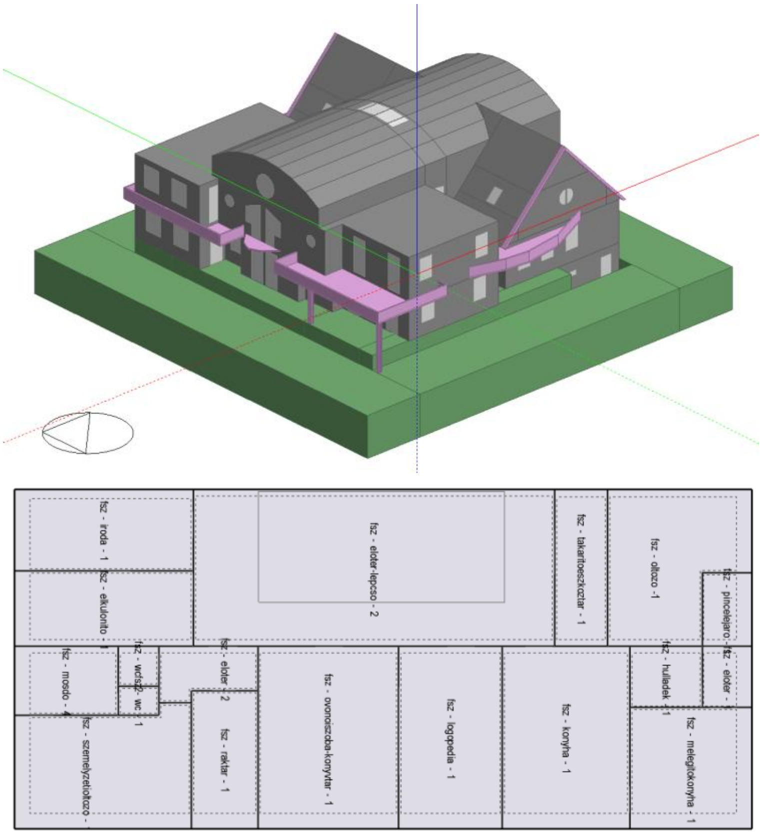

Figure 7.2.12. DesignBuilder – Geometry of a building

The properties of the structures should also be specified in the program. DesignBuilder has its own database containing various construction materials. All properties of these materials could be checked and modified, and it is also possible to create new construction materials as well.

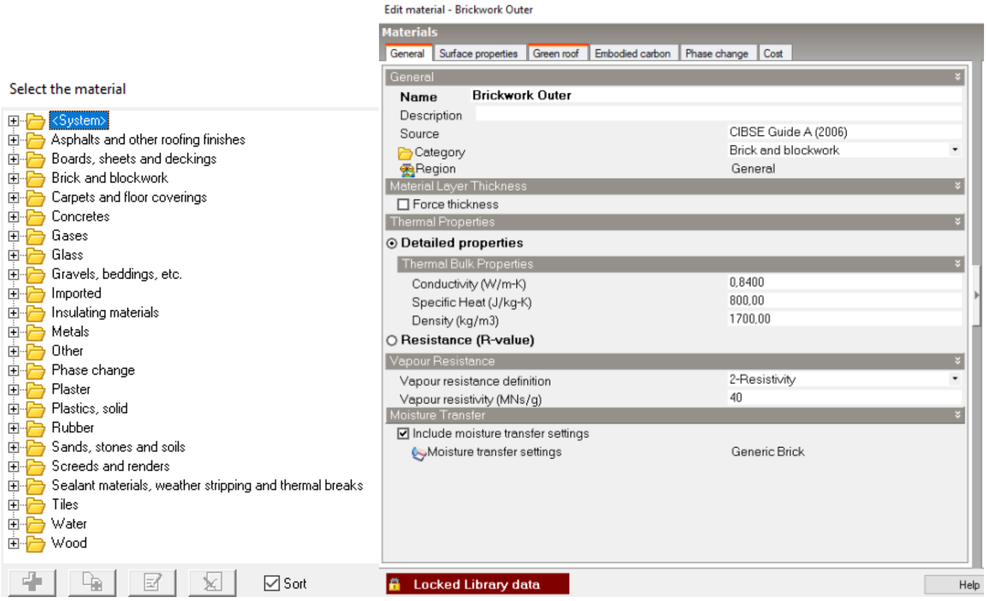

Figure 7.2.13. DesignBuilder – Materials

Not only default materials, but also predetermined constructions could be found in the program too. These constructions could also be modified and new ones could be created. The constructions could be specified layer by layer, setting their materials and their thickness.

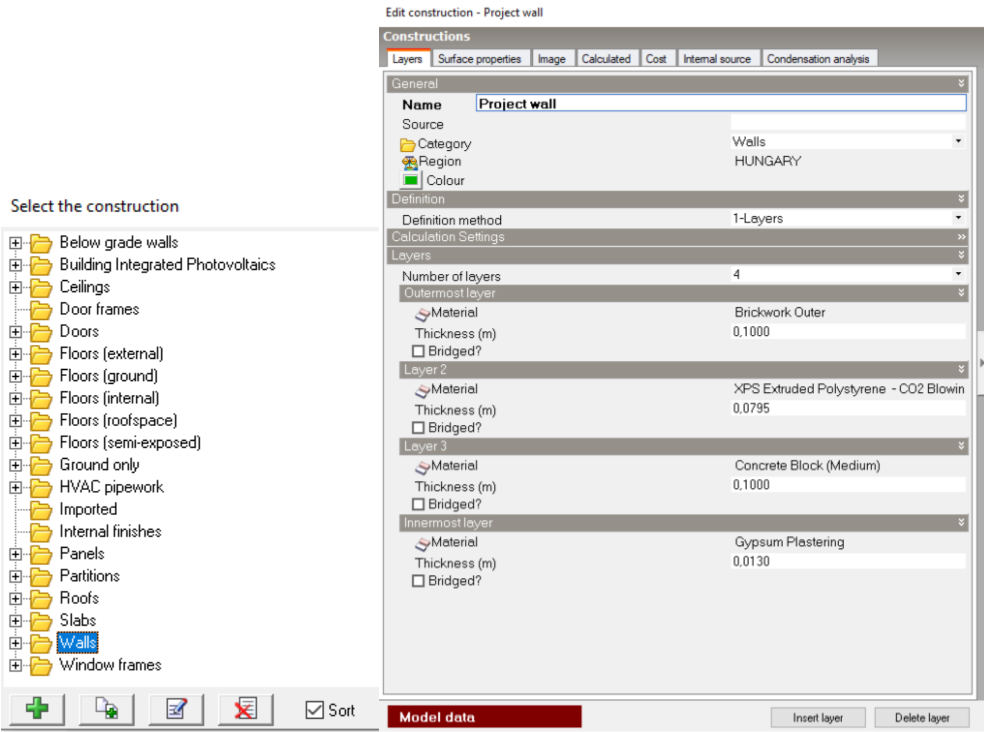

Figure 7.2.14. DesignBuilder – Constructions

The structure of the building covers the openings as well. The properties of the windows and the doors could be set similarly to the properties of constructions.

Figure 7.2.15. DesignBuilder – Openings

Two different display modes could be used to visualize the examined building in DesignBuilder. Applying the default display mode (Model Data), the construction of each structural elements could be checked and visualized whether the program actually applies the construction material considered necessary on the given surface. The different types of constructions are marked with different colours, which colours could be modified. Using the other display mode (Rendered View), the building could be visualized more realistically, a virtually “tour” could be done.

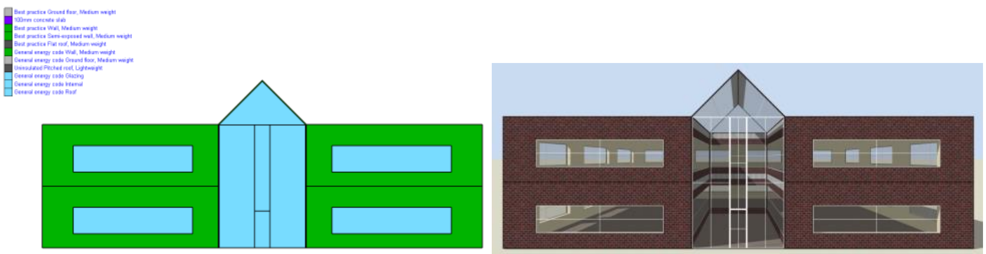

Figure 7.2.16. DesignBuilder – Model data, Rendered view

The different shading objects such as buildings, mountains, trees could be modelled in DesignBuilder using standard component blocks. The sunpath diagram of the building could be checked at different times of the day on different days of the year. Day-running simulations could also be created to examine the solar loads of the building. Different shading options could also be applied on the openings. These shadings could be external shading structures (local shading) or window directly shading elements (window shading) which could be operated according to a given schedule.

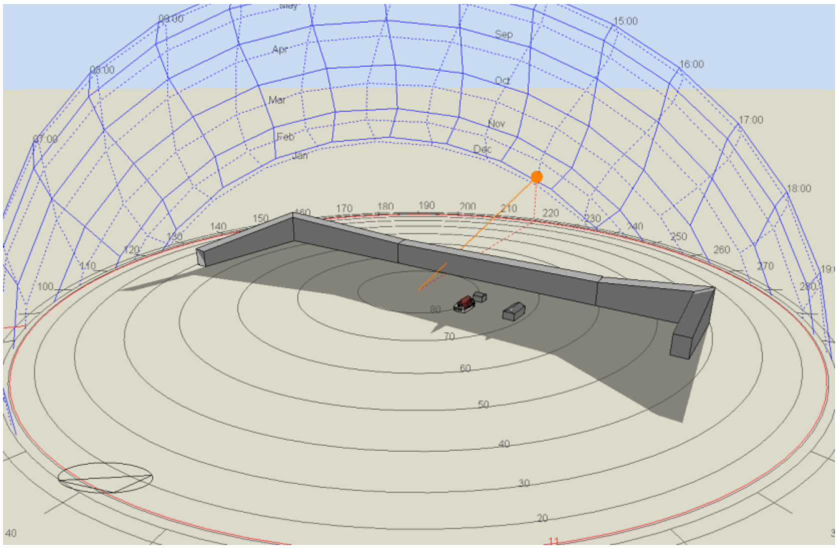

Figure 7.2.17. DesignBuilder – Sunpath diagram

The effect of shading could clearly be observed in the simulation results. The figure shows the solar gains of the same room on a typical summer week with (above) and without (below) shading. It is visible that the solar loads could be significantly reduced with the help of the external shading structures applied on the openings of this room, its effect can not be neglected.

Figure 7.2.18. DesignBuilder – Solar gains of exterior windows with and without shading

The characteristics of the lighting, such as its operation schedule and its properties could be given; and lighting control could also be applied.

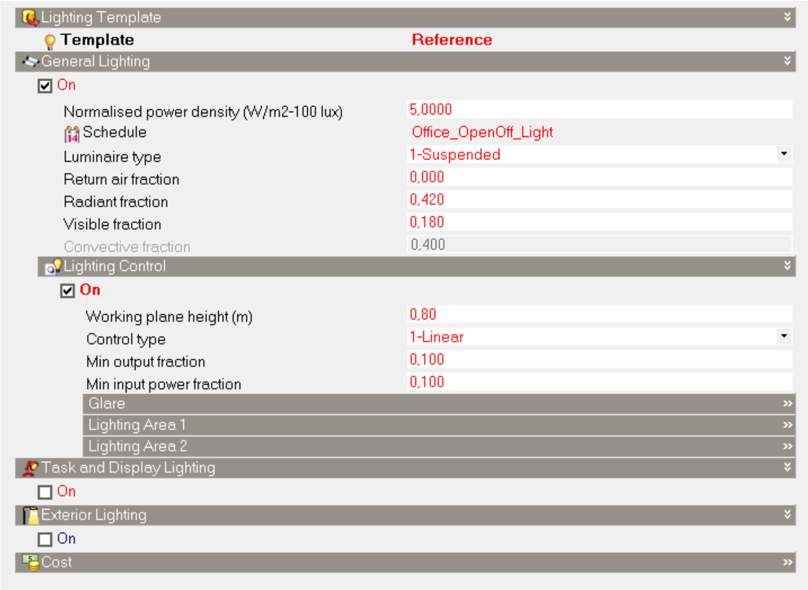

Figure 7.2.19. DesignBuilder – Lighting tab

The program includes predefined activity templates. Applying them, the room-specific properties - defined by DesignBuilder - automatically load, such as the occupancy, the setpoint temperature values, the power density of equipment, the domestic hot water consumption, etc. All of these properties could be modified individually.

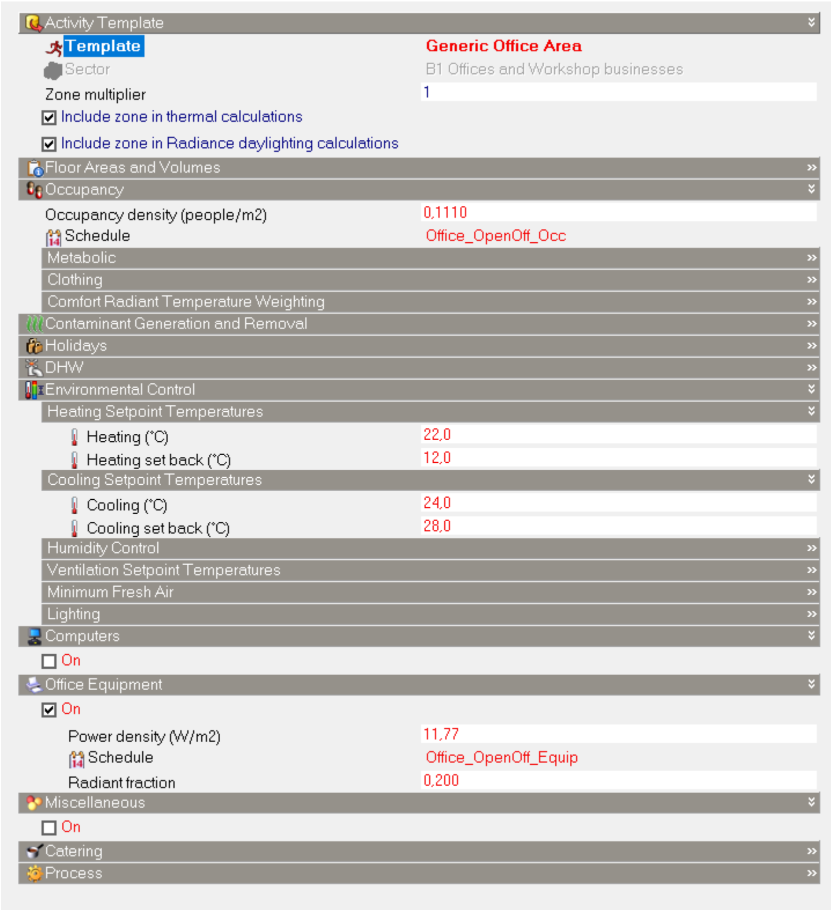

Figure 7.2.20. DesignBuilder – Activity tab

There are several options to set the occupancy in the building. The recommended solution is to create a compact schedule which determine daily schedules with specified time periods for different types of days. The number of people could be given as an input data, the schedule shows the percentage change of this amount of people. On the figure left side an example of the compact schedule could be seen and it presents the heat gain from occupancy on the right side. It could be observed that the heat gain fits exactly into the given schedule. Setting a schedule is required not only in the case of occupancy, but it is necessary for example in the case of ventilation, lighting, usage of computers and heating. Their schedule could be given in a very similar way.

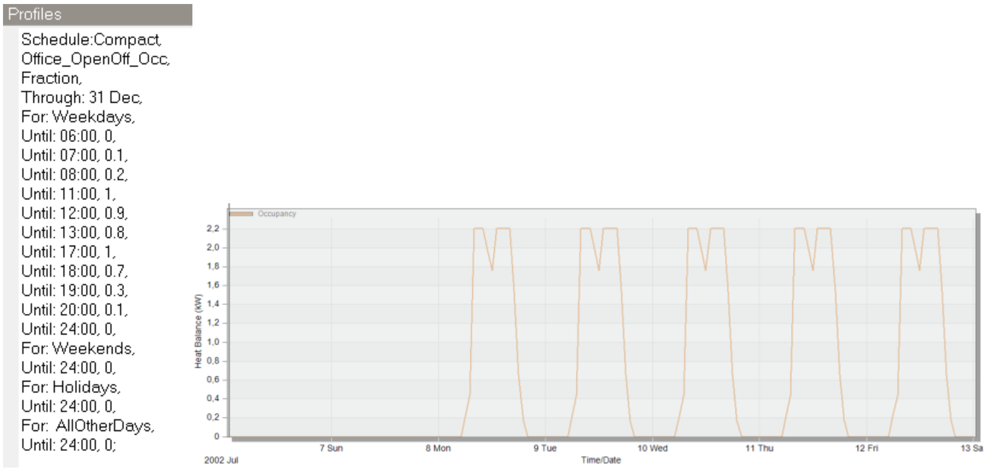

Figure 7.2.21. DesignBuilder – Occupancy

Using the DesignBuilder for building energy simulation, simple and detailed HVAC system settings could be applied. Applying simple HVAC system settings, the operation parameters of the system could be specified in a simplified way. Different templates could be found in the simulation program for this case as well, which templates could be used with or without modifications of the properties and set values. The calculation time of these simulations is significantly smaller than models using detailed HVAC system settings, but their results are corresponding less accurate.

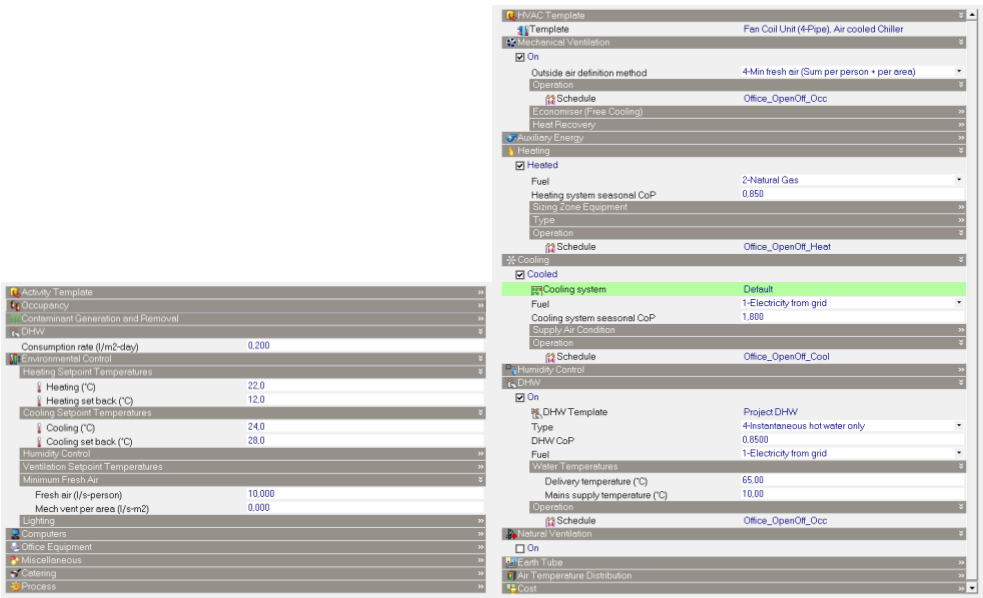

Figure 7.2.21. DesignBuilder – Simple HVAC

Applying detailed HVAC system settings, circuit diagrams could be developed to design the building services systems. Templates are also available for this case, but the loops could be specified separately as well on both the supply and both the demand side. These loops could be connected and the properties of the system components could be specified precisely. The modelled zones must be divided into groups according to the building services systems available in them.

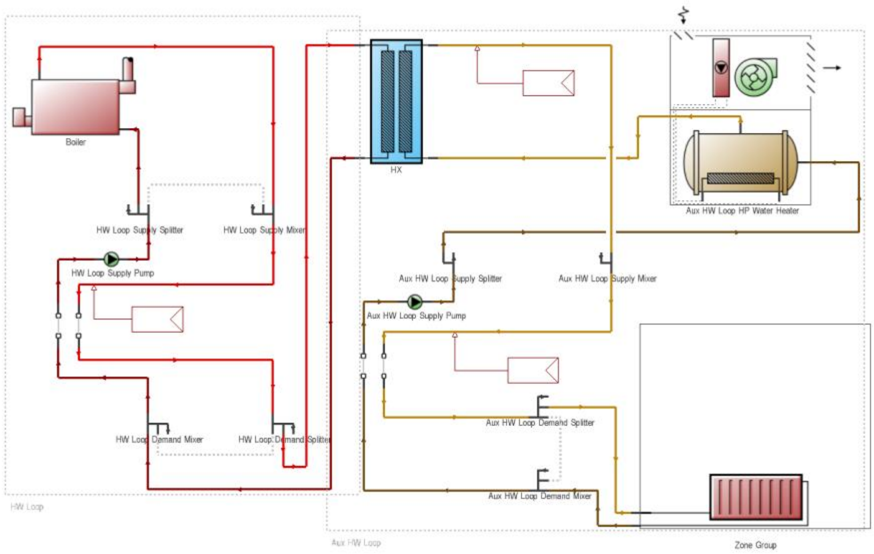

Figure 7.2.22. DesignBuilder – Detailed HVAC

Renewable energy sources could be integrated into the HVAC system applying either simple or detailed HVAC system settings. The figure shows example parts of circuit diagrams including a solar collector (left side) and a ground heat exchanger (right side).

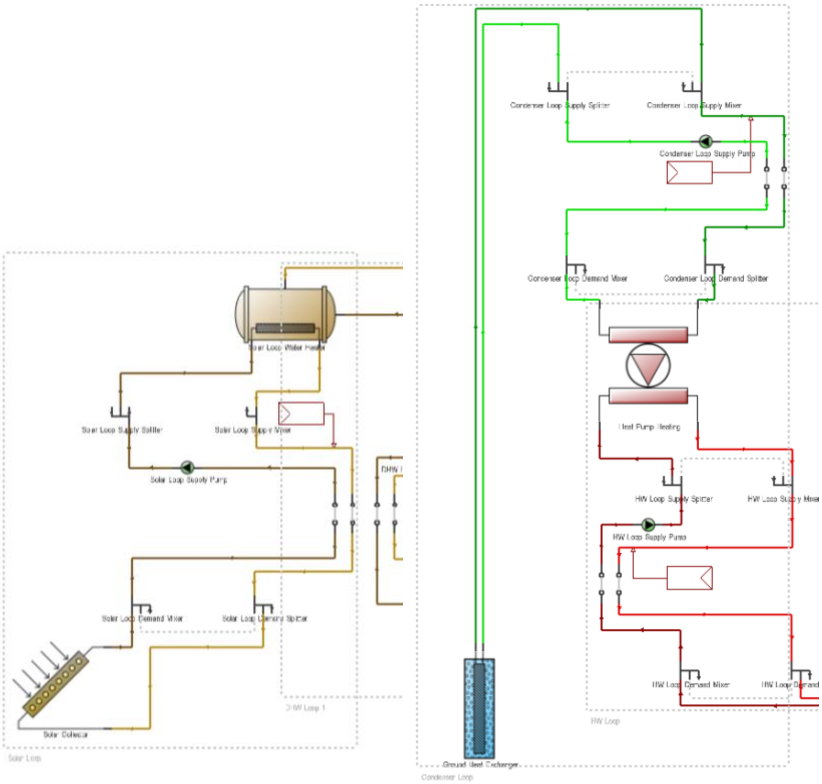

Figure 7.2.23. DesignBuilder – Renewable energy sources

Several types of simulations could be run, the properties of them could be set. Both the simulation period (annual, summer-winter weeks, specified time periods, etc.), both the output intervals could be specified. The more types of data with higher resolutions are required, the longer the simulation time will be. During the display of the simulation results, the different types of data could be examined separately and the display mode could also be selected.

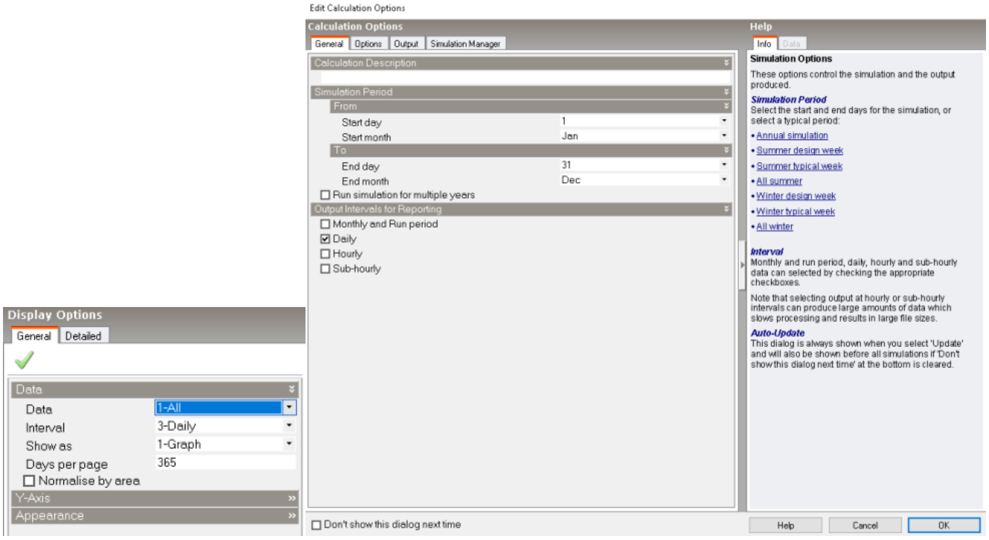

Figure 7.2.24. DesignBuilder – Simulation

This figure shows the daily data of an examined building for one year time period: various energy needs, loads and comfort parameters could be observed. The checking of the calculated results are necessary in all cases: a possibly incorrectly given parameter can cause large errors. For example it may turn out that the examined structural materials and building systems are not suitable for the analysed building. The results could be checked and analysed not only for the whole building, but also for individual zones as well.

Figure 7.2.25. DesignBuilder – Simulation results

7.2.5 RESULT ANALYSIS, GOALS OF SIMULATION

For building analysis, designers frequently use dynamic thermal simulation programs to calculate the indoor thermal and energy behaviour of a building [8] [9]. Building energy simulation (BES) software tools can evaluate a wide range of thermal or human behavioural response to stimuli [10]. These simulations make it possible to compare different design or retrofitting scenarios from the perspective of annual energy consumption and indoor comfort in a very time- and resource-efficient way. Using these analysis techniques, optimal energy savings can be achieved, and thus greenhouse gas emissions from buildings can be reduced. In many cases, the goal of design and simulations is to optimize indoor comfort levels and building energy consumption. Practitioners would use BES tools for predicting overheating, calculating heating and cooling loads, sizing equipment, evaluating alternative technologies (energy efficiency and renewable energy), regulatory compliance, or more recently, integrated performance design or rating [11] [12]. In several design methodologies, BES serves as an integrated, well-performing support tool for optimising the entire design process [13] [14]. [15]

BES is widely used in different phases in the life cycle of a building project. In the early design stage, energy consumption estimates and comparisons are crucial as feedback to the design team and to support decision-making. Later on, in the design development phase, simulation can show code compliance and help designers to determine the cooling and heating capacity of heating, ventilation and air-conditioning (HVAC) systems. Also, in this phase, BPS is a useful tool to support the sustainable rating process (such as LEED) [16]. After a building is completed, BES models can be used for performance diagnostics and integration with real-time building energy system controls. In retrofitting projects, BES can evaluate the impact of different intervention options to maximise energy savings and emissions reduction. [15]

In fact, the energy consumption of a building is a function of a large number of parameters in regard to:

- building characteristics,
- the characteristics, control and maintenance of energy systems,
- weather conditions,
- occupants' behaviour,
- other sociological parameters [17].

Therefore, energy consumption predictions always contain a degree of uncertainty depending on the level of confidence in each of these input parameters [18] [19]. It is highly important to determine the exact goal and expected level of certainty of our simulations before we start to build up BES models. After simulations are run, results should be analysed using the perspective of our goal settings. [15]

7.2.6 REFERENCES

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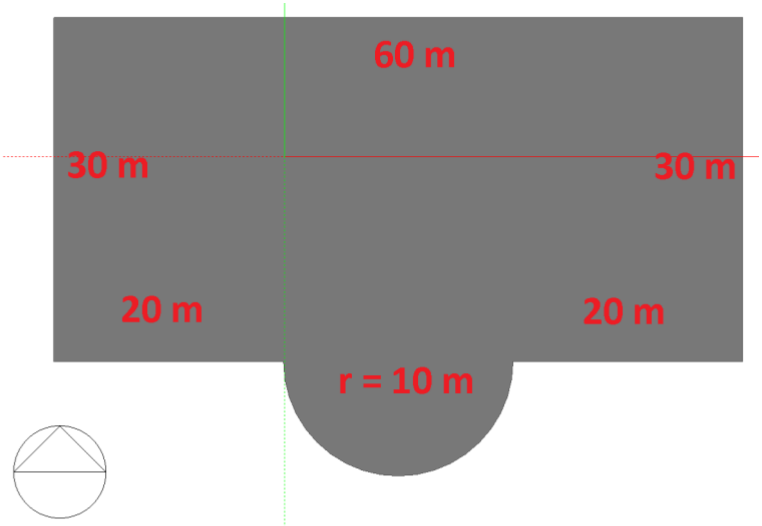
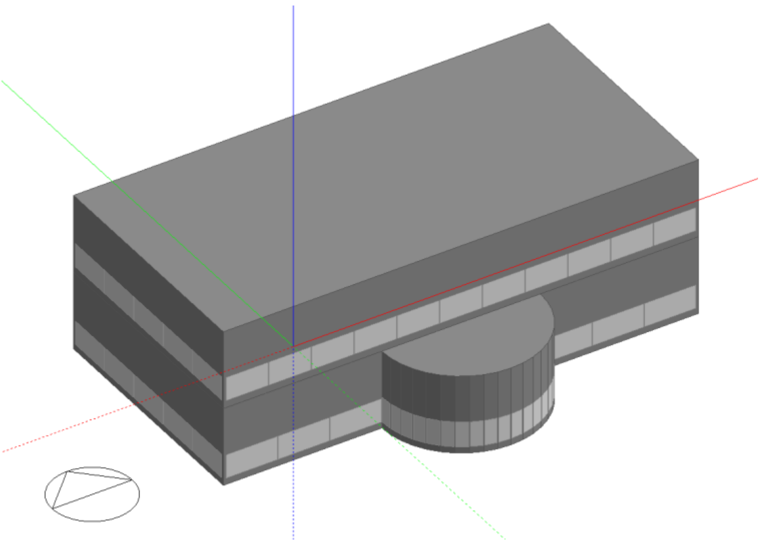
ANNEX 1. GEOMETRY

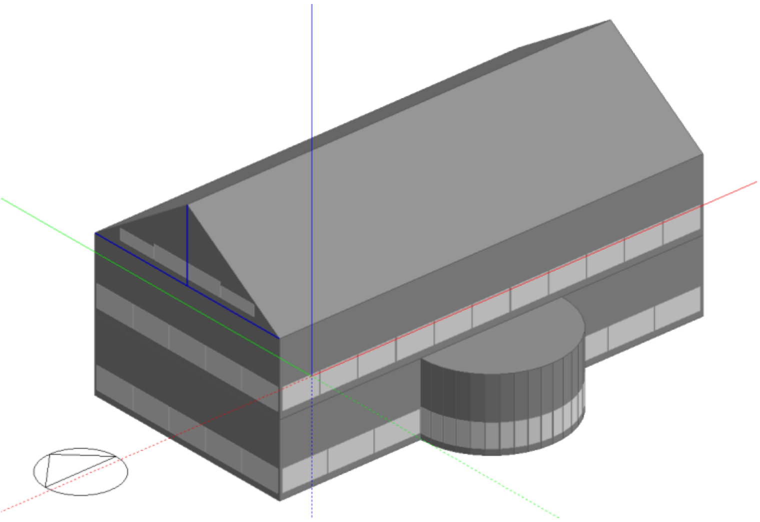
- Select location template: BUDAPEST/PESTSZENTL.
- Open a new file and add a 10 metre high building block.



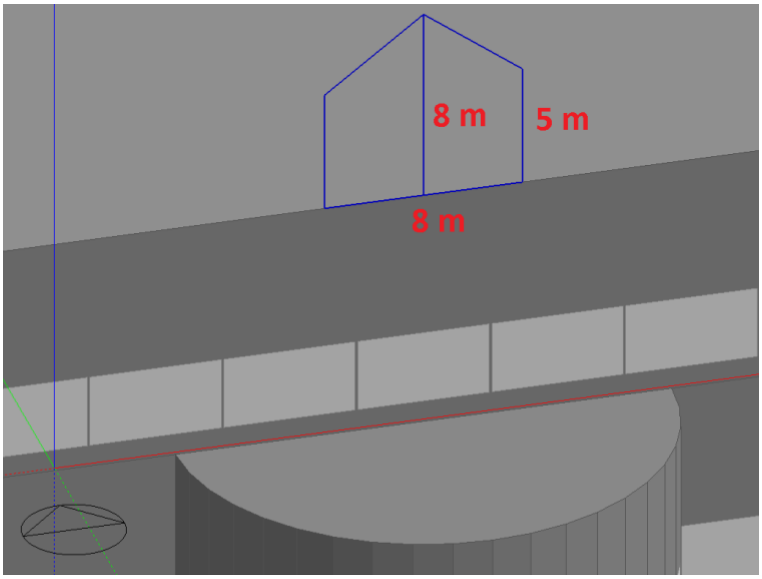
- Name it as „Ground floor”.
- Add a 30 X 60 X 10 metre block on the top of the „Ground floor”.



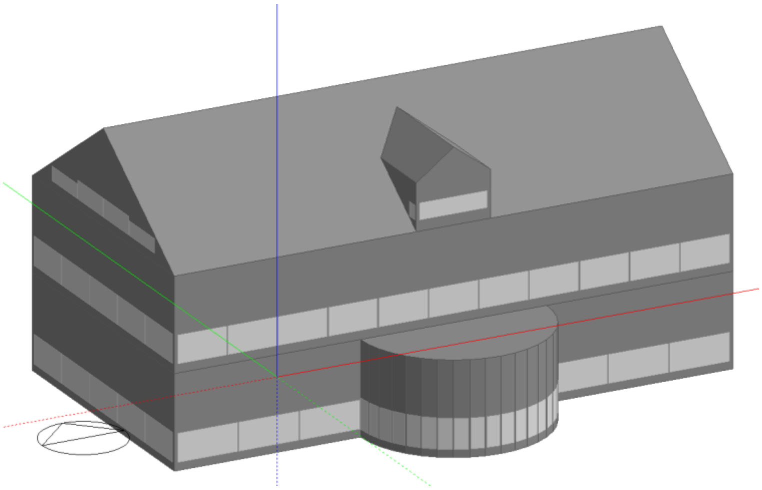
- Name it as „First floor”.
- Add a 30 X 60 X 10 metre high block on the top of the „First floor”.
- Cut the upper block and create a pitched roof.
- Delete the unnecessary blocks.



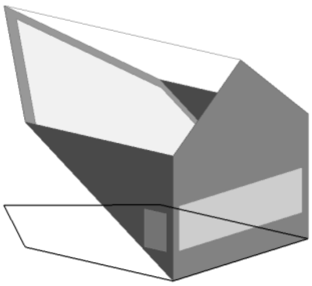
- Name the new block as „Roof".
- Use construction lines to locate an outline block in the centre of South facade.



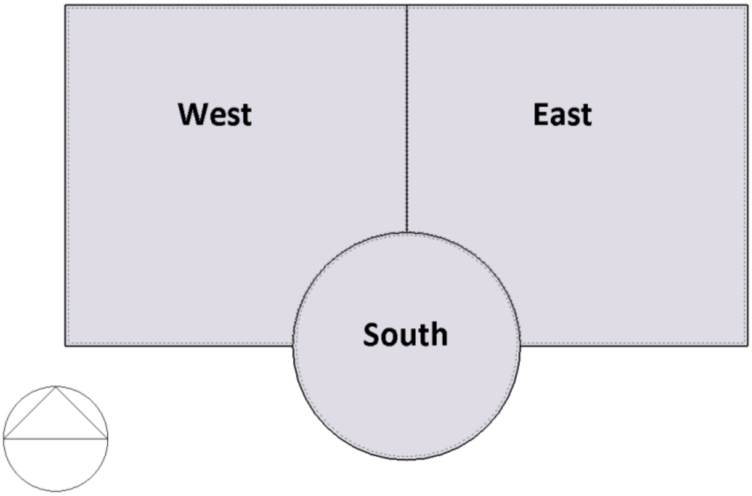
- Draw the vertical plane of the outline block and extrude it 40 metre long.
- Cut the outline block along the South roof.
- Delete the unnecessary block.
- Convert the outline block to building block.

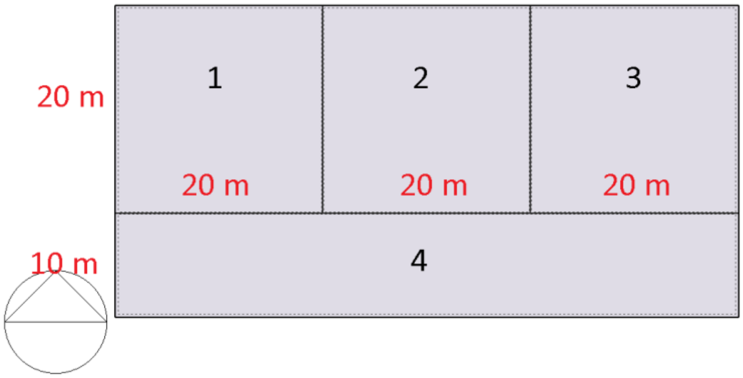


- Name the block as „Little” block.
- Draw a hole to the „Roof” and „Little” blocks connection.



- Draw partitions to divide the „Ground floor” and the „First floor”into thermal zones.
- Name the zones according to the figures.



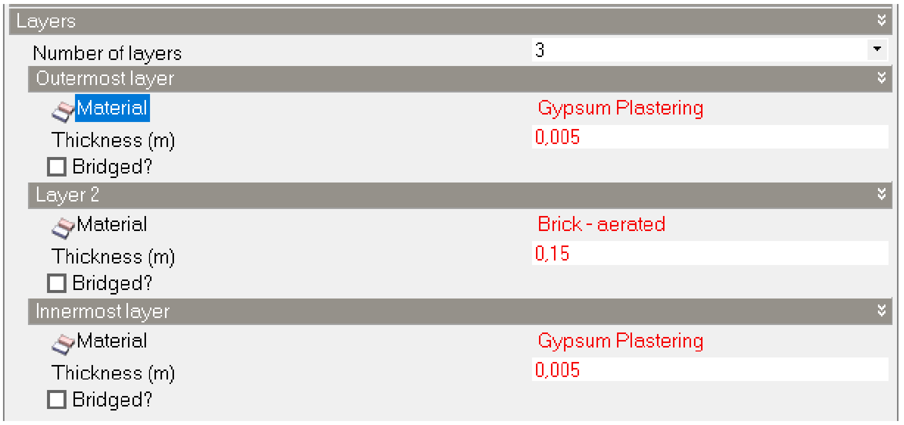


- Visualise the model.

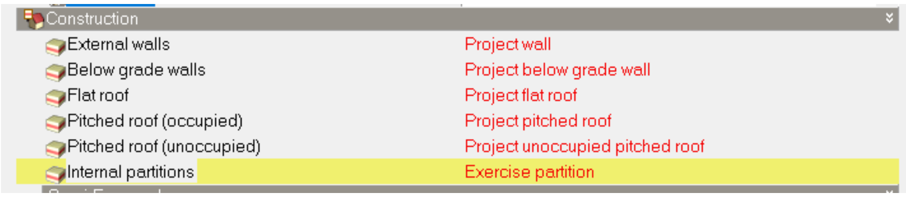
- Save the model and name it „Practice 1”.

ANNEX 2. CONSTRUCTIONS, OPENINGS

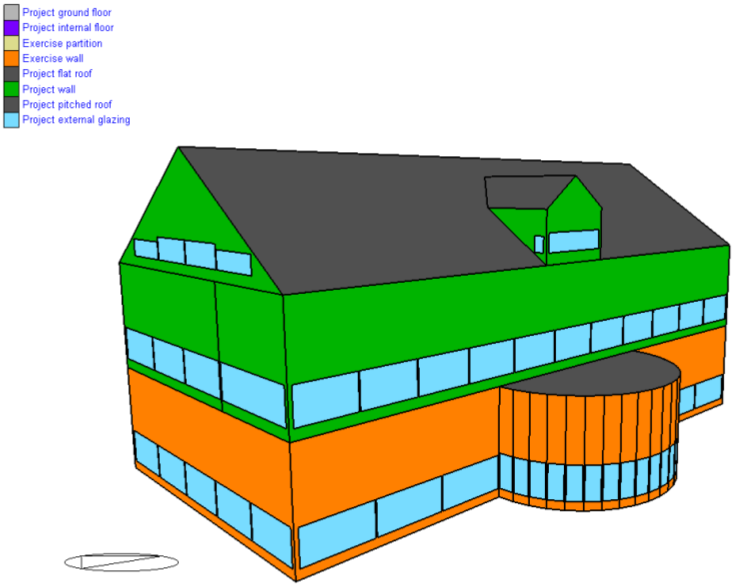
- Open file „Practice 1”.
- Create a copy of „Project partition” construction and name it „Exercise partition”.
- Edit the „Exercise partition” according to the data in the following table.



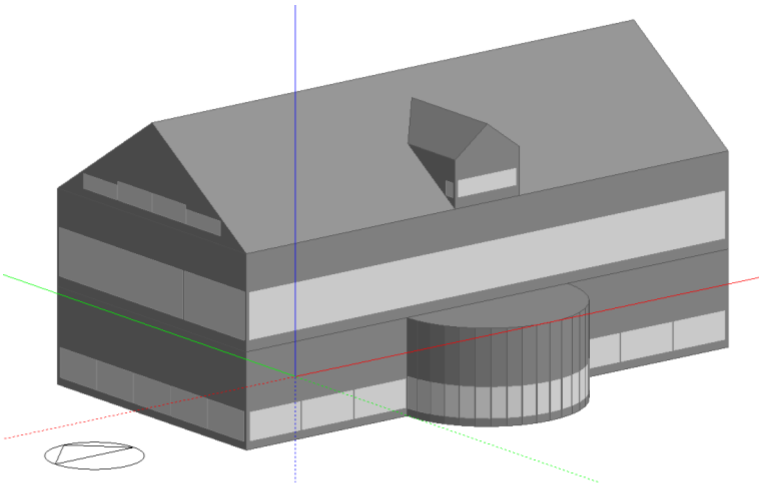
- Load „Exercise partition” as internal partition.



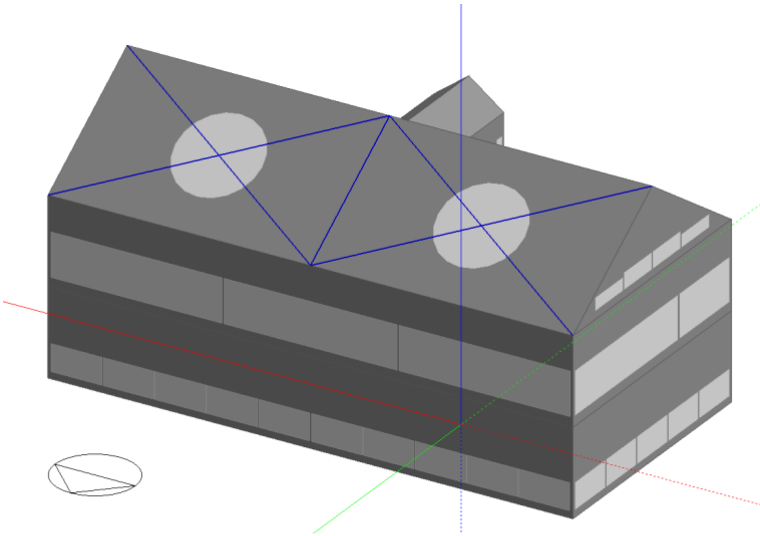
- Create a copy of „Project wall” and name it „Exercise wall”.
- Set U-value to 0,3 W/m2K and save the modifications.
- Change the colour of „Exercise wall” to orange.
- Use „Exercise wall” as the external wall of the „Ground floor” block.
- Visualise the model.



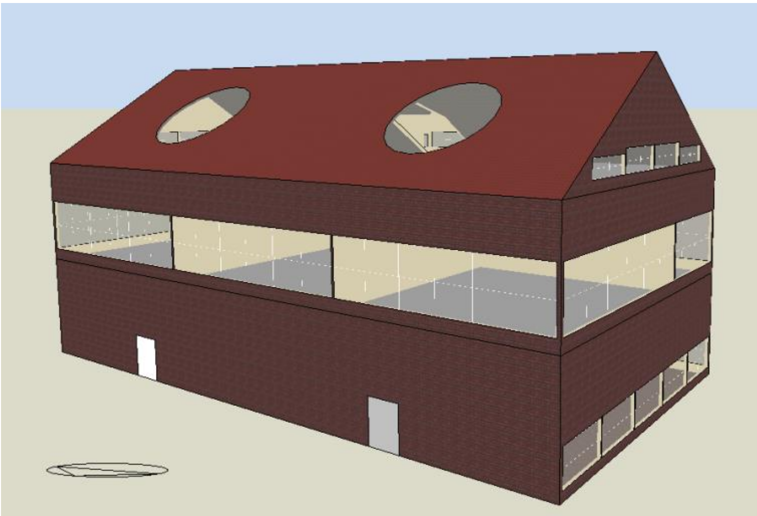
- Change „First floor” block openings to use Continuous horizontal type with 50 % window to wall ratio and 1 m sill height.



- Draw two sloped roof windows (circle, r=5 m) on the northern roof according to the following figure.



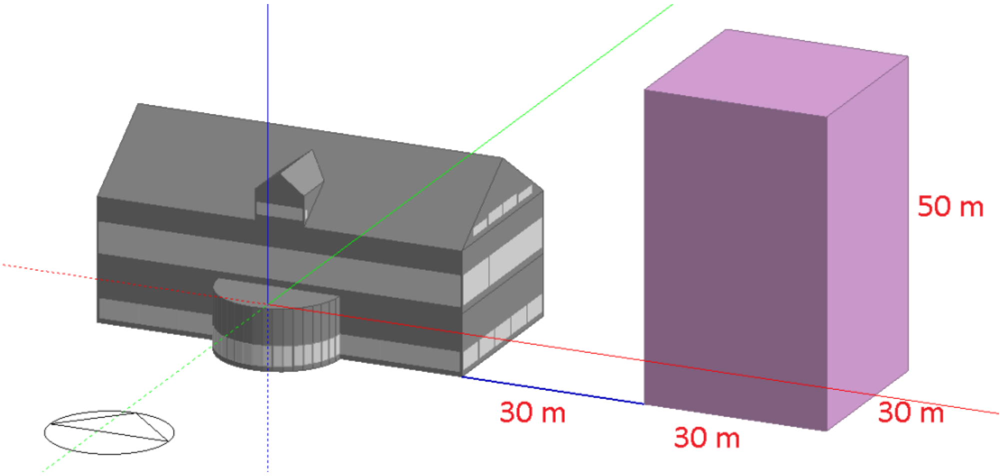
- Delete the openings of the „Ground floor” block’s northern façade.
- Draw 3X4 m external door in the middle of „East” zone’s northern facade.
- Copy the door into the middle of the „West” zone’s northern facade.
- Change the construction of the „West” zone’s external door to Opaque Door, Nonswinging, U-0.500 (2,839).
- Visualise the model



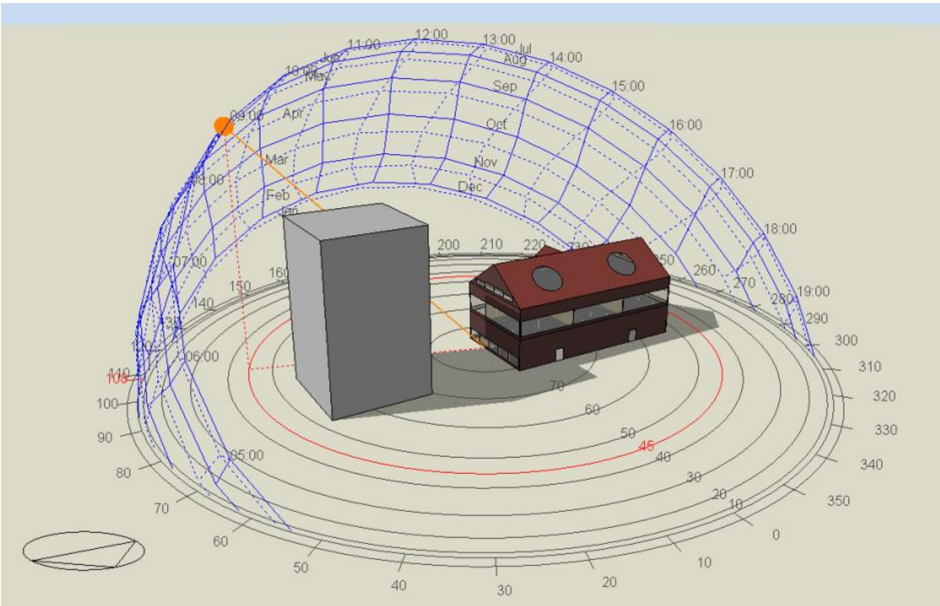
- Save the model and name it „Practice 2”.

ANNEX 3. LIGHTING, SHADING

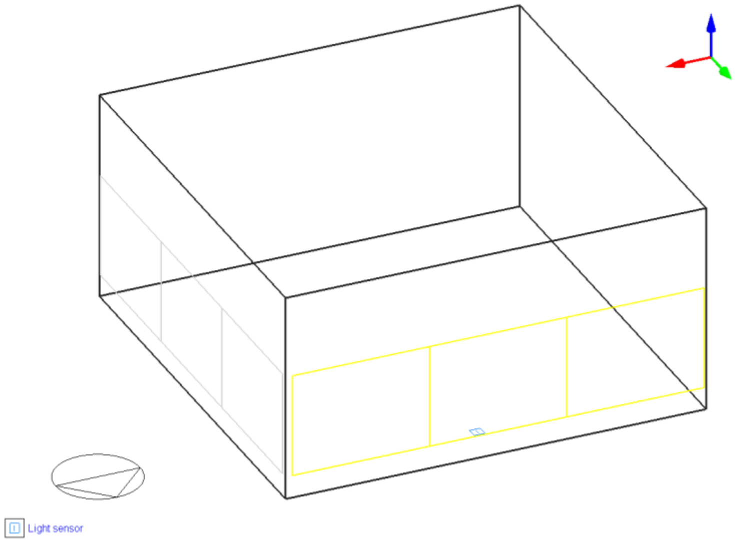
- Open file „Practice 2".
- Create a 30 X 30 X 50 metre high component block to the east side of the building to examine the shading effect of a neighbouring building. Keep 30 metre distance between the blocks.



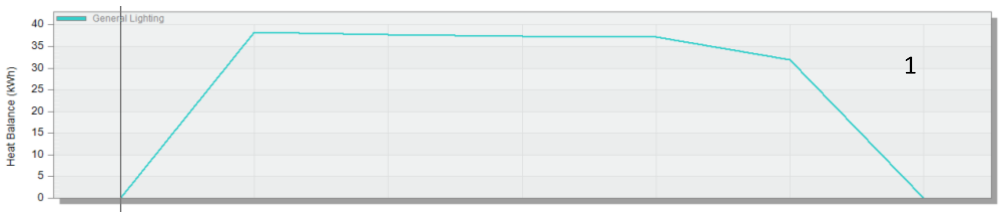
- Use sunpath diagram and show shadows to examine the shading effect of the component block in determined time: 15th July, 9 am.

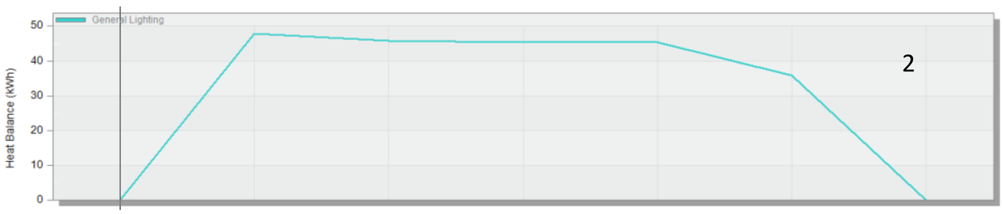


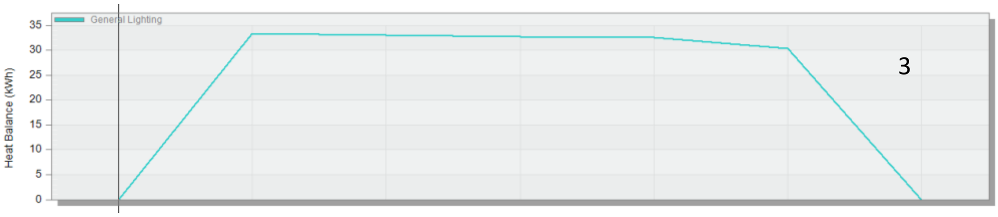
➢ Select „T8 (25 mm diam) Fluorescent – triphopspor – with LINEAR dimming daylighting control” lighting template on building level.
➢ Set the normalised power density to 5 W/m2 – 100 lux.
➢ Set the working plane height to 0,5 m.
➢ Move the lighting sensor in zone „3” 8 metre closer to the northern outer wall.



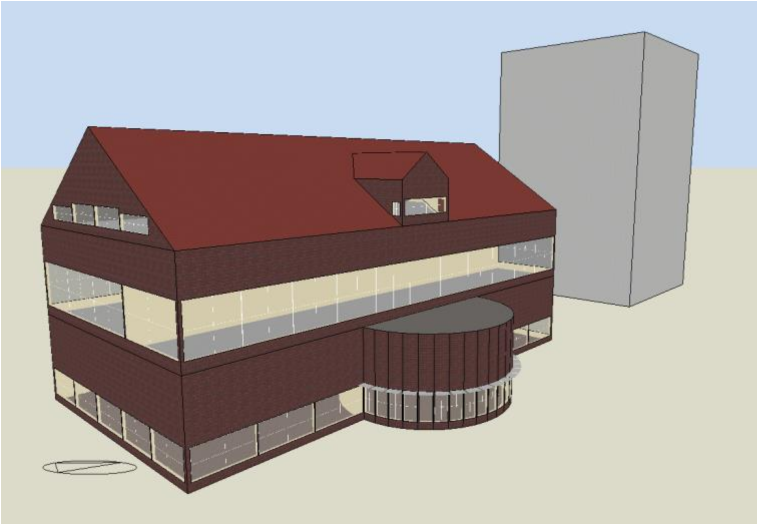
➢ Run daily and hourly simulation to a winter typical week using 4 time steps per hour.
➢ Compare the daily internal gains generated by the lighting in zone „1”, zone „2”, zone „3”.



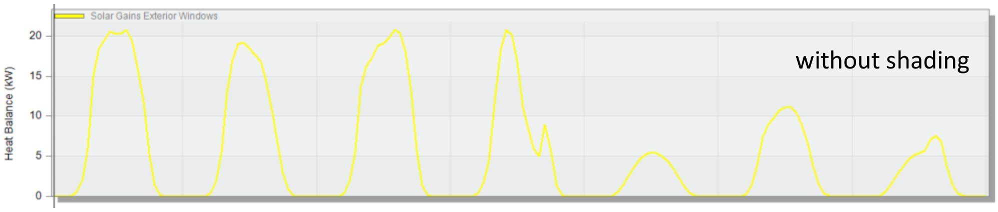


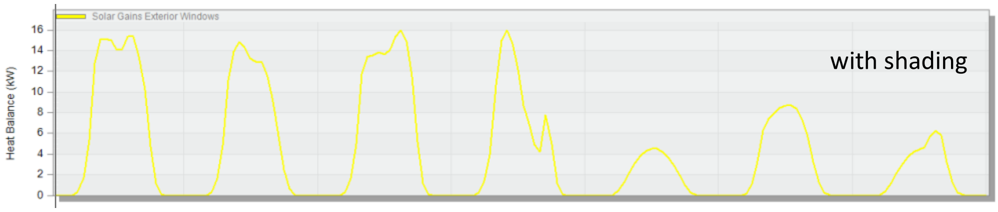


- Use local shading in zone „South”.
- Select type „1.0m Overhang „.
- Visualise the result.



- Run hourly simulation for a summer typical week and compare the solar gains of exterior windows in zone „South” with and without local shading.

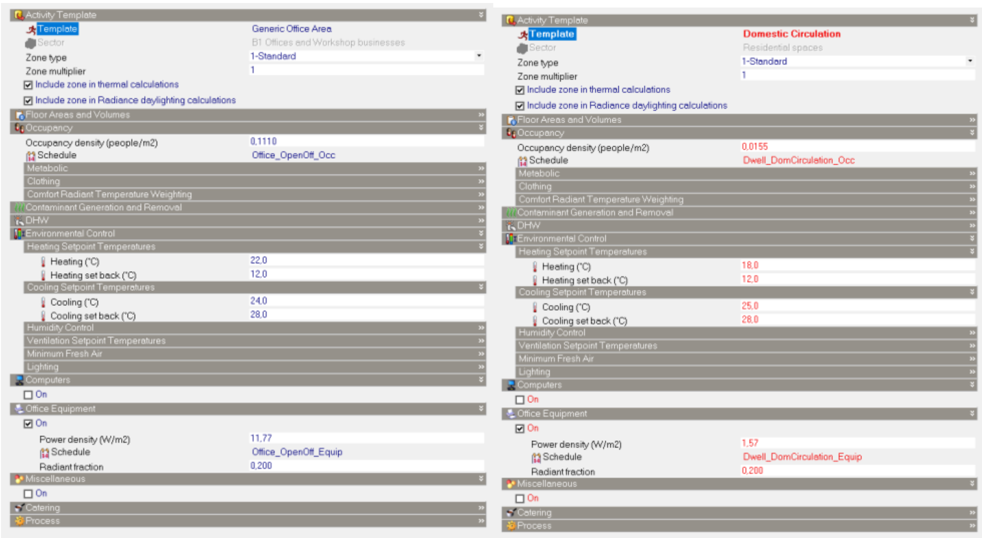




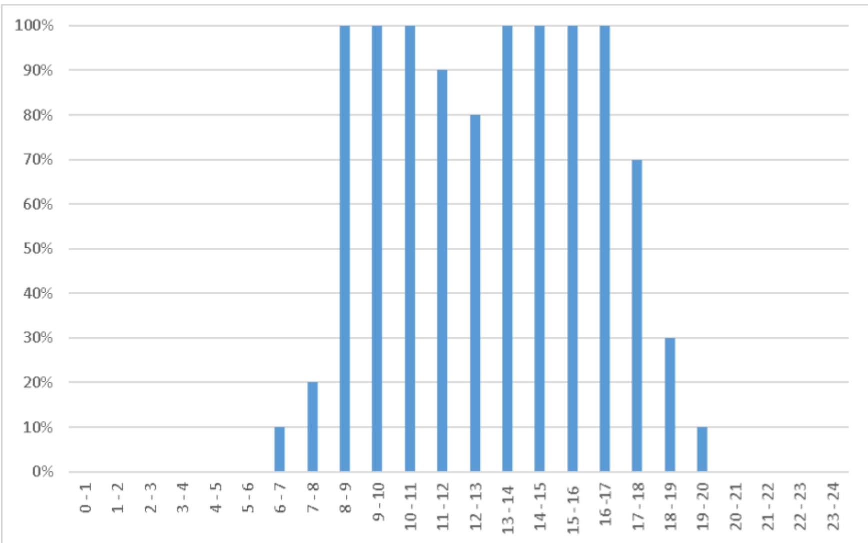
- Save the model using local shading in the „South” zone and name it „Practice 3”.

ANNEX 4. SCHEDULES, TEMPLATES

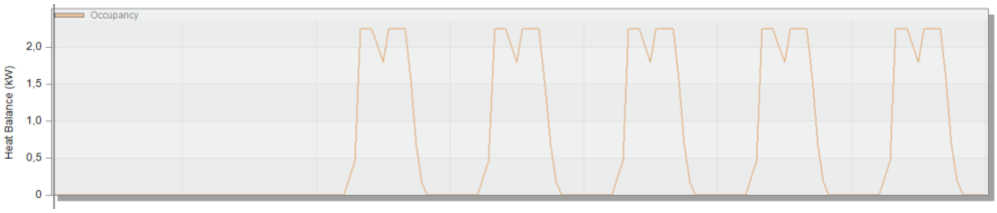
- Open file „Practice 3”.
- Change the activity template of the zone „4” to „Residential spaces – Domestic circulation”.
- Compare the setpoint data of the zone to the data of zone „3”.



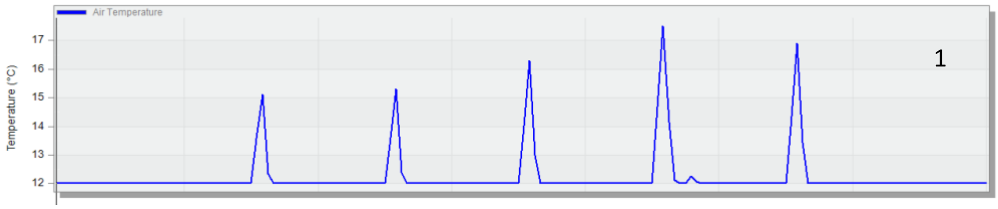
- Modify the occupancy schedule of „South” zone according to the following diagram. The data of the diagram are valid for weekdays, any other days the building is unoccupied.
- Name the schedule to „Exercise schedule”.

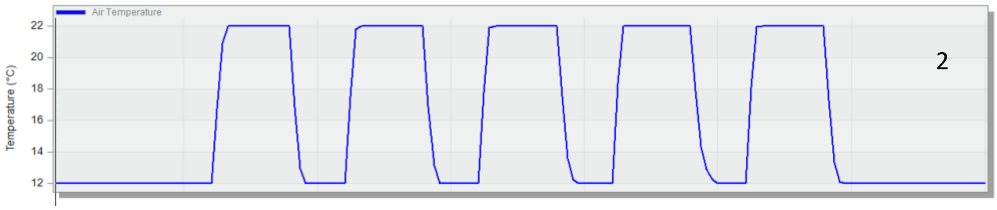


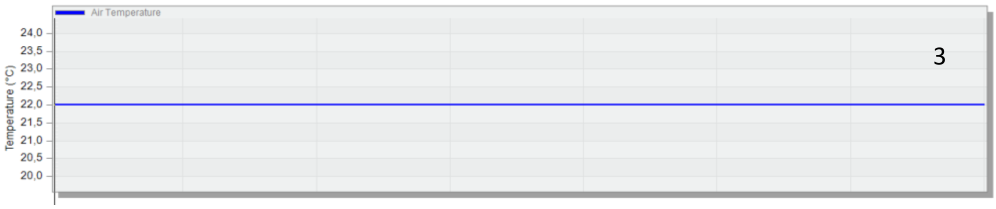
- Run hourly simulation for a summer design week and check the occupancy data in the „South" zone.



- Modify the heating operation schedule of „1" zone to have set back operation every time and full heating in weekdays between 12-14.
- Name the schedule to „Exercise heating schedule 1".
- Modify the heating operation schedule of „3" zone to have full heating operation every time.
- Name the schedule to „Exercise heating schedule 3".
- Run a winter design week hourly simulation and check the air temperature in zone „1", zone „2" and zone „3" and compare them with the heating and heating set back temperatures.







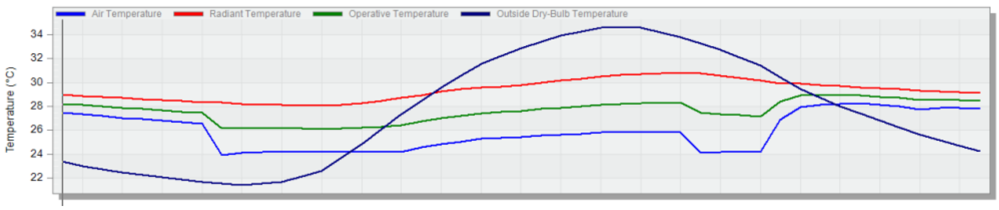
- Save the model and name it „Practice 4".

ANNEX 5. LOAD CALCULATION, SIMPLE HVAC

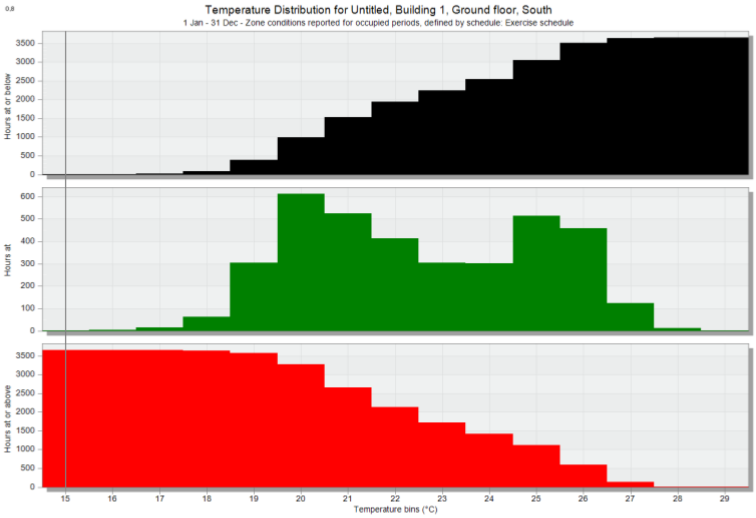
- Open file „Practice 4”.
- Set the zone type of the „Little” and „Roof” blocks to Semi-exterior unconditioned.
- Run heating design calculation and check the different kind of heat losses in Zone „4”.
- Modify the heating setpoint temperature of Zone „4” to 25 °C and check how much it influence the heat losses.

Glazing kW	-18,17	-22,40
Walls kW	-3,87	-4,62
Ceilings (int) kW	-3,67	-4,40
Floors (int)	6,98	-0,9
Partitions (int)	2,72	-1,07

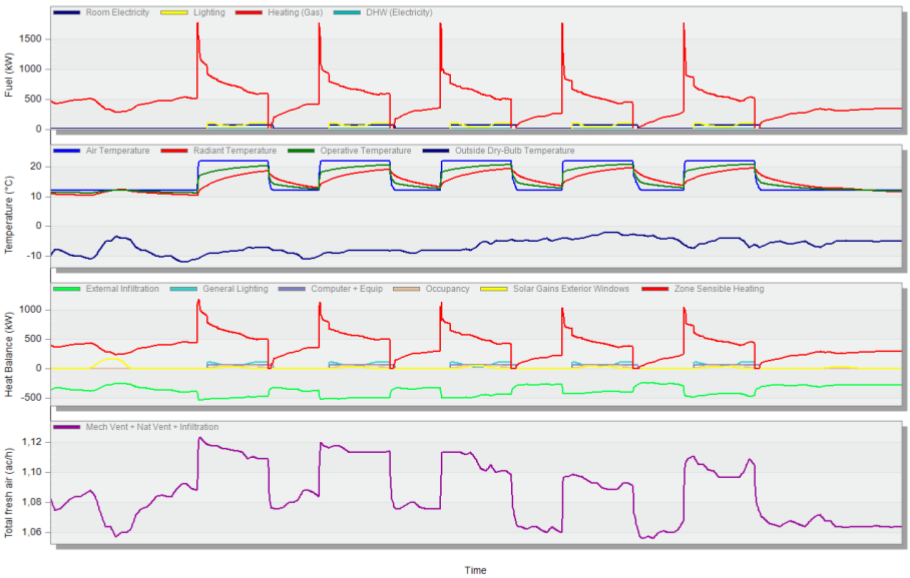
- Run cooling design calculation with 1,3 design margin and view the simulation results in different zones.
- Check the total cooling load and the design capacity (457,66 kW and 594,96 kW).
- Check which are the peak hours in the building.



- Run annual daily simulation with Temperature distribution output.
- Check the distribution of comfort data in the „South” zone.



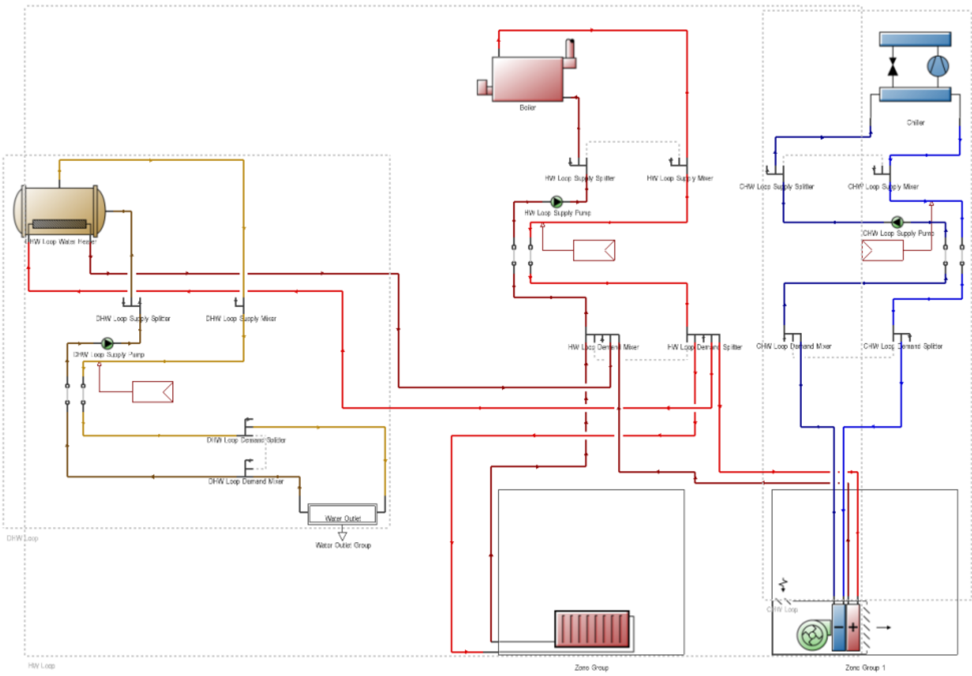
- In building level clear all data to default down to zone level on Activity tab.
- Set the infiltration to 1 ac/h constant rate.
- On HVAC tab set „Radiator heating, Boiler HW, Nat vent" template.
- Modify the DHW template, set the delivery temperature of DHW to 55 °C and name the template „Exercise DHW".
- Set the outside air definition method to „Min fresh air (Per person)".
- On activity tab set the minimum fresh air to 30 l/s-person.
- Run sub-hourly simulation (do not forget to uncheck temperature distribution output) for a winter design week using 10 time steps per hour.
- Visualise the results.



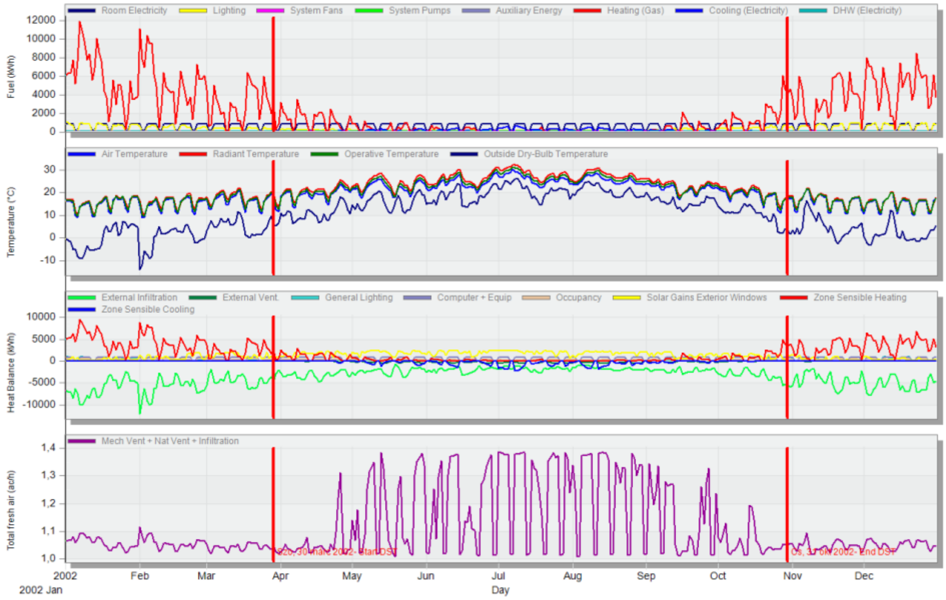
- Save the model and name it „Practice 5”.

ANNEX 6. DETAILED HVAC, RENEWABLE INTEGRATION

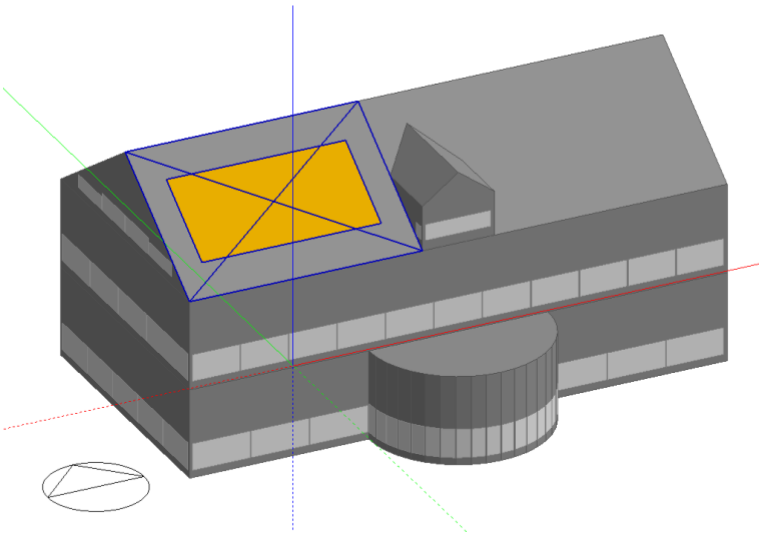
- Open file „Practice 4”.
- Set the model options to use detailed HVAC system.
- Add hot water plant loop.
- Add chilled water plant loop.
- Add a zone group which serves the „Ground floor”.
- Add a zone group which serves the „First floor”.
- Use water radiator to heat „Ground floor” zone group.
- Use fain coil unit to heat and chill the „First floor” zone group.
- Connect the components.
- Modify the chiller template to „Air cooled default”.
- Load a „DHW Instantaneous Electric” HVAC template to serve hot water to „East” and „West” zones.
- Edit the DHW loop water heater to have external heating plant connection.
- Connect it to the Boiler.



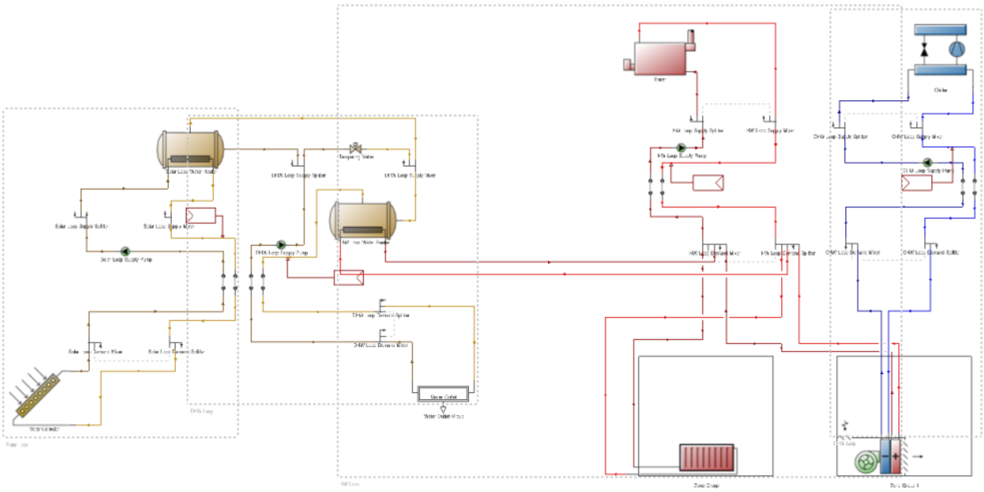
- Run an annual simulation with daily output intervals for reporting and 4 time steps per hour.
- Visualise the results.



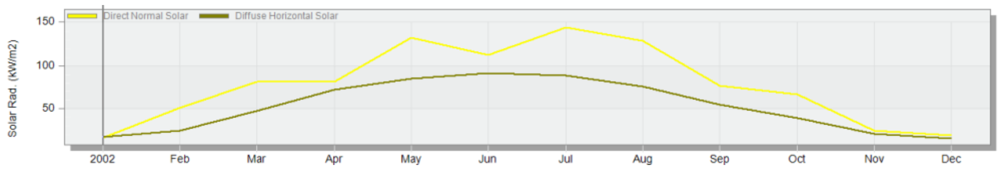
➢ Add a 10 X 20 metre Solar Collector – Hot Water on the left side of the south roof.



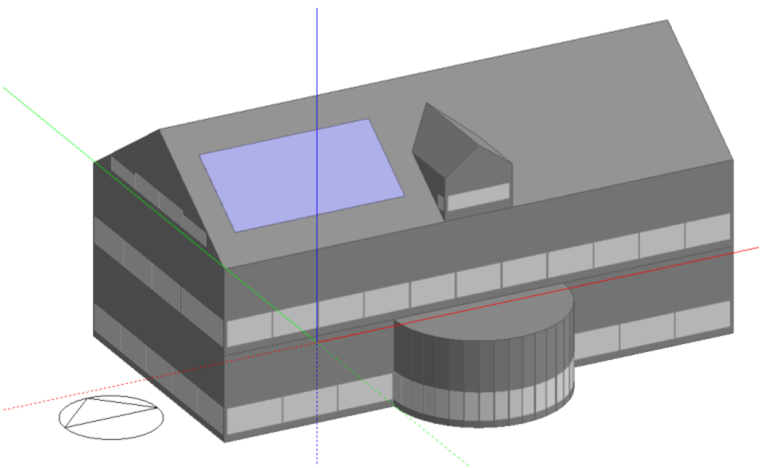
➢ Delete DHW Loop on HVAC system tab.
➢ Load a „Solar Assisted DHW” HVAC Template and replace the deleted DHW Loop part with the appropriate part. Connect the systems the way that not only the Solar Collector would be able to produce hot water but the already existing boiler too.
➢ Add the „Ground floor” block to served zones in water outlet.



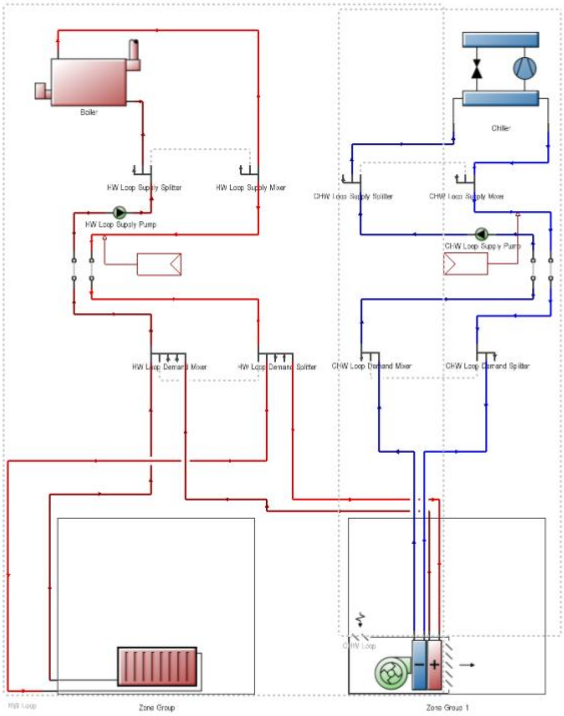
- Run an annual simulation with monthly output intervals.
- Visualise the results and check site data.



- Change the solar collector type to Photovoltaic.



- Delete the DHW loop.



- On generation tab check Include electric load centres.
- Modify the Load centre 1: create a copy of „DC with inverter” and name it „Exercise inverter”. On Generator list select the created PV solar collector.
- Run annual simulation with 4 time steps per hour and check All Summary from Summary Tables - Summary Annual Reports on Output tab.
- Check how much energy the PV produce.

Electric Loads Satisfied

	Electricity [kWh]	Percent Electricity [%]
Fuel-Fired Power Generation	0.000	0.00
High Temperature Geothermal*	0.000	0.00
Photovoltaic Power	37147.860	9.64
Wind Power	0.000	0.00
Power Conversion	-1857.39	-0.5
Net Decrease in On-Site Storage	0.000	0.00
Total On-Site Electric Sources	35290.467	9.15
Electricity Coming From Utility	355258.197	92.15
Surplus Electricity Going To Utility	5039.076	1.31
Net Electricity From Utility	350219.121	90.85
Total On-Site and Utility Electric Sources	385509.588	100.00
Total Electricity End Uses	385509.588	100.00

- Save the model and name it „Practice 6".

The views and opinions expressed in this publication are the sole responsibility of the author(s) and do not necessarily reflect the views of the European Commission.

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