ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

FSv – Fakulta stavební

K124 – Katedra konstrukcí pozemních staveb

Dům Stromů Průhonice - Optimalizace architektonického, materiálového a energetického řešení

House of Trees Průhonice - Optimization of architectural, material and energy solution

Diplomová práce

Studijní program:	Budovy a prostředí
Studijní obor:	Budovy a prostředí
Vedoucí práce:	prof. Ing. Jan Tywoniak CSc.
Konzultanti:	Univ. Prof. Dipl.-Ing. Dr. techn. Martin Treberspurg, Dipl.-Ing. Roman Smutny

Bc. Filip Sládeček

Praha ZS 2016/2017

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ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

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Zadávající katedra: Katedra konstrukcí pozemních staveb

Studijní program: Budovy a prostředí

Studijní obor: Budovy a prostředí

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Názcv diplomovć prácc: Dům Stromů Průhonice - Optimalizacc architektonického, materiálového a energetického řešení

Název diplomové práce anglicky: House of Trees Průhonice - Optimization of architectural, material and energy solution

Pokyny pro vypracování:
Úprava původního architektonického návrhu.
Výběr vhodného konstrukčního systému.
Výběr vhodných stavebních materiálů, práce ve variantách.
Koncepční návrh technických systémů stavby, porovnání variant dostupných systémů, důraz na obnovitelné zdroje energie, výběr nejlepší varianty.
Porovnání technologických nároků budovy v pasivním a aktivním standardu.

Seznam doporučené literatury:

Jméno vedoucího diplomové práce: prof.Ing.Jan Tywoniak,CSc., konzultant Univ.Prof. Dipl.-Ing. Dr.techn. Martin Treberspurg

Datum zadání diplomové práce: 3.10.2016 Termín odevzdání diplomové práce: 8.1.2017

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V Praze dne……………… **……………………….**

Bc. Filip Sládeček

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Abstract

House of Trees in Prague Průhonice is a project for a small public building offering education about nature. In this thesis, the original architectural study of the building is improved, a new structural system determined and the best material solution for the object´s elements found. Then, the project is processed in two energy standards - Passive House Classic and Passive House Premium. Natural materials, renewable sources of energy, and sustainability in the whole life cycle of the building are the main topics. The final results are compared to each other considering all positives and negatives.

Abstrakt

Dům Stromů Průhonice je projekt malé veřejné budovy, která nabízí vzdělávání o přírodě. Tato práce se věnuje úpravě původní architektonické studie, navržení nového konstrukčního systému a nalezení nejlepšího materiálového řešení pro stavební prvky budovy. Poté je projekt zpracován ve dvou energetických standardech – Pasivní Dům Classic a Pasivní Dům Premium. Hlavními tématy jsou přírodní materiály, obnovitelné zdroje energie a udržitelnost v celém životním cyklu budovy. Posléze jsou výsledky této práce zhodnoceny a vzájemně porovnány s přihlédnutím na všechna pozitiva a negativa daného návrhu.

Key words:

educational centre, architectural adjustment, structural system design, material optimization, natural materials, renewable energy, energy optimization, passive house classic, passive house premium, sustainable building

Klíčová slova:

výukové centrum, architektonické úpravy, návrh konstrukčního systému, materiálová optimalizace, přírodní materiály, obnovitelná energie, energetická optimalizace, pasivní dům classic, pasivní dům premium, udržitelná výstavba

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1 Introduction of the Project

1.1 Personal Motivation

It has always been a part of human nature to protect itself against difficulties connected with adverse weather. Much time has passed since humans first began constructing proper forms of shelter in order to survive. The first hiding places were simple: a naturally carved cave in the rock was enough to live in. Then, as time went by, the first buildings appeared with stone and wooden structures. If we skip centuries of evolution and look at the present situation we will see that the humankind developed incredible materials, structures and technological systems. It was found that over time, the better our buildings were the less time we needed to spend outside fighting the elements and other dangers. Architecturally speaking, everything today is evolving faster and faster with the focus more often on short term, economic efficiency. However, with even little study or scant observation it is quite evident that this line of thinking shows that “human progress” more often is detrimental to our ecological systems and that everything which provides short term comfort has its price and the resources which our planet Earth provides are not infinite.

In order to protect nature and the environment, and even to protect ourselves, the building design becomes more than just a creation of places where we can hide from bad weather and spend a night. The term “sustainability in building design” was created for the purpose of lowering the requirements during the complete life cycle of the building while creating a healthy indoor environment where people can spend majority of their time without harming the environment outdoors.

My motivation consists of improving the sustainability in building design as much as possible. As a former student of “Architecture and Civil Engineering” I would like to use my knowledge to create a compromise between proper building design and quality architecture in order to form the most possible sustainable whole.

1.2 Thesis Structure

The thesis is divided into three sections:

The first section is about improving the former design of “House of Trees” architecturally. In the second part the most appropriate structural system is designed, described and the main load bearing components are calculated. This part is also dealing with possible materials and their variants. The third part is about designing the most suitable technical equipment according to the application of the Passive House Classic (PHC) and Passive House Premium (PHP) energy standards to the building project. The end of the third section and this thesis is about comparison of learned data.

1.3 Objectives and key questions

The original design of the building is an architectural study with many inadequacies and this thesis is a great opportunity to discover exactly what they are and improve them as much as possible. The building should not be improved only aesthetically but also, perhaps more importantly, from a structural and technical aspect. The 21th century offers a lot of new technology which can be used to achieve quality construction with low energy demands and great indoor environment. Another main goal is to find the best possible materials in order to design the most appropriate solution to the building´s envelope, suitable to its concept and environmentally friendly at the same time. One of the main questions is dealing with the difference between two energy standard variants of the building and finding out the amount of technical equipment and their combinations in order to achieve them. Work with variants creates a major aspect of the House of Trees master thesis.

Another question discussed in this project: is there any need of improving the building´s thermal envelope once it has already been in PHC standard?

The general goal of this Master's thesis is to design a modern building fitting to its surrounding environment, using the proper materials to find out the best technical solution in order to create the most sustainable whole.

1.4 Methodology

In the process of creating this Master thesis, many software tools were used. For the architectural purposes there were three computer programmes used. The first of them is a software for 3D building information modelling (BIM) called Autodesk Revit Architecture 2016, [Revit 2017] where the whole model of House of Trees was made including the floor plan and cross section. The following stage proceeded in Autodesk 3ds Max 2016 [3ds Max 2017] which cooperates with Revit and for the purposes of this thesis served as a tool for visualisation rendering. The final phase of the architectural part was continued in Adobe Photoshop CS6 2012 [Photoshop 2012] where the final adjustments were made.

In some cases, the software Edubeam 2016 [Edubeam 2016] was used for the purposes of static calculation. Edubeam is a free software for basic calculations of internal forces, deformed shapes of the elements, reactions and more. For more complex static design, the Scia Engineer 16.1 [Scia 2016] was used. Scia supports a wide range of national standards. The most important standards for the thesis requirements are Eurocodes [EN 1990] and [EN 1995]. The same standards are used for the statics calculation in chapter 4.1.2.

All construction details were made with 2D modelling in ArchiCAD [ArchiCAD 2016]. All tables and graphic of the calculations were created in Microsoft Excel 2016. [Excel 2016]

The calculation of the materials environmental impact is based on the information from the Envimat database. [Envimat, 2016; for more about environmental methodology see chapter 5.1]

For the calculation of the object´s energy balance and for the comparison of PHC and PHP, the Passive House Planning Package Version 8 (PHPP) was used [PHPP 2013].

1.5 State of Art

1.5.1 Solar Architecture

1.5.1.1 Jacobs House (Solar Hemicycle)

One of the greatest examples of solar architecture can be found in Middleton, Wisconsin, where one of the most famous American architects Frank Lloyd Wright built a house called Jacob House, or Solar Hemicycle House.

Figure 1*: Jacobs House* [JACOBS, H., 1978]

[JACOBS, H., (1978)]

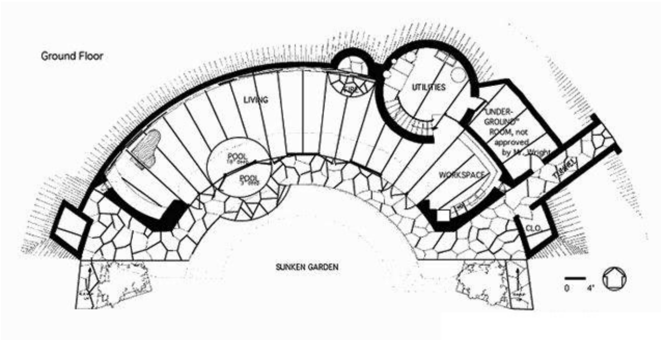


Figure 2*: Jacobs House ground floor*
[JACOBS, H., (1978)]

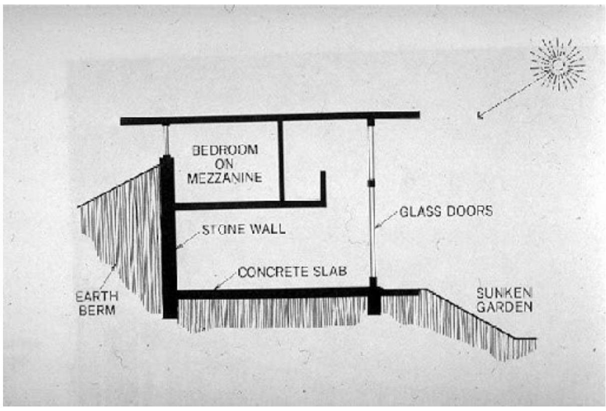


Figure 3*: Jacobs House cross section*

[JACOBS, H., (1978)]

The house is a unique piece of architecture which provides an open space interior with a sufficient amount of light due to the full glazed southern façade. The protection against cold winds is designed on the eastern, northern and western side of the building. These sides are bermed up to the height of the clerestory windows at the second floor level.
The Jacobs House uses the power of the Sun for heating during the winter, when the Sun is low and can heat up the floor in order to provide radiant heating. During the summer, when the Sun is high, the building shape and overhang do not allow the direct sunlight to overheat the interior.
The Solar Hemicycle House is a great example of solar architecture and many contemporary home styles owe much to this original concept. [Coleman (1989)]

1.5.2 Passive House Classes

Passive Houses are considered building with especially high level of thermal comfort with minimum energy consumption. In general, the Passive House Standard provides great cost-effectiveness mainly in the case of new builds. The categories Passive House Classic, Plus or Premium can be accomplished depending on the renewable primary energy (PER) demand and generation of renewable energy. [Passive House Institute, (2016)]

			Criteria[1]			Alternative Criteria[2]
Heating						
Heating demand	[kWh/(m²a)]	≤	15			-
Heating load[3]	[W/m²]	≤	-			10
Cooling						
Cooling + dehumidification demand	[kWh/(m²a)]	≤	15 + dehumidification contribution[4]			variable limit value[5]
Cooling load[6]	[W/m²]	≤	-			10
Airtightness						
Pressurization test result n_{50}	[1/h]	≤	0.6			
Renewable Primary Energy (PER)[7]			Classic	Plus	Premium	
PER demand[8]	[kWh/(m²a)]	≤	60	45	30	±15 kWh/(m²a) deviation from criteria...
Renewable energy generation[9] (with reference to projected building footprint)	[kWh/(m²a)]	≥	-	60	120	...with compensation of the above deviation by different amount of generation

[2] Two alternative criteria which are enclosed by a double line together may replace both of the adjacent criteria on the left which are also enclosed by a double line.

[7] The requirements for the PER demand and generation of renewable energy were first introduced in 2015. As an alternative to these two criteria, evidence for the Passive House Classic Standard can continue to be provided in a transitional phase by proving compliance with the previous requirement for the non-renewable primary energy demand (PE) of $Q_P \leq 120$ kWh/(m²a). PHI may specify other national values based on national primary energy factors.

[8] Energy for heating, cooling, dehumidification, DHW, lighting, auxiliary electricity and electrical appliances is included. The limit value applies for residential buildings and typical educational and administrative buildings. In case of uses deviating from these, if an extremely high electricity demand occurs then the limit value can also be exceeded after consultation with the Passive House Institute. Evidence of efficient use of electrical energy for all significant devices and systems is necessary for this with the exception of existing devices which have already been owned by the user previously and for which an improvement of the electrical efficiency by means of upgrading or renewal would prove uneconomical over the lifecycle.

Table 1: *Passive house criteria* [Passive House Institute 2016]

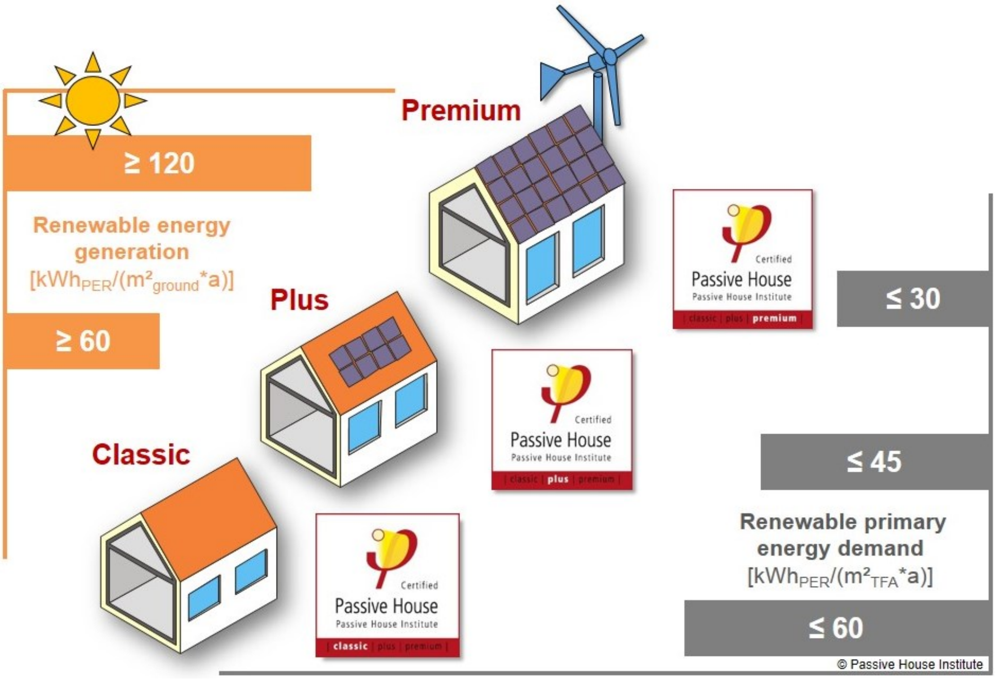


Figure 4*: Passive house classes* [Passive House Institute, 2016]

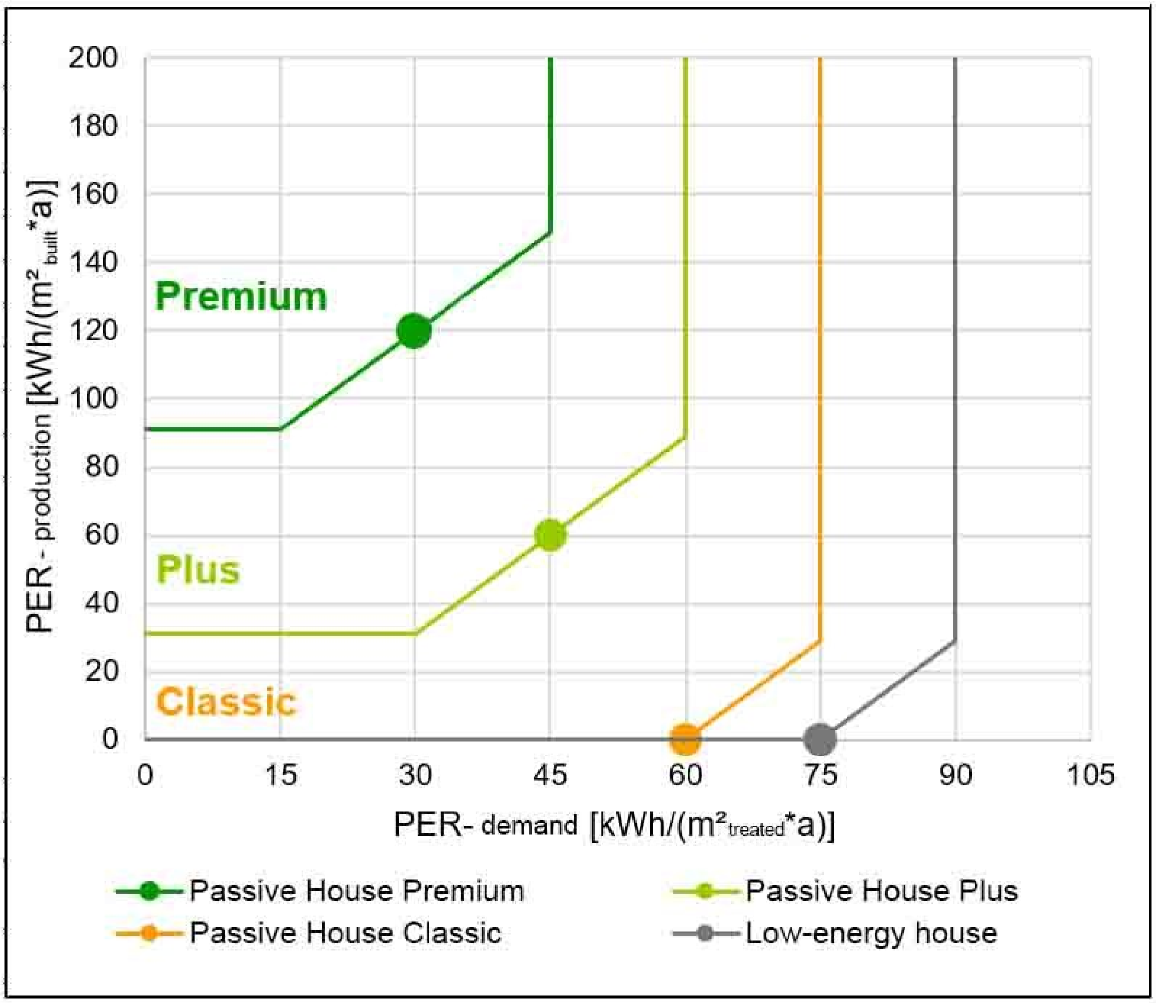


Figure 5: *Passive house classes diagram* [Passive House Institute, 2016]

2 Introduction of House of Trees

2.1 Localization of project

The project is situated in Czech Republic in the Dendrologic Garden located in the suburban part of Prague called Průhonice. [see Figure 6 and Figure 7] Průhonice is known for its big park covering 250 ha and Castle of Průhonice. The D1 highway is located between the Park (approximately one kilometre as crow flies) and the Garden. This motorway heads either to Prague at the North-West or Jihlava, Brno and other big Czech cities at the South-East.

Around the Garden there are Commercial Facilities including a waterpark and shopping centres. Across the Highway there is a Residential district with Public infrastructure and the already above mentioned Park.

The Dendrologic Garden has three public entrances and two employee entrances. In the garden, there are various collections of trees and plants and water surface in the form of the Black Pond.

Our plat is situated in the southern parts of the Garden and covers an area of 3200 m^2. [see Figure 8]

Figure 6: *Localization of the Czech Republic*

Figure 7: *Localization of Průhonice*

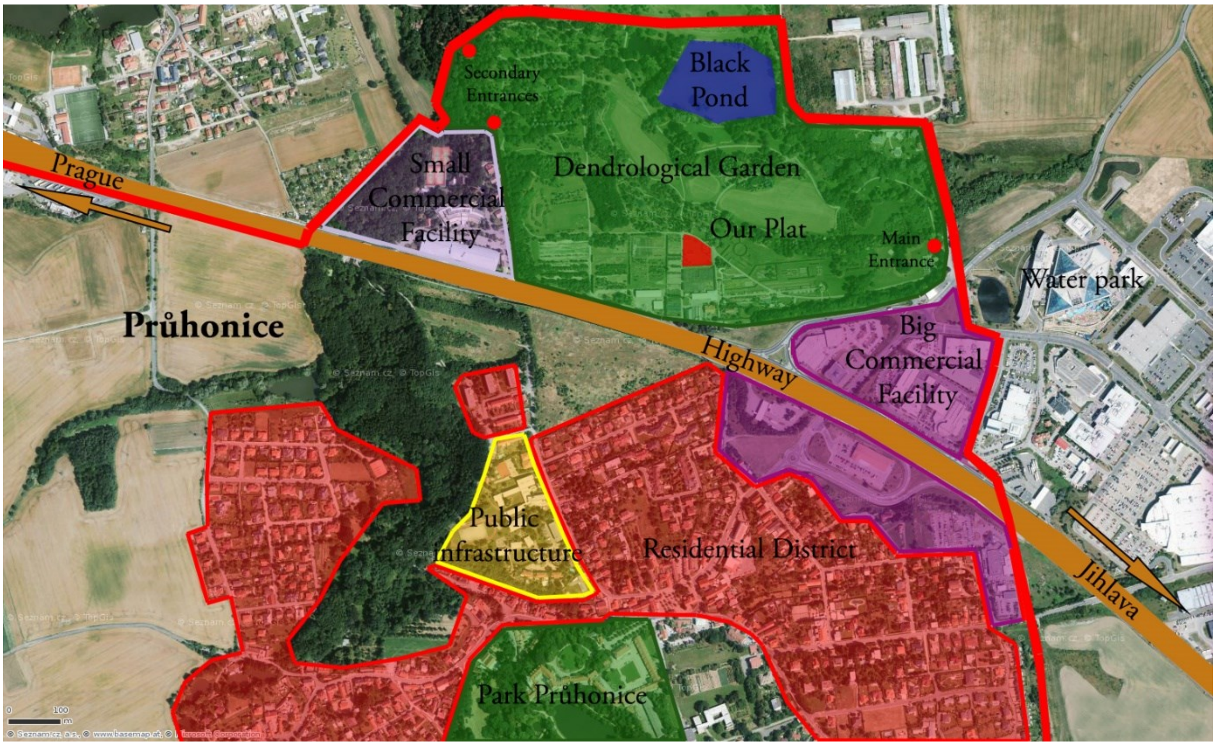


Figure 8: *Connections and surroundings*

The background images were taken from sources [Seznam 2016] and [Google 2016]

2.2 Purpose

Dendrologic garden in Prague Průhonice develops and fulfils a regional concept of Environmental Learning, Education and Enlightenment (ELEE) and according to the marked out goals continues with the Czech State program of ELEE (year 2000) and Region Developing Program (year 2001). According to ELEE plan, Dendrological Garden "Realizes effective enlightenment programmes and events for public, focused on nature protection, sustainable development and exploring nature. These programmes are targeted at so far passive part of the public". The upcoming areal should enable and improve education for broad layers of the population in the area of Biology, Dendrology, Ecology of trees and gardening through:

- Education programmes for schools
- Thematic expositions
- Lectures
- Projections of films about protection and creation environment
- Professional expositions

The goal is to face the alienation of children from the environment, support and fulfil free time activities for parents and kids together and develop a way for families to spend free time. Furthermore, Dendrologic Garden aims to educate young students in an interactive way that appeals to them specifically while increasing professional qualifications of employees who participate in creating a more sustainable environment.

Translated by Filip Sládeček from [SMOLA 2013]

3 Architectural Part

3.1 Original Design

3.1.1 Concept

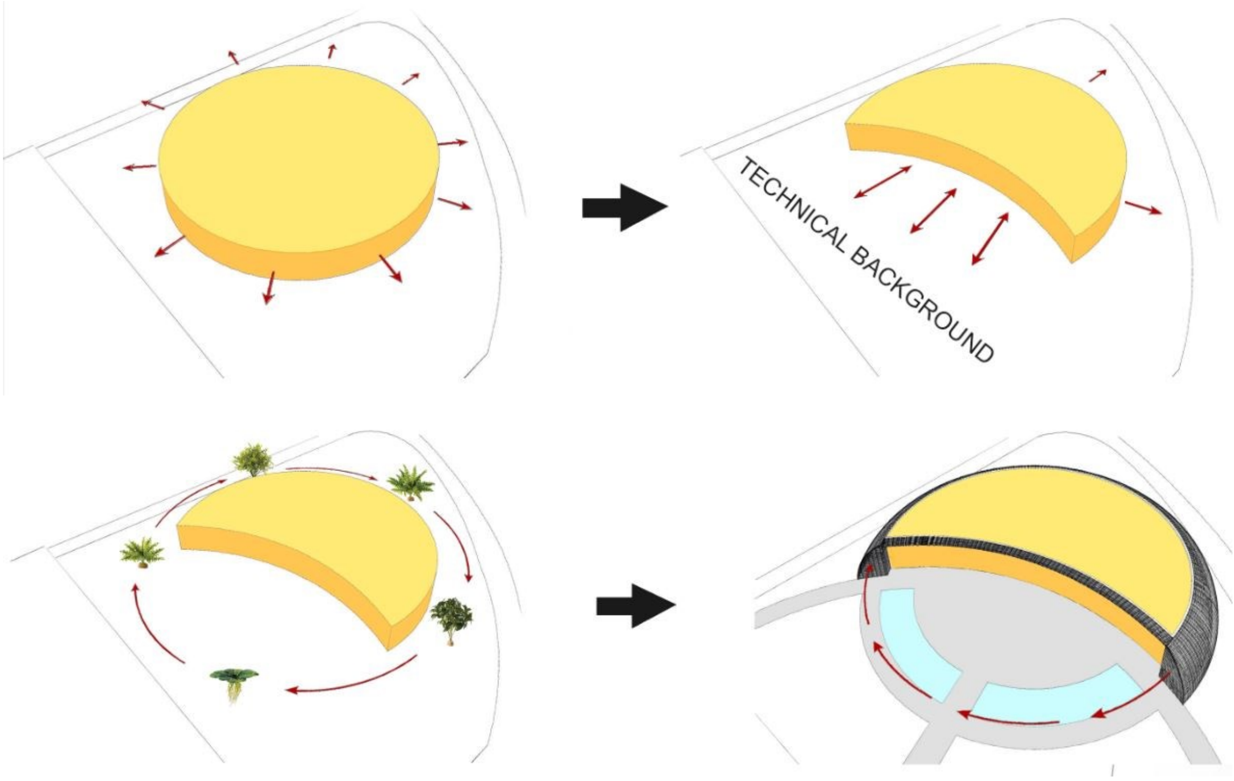


Figure 9:*Original concept*

The concept of House of trees is about creating a simple shaped building opened to the technical background on the south in order to enable the possibility for visitors to undertake educational tours there. A semi-transparent wooden cage surrounds the building The design of the outdoor exposition is covered by various plants. The façade under the cage is designed “green”, with living plants. The outdoor exhibition continues with examples of water plants which grow in front of the building in the pond. The roof of the House of Trees is covered with extensive greenery.

The front of the building is designed as a double glazed façade.

3.1.2 Site Plan

The original site plan is almost the same as the new one. In order not to duplicate materials, the site plan can be seen in chapter 3.3.4.

3.1.3 Floor plan

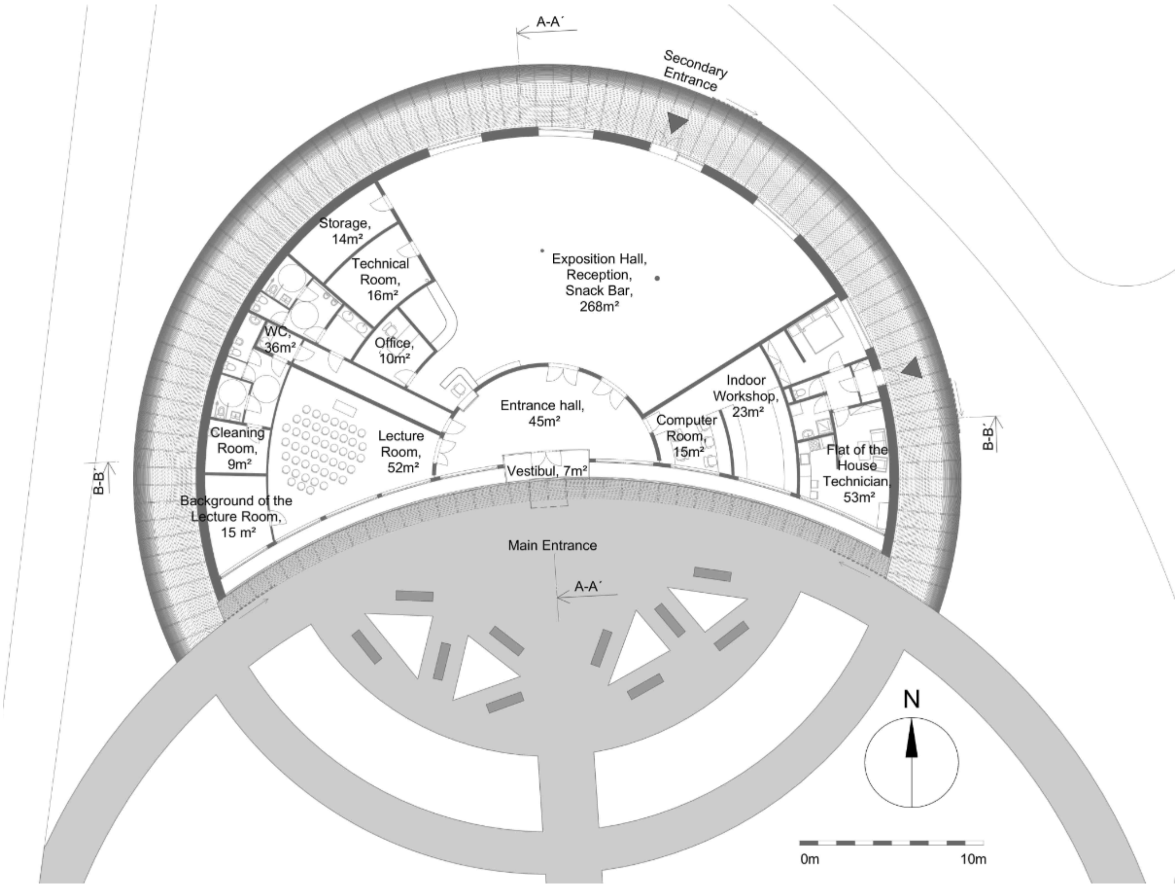


Figure 10: *Original floor plan*

<u>Object information:</u>

Built up area – 618 m2

Floor area – 557 m2

Building volume – 2470 m^3

3.1.4 Cross Sections

Figure 11: *Cross section A-A´*

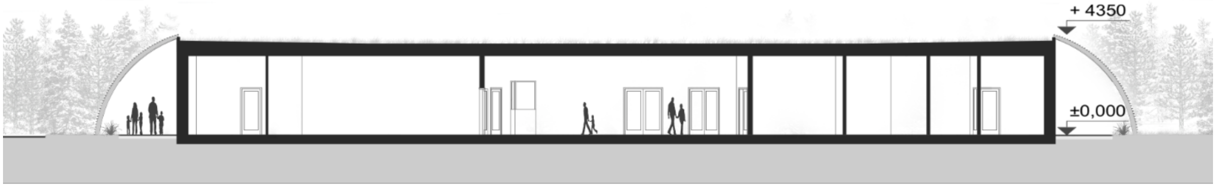


Figure 12: *Cross section B-B´*

3.1.5 Elevations

Figure 13: *Original south elevation*

Figure 14: *Original north elevation*

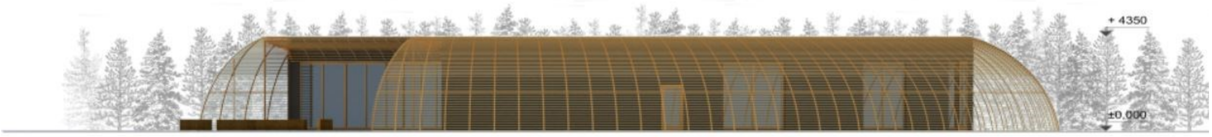


Figure 15: *Original east elevation*

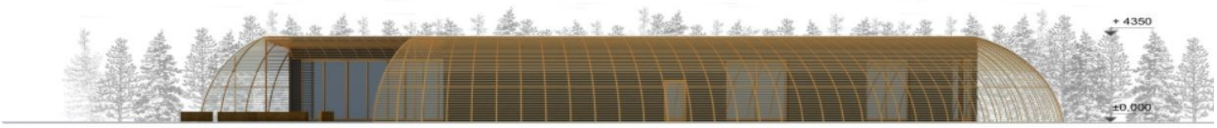


Figure 16*: Original west elevation*

3.1.6 Structural System

The structural system solution of the House of Trees was firstly designed as a reinforced concrete system with combination of loadbearing columns and walls founded on reinforced concrete slab. Construction of the roof is also from reinforced concrete.

Construction of the wooden cage was not part of the original design.

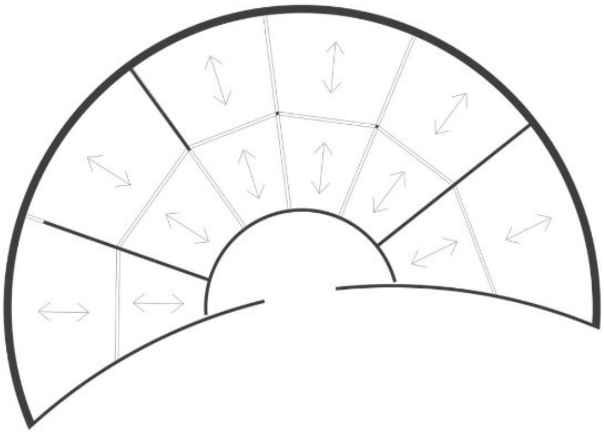


Figure 17: *Original structural system*

3.1.7 Energy, Ventilation and Rain Water Management

Energy, ventilation and rain water management were only secondary tasks of the original project. There were no calculations made as a part of this task. The other managements were not part of the first project.

For the main source of energy, the heat pump is designed with ground collectors and the semi-transparent photovoltaic foils on the front glazed façade. The roof is not used for photovoltaics.

Ventilation in the building is designed as mechanical with a heat recovery system. The front side of the building is designed as a double glazed façade in order to prevent overheating during the summer and thermal losses through winter.

The rain water management consist of two downpipes in the centre of the building. The rain water is stored in the tanks under the building.

3.1.8 Visualizations

Figure 18: *Original visualization 1*

Figure 19: *Original visualization 2*

Figure 20: *Original visualization 3 – view from the cage*

3.2 Green Architecture

3.2.1 The 'Sun-Root' Living Roof System

Every photovoltaic system loses efficiency when temperatures are too high. The Sun-Root system allows to use the advantages of both a green roof and roof photovoltaic panels in order to create the most advantageous whole.

The extensive green roofs have been used for a very long time to insulate during the winter and cool down through the summer. Evaporation of rain water from the substrate and greenery produces cooler environment which increases the efficiency of photovoltaic panels.

Sun Root modules are made of recycled plastic and can be placed on the roof without any penetration of the roof area. The weight of the substrate and gravel is used to fix Sun Root elements to the rooftop. [Breuning, 2012]

Figure 21: *Sun-Root system 1* [Breuning, 2012]

Figure 22*: Sun-Root system 2* [Breuning, 2012]

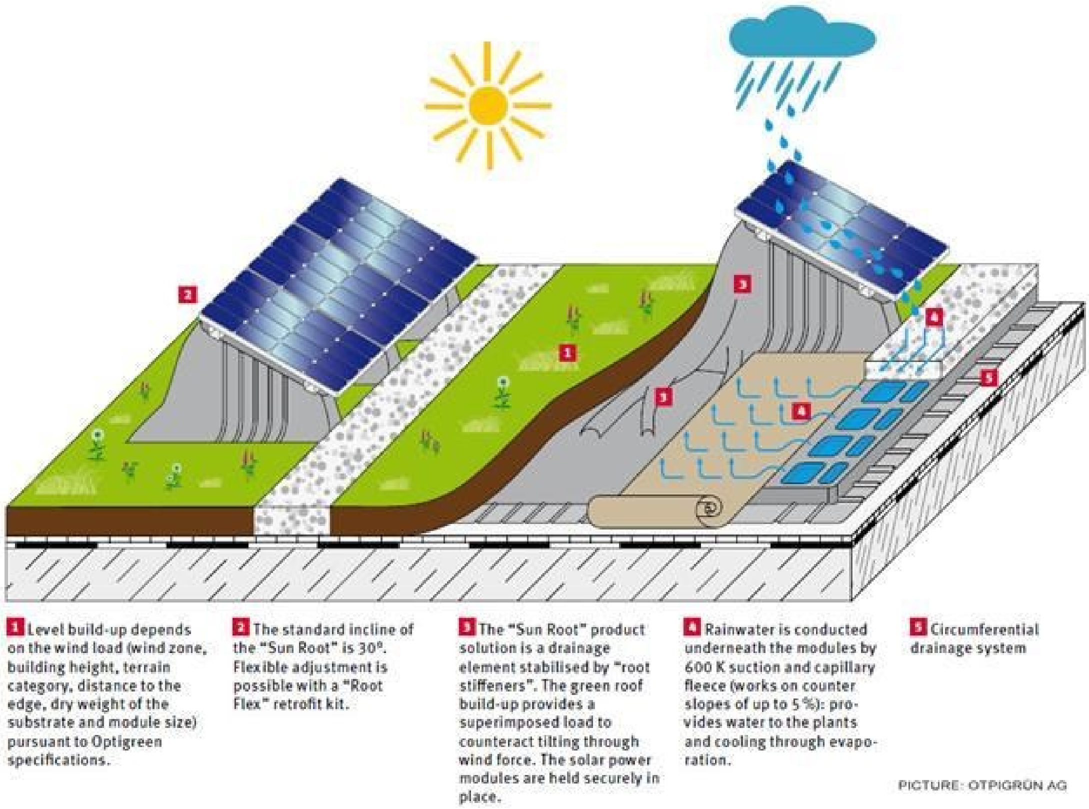


Figure 23*: Sun-Root system schema 1* [Breuning, 2012]

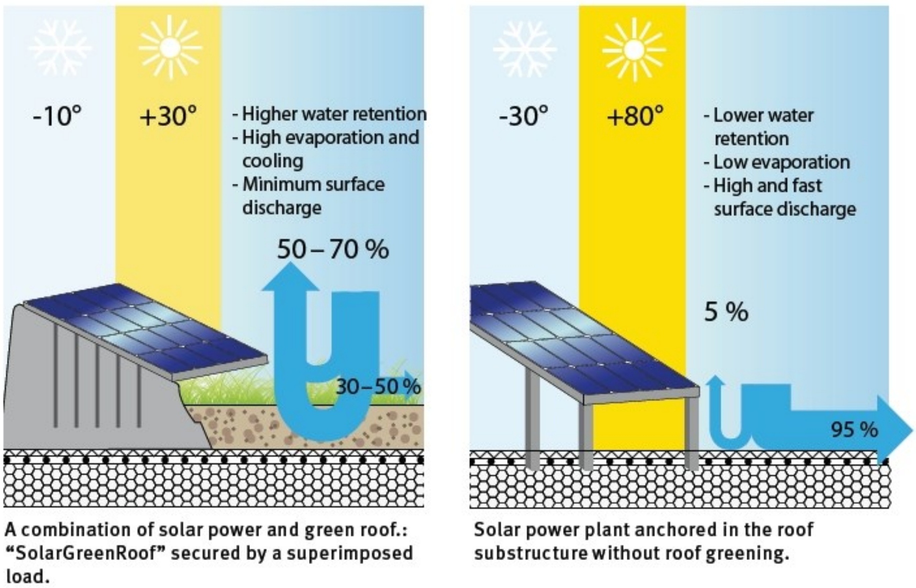


Figure 24: *Sun-Root system schema 2* [Breuning, 2012]

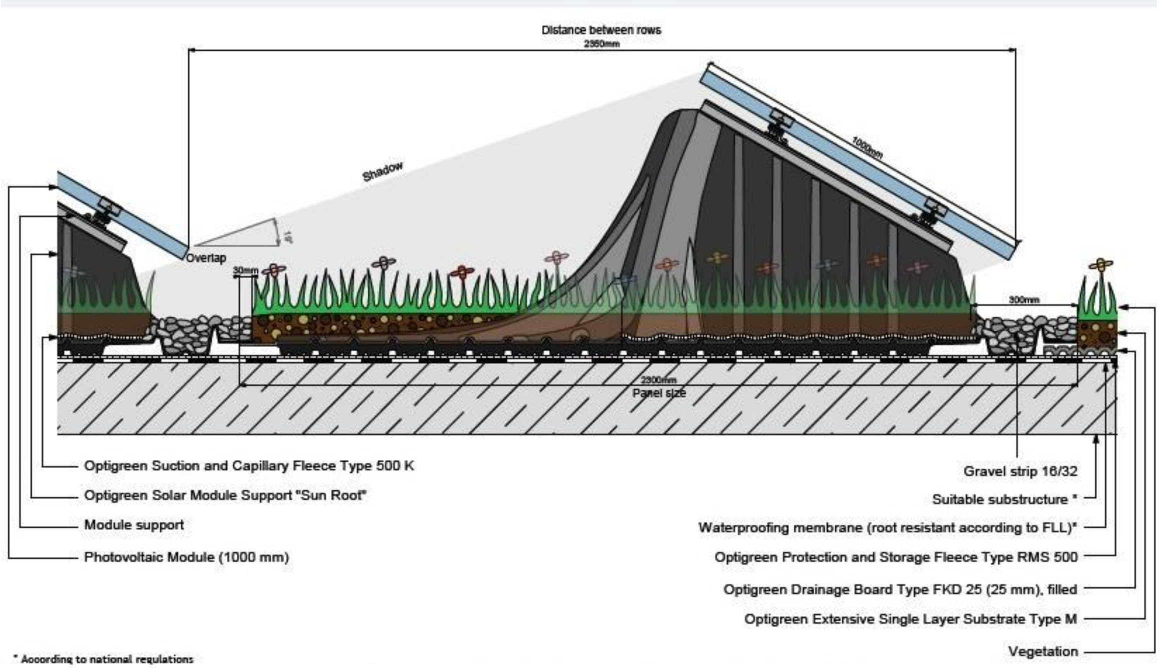


Figure 25: *Sun-Root system optimal position* [Breuning, 2012]

3.2.2 Geomoss

The Geomoss is a system designed by the French company Gébois and is developed to implement a vegetation layer into the façade. The Extensive greenery (moss) grows in the ceramic foam which is implanted to the ceramic modules suspended on aluminium profiles. The profiles are fixed directly to the external wall.

The ceramic foam (polymer foam impregnated with the ceramic mixture and burned in the furnace) can absorb moisture due to its cellular structure with a large inner surface and gradually water the moss. Irrigation is provided by a drip pipe system. Annual consumption of the water is very low (400 l per year, depending on the façade orientation) due to the absorbency of the ceramic foam.

[Happy materials, 2009]

Figure 26: *Geomoss modules*

[Happy materials, 2009]

Figure 28*:* Geomoss
[Happy materials, 2009]

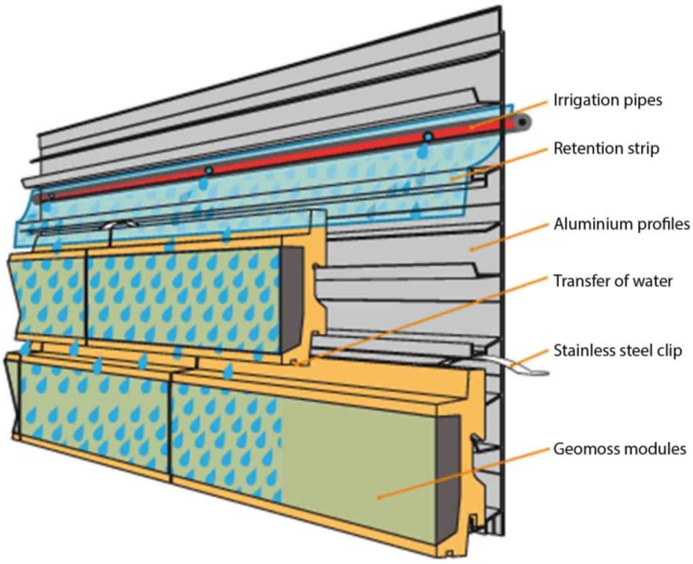


Figure 27: *Geomoss composition*
[Happy materials, 2009]

3.2.3 R&Sie Architects: Vegetation façade without any soil

In Paris the architectural group R&Sie Architects designed a vegetation façade created with ferns using hydroponics to grow without any soil. The system is implemented with 300 glass beakers "blowing" components for bacterial culture and collecting raining for watering plants with an individual mechanical drop by drop system with nutritional adding on proportioning controls.

Light refraction in the glass beakers in front of the windows is increasing the light gain in the interior. [R&Sie, 2009]

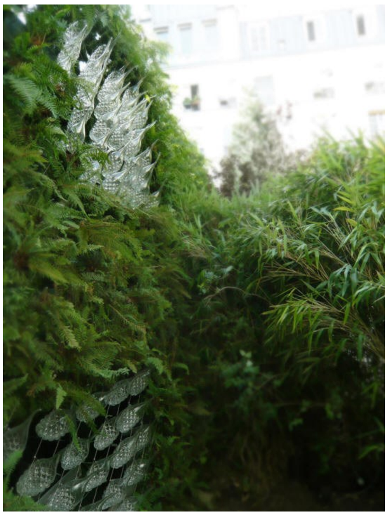



Figure 29: *R&Sie Architects vegetation façade* [R&Sie, 2009]

3.3 Adjusted architectural design

3.3.1 Motivation for adjustments

The localization and purpose of the House of Trees has a huge potential to be an excellent example of the connection between building and nature. The original concept fulfilled only a small part of its real potential. The wooden cage separated the surroundings of the house instead of communicating with it and the whole effect of the House of Trees was rather unfavourable than favourable as far as connection with nature was concerned. Around the building there were no trees and no place for outdoor activities designed despite the original goal of teaching young people about exterior environment.

All the above mentioned reasons are the huge motivation for improving the first concept and designing a better and more fitting version of the House of Trees.

3.3.2 Concept

The new concept of the House of Trees reflects the need of communication with the nature. The shape and the idea of outdoor exposition with various greenery is almost the same as before but more attention is paid to the connection with the surrounding natural environment of the Dendrologic Garden. Three new trees growing though the wooden cage are designed. The biggest one, even through the North-East part of the building. The cage covering the exhibition is now more open to the surroundings and serves as the support for various vine plants. The whole idea of the wooden cage and external façade of the building is about showing the different kinds and systems of living walls and green facades including the explanation of the plants needs and the best treatment with them. The Technical room is accessible from the outdoor exposition and has a glazed door in order to enable visitors to see inside.

The next part of the new concept is about designing of the Outdoor workshop which is approachable from the northern part of the building and outside exposition.

The front glass façade is tilted and shaded with an overhang in order to prevent the interior from overheating during the summer yet not reflecting sun through winter.

3.3.3 Tilt and Overhang Optimization

For optimization of the tilt of the southern glazed façade as well as the overhang above it, the simplified model of 6 variants was created in order to find out the best possible variant. The first variant is without any shading and serves only to see the difference. The second one is only with a 1,5 m wide overhang, the third model has a 1,5 m wide overhang and is tilted about 5°, the forth variant is tilted about 10° and has a 1,5 m wide overhang, the fifth simplified model has a 2 m wide overhang and is tilted about 10° and the last variant is tilted about 15° and has a 1,5 m wide overhang. The best variant means the most suitable compromise between appropriate architectural design and optimal shading. The simplified models were created in the Revit Architecture software. This software has a possibility to position the model to the exact place on the earth in order to simulate local conditions including the sun rays tracking on any day of the year. The position of the Sun can be monitored in minimally 15 min intervals from sunrise to sunset.

The area of shaded and sunlit floor of the models was watched for determination of the optimal variant.

The picture below shows the sun rays monitoring on 9. July at 12:00. The image serves only as an example of how the software works. For the optimization the whole days of different months were monitored.

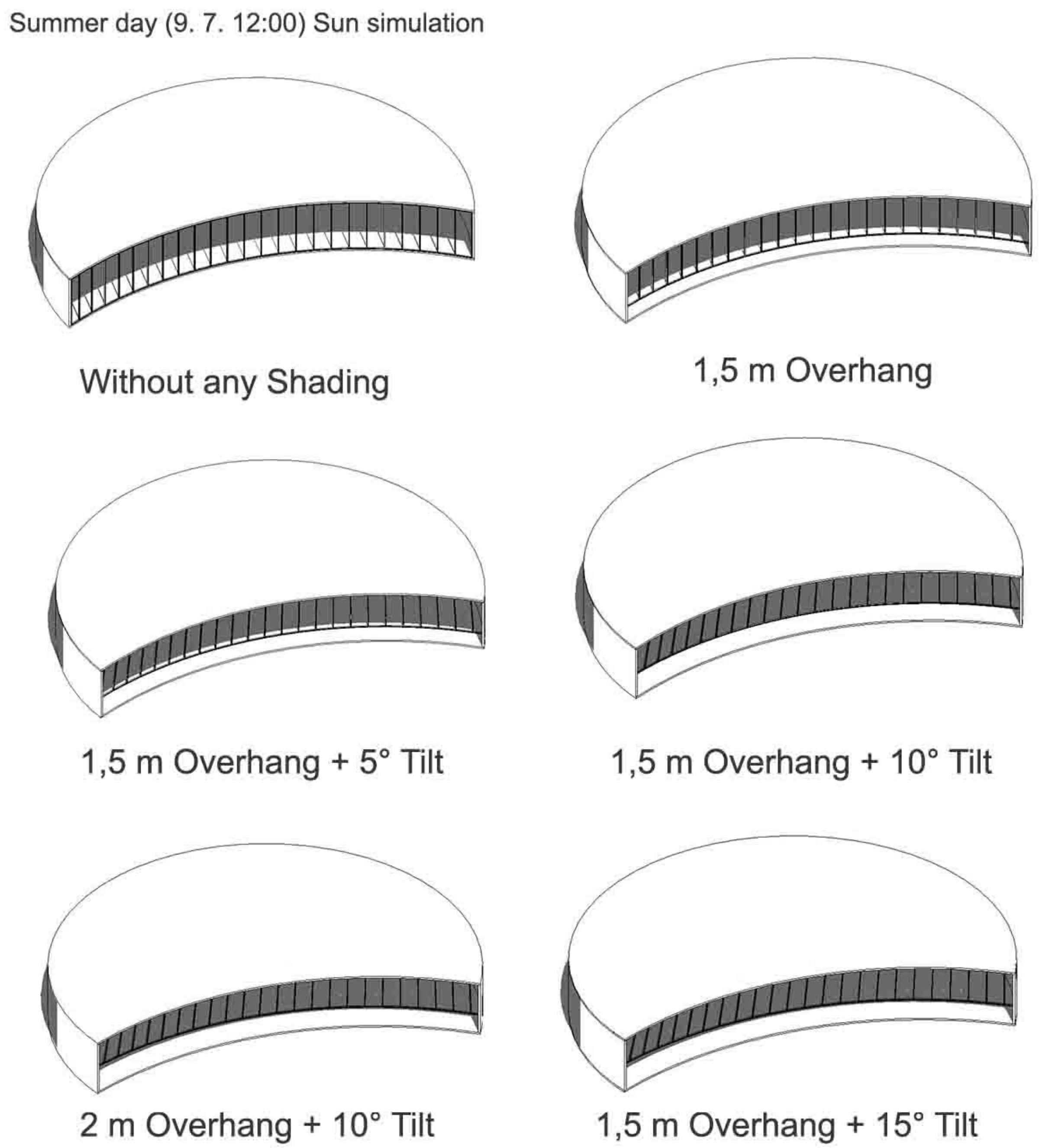


Figure 30: *Sun and shadow simulation*

The forth variant with a 1,5 m overhang and 10° tilt is considered as the best one reflecting the architectural impression as well as the amount of shading.

3.3.4 Site Plan

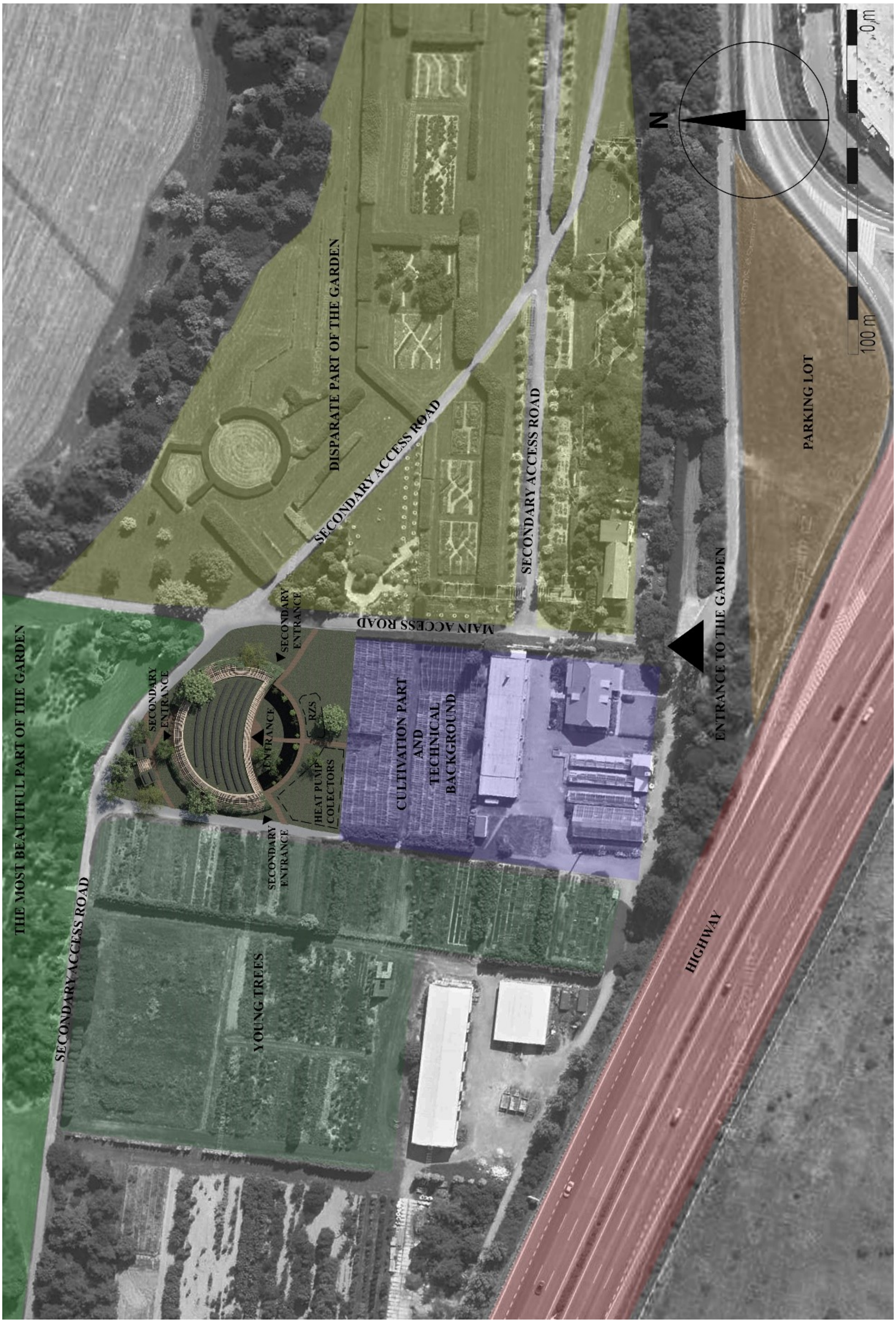


Figure 31: *New site plan*

3.3.5 Floor plan

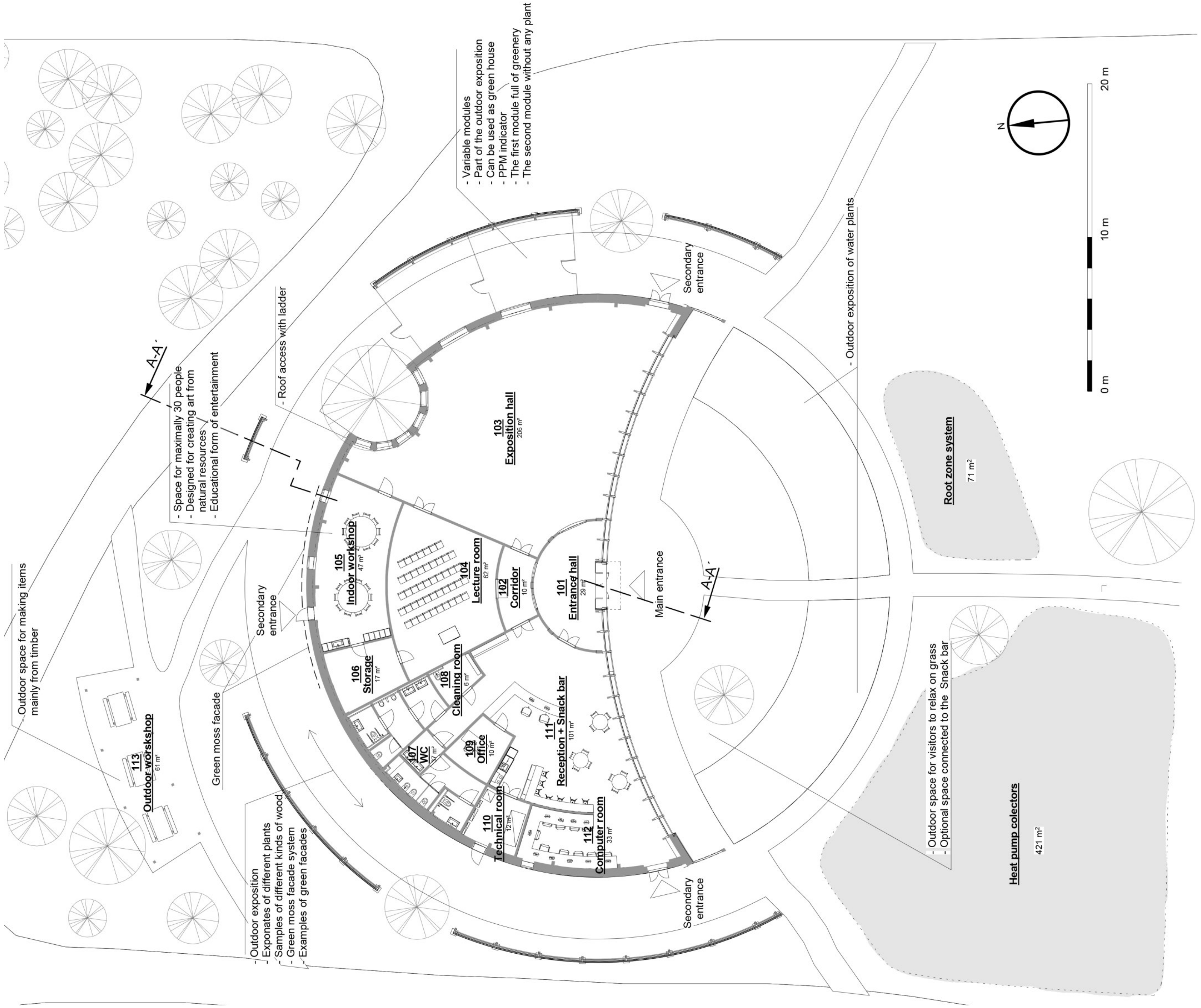


Figure 32: *New floor plan*

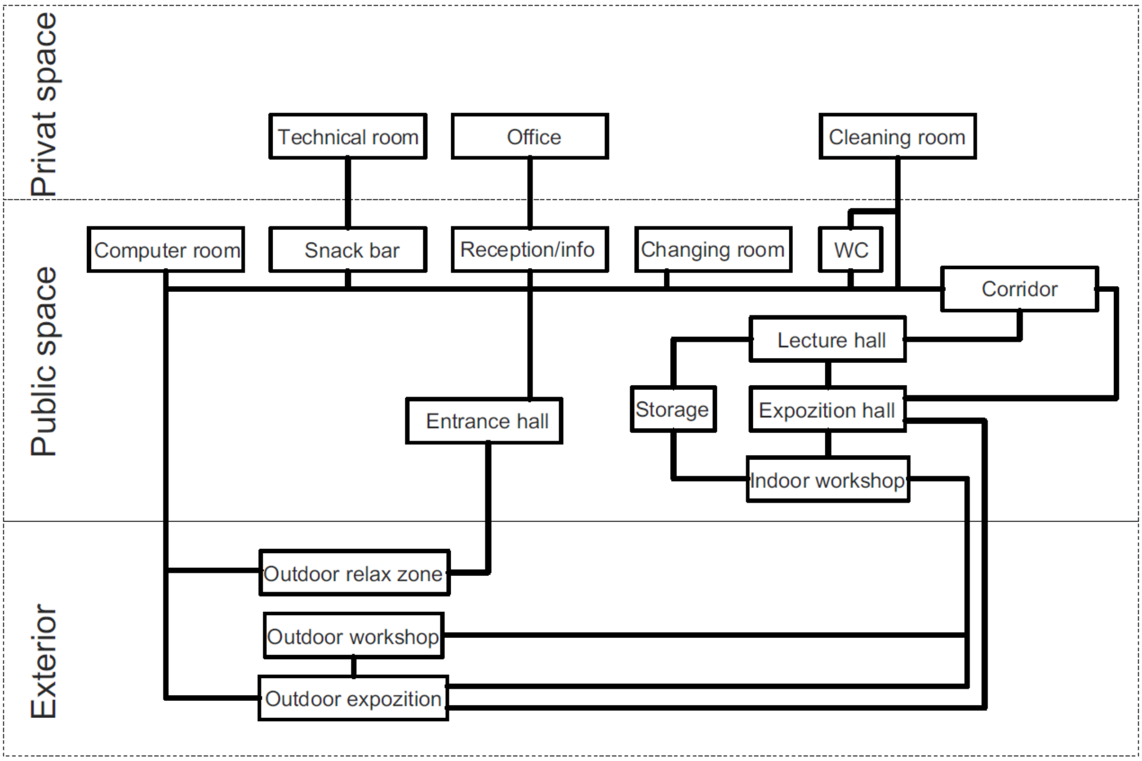


Figure 33: *Diagram of room connections*

<u>Object information:</u>

Built up area – 624 m2

Floor area – 570 m2

Building volume – 3120 m^3

The new floor plan is completely different from the original one. The size of the entrance hall is now smaller – 29m^2 instead of the original 45m^2. The Vestibule and the Flat of the house technician is considered unnecessary and is not part of the new design. The reception and the snack bar is now separated from the exposition hall and together with the computer room have source of natural light on the South and direct access to the outdoor relaxation space on grass. The lecture room (now 10m^2 bigger) and the Exposition room (now 60m^2 smaller) are both approachable from the reception through shared corridor. The indoor workshop (25m^2 bigger than the original one) is designed on the North side of the building in order to be in the contact with the Outdoor workshop.

There are four possible entrances to the building. One main entrance is in the centre of the southern façade. The second and the third entries are situated in the exposition hall and snack bar. The fourth entrance is designed in the indoor workshop. The maintenance access to the roof is designed on the north side of the building next to the tree growing through the object. This place is specific with no construction of the outdoor cage and creates a safe place for a ladder placement.

The outdoor exhibition is now more open to the surrounding natural environment. On the North side of the exterior wall there is Geomoss façade system designed. One part of the wooden cage is used for variable modules which can be used as green houses for seasonal usage. The green houses are not part of the indoor environment of the building but has temperature measures which control the ventilation through openable windows. The PPM indicator is part of the modules and has educational form for visitors to see and feel the difference between the environment with and without greenery. Another part of the outside exposition is sample of R&Sie hydrophobic system of nourishment of ferns without any soil.

3.3.6 Room Program

Entrance hall

Separated from outdoor space by vestibule and designed for approximately 50 visitors during the rush hour. The Entrance hall works as a gathering space and needs to be ventilated properly. Temperatures should not be lower than 20°C in winter or higher than 26°C in summer. There is no special lighting condition needed.

Exposition hall

The biggest room in the building is designed to provide enough space for various exhibits as cut-outs from trees, unique examples of tree roots, miscellaneous xylocarp etc. This room is also considered as a gathering space with an indoor temperature around 20°C, and proper ventilation in order to supply the space with enough fresh air. This room has two exits in case of fire and for the connection with the outdoor exhibition. The Design of the Exposition hall is able to offer quality and steady light conditions. Considered number of people in exposition hall is about 60.

Reception, Snack Bar and Computer room

Reception is a place where the tour around the building begins. Guests can buy the tickets or small souvenirs including scientific books here. The Snack bar is designed to offer visitors something small to eat or drink and there is an internet access in the Computer room. These three rooms are connected and designed to be comfortable for both employees and visitors of House of Trees, providing an indoor environment with a minimal temperature of 20°C in the winter and a maximal temperature of 26°C in the summer. The whole area is designed for approximately 40 people and must be properly ventilated including the occasional ventilation in Snack bar.

Lecture Hall

In the Lecture room various educational courses will take place as the start of the exhibition. The area is designed for approximately 30 people and has two exits for the case of fire. The temperature should not drop below 20°C during the winter and not exceed 26°C through the summer. The whole area is supposed to be ventilated properly. Natural light is not required in this room.

Indoor Workshop

The Indoor workshop is a space for approximately 30 people. The area is designed for visitors to make handmade products from natural resources as part of the educational entertainment program. The room has to be ventilated, naturally lighted and temperatures should not drop below 20°C in the winter or exceed 26°C in the summer. There are two exits from the Indoor workshop in order to provide fire escape and also to connect the room with the Outdoor workshop situated on the North of the site.

Outdoor Workshop

Accessible from outdoor exhibition and the Indoor workshop, the Outdoor workshop is designed for making various products mainly from wood but also from other natural resources. The area is designed for about 30 people.

Storage

The Storage is considered to be a place for the Indoor workshop to store the resources needed for work with visitors. Additionally, the technical background of the Lecture hall is situated here. The temperature in the area should be minimally around 20°C in the winter and maximally about 26°C in the summer. No mechanical ventilation is necessary in the Storage.

WC

Minimal temperature in the area should not be lesser than 24°C during the winter or higher than 26°C thought the summer. The WC rooms are designed as both regularly and occasionally ventilated.

Office

The Office is place for the House of Trees manager and should be properly ventilated and naturally lighted through the skylight. Temperature in this room should not be lower than 20°C in winter or higher than 26°C in summer.

3.3.7 Cross Section

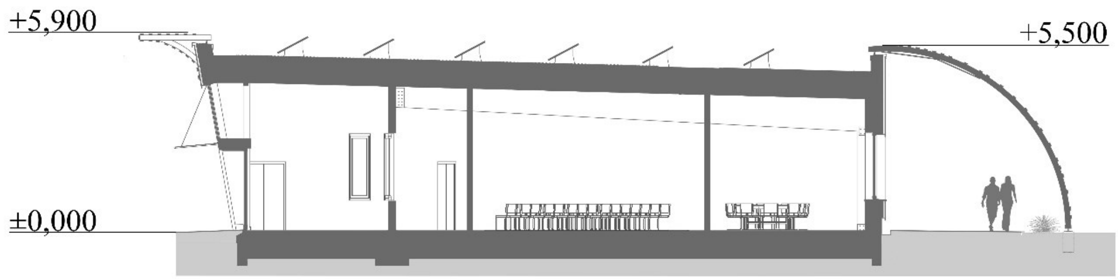


Figure 34: *New cross section A-A´*

3.3.8 Elevations

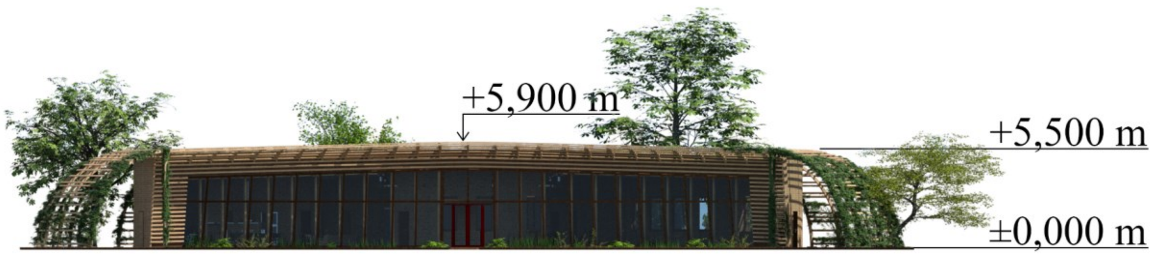


Figure 35: *Front side elevation*

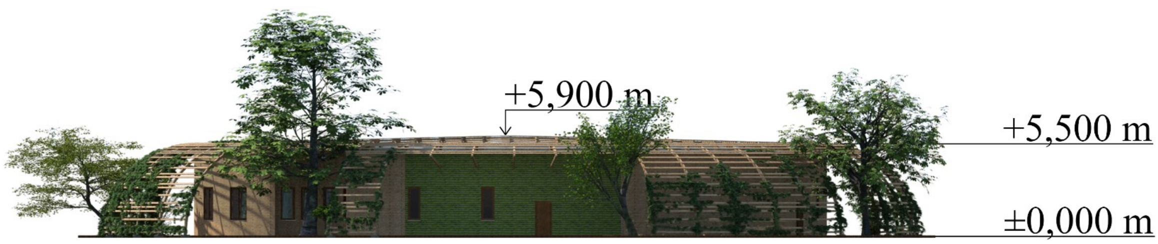


Figure 36: *Back side elevation*

Figure 37: *Left side elevation*

Figure 38: *Right side elevation*

3.3.9 Structural System

The original structural system was designed from a reinforced concrete system with internal columns of uncalculated spans which would limit possible future changes of the floor plan. But the main reason for reconsidering the whole structural system is about material. The House of trees should be designed primary from wood as the name of the building itself implies. The new construction should also facilitate future changes of the floor plan as well as creation of big exposition areas without any limiting constructions inside.

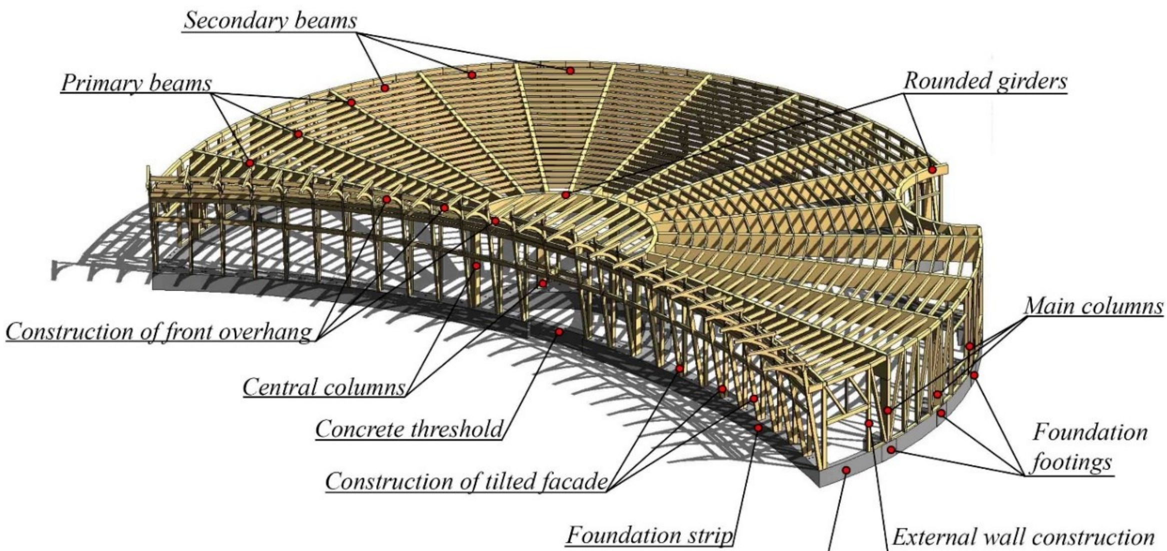


Figure 39: *New structural system*

The whole new structural system is designed from wood. The roof structure creates radial shaped construction of 14 m long trapezoidal glue-laminated wood beams inclined to the edges of the building by 1,5°. The beams are connected to the round glue-laminated wood girder on the thinner side and to the glue-laminated wood columns on the other side. The central girder is supported with 5 glue-laminated wood columns. The maximal span between two beams is 4,34 m. The secondary roof components are beams fixed in between the primary beams creating the area for OSB boards and roof composition above.

The hole on the North-East side of the object is created from round glue-laminated girder as well.

The exterior wall is made of wooden frames with diagonal wooden stiffeners and OSB boards. The wooden frames are reinforced in the place of doors and windows.

The tilt of the front façade is designed from couple of wooden columns. One column is vertical and the other is tilted by 10°.

The wooden cage construction is considered to be from curved glued solid timber beam attached to the building attic on one side and to the precast concrete footings on the other side [see Figure 47]. The maximal span between every two beams is 2 m at the object side and 2,8 m on the other side. The horizontal components of the cage are designed from larch timber laths.

Foundations of the house are created from reinforced concrete footings under every column and strip foundation under the front façade and central columns. Under the external wall and main entrance door, the concrete thresholds are designed.

3.3.10 Energy, ventilation and rain water management

The rain water management of the new design is considering the roof structure as water accumulator which can absorb and keep almost 95 l of rain water per m^2. Remaining water is drained in the direction of the roof inclination, through the attic and then to the perforated drain pipes under the outdoor exposition in order to supply the plants with water as well as to infiltrate it to the surrounding ground.

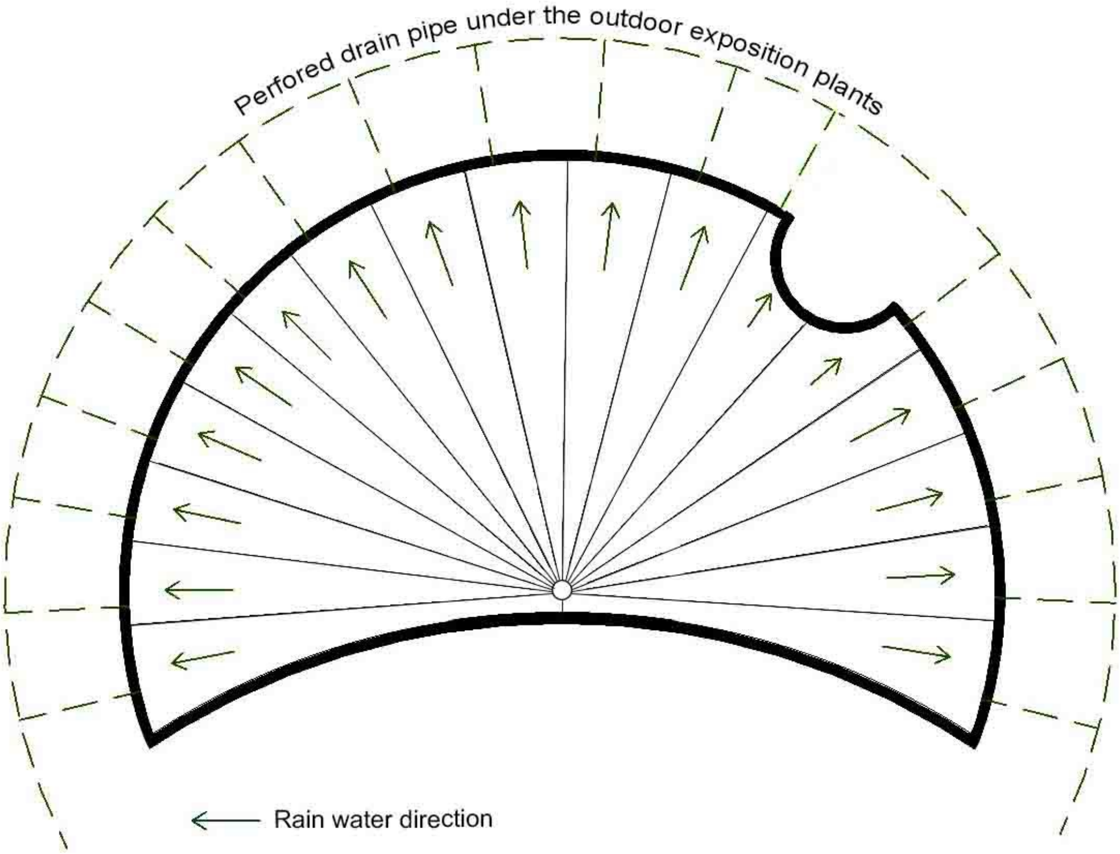


Figure 40*: Rain water treatment schema*

The wastewater (sewage) management is designed as root zone system situated in front of the object covering approximately 71 m^2 [for calculation see Annex 1]

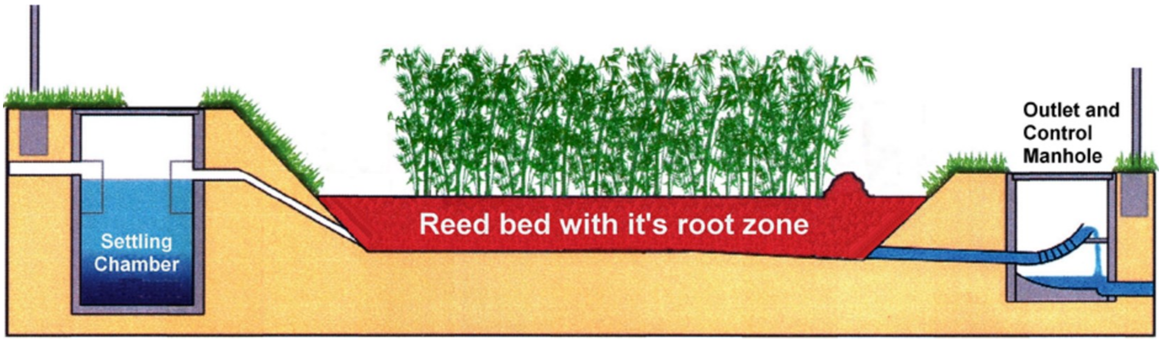


Figure 41: *Root zone system schema* [Rhizotechniki 2012]

Root zone system is natural method of wastewater and sludge treatment, based on self-regulative processes of active soil systems.

Wastewater or sludge streams through a soil matrix planted with specific and modified strains of reeds (*Phragmites australis*) which are contained in a waterproof polymeric membrane.

The active co-operation between soil, roots and micro-organisms guarantees very effective biochemical reactions. This makes it possible even for highly toxic elements to be decomposed by the Root Zone method.

Professor Kickuth developed and firstly applied the Root zone system in Germany in 1974. [Rhizotechniki 2012]

3.3.11 Visualizations

Figure 42: *New visualization 1*

Figure 43: *New visualization 2*

Figure 44*: New visualization 3*

Figure 45*: New visualization 4*

4 Construction

4.1.1 Construction details

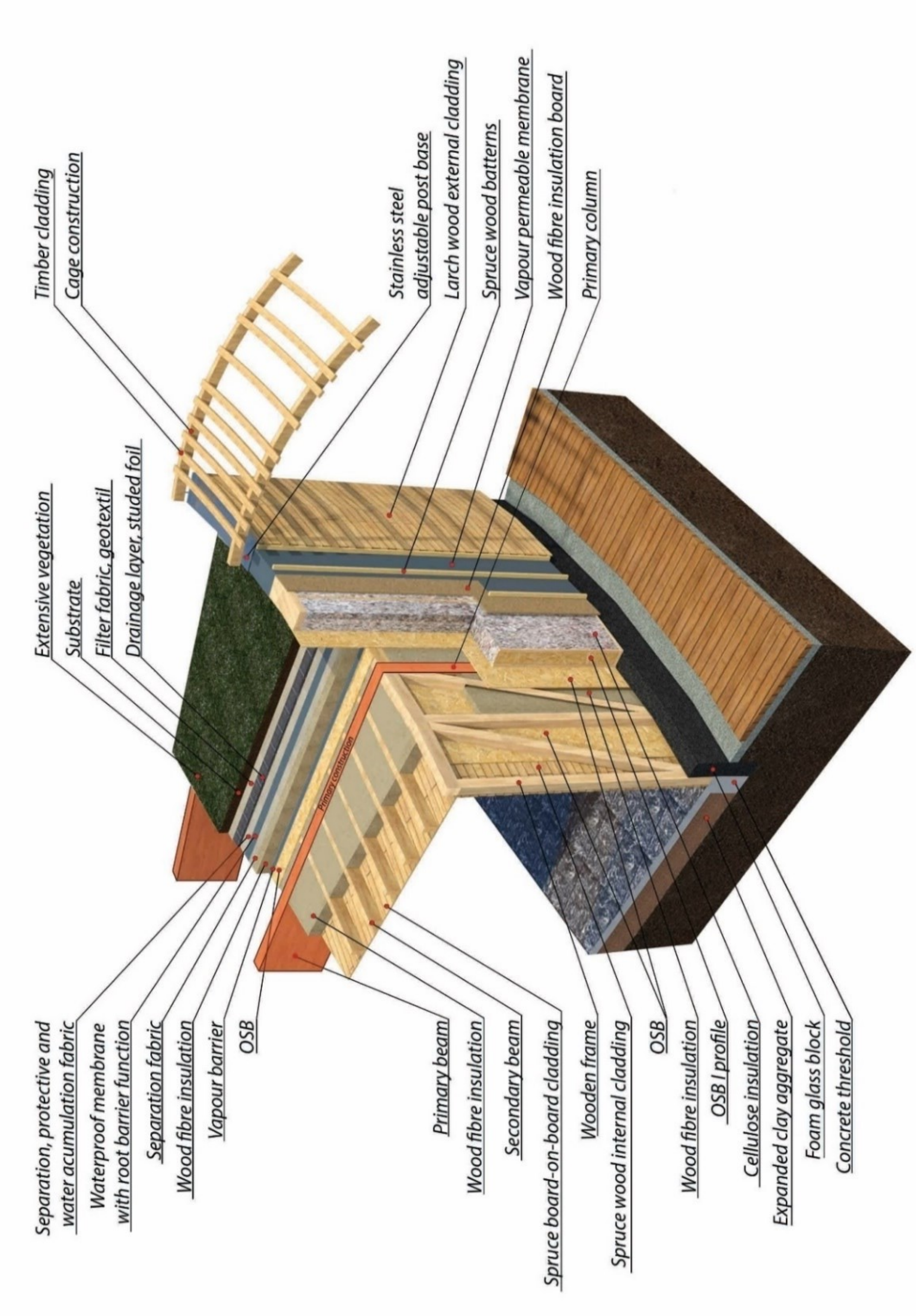


Figure 46: *3D schema of the external wall (cellulose fibre insulation variant) and roof composition*

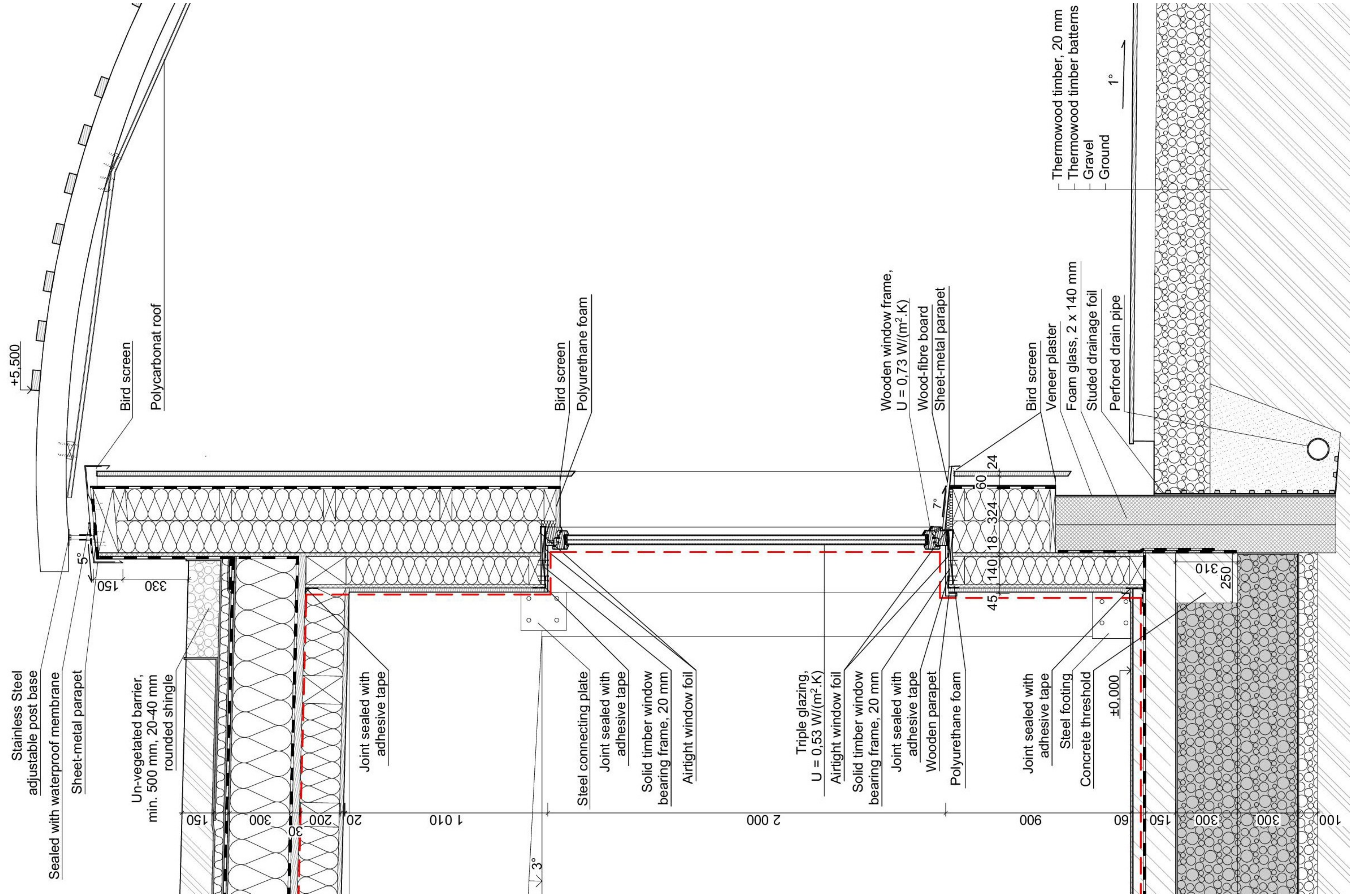


Figure 47: *External wall section drawing*

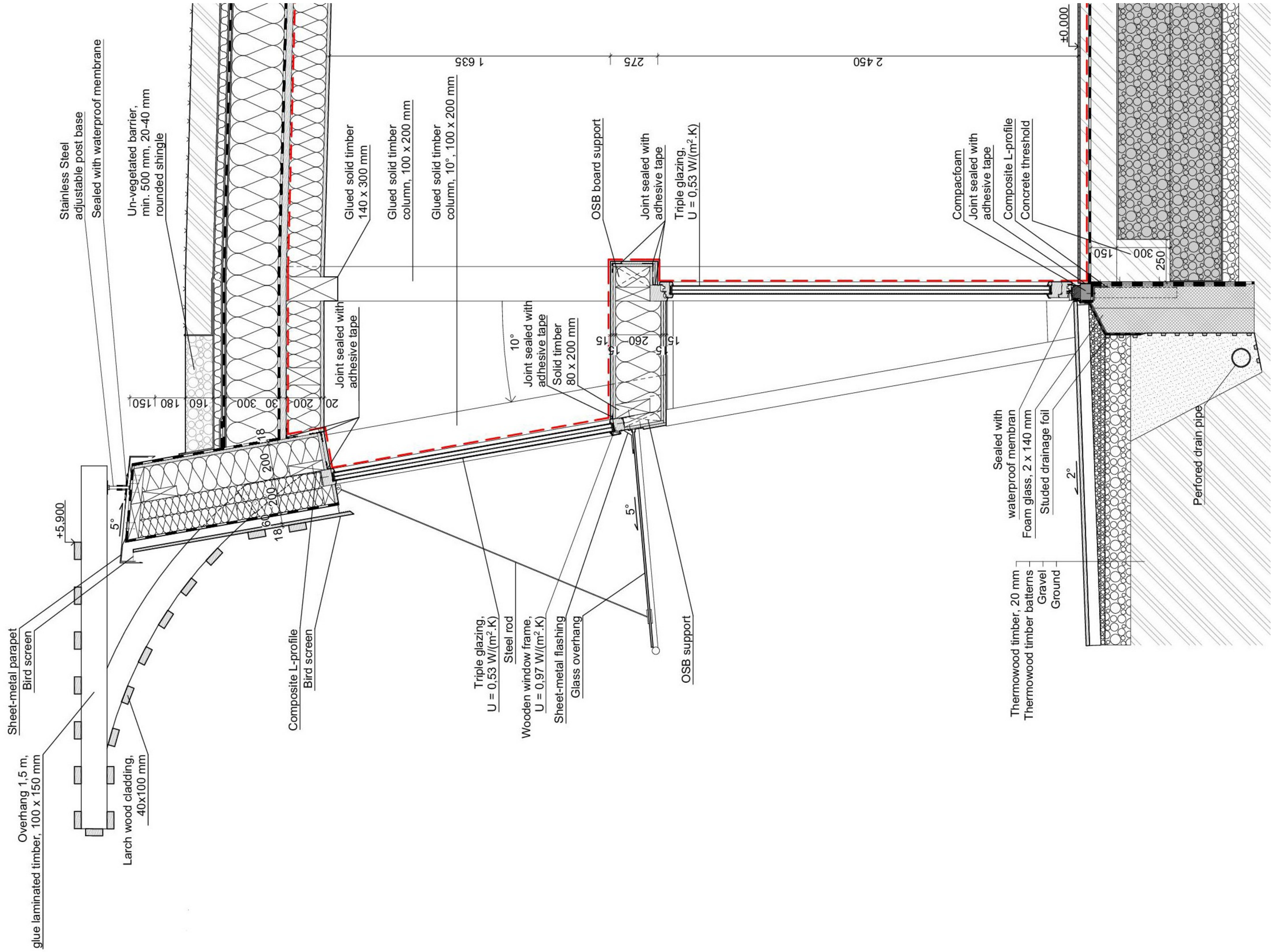


Figure 48: *Southern glazed façade section drawing*

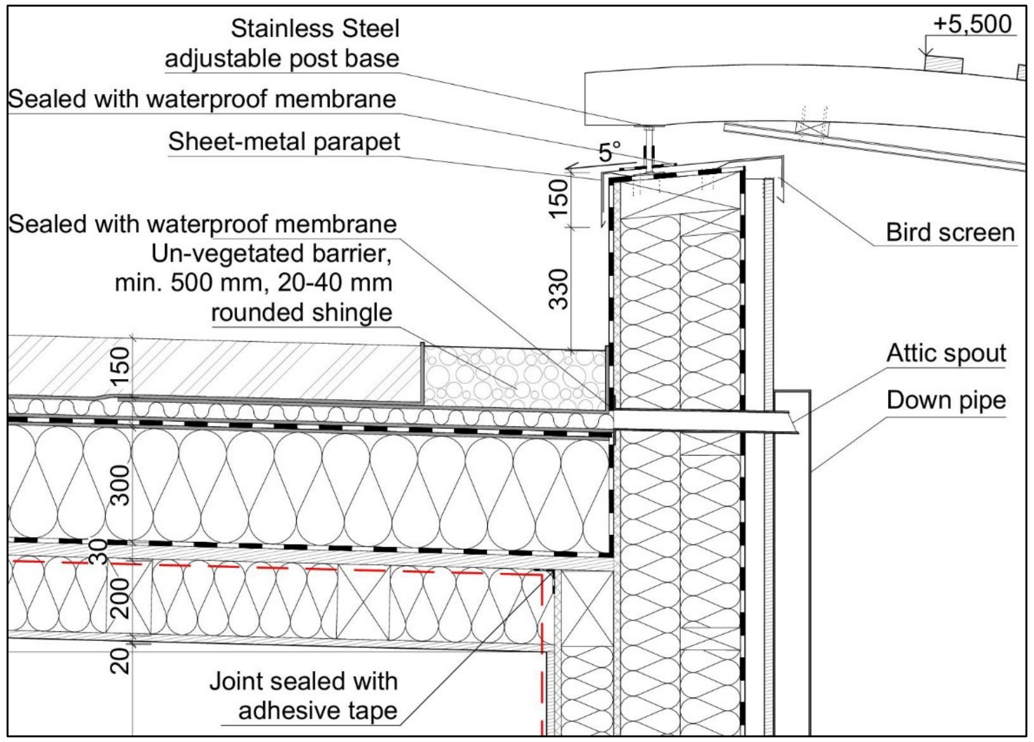


Figure 50: *Attic spout detail*

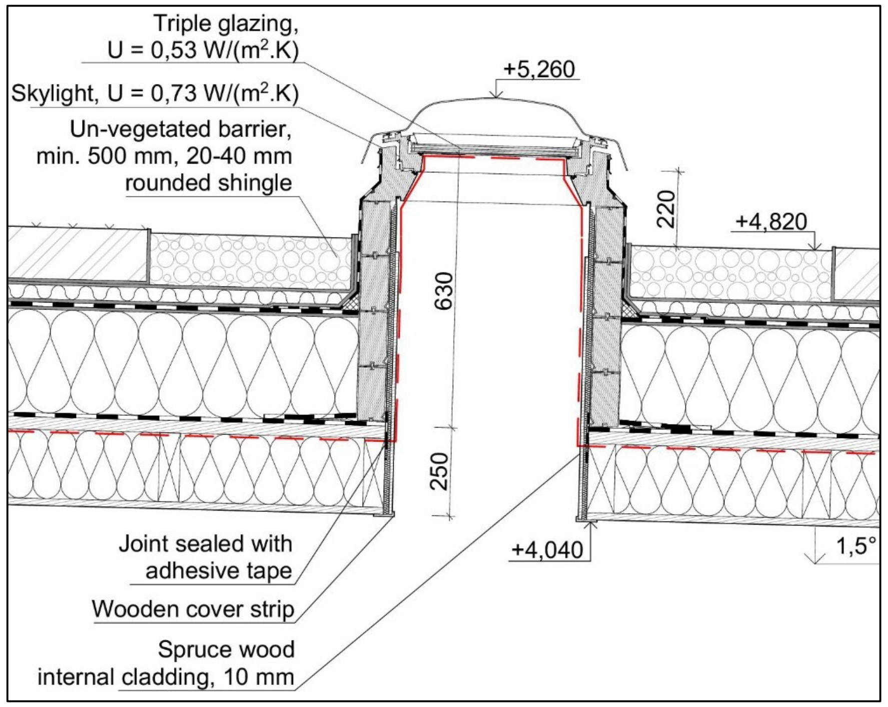


Figure 49: *Skylight in the Office detail*

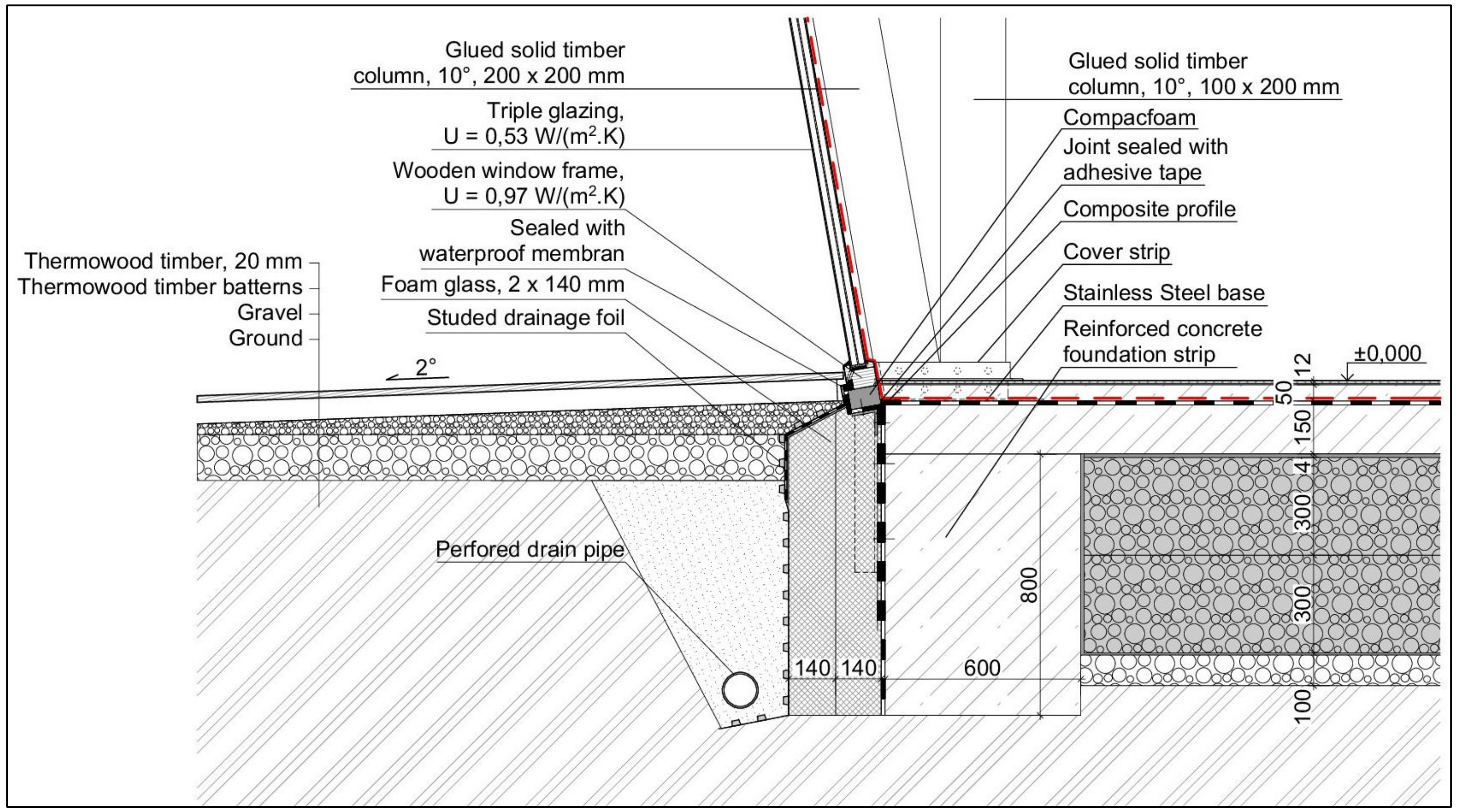


Figure 51: *Front glazed façade connection with ground*

4.1.2 Statics

4.1.2.1 OSB

For dimensioning the horizontal construction, the step by step procedure from the first layer to the main load bearing beam is necessary. The first support layer is OSB board. The calculation examines the Ultimate limit state and the Serviceability Limit State of the OSB boards

[see Annex 3].

[For the composition of the roof see chapter 5.1.1.1; for load calculation see

Annex 2]

As the calculation shows, the OSB/2 boards 30 mm thick are designed. OSB/2 are load-bearing boards for use in dry conditions.

4.1.2.2 Secondary beam

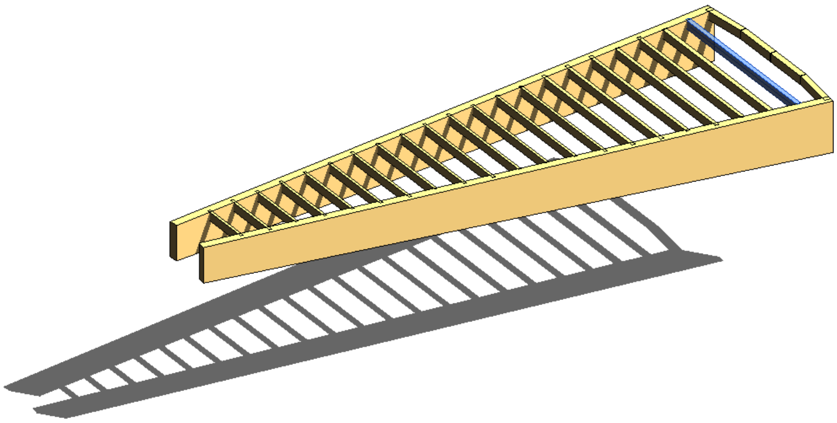


Figure 52: *Secondary beam*

The lengths of the secondary beams differ according to the distance from the edge of the house. The calculation is necessary for every beam [see Annex 5], but for the step by step calculation the longest and also the most loaded beam is calculated [see Annex 4]. The material of the beams is glue-laminated timber.

The beams are designed from glue-laminated timber GL24h. As the calculation shows, every beam is 100 mm wide and 200 mm high even though the dimensions could be different because of the loads are smaller according to the distance from the edge of the building. The heights of the beams are always the same because of the insulation in between them which should not change. Regarding the width of the beams, there are fire safety measures [see 4.1.3] and different dimensions would complicate them.

4.1.2.3 Primary beam

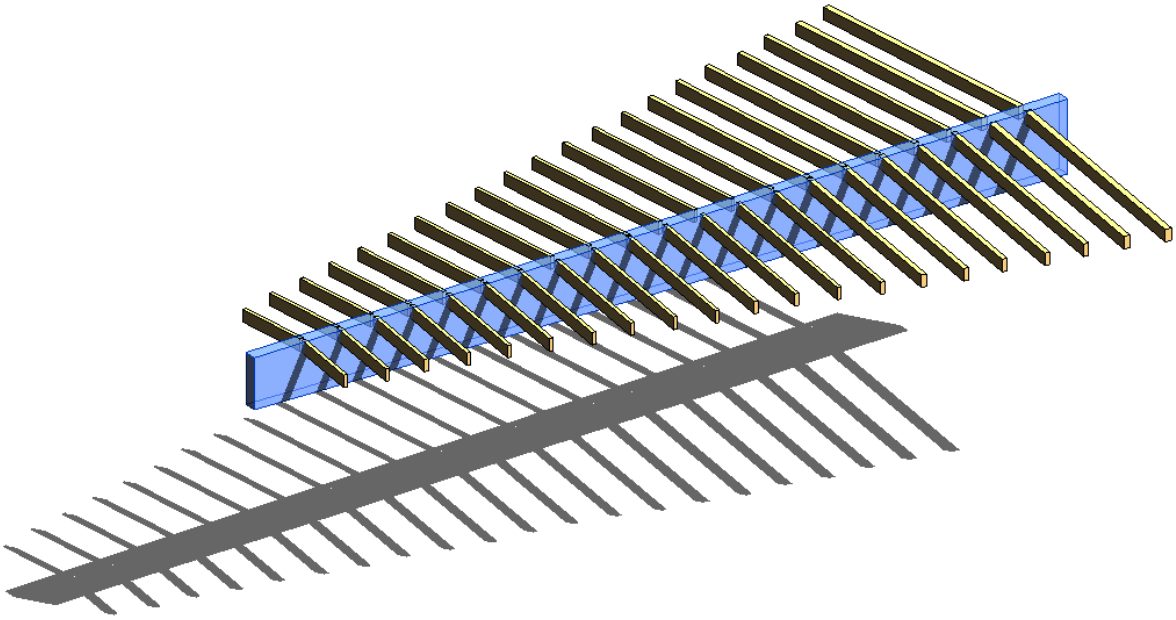


Figure 53: *Primary beam*

For the calculation of the primary beam the force of each rafter reacting to the beam is considered on each side. The Scia engineer software is used for calculation with 21 forces from rafters and continuous load from weight of the trapezoidal beam. The inclination 1,5° is reflected as well [see

Annex 6].

The beam is designed from glue-laminated timber GL28h and is 14 m long, 200 mm wide, 1200 mm high on more loaded side and 840 mm on the other side. The angel creating the trapezoidal shape is 1,5°.

4.1.2.4 Girder

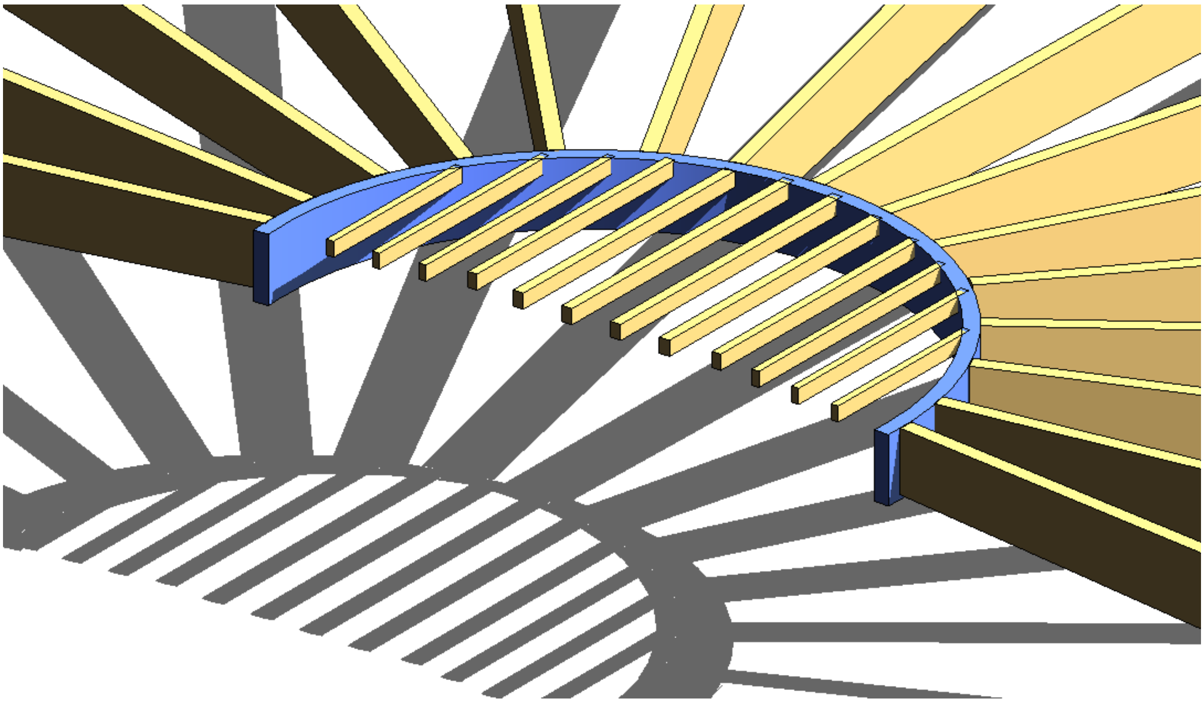


Figure 54: *Girder*

In order to proceed with calculation, the round shape of the central girder is simplified to the simple line. The main load is created with the primary beams on one side, secondary beams on the other side and weight of the girder itself. All necessary forces were calculated in the Edubeam software [see Annex 7].

The girder is designed from glue-laminated timber GL28h and is 200 mm wide, 900 mm high and its axial radius is 4,3 m. The total length of the simplified model is 14,1 m.

4.1.2.5 Column 1

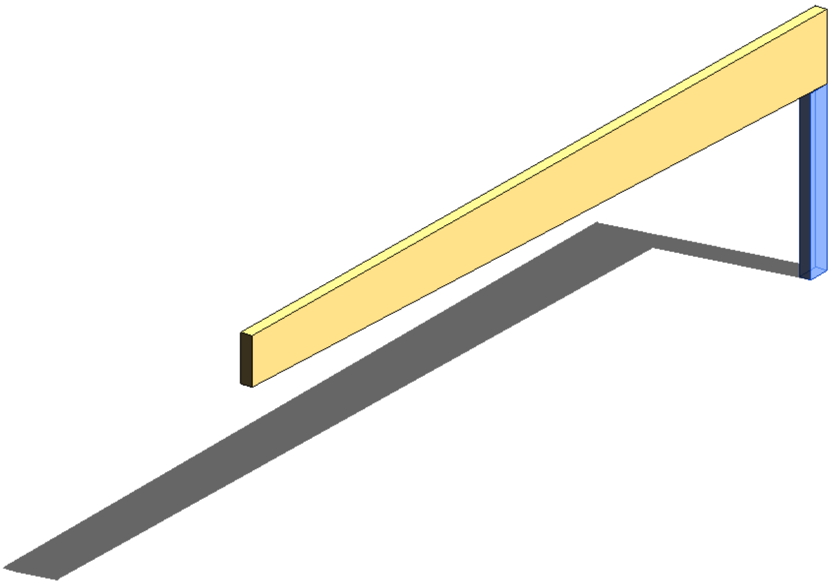


Figure 55: *Column 1*

For the calculation of the first column on the farther side of the building the force calculated in Scia Engineer software and predicted weight of the column itself is used [see Annex 8].

The column is designed from glue-laminated timber GL24h and is 3 m high, 200 mm thick and 400 mm wide. Regarding the loads, the dimensions are more than satisfactory but the volume of the wood matters due to the fire safety. [see 4.1.3].

4.1.2.6 Column 2

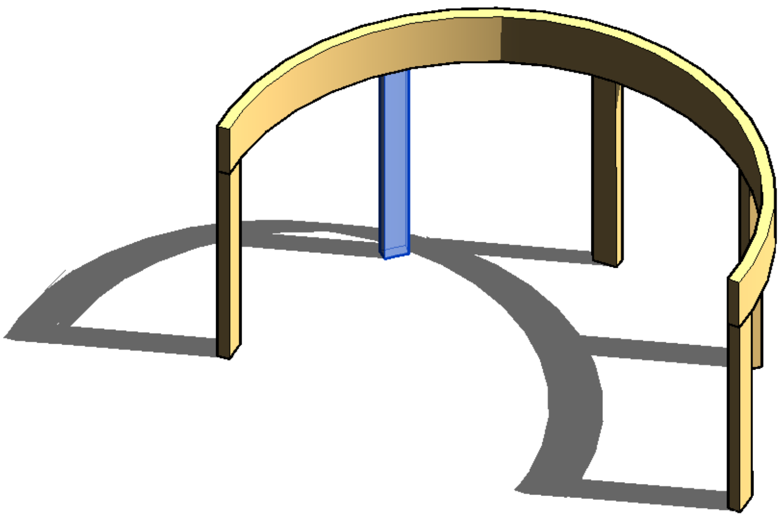


Figure 56: *Column 2*

For the calculation of the second column the biggest force produced from the girder calculated in Edubeam software is used [see Annex 9].

The designed material and the reason of its oversized dimensions are the same as in the previous column description.

4.1.2.7 Weight of the Cage Calculation

The cage was calculated only for the image of the final weight reacting to the components of the external wall. The loads from the weight of the polycarbonate roof, snow, timber laths and the main beam were considered. For the calculation, the Edubeam software was used. [see Annex 10]

The main beam is designed from glue-laminated timber GL24h and is 150 mm high, 100 mm wide and its radius is 5,5 m. The horizontal laths are considered to be from glue-laminated timber GL24h as well and each of them is 40 mm high and 100 mm wide. The radius of laths differs according to the distance from the building.

The final force reacting to the wall´s components is 2,92 kN which is approximately 298 kg. This weight is considered as safe in terms of external wall stability.

4.1.3 Fire safety

The house of Trees is a small multifunctional ground floor building with 570 m^2 of floor area. The whole load bearing construction is designed from wood which is considered as flammable material. The interior surfaces of the house are designed also from wood due to the educational and architectural reasons.

4.1.3.1 Fire Compartments

The House of Trees is 38 m long and 20 m wide. According to the tab. 11 ČSN-73-0802 [ČSN-73-0802 2015], these dimensions are under the limit for the worst coefficient “a”. Therefore, there is no need to divide the object into more than one fire compartments.

4.1.3.2 Fire Resistance Grade

For determining the fire resistance grade (FRG), the fire load of the building must be specified. Based on the object functions and without any further calculations, the building´s fire load is considered in range from 40 to 60 kg/m^2.

According to the tab. 8 ČSN-73-0802, the FRG can be determined. The information as fire height of the building (0 m for ground floor buildings), fire properties of the structural system (timber construction is flammable) and the building´s fire load (40-60 kg/m^2) have to be known. The FRG of the object would be at worst classified in the II. FRG.

4.1.3.3 Fire Resistance of the Load Bearing Constructions

The next part of the fire safety calculation is dedicated to the fire resistance of the load bearing components of the object.

According to the standard [ČSN EN 1995-1-2 (731701), 2006] the fire resistance of basic timber components can be determined from their dimensions.

Dimensions of the cross section [mm]	Fire resistance R [min]											
b **h**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**
60	10	15	15	15	15	15	15	15	15	15	15	15
80	15	20	20	20	20	20	25	25	25	25	25	25
100	20	20	25	25	30	30	30	30	30	30	30	30
120	20	25	30	30	30	30	30	30	30	30	30	30
140	25	30	30	30	30	30	30	30	45	45	45	45
160	25	30	30	30	30	45	45	45	45	45	45	45
180	25	30	30	30	45	45	45	45	45	45	45	45
200	25	30	30	45	45	45	45	45	60	60	60	60

Table 2: *Beams fire resistance* [ČSN EN 1995-1- 2006]

The dimensions of secondary beams are 200 x 100 mm and therefore would resist the fire for 30 minutes. But this table shows fire resistance of beams unprotected from three sides.

Designed beams in the House of Tress project are protected with the spruce board-on-board cladding and their fire resistance could be even better.

Dimensions of the cross section [mm]		Fire resistance R [min]											
b	**h**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**	**260**	**280**	**300**
120		5	10	15	15	15	15	15	15	15	15	15	15
140		10	10	15	15	20	20	20	20	20	20	20	20
160		10	10	15	20	20	20	25	25	25	25	25	25
180		10	10	15	20	20	25	25	30	30	30	30	30
200		10	10	15	20	25	25	30	30	30	30	30	30

Table 3: *Columns fire resistance* [ČSN EN 1995-1-2 2006]

The maximal column dimensions in the table are 200 x 300 mm. With these dimensions, the columns can resist the fire for 30 minutes. Designed columns in project are 200 mm wide and 400 mm deep. The considered fire resistance could be even better.

After the comparison with the tab. 12 ČSN-73-0802, it is possible to claim, that the main load bearing constructions are fire resistant enough for the II. FRG.

4.1.3.4 Fire resistance of the building´s elements

For the building´s elements, there is no fire resistance calculated. Therefore, the building´s envelope is considered as fire open construction and the separation distances have to be determined from these constructions.

4.1.3.5 Evacuation time

From every part of the fire compartment except from the WC and the Storage, there is a possibility of two escape routes. The picture of the House of Trees fire safety is solved by simplifying the task to the easy calculation of evacuation time from the Lecture room which is situated approximately in the centre of the object and it makes it the space, furthermost from the emergency exit.

The following formula is used for the calculation of the evacuation time:

$$t_u = \frac{0{,}75 \, . \, l_u}{v_u} + \frac{E \, . \, s}{K_u \, . \, u}$$ [ČSN-73-0802, 2015]

Where:

t_u = evacuation time [min]

l_u = length of the escape route [m]

v_u = speed of the escaping people [m/min]

E = number of evacuated persons

s = evacuation condition factor

K_u = unit capacity of the escape lane [persons/min]

u = countable number of escape lanes

As already told, the longest possible escape route is measured from the Lecture Room and is 32 m long. The number of evacuated people was calculated according to the standard [ČSN-73-0818, 1997]

Number of persons in specific room	Area of the room [m^2]	Designed number of people according to the project	Area per 1 person according to the standard	Coeficient for the designed number of persons	Number of people according to the area of the room	Multiplied number of people according to the project	Final number
Indoor workshop	47	30	3	1,3	16	39	**39**
Lecture room	62	30	0,8	/	78	/	**78**
Exposition hall	206	60	3	/	69	/	**69**
Reception + Snack bar	101	30	1,4	/	72	/	**72**
Computer room	33	10	2,5	/	13	/	**13**

Table 4: *Building occupancy according to the fire safety standard* [information taken from, ČSN-73-0818, 1997]

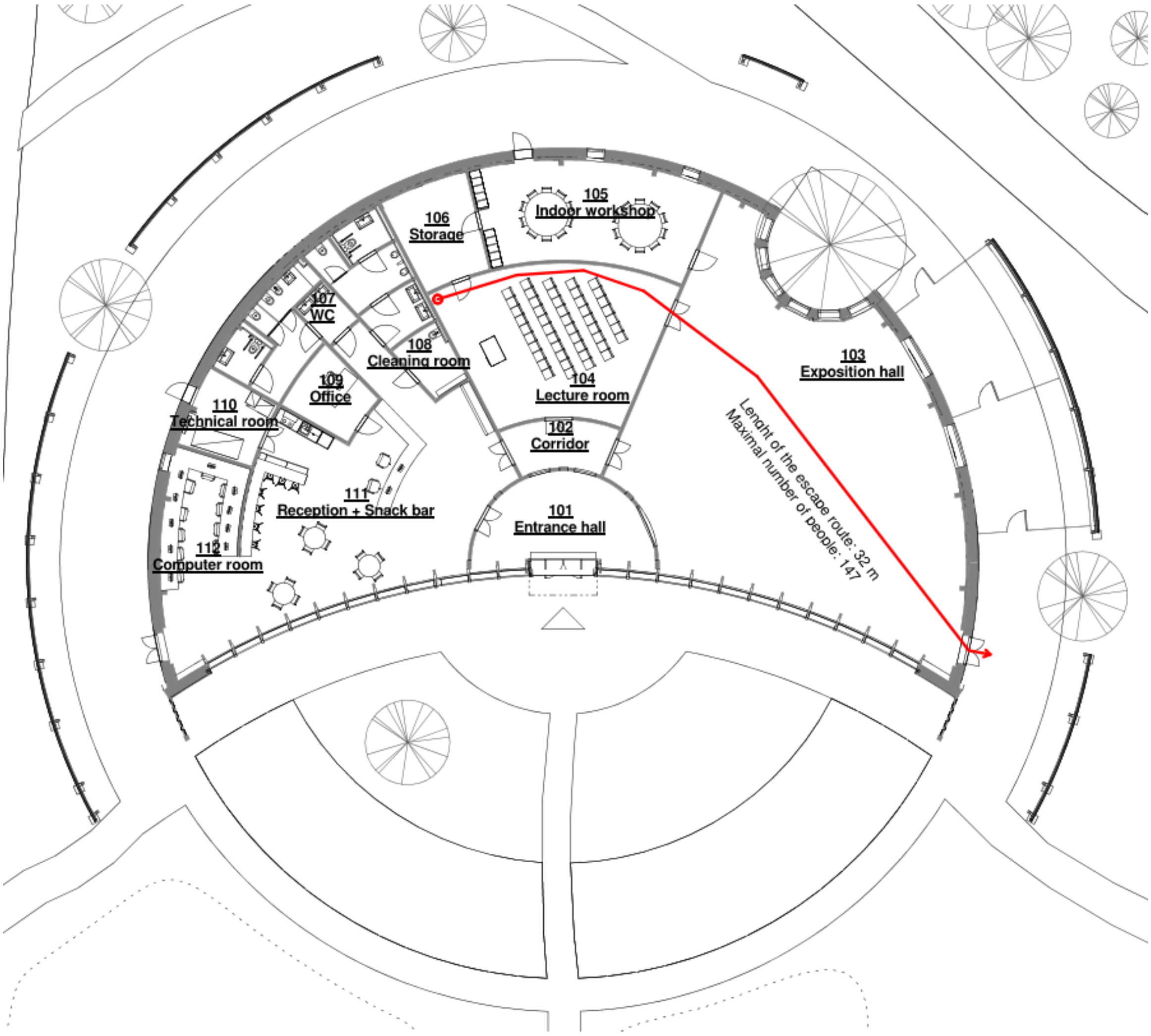


Figure 57: *Schema of the escape route*

The number of evacuated people is measured as the sum of the persons in the lecture room and exposition hall. According to the Table of occupancy is the final number equalled 147.

The object is designed as barrier free and therefore is the evacuation condition factor (s) considered as 1,5 (escaping people with limited movement ability). According to the standard is the Speed of escaping people (v_u) equalled as 30 m/min on the plane. The Unit capacity of the escape lane (K_{u}) is equalled 40 persons/min [ČSN-73-0802, 2015]. Every door in the escape route are at least 0,8 m wide. Therefore, the countable number of escape lanes (u) is considered as 1,5.

$$t_u = \frac{0{,}75 \,.\, 32}{30} + \frac{147 \,.\, 1{,}5}{40 \,.\, 1{,}5} = 4{,}475\ min$$

The final number serves only for rough idea and would be even lower than 4,475 minutes for that the calculation was simplified. The number of escaping people is 147 at the beginning of the rout in the Lecture room where would be only 78 persons.

4.1.3.6 Smoke Amount Calculation

For the calculation of the smoke amount, there is empirical formula used.

$$t_e = 1{,}25 {h_s}^{0{,}5}/a \qquad \text{[ČSN-73-0802, 2015]}$$

t_e = time limit after which is the fire compartment filled with smoke up to the level of 2,5 m above floor [min]

h_s = headroom of the fire compartment [m]

a = 1,3

$$t_e = 1{,}25.\,4^{0{,}5}/1{,}3 = 1{,}923 \text{ min}$$

The t_e is lower than the evacuation time. But the coefficient “a” was used without any calculation. If the calculation was made, the final coefficient “a” could be reduced and therefore, the t_e value could be increased. But without the detailed calculation it can be said, that the additional fire and smoke protection measures would be necessary.

4.1.3.7 Separation Distances

According to the tab. F.1 ČSN-73-0802, the separation distances from radiation areas of the building elements can be determined. The height of the building (5,5 m), the percentage area of the fire open elements (100%), the building´s fire load (50 kg/m^2) and the length of the building element (9 m is the shortest option and is used for this calculation) have to be known. The final separation distance is 13,3 m to every direction from the object.

The separation distance due to the falling parts would be much lower than the separation distance from the radiation areas of the building´s elements and therefore is not calculated.

Separation distances from the radiation areas of the roof and from the falling parts of the roof do not have to be calculated since the object is in the II. FRG and has flat roof.

4.1.3.8 Fire-Fighters Arrival

The possibility of the fire-fighters intervention is not limited by any barriers in the way of arrival.

5 Passive House Classic Variant

5.1 Material optimization

The material optimization consists of the comparison of environmental influence and thermal properties.

For the necessary information about the environmental influence of the materials, the internet database Envimat.cz was used. There are two groups of evaluated parameters as the content of this website. The first one is about environmental influence during the life cycle assessments of materials:

Primary energy input (PEI) [MJ]
Global warming potential (GWP) [kg CO2,ekv.]
Acidification potential (AP) [g SO2,ekv.]
Photochemical Ozone Creation Potential (POCP) [g C2H4,ekv.]
Ozone Depletion Potential (ODP) [g CFC2,ekv.]
Eutrophication Potential EP [g PO4 3- ekv.]

The second group deals with technical properties of materials:

Thermal conductivity coefficient (λ) [W/(m.K)]
Heat transfer coefficient (U) [W/(m^2.K)], (for the whole constructions)
Weight (m) [Kg]

Envimat uses the International Database of materials Ecoinvent for the environmental profiles calculation. [Envimat, 2016]

The Microsoft Excel software was used for the actual calculation of the environmental influence of the object components. All considered compositions should have approximately equal thermal proprieties. The weight per m^2 of every material of the examined composition was calculated and multiplied by every above mentioned numbers from the environmental influence group. The result is demonstrated in form of two diagrams where one of the compositions is always the reference in order to see differences. The first diagram shows the environmental profiles of considered compositions while the second one is about environmental impact of the compositions according to the specific weight of the examined number. The PEI, for example, has weight of 40% while EP has weight of only 5%.

5.1.1 Roof

5.1.1.1 Composition

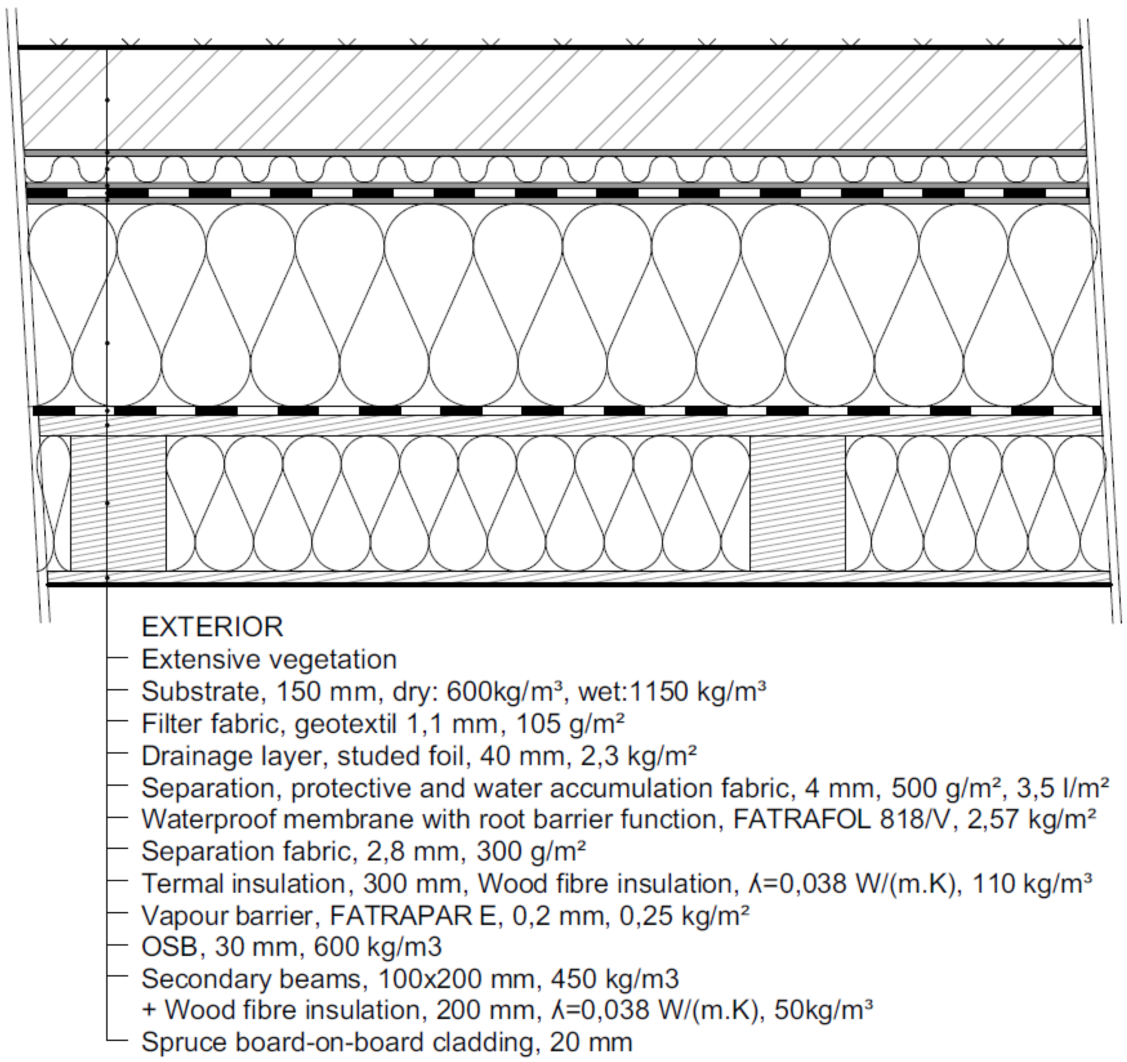


Figure 58: *Composition of the roof (wood-fibre insulation variant)*

5.1.1.2 Possible Insulation Materials

For the material optimization of the roof there are three examined insulation materials. The first one is wood-fibre insulation, the second one is mineral wool insulation and the last one is expanded polystyrene (EPS). The EPS is part of the calculation only for comparison with the other two natural materials.

Basic material properties:

a) Wood-fibre insulation: λ = 0,038 W/(m.K)
   ρ = 50 kg/m^3
   c = 2100 J/(kg.K)
   μ = 0,5

b) Mineral wool insulation: λ = 0,036 W/(m.K)
   ρ = 32 kg/m3
   c = 800 J/(kg.K)
   μ = 1

c) Expanded polystyrene: λ = 0,035 W/(m.K)
   ρ = 30 kg/m^3
   c = 1270 J/(kg.K)
   μ = 30-80

[Envimat, 2016; Dataholz, 2016; Isover, 2016]

The wood fibre insulation in Envimat database weights 300 kg/m3 and its thermal conductivity is 0,038 W/(m.K), which is very low number if the weight is considered. The weight of the wood fibre insulation has been reduced to 50 kg/m3, which is the usual mass of the wood fibre insulation with thermal conductivity around 0,04 W/(m.K).
[For the environmental influence calculation of the roof, see Annex 11]

5.1.1.3 Result

The lowest environmental impact has the wood fibre insulation and therefore is designed as the best possibility. The wooden character of this kind of insulation is convenient as well.

5.1.2 Exterior wall

5.1.2.1 <u>Composition</u>

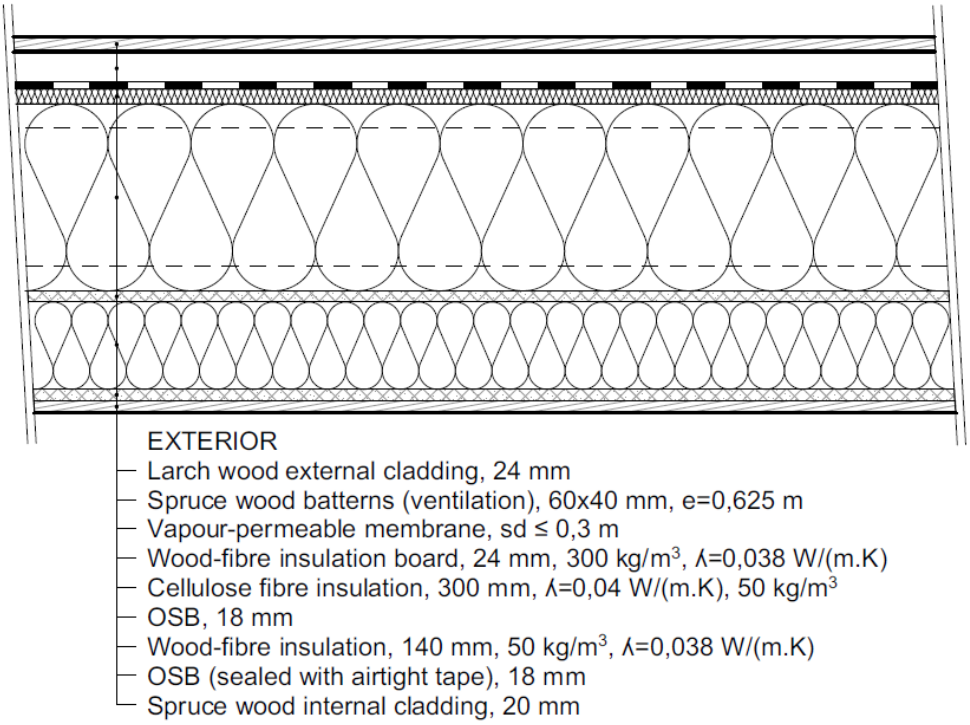


Figure 59: *Composition of the exterior wall (cellulose fibre insulation variant)*

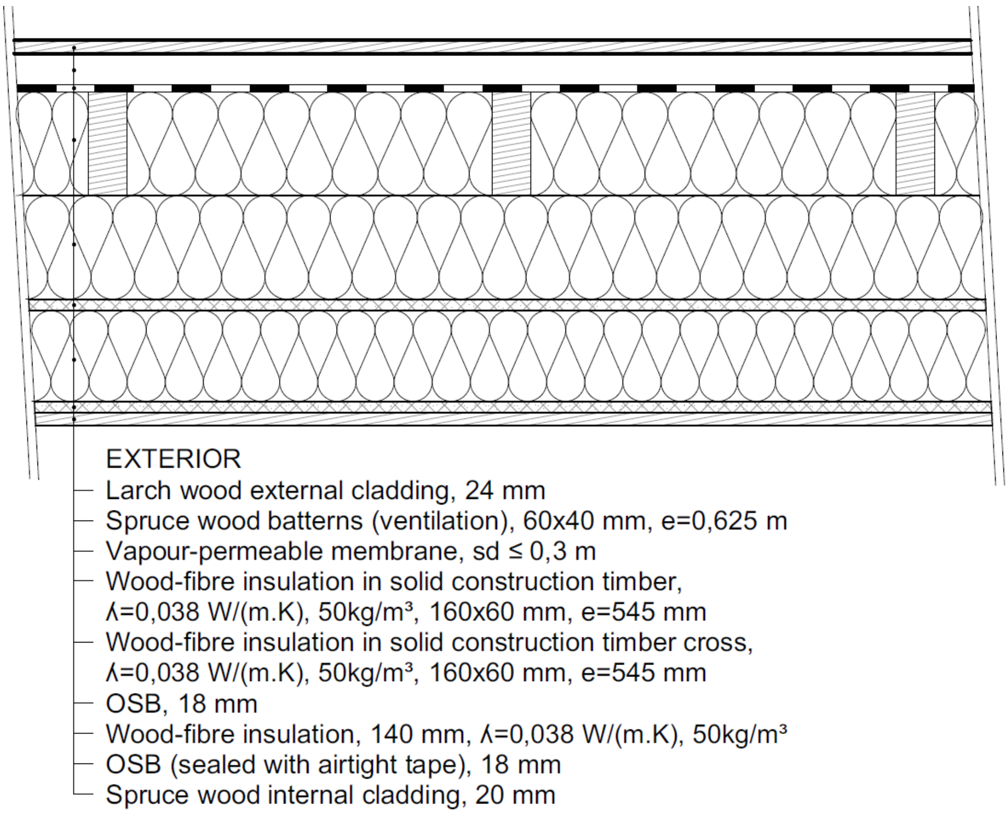


Figure 60: *Composition of the exterior wall (wood-fibre insulation variant)*

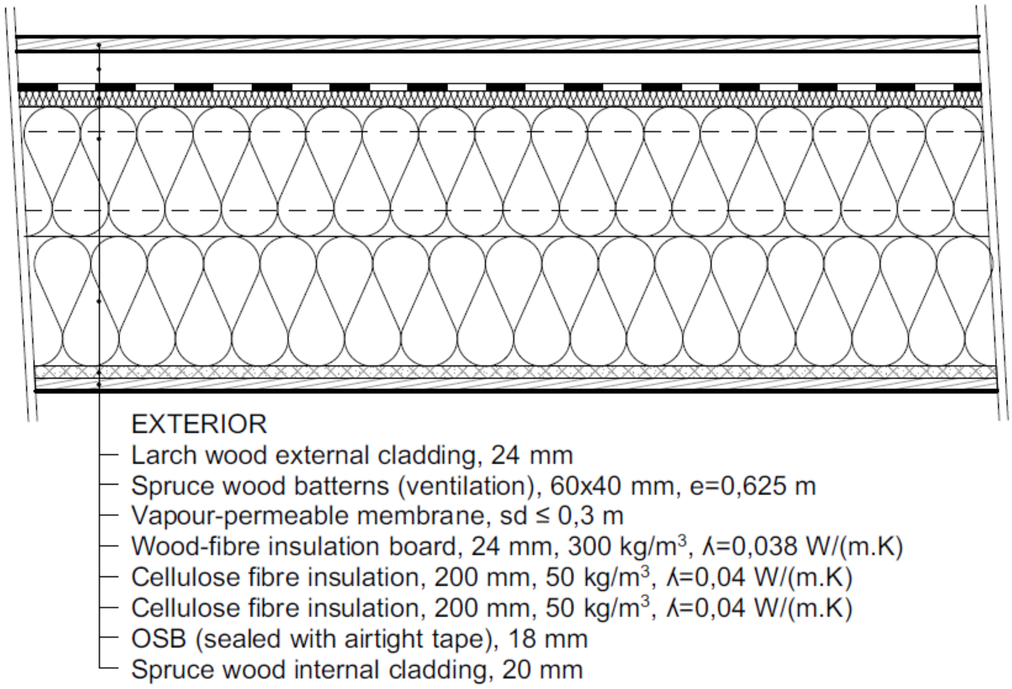


Figure 61: *Composition of the south exterior wall (cellulose fibre insulation variant)*

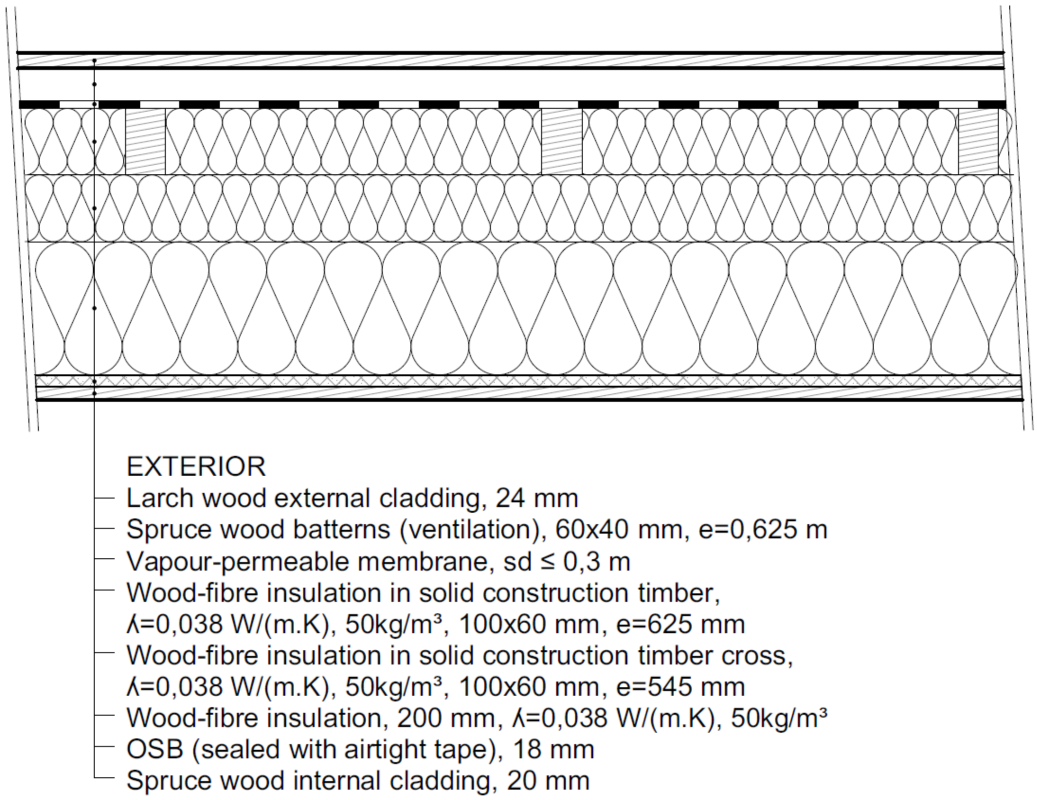


Figure 62: *Composition of the south exterior wall (wood-fibre insulation variant)*

5.1.2.2 Possible Insulating Materials

There are three considered insulation materials for the exterior wall. The first one is cellulose fibre insulation, the second one is wood-fibre insulation and the last one is mineral wool insulation.

Basic material properties:

a) Cellulose fibre insulation: $\lambda = 0{,}04$ W/(m.K)
$\rho = 50$ kg/m^3
c = 2110 J/(kg.K)
$\mu = 1$

b) Wood-fibre insulation: $\lambda = 0{,}038$ W/(m.K)
$\rho = 50$ kg/m3
c = 2100 J/(kg.K)
$\mu = 0{,}5$

c) Mineral wool insulation: $\lambda = 0{,}036$ W/(m.K)
$\rho = 32$ kg/m^3
c = 800 J/(kg.K)
$\mu = 1$

[Envimat, 2016; Dataholz, 2016; Isover, 2016]

[For the environmental influence calculation of the exterior wall, see Annex 12]

5.1.2.3 Result

As the environmental impact calculation shows, the best choice for insulating the exterior walls of the House of Trees is wood fibre insulation.

5.1.3 Partitions

5.1.3.1 Composition

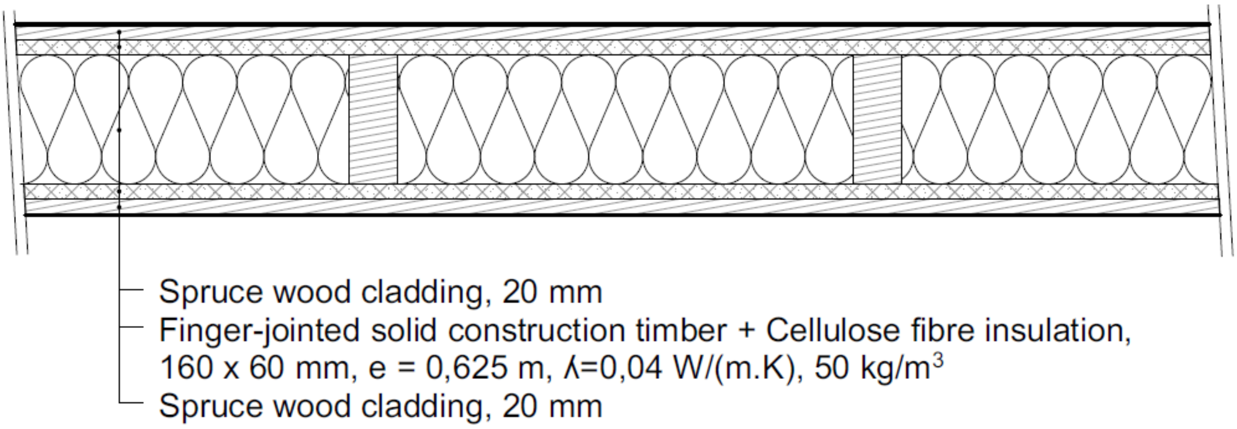


Figure 63: *Composition of the internal wall (cellulose fibre insulation variant)*

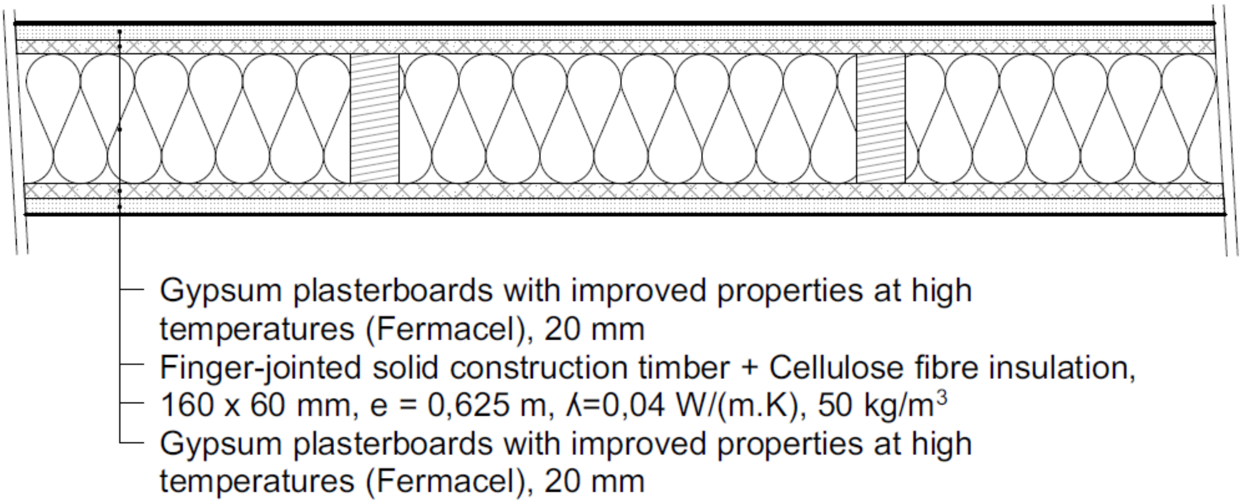


Figure 64: *Fire resistant composition of the internal wall (cellulose fibre insulation variant)*

5.1.3.2 Possible materials

Three possible insulating materials are considered. The first one is cellulose fibre insulation, the second one is mineral wool insulation and the last one is glass wool insulation.

Basic material properties:

a) Cellulose fibre insulation: $\lambda = 0{,}04$ W/(m.K)

$\rho = 50$ kg/m^3

c = 2110 J/(kg.K)

$\mu = 1$

b) Mineral wool insulation: $\lambda = 0{,}036$ W/(m.K)

$\rho = 32$ kg/m^3

c = 800 J/(kg.K)

$\mu = 1$

c) Glass wool insulation: $\lambda = 0{,}04$ W/(m.K)

$\rho = 40$ kg/m3

c = 840 J/(kg.K)

$\mu = 1$

[Envimat, 2016; Dataholz, 2016; Isover, 2016]

[For the environmental influence calculation of the interior partitions see Annex 13]

5.1.3.3 Result

The best possibility for insulating the interior partitions is cellulose fibre insulation.

5.1.4 Floor above ground

5.1.4.1 Composition

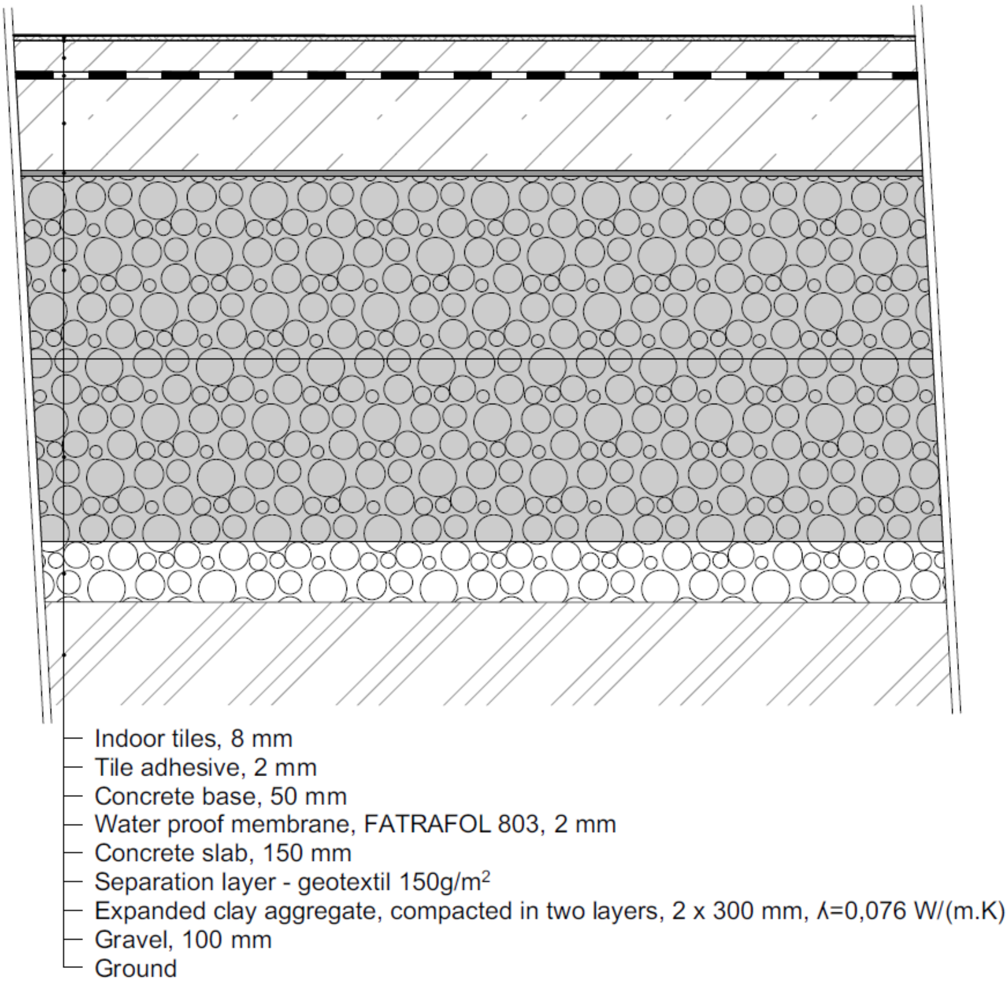


Figure 65: *Composition of floor above ground*

5.1.4.2 Possible insulating materials

There are three possible insulation materials for the floor above ground. The first one is foam glass gravel, the second one is expanded clay aggregate (Keramzit) and the third one is Extruded polystyrene (XPS).

Basic material properties:

a) Foam glass gravel: λ = 0,077 W/(m.K)

ρ = 110 kg/m^3

c = 850 J/(kg.K)

μ = /

b) Expanded clay aggregate: λ = 0,076 W/(m.K)

ρ = 260 kg/m^3

c = 1260 J/(kg.K)

μ = /

c) Extruded polystyrene: λ = 0,034 W/(m.K)

ρ = 25 kg/m3

c = 2060 J/(kg.K)

μ = 20-100

[Envimat, 2016; Tzb-info, 2016; Refaglass, 2016]

[For the environmental influence calculation of the floor above ground, see Annex 14]

5.1.4.3 Result

According to the calculation is the XPS insulation the best choice for insulating the floor above ground. The reason for this results lies in its very low weight and its great insulating properties, which allows to use much less of it. Although the numbers highlight the XPS insulation, the House of Trees is supposed to be designed mostly from natural materials and therefore is the best possibility the second insulation material in order – expanded clay aggregate.

6 Passive House Classic

6.1 Energy concept optimization

6.1.1 Heating

6.1.1.1 Heat Distribution

There are many possibilities for the heat distribution in House of Trees. In the process of designing, the floor heating, supply air heating and classic radiator heating were considered as heat distribution system.

The floor heating usually requires an insulation layer under the heating pipes, or extra concrete slab for heat accumulation. The insulation should be water resistant in case of accident. The composition of floor above ground is designed with insulation layer under the concreate construction. In order to avoid thicker composition due to the usage of extra insulation layer or concrete, the floor heating is decided as not fitting to the House of Trees design. But the floor accumulates a lot of the solar heat gains so it can be partly considered as floor heating.

The classic radiator heating would be without any problem. This system represents reliable distribution of heat to the target area. But nonetheless is the supply air heating considered as the beast way for heating the object. The mechanical ventilation would be designed anyway in the object because of the sufficient air supply demand and heat recovery which is necessary for passive houses. The connection of supply air and space heating distribution is considered as favourable. The other reason for this type of heating is the construction and inner surfaces of the building. The whole object is designed from timber and majority of indoor surfaces is designed from wood as well. This design represents warm materials without any unfavourable cold radiation.

6.1.1.2 Heat Source

As far as the energy source is concerned the heat pump with ground collectors and biomass boiler was considered.

The heat pump with ground collectors would be a fitting source of the energy for House of Trees. There is a lot of free area usable for ground collectors around the object. The heat of the ground represents renewable source of energy and there would be no chimney needed if this variant was used. But there would be an electricity required to run the pump and an electric backup heater inside the water storage for the case of insufficient heat production from ground collectors.

The biomass boiler represents the second option for energy source. The locality of House of Trees is convenient for this type of boiler. The waste wood from Dendrologic garden and Průhonice Park could be chopped, dried and used as renewable fuel for the boiler. The preparation of woodchips would be either in the area of the Garden or the Park. This way would mean stable source of energy without any backup heaters. But the system is much bigger not only because of the larger size of the boiler but even because of the storage for woodchips. Another disadvantage of biomass boiler is the need of the chimney.

The decision which energy source would be the best one will be made after the calculations.

6.1.2 Electricity

The House of Trees is designed as connected to the electricity grid. The amount of solar energy production and battery usage with smart grid system utilization differs according to the energy standard of the building.

6.1.2.1 Electricity Demand

The equipment and artificial lightning of the House of Trees is designed as the most energy efficient products with low power rating appropriate for passive houses. For example, the computers in the Office and the Computer room are considered as Intel NUC [Intel 2016]. These computers are very small (115 x 111 x 48 mm) and their technical specifications are more than sufficient for purposes of the building. Their power rating is approximately 10 W for standard work. The lighting is designed from energy-saving LED lights. [For more detailed electricity demand calculation see Annex 37]

Figure 66: *Intel NUC* [Intel 2016]

6.1.2.2 Solar System

The solar energy production is necessary in order to achieve better energy standard than Passive House Classic. Although there is a lot of free area possible for photovoltaic installation around the building, the architectural design is about to keep photovoltaics as hidden as possible from the eyes of visitors. By following this rule, the only place thinkable for solar panels is on the roof of the building.

The Sun Root System is used for placing the solar panels on the roof. The usage of the roof and inclination of the panels differs according to the specific energy standard of the building.

A very efficient Monocrystalline solar panels from the LG company [LG 2016] with 320 Wp are designed for the purposes of electricity production. Every panel is 1640 mm long, 1000 mm wide and 40 thick.

Mechanical Properties

Cells	6 x 10
Cell Vendor	LG
Cell Type	Monocrystalline / N-type
Cell Dimensions	156.75 x 156.75 mm / 6 x 6 inch
# of Busbar	12 (Multi Wire Busbar) NEW
Dimensions (L x W x H)	1640 x 1000 x 40 mm 64.57 x 39.37 x 1.57 inch
Front Load	6000 Pa / 125 psf NEW
Rear Load	5400 Pa / 113 psf NEW
Weight	17.0 ± 0.5 kg / 37.48 ± 1.1 lbs
Connector Type	MC4, MC4 Compatible, IP67
Junction Box	IP67 with 3 Bypass Diodes
Length of Cables	2 x 1000 mm / 2 x 39.37 inch
Glass	High Transmission Tempered Glass
Frame	Anodized Aluminum

Electrical Properties (STC *)

	320 W
MPP Voltage (Vmpp)	33.6
MPP Current (Impp)	9.53
Open Circuit Voltage (Voc)	40.9
Short Circuit Current (Isc)	10.05
Module Efficiency (%)	19.5
Operating Temperature (°C)	-40 ~ +90
Maximum System Voltage (V)	1000
Maximum Series Fuse Rating (A)	20
Power Tolerance (%)	0 ~ +3

* STC (Standard Test Condition): Irradiance 1000 W/m², Module Temperature 25 °C, AM 1.5

Figure 67: *Solar panel LG NeONTM 2 properties* [LG 2016]

6.1.2.3 Battery

With solar electricity production, the usage of battery is appropriate. However, the proper design of battery capacity is difficult with no hour weather data. The PHPP energy software used for energy calculations works only with monthly and annual data so it is impossible to monitor the recharging and discharging of the battery and design the right capacity based on this monitoring.

Nevertheless, the Powerwall battery from the Tesla Motors company [Tesla 2016] would be appropriate for electricity storage. It comes in two capacity variants, 6,4 kWh and 13,5 kWh. The battery system works with weather prediction and can partly regulate energy consumption and demand according to the upcoming sunny or cloudy days. The Powerwall can be hung on the wall, is very space saving due to its dimensions and has integrated inverter. According to the battery capacity, number of batteries and electricity production, the House of Trees could be designed either as totally or at least partly energy independent in terms of electricity.

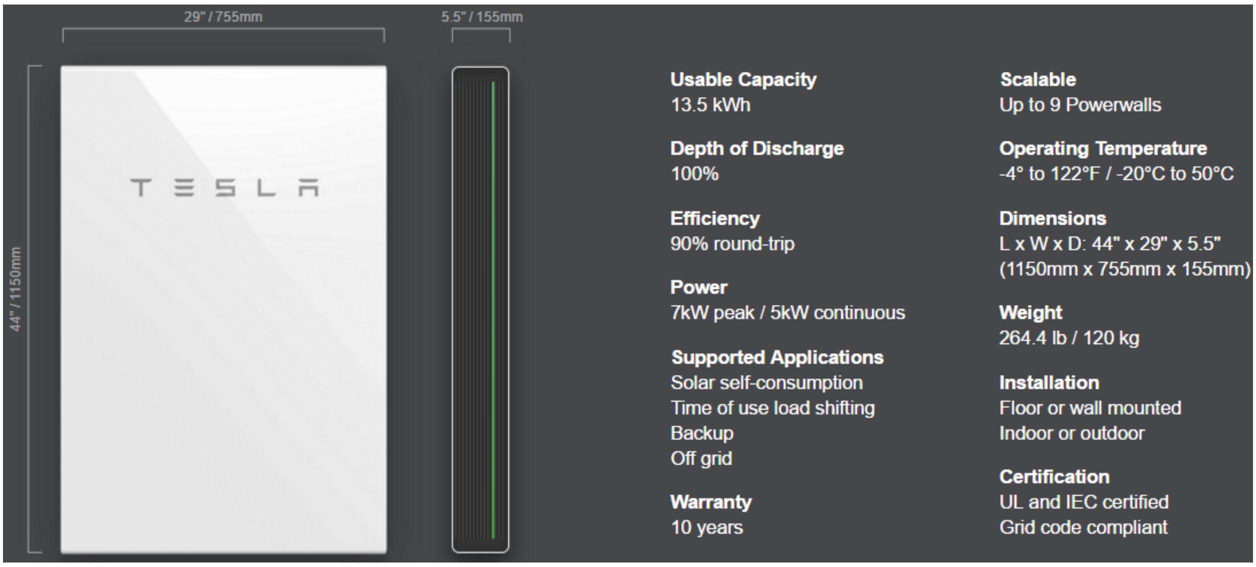


Figure 68:*Tesla Powerwall, 13,5 kWh capacity variant* [Tesla 2016]

6.1.3 Domestic Hot Water Preparation

There is very low demand of domestic hot water (DHW) for the purposes of the House of Trees. Every visitor is supposed to use hot water only for hands washing once per visit. There are no showers designed in the object and only higher hot water consumption may occur in the Snack bar area.

There are two DHW preparation possibilities found as appropriate for the House of Trees demand. The first one is classic preparation in the water storage in the Technical room. This variant requires longer pipes with circulation circuit and the temperature in pipes and storage has to reach temperature approximately 70°C once per week in order to avoid Legionella bacteria, but allows steady source of DHW during the whole day. The second possibility is direct water heater near every group of wash-basins. This option does not require neither long pipes nor circulation circuit but has higher energy demand in order to cover DHW consumption.

6.1.4 Ventilation

In order to achieve passive house energy standard, the heat recovery and proper ventilation is necessary. The ventilation system in House of Trees serves for heating during cold days and through night ventilation mediate cooling during hot days.

The main supply and exhaust air ventilation pipes lead through the WC room and then in between the primary load bearing beams to the centre of the object, where the headroom of the building is almost the highest and ventilation pipes do not create visual distraction. The secondary pipes lead from the centre of the house in between the primary beams in the direction to the exterior wall. The occasional exhaust air from the Snack bar is ventilated through the kitchen hood above the cooker. [see Figure 69 - Figure 72]

There is one ventilation unit with maximal volume flow 4000 m^3/h designed in the Technical room. The supply air is taken from the Outdoor exposition area and the exhaust air is blown to the roof area.

There are two distribution variants considered optimal for the House of Trees ventilation. The first one represent ventilation distribution designed from aluminium pipes of various diameters insulated with 25mm thick mineral wool insulation. The air diffusers and outlets can be designed from rectangular shaped grilles or from perforated pipes. The second possibility represent textile air distribution. The supply air diffusion is possible through fabric perforation which creates slow air flow.

The textile ducts distribution is considered as the better variant for the House of Trees design.

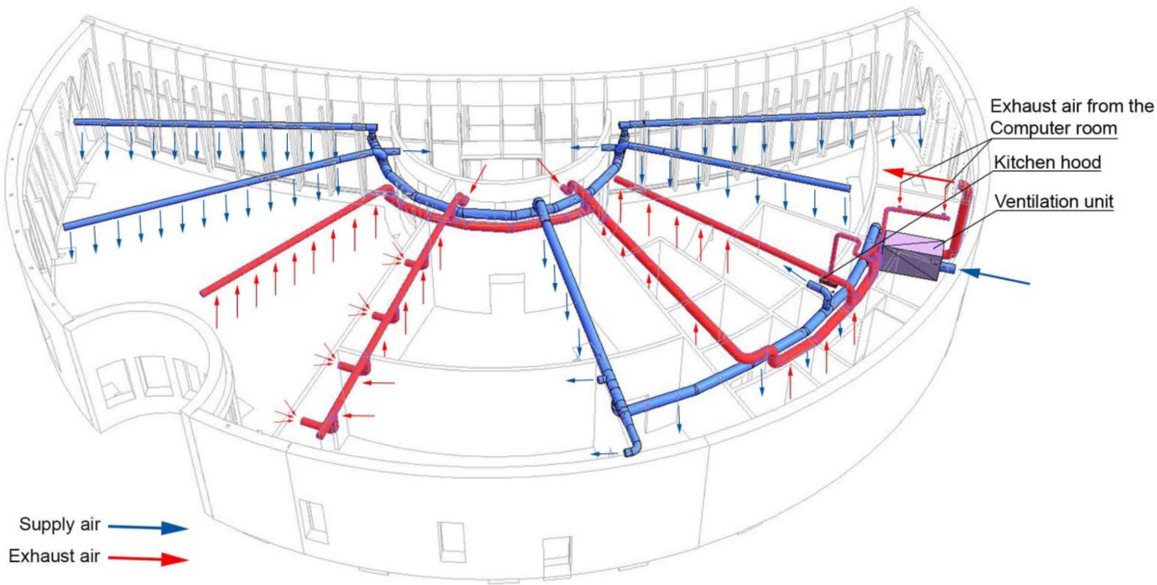


Figure 69: *Ventilation 3D schema 1 – direction of supply and exhaust air flow*

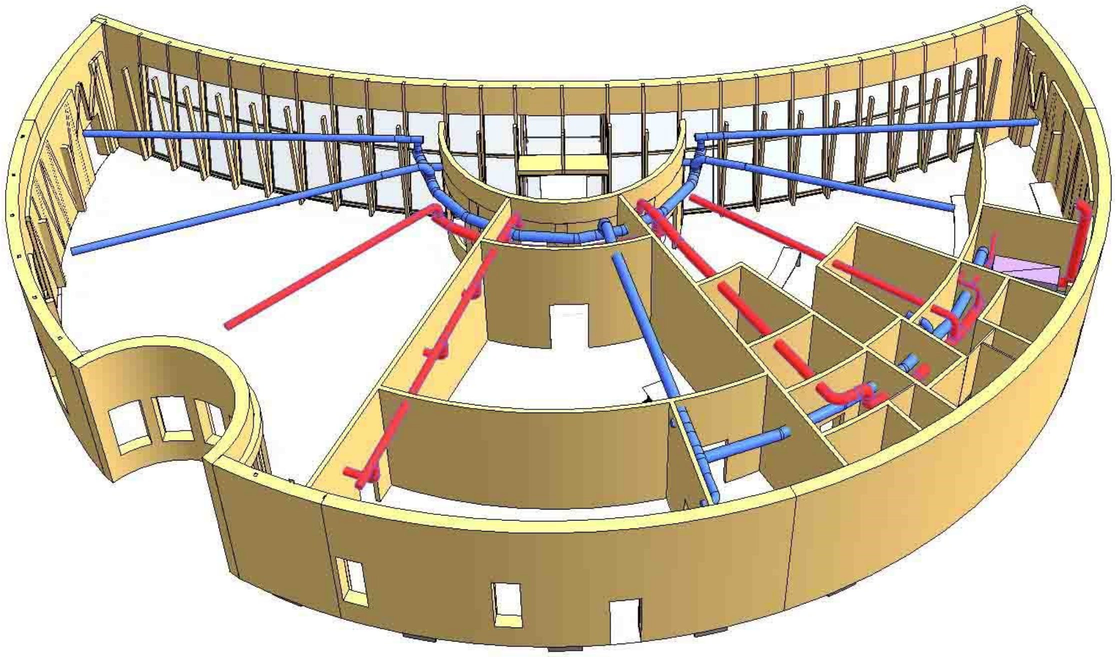


Figure 70: *Ventilation 3D schema 2*

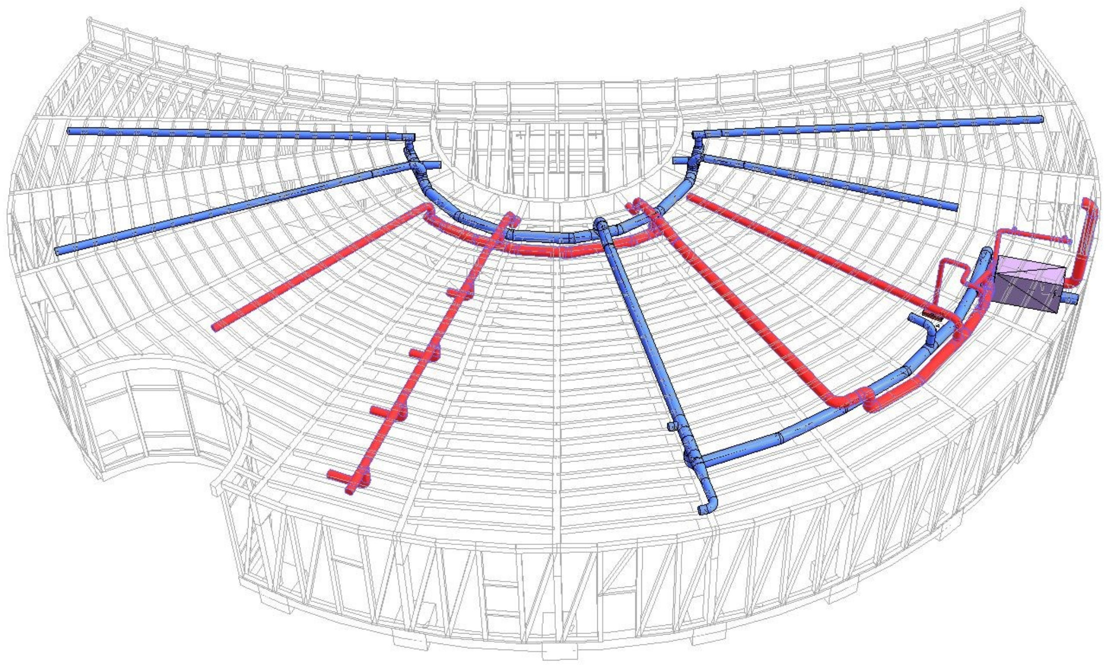


Figure 71: *Ventilation 3D schema 3*

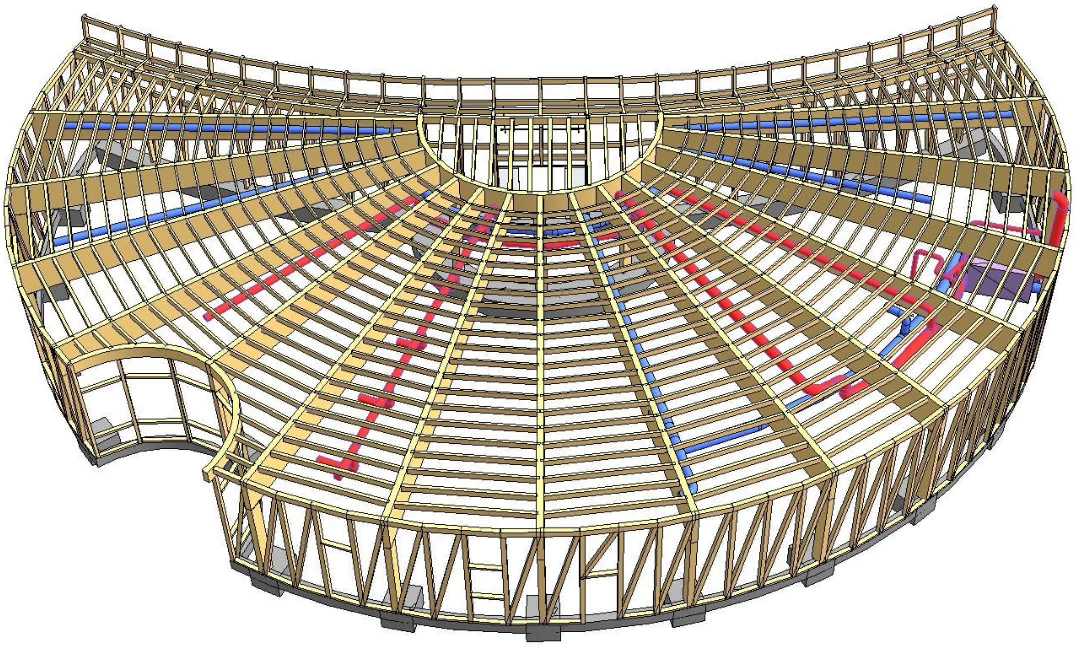


Figure 72: *Ventilation 3D schema 4*

6.1.5 Shading

There are no other shading systems required than front façade tilt, 1,5 m wide overhang and wooden cage around object. The cage and vine plants growing on it make sufficient shading which changes according to the part of the year because of the plants leafs. These measures together with nigh ventilation create optimal indoor environment during the whole year.

6.1.6 Technical Room Design

In this chapter, three designs of technical equipment placement in the technical room take place.

<u>The technical equipment consists of:</u>

Ventilation unit ComfoAir with maximum volume flow 4000 m^3/h. The unit is 2450 mm long, 1750 mm wide and 1400 mm high. [Zehnder 2016]

Battery [see chapter 6.1.2.3]

Heat pump IVT GEO 312 C with ground collectors and integrated 190 l water storage. The HP is 660 mm long, 600 mm, wide and 1800 mm high. Its nominal power is 3-12 kW [IVT 2017]

Biomass boiler MODERATOR UNICA Sensor with maximum nominal power 10 kW. The boiler is 1145 mm long, 495 mm wide and 835 mm high. The minimal diameter of the chimney for this boiler is 180 mm. [Kvalitnikotle 2017]

DHW water storage THERMONA THERM 100/S with 100 l volume. The storage is 535 mm long, 500 mm wide and 840 mm high. [GAS-TM 2017]

Expansion tank Aquamat REFIX DE 12/10 with 12 l volume, 280 mm diameter and 310 mm height. [GAS-TM 2017]

The wood chips storage has approximately 2 m^2 area.

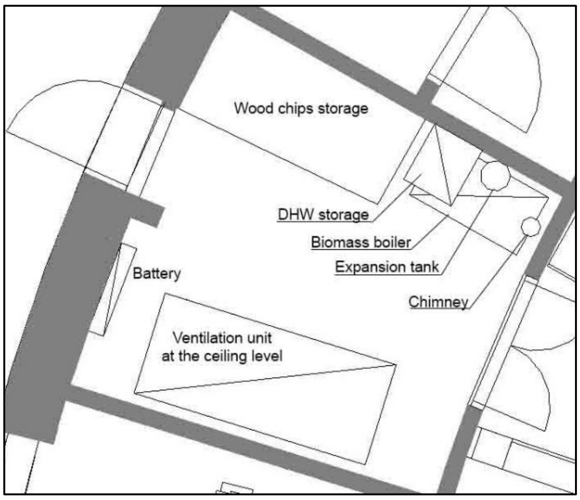


Figure 74: *Technical room with biomass boiler*

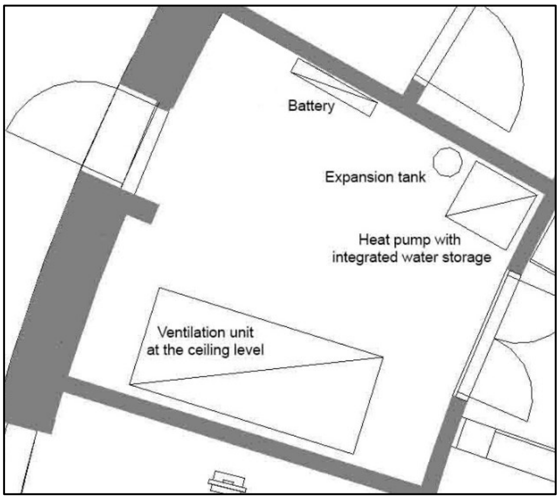


Figure 73: *Technical room with heat pump only for heating*

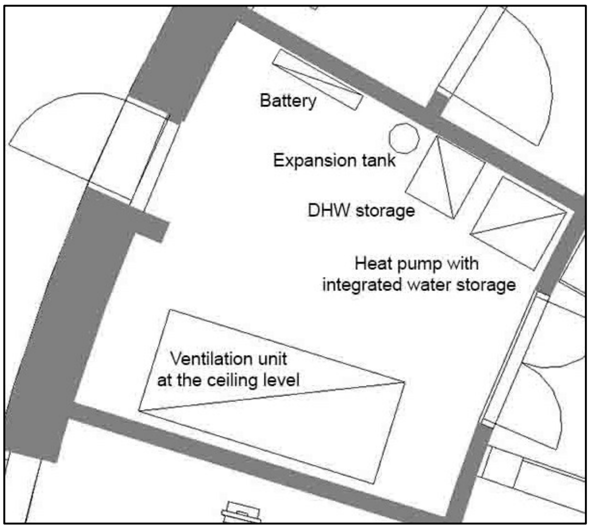


Figure 75: *Technical room with heat pump for both heating and DHW preparation*

6.2 Energy Calculations

6.2.1 Passive House Planning Package energy model [PHPP 2013]

6.2.1.1 Model Description

The PHPP is created in Microsoft Excel environment. There are three major parts containing Heating, Cooling and Primary energy calculation. In total, there are 35 different calculation worksheets. Some of them are not needed for the calculation purposes of the House of Trees.

There are three variants of the space heating and DHW preparation calculated. The first variant represents both space heating and DHW preparation with biomass boiler using the wood chips as an energy source. In the second variant, the space heating is covered by heat pump with ground collectors while the DHW is heated with electricity. And the third variant consider heat pump with ground collectors for both space heating and DHW preparation.

6.2.1.1.1 Verification Worksheet: Building Data Documentation and Passive House Standard or EnerPHit Verification

The project data, like the building designation, location, designer, enclosed volume, and the expected number of occupants, are determined in the first part of this worksheet. In the second part, there are final results from the PHPP calculation which are described in the following chapters. Another values entered in this worksheet are “Interior temperature in winter” and “Interior temperature in summer”, together with type of the object and internal heat gains specifications.

The building is considered as non-residential with internal heat gains using the School utilisation pattern with standard values contained in the PHPP. These values consider internal heat gains equal 2,8 W/m^2.

The Verification worksheet for each variant can be seen in Annex 15 - Annex 17.

6.2.1.1.2 Climate Worksheet

This worksheet contains climate data for many specific locations. For the purposes of the House of Trees calculation the data for Prague are used. Nevertheless, the climate data for the heating load and the cooling load are available only for Germany: PHPP Standard climate selection. There is only a little difference between Germany and Czech Republic climate data and therefore the data for the heating and cooling load are adopted from the Germany: PHPP Standard selection.

The only number which has to be determined manually in this sheet is building location altitude. The House of Trees is in the 292 m altitude.
The Climate worksheet can be seen in Annex 18.

6.2.1.1.3 U-Values Worksheet: Calculation of Building Element U-Values

As the name suggests, this worksheet serves for the calculation of the overall heat transfer coefficients of the building elements. The U-value calculations in the PHPP comply with ISO 6946. The thickness and heat transfer coefficient of every material in specific element has to be determined. Non homogenous layers such as insulation in timber frame construction can be calculated by percentage determination of material representation in the specific layer.

1	Exterior wall

Heat transfer resistance [m²K/W] interior R_{si}: 0,13
exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce wood cladding	0,180					20
2.	OSB	0,130					18
3.	Wood-fibre insulation	0,038	Spruce wood batterns	0,180			140
4.	OSB	0,130					18
5.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	160
6.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	160
7.	Vapour-permeable membra	0,350					2
8.							
		Percentage of sec. 1		Percentage of sec. 2		Percentage of sec. 3	Total
		75%		14,5%		11,0%	51,8 cm

U-Value: 0,101 W/(m²K)

2	Roof

Heat transfer resistance [m²K/W] interior R_{si}: 0,10
exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce board-on-board c	0,180					20
2.	Wood-fibre insulation	0,038	Secondary beams	0,180			200
3.	OSB	0,130					30
4.	Vapour barrier	0,350					2
5.	Wood-fibre insulation	0,038					300
6.	Water proof membrane	0,350					2
7.	Substrate	0,700					150
8.							
		Percentage of sec. 1		Percentage of sec. 2		Percentage of sec. 3	Total
		78%		22,4%			70,4 cm

U-Value: 0,083 W/(m²K)

3	Floor above ground

Heat transfer resistance [m²K/W] interior R_{si}: 0,10
exterior R_{se}: 0,00

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Indoor tiles	1,010					8
2.	Tile adhesive	0,700					2
3.	Concrete base	1,360					50
4.	Water proof membrane	0,350					4
5.	Concrete slab	1,360					150
6.	Expanded clay aggregate	0,076					600
7.	Gravel	0,650					100
8.							
		Percentage of sec. 1		Percentage of sec. 2		Percentage of sec. 3	Total
		100%					91,4 cm

U-Value: 0,120 W/(m²K)

Figure 76: *U-values of building elements*

The U-Values worksheet can be seen in Annex 19.

6.2.1.1.4 Areas Worksheet: Data Entries of Opaque Building Elements and Thermal Bridges

In this worksheet the data entries for the whole thermal envelop of the building take place.

The PHPP has no possibility to determine rounded shapes. The object exterior wall was divided into 28 segments in order to follow the House of Trees shape [see Figure 77]. Every segment has its own orientation and inclination as well as the most exterior layer area, specific element properties, reduction factor shading, exterior absorptivity and exterior emissivity. The tilt of the south glazed façade is determined in this worksheet as well.

The reduction factor shading was determined according to the location of the wooden cage in front of the exterior wall, overhang and trees.

Exterior absorptivity factor ranges from 0 (surface with reflective coating/mirror) to 1 (absolutely black surface). Value 0,6 was determined for the exterior wall and 0,8 for the roof.

The emission coefficient influences heat radiation of the surface to the environment and to the cold sky. For the most commonly used materials is the emissivity number 0,9.

The treated floor area is another value determined in this sheet. It is very important number which basically means the useful area. The calculation is based on the different usage of specific room. The real area of the entrance hall and the Technical room is lowered by 40% and together with other rooms creates almost 550 m^2 of treated floor area. For the non-residential buildings is the calculation based on the German norm DIN 277.

The calculation of the thermal bridges is not part of this work.

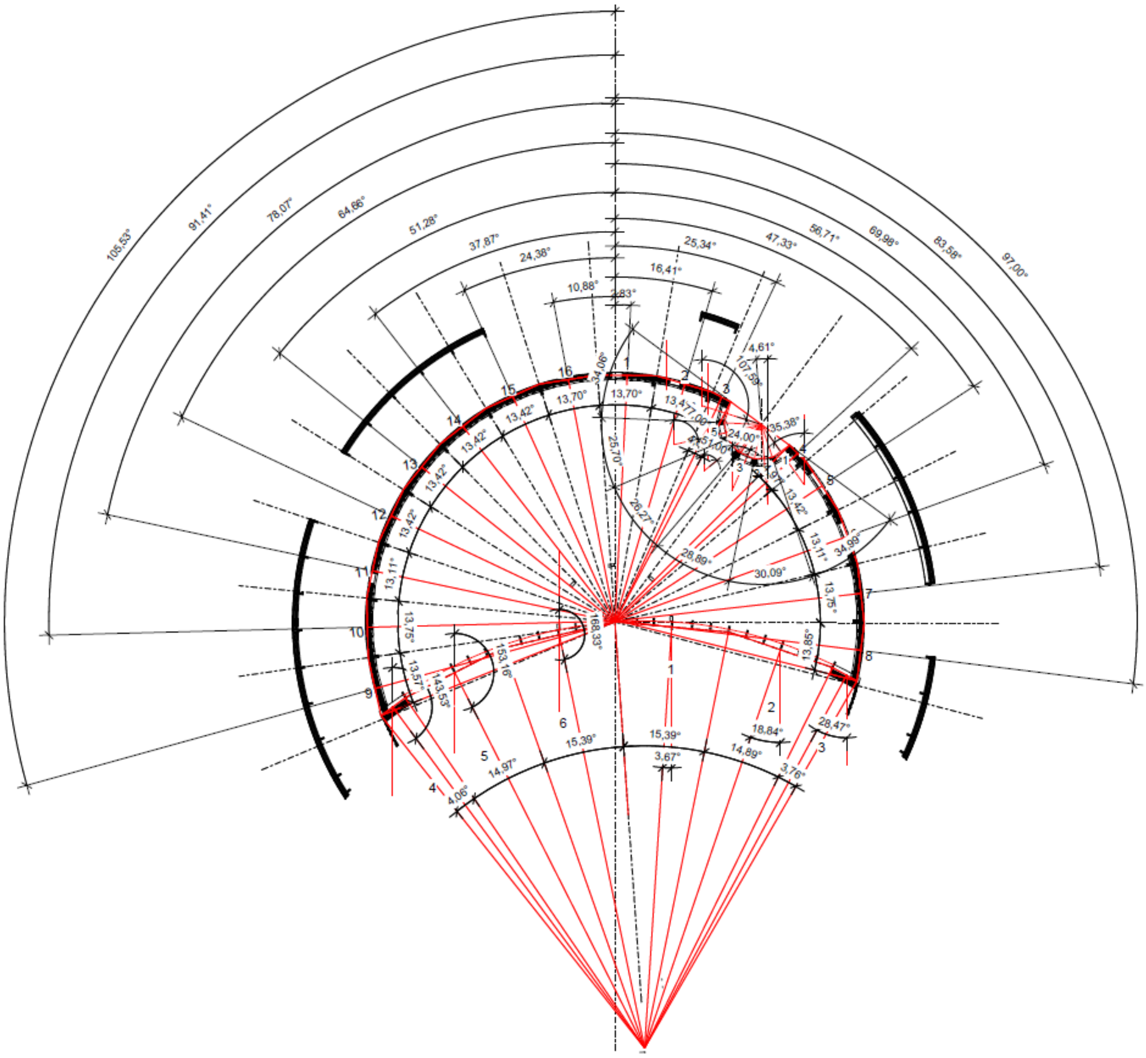


Figure 77: *Distribution of the object to the 28 segments with different orientation*

The Areas worksheet can be seen in Annex 20: Areas Worksheet.

6.2.1.1.5 Ground worksheet: Calculating the Heat Losses from Below-Ground Building Components

Heat losses of below-ground building elements are calculated in this worksheet. The calculation follows the EN ISO 13370 procedures.

The ground characteristics of Moist clay were used for the calculation. The heat conductivity of the ground is 2 W/m.K and its volume specific heat capacity is 2 MJ/m^3.K. The area of the floor slab (623,2 m^2) and its perimeter length (109,9 m) has to be determined as well as the length, orientation (horizontal/vertical), thickness and thermal conductivity of the floor slab insulation. Another part of this sheet works with the ground water influence. For the purposes of this project is the ground water table depth determined as 3 m and its flow rate as 0,05 m/d.

The Ground worksheet can be seen in Annex 21.

6.2.1.1.6 Components: User-Defined Components and Database of Certified Passive House Suitable Components

This worksheet serves as the database of the certified passive house suitable components and also for user-defined components. U-values of various glazing and window frames can be found here. Regarding the window frames, glazing edge thermal bridge, installation thermal bridge and the frame dimensions are determined here as well.

The triple glazing with thermal conductivity 0,53 $W/m^2.K$ is designed. As far as the window frames are concerned, the wooden frames with thermal conductivity 0,73 $W/m^2.K$ are used for the windows and wooden frames with thermal conductivity 0,97 $W/m^2.K$ are used for the south glazed façade.

Another component determined in this worksheet is the Ventilation unit with heat recovery and the Passive House compact unit with exhaust air heat pump which is not used in this project. The designed ventilation unit has 85% heat recovery efficiency.

The Components worksheet can be seen in Annex 22.

6.2.1.1.7 Windows Worksheet: Window Area Calculations, Window U-Values and Solar Radiation

In this worksheet the windows are modelled. The orientation of the windows is derived from the specific area in which is the window installed, as input in the Areas worksheet. The window dimensions have to be entered as well as the installation situation, where for the windows installed directly to the buildings envelope is selected number "1" and number "0" if two windows are abutted symmetrically against each other [see Figure 78]. The type of glazing and window frame is selected from the drop-down list where chosen components from the Components worksheet are available.

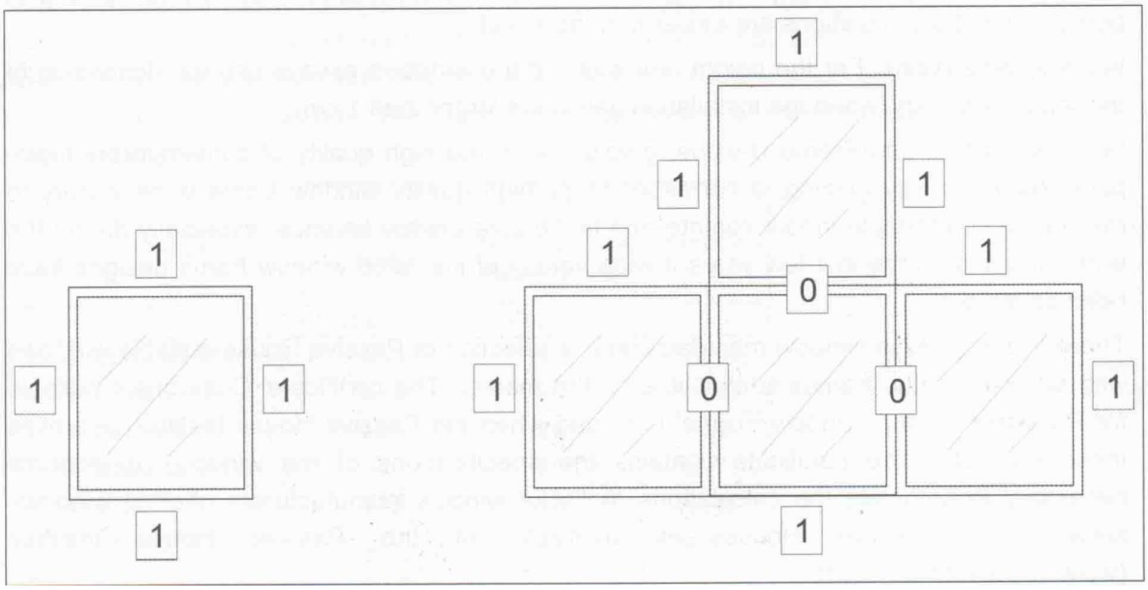


Figure 78: *Abutted windows with installation factor*

Another calculation is about "solar irradiation reduction factor". This number consider the shading, dirt on the windows, incidence angle and the frame area. The shading factor can be specified more precisely in the Shading worksheet.
The Windows worksheet can be seen in Annex 23.

6.2.1.1.8 Shading Worksheet: Calculation of shading reduction factors

In this worksheet the calculation of total shading factor for glazing surfaces takes place. The most important numbers for this thesis are the "overhang depth" and the "distance from upper glazing edge to overhang". These numbers are measured from the glazing edge and due to this fact is the depth of the overhang over the southern glazed façade equal 2,06 m instead of 1,5 m. The distance from upper glazing edge to overhang is 1,33 m. For the rest of the buildings windows is situation more complicated because of the wooden cage which is semi-transparent and its shading factor differs throughout the year due to the leafs of the vine plants. Nevertheless, there are "Additional reduction factor winter shading" and "Additional reduction factor summer shading" numbers which can be used for the specific calculation of the shading function of the cage. The non-transparent area shades approximately 50% of the exterior wall. With the estimated influence of the plants, the final numbers are 65% for winter and 40% for summer additional shading. The major influence to the solar gains has the southern glazed façade and the rest of the windows has only a little impact to the indoor environment.

The “horizontal obstruction shading factor (HOSF)” and “vertical shading factor (VSF)” are another number which can be determined in this sheet. The HOSF accounts for continuous horizontal obstruction located in front of the windows [see Figure 79]. In the case of House of Trees, the only obstructions create trees and plants around the object. The height and distance is estimated from the map. The VSF accounts for the shading effect of an exterior vertical element. In this case, the VSF is influenced only with the side of reveal of a window casing [see Figure 80].

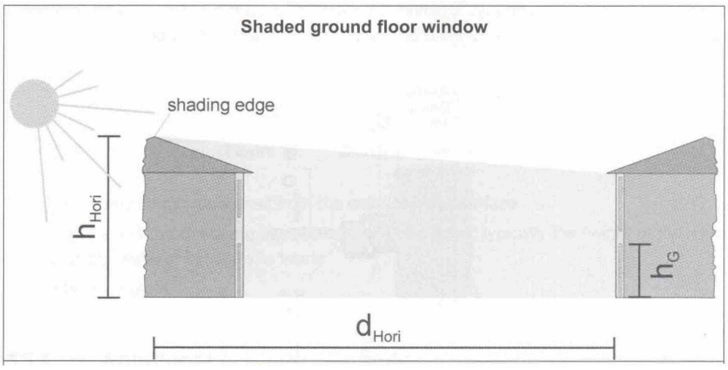


Figure 79: *Shading by a continuous horizontal obstruction*

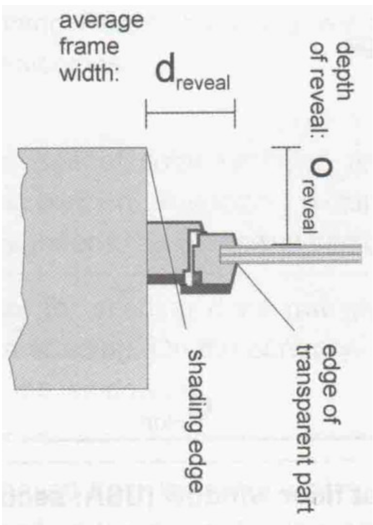


Figure 80: *Shading by a window reveal (horizontal section)*

The Shading worksheet can be seen in Annex 24: Shading Worksheet.

6.2.1.1.9 Ventilation Worksheet: Entering Basic Data and Standard Planning Information for the Ventilation System

This worksheet serves primary for calculation of residential building ventilation. For the non-residential buildings is the Additional Ventilation worksheet more appropriate. However, the very important numbers have to be selected in Ventilation worksheet, such as the "room height" for the calculation of the building´s volume, "Air change rate at pressure test", "Wind protection coefficient" and "Wind protection coefficient, f". The height of the object differs due to the inclination but for the purposes of the calculation is determined as 4 m. The Wind protection coefficients are determined according to the table contained in the worksheet. Air change rate at pressure test is considered as 0,6 1/h, which is the highest air leakage rate permitted for Passive houses. The final calculated number is the "Infiltration air change rate". There is no possibility to perform the air leakage test and therefore the standard value used is 0,042 1/h.

The numbers regarding the "Ventilation unit" and "Heat recovery efficiency design" can be seen in this worksheet as well.

The Ventilation worksheet can be seen in Annex 25.

6.2.1.1.10 Additional Ventilation Worksheet: Planning Ventilation systems with multiple ventilation units

This worksheet is conceived as an extension of the Ventilation worksheet. Multiple ventilation units can be determined here, but there is only one unit designed for the House of Trees. The used unit is selected from the drop-down list connected to the Components worksheet.

The very important number determined here is the air quantity for the object. Since the building educational centre, the air quantity of 18 m^3 for person and hour is selected. This number corresponds with the recommended range of the air amount for the schools and day care centres (15-18 m^3/(person.h)) taken from the appropriate sources [see Kah et al. 2010].

The final volume flow necessary for 162 people is 2916 m^3/h in heating period.

Another important values are utilisation times, where the number of hours in day, days in week and weeks in year during which is the building used, are determined.

The Additional Ventilation worksheet can be seen in Annex 26.

6.2.1.1.11 Annual Heating Worksheet: Calculating the Annual Heating Demand According to the PHPP Method

This worksheet is only informative and all values are automatically retrieved from other worksheets. No data entry is required.

The PHPP method follows the European Standard EN 13790 [DIN EN ISO 13790].
The calculation of heating demand follows the formula from the Figure 81.

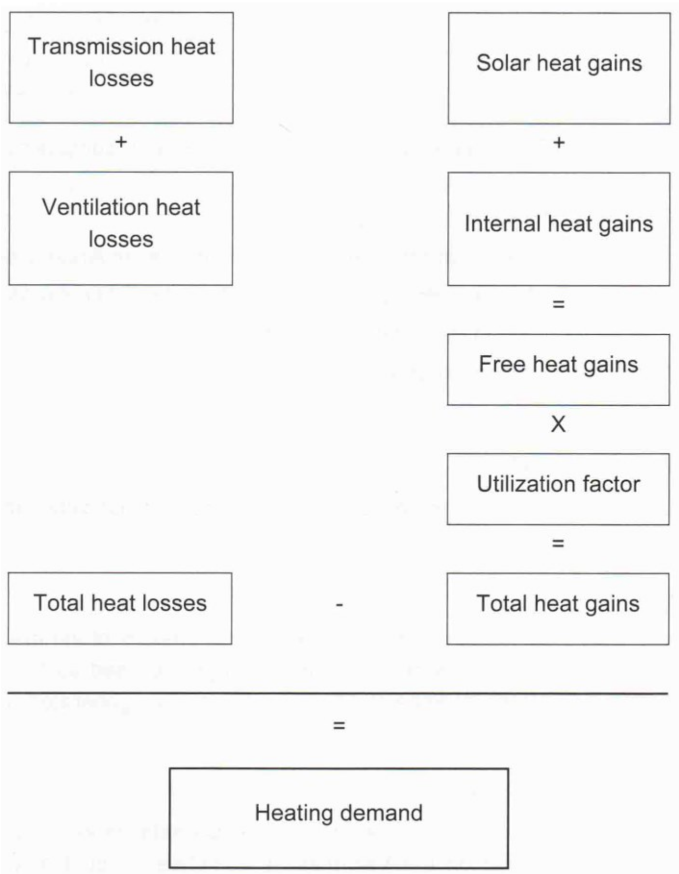


Figure 81: *Energy balance diagram*

The solar gains create majority of heat gains during the heating period. This proves the successful design of southern glazed façade through which the Sun supports the heating demand. The heating demand for annual method calculation is 12,6 kWh/(m^2.a) [see Figure 82].

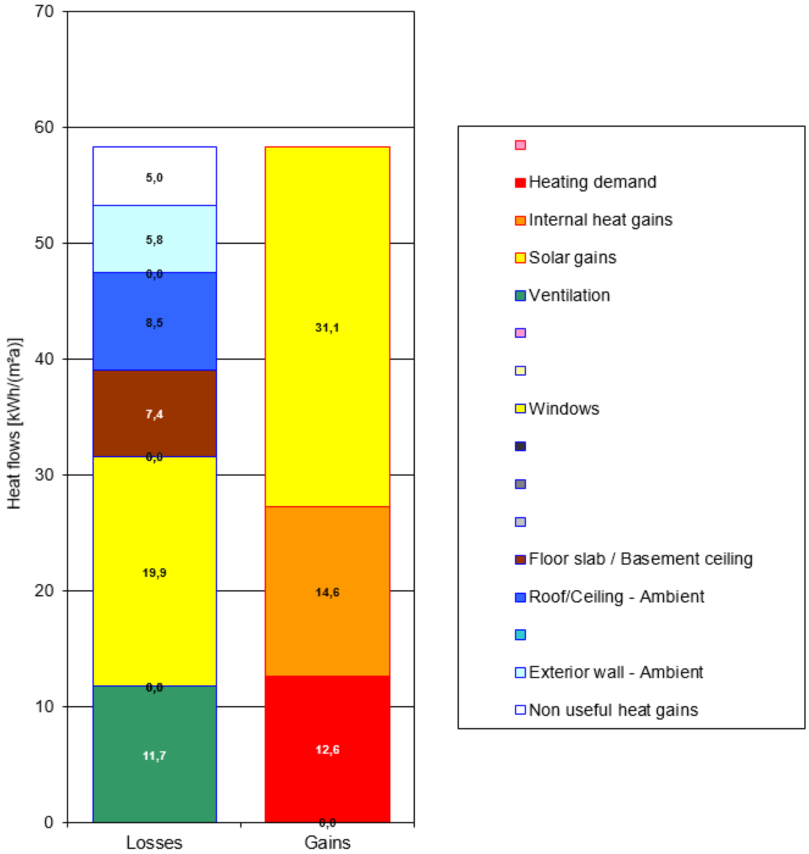


Figure 82: *Energy balance heating (annual method)*

The Annual Heating worksheet can be seen in Annex 27.

6.2.1.1.12 Heating Worksheet: Calculating the Annual Heating Demand According to EN 13790 / Monthly Method

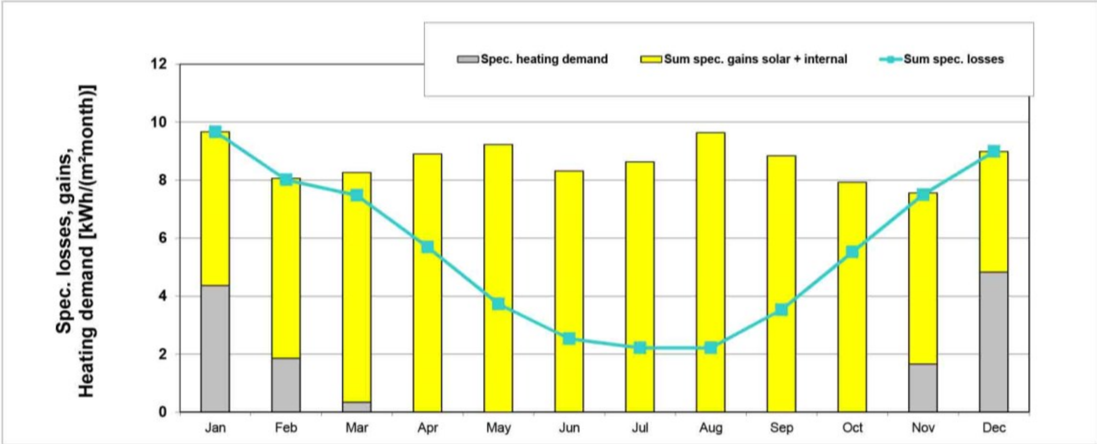
The energy balance of annual heating is calculated using a heating period method. However, the monthly method of the EN 13790 performs an energy balance for each month of the year. For this calculation, all the building data are adopted from the Annual Heating worksheet.

The storage capacity number is required for this calculation. This value is adopted from the Verification worksheet. The heating demand for monthly method calculation is 13,1 kWh/(m^2.a) [see Figure 83].

Climate: [CZ] - Praha
Building: House of Trees Průhonice

Interior temperature: 20 °C
Building type: Multifunctional building
Treated floor area A_{TFA}: 550 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating degree hours - External	16,1	13,2	12,0	8,7	5,0	2,8	2,2	2,2	4,7	8,3	12,1	14,8	102	kKh
Heating degree hours - Ground	7,8	7,0	7,8	7,5	7,8	7,5	7,8	7,8	7,5	7,8	7,5	7,8	91	kKh
Losses - Exterior	4732	3878	3528	2566	1469	828	637	637	1379	2455	3562	4360	30031	kWh
Losses - Ground	582	525	582	563	582	563	582	582	563	582	563	582	6849	kWh
Sum spec. losses	9,7	8,0	7,5	5,7	3,7	2,5	2,2	2,2	3,5	5,5	7,5	9,0	67,1	kWh/m²
Solar gains - North	14	22	35	47	65	66	66	54	33	24	11	9	447	kWh
Solar gains - East	35	64	102	149	184	184	184	171	113	80	32	25	1325	kWh
Solar gains - South	1669	2204	2910	3354	3379	2916	3057	3653	3425	2980	2034	1075	32654	kWh
Solar gains - West	14	20	38	51	66	62	62	62	43	29	15	9	470	kWh
Solar gains - Horiz.	4	7	13	20	27	26	26	24	15	10	4	3	180	kWh
Solar gains - Opaque	33	56	105	160	208	205	203	190	123	82	37	23	1426	kWh
Internal heat gains	1145	1034	1145	1108	1145	1108	1145	1145	1108	1145	1108	1145	13485	kWh
Sum spec. gains solar + internal	5,3	6,2	7,9	8,9	9,2	8,3	8,6	9,6	8,8	7,9	5,9	4,2	90,9	kWh/m²
Utilisation factor	100%	99%	90%	64%	40%	30%	26%	23%	40%	70%	99%	100%	59%	
Annual heating demand	2400	1022	193	3	0	0	0	0	0	8	912	2653	7190	kWh
Spec. heating demand	**4,4**	**1,9**	**0,4**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**1,7**	**4,8**	**13,1**	kWh/m²



Annual heating demand: Comparison

Monthly method	*(W. 'Heating')*	7190	kWh/a	13,1	kWh/(m²a) reference to treated floor area according to PHPP
Annual method	*(W. 'Annual heating')*	6921	kWh/a	12,6	kWh/(m²a) reference to treated floor area according to PHPP

Figure 83: *Specific annual heating demand – monthly and annual method*

The Heating worksheet can be seen in Annex 28.

6.2.1.1.13 <u>Heating Load Worksheet: Determining the Space Heating Load</u>

This worksheet serves for calculation of the maximal building heating load and determines heat losses as well as heat gains and the thermal inertia in an adequate manner. This calculation is suitable only for Passive houses.

The maximal heating load can occur in two situations: on a cold but sunny day with cloudless sky, or on a moderately cold but overcast day with minimal solar radiation. Each situation is calculated and the maximum from both of them is the final heating load [see figure]. The final heating load for the object is 6,728 kW.

The maximum heating load transportable through the supply air is calculated on this sheet as well. The minimal temperature of the supply air sufficient for the building heating is 40°C.

The Heating load worksheet can be seen in Annex 29.

6.2.1.1.14 SummVent Worksheet: Ventilation in Summer

As already mentioned in the 6.1.4 and 6.1.5 chapter, the night ventilation together with background ventilation is designed for the cooling of the House of Trees. In this worksheet, the necessary values for summer ventilation are determined.

For the hygienic reasons, the air change in the summer should be approximately 50% higher than in the winter. The air exchange via ventilation system with supply air is determined as 0,48 1/h with the ventilation unit containing the automatic bypass, controlled by temperature difference.

The minimum acceptable indoor temperature for the additional summer ventilation for cooling (night cooling) is chosen as 22°C with mechanical type of additional ventilation, which is automatically controlled. The control is based on the temperature difference and the corresponding air exchange rate is determined as 0,2 1/h.

The SummVent worksheet can be seen in Annex 30.

6.2.1.1.15 Summer Worksheet: Calculation of the Frequency of Overheating

In this worksheet the information about summer comfort in the object take place. The comfort is determined using the frequency in which temperatures rise above the established comfort limit expressed as the percentage of the total time of the year.

The final frequency of overheating is 4,3% with the overheating limit 26°C. In general, values under 10% of overheating frequency are desirable [see Table 5].

$h_{>25\,°C}$	Assessment
> 15 %	catastrophic
10 – 15 %	poor
5 – 10 %	acceptable
2 – 5 %	good
0–2%	excellent

Table 5: *Assessment of the frequency of overheating*

The PHPP calculates with the values considering the whole object. There is no calculation for specific rooms possible.

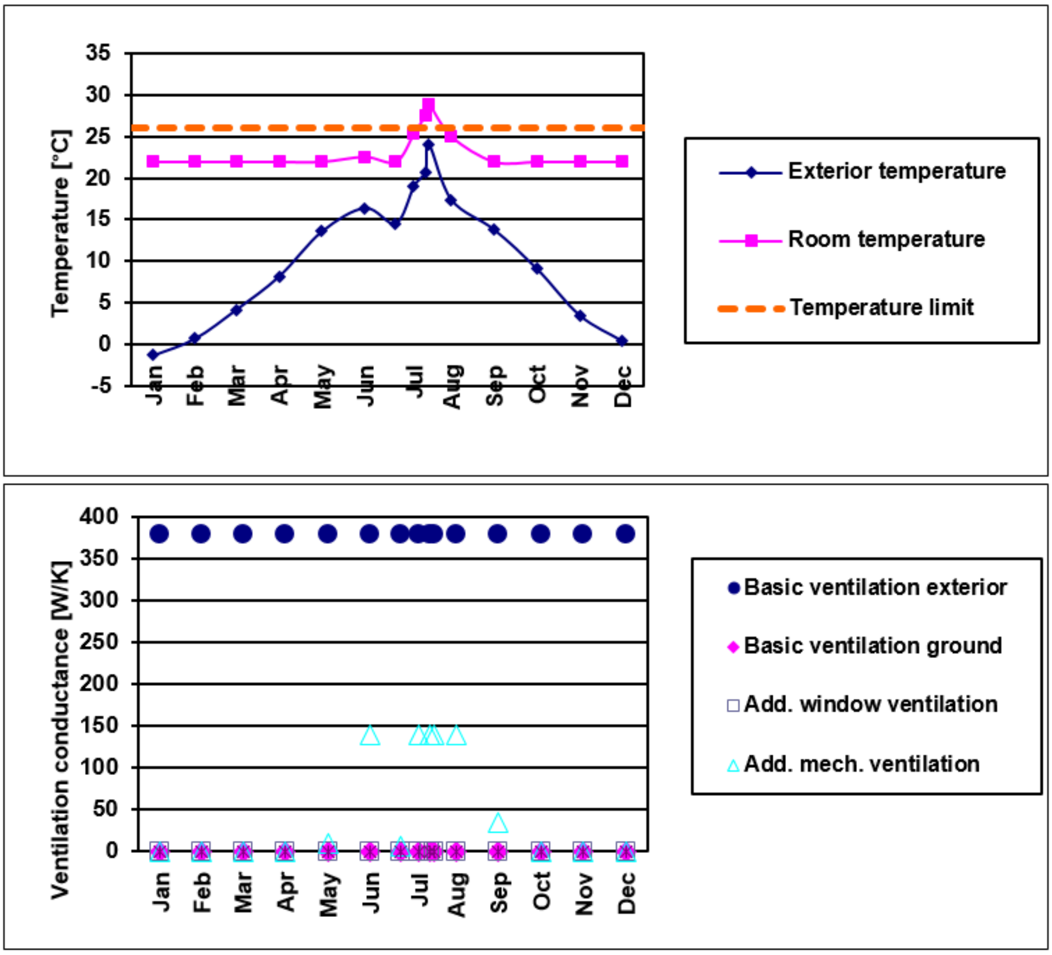


Figure 84: *Temperatures and additional ventilation demand in summer*

The Summer worksheet can be seen in Annex 31.

6.2.1.1.16 DHW + Distribution worksheet: Calculating the Heat Losses Through Plumbing

The heat losses of the distribution system for space heating and DHW are calculated in this worksheet. The heat lost through space heating pipes can act as an internal heat source. Therefore, the annual heating demand is reduced by a portion of the emitted heat from space heating plumbing.

The secondary calculations can be used for determining the heat loss coefficient Ψ for the distribution lines and hot water storage losses. The necessary inputs for Ψ calculation are nominal width of the pipes, insulation thickness, thermal conductivity of the insulation and reflectivity of the insulation surface. The final result has to be used for the primary calculation. The specific heat losses storage (W/K), room temperature and typical temperature of DHW is necessary for water storage heat losses calculation.

For the purposes of the calculation is the nominal width of the ventilation ducts 250 mm with 30 mm thick insulation. The ducts length is 147 m and the design flow temperature of supply air is 40°C.

The DHW distribution losses differs according to the type of the DHW preparation. The circulation pipes are not needed for the direct water heater near every group of washing-basins and therefore are not included. For the storage hot water preparation is circulation plumbing considered as 60 m long with exterior diameter equal 12 mm and insulated with 24 mm thick insulation. The length of individual pipes is considered in both cases and is determined as 6 m for 9 water basins, one sink and one bidet. The already mentioned amount of hot water per person and day is 1 l. Designed water storage is for 100 l and its thermal loss is 43 W. Another important number is “daily circulation period of operation” (9 h), “tap openings per person per day” (1) and “utilization days per year” (300).

The lengths of the pipes were measured in the 3D model. [see Figure 70 and Figure 85]

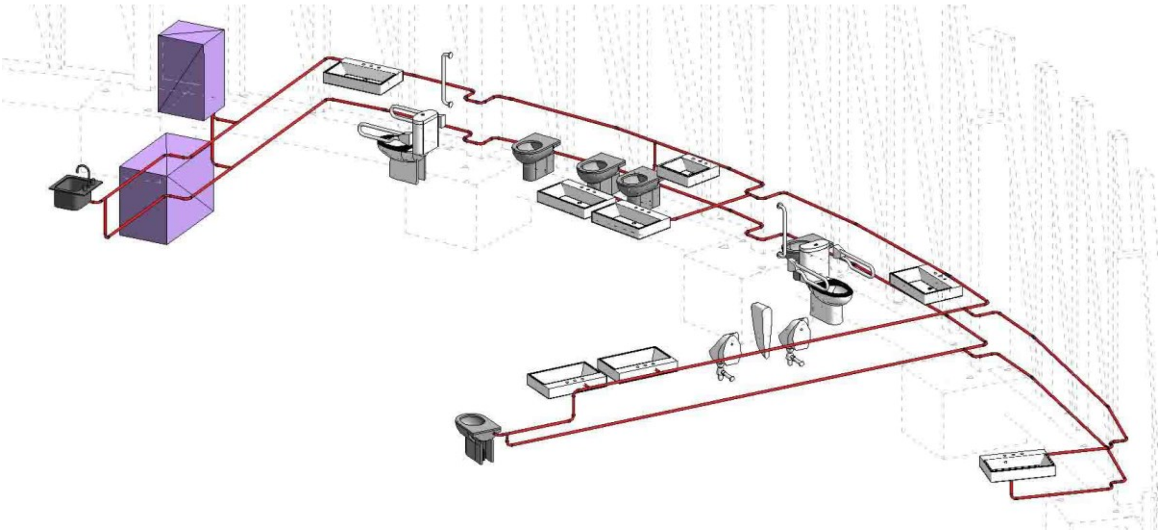


Figure 85: *3D model of circulation pipes*

The final heat losses of DHW with circulation pipes are 8,8 kWh/(m²a) and for DHW without circulation are 7,6 kWh/(m²a).

The DHW + distribution worksheet for DHW with circulation variant can be seen in Annex 32.
The DHW + distribution worksheet for DHW without circulation variant can be seen in Annex 33.

6.2.1.1.17 PV Worksheet: Calculating the Yields from a PV Array
This worksheet is used for the calculation of the yields from a photovoltaic system. “Nominal current”, “Nominal voltage” and “Temperature coefficient short-circuit current” are the numbers which have to be taken from manufacture´s data sheet. The technology of PV modules can be selected from the drop-down list.

Another data necessary to determinate are “Number of modules”, “Deviation from North”, “Angle of inclination from horizontal”, “Height of module array”, “Height of horizon”, “Horizontal distance”, “Additional reduction factor shading” and “Efficiency of the inverter”.

The PV modules are following the convex shape of the southern side of the object. For the purposes of the PV electricity yields calculation is the convex shape simplified to the simple line with deviation 176° from north. After the PHPP calculation, the comparison with PVGis [PVGis 2016], the internet free solar photovoltaic energy calculator, was made. Than the numbers were adapted in order to get similar results in both PVGis and PHPP calculation.
In order to find out how big difference would make the various deviation of every PV module, the number of modules was divided into three parts. The first part contains 25% of PV modules and has deviation 155° from north. The second part represent 50% of PV modules and its deviation is 176° from north. The third part is deviated from north about 197° and contains also 25% of modules. The PHPP calculation offers only one direction of modules and cannot be divided into three groups. The PVGis software was used for the verification and the results show than the different deviation does not make any major difference. The maximal number of PV modules with 30° of inclination from horizontal which would fit into the area of the roof would be 116. That makes approximately 28 modules in each group containing 25% of the PV modules and 60 modules in the 50% group. The final results show that the simplified model of PV installation would produce 35 200 kWh per year. The second model which is divided into three groups in order to follow the building shape would produce 35 040 kWh per year. The difference only 160 kWh per year is considered insignificant and the following calculations use the simplified model.

The convex shape of PV modules installation would provide more constant electricity production during the whole day.

For the comparison of PVGis and PHPP calculation see Annex 34.

The Passive House Classic can be achieved without any energy generation from photovoltaics. But there are 22 modules designed for the basic electricity supply. [see Figure 86]

Mono-Si			
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K
Further specifications			
Latitude:		50,1	°
Number of modules	n_M	22	
Deviation from North		176	°
Angle of inclination from horizontal		30	°
Height of module array		0,45	m
Height of horizon	h_{Hori}	0	m
Horizontal distance	a_{Hori}	3	m
Additional reduction factor shading	r_{other}	100%	
Efficiency of the inverter	η_{HRV}	96%	
Annual yield of the inverter		**6630**	kWh
Annual losses due to shading		**0**	kWh
PE value (non-renewable)		**0,4197**	
CO_2-equivalent emission value		**63,1**	g/kWh

Figure 86: *PV production calculation, 22 panels, 30° inclination*

The whole PV worksheet can be seen in Annex 35.

6.2.1.1.18 Use Non-Res Worksheet: Non-Residential Buildings User Profiles for the Calculation in Electricity Non-Res and IHG Non-Res

The user profiles for non-residential buildings are given in this worksheet. There is possibility either to determine the profiles with user own data or to use predefined use-profiles according to [DIN V 18599-10]. The typical use in part of the building is described in every profile which is defined with each entry in a row.

Every room of the House of Trees was determined in this sheet specifying the utilization hours, annual utilization days, illumination level, height of the illumination level, Relative absenteeism, Part use factor of building operating period for lighting and Average occupancy [m²/Pers.]

The Non-res worksheet can be seen in Annex 36.

6.2.1.1.19 Electricity Non-Res Worksheet: Calculation of the Electricity Demand for Non-Residential Buildings

The electricity demand for lightning can be determined in the first part of this worksheet. The room type from the Non-res Worksheet must be selected. The façade shading is automatically adopted from the Windows worksheet. The room geometry, window width, windowsill height, and shading, the day lightning degree is evaluated in the column "Daylight Utilization". For the installed lightning power, the VDI 3807 guideline was used and adjusted according to its older date of publishing. [VDI 3807 2008]

The second part of this worksheet is dedicated to the electricity demand for electronic and kitchen devices. As already told, there are very energy efficient devices used in the object. The power rating of every computer and monitor is 10 W. For the cooking in the snack bar, there is natural gas from the gas tank used. There will be low energy demands for the cooking and therefore the gas tank would be sufficient as the source of the heat. The dishwasher is connected to the DHW storage. This connection is possible only in the DHW with circulation variant. Otherwise is the water for dishwashing heated with electricity.

The Electricity non-res worksheet can be seen in Annex 37.

6.2.1.1.20 Aux. Electricity Worksheet: Calculating the Auxiliary Electricity Demand

The "auxiliary energy" term means all electrical consumption necessary to run or control the building´s mechanical systems, such as heating, ventilation and DHW systems. The calculation of auxiliary energy takes place in this worksheet.

For the variant with space heating and DHW preparation covered by biomass boiler is the auxiliary primary energy demand 16,5 kWh/year. [see Annex 38]
For the variant with space heating and DHW preparation covered by heat pump is the auxiliary primary energy demand 21,7 kWh/year. [see Annex 39]
For the variant with space heating covered by heat pump and DHW preparation covered by electricity is the auxiliary primary energy demand 20,5 kWh/year. [see Annex 40]

6.2.1.1.21 HP Worksheet: Calculating Heat Pumps

This worksheet serves for the annual primary energy demand and coefficient of performance (COP) calculation. This sheet is connected with HP ground worksheet which contains additional information regarding ground collectors.

The type of the heat pump and distribution system must be selected, together with storage location and its specific heat losses (1,8 W/K), if there is any storage of hot water in the heating system. In the second part of the worksheet, the possibility for DHW preparation by heat pump can be determined. The information for DHW preparation consist of location of water storage with its specific heat losses (1,3 W/K), type of the backup heater (continuous-flow heater, electrical), if the heat pump for space heating is the same one as for DHW heating (yes) etc. Than the depth of ground heat exchanger (1,5 m) and power of pump for ground heat exchanger (0,1 kW) must be determined.

Results from HP worksheet can be seen in Figure 87 and Figure 88 or in Annex 41 and Annex 42.

Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	208	kWh/a
Energy by direct electricity	$Q_{E,dir}$	886	kWh/a
Space heat supplied by HP	$Q_{HP,Heating}$	8652	kWh/a
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	1039	kWh/a
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	2763	kWh/a
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	8736	kWh/a
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	955	kWh/a
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	2563	kWh/a
Electrical consumption of HP	Qel_{HP}	4609	kWh/a

		1. HP: Heating or heating & DHW	2. HP: Domestic hot water
Seasonal performance factor of heat pump	SPF_{H-1}	2,59	
Seasonal performance factor of system	SPF_{H-3}	2,30	
Heat generation efficiency DHW & heating		43%	
		kWh/a	kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	5704	10,4
Annual primary energy demand		14829	27,0
		kg/a	kg/(m²a)
Annual CO_2-equivalent emissions		3878	7,1

Figure 87: *Information about the heat pump for space heating and DHW preparation*

		1. HP: Heating or heating & DHW		2. HP: Domestic hot water
Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	147	kWh/a	
Energy by direct electricity	$Q_{E,dir}$	26	kWh/a	
Space heat supplied by HP	$Q_{HP,Heating}$	8710	kWh/a	
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	0	kWh/a	
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	0	kWh/a	
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	8710	kWh/a	
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	0	kWh/a	
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	0	kWh/a	
Electrical consumption of HP	Qel_{HP}	3208	kWh/a	
Seasonal performance factor of heat pump	SPF_{H-1}	2,60		
Seasonal performance factor of system	SPF_{H-3}	2,58		
Heat generation efficiency DHW & heating		39%		
		kWh/a		kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	3380		6,1
Annual primary energy demand		8788		16,0
		kg/a		kg/(m²a)
Annual CO_2-equivalent emissions		2299		4,2

Figure 88: *Information about the heat pump for space heating*

6.2.1.1.22 HP Ground Worksheet: Subsoil Heat Exchanger as a Source for the Heat Pump

This worksheet is connected with HP worksheet and should be filled if geothermal probes or a horizontal subsoil heat exchanger are selected as the heat source in the HP worksheet.

The horizontal subsoil heat exchanger is used in the House of Trees design. The main information for specific heat exchange rate calculation consist of inner radius of pipe (0,02 m), exterior radius of pipe (0,023 m), thermal conductivity of pipe (0,35 W/(mK)), pipe spacing (0,9 m), base area (421 m^2) and brine characteristics with its mass flow (1 kg/s). The depth of pipes is adopted from the HP worksheet.

The HP ground worksheet can be seen in Annex 43.

6.2.1.1.23 Boiler Worksheet: Calculating the Performance Ratio of Boilers

The boiler performance ratio for the residual space heating and DHW supply is calculated in this worksheet. The DIN V 4701-10 serves for calculation of the performance ratio.

The input parameters for the calculation are already transferred from appropriate worksheets. The only two information selected in this worksheet are the boiler type and characteristic data of the heat generator. Because there is no possibility to choose wood chips as fuel for heating, the boiler type is selected as “wood pellet burning (direct and indirect release of heat)”. Regarding the heat generator characteristic data, the letter N is selected. That means that standard values in accordance with DIN V 4701-10 are applied.

The Boiler worksheet can be seen in Annex 44.

6.2.1.1.24 PE Value Worksheet: Calculating the Primary Energy Demand and CO_2 Emissions

The total primary energy (PE) demand calculation takes place in this worksheet. By stating the percentage of space heat provided by each system, the combination of different heating systems is possible. This applies to the DHW system as well. For the purposes of House of Trees calculation, there is no combination for heating and DHW systems necessary.

The primary energy demand is calculated using the non-renewable primary energy factor of the energy carrier. The primary energy factors are taken from [DIN V 4701-10] and [Gemis] (adjusted for European conditions). Another calculation contained in this sheet is "total emissions CO2-Equivalent", "specific PE demand - mechanical system", "total emissions CO2-equivalent - mechanical system", "solar electricity specific demand", "PE value: conservation by solar electricity" and "saved CO_2 emissions through solar electricity".

Unfortunately, the Passive House Classes were introduced together with PHPP version 9 in 2015. Now the most actual version is 9.6 from the year 2016. The new version of PE calculation differs from the older version which is used for this Thesis. There are two PE values in the new version of PHPP: The non-renewable and renewable. The renewable PE has different primary energy factor and is the most important number which is used to classify the Passive Houses. The PE factor for renewable PE also differs according to the system for which is the energy used and according to the season in which is the energy used. The renewable PE factor for DHW preparation with electricity is 1,3 while the factor for non-renewable PE is 1,8. For example, the renewable PE factor for cooling equals 1,1. The wood chips are available as the source of energy in the PHPP 9.6. Its renewable PE factor is 1,1 while is the non-renewable equals 0,2. Renewable PE factor for gas is 1,75 and its non-renewable PE factor is 0,2. This approach considers that in the future building design, there will be only renewable sources of energy used. [PHPP 2016]

Another change is about PV production. In the PHPP 8, the calculation of electricity production took into consideration the treated floor area. In the new version of PHPP, the electricity production is calculated according to the built up area of the object. The built area of the House of Trees is about 624 m^2. In addition, there is a non-renewable PE value factor for photovoltaics in PHPP 8 version. This factor considers the efficiency of the PV production according to the panel´s orientation, angle of inclination from horizontal, shading, efficiency of the inverter etc. It is based on the fact that there is a non-renewable PE production during the photovoltaic panels manufacturing. The more efficient the panels are the lower the non-renewable PE value is. In the PHPP 9.6 version, the non-renewable PE value factor is equal "0" while the renewable factor is equal "1". This is a different approach which considers that all produced energy from photovoltaics is renewable. [PHPP 2016]

These differences made the final calculation and Passive House classification more difficult. The copy of PE worksheet was made and the primary energy factors were changed. The area for the PV calculation was changed as well. The results from the new worksheet named "PE values renewable" can be used for the passive house classification.

For the PE value worksheet of each variant, see Annex 45 - Annex 47.
For the PE value renewable worksheet of each variant, see Annex 48 - Annex 50.

6.2.1.2 Results

After the PHPP calculation, the results show that there is no problem to achieve Passive House Classic standard [see Figure 89 and Table 6].

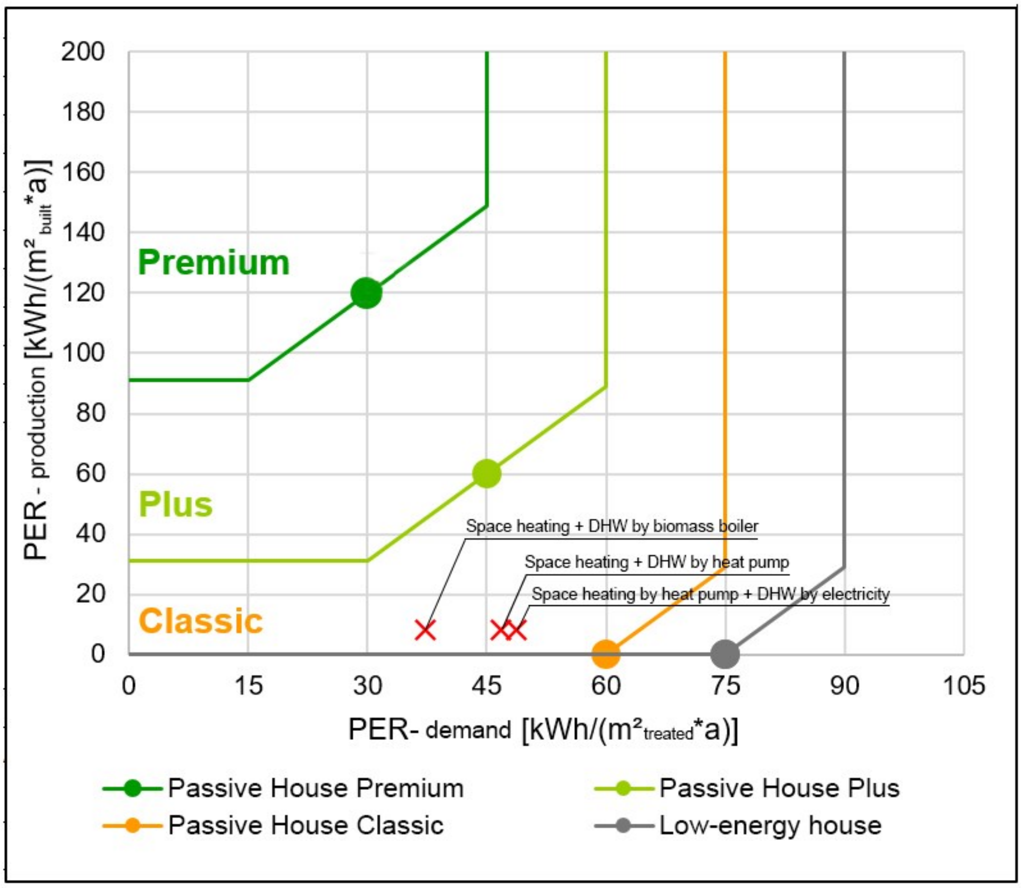


Figure 89: *Passive House Classic results* [PHPP 2016]

	Space heating + DHW by biomass boiler	Space heating by heat pump + DHW by electricity	Space heating + DHW by heat pump
PE non-renewable demand [kWh/(m²a)]	47,4	88,3	81,1
PE renewable demand [kWh/(m²a)]	**37**	**48**	**46,5**
Total emissions CO_2-Equivalent [kg/(m²a)]	12,3	22,7	20,9
PE renewable production [kWh/(m²a)]	10,6	10,6	10,6

Table 6: *Passive House Classic results*

7 Passive House Premium Variant

For the Passive House Premium Variant, the same PHPP model was used. It is certain, that to achieve higher Passive House energy standard would require additional adjustments in terms of either thermal envelope or technical equipment. A huge solar electricity production is necessary for PHP energy standard.

From the PHPP energy classes diagram [see Figure 5] and Passive house classes criteria [see Table 1], it can be seen, that the requirements for the specific demand of renewable primary energy needed for PHP can be reduced with higher renewable electricity production and conversely.

If there is approximately 150 kWh/(m²a) renewable energy production from PV system, the required renewable PE demand limit can be 45 kWh/(m²a). This number is already reached in the first variant of the energy design. In the second and third variant, there are some adjustments necessary.

7.1 Required adjustments

7.1.1 Construction adjustments

The thermal envelope of the object is already on very high quality level. But in order to lower renewable PE demands below the 45 kWh/(m²a) limit, the U-values of the building elements can be improved. The adjustments were made in the U-values worksheet in the PHPP software. The thickness of the wall insulation was increased by 80 mm, the thickness of the roof insulation was increased by 100 mm and the thickness of the floor above ground insulation was increased by 200 mm [see Figure 90].

1 Exterior wall

Heat transfer resistance [m²K/W] interior R_{si}: 0,13 exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce wood cladding	0,180					20
2.	OSB	0,130					18
3.	Wood-fibre insulation	0,038	Spruce wood batterns	0,180			140
4.	OSB	0,130					18
5.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	200
6.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	200
7.	Vapour-permeable membra	0,350					2
8.							
	Percentage of sec. 1	75%	Percentage of sec. 2	14,5%	Percentage of sec. 3	11,0%	Total 59,8 cm

U-Value: **0,087** W/(m²K)

2 Roof

Heat transfer resistance [m²K/W] interior R_{si}: 0,10 exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce board-on-board c	0,180					20
2.	Wood-fibre insulation	0,038	Secondary beams	0,180			300
3.	OSB	0,130					30
4.	Vapour barrier	0,350					2
5.	Wood-fibre insulation	0,038					300
6.	Water proof membrane	0,350					2
7.	Substrate	0,700					150
8.							
	Percentage of sec. 1	78%	Percentage of sec. 2	22,4%	Percentage of sec. 3		Total 80,4 cm

U-Value: **0,073** W/(m²K)

3 Floor above ground

Heat transfer resistance [m²K/W] interior R_{si}: 0,10 exterior R_{se}: 0,00

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Indoor tiles	1,010					8
2.	Tile adhesive	0,700					2
3.	Concrete base	1,360					50
4.	Water proof membrane	0,350					4
5.	Concrete slab	1,360					150
6.	Expanded clay aggregate	0,076					800
7.	Gravel	0,650					100
8.							
	Percentage of sec. 1	100%	Percentage of sec. 2		Percentage of sec. 3		Total 111,4 cm

U-value supplement W/(m²K)

U-Value: **0,091** W/(m²K)

Figure 90: *U-values for Passive House Premium variant*

7.1.2 Technical adjustments

7.1.2.1 Electricity Demand Adjustments

The majority of electricity demand consist of the auxiliary electricity and the electricity for the lightning. These demands could be reduced with even more efficient devices and more energy-saving LED lights. In the Passive House Classic calculation, there were already very efficient devices designed and therefore, no adjustments are made in this chapter.

7.1.2.2 Solar system

The solar system is the main part of the Passive House Premium design. The original design accounted with PV panels with angle of inclination from horizontal about 30° which is ideal angle for the highest efficiency of the electricity production. The rows of the panels are 2,35 m far from each other in order to avoid inappropriate shading. [see Figure 25]

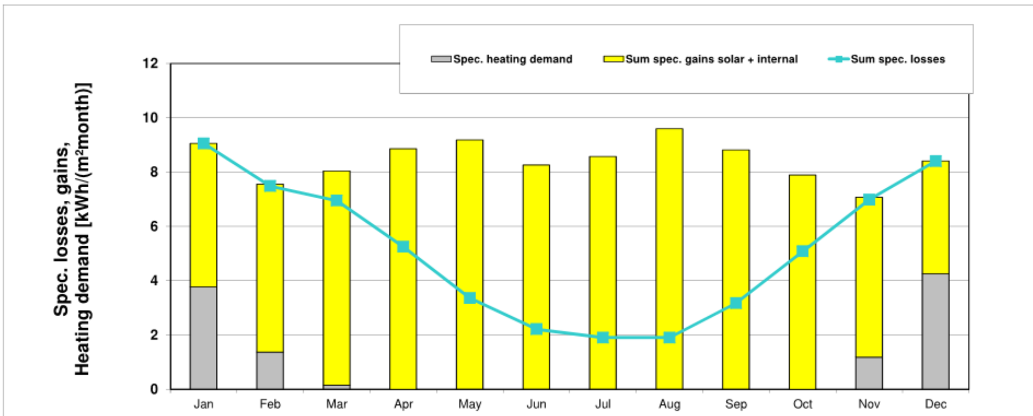
There can be 116 PV panels with ideal inclination placed on the roof but this amount is insufficient in order to achieve PHP energy standard. But the roof offers approximately 620 m^2 area which can be used for more PV panels at the cost of lower efficiency. Every module covers area of 1,6 m^2, that means that there can be approximately 380 modules installed on the roof top. The inclination of the panels would be either none or very low (1,5°) because of the rain water treatment and cleaning.

7.1.3 PHPP Calculation

7.1.3.1 Heating Demand

The new annual heating demands for both the annual and monthly method can be seen in following Figure 91. The whole worksheet can be seen in Annex 51.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating degree hours - External	16,1	13,2	12,0	8,7	5,0	2,8	2,1	2,1	4,7	8,3	12,1	14,8	102	kKh
Heating degree hours - Ground	7,8	7,0	7,8	7,5	7,8	7,5	7,8	7,8	7,5	7,8	7,5	7,8	91	kKh
Losses - Exterior	4538	3719	3381	2459	1405	790	607	607	1319	2351	3415	4180	28771	kWh
Losses - Ground	442	399	442	428	442	428	442	442	427	442	428	442	5203	kWh
Sum spec. losses	9,1	7,5	7,0	5,2	3,4	2,2	1,9	1,9	3,2	5,1	7,0	8,4	61,8	kWh/m²
Solar gains - North	14	22	35	47	65	66	66	54	33	24	11	9	447	kWh
Solar gains - East	35	64	102	149	184	184	184	171	113	80	32	25	1325	kWh
Solar gains - South	1669	2204	2910	3354	3379	2916	3057	3653	3425	2980	2034	1075	32654	kWh
Solar gains - West	14	20	38	51	66	62	62	62	43	29	15	9	470	kWh
Solar gains - Horiz.	4	7	13	20	27	26	26	24	15	10	4	3	180	kWh
Solar gains - Opaque	29	49	91	140	182	179	178	166	107	72	33	20	1247	kWh
Internal heat gains	1145	1034	1145	1108	1145	1108	1145	1145	1108	1145	1108	1145	13485	kWh
Sum spec. gains solar + internal	5,3	6,2	7,9	8,9	9,2	8,3	8,6	9,6	8,8	7,9	5,9	4,2	90,6	kWh/m²
Utilisation factor	100%	99%	86%	59%	37%	27%	22%	20%	36%	64%	99%	100%	56%	
Annual heating demand	2070	757	87	1	0	0	0	0	0	2	652	2336	5905	kWh
Spec. heating demand	**3,8**	**1,4**	**0,2**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**1,2**	**4,2**	**10,7**	kWh/m²



Annual heating demand: Comparison					
Monthly method	(W. 'Heating')	5905	kWh/a	10,7	kWh/(m²a) reference to treated floor area according to PHPP
Annual method	(W. 'Annual heating')	5541	kWh/a	10,1	kWh/(m²a) reference to treated floor area according to PHPP

Figure 91: *Specific annual heating demand after building´s thermal envelope improvement – monthly and annual method*

7.1.3.2 Heating Load

The heating load for the PHP energy variant is 6,289 kW after the adjustments. The sufficient supply air temperature for heating is only 38° now.

For the PHP Heating load worksheet see Annex 52.

7.1.3.3 Space Heat Distribution

With the reduced heating load and supply air temperature, the specific losses through the space heat distribution are reduced as well. [see Figure 92]

Passive House planning: **HEAT DISTRIBUTION AND DHW SYSTEM**

Building:	House of Trees Průhonice	
Interior temperature:	20	°C
Building type:	Multifunctional building	
Treated floor area A_{TFA}:	550	m²
Occupancy:	162,0	Pers
Number of dwelling units:	1	
Annual heating demand $q_{Heating}$	5905	kWh/a
Length of heating period:	217	d
Average heating load P_{ave}:	1,1	kW
Marginal utilisability of additional heat gains:	50%	

Space heat distribution				Parts: Warm region 1	Cold region 2	Cold region 3	Total		
Length of distribution pipes	L_H *(Project)*			147,00				m	
Heat loss coefficient per m pipe	Ψ *(Project)*			0,890				W/(mK)	
Temp. of the room through which the pipes pass	ϑ_X *Mechanical Room*			20				°C	
Design flow temperature	ϑ_{dist} *Flow, Design Value*			38,0				°C	
Design system heating load	$P_{heating}$ *(exist./calc.)*			6,3				kW	
Flow temperature control (check)				x					
Design return temperature	ϑ_R	$=0.714*(\vartheta_{dist}-20)+20$		32,9				°C	
Annual heat emission per m of plumbing	q^*_{HL}	$= \Psi\ (\vartheta_m-\vartheta_X)\ t_{Heating}*0.024$		20				kWh/(m·a)	
Possible utilization factor of released heat	η_G			50%				-	
Annual losses	Q_{HL}	$= L_H \cdot q^*_{HL} \cdot (1-\eta_G)$		1459	0	0	1459	kWh/a	
Specif. losses	q_{HL}	$= \Sigma Q_{HL} / A_{TFA}$						kWh/(m²a)	2,7
Performance ratio of heat distribution	$ea_{,HL}$	$= (q_H + q_{HV}) / q_H$					125%	-	

Figure 92: *Passive House Premium space heat distribution*

7.1.3.4 PV

The three variants of PV number, placement, and its angle of inclination from horizontal were calculated in the PHPP software. The first one considers 116 PV modules with the angle of inclination 30°. The second one consist of 380 PV modules which follows the roof´s angle of inclination -1,5°. And in the last variant, there are also 380 PV modules but their angle on inclination is 1,5°. [see Figure 93 - Figure 95]

Mono-Si			
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K
Further specifications			
Latitude:		50,1	°
Number of modules	n_M	116	
Deviation from North		176	°
Angle of inclination from horizontal		30,0	°
Height of module array		0,45	m
Height of horizon	h_{Hori}	0	m
Horizontal distance	a_{Hori}	3	m
Additional reduction factor shading	r_{other}	100%	
Efficiency of the inverter	η_{HRV}	96%	
Annual yield of the inverter		34957	kWh
Annual losses due to shading		0	kWh
PE value (non-renewable)		0,4	
CO_2-equivalent emission value		63,1	g/kWh

Figure 93: *PV design, variant 1*

Mono-Si			
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K
Further specifications			
Latitude:		50,1	°
Number of modules	n_M	380	
Deviation from North		176	°
Angle of inclination from horizontal		-1,5	°
Height of module array		0	m
Height of horizon	h_{Hori}	0	m
Horizontal distance	a_{Hori}	3	m
Additional reduction factor shading	r_{other}	100%	
Efficiency of the inverter	η_{HRV}	96%	
Annual yield of the inverter		95859	kWh
Annual losses due to shading		0	kWh
PE value (non-renewable)		0,5	
CO_2-equivalent emission value		75,4	g/kWh

Figure 94: *PV design, variant 2*

Mono-Si			
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K
Further specifications			
Latitude:		50,1	°
Number of modules	n_M	380	
Deviation from North		176	°
Angle of inclination from horizontal		1,5	°
Height of module array		0	m
Height of horizon	h_{Hori}	0	m
Horizontal distance	a_{Hori}	3	m
Additional reduction factor shading	r_{other}	100%	
Efficiency of the inverter	η_{HRV}	96%	
Annual yield of the inverter		98374	kWh
Annual losses due to shading		0	kWh
PE value (non-renewable)		0,5	
CO_2-equivalent emission value		73,5	g/kWh

Figure 95: *PV design, variant 3*

7.1.3.5 Heat Pump

After the improvement of the U-values of the building´s elements, there is a big difference in the heat pump calculation of the second variant in which the space heating is covered by heat pump while the DHW is heated with electricity. The heat generation efficiency of the HP in the second variant is now 28% instead of the original 39%. The heat pump properties for the third variant are the same as before. [see Figure 96 and Figure 97]

Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	123	kWh/a	
Energy by direct electricity	$Q_{E,dir}$	0	kWh/a	
Space heat supplied by HP	$Q_{HP,Heating}$	7364	kWh/a	
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	0	kWh/a	
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	0	kWh/a	
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	7364	kWh/a	
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	0	kWh/a	
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	0	kWh/a	
Electrical consumption of HP	Qel_{HP}	1945	kWh/a	
		1. HP: Heating or heating & DHW		2. HP: Domestic hot water
Seasonal performance factor of heat pump	SPF_{H-1}	3,56		
Seasonal performance factor of system	SPF_{H-3}	3,56		
Heat generation efficiency DHW & heating		28%		
		kWh/a		kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	2069		3,8
Annual primary energy demand		5379		9,8
		kg/a		kg/(m²a)
Annual CO_2-equivalent emissions		1407		2,6

Figure 96: *Heat pump, the second variant*

Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	187	kWh/a	
Energy by direct electricity	$Q_{E,dir}$	786	kWh/a	
Space heat supplied by HP	$Q_{HP,Heating}$	7288	kWh/a	
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	1041	kWh/a	
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	2921	kWh/a	
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	7364	kWh/a	
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	965	kWh/a	
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	2712	kWh/a	
Electrical consumption of HP	Qel_{HP}	4060	kWh/a	
		1. HP: Heating or heating & DHW		2. HP: Domestic hot water
Seasonal performance factor of heat pump	SPF_{H-1}	2,65		
Seasonal performance factor of system	SPF_{H-3}	2,35		
Heat generation efficiency DHW & heating		43%		
		kWh/a		kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	5032		9,2
Annual primary energy demand		13084		23,8
		kg/a		kg/(m²a)
Annual CO_2-equivalent emissions		3422		6,2

Figure 97: *Heat pump, the third variant*

7.1.3.6 PE Values

After the adjustments, the PE values as well as the PE values renewable are different. The final results are discussed in the following chapter 7.1.4.

For the PE value worksheet of each variant, see Annex 53 - Annex 55.

For the PE value renewable worksheet of each variant, see Annex 56 - Annex 58.

7.1.4 Results

After the additional adjustments and PHPP calculation, the results show that the Passive House Premium can be achieved with the improved thermal envelope of the building and the whole roof covered with photovoltaics.

The second variant with the space heating provided by the heat pump and DHW heated by electricity is affected the most by the improvement of the building´s thermal envelope. The heat generation efficiency of the heat pump in this variant is reduced significantly. After the calculation, the third variant is even worse than the second one because of the DHW preparation by the heat pump. The heat generation efficiency of the HP for DHW and heating remained the same as before in this case. The thermal envelope improvement cannot reduce neither the DHW demand nor its required temperature. The first variant remained almost the same as before with reduction only by 0,6 kWh/(m^{2}a).

	Space heating + DHW by biomass boiler	Space heating by heat pump + DHW by electricity	Space heating + DHW by heat pump
PE non-renewable demand [kWh/(m²a)]	46,9	82,6	78,3
PE renewable demand [kWh/(m²a)]	**36,4**	**43,9**	**44,5**
Total emissions CO_2-Equivalent [kg/(m²a)]	12,3	21,2	20,2
PE renewable production [kWh/(m²a)]	/	/	/

Table 7: *Passive House Premium results after the thermal envelope improvement*

With the usage of the whole roof area and very efficient PV panels, the production of 157,7 kWh/(m^{2}a) can be achieved with the angle of inclination 1,5° and 153,6 kWh/(m^{2}a) with the angle of inclination -1,5°. Only this placing and orientation of PV modules can produce enough renewable energy demanded for the PHP energy standard. The whole roof filled with ideally inclined PV modules can produce 56 kWh/(m^{2}a). [see Table 8] Despite the lowest efficiency, the roof following inclination is considered as the best one.

	PE renewable production [kWh/(m²a)]
116 panels 30° inclination	**56**
380 panels -1,5° inclination	**153,6**
380 panels 1,5° inclination	**157,7**

Table 8: *Specific solar electricity production*

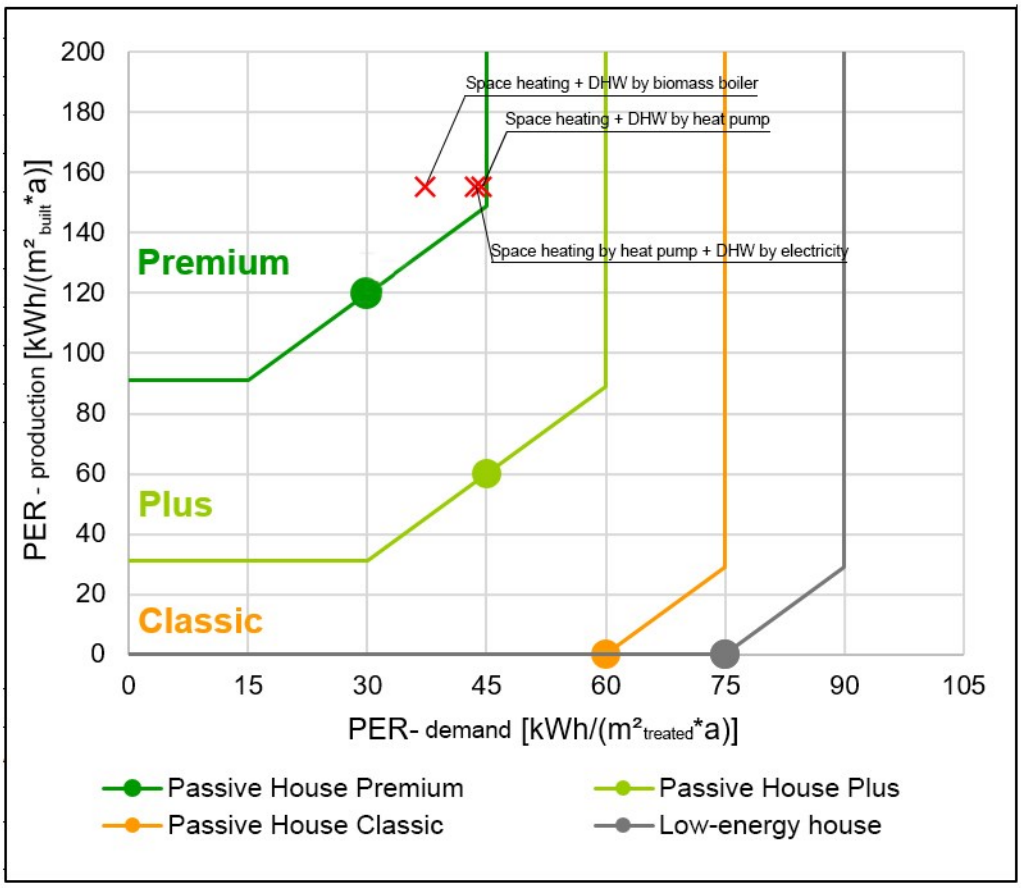


Figure 98: *Passive House Premium results* [PHPP 2015]

8 Comparison of results and conclusions

8.1 Comparison of results

After the both Passive House Classic and Passive House Premium calculation, there is a comparison of results appropriate. The final table containing important data from previous chapters was made. [see Table 9]

			Space heating + DHW by biomass boiler	Space heating by heat pump + DHW by electricity	Space heating + DHW by heat pump
Passive House Classic	Specific annual heating demand 13,1 kWh/(m²a)	PE non-renewable demand [kWh/(m²a)]	47,4	88,3	81,1
		PE renewable demand [kWh/(m²a)]	**37**	**48**	**46,5**
		Total emissions CO_2-Equivalent [kg/(m²a)]	12,3	22,7	20,9
		PE renewable production [kWh/(m²a)]	**10,6**	**10,6**	**10,6**
		Heat pump heat generation efficiency [%]	/	39	43
Passive House Premium	Specific annual heating demand 10,7 kWh/(m²a)	PE non-renewable demand [kWh/(m²a)]	46,9	82,6	78,3
		PE renewable demand [kWh/(m²a)]	**36,4**	**43,9**	**44,5**
		Total emissions CO_2-Equivalent [kg/(m²a)]	12,3	21,2	20,2
		PE renewable production [kWh/(m²a)]	**153,6**	**153,6**	**153,6**
		Heat pump heat generation efficiency [%]	/	28	43

Table 9: *The final comparison table*

8.2 Conclusions

As expected, the Passive House Classic energy standard is easier to achieve. With the lowest renewable primary energy demand and no requirements for energy production, it is the most comfortable Passive House energy standard to realize. On the other hand, the Passive House Premium energy standard is relatively difficult to reach. But when the PHP is designed properly, then the final result represents almost independent object with huge amount of produced energy.

Is there any need of improving the building´s thermal envelope once it has already been in PHC standard?

In this thesis, the thermal envelope had to be improved in order to achieve PHP standard for the second and third variant. The first energy variant using the biomass boiler for both space heating and DHW preparation did not need any thermal envelope improvement. But after the object is well insulated, an additional insulation does not do a big difference in the final results. The second and third energy variant of the House of Trees was only a few points over the limit for PHP standard and there was only a little insulation improvement needed. The big opportunity in terms of reducing the renewable primary energy demand represent the lightning and auxiliary electricity demand. There were already a very energy efficient electrical devices and lights designed, but these things improve very fast nowadays.

Regarding the photovoltaic design, there are a lot of PV panels with not ideal angle of inclination designed in order to achieve PHP energy standard. This measures would definitely affect the green roof design, rainwater treatment and possibly even the architectural design of the building. The undivided layer of photovoltaics would create shading inappropriate for the plants. Even the cooling through the Sun-Root system would not be effective. The inclination of the PV panels follows the roof at the cost of lower efficiency but the rain water treatment would be affected in terms of the water accumulation in the roof composition. Also the cleaning of the undivided photovoltaic area would be difficult. Either the PV panels would have to be resistant enough to withstand the weight of the person or there would have to be gaps between the PV rows. That would again lead to the lower number of modules and reduced energy production. Another solution could be an automatic cleaning system of PV panels.

All three energy variants designed are suitable for both PHC and PHP. But the first one would reach the PHP limits with no additional adjustments regarding the building´s thermal envelope. This variant also uses the local wood for heating and DHW preparation. These facts make the first variant the best one. Another two energy variants use the heat pump as the main source of energy. The electricity demand for the HP operation differs according to the HP heat generation efficiency. The second energy variant represents the HP with better heat generation efficiency than the third variant. This fact together with more appropriate way of DHW preparation makes the second variant the better one. Another thing is, that the heat pump in the PHP energy standard can be supplied with the photovoltaic electricity for the whole year. That is unfortunately something the PHPP version 8 cannot calculate. The combination with the proper battery design would make the second and third energy variant independent in terms of electricity from the grid demand.

I believe that the original design of the House of Trees has been improved and that every task and question stated in the beginning of this Thesis has been reached. The new architectural design together with the material and energy optimisation has made the House of Trees a better and more sustainable building than it was before.

9 List of Figures

10 List of Tables

11 List of References

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12 Annex

Annex 1*: Root Zone System Calculation* [ČSN 75 6402, 1998]

Effective volume of horizontal root filter

Average daily waste water influx	Q24 =	3,24	[m^3/day]
Average daily concetration of BSK5 on the influx	C_p =	3000	[g/m^3]
Avarage daily concetration of BSK5 on the reflux	C_o =	451,95	[g/m^3]
Velocity of BSK5 decomposition with avarage annual temperature 10°C	K10 =	0,18	[1/d]
Porosity (depending of the aggregate)	n =	0,4	
Specific production of BSK5		60	[g/(person.d)]

$$V = \frac{Q_{24} . (\ln C_p \ - \ln C_o)}{k_{10} . n} = \qquad 85{,}17582 \ m^3$$

Avarage daily waste water influx	Q24 =	3,24	[m^3/day]
Avarage daily concentration of BSK5 on the influx	C_p =	3000	[g/m^3]
Avarage daily concentration of BSK5 on the reflux	C_o =	451,95	[g/m^3]
Velocity of BSK5 decomposition with avarage annual temperature 10°C	K10 =	0,18	[1/d]
Porosity (depending of the aggregate)	n =	0,4	
Specific production of BSK5		60	[g/(person.d)]
Depth of the horizontal root zone systém	h =	1,2	[m]

$$Cp = \frac{60 . n_p}{Q24} = \qquad 3000 \ g/m^3$$

$$C_0 = 0{,}15 . Cp + 1{,}95 = \qquad 451{,}95 \ g/m^3$$

$$V = \frac{Q_{24} . (\ln C_p \ - \ln C_o)}{k_{10} . n . h} \qquad \mathbf{70{,}97985 \ m^2}$$

Annex 2: *Loads Calculation*

Load	Count	Roof composition	Width [m]	Thickness [m]	Density [kg/m³]	Basis weight [kg/m²]	Water accumulation [kg(l)/m³]	gk [kg/m´]	gk [kN/m´]		gn qn [kN/m´]	
Permanent load	KVH profiles count / OSB count	Substrate		0,15	600			90	0,9	1,35	**1,215**	
		Filter fabric, geotextil		0,0011		0,105		0,105	0,00105	1,35	**0,0014175**	
		Drainage layer, studed foil		0,04		2,3		2,3	0,023	1,35	**0,03105**	
		Separation, protective and water acumulation fabric		0,004		0,5		0,5	0,005	1,35	**0,00675**	
		Waterproof membrane with root barrier function				2,57		2,57	0,0257	1,35	**0,034695**	
		Separation fabric		0,0028		0,3		0,3	0,003	1,35	**0,00405**	
		Termal insulation, woodfibre insulation		0,2	110			22	0,22	1,35	**0,297**	
		Vapour barrier		0,0002		0,25		0,25	0,0025	1,35	**0,003375**	
		OSB board		0,03	600			18	0,18	1,35	**0,243**	**Σqn (for OSB) = 1,836 kN/m´**
	KVH profiles count	KVH rafters	0,1	0,2	450			9	0,09	1,35	**0,1215**	
		+ Cellulose insulation		0,2	50			10	0,1	1,35	**0,135**	
		Spruce board-on-board cladding		0,02	290			5,8	0,058	1,35	**0,0783**	**Σqn (for KVH) = 2,050 kN/m´**
								Σgk (OSB)=	1,36025 kN/m´			(without KVH weight)
								Σgk (KVH)=	1,51825 kN/m´			
								qk [kg/m´]	qk [kN/m´]		qn qn [kN/m´]	
Live load		Snow load										
		μi = 0,8	Ce = 1	Ct = 1	sk = 0,59 kN/m²							
		s = μi . Ce . Ct . sk = 0,472 kN/m²							0,472	1,5	**0,708**	
		Substrate		0,15			550	3,5	0,035	1,5	**0,0525**	
		Drainage layer		0,04			8,7	8,7	0,087	1,5	**0,1305**	
		Separation, protective and water acumulation fabric		0,004			3,5	82,5	0,825	1,5	**1,2375**	**Σgn = 2,129 kN/m´**
								Σqk=	1,419 kN/m´			

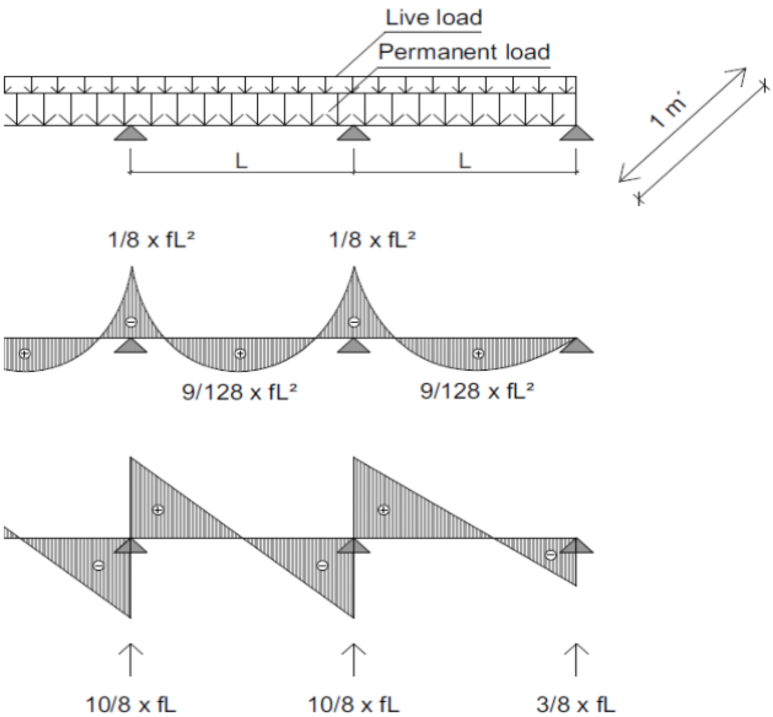
Annex 3: *OSB Calculation*

Coefficients	
OSB (2x18 mm)	
f m,k	16 Mpa
f v,k	2,7 Mpa
Eo, mean	3500 Mpa

Environment	1
Permanent load	
kmod	0,4
$k_1$def	1,5

$k_2$def	0,5
γm	1,2
Kcr	1
Ψ2	0,6

Internal forces



f =Σqn + Σgn = 3,965 kN/m

L = 0,625 m

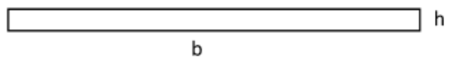
$Mmax = \frac{1}{8} f . L^2 =$ 0,193595581 kNm

V $max = \frac{10}{8} f . L =$ 3,097529297 kN

Ultimate limit state

Bend tension

$$\sigma_{m,d} = \frac{Med}{Wy} =$$ 1290,6372 kPa | 1,290637 MPa



$$Wy = \frac{1}{6}\, b \,.\, h^2 =$$ 0,00015 m³

b = 1 m´
h = 0,03 m

f m,d = k, mod . $\left(Kmod \,.\, \frac{f\ m,k}{\gamma m}\right) =$ 5,333333 Mpa

σ m, d =	1,290637	<	5,33	= f m, d	=> OK

Shear

$$\tau\ v,d\ \le Kcr \,.\, f\ v,d = Kcr \,.\, \left(Kmod \,.\, \frac{f\ v,k}{\gamma m}\right)$$

$$\tau\ v,d = \frac{V \max \,.\, Sy}{b \,.\, ly} Kcr\ = \frac{3 \,.\, Vmax}{2 \,.\, b \,.\, h}$$ 154,8764648 kPa

$$Kcr \,.\, \left(Kmod \,.\, \frac{f\ v,k}{\gamma m}\right) =$$ 900 kPa

τ v, d =	154,8765	<	900	= Kcr. F v, (	=> OK

Serviceability Limit State

$$Wg, inst = \frac{5}{384} \,.\, \frac{f\ g,k \,.\, L^4}{Eo, mean \,.\, ly}$$ 0,000463298 m = 0,46 mm

$$Wq, inst = \frac{5}{384} \,.\, \frac{f\ q,k \,.\, L^4}{Eo, mean \,.\, ly}$$ 0,000537009 m = 0,54 mm

$$Wfin = Wg, inst \,.\, (1 + k1def) + Wq, inst \,.\, (1 + \Psi 2 \,.\, k2def) < \frac{L}{300}$$

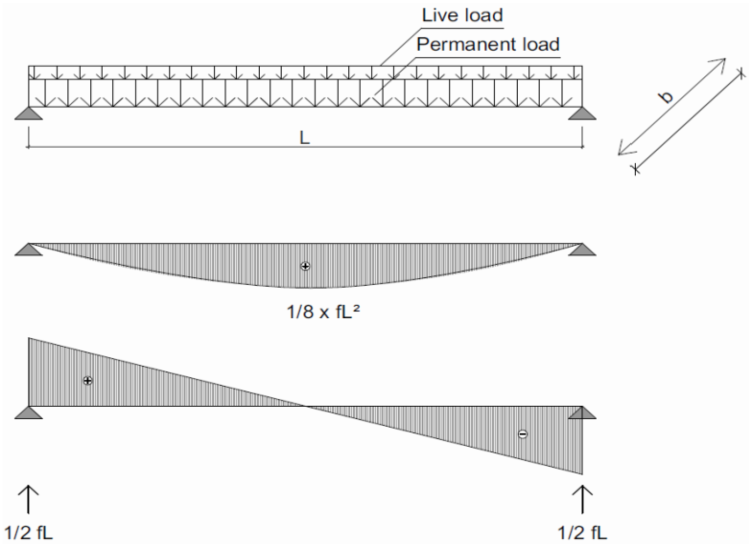
1,856358278 mm	<	2,08 mm	=> OK

Annex 4: *Secondary Beam Calculation*

Coefficients

GL24h			Environment	1		k₂def	0,25
f m,k	24 Mpa		Permanent load			γm	1,25
f v,k	2,7 Mpa		kmod	0,9		Kcr	0,67
Eo, mean	11600 Mpa		$k_1$def	0,6		Ψ2	0,6

Internal forces



f = (gn + qn) . b + Rafter weight = 2,733 kN/m
L = 3,990 m
b = 0,625 m

$Mmax = \frac{1}{8} f . L^2 =$ 5,438 kNm

V $max = \frac{10}{8} f . L =$ 13,630 kN

Ultimate limit state

Bend tension

$\sigma_{m,d} = \frac{Med}{Wy} =$ 8157,5665 kPa = 8,158 MPa

h = 0,2 m
b = 0,1 m

$Wy = \frac{1}{6}\, b \,. h^2 =$ 0,0006667 m³

f m,d = k, mod . $\left(Kmod \,. \frac{f\,m,k}{\gamma m}\right) =$ 17,280 Mpa

σ m, d =	8,157566514	<	17,28	= f m, d	=> OK

Shear

$\tau\, v,d \le Kcr \,. f\, v,d = Kcr \,. \left(Kmod \,. \frac{f\, v,k}{\gamma m}\right)$

$\tau\, v,d = \frac{V\max \,. Sy}{b\,. ly} Kcr = \frac{3\,. Vmax}{2\,. b\,. h}$ 1022,251 kPa

$Kcr \,. \left(Kmod \,. \frac{f\, v,k}{\gamma m}\right) =$ 1302,48 kPa

τ v, d =	1022,251443	<	1302,48	= Kcr. F v,	=> OK

Serviceability Limit State

$$Wg,inst = \frac{5}{384} \cdot \frac{f\ g,k\ .\ L^4}{Eo,mean\ .\ ly}$$

0,004433431 m	=	4,433431 mm

$$Wq,inst = \frac{5}{384} \cdot \frac{f\ q,k\ .\ L^4}{Eo,mean\ .\ ly}$$

0,003784653 m	=	3,784653 mm

$$Wfin = Wg,inst\ .\ (1 + k1def) + Wq,inst\ .\ (1 + \Psi 2\ .\ k2def) < \frac{L}{300}$$

11,44584095 mm	<	13,3 mm	=> OK

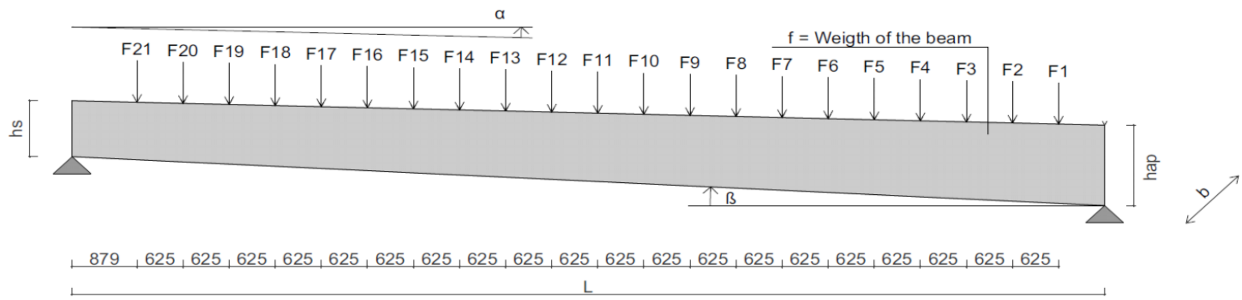
Annex 5: *Calculation of Every Secondary Beam*

Number of the Beam	Length [m]	Width [m]	Height [m]	fgk kN/m^2	fqk kN/m^2	fgn kN/m^2	fqn kN/m^2	f kN/m	Mmax kNm	Vmax kN	Wy m^3	$\sigma m,d$ Mpa	f m, d Mpa	$\tau v,d$ kPa	Kcr. F v, d kPa	Wg,inst mm	Wq,inst mm	Wfin mm	L/300 mm	Vmax gk . 2 kN	Vmax qk . 2 kN	Vmax f . 2 kN
1	3,990	0,1	0,2	1,039	0,887	1,403	1,330	2,733	5,438	5,452	0,000667	**8,158**	**17,280**	**408,901**	**1 302,480**	4,433	3,785	**11,446**	**13,300**	4,15	3,54	**10,904**
2	3,843	0,1	0,2	1,039	0,887	1,403	1,330	2,733	5,045	5,251	0,000667	**7,568**	**17,280**	**393,836**	**1 302,480**	3,815	3,257	**9,850**	**12,810**	3,99	3,41	**10,502**
3	3,696	0,1	0,2	1,039	0,887	1,403	1,330	2,733	4,666	5,050	0,000667	**7,000**	**17,280**	**378,771**	**1 302,480**	3,264	2,787	**8,427**	**12,320**	3,84	3,28	**10,101**
4	3,548	0,1	0,2	1,039	0,887	1,403	1,330	2,733	4,300	4,848	0,000667	**6,450**	**17,280**	**363,604**	**1 302,480**	2,772	2,366	**7,156**	**11,827**	3,69	3,15	**9,696**
5	3,401	0,1	0,2	1,039	0,887	1,403	1,330	2,733	3,951	4,647	0,000667	**5,927**	**17,280**	**348,539**	**1 302,480**	2,340	1,998	**6,042**	**11,337**	3,53	3,02	**9,294**
6	3,253	0,1	0,2	1,039	0,887	1,403	1,330	2,733	3,616	4,445	0,000667	**5,423**	**17,280**	**333,406**	**1 302,480**	1,960	1,673	**5,059**	**10,844**	3,38	2,89	**8,891**
7	3,106	0,1	0,2	1,039	0,887	1,403	1,330	2,733	3,295	4,244	0,000667	**4,943**	**17,280**	**318,290**	**1 302,480**	1,628	1,389	**4,202**	**10,353**	3,23	2,75	**8,488**
8	2,958	0,1	0,2	1,039	0,887	1,403	1,330	2,733	2,990	4,042	0,000667	**4,484**	**17,280**	**303,174**	**1 302,480**	1,340	1,144	**3,459**	**9,861**	3,07	2,62	**8,085**
9	2,811	0,1	0,2	1,039	0,887	1,403	1,330	2,733	2,699	3,841	0,000667	**4,048**	**17,280**	**288,058**	**1 302,480**	1,092	0,932	**2,819**	**9,369**	2,92	2,49	**7,682**
10	2,663	0,1	0,2	1,039	0,887	1,403	1,330	2,733	2,423	3,639	0,000667	**3,635**	**17,280**	**272,942**	**1 302,480**	0,880	0,751	**2,272**	**8,878**	2,77	2,36	**7,278**
11	2,516	0,1	0,2	1,039	0,887	1,403	1,330	2,733	2,162	3,438	0,000667	**3,243**	**17,280**	**257,826**	**1 302,480**	0,701	0,598	**1,809**	**8,386**	2,61	2,23	**6,875**
12	2,368	0,1	0,2	1,039	0,887	1,403	1,330	2,733	1,916	3,236	0,000667	**2,874**	**17,280**	**242,710**	**1 302,480**	0,550	0,470	**1,421**	**7,894**	2,46	2,10	**6,472**
13	2,221	0,1	0,2	1,039	0,887	1,403	1,330	2,733	1,685	3,035	0,000667	**2,527**	**17,280**	**227,594**	**1 302,480**	0,426	0,363	**1,099**	**7,403**	2,31	1,97	**6,069**
14	2,073	0,1	0,2	1,039	0,887	1,403	1,330	2,733	1,468	2,833	0,000667	**2,203**	**17,280**	**212,478**	**1 302,480**	0,323	0,276	**0,835**	**6,911**	2,15	1,84	**5,666**
15	1,926	0,1	0,2	1,039	0,887	1,403	1,330	2,733	1,267	2,631	0,000667	**1,900**	**17,280**	**197,362**	**1 302,480**	0,241	0,205	**0,621**	**6,419**	2,00	1,71	**5,263**
16	1,778	0,1	0,2	1,039	0,887	1,403	1,330	2,733	1,080	2,430	0,000667	**1,620**	**17,280**	**182,246**	**1 302,480**	0,175	0,149	**0,452**	**5,928**	1,85	1,58	**4,860**
17	1,631	0,1	0,2	1,039	0,887	1,403	1,330	2,733	0,909	2,228	0,000667	**1,363**	**17,280**	**167,130**	**1 302,480**	0,124	0,106	**0,319**	**5,436**	1,69	1,45	**4,457**
18	1,483	0,1	0,2	1,039	0,887	1,403	1,330	2,733	0,752	2,027	0,000667	**1,127**	**17,280**	**152,014**	**1 302,480**	0,085	0,072	**0,219**	**4,944**	1,54	1,32	**4,054**
19	1,336	0,1	0,2	1,039	0,887	1,403	1,330	2,733	0,610	1,825	0,000667	**0,914**	**17,280**	**136,898**	**1 302,480**	0,056	0,048	**0,144**	**4,453**	1,39	1,18	**3,651**
20	1,188	0,1	0,2	1,039	0,887	1,403	1,330	2,733	0,482	1,624	0,000667	**0,724**	**17,280**	**121,782**	**1 302,480**	0,035	0,030	**0,090**	**3,961**	1,23	1,05	**3,248**
21	1,041	0,1	0,2	1,039	0,887	1,403	1,330	2,733	0,370	1,422	0,000667	**0,555**	**17,280**	**106,666**	**1 302,480**	0,021	0,018	**0,053**	**3,469**	1,08	0,92	**2,844**

Annex 6: *Primary Beam Calculation*

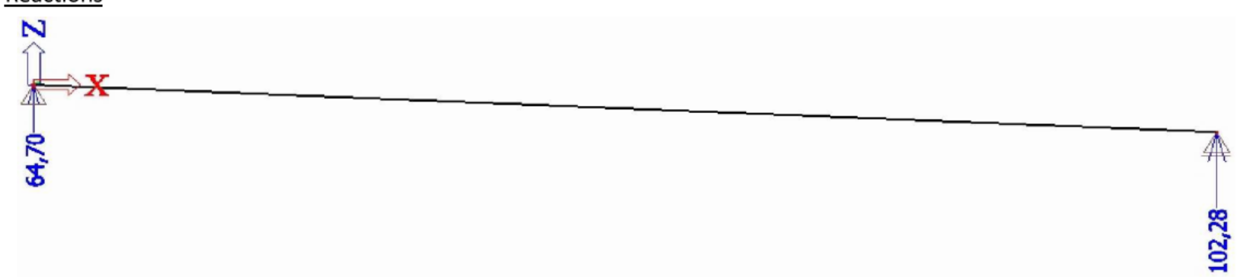
Coefficients	
GL28h	
f m,k	28 Mpa
f v,k	3,2 Mpa
f c,90,g,k	3 Mpa
Eo, mean	12600 Mpa
l =	14 m
b=	0,2 m
hs	0,84 m
hap	1,2 m
α =	1,5 °
β =	3 °

Environment	1
Permanent load	
kmod	0,9
$k_1$def	0,6
$k_2$def	0,25
ϒm	1,25
Kcr	0,67
Ψ2	0,6



Internal Forces from Scia Engineer Software

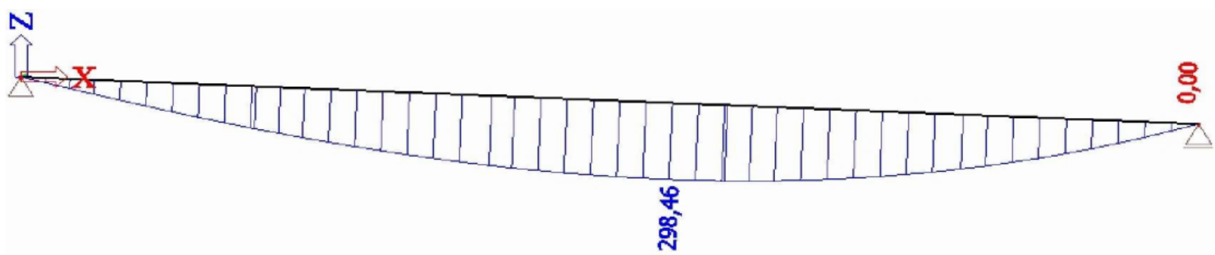
Reactions



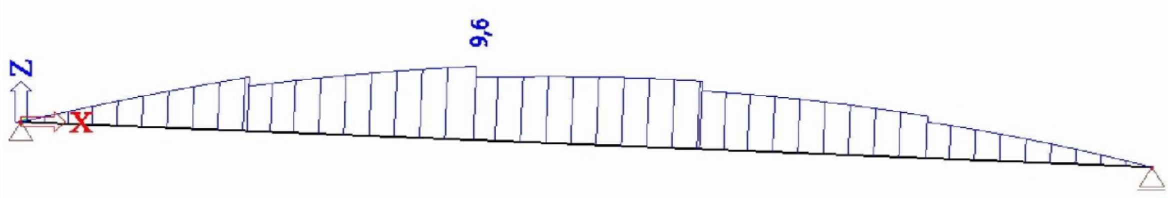
Vd1 = 64,7 kN

Vd2 = 102,28 kN

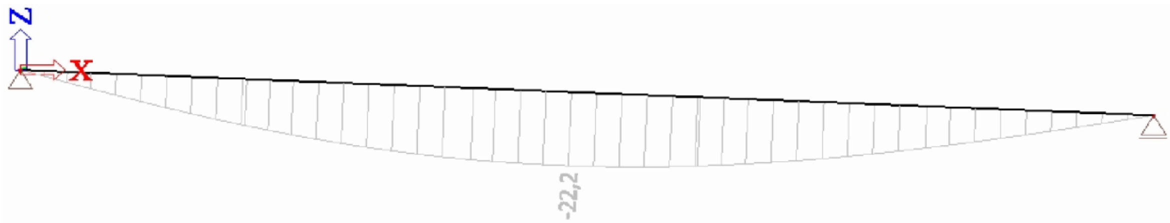
Internal forces



Tention



Relative deformation



Design strenghts

$$fm,g,d = kmod\,.\left(\frac{fm,g,k}{\gamma m}\right) =$$ 20,16 Mpa

$$fv,g,d = kmod\,.\left(\frac{fv,g,k}{\gamma m}\right) =$$ 2,304 Mpa

$$fc,90,g,d = kmod\,.\left(\frac{fc,90,g,k}{\gamma m}\right) =$$ 2,16 Mpa

The height of the beam at the point of maximum stress

$$hxm = hs + \frac{(hap\ - hs)}{l} =$$ 0,865714 m

Assessment of the beam at the point of maximum bending stress

Outmost fiber of the beam on the tension side

$\sigma_{m,0,d}$ = **9,6 MPa** (number counted in Scia Engineer software)

α=0° -> $k_{m,\alpha}$ = 1

$$\frac{\sigma m,0,d}{(km,a\,.\,fm,g,d)} =$$ **0,47619 < 1**

Outmost fiber of the beam on the pressed side

α= 1,5 °

$$k_{m,\alpha} = \frac{1}{\sqrt{1+(\frac{f\ m,d}{1,5\ x\ f\ v,d}\ x\ tg\alpha)^2+(\frac{f\ m,d}{f\ c,90,d}\ x\ tg^2\alpha)^2}} =$$

$k_{m,\alpha}$ = **0,931375 < 1**

Shear

$$\tau d1 = 1{,}5\,.\frac{Vd1}{b.hs}$$ 0,577679 Mpa

$$\tau d2 = 1{,}5\,.\frac{Vd2}{b.hap}$$ 0,63925 Mpa

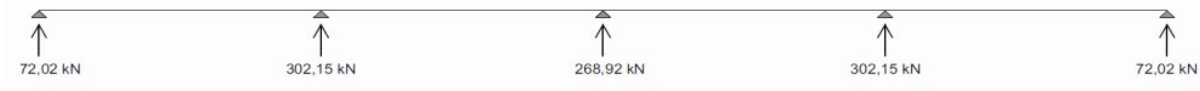
$$\frac{\tau d2}{fv,g,d} =$$ **0,277452 < 1**

Annex 7*: Round Girder Calculation*

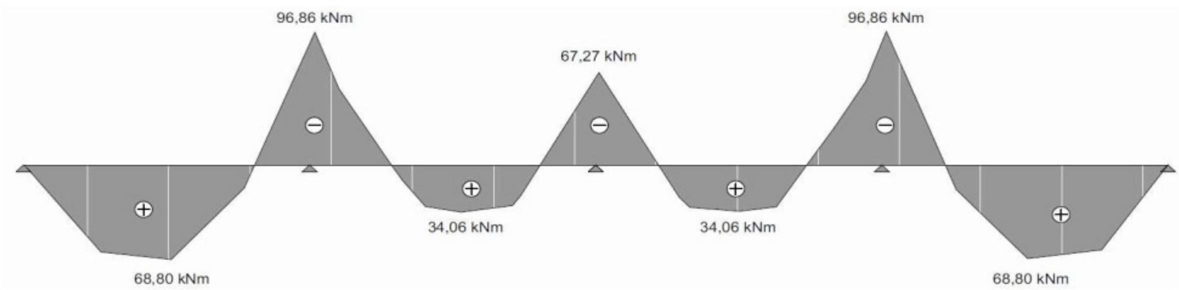
Coefficients

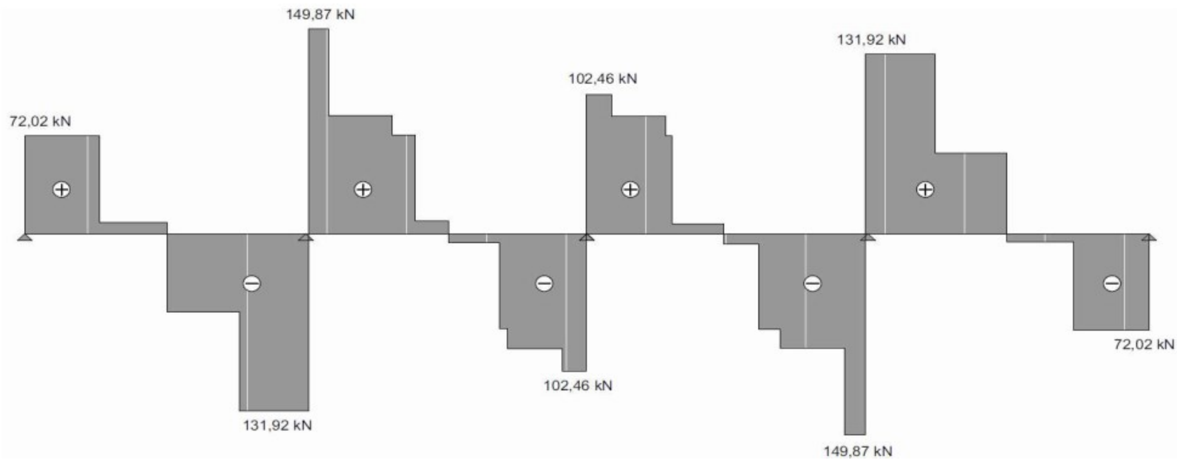
GL28h			Environment	1		$k_2$def	0,25
f m,k	28 Mpa		Permanent load			γm	1,25
f v,k	3,2 Mpa		kmod	0,9		Kcr	0,67
Eo, mean	12600 Mpa		$k_1$def	0,6		Ψ2	0,6

Reactions



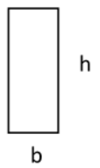
Internal forces





Dimensions

b =	0,2 m
h =	0,9 m



Fbeam = **64 kN**

FKVH = **various kN**

Weight of the girder = **81 kN/m**

$$Mmax = \frac{1}{8} f . L^2 =$$ 96,860 kNm

$$V\, max = \frac{10}{8} f . L =$$ 149,870 kN

Bend tension

$$\sigma_{m,d} = \frac{Med}{Wy} =$$ 3587,4074 kPa = 3,587 MPa

$$Wy = \frac{1}{6}\, b . h^2 =$$ 0,027 m³

f m,d = k, mod . $\left(Kmod . \frac{f\ m,k}{\gamma m}\right) =$ 20,160 Mpa

σ m, d =	3,587407407	<	20,16	= f m, d	=> OK

Shear

$$\tau\ v, d \leq Kcr .\ f\ v, d = Kcr . \left(Kmod . \frac{f\ v, k}{\gamma m}\right)$$

$$\tau\ v, d = \frac{V \max\ .\ Sy}{b\, .\, ly} Kcr = \frac{3\, .\, Vmax}{2\, .\, b\, .\, h}$$ 1248,916667 kPa

$$Kcr . \left(Kmod . \frac{f\ v, k}{\gamma m}\right) =$$ 1543,68 kPa

τ v, d =	1248,916667	<	1543,68	= Kcr. F v,	=> OK

Annex 8: *Column 1 Calculation*

l =	3	m
b =	0,2	m
h =	0,4	m
A =	0,08	m^2
N =	102,28	kN
Column =	1,08	kN
Nd =	**103,36**	**kN**

Coefficients								
GL24h			Environment		1	γm		1,25
Eo, mean	11600	MPa	Permanent load			Kcr		0,67
f c,0,g,k	24	MPa	kmod		0,6	Ψ2		0,6
E0,g05	9400	MPa	$k_1$def		0,6	$k_2$def		0,25

$$fc,0,d = kmod\,.\frac{fc,0,g,k}{\gamma m} = \quad 11{,}52 \text{ Mpa}$$

$$\frac{Nd}{fc,0,d\,.\,kcr\,.\,A} \leq 1$$

Slenderness ratio

$$Iy = \frac{1}{12}.b.h^3 = \quad 0{,}001066667 \text{ m}^4 \qquad Iz = \frac{1}{12}.b^3.h = \quad 0{,}000267 \text{ m}^4$$

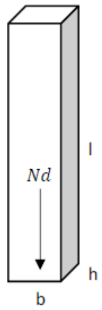
$$iy = \sqrt{\frac{Iy}{A}} = \quad 0{,}115470054 \text{ m} \qquad iz = \sqrt{\frac{Iz}{A}} = \quad 0{,}057735 \text{ m}^4$$

$$\gamma y = \frac{l}{iy} = \quad 25{,}98076211 \qquad \gamma z = \frac{l}{iz} = \quad 51{,}96152$$

$$\sigma c,cr,l,z = \frac{\pi^2.E0,g05}{\gamma z^2} = \quad 34{,}36084$$

$$\gamma rel,z = \sqrt{\frac{fc,0,d}{\sigma c,cr,l,z}} \geq 0{,}3$$

γrel, z =	**0,579021**	**≥**	**0,3**



$$kz = 0{,}5\,.\,(1 + \beta c\,.\,(\gamma rel,z - 0{,}3) + \gamma rel,z^{\,2}) = \quad 0{,}695535$$

$$kc,z = \frac{1}{kz + \sqrt{kz^2 - \gamma rel,z^{\,2}}} = \quad 0{,}925158$$

$$\frac{Nd}{fc,0,d\,.\,kcr\,.\,A} \leq 1$$

0,121225	**≤ 1**

Annex 9: *Column 2 Calculation*

l =	3,7	m
b =	0,4	m
h =	0,2	m
A =	0,08	m^2
N =	302,15	kN
Column =	1,332	kN
Nd =	**303,482**	**kN**

Coefficients							
GL24h			Environment	1	γm	1,25
Eo, mean	11600	MPa	Permanent load		Kcr	0,67
f c,0,g,k	24	MPa	kmod	0,6	Ψ2	0,6
E0,g05	9400	MPa	$k_1$def	0,6	$k_2$def	0,25

$$fc,0,d = kmod\,.\frac{fc,0,g,k}{\gamma m} =$$ 11,52 Mpa

$$\frac{Nd}{fc,0,d\,.\,kcr\,.\,A} \leq 1$$

Slenderness ratio

$$Iy = \frac{1}{12}\,.\,b\,.\,h^3 =$$ 0,000266667 m^4

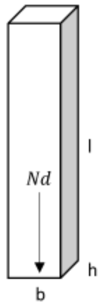
$$Iz = \frac{1}{12}\,.\,b^3\,.\,h =$$ 0,001067 m^4

$$iy = \sqrt{\frac{Iy}{A}} =$$ 0,057735027 m

$$iz = \sqrt{\frac{Iz}{A}} =$$ 0,11547 m^4

$$\gamma y = \frac{l}{iy} =$$ 64,08587988

$$\gamma z = \frac{l}{iz} =$$ 32,04294



$$\sigma c,cr,l,z = \frac{\pi^2.\,E0,g05}{\gamma z^2} =$$ 90,35723

$$\gamma rel,z = \sqrt{\frac{fc,0,d}{\sigma c,cr,l,z}} \geq 0,3$$

γrel, z =	**0,357063**	**≥**	**0,3**

$$kz = 0,5\,.\,(1 + \beta c\,.\,(\gamma rel,z - 0,3) + \gamma rel,z^{\,2}) =$$ 0,569453

$$kc,z = \frac{1}{kz + \sqrt{kz^2 - \gamma rel,z^{\,2}}} =$$ 0,987113

$$\frac{Nd}{fc,0,d\,.\,kcr\,.\,A} \leq 1$$

0,333598	**≤ 1**

Annex 10*: Weight of the Cage Calculation*

Material properities				
	Wood		Polycarbonate	
Density	450	kg/m3	1200	kg/m3

Cage dimensions	
Radius (r)	5,5 m

Beam dimensions		Laths dimensions	
Width	0,1 m	Width	0,1 m
Height	0,15 m	Height	0,04 m
W . H =	0,015 m^2	WxH	0,004 m^2
Lenght	8,668 m		

Weight of the beam

$f = W.H.450\,.1{,}35 =$ **0,091125** kN/m

Roof dimensions			
Thickness	0,008 m	Radius 2	21,8 m
Width	3 m	Circular sector	7 °
Radius 1	19 m		
T . W =	0,024 m^2		

Weight of the polycarbonate roof

Load width of the roof 2,4 m

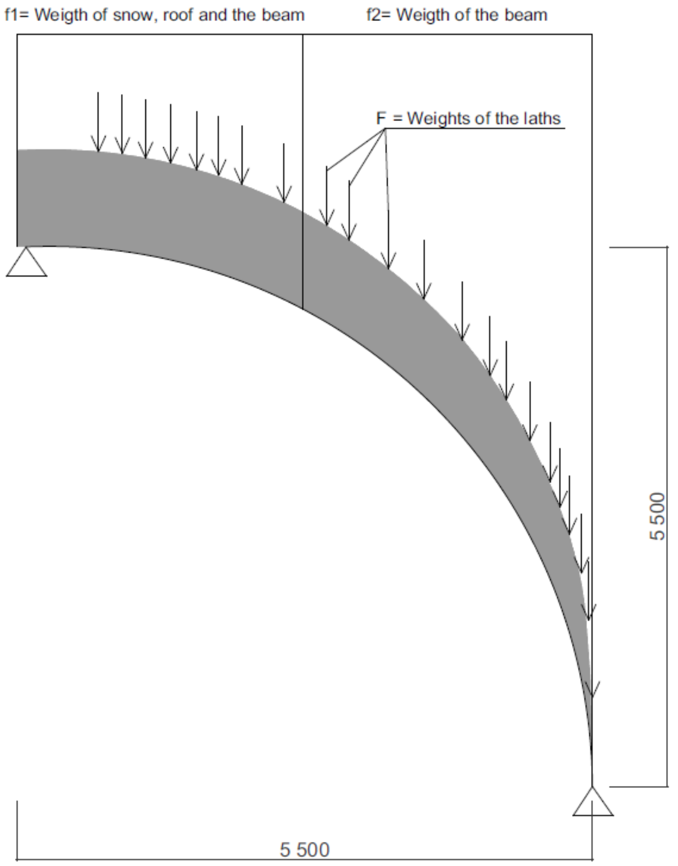
$f = T.1200\,.\,2{,}4\,.1{,}35 =$ **0,031104** kN/m

Weight of the snow

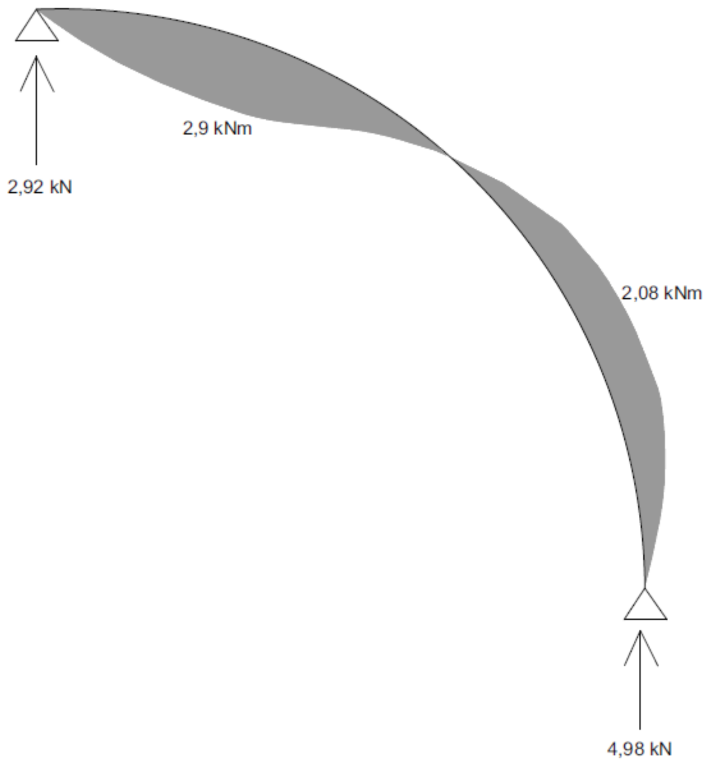
Snow load = 0,472 kN/m^2
[see live loads calculation]

$f = 0{,}472.2{,}4\,.1{,}5 =$ **1,6992** kN/m

Number of lath	Radius of the lath	Weights of the laths			
	[m]	[kg]	[kN]		[kN]
1	19,433	4,274	0,042735399	1,35	**0,057693**
2	19,679	4,328	0,043276381	1,35	**0,058423**
3	19,926	4,382	0,043819563	1,35	**0,059156**
4	20,163	4,434	0,044340753	1,35	**0,05986**
5	20,415	4,489	0,04489493	1,35	**0,060608**
6	20,657	4,543	0,045427116	1,35	**0,061327**
7	20,897	4,595	0,045954903	1,35	**0,062039**
8					
9	21,349	4,695	0,046948903	1,35	**0,063381**
10					
11	21,792	4,792	0,047923111	1,35	**0,064696**
12	22,008	4,840	0,04839812	1,35	**0,065337**
13					
14	22,416	4,930	0,049295359	1,35	**0,066549**
15					
16	22,796	5,013	0,050131022	1,35	**0,067677**
17		0,000		1,35	
18	23,146	5,090	0,050900712	1,35	**0,068716**
19		0,000			
20	23,456	5,158	0,051582438	1,35	**0,069636**
21	23,601	5,190	0,05190131	1,35	**0,070067**
22					
23	23,858	5,247	0,052466482	1,35	**0,07083**
24					
25	24,075	5,294	0,05294369	1,35	**0,071474**
26	24,168	5,315	0,053148208	1,35	**0,07175**
27	24,251	5,333	0,053330734	1,35	**0,071996**
28					
29	24,384	5,362	0,053623217	1,35	**0,072391**
30					
31	24,472	5,382	0,053816739	1,35	**0,072653**
32	24,499	5,388	0,053876115	1,35	**0,072733**



Cage calculation - loads



Cage calculation - internal forces and reaction

Annex 11: *Environmental Impact of the Roof* [Envimat, 2016]

Reference: Wood-fibre insulation

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm¹]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Substrate	0,15	1	/	0,15	600	90	0,700	0,2143	0,0439	**3,9513**	0,0029	**0,2642**	0,0224	**2,0185**	0,0050	**0,4500**	1,73385E-05	**0,0015605**	0,00057471	**0,0517**
2	Filter fabric, geotextil	0,0011	1	/	0,0011	95	0,1045	/	/	47,5942	**4,9736**	3,0685	**0,3207**	20,1850	**2,1093**	16,3000	**1,7034**	0,00014798	**0,0000155**	0,53983	**0,0564**
3	Drainage layer, studed foil	0,04	1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
4	Separation, protective and water accumulation fabric	0,004	1	/	0,004	125	0,5	/	/	47,5942	**23,7971**	3,0685	**1,5343**	20,1850	**10,0925**	16,3000	**8,1500**	0,00014798	**0,0000740**	0,53983	**0,2699**
5	Waterproof membrane with root barrier function	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
6	Separation fabric	0,0028	1	/	0,0028	105	0,294	/	/	47,5942	**13,9927**	3,0685	**0,9021**	20,1850	**5,9344**	16,3000	**4,7922**	0,00014798	**0,0000435**	0,53983	**0,1587**
7	Wood fibre insulation	0,3	1	/	0,3	50	15	0,038	7,8947	5,0954	**76,4316**	0,1854	**2,7803**	0,6296	**9,4435**	0,2350	**3,5250**	2,55193E-05	**0,0003828**	0,0399833	**0,5997**
8	Vapour barrier	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
9	OSB	0,03	1	/	0,03	650	19,5	0,130	0,2308	12,5057	**243,8612**	0,4813	**9,3858**	2,0371	**39,7231**	0,9170	**17,8815**	2,46108E-05	**0,0004799**	0,295185	**5,7561**
10	Secondary beams	0,2	0,1	1,6	0,032	400	12,8	0,180	1,1111	3,3526	**42,9138**	0,1874	**2,3982**	1,1679	**14,9495**	0,4930	**6,3104**	1,73385E-05	**0,0002219**	0,096565	**1,2360**
11	Wood fibre insulation	0,2	1	/	0,2	50	10	0,038	5,2632	5,0954	**50,9544**	0,1854	**1,8535**	0,6296	**6,2957**	0,2350	**2,3500**	2,55193E-05	**0,0002552**	0,0399833	**0,3998**
12	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,7519**						U =	**0,072857147**		**769,289099**		**28,5072**		**128,5306**		**51,3025**		**0,0031745**		**10,7956**

Variant 2: Expanded polystyrene

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm¹]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Substrate	0,15	1	/	0,15	600	90	0,700	0,2143	0,0439	**3,9513**	0,0029	**0,2642**	0,0224	**2,0185**	0,0050	**0,4500**	1,73385E-05	**0,0015605**	0,00057471	**0,0517**
2	Filter fabric, geotextil	0,0011	1	/	0,0011	95	0,1045	/	/	47,5942	**4,9736**	3,0685	**0,3207**	20,1850	**2,1093**	16,3000	**1,7034**	0,00014798	**0,0000155**	0,53983	**0,0564**
3	Drainage layer, studed foil	0,04	1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
4	Separation, protective and water accumulation fabric	0,004	1	/	0,004	125	0,5	/	/	47,5942	**23,7971**	3,0685	**1,5343**	20,1850	**10,0925**	16,3000	**8,1500**	0,00014798	**0,0000740**	0,53983	**0,2699**
5	Waterproof membrane with root barrier function	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
6	Separation fabric	0,0028	1	/	0,0028	105	0,294	/	/	47,5942	**13,9927**	3,0685	**0,9021**	20,1850	**5,9344**	16,3000	**4,7922**	0,00014798	**0,0000435**	0,53983	**0,1587**
7	Expanded polystyrene	0,3	1	/	0,3	30	9	0,035	8,5714	105,0730	**945,6570**	4,2121	**37,9089**	14,9000	**134,1000**	2,5490	**22,9410**	0,00013195	**0,0011876**	6,7545	**60,7905**
8	Vapour barrier	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
9	OSB	0,03	1	/	0,03	650	19,5	0,130	0,2308	12,5057	**243,8612**	0,4813	**9,3858**	2,0371	**39,7231**	0,9170	**17,8815**	2,46108E-05	**0,0004799**	0,295185	**5,7561**
10	Secondary beams	0,2	0,1	1,6	0,032	400	12,8	0,180	1,1111	3,3526	**42,9138**	0,1874	**2,3982**	1,1679	**14,9495**	0,4930	**6,3104**	1,73385E-05	**0,0002219**	0,096565	**1,2360**
11	Wood fibre insulation	0,2	1	/	0,2	50	10	0,038	5,2632	5,0954	**50,9544**	0,1854	**1,8535**	0,6296	**6,2957**	0,2350	**2,3500**	2,55193E-05	**0,0002552**	0,0399833	**0,3998**
12	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,7519**						U =	**0,069433928**		**1 638,5145**		**63,6359**		**253,1871**		**70,7185**		**0,0039792**		**70,9863**

Variant 3: Mineral wool insulation

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm¹]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Substrate	0,15	1	/	0,15	600	90	0,700	0,2143	0,0439	**3,9513**	0,0029	**0,2642**	0,0224	**2,0185**	0,0050	**0,4500**	1,73385E-05	**0,0015605**	0,00057471	**0,0517**
2	Filter fabric, geotextil	0,0011	1	/	0,0011	95	0,1045	/	/	47,5942	**4,9736**	3,0685	**0,3207**	20,1850	**2,1093**	16,3000	**1,7034**	0,00014798	**0,0000155**	0,53983	**0,0564**
3	Drainage layer, studed foil	0,04	1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
4	Separation, protective and water accumulation fabric	0,004	1	/	0,004	125	0,5	/	/	47,5942	**23,7971**	3,0685	**1,5343**	20,1850	**10,0925**	16,3000	**8,1500**	0,00014798	**0,0000740**	0,53983	**0,2699**
5	Waterproof membrane with root barrier function	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
6	Separation fabric	0,0028	1	/	0,0028	105	0,294	/	/	47,5942	**13,9927**	3,0685	**0,9021**	20,1850	**5,9344**	16,3000	**4,7922**	0,00014798	**0,0000435**	0,53983	**0,1587**
7	Mineral wool insulation	0,3	1	/	0,3	32	9,6	0,036	8,3333	20,1923	**193,8461**	1,1331	**10,8778**	8,3583	**80,2397**	1,8300	**17,5680**	0,000055368	**0,0005315**	0,44541	**4,2759**
8	Vapour barrier	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
9	OSB	0,03	1	/	0,03	650	19,5	0,130	0,2308	12,5057	**243,8612**	0,4813	**9,3858**	2,0371	**39,7231**	0,9170	**17,8815**	2,46108E-05	**0,0004799**	0,295185	**5,7561**
10	Secondary beams	0,2	0,1	1,6	0,032	400	12,8	0,180	1,1111	3,3526	**42,9138**	0,1874	**2,3982**	1,1679	**14,9495**	0,4930	**6,3104**	1,73385E-05	**0,0002219**	0,096565	**1,2360**
11	Wood fibre insulation	0,2	1	/	0,2	50	10	0,038	5,2632	5,0954	**50,9544**	0,1854	**1,8535**	0,6296	**6,2957**	0,2350	**2,3500**	2,55193E-05	**0,0002552**	0,0399833	**0,3998**
12	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,7519**						U =	**0,070601097**		**886,7036**		**36,6047**		**199,3268**		**65,3455**		**0,0033232**		**14,4718**

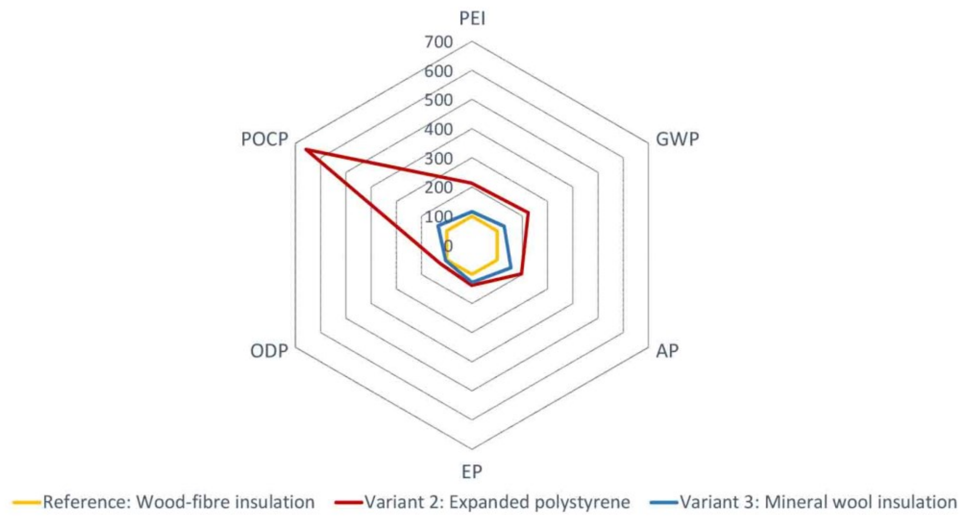
ENVIRONMENTAL PROFILE OF THE EXTERIOS WALL		Referenc	Variant 2	Variant 3
PEI	MJ	**769,2890987**	**1638,514499**	**886,7035787**
GWP	kg CO_2 ekv.	**28,50724515**	**63,63585015**	**36,60471015**
AP	g SO_2 ekv.	**128,5306415**	**253,1871365**	**199,3268165**
EP	g $(PO_4)^{3-}$ ekv.	**51,30245**	**70,71845**	**65,34545**
ODP	g R-11 ekv.	**0,003174457**	**0,003979218**	**0,0033232**
POCP	g C_2H_4 ekv.	**10,79557916**	**70,98632966**	**14,47176566**

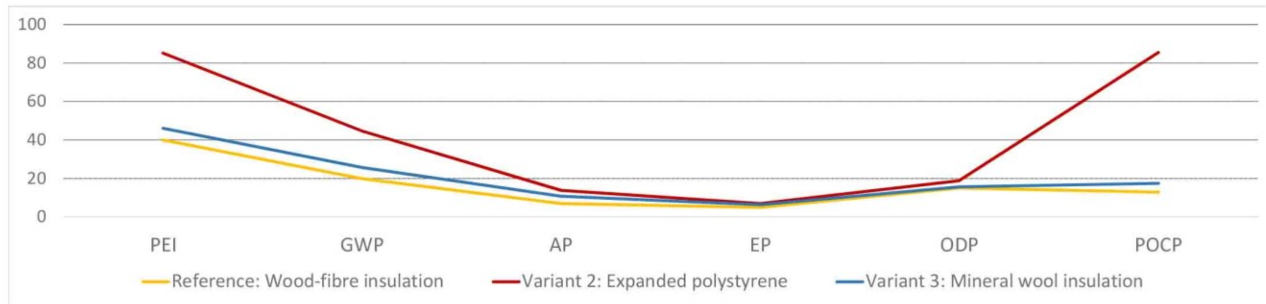
Hodnoty do grafu	Referenc	Variant 2	Variant 3
PEI	100	212,9907341	115,2627251
GWP	100	223,2269369	128,4049369
AP	100	196,9858187	155,0811652
EP	100	137,8461457	127,3729617
ODP	100	125,351123	104,6856297
POCP	100	657,54999	134,0527029

WEIGHT OF THE ENVIRONMENTAL IMPACT PARAMETERS	
PEI	40
GWP	20
AP	7
EP	5
ODP	15
POCP	13
	100

ENVIRONMENTAL IMPACT EVALUATION

		Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS	Weights [%]	Multiplier	Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS
PEI	MJ	100	212,99	115,26	40	0,4	40	85,19629364	46,10509
GWP	kg CO_2 ekv.	100	223,23	128,40	20	0,2	20	44,64538738	25,680987
AP	g SO_2 ekv.	100	196,99	155,08	7	0,07	7	13,78900731	10,855682
EP	g $(PO_4)^{3-}$ ekv.	100	137,85	127,37	5	0,05	5	6,892307287	6,3686481
ODP	g R-11 ekv.	100	125,35	104,69	15	0,15	15	18,80266845	15,702844
POCP	g C_2H_4 ekv.	100	657,55	134,05	13	0,13	13	85,4814987	17,426851
						Σ	**100**	**254,8071628**	**122,1401**





Annex 12: *Environmental Impact of the Exterior Wall* [Envimat, 2016]

Referenc: Cellulose fibre insulation

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Larch wood external cladding	0,024	1	/	0,024	400	9,6	0,180	0,1333	3,3526	**32,1853**	0,1874	**1,7986**	1,1679	**11,2121**	0,4930	**4,7328**	1,73385E-05	**0,0001664**	0,096565	**0,9270**
2	Spruce wood batterns (ventilation)	0,06	0,04	1,6	0,00384	400	1,536	0,180	0,3333	3,3526	**5,1497**	0,1874	**0,2878**	1,1679	**1,7939**	0,4930	**0,7572**	1,73385E-05	**0,0000266**	0,096565	**0,1483**
3	Vapour-permeable membrane	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
4	Wood-fibre insulation board	0,024	1	/	0,024	300	7,2	0,038	0,6316	5,0954	**36,6872**	0,1854	**1,3345**	0,6296	**4,5329**	0,2350	**1,6920**	2,55193E-05	**0,0001837**	0,0399833	**0,2879**
5	Cellulose fibre insulation	0,3	1	/	0,290305476	50	14,5152738	0,040	7,5000	7,1441	**103,6980**	0,3678	**5,3386**	2,9049	**42,1654**	0,6380	**9,2607**	0,00004046	**0,0005873**	0,12182	**1,7683**
6	OSB I profiles	0,3	/	1,834	0,009694524	650	6,3014406	0,130	2,3077	12,5057	**78,8039**	0,4813	**3,0330**	2,0371	**12,8365**	0,9170	**5,7784**	2,46108E-05	**0,0001551**	0,295185	**1,8601**
7	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
8	Wood-fibre insulation	0,14	1	/	0,14	50	7	0,038	3,6842	5,0954	**35,6681**	0,1854	**1,2975**	0,6296	**4,4070**	0,2350	**1,6450**	2,55193E-05	**0,0001786**	0,0399833	**0,2799**
9	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
10	Spruce wood internal cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,606**						**U =**	**0,078887966**		**752,442840**		**29,6365**		**148,2693**		**50,3660**		**0,0020137**		**13,6986**

Variant 2: Wood-fibre insulation

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Larch wood external cladding	0,024	1	/	0,024	400	9,6	0,180	0,1333	3,3526	**32,1853**	0,1874	**1,7986**	1,1679	**11,2121**	0,4930	**4,7328**	1,73385E-05	**0,0001664**	0,096565	**0,9270**
2	Spruce wood batterns (ventilation)	0,06	0,04	1,6	0,00384	400	1,536	0,180	0,3333	3,3526	**5,1497**	0,1874	**0,2878**	1,1679	**1,7939**	0,4930	**0,7572**	1,73385E-05	**0,0000266**	0,096565	**0,1483**
3	Vapour-permeable membrane	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
5	Wood-fibre insulation	0,32	1	/	0,300610952	50	15,0305476	0,038	8,4211	5,0954	**76,5873**	0,1854	**2,7860**	0,6296	**9,4627**	0,2350	**3,5322**	2,55193E-05	**0,0003836**	0,0399833	**0,6010**
6	Spruce wood batterns	0,16	0,06	1,834	0,009694524	400	3,8778096	0,180	0,8889	3,3526	**13,0009**	0,1874	**0,7265**	1,1679	**4,5290**	0,4930	**1,9118**	1,73385E-05	**0,0000672**	0,096565	**0,3745**
7	Spruce wood batterns cross	0,16	0,06	1,834	0,009694524	400	3,8778096	0,180	0,8889	3,3526	**13,0009**	0,1874	**0,7265**	1,1679	**4,5290**	0,4930	**1,9118**	1,73385E-05	**0,0000672**	0,096565	**0,3745**
8	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
9	Wood-fibre insulation	0,14	1	/	0,14	50	7	0,038	3,6842	5,0954	**35,6681**	0,1854	**1,2975**	0,6296	**4,4070**	0,2350	**1,6450**	2,55193E-05	**0,0001786**	0,0399833	**0,2799**
10	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
11	Spruce wood internal cladding	0,02	1		0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,602**						**U =**	**0,077126702**		**635,8428**		**24,1694**		**107,2553**		**40,9905**		**0,0016056**		**11,1323**

Variant 3: Mineral wool insulation

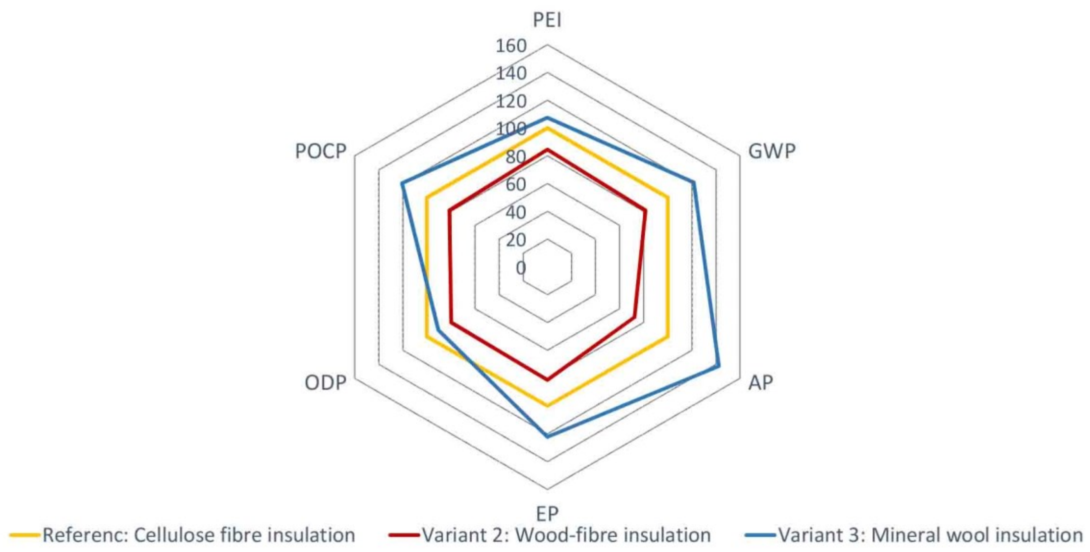
Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Larch wood external cladding	0,024	1	/	0,024	400	9,6	0,180	0,1333	3,3526	**32,1853**	0,1874	**1,7986**	1,1679	**11,2121**	0,4930	**4,7328**	1,73385E-05	**0,0001664**	0,096565	**0,9270**
2	Spruce wood batterns (ventilation)	0,06	0,04	1,6	0,00384	400	1,536	0,180	0,3333	3,3526	**5,1497**	0,1874	**0,2878**	1,1679	**1,7939**	0,4930	**0,7572**	1,73385E-05	**0,0000266**	0,096565	**0,1483**
3	Vapour-permeable membrane	0,002	1	/	0,002	900	1,8	0,350	0,0057	78,2201	**140,7962**	2,1026	**3,7847**	7,9502	**14,3104**	0,6100	**1,0980**	6,9391E-07	**0,0000012**	0,41516	**0,7473**
5	Mineral wool insulation	0,32	1	/	0,300610952	32	9,619550464	0,036	8,8889	20,1923	**194,2408**	1,1331	**10,8999**	8,3583	**80,4031**	1,8300	**17,6038**	0,000055368	**0,0005326**	0,44541	**4,2846**
6	Spruce wood batterns	0,16	0,06	1,834	0,009694524	400	3,8778096	0,180	0,8889	3,3526	**13,0009**	0,1874	**0,7265**	1,1679	**4,5290**	0,4930	**1,9118**	1,73385E-05	**0,0000672**	0,096565	**0,3745**
7	Spruce wood batterns cross	0,16	0,06	1,834	0,009694524	400	3,8778096	0,180	0,8889	3,3526	**13,0009**	0,1874	**0,7265**	1,1679	**4,5290**	0,4930	**1,9118**	1,73385E-05	**0,0000672**	0,096565	**0,3745**
8	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
9	Mineral wool insulation	0,14	1	/	0,14	32	4,48	0,036	3,8889	20,1923	**90,4615**	1,1331	**5,0763**	8,3583	**37,4452**	1,8300	**8,1984**	0,000055368	**0,0002480**	0,44541	**1,9954**
10	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
11	Spruce wood internal cladding	0,02	1		0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,406**						**U =**	**0,073323497**		**808,2898**		**36,0622**		**211,2338**		**61,6155**		**0,0018241**		**16,5315**

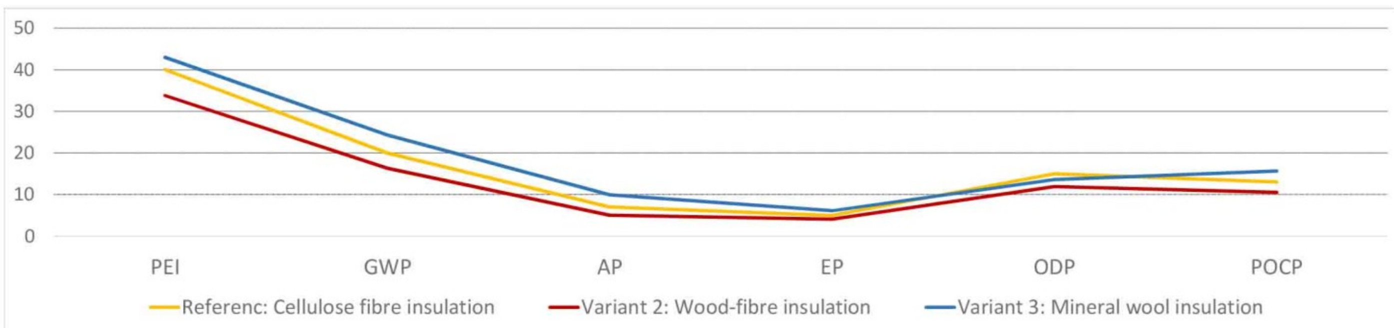
ENVIRONMENTAL PROFILE OF THE EXTERIOS WALL		Referenc	Variant 2	Variant 3
PEI	MJ	**752,4428397**	**635,8428117**	**808,289831**
GWP	kg CO_2 ekv.	**29,63653433**	**24,16942628**	**36,06219882**
AP	g SO_2 ekv.	**148,2693494**	**107,2552666**	**211,2338335**
EP	g $(PO_4)^{3-}$ ekv.	**50,36601371**	**40,99054695**	**61,61554561**
ODP	g R-11 ekv.	**0,002013677**	**0,001605606**	**0,001824066**
POCP	g C_2H_4 ekv.	**13,6985891**	**11,1322602**	**16,53148698**

Hodnoty do grafu			
	Referenc	Variant 2	Variant 3
PEI	100	84,50380256	107,4220909
GWP	100	81,55280914	121,6815651
AP	100	72,33812453	142,4662848
EP	100	81,38533096	122,3355614
ODP	100	79,73505132	90,58385059
POCP	100	81,26574293	120,6802165

WEIGHT OF THE ENVIRONMENTAL IMPACT PARAMETERS	
PEI	40
GWP	20
AP	7
EP	5
ODP	15
POCP	13
	100

ENVIRONMENTAL IMPACT EVALUATION									
		Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS	Weights [%]	Multiplier	Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS
PEI	MJ	100	84,50	107,42	40	0,4	40	33,80152103	42,9688363
GWP	kg CO_2 ekv.	100	81,55	121,68	20	0,2	20	16,31056183	24,336313
AP	g SO_2 ekv.	100	72,34	142,47	7	0,07	7	5,063668717	9,97263993
EP	g $(PO_4)^{3-}$ ekv.	100	81,39	122,34	5	0,05	5	4,069266548	6,11677807
ODP	g R-11 ekv.	100	79,74	90,58	15	0,15	15	11,9602577	13,5875776
POCP	g C_2H_4 ekv.	100	81,27	120,68	13	0,13	13	10,56454658	15,6884281
						Σ	**100**	**81,7698224**	**112,670573**





Annex 13: *Environmental Impact of the Partitions* [Envimat, 2016]

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
	Reference: Mineral wool insulation																				
1	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
2	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
3	Mineral wool insulation	0,16	1	/	0,16	32	5,12	0,036	4,4444	20,1923	**103,3846**	1,1331	**5,8015**	8,3583	**42,7945**	1,8300	**9,3696**	0,000055368	**0,0002835**	0,44541	**2,2805**
4	Solid construction timber	0,16	0,06	1,6	0,01536	400	6,144	0,180	0,8889	3,3526	**20,5986**	0,1874	**1,1511**	1,1679	**7,1758**	0,4930	**3,0290**	1,73385E-05	**0,0001065**	0,096565	**0,5933**
5	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
6	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,236**						U =	**0,202282158**		**470,258816**		**21,2133**		**116,3248**		**41,7444**		**0,0012433**		**11,3262**

Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
	Variant 2: Cellulose fibre insulation																				
1	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
2	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
3	Cellulose fibre insulation	0,16	1	/	0,14464	50	7,232	0,040	4,0000	7,1441	**51,6658**	0,3678	**2,6599**	2,9049	**21,0082**	0,6380	**4,6140**	0,00004046	**0,0002926**	0,12182	**0,8810**
4	Solid construction timber	0,16	0,06	1,6	0,01536	400	6,144	0,180	0,8889	3,3526	**20,5986**	0,1874	**1,1511**	1,1679	**7,1758**	0,4930	**3,0290**	1,73385E-05	**0,0001065**	0,096565	**0,5933**
5	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
6	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,236**						U =	**0,222264438**		**418,540082**		**18,0717**		**94,5386**		**36,9888**		**0,0012524**		**9,9267**

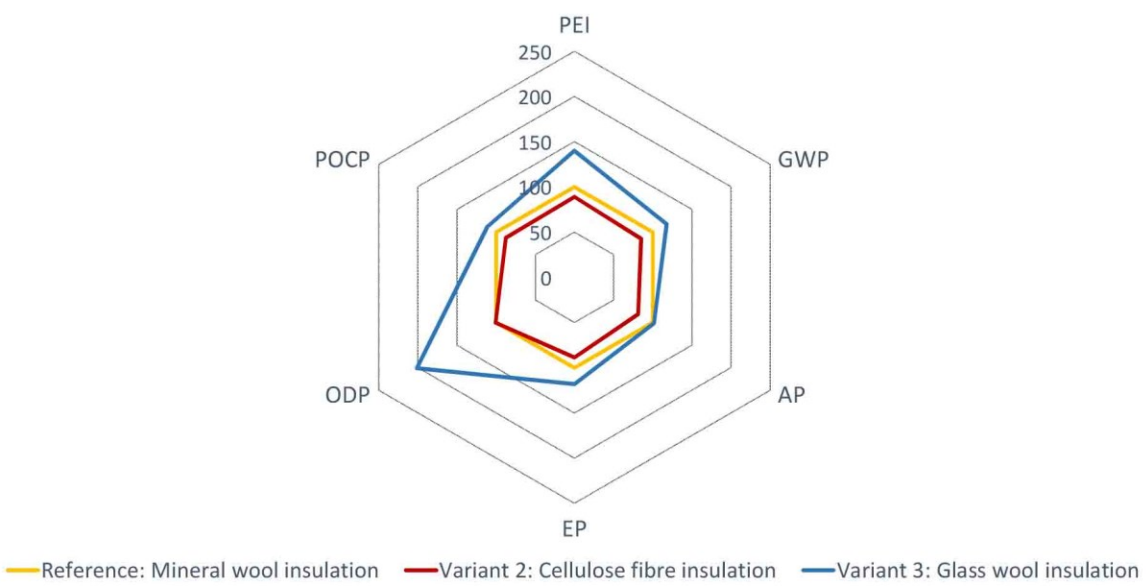
Layer	Material	Thickness [m]	Width [m]	Number in 1 m²	V [m³]	m [kg/m³]	[kg/bm²]	λ [W/mK]	R [m²K/W]	PEI MJ/kg	MJ	GWP kg CO_2 ekv./kg	kg CO_2 ekv.	AP g SO_2 ekv./kg	g SO_2 ekv.	EP g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	ODP g R-11 ekv./kg	g R-11 ekv.	POCP g C_2H_4 ekv./kg	g C_2H_4 ekv.
	Variant 3: Glass wool insulation																				
1	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
2	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
3	Glass wool insulation	0,16	1	/	0,16	40	6,4	0,040	4,0000	45,5342	**291,4189**	1,4958	**9,5731**	6,9675	**44,5920**	2,6440	**16,9216**	0,00024108	**0,0015429**	0,55668	**3,5628**
4	Solid construction timber	0,16	0,06	1,6	0,01536	400	6,144	0,180	0,8889	3,3526	**20,5986**	0,1874	**1,1511**	1,1679	**7,1758**	0,4930	**3,0290**	1,73385E-05	**0,0001065**	0,096565	**0,5933**
5	OSB	0,018	1	/	0,018	650	11,7	0,130	0,1385	12,5057	**146,3167**	0,4813	**5,6315**	2,0371	**23,8338**	0,9170	**10,7289**	2,46108E-05	**0,0002879**	0,295185	**3,4537**
6	Spruce board-on-board cladding	0,02	1	/	0,02	400	8	0,180	0,1111	3,3526	**26,8211**	0,1874	**1,4989**	1,1679	**9,3434**	0,4930	**3,9440**	1,73385E-05	**0,0001387**	0,096565	**0,7725**
	Σ	**0,236**						U =	**0,222264438**		**658,293120**		**24,9849**		**118,1223**		**49,2964**		**0,0025027**		**12,6084**

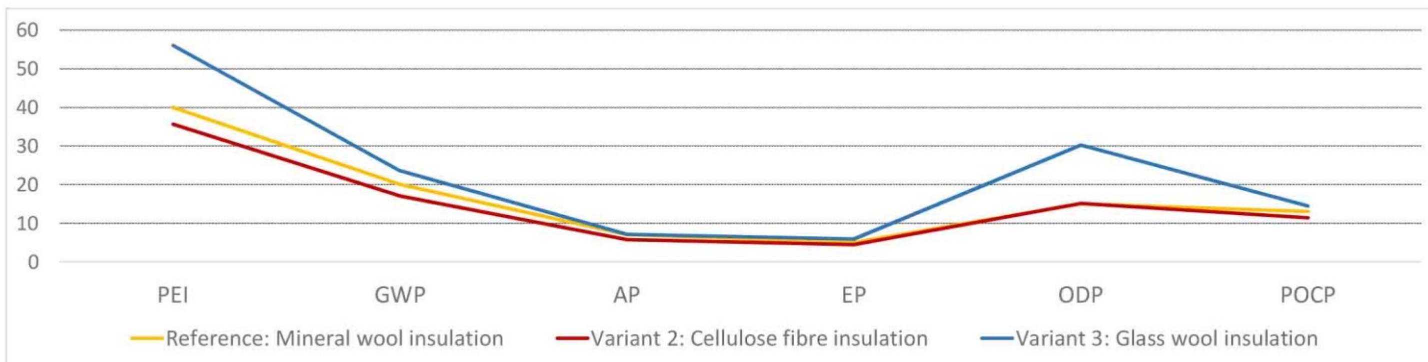
ENVIRONMENTAL PROFILE OF THE EXTERIOS WALL		Referenc	Variant 2	Variant 3
PEI	MJ	**470,2588162**	**418,5400821**	**658,2931202**
GWP	kg CO_2 ekv.	**21,21328575**	**18,07167103**	**24,98493375**
AP	g SO_2 ekv.	**116,3248099**	**94,53855072**	**118,1223139**
EP	g $(PO_4)^{3-}$ ekv.	**41,744392**	**36,988808**	**49,296392**
ODP	g R-11 ekv.	**0,001243321**	**0,001252443**	**0,002502748**
POCP	g C_2H_4 ekv.	**11,32616356**	**9,9266666**	**12,60841636**

Hodnoty do grafu			
	Referenc	Variant 2	Variant 3
PEI	100	89,00207028	139,9852799
GWP	100	85,19034365	117,7796502
AP	100	81,27118435	101,5452456
EP	100	88,60784941	118,0910528
ODP	100	100,7337255	201,2954998
POCP	100	87,64368047	111,3211574

WEIGHT OF THE ENVIRONMENTAL IMPACT PARAMETERS	
PEI	40
GWP	20
AP	7
EP	5
ODP	15
POCP	13
	100

ENVIRONMENTAL IMPACT EVALUATION									
		Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS	Weights [%]	Multiplier	Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS
PEI	MJ	100	89,00	139,99	40	0,4	40	35,60082811	55,994112
GWP	kg CO_2 ekv.	100	85,19	117,78	20	0,2	20	17,03806873	23,55593
AP	g SO_2 ekv.	100	81,27	101,55	7	0,07	7	5,688982905	7,1081672
EP	g $(PO_4)^{3-}$ ekv.	100	88,61	118,09	5	0,05	5	4,43039247	5,9045526
ODP	g R-11 ekv.	100	100,73	201,30	15	0,15	15	15,11005882	30,194325
POCP	g C_2H_4 ekv.	100	87,64	111,32	13	0,13	13	11,39367846	14,47175
						Σ	**100**	**89,2620095**	**137,22884**





Annex 14: *Environmental Influence of the Floor Above Ground* [Envimat, 2016]

Reference: Foam glass gravel

Layer	Material	Thickness	Width	Number in 1 m^2	V	m		λ	R	PEI		GWP		AP		EP		ODP		POCP	
		[m]	[m]		[m^3]	[kg/m^3]	[kg/bm^2]	[W/mK]	[m^2K/W]	MJ/kg	MJ	kg CO_2 ekv./kg	kg CO_2 ekv.	g SO_2 ekv./kg	g SO_2 ekv.	g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	g R-11 ekv./kg	g R-11 ekv.	g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Indoor tiles	0,008	1	/	0,008	2000	16	1,010	0,0079	14,1064	**225,7024**	0,7817	**12,5077**	2,7697	**44,3152**	1,1610	**18,5760**	0,000091639	**0,0014662**	0,13268	**2,1229**
2	Tile adhesive	0,002	1	/	0,002	1300	2,6	0,700	0,0029	23,6585	**61,5121**	1,1046	**2,8720**	4,5856	**11,9226**	1,8780	**4,8828**	0,00016298	**0,0004237**	0,3051	**0,7933**
3	Concrete base	0,05	1	/	0,05	2380	119	1,36	0,0368	0,574926	**68,4162**	0,109891	**13,0770**	0,184899	**22,0030**	0,046	**5,4740**	3,70555E-06	**0,0004410**	0,00677773	**0,8065**
4	Water proof membrane, FATRAFOL	0,004	1	/	0,004	900	3,6	0,350	0,0114	78,2201	**281,5924**	2,1026	**7,5694**	7,9502	**28,6207**	0,6100	**2,1960**	6,9391E-07	**0,0000025**	0,41516	**1,4946**
5	Concrete slab	0,15	1	/	0,15	2380	357	1,36	0,1103	0,574926	**205,2486**	0,109891	**39,2311**	0,184899	**66,0089**	0,046	**16,4220**	3,70555E-06	**0,0013229**	0,00677773	**2,4196**
6	Separation layer - geotextil	0,0028	1	/	0,0028	55	0,154	/	/	47,5942	**7,3295**	3,0685	**0,4725**	20,1850	**3,1085**	16,3000	**2,5102**	0,00014798	**0,0000228**	0,53983	**0,0831**
7	Foam glass	0,6	1	/	0,6	110	66	0,077	7,7922	35,0611	**2 314,0326**	1,5719	**103,7454**	3,9223	**258,8718**	1,2940	**85,4040**	0,00017387	**0,0114754**	0,1733	**11,4378**
8	Gravel	0,1	1	/	0,1	1650	165	0,650	0,1538	0,1243	**20,5074**	0,0044	**0,7257**	0,0254	**4,1931**	0,0090	**1,4850**	4,8857E-07	**0,0000806**	0,0010997	**0,1815**
	Σ	**0,9168**						U =	**0,123223741**		**3 184,341098**		**180,2008**		**439,0438**		**136,9500**		**0,0152351**		**19,3393**

Variant 2: Expanded clay aggregate

Layer	Material	Thickness	Width	Number in 1 m^2	V	m		λ	R	PEI		GWP		AP		EP		ODP		POCP	
		[m]	[m]		[m^3]	[kg/m^3]	[kg/bm^2]	[W/mK]	[m^2K/W]	MJ/kg	MJ	kg CO_2 ekv./kg	kg CO_2 ekv.	g SO_2 ekv./kg	g SO_2 ekv.	g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	g R-11 ekv./kg	g R-11 ekv.	g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Indoor tiles	0,008	1	/	0,008	2000	16	1,010	0,0079	14,1064	**225,7024**	0,7817	**12,5077**	2,7697	**44,3152**	1,1610	**18,5760**	0,000091639	**0,0014662**	0,13268	**2,1229**
2	Tile adhesive	0,002	1	/	0,002	1300	2,6	0,700	0,0029	23,6585	**61,5121**	1,1046	**2,8720**	4,5856	**11,9226**	1,8780	**4,8828**	0,00016298	**0,0004237**	0,3051	**0,7933**
3	Concrete base	0,05	1	/	0,05	2380	119	1,36	0,0368	0,574926	**68,4162**	0,109891	**13,0770**	0,184899	**22,0030**	0,046	**5,4740**	3,70555E-06	**0,0004410**	0,00677773	**0,8065**
4	Water proof membrane, FATRAFOL	0,004	1	/	0,004	900	3,6	0,350	0,0114	78,2201	**281,5924**	2,1026	**7,5694**	7,9502	**28,6207**	0,6100	**2,1960**	6,9391E-07	**0,0000025**	0,41516	**1,4946**
5	Concrete slab	0,15	1	/	0,15	2380	357	1,36	0,1103	0,574926	**205,2486**	0,109891	**39,2311**	0,184899	**66,0089**	0,046	**16,4220**	3,70555E-06	**0,0013229**	0,00677773	**2,4196**
6	Separation layer - geotextil	0,0028	1	/	0,0028	55	0,154	/	/	47,5942	**7,3295**	3,0685	**0,4725**	20,1850	**3,1085**	16,3000	**2,5102**	0,00014798	**0,0000228**	0,53983	**0,0831**
7	Expanded clay aggregate	0,6	1	/	0,6	260	156	0,076	7,8947	5,0067	**781,0436**	0,3275	**51,0900**	2,3684	**369,4704**	0,2120	**33,0720**	0,000039505	**0,0061628**	0,098967	**15,4389**
8	Gravel	0,1	1	/	0,1	1650	165	0,650	0,1538	0,1243	**20,5074**	0,0044	**0,7257**	0,0254	**4,1931**	0,0090	**1,4850**	4,8857E-07	**0,0000806**	0,0010997	**0,1815**
	Σ	**0,9168**						U =	**0,121686354**		**1 651,352138**		**127,5454**		**549,6424**		**84,6180**		**0,0099225**		**23,3404**

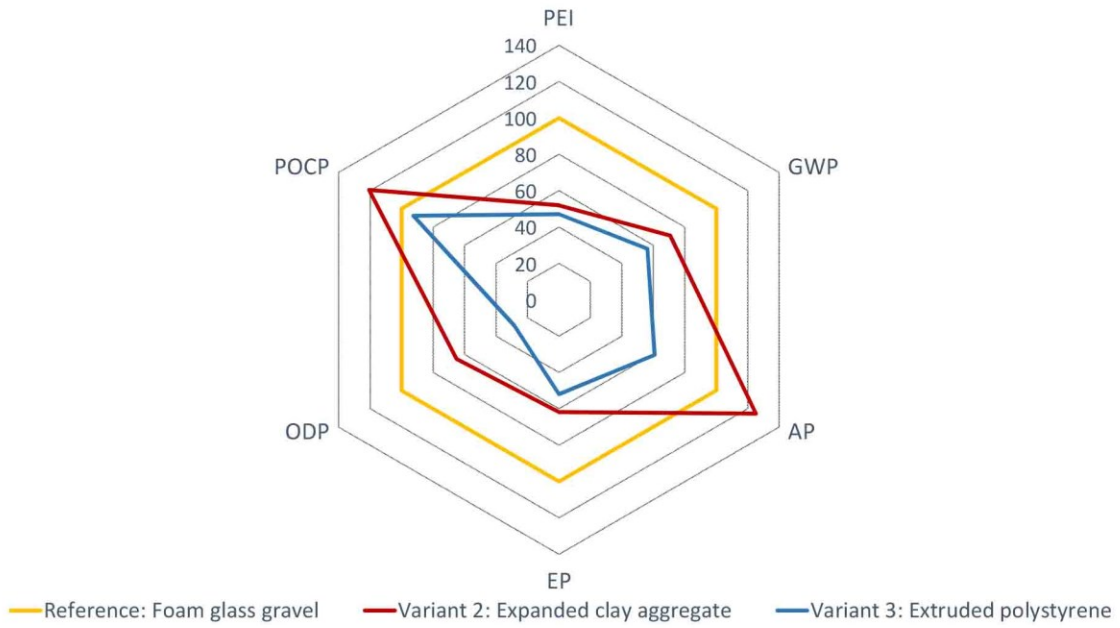
Variant 3: Extruded polystyrene

Layer	Material	Thickness	Width	Number in 1 m^2	V	m		λ	R	PEI		GWP		AP		EP		ODP		POCP	
		[m]	[m]		[m^3]	[kg/m^3]	[kg/bm^2]	[W/mK]	[m^2K/W]	MJ/kg	MJ	kg CO_2 ekv./kg	kg CO_2 ekv.	g SO_2 ekv./kg	g SO_2 ekv.	g $(PO_4)^{3-}$ ekv./kg	g $(PO_4)^{3-}$ ekv.	g R-11 ekv./kg	g R-11 ekv.	g C_2H_4 ekv./kg	g C_2H_4 ekv.
1	Indoor tiles	0,008	1	/	0,008	2000	16	1,010	0,0079	14,1064	**225,7024**	0,7817	**12,5077**	2,7697	**44,3152**	1,1610	**18,5760**	0,000091639	**0,0014662**	0,13268	**2,1229**
2	Tile adhesive	0,002	1	/	0,002	1300	2,6	0,700	0,0029	23,6585	**61,5121**	1,1046	**2,8720**	4,5856	**11,9226**	1,8780	**4,8828**	0,00016298	**0,0004237**	0,3051	**0,7933**
3	Concrete base	0,05	1	/	0,05	2380	119	1,36	0,0368	0,574926	**68,4162**	0,109891	**13,0770**	0,184899	**22,0030**	0,046	**5,4740**	3,70555E-06	**0,0004410**	0,00677773	**0,8065**
4	Water proof membrane, FATRAFOL	0,004	1	/	0,004	900	3,6	0,350	0,0114	78,2201	**281,5924**	2,1026	**7,5694**	7,9502	**28,6207**	0,6100	**2,1960**	6,9391E-07	**0,0000025**	0,41516	**1,4946**
5	Concrete slab	0,15	1	/	0,15	2380	357	1,36	0,1103	0,574926	**205,2486**	0,109891	**39,2311**	0,184899	**66,0089**	0,046	**16,4220**	3,70555E-06	**0,0013229**	0,00677773	**2,4196**
6	Separation layer - geotextil	0,0028	1	/	0,0028	55	0,154	/	/	47,5942	**7,3295**	3,0685	**0,4725**	20,1850	**3,1085**	16,3000	**2,5102**	0,00014798	**0,0000228**	0,53983	**0,0831**
7	Extruded polystyrene	0,26	1	/	0,26	25	6,5	0,034	7,6471	96,5145	**627,3443**	3,8205	**24,8333**	13,3920	**87,0480**	3,0120	**19,5780**	0,00008839	**0,0005745**	1,5365	**9,9873**
8	Gravel	0,1	1	/	0,1	1650	165	0,650	0,1538	0,1243	**20,5074**	0,0044	**0,7257**	0,0254	**4,1931**	0,0090	**1,4850**	4,8857E-07	**0,0000806**	0,0010997	**0,1815**
	Σ	**0,5768**						U =	**0,125467833**		**1 497,652748**		**101,2887**		**267,2200**		**71,1240**		**0,0043342**		**17,8887**

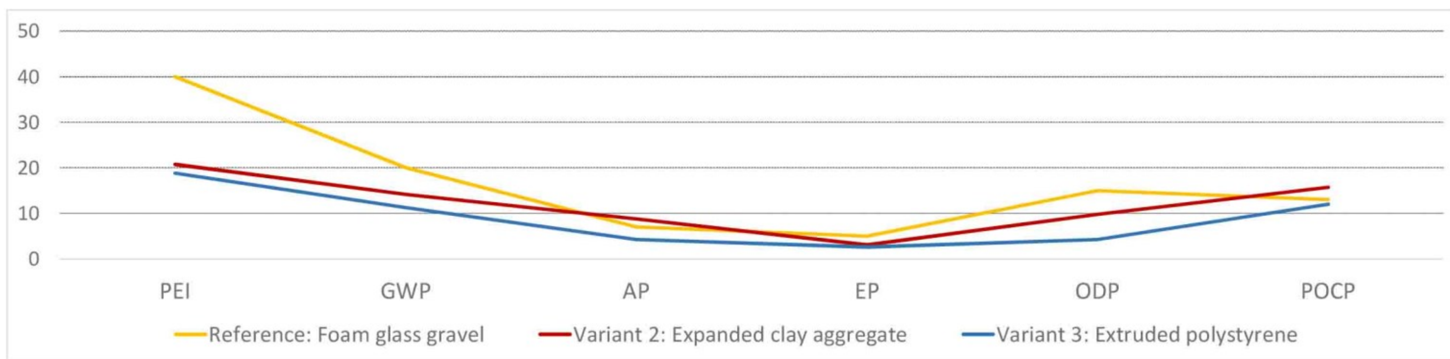
ENVIRONMENTAL PROFILE OF THE EXTERIOS WALL		Referenc	Variant 2	Variant 3
PEI	MJ	**3184,341098**	**1651,352138**	**1497,652748**
GWP	kg CO_2 ekv.	**180,200801**	**127,545401**	**101,288651**
AP	g SO_2 ekv.	**439,043839**	**549,642439**	**267,220039**
EP	g $(PO_4)^{3-}$ ekv.	**136,95**	**84,618**	**71,124**
ODP	g R-11 ekv.	**0,015235135**	**0,009922495**	**0,00433425**
POCP	g C_2H_4 ekv.	**19,3392998**	**23,3403518**	**17,8887498**

Hodnoty do grafu			
	Referenc	Variant 2	Variant 3
PEI	100	51,85851914	47,03179408
GWP	100	70,77959715	56,20876846
AP	100	125,1907874	60,86409039
EP	100	61,78751369	51,93428258
ODP	100	65,12902542	28,44904157
POCP	100	120,6887118	92,49946991

WEIGHT OF THE ENVIRONMENTAL IMPACT PARAMETERS	
PEI	40
GWP	20
AP	7
EP	5
ODP	15
POCP	13
	100



ENVIRONMENTAL IMPACT EVALUATION									
		Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS	Weights [%]	Multiplier	Referenc Wood-fibre	Variant 1 Mineral wool	Variant 2 EPS
PEI	MJ	100	51,86	47,03	40	0,4	40	20,74340766	18,8127176
GWP	kg CO_2 ekv.	100	70,78	56,21	20	0,2	20	14,15591943	11,2417537
AP	g SO_2 ekv.	100	125,19	60,86	7	0,07	7	8,763355117	4,26048633
EP	g $(PO_4)^{3-}$ ekv.	100	61,79	51,93	5	0,05	5	3,089375685	2,59671413
ODP	g R-11 ekv.	100	65,13	28,45	15	0,15	15	9,769353812	4,26735624
POCP	g C_2H_4 ekv.	100	120,69	92,50	13	0,13	13	15,68953253	12,0249311
						Σ	**100**	**72,21094423**	**53,2039591**



Annex 15: *Verification Worksheet - Space Heating and DHW Preparation by Biomass Boiler*

Passive House verification

Building:	House of Trees Průhonice
Street:	
Postcode / City:	Prague Průhonice
Country:	Czech Republic
Building type:	Multifunctional building
Climate:	[CZ] - Praha — Altitude of building site (in [m] above sea level): 292
Home owner / Client:	
Street:	
Postcode/City:	
Architecture:	Bc. Filip Sládeček
Street:	
Postcode / City:	
Mechanical system:	
Street:	
Postcode / City:	

Year of construction:	2016		Interior temperature winter:	20,0	°C	Enclosed volume V_e m³:	3120,0
No. of dwelling units:			Interior temperature summer:	26,0	°C	Mechanical cooling:	0
No. of occupants:	162,0		Internal heat sources winter:	2,8	W/m²		
Spec. capacity:	132	Wh/K per m² TFA	Ditto summer:	2,8	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	549,8	m²		
Space heating	Heating demand	**13**	**kWh/(m²a)**	15 kWh/(m²a)	**yes**
	Heating load	**12**	**W/m²**	10 W/m²	**-**
Space cooling	Overall specif. space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 26 °C)	4,3	%	-	-
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	**47**	**kWh/(m²a)**	120 kWh/(m²a)	**yes**
	DHW, space heating and auxiliary electricity	25	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity	17	kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	**0,6**	**1/h**	0,6 1/h	**yes**

* empty field: data missing; '-': no requirement

Passive House?	**yes**

Annex 16: *Verification Worksheet - Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House verification

Building:	House of Trees Průhonice						
Street:							
Postcode / City:	Prague Průhonice						
Country:	Czech Republic						
Building type:	Multifunctional building						
Climate:	[CZ] - Praha					Altitude of building site (in [m] above sea level):	292
Home owner / Client:							
Street:							
Postcode/City:							
Architecture:	Bc. Filip Sládeček						
Street:							
Postcode / City:							
Mechanical system:							
Street:							
Postcode / City:							
Year of construction:	2016		Interior temperature winter:	20,0	°C	Enclosed volume V_e m³:	3120,0
No. of dwelling units:			Interior temperature summer:	26,0	°C	Mechanical cooling:	0
No. of occupants:	162,0		Internal heat sources winter:	2,8	W/m²		
Spec. capacity:	132	Wh/K per m² TFA	Ditto summer:	2,8	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	549,8	m²		
Space heating	Heating demand	**13**	**kWh/(m²a)**	15 kWh/(m²a)	**yes**
	Heating load	**12**	**W/m²**	10 W/m²	**-**
Space cooling	Overall specif. space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 26 °C)	4,3	%	-	**-**
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	**88**	**kWh/(m²a)**	120 kWh/(m²a)	**yes**
	DHW, space heating and auxiliary electricity	55	kWh/(m²a)	-	**-**
	Specific primary energy reduction through solar electricity	26	kWh/(m²a)	-	**-**
Airtightness	Pressurization test result n_{50}	**0,6**	**1/h**	0,6 1/h	**yes**

* empty field: data missing; '-': no requirement

Passive House?	**yes**

Annex 17: *Verification Worksheet - Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House verification

Building:	House of Trees Průhonice
Street:	
Postcode / City:	Prague Průhonice
Country:	Czech Republic
Building type:	Multifunctional building
Climate:	[CZ] - Praha — Altitude of building site (in [m] above sea level): 292
Home owner / Client:	
Street:	
Postcode/City:	
Architecture:	Bc. Filip Sládeček
Street:	
Postcode / City:	
Mechanical system:	
Street:	
Postcode / City:	

Year of construction:	2016		Interior temperature winter:	20,0	°C	Enclosed volume V_e m³:	3120,0
No. of dwelling units:			Interior temperature summer:	26,0	°C	Mechanical cooling:	0
No. of occupants:	162,0		Internal heat sources winter:	2,8	W/m²		
Spec. capacity:	132	Wh/K per m² TFA	Ditto summer:	2,8	W/m²		

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	549,8	m²		
Space heating	Heating demand	**13**	**kWh/(m²a)**	15 kWh/(m²a)	**yes**
	Heating load	**12**	**W/m²**	10 W/m²	**-**
Space cooling	Overall specif. space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 26 °C)	4,3	%	-	**-**
Primary energy	Heating, cooling, dehumidification, DHW, auxiliary electricity, lighting, electrical appliances	**81**	**kWh/(m²a)**	120 kWh/(m²a)	**yes**
	DHW, space heating and auxiliary electricity	49	kWh/(m²a)	-	**-**
	Specific primary energy reduction through solar electricity	26	kWh/(m²a)	-	**-**
Airtightness	Pressurization test result n_{50}	**0,6**	**1/h**	0,6 1/h	**yes**

* empty field: data missing; '-': no requirement

Passive House?	**yes**

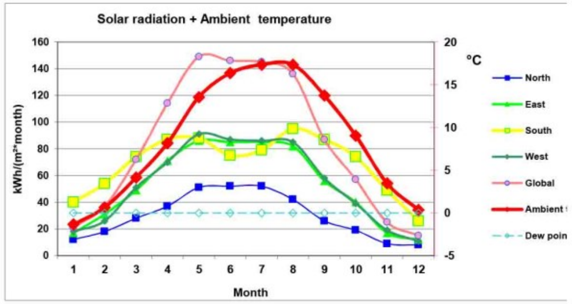
Annex 18: *Climate Worksheet*

Passive House planning: **CLIMATE DATA**

		Building:	House of Trees Průhonice
		Climate building	[CZ] - Praha
		Monthly data:	[CZ] - Praha
Region:	Central Europe	Annual data:	
		Use annual climate data set	no
Climate data set:	[CZ] - Praha	Results:	
		Annual heating demand	11,8 kWh/(m²a)
Weather station (altitude):	250,0 m	Heating load	12,3 W/m²
Building location (altitude):	292 m	Primary energy	44,3 kWh/(m²a)

Transfer to annual method (Annual Heating)

H_T	217	d/a
G_t	86	kKh/a
North	135	kWh/(m²a)
East	242	kWh/(m²a)
South	407	kWh/(m²a)
West	241	kWh/(m²a)
Horizontal	352	kWh/(m²a)



	Month	1	2	3	4	5	6	7	8	9	10	11	12	Heating load		Coolin
	Days	31	28	31	30	31	30	31	31	30	31	30	31	Weather 1	Weather 2	Weather 1
Parameters for PHPP calculated ground temperatures:	[CZ] - Praha	Latitude:	50,1	Longitude °	14,4	Altitude m	250	Daily temperature swing Summer (K)				Radiation data:	kWh/(m²month)	Radiation: W/m²		Radiatio
Phase shift months	Ambient temp	-1,4	0,6	4,1	8,1	13,5	16,3	17,3	17,3	13,7	9,0	3,4	0,3	-10,6	-1,2	24,0
0,60	North	12	18	28	37	51	52	52	42	26	19	9	8	10	5	100
Damping	East	17	31	49	71	86	85	85	82	56	40	17	12	30	5	180
-0,31	South	40	54	74	87	88	75	79	95	87	74	49	26	90	10	200
Depth m	West	18	26	51	70	91	87	86	85	58	39	19	11	35	5	180
1,00	Global	21	37	72	114	149	146	145	136	87	57	25	15	40	10	330
[CZ] - Brno	Dew point	N.a.														15,9
1,00	Sky temp	-10,1	-8,1	-4,6	-0,6	4,8	7,6	8,6	8,6	5,0	0,3	-5,3	-8,4			15,0
	Ground temp	10,3	9,8	9,8	10,3	11,2	12,1	12,9	13,4	13,4	12,9	12,0	11,1	9,3	9,3	13,9

Annex 19: *U-Values Worksheet*

Passive House planning: U-VALUES OF BUILDING ELEMENTS

Building: House of Trees Průhonice

Wedge-shaped building assemblies (tapered insulation), unventilated air layers and unheated attics

---> Auxiliary calculation to the right

Assembly no.	Building assembly description	Interior insulation?
1	Exterior wall	

Heat transfer resistance [m²K/W] interior R_{si}: 0,13 exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce wood cladding	0,180					20
2.	OSB	0,130					18
3.	Wood-fibre insulation	0,038	Spruce wood batterns	0,180			140
4.	OSB	0,130					18
5.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	160
6.	Wood-fibre insulation	0,038			Spruce wood batterns	0,180	160
7.	Vapour-permeable membra	0,350					2
8.							
	Percentage of sec. 1	75%	Percentage of sec. 2	14,5%	Percentage of sec. 3	11,0%	Total 51,8 cm

U-value supplement W/(m²K) **U-Value: 0,101** W/(m²K)

Assembly no.	Building assembly description	Interior insulation?
2	Roof	

Heat transfer resistance [m²K/W] interior R_{si}: 0,10 exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce board-on-board c	0,180					20
2.	Wood-fibre insulation	0,038	Secondary beams	0,180			200
3.	OSB	0,130					30
4.	Vapour barrier	0,350					2
5.	Wood-fibre insulation	0,038					300
6.	Water proof membrane	0,350					2
7.	Substrate	0,700					150
8.							
	Percentage of sec. 1	78%	Percentage of sec. 2	22,4%	Percentage of sec. 3		Total 70,4 cm

U-value supplement W/(m²K) **U-Value: 0,083** W/(m²K)

Assembly no.	Building assembly description	Interior insulation?
3	Floor above ground	

Heat transfer resistance [m²K/W] interior R_{si}: 0,10 exterior R_{se}: 0,00

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Indoor tiles	1,010					8
2.	Tile adhesive	0,700					2
3.	Concrete base	1,360					50
4.	Water proof membrane	0,350					4
5.	Concrete slab	1,360					150
6.	Expanded clay aggregate	0,076					600
7.	Gravel	0,650					100
8.							
	Percentage of sec. 1	100%	Percentage of sec. 2		Percentage of sec. 3		Total 91,4 cm

U-value supplement W/(m²K) **U-Value: 0,120** W/(m²K)

Assembly no.	Building assembly description					Interior insulation?
4	Partition wall					

Heat transfer resistance [m²K/W] interior R_{si}: 0,13
exterior R_{se}: 0,13

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce board-on-board c	0,180					20
2.	OSB	0,130					18
3.	cellulose fibre insulat	0,040	Solid construction	0,180			160
4.	OSB	0,130					18
5.	Spruce board-on-board c	0,180					20
6.							
7.							
8.							
	Percentage of sec. 1		Percentage of sec. 2		Percentage of sec. 3		Total
	86%		14,5%				23,6 cm

U-value supplement W/(m²K) **U-Value: 0,280** W/(m²K)

Assembly no.	Building assembly description					Interior insulation?
5	Exterior wall - south					

Heat transfer resistance [m²K/W] interior R_{si}: 0,13
exterior R_{se}: 0,04

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Spruce wood cladding	0,180					20
2.	OSB	0,130					18
3.	Wood-fibre insulation	0,038	Solid construction t	0,180			200
4.	Wood-fibre insulation	0,038			Solid construction tim	0,180	200
5.	Vapour permeable membra	0,350					2
6.							
7.							
8.							
	Percentage of sec. 1		Percentage of sec. 2		Percentage of sec. 3		Total
	83%		7,7%		9,6%		44,0 cm

U-value supplement W/(m²K) **U-Value: 0,109** W/(m²K)

Annex 20: *Areas Worksheet*

Passive House planning: **AREAS DETERMINATION**

Building: House of Trees Průhonice — Heating demand 12 kWh/(m²a)

Summary

Group Nr.	Area group	Temp.-zone	Area	Unit	Comment	Building assembly overview	Average U-Value [W/(m²K)]	Radiation-gains heating season	Radiation-load cooling period [kWh/a]
								7 months	8 months
1	Treated floor area		549,78	m²	*Treated floor area according to PHPP manual*				
2	North windows	A	10,80	m²	Results come from the 'Windows' worksheet. Window areas are subtracted from individual opaque areas. which is displayed in the "Windows" worksheet.	North windows	0,817	140	339
3	East windows	A	17,20	m²		East windows	0,747	422	1082
4	South windows	A	150,12	m²		South windows	0,670	16330	23239
5	West windows	A	6,00	m²		West windows	0,788	152	387
6	Horizontal windows	A	0,54	m²		Horizontal windows	1,154	61	174
7	Exterior door	A	0,00	m²	*Please subtract area of door from respective building assembly*	Exterior door			
8	Exterior wall - Ambient	A	364,82	m²	*Temperature zone "A" is ambient air*	Exterior wall - Ambient	0,102	23	160
9	Exterior wall - Ground	B	0,00	m²	*Temperature zone "B" is the ground*	Exterior wall - Ground			
10	Roof/Ceiling - Ambient	A	655,32	m²		Roof/Ceiling - Ambient	0,083	98	679
11	Floor slab / Basement ceiling	B	623,16	m²		Floor slab / Basement ceiling	0,120		
12			0,00	m²	*Temperature zones "A", "B","P" and "X" may be used. NOT "I"*				
13			0,00	m²	*Temperature zones "A", "B","P" and "X" may be used. NOT "I"* Factor for X				
14		X	0,00	m²	*Temperature zone "X": Please provide user-defined reduction factor (0 < ft < 1):* 75%				
						Thermal bridges - Overview	Ψ [W/(mK)]		
15	Thermal bridges Ambient	A	0,00	m	*Units in m*	Thermal bridges Ambient			
16	Perimeter thermal bridges	P	0,00	m	*Units in m; temperature zone "P" is perimeter (see Ground worksheet)*	Perimeter thermal bridges			
17	Thermal bridges FS/BC	B	0,00	m	*Units in m*	Thermal bridges FS/BC			
18	Partition wall to neighbour	I	0,00	m²	*No heat losses, only considered for the heating load calculation*	Partition wall to neighbour			
Total thermal envelope			1827,96	m²		Average therm. envelope	0,161		

Go to building components list

Area input

Sort: BY ID

Area Nr.	Building assembly description	Group Nr.	Assigned to group	Quantity	x (	a [m]	x	b [m]	+	User determined [m²]	-	User subtraction [m²]	-	Subtraction window areas [m²]	) =	Area [m²]	Selection of building element assembly / certified building system	U-Value [W/(m²K)]	Deviation from North	Angle of inclination from the horizontal	Orientation	Reduction factor shading	Exterior absorptivity	Exterior emissivity
	Treated floor area	1	Treated floor area	1	x (		x		+	549,78	-				) =	549,8								
	North windows	2	North windows	Please complete in Windows worksheet only!												10,8	From 'Windows' worksheet	0,817						
	East windows	3	East windows													17,2	From 'Windows' worksheet	0,747						
	South windows	4	South windows													150,1	From 'Windows' worksheet	0,670						
	West windows	5	West windows													6,0	From 'Windows' worksheet	0,788						
	Horizontal windows	6	Horizontal windows													0,5	From 'Windows' worksheet	1,154						
	Exterior door	7	Exterior door		x (		x		+		-		) -		=		U-value exterior door:							
1	Major ex. Wall 1	8	Exterior wall - Ambient	1	x (		x		+	21,03	-		) -	1,6	=	19,4	01ud Exterior wall	0,101	3	90	North	0,90	0,60	0,90
2	Major ex. Wall 2	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	1,6	=	19,0	01ud Exterior wall	0,101	16	90	North	0,90	0,60	0,90
3	Major ex. Wall 3	8	Exterior wall - Ambient	1	x (		x		+	7,20	-		) -	0,0	=	7,2	01ud Exterior wall	0,101	25	90	North	0,90	0,60	0,90
4	Major ex. Wall 4	8	Exterior wall - Ambient	1	x (		x		+	7,63	-		) -	0,0	=	7,6	01ud Exterior wall	0,101	47	90	East	0,90	0,60	0,90
5	Major ex. Wall 5	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	4,0	=	16,6	01ud Exterior wall	0,101	57	90	East	0,40	0,60	0,90
6	Major ex. Wall 6	8	Exterior wall - Ambient	1	x (		x		+	20,12	-		) -	4,0	=	16,1	01ud Exterior wall	0,101	70	90	East	0,40	0,60	0,90
7	Major ex. Wall 7	8	Exterior wall - Ambient	1	x (		x		+	21,10	-		) -	0,0	=	21,1	01ud Exterior wall	0,101	84	90	East	0,40	0,60	0,90
8	Major ex. Wall 8	8	Exterior wall - Ambient	1	x (		x		+	21,26	-		) -	3,2	=	18,1	01ud Exterior wall	0,101	97	90	East	0,40	0,60	0,90
9	Major ex. Wall 9	8	Exterior wall - Ambient	1	x (		x		+	20,83	-		) -	3,2	=	17,6	01ud Exterior wall	0,101	254	90	West	0,40	0,60	0,90
10	Major ex. Wall 10	8	Exterior wall - Ambient	1	x (		x		+	21,10	-		) -	0,0	=	21,1	01ud Exterior wall	0,101	269	90	West	0,40	0,60	0,90
11	Major ex. Wall 11	8	Exterior wall - Ambient	1	x (		x		+	20,12	-		) -	1,2	=	18,9	01ud Exterior wall	0,101	282	90	West	0,40	0,60	0,90
12	Major ex. Wall 12	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	1,6	=	19,0	01ud Exterior wall	0,101	295	90	West	0,40	0,60	0,90
13	Major ex. Wall 13	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	0,0	=	20,6	01ud Exterior wall	0,101	309	90	West	0,40	0,60	0,90
14	Major ex. Wall 14	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	0,0	=	20,6	01ud Exterior wall	0,101	322	90	North	0,40	0,60	0,90
15	Major ex. Wall 15	8	Exterior wall - Ambient	1	x (		x		+	20,60	-		) -	0,0	=	20,6	01ud Exterior wall	0,101	336	90	North	0,90	0,60	0,90
16	Major ex. Wall 16	8	Exterior wall - Ambient	1	x (		x		+	21,03	-		) -	1,6	=	19,4	01ud Exterior wall	0,101	349	90	North	0,90	0,60	0,90
17	Ex. Wall tree hole 1	8	Exterior wall - Ambient	1	x (		x		+	8,15	-		) -	2,0	=	6,2	01ud Exterior wall	0,101	325	90	North	0,70	0,60	0,90
18	Ex. Wall tree hole 2	8	Exterior wall - Ambient	1	x (		x		+	7,01	-		) -	2,0	=	5,0	01ud Exterior wall	0,101	355	90	North	0,70	0,60	0,90
19	Ex. Wall tree hole 3	8	Exterior wall - Ambient	1	x (		x		+	6,73	-		) -	2,0	=	4,7	01ud Exterior wall	0,101	24	90	North	0,70	0,60	0,90
20	Ex. Wall tree hole 4	8	Exterior wall - Ambient	1	x (		x		+	6,12	-		) -	2,0	=	4,1	01ud Exterior wall	0,101	51	90	East	0,70	0,60	0,90
21	Ex. Wall tree hole 5	8	Exterior wall - Ambient	1	x (		x		+	5,99	-		) -	2,0	=	4,0	01ud Exterior wall	0,101	77	90	East	0,70	0,60	0,90
22	Ex. Wall tree hole 6	8	Exterior wall - Ambient	1	x (		x		+	7,94	-		) -	2,0	=	5,9	01ud Exterior wall	0,101	108	90	East	0,70	0,60	0,90
23	Exterior wall south 1	8	Exterior wall - Ambient	1	x (		x		+	45,41	-		) -	37,5	=	7,9	05ud Exterior wall - south	0,109	199	100	South	0,50	0,60	0,90
24	Exterior wall south 2	8	Exterior wall - Ambient	1	x (		x		+	43,93	-		) -	37,5	=	6,4	05ud Exterior wall - south	0,109	184	100	South	0,50	0,60	0,90
25	Exterior wall south 3	8	Exterior wall - Ambient	1	x (		x		+	11,09	-		) -	0,0	=	11,1	05ud Exterior wall - south	0,109	208	100	South	0,50	0,60	0,90
26	Exterior wall south 4	8	Exterior wall - Ambient	1	x (		x		+	11,98	-		) -	0,0	=	12,0	05ud Exterior wall - south	0,109	144	100	South	0,50	0,60	0,90
27	Exterior wall south 5	8	Exterior wall - Ambient	1	x (		x		+	44,17	-		) -	37,5	=	6,6	05ud Exterior wall - south	0,109	153	100	South	0,50	0,60	0,90
28	Exterior wall south 6	8	Exterior wall - Ambient	1	x (		x		+	45,41	-		) -	37,5	=	7,9	05ud Exterior wall - south	0,109	168	100	South	0,50	0,60	0,90
29	Roof	10	Roof/Ceiling - Ambient	1	x (		x		+	655,86	-		) -	0,5	=	655,3	02ud Roof	0,083	0	2	Hor	0,50	0,80	0,90
30	Floor above ground	11	Floor slab / Basement ceiling	1	x (		x		+	623,16	-		) -	0,0	=	623,2	03ud Floor above ground	0,120	0	0	Hor	0,00	0,80	0,90

Annex 21: *Ground Worksheet*

Passive House planning: **HEAT LOSSES THROUGH THE GROUND**

Building section 1

Ground characteristics			
Thermal conductivity	λ	2,0	W/(mK)
Heat capacity	ρc	2,0	MJ/(m³K)
Periodic penetration depth	δ	3,17	m

Climate data			
Avg indoor temp. winter	T_i	20,0	°C
Avg indoor temp. summer	T_i	26,0	°C
Avg ground surface temperature	$T_{g,ave}$	9,6	°C
Amplitude of $T_{g,ave}$	$T_{g,\wedge}$	9,4	°C
Phase shifting of $T_{e,m}$	τ	1,0	Months
Length of the heating period	n	7,1	Months
Heating degree hours - exterior	G_t	85,6	kKh/a

Building data							
Area of ground floor slab / basement ceiling	A	623,2	m²	U-value floor slab/basement ceiling	U_f	0,120	W/(m²K)
Perimeter length	P	109,9	m	TBs floor slab / basement ceiling	Ψ_B*l	0,00	W/K
Charact. dimension of floor slab	B'	11,34	m	U-value floor slab / basement ceiling incl. TBs	U_f'	0,120	W/(m²K)
				Equivalent thickness floor	d_t	16,64	m

Floor slab type (select only one)

x	Slab on grade							
	Perimeter insulation width/depth	D	900,00	m	Orientation of perimeter insulation	horizontal		
	Perimeter insulation thickness	d_n	280,00	m	(check only one field)	vertical	x	
	Conductivity perimeter insulation	λ_n	0,040	W/(mK)				

	Heated basement or floor slab completely / partially below ground level							
	Basement wall height below ground level	z		m	U-Value wall below ground	U_{wB}		W/(m²K)

	Unheated basement							
	Height aboveground wall	h		m	U-Value wall above ground	U_W		W/(m²K)
	Basement wall height below ground level	z		m	U-Value wall below ground	U_{WB}		W/(m²K)
	Air change unheated basement	n		h^{-1}	U-Value basement floor slab	U_{fB}		W/(m²K)
	Air flow basement	V		m³				

	Suspended floor above a ventilated crawl space (at max. 0.5 m below ground)							
	U-Value crawl space	U_{Crawl}		W/(m²K)	Area of ventilation openings	εP		m²
	Height of crawl space wall	h		m	Wind velocity at 10 m height	v	4,0	m/s
	U-Value crawl space wall	U_W		W/(m²K)	Wind shield factor	f_W	0,05	-

Additional thermal bridge heat losses at perimeter							
				Steady-state fraction	$\Psi_{P,stat}$*l	0,000	W/K
Phase shift	β		Months	Harmonic fraction	$\Psi_{P,harm}$*l	0,000	W/K

Groundwater correction							
Depth of the groundwater table	z_W	3,0	m	Groundwater correction factor	G_W	-25,4975551	-
Groundwater flow rate	q_W	0,05	m/d				

Interim results

Phase shift	β	1,43 Months	Steady-state heat flow	Φ_{stat}	781,8 W
Steady-state transmittance	L_S	74,92 W/K	Periodic heat flow	Φ_{harm}	0,1 W
Exterior periodic transmittance	L_{pe}	0,02 W/K	Heat losses during heating period	Q_{tot}	4075 kWh
Transmittance building	L_0	74,92 W/K			

Monthly average temperatures in the ground for monthly method (building assembly 1)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average value
Winter	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6
Summer	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6

Design ground temperature for 'Heating load' worksheet 9,6 **For 'Cooling load' worksheet** 9,6

Reduction factor for 'Annual heating' worksheet 0,64

Total result (all building parts)

Phase shift	β	1,43 Months	Steady-state heat flow	Φ_{stat}	781,8 W
Steady-state transmittance	L_S	74,92 W/K	Periodic heat flow	Φ_{harm}	0,1 W
Exterior periodic transmittance	L_{pe}	0,02 W/K	Heat losses during heating period	Q_{tot}	4075 kWh
Transmittance building	L_0	74,92 W/K	Charact. dimension of floor slab	B'	11,34 m

Monthly Average temperatures in the ground for monthly method (all building assemblies)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average value
Winter	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6
Summer	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6	9,6

Design ground temperature for 'Heating load' worksheet 9,6 **For 'Cooling load' worksheet** 9,6

Reduction factor for 'Annual heating' worksheet **0,64**

Passive House planning: PASSIVE HOUSE - COMPONENT

Go to: 'AREAS'
Glazing
Window frame

http://www.passiv.de/komponentendatenbank/en-EN
Ventilation units
Compact units

Building assemblies (U-Values)

ID	Building system	Building assembly	Total thickness	U-Value	Interior insulation
		1			
	Summary of the constructions calculated in 'U values' worksheet		m	W/(m²K)	-
01ud	Exterior wall	Exterior wall	0,518	0,101	
02ud	Roof	Roof	0,704	0,083	
03ud	Floor above ground	Floor above ground	0,914	0,120	
04ud	Partition wall	Partition wall	0,236	0,280	
05ud	Exterior wall - south	Exterior wall - south	0,440	0,109	
06ud					
07ud					
08ud					
09ud					
10ud					

Glazing

ID	Description	g-Value	U_g-Value
			W/(m²K)
01ud			
02ud	Saint-Gobain Glass Germany - SGG PLANITHERM ULTRA N II (4:/18	0,50	0,53
03ud			
04ud			
05ud			
06ud			
07ud			
08ud			
09ud			
10ud			

Window frames

ID	Description	U_f-Value				Frame width				Glazing edge thermal bridge				Installation thermal bridge				Curtain wall facades:
		left	right	bottom	above	left	right	bottom	above	$\Psi_{Glazing\ edge}$ left	$\Psi_{Glazing\ edge}$ right	$\Psi_{Glazing\ edge}$ bottom	$\Psi_{Glazing\ edge}$ top	$\Psi_{Installation}$ left	$\Psi_{Installation}$ right	$\Psi_{Installation}$ bottom	$\Psi_{Installation}$ top	χ_{GC}-value Glass carrier
		W/(m²K)	W/(m²K)	W/(m²K)	W/(m²K)	m	m	m	m	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/K
01ud	Variotec - Energyframe - with Thermix	0,73	0,73	0,73	0,73	0,127	0,127	0,145	0,127	0,031	0,031	0,031	0,031	0,040	0,040	0,040	0,040	
02ud	MBJ Fassadentechnik - System Holz - PH - with Swisspacer V	0,97	0,97	0,97	0,97	0,025	0,025	0,025	0,025	0,034	0,034	0,034	0,034	0,070	0,070	0,070	0,070	0,004
03ud																		
04ud																		
05ud																		
06ud																		
07ud																		
08ud																		
09ud																		
10ud																		

Ventilation units with heat recovery

ID	Description	Heat recovery efficiency	Electric efficiency	Additional Device Data: Entry area		External pressure per line	Fittings Dpintern	Frost protection required	Noise protection			Additional info
	User defined area	%	Wh/m³	m³/h	m³/h	Pa	Pa		35 dB(A)	Supply air dB(A)	Extract air dB(A)	
01ud												
02ud	ComfoAir XL 6000 - Zehnder	85%	0,42	2000	4000	308	93	yes	–	83	73	-
03ud												
04ud												
05ud												
06ud												
07ud												
08ud												
09ud												
10ud												

Annex 23: *Windows Worksheet*

Passive House planning: **REDUCTION FACTOR SOLAR RADIATION, WINDOW U-VALUE**

Building: House of Trees Průhonice | Annual heating demand: 12 kWh/(m²a) | Heating degree hours: 85,6

Climate: [CZ] - Praha Window area orientation	Global radiation (cardinal points)	Shading	Dirt	Non-perpendicular incident radiation	Glazing fraction	g-Value	Solar irradiation reduction factor	Window area	Window U-Value	Glazing area	Average global radiation	Transmission losses	Heat gains solar radiation
maximum:	kWh/(m²a)	0,75	0,95	0,85				m²	W/(m²K)	m²	kWh/(m²a)	kWh/a	kWh/a
North	135	0,38	0,95	0,85	0,620	0,50	0,19	10,80	0,82	6,70	140	755	144
East	242	0,41	0,95	0,85	0,711	0,50	0,24	17,20	0,75	12,23	212	1099	432
South	407	0,82	0,95	0,85	0,953	0,50	0,63	150,12	0,67	143,11	345	8606	16283
West	241	0,40	0,95	0,85	0,657	0,50	0,21	6,00	0,79	3,94	246	405	156
Horizontal	352	0,96	0,95	0,85	0,866	0,50	0,67	0,54	1,15	0,47	345	53	63
		Total or average value for all windows.				0,50	0,55	184,66	0,69	166,44		10918	17079

Go to glazing list | Go to window frames list

If there are diagonal windows in the project please adapt the Ug value manually!

Quantity	Description	Deviation from north	Angle of inclination from the horizontal	Orientation	Window rough openings: Width	Window rough openings: Height	Installed in: Selection from 'Areas' worksheet	Glazing: Selection from 'Components' worksheet	Frame: Selection from 'Components' worksheet	g-Value: Perpendicular radiation	U-Value: Glazing	U-Value: Frames (avg.)	Ψ Glazing edge: $\Psi_{Glazing\ edge}$ (avg.)	Installation situation: left	right	bottom	top	$\Psi_{Installation}$ (avg.)	Results: Window Area	Glazing Area	U-Value Window	Glazed fraction per window	Transmission losses	Solar gains
		Degrees	Degrees		m	m		Sort: AS LIST	Sort: AS LIST	-	W/(m²K)	W/(m²K)	W/(mK)	W/(mK) or 1/0				W/(mK)	m²	m²	W/(m²K)	%	kWh/a	kWh/a
1	Exterior w. 1	2,83	90	North	0,800	2,000	1-Major ex. Wall 1	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	1,6	0,94	0,84	59%	115	19
1	Exterior w. 2	16,41	90	North	0,800	2,000	2-Major ex. Wall 2	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	1,6	0,94	0,84	59%	115	20
1	Exterior w. 5	56,71	90	East	2,000	2,000	5-Major ex. Wall 5	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	4,0	3,02	0,71	75%	244	94
1	Exterior w. 6	69,98	90	East	2,000	2,000	6-Major ex. Wall 6	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	4,0	3,02	0,71	75%	244	104
1	Exterior d. 8	97	90	East	1,600	2,000	8-Major ex. Wall 8	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	3,2	2,33	0,73	73%	201	101
1	Exterior d. 9	254,47	90	West	1,600	2,000	9-Major ex. Wall 9	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	3,2	2,33	0,73	73%	201	110
1	Exterior w. 11	281,93	90	West	0,800	1,500	11-Major ex. Wall 11	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	1,2	0,67	0,86	56%	89	20
1	Exterior d. 12	295,34	90	West	0,800	2,000	12-Major ex. Wall 12	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	1,6	0,94	0,84	59%	115	26
1	Exterior d. 16	349,12	90	North	0,800	2,000	16-Major ex. Wall 16	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	1,6	0,94	0,84	59%	115	19
1	Exterior w TH1	324,62	90	North	1,000	2,000	17-Ex. Wall tree hole 1	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	30
1	Exterior w TH2	355,39	90	North	1,000	2,000	18-Ex. Wall tree hole 2	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	28
1	Exterior w TH3	24	90	North	1,000	2,000	19-Ex. Wall tree hole 3	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	29
1	Exterior w TH4	51	90	East	1,000	2,000	20-Ex. Wall tree hole 4	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	34
1	Exterior w TH5	77	90	East	1,000	2,000	21-Ex. Wall tree hole 5	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	42
1	Exterior w TH6	107,59	90	East	1,000	2,000	22-Ex. Wall tree hole 6	02ud Saint-Gobain Glass Germany - SGG I	01ud Variotec - Energyframe - with Therm	0,50	0,53	0,73	0,031	1	1	1	1	0,040	2,0	1,29	0,80	64%	137	57
6	Exter. south1	198,84	100	South	1,390	4,500	23-Exterior wall south 1	02ud Saint-Gobain Glass Germany - SGG I	02ud MBJ Fassadentechnik - System Holz	0,50	0,53	0,97	0,034	0	0	1	1	0,070	37,5	35,78	0,64	95%	2071	4035
6	Exter. south2	183,67	100	South	1,390	4,500	24-Exterior wall south 2	02ud Saint-Gobain Glass Germany - SGG I	02ud MBJ Fassadentechnik - System Holz	0,50	0,53	0,97	0,034	0	1	1	1	0,070	37,5	35,78	0,69	95%	2232	4233
6	Exter. south5	153,16	100	South	1,390	4,500	27-Exterior wall south 5	02ud Saint-Gobain Glass Germany - SGG I	02ud MBJ Fassadentechnik - System Holz	0,50	0,53	0,97	0,034	1	0	1	1	0,070	37,5	35,78	0,69	95%	2232	3850
6	Exter. south6	168,33	100	South	1,390	4,500	28-Exterior wall south 6	02ud Saint-Gobain Glass Germany - SGG I	02ud MBJ Fassadentechnik - System Holz	0,50	0,53	0,97	0,034	0	0	1	1	0,070	37,5	35,78	0,64	95%	2071	4164
1	Skylight	0	1,5	Horizontal	0,600	0,900	29-Roof	02ud Saint-Gobain Glass Germany - SGG I	02ud MBJ Fassadentechnik - System Holz	0,50	0,53	0,97	0,034	1	1	1	1	0,070	0,5	0,47	1,15	87%	53	63

Installation situation: user-defined value for $\Psi_{Installation}$ or '1': $\Psi_{Installation}$ from 'Components' worksheet, '0': in the case of abutting windows

Results: U- and Ψ-values from 'Components' worksheet can be shown through clicking the '+' sign on the top edge of the sheet.

Annex 24: *Shading Worksheet*

Passive House planning: CALCULATING SHADING FACTORS

Climate: [CZ] - Praha

Building: House of Trees Průhonice

Latitude: 50,1 °

Orientation	Glazing area	Reduction factor winter	Reduction factor summer
	m²	r_{Sw}	r_{Ss}
North	6,70	44%	29%
East	12,23	48%	33%
South	143,11	81%	67%
West	3,94	46%	33%
Horizontal	0,47	96%	97%

Space heating demand:	12,3	kWh/(m²a)
Useful cooling demand:	2,3	kWh/(m²a)
Frequency of overheating:	5,5%	

Quantity	Description	Deviation from North	Angle of inclination from the horizontal	Orientation	Glazing width	Glazing height	Glazing area	Horizon: Height of the shading object	Horizon: Horizontal distance	Reveal: Window reveal depth	Reveal: Distance from glazing edge to reveal	Overhang: Overhang depth	Overhang: Distance from upper glazing edge to overhang	Additional reduction factor winter shading	Additional reduction factor summer shading	Reduction factor z for temporary sun protection
		Degrees	Degrees		m	m		m	m	m	m	m	m	%	%	%
					w_G	h_G	A_G	h_{Hori}	d_{Hori}	o_{Reveal}	d_{Reveal}	o_{over}	d_{over}	$r_{other,w}$	$r_{other,s}$	z
1	Exterior w. 1	3	90	North	0,55	1,73	0,9	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w. 2	16	90	North	0,55	1,73	0,9	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w. 5	57	90	East	1,75	1,73	3,0	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w. 6	70	90	East	1,75	1,73	3,0	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior d. 8	97	90	East	1,35	1,73	2,3	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior d. 9	254	90	West	1,35	1,73	2,3	4,00	28,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w. 11	282	90	West	0,55	1,23	0,7	4,00	28,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior d. 12	295	90	West	0,55	1,73	0,9	4,00	28,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior d. 16	349	90	North	0,55	1,73	0,9	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH1	325	90	North	0,75	1,73	1,3	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH2	355	90	North	0,75	1,73	1,3	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH3	24	90	North	0,75	1,73	1,3	8,00	39,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH4	51	90	East	0,75	1,73	1,3	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH5	77	90	East	0,75	1,73	1,3	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
1	Exterior w TH6	108	90	East	0,75	1,73	1,3	5,00	35,00	0,32	0,127	0,00	0,00	65%	40%	
6	Exter. south1	199	100	South	1,34	4,45	35,8	4,00	28,00	0,22	0,010	2,06	1,33	100%	100%	
6	Exter. south2	184	100	South	1,34	4,45	35,8	4,00	28,00	0,22	0,010	2,06	1,33	100%	100%	
6	Exter. south5	153	100	South	1,34	4,45	35,8	4,00	28,00	0,22	0,010	2,06	1,33	100%	100%	
6	Exter. south6	168	100	South	1,34	4,45	35,8	4,00	28,00	0,22	0,010	2,06	1,33	100%	100%	
1	Skylight	0	2	Horizontal	0,55	0,85	0,5	0,62	0,80							

Description	Winter: Horizontal shading reduction factor	Winter: Reveal shading reduction factor	Winter: Overhang shading reduction factor	Winter: Total shading reduction factor	Summer: Horizontal shading reduction factor	Summer: Reveal shading reduction factor	Summer: Overhang shading reduction factor	Summer: Total shading reduction factor
	%	%	%	%	%	%	%	%
	r_H	r_R	r_O	r_S	r_H	r_R	r_O	r_S
Exterior w. 1	84%	80%	100%	44%	85%	82%	100%	28%
Exterior w. 2	84%	79%	100%	43%	85%	82%	100%	28%
Exterior w. 5	88%	88%	100%	50%	90%	94%	100%	34%
Exterior w. 6	88%	87%	100%	50%	90%	95%	100%	34%
Exterior d. 8	88%	84%	100%	48%	90%	94%	100%	34%
Exterior d. 9	88%	85%	100%	48%	91%	94%	100%	34%
Exterior w. 11	87%	72%	100%	41%	90%	88%	100%	32%
Exterior d. 12	88%	73%	100%	42%	90%	87%	100%	31%
Exterior d. 16	84%	80%	100%	44%	85%	82%	100%	28%
Exterior w TH1	84%	81%	100%	44%	86%	87%	100%	30%
Exterior w TH2	84%	83%	100%	46%	85%	85%	100%	29%
Exterior w TH3	84%	82%	100%	45%	85%	86%	100%	29%
Exterior w TH4	88%	79%	100%	45%	90%	88%	100%	32%
Exterior w TH5	87%	76%	100%	43%	90%	90%	100%	33%
Exterior w TH6	88%	77%	100%	44%	91%	90%	100%	33%
Exter. south1	95%	93%	92%	81%	95%	92%	78%	67%
Exter. south2	96%	93%	93%	83%	95%	91%	77%	66%
Exter. south5	94%	92%	91%	79%	94%	92%	79%	68%
Exter. south6	96%	93%	92%	82%	95%	91%	77%	67%
Skylight	96%	100%	100%	96%	97%	100%	100%	97%

Annex 25: *Ventilation Worksheet*

Passive House planning: **VENTILATION DATA**

Building: House of Trees Průhonice

Treated floor area A_{TFA}		m²	550	(Areas worksheet)
Room height h		m	4,00	
Volume for ventilation (A_{TFA}*h) =	V_V	m³	2199	(Worksheet Annual heating)

Type of ventilation system

x	Balanced PH ventilation	Please check
	Pure extract air	

Infiltration air change rate

Wind protection coefficients e and f		
Coefficient e for screening class	Several sides exposed	One side exposed
No screening	0,10	0,03
Moderate screening	0,07	0,02
High screening	0,04	0,01
Coefficient f	15	20

			For annual demand:	For heating load:				
Wind protection coefficient, e			0,07	0,18				
Wind protection coefficient, f			15	15	Net air volume for press. test	V_{n50}	Air permeability	q_{50}
Air change rate at press. test	n_{50}	1/h	0,60	0,60	2199	m³	0,72	m³/(hm²)

			For annual demand:	For heating load:
Excess extract air		1/h	0,00	0,00
Infiltration air change rate	$n_{V,Rest}$	1/h	0,042	0,105

Selection of ventilation data input - Results

The PHPP offers two methods for dimensioning the air quantities and choosing the ventilation unit. Fresh air or extract air quantities for residential buildings and parameters for ventilation systems can be determined using the standard planning option in the 'Ventilation' sheet. The 'Additional Vent' sheet has been created for more complex ventilation systems and allows up to 10 different ver
Furthermore, air quantities can be determined on a room-by-room or zone-by-zone basis. Please select your design method here.

	Ventilation unit / Heat recovery efficiency design		Average air exchange	Average air change rate	Extract air excess (Extract air system)	Effective heat recovery efficiency unit	Specific power input	Heat recovery efficiency SHX
	Standard design	(Ventilation worksheet see below)						
x	Multiple vent. units, non-res buildings	(Worksheet Additional vent)	m³/h	1/h	1/h	[-]	Wh/m³	
			646	0,29	0,00	84,9%	0,42	0,0%

SHX efficiency η^*_{SHX} 0%

Annex 26: *Additional Ventilation Worksheet*

Passive House planning: **EXTENDED DATA INPUT FOR BALANCED VENTILATION**

Planning ventilation systems with multiple ventilation units

Building: House of Trees Průhonice

Ventilation unit / Heat recovery efficiency design			
In Ventilation sheet (standard design)			*(Ventilation worksheet)*
In Additional Vent sheet (this sheet)		x	*(Additional vent)*
Treated floor area A_{TFA}	m²	550	*(Areas worksheet)*
Room height h	m	4,00	*(Worksheet Annual heating)*
Room air volume for ventilation (A_{TFA}*h) = V_V	m³	2199	*(Worksheet Annual heating)*
Number of occupants	P	162,0	*(Ventilation worksheet)*
Room temperature	°C	20	*(Worksheet Annual heating)*
Average external temp. heating period	°C	4,1	*(Ventilation worksheet)*
Average ground temp.	°C	9,6	*(Ground worksheet)*
Ventilation type			
Balanced PH ventilation		x	*(Ventilation worksheet)*
Pure extract air			*(Ventilation worksheet)*

Results of ventilation design and unit selection:

Venti-lation Unit no.	Description of the unit	Design V_{SUP} m³/h	Design V_{ETA} m³/h	Average value / yr. V_{SUP} m³/h	Average value / yr. V_{ETA} m³/h	Air ch.rt. 1/h	Effective heat recovery efficiency	Spec. input power	Heat recov. efficiency SHX
1	Ventilation 1	2916	2916	775	775	---	84,9%	0,42	0%
2						---			
3						---			
4						---			
5						---			
6						---			
7						---			
8						---			
9						---			
10						---			
Result for overall vent. syst.		**2916**	**2916**	**775**	**775**	**0,35**	**84,9%**	**0,42**	**0%**

Recommendations for dimensioning air quantities

Use of low odour and low-emission building materials/ furnishings:
It is strongly recommended to use building materials that cause no or only little pollution instead of increasing the outdoor air volume flow in order to reduce preventable pollution.
This holds true independently from the chosen approach for the air quality determination; emissions of all sources in the room should be considered, e.g. furniture, carpets and ventilation or air-conditioning unit.

Assessment of volume flow rates according to the number of persons
Also in non-residential buildings, the number of persons is fundamentally important for assessing the volume air flow rates. For good indoor air quality the amounts of 20 to 30 m³/h/person are completely sufficient.
Higher outdoor air amounts may lead to excessively dry indoor air in winter. The air flow rates are specified by classification according to EN 13779. The classification must be agreed with the client in advance.
IDA 3 is adequate for office buildings. IDA 4 has proven satisfactory for school buildings as purge ventilation is carried out during breaks anyway. For typical external air CO2 concentrations of around 400-500 ppm, it is possible to comply even with 1500 ppm. Exceeding this figure temporarily is permissible.

Fresh air flow rates per person:
- Recommended for residential buildings: around 30 m³/(h person)
- Recommended for offices and similar uses: around 30 m³/(h person) (AMEV: 28 m³/(h person); EN 13779 / IDA 3: at least 24 m³/(h person))
- Recommended for schools and day care centres: 15 to 20 m³/(h person) (Source: Guidelines for energy-efficient educational buildings, Passive House Institute, 2010)
- Recommendation for sport halls: 60 m³/(h person) (DIN 18032-1)

Purging phase for intermittent ventilation operation
Due to the purge ventilation phase, the ventilation operation period is extended accordingly (utilisation time + purge ventilation phase). Please consider this for the ventilation design.
Emissions have to be removed. Flushing the building prolongs the utilization time of the ventilation system (utilization time + flushing phase). Please consider this at design stage.

Design of air quantities
When designing the air quantities, please consider the design recommendations given above.
The ventilation operation period can be determined on the basis of the daily utilisation hours including purging phase if applicable. In addition, time periods with reduced ventilation requirements (operation modes) can be
Taken into account by means of reduction factors.

Room nr.	Amount a	Room name	Assignment to ventilation unit (by number)	Area A m²	Clear height h m	Room vol. A x h m³	Volume flow per room V_{SUP} m³/h	Volume flow per room V_{ETA} m³/h	Volume flow per room V_{TRANS} m³/h	Air chng. rate per room n 1/h	Utilisation times h/d h	Utilisation times d/week d	Utilisation times weeks/yr Weeks	Reduction Red.1	Operation Red. 1	Reduction Red.2	Operation Red.2	Reduction Red.3	Operation Red. 3	Cross check	Average volume flows V_{SUP} m³/h	Average volume flows V_{ETA} m³/h	Average volume flows V_{TRANS} m³/h	Average air change rate 1/h
1	1	HoT	1	570	4,00	2280	2916	2916		1,28	9	6	43	100%	100%						775	775		0,34

Annex 27: *Annual Heating Worksheet*

Passive House planning: **SPECIFIC ANNUAL HEATING DEMAND (annual method)**

Climate:	[CZ] - Praha	Interior temperature:	20,0	°C
Building:	House of Trees Průhonice	Building type:	Multifunctional building	
		Treated floor area A_{TFA}:	549,8	m²

Building assembly	Temperature zone	Area m²		U-Value W/(m²K)		Temp. factor f_t		G_t kKh/a		kWh/a	per m² treated floor area
Exterior wall - Ambient	A	364,8	*	0,102	*	1,00	*	85,6	=	3191	5,80
Exterior wall - Ground	B		*		*	0,64	*		=		
Roof/Ceiling - Ambient	A	655,3	*	0,083	*	1,00	*	85,6	=	4651	8,46
Floor slab / Basement ceiling	B	623,2	*	0,120	*	0,64	*	85,6	=	4075	7,41
	A		*		*	1,00	*		=		
	A		*		*	1,00	*		=		
	X		*		*	0,75	*		=		
Windows	A	184,7	*	0,691	*	1,00	*	85,6	=	10918	19,86
Exterior door	A		*		*	1,00	*		=		
Exterior TB (length/m)	A		*		*	1,00	*		=		0,00
Perimeter TB (length/m)	P		*		*	0,64	*		=		0,00
Ground TB (length/m)	B		*		*	0,64	*		=		0,00
Total of all building envelope areas		1828,0									kWh/(m²a)
Transmission heat losses Q_T									Total	22834	41,5

					A_{TFA} m²		Clear room height m		m³		
Ventilation system:	Effective air volume, VV				549,8	*	4,00	=	2199,1		
Effective heat recovery efficiency of heat recovery	η_{eff}	85%									
Efficiency of subsoil heat exchanger	η_{SHX}	0%		$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h	
	Energetically effective air exchange nV			0,410	* (1 -	0,85	) +	0,042	=	0,104	
		V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation heat losses Q_V		2199,1	*	0,104	*	0,33	*	85,6	=	6441	11,7

		Q_T kWh/a		Q_V kWh/a		Reduction factor night/weekend Saving		kWh/a	kWh/(m²a)
Total heat losses Q_L	(	22834	+	6441	)	1,0	=	29275	53,2

Orientation of the area	Reduction factor See 'Windows' sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1. North	0,22	*	0,50	*	10,80	*	140	=	168	
2. East	0,27	*	0,50	*	17,20	*	212	=	499	
3. South	0,63	*	0,50	*	150,12	*	345	=	16178	
4. West	0,24	*	0,50	*	6,00	*	246	=	180	
5. Horizontal	0,67	*	0,50	*	0,54	*	345	=	63	
Available solar heat gains Q_S								Total	17088	31,1

	kh/d		Length heating period d/a		Spec. power ql W/m²		A_{TFA} m²	kWh/a	kWh/(m²a)
Internal heat gains Q_I	0,024	*	217	*	2,80	*	549,8 =	8022	14,6
			Free heat QF				Q_S + Q_I =	25110	45,7
			Ratio of free heat to losses				Q_F / Q_V =	0,86	
Utilisation factor heat gains hG			$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$ =					89%	
Heat gains Q_G							η_G * Q_F =	22354	40,7
Annual heating demand Q_H							Q_L - Q_G =	6921	13

Limiting value	15 kWh/(m²a)	Requirement met? (Yes/No)	yes

Annex 28: *Heating Worksheet*

Passive House planning: **SPECIFIC ANNUAL HEATING DEMAND (monthly method)**

(This page displays the sums of the monthly method over the heating period)

Climate: [CZ] - Praha | Interior temperature: 20 °C

Building: House of Trees Průhonice | Building type: Multifunctional building

Spec. Capacity: 132 Wh/(m²K) | Treated floor area A_{TFA}: 549,8 m²

Building assembly	Temperature zone	Area m²		U-Value W/(m²K)		Month. red. fac.		G_t kKh/a		kWh/a	per m² treated floor area
Exterior wall - Ambient	A	364,8	*	0,102	*	1,00	*	85	=	3176	5,78
Exterior wall - Ground	B		*		*	1,00	*		=		
Roof/Ceiling - Ambient	A	655,3	*	0,083	*	1,00	*	85	=	4629	8,42
Floor slab / Basement ceiling	B	623,2	*	0,120	*	1,00	*	53	=	3978	7,24
	A		*		*	1,00	*		=		
	A		*		*	1,00	*		=		
	X		*		*	0,75	*		=		
Windows	A	184,7	*	0,691	*	1,00	*	85	=	10866	19,76
Exterior door	A		*		*	1,00	*		=		
Exterior TB (length/m)	A		*		*	1,00	*		=		0,00
Perimeter TB (length/m)	P		*		*	1,00	*		=		0,00
Ground TB (length/m)	B		*		*	1,00	*		=		0,00
Transmission heat losses Q_T									Total	22648	41,2 kWh/(m²a)

	A_{TFA} m²		Clear room height m		m³
Effective air volume V_V	550	*	4,00	=	2199

	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HR}		$n_{V,Res}$ 1/h		$n_{V,equi,fraction}$ 1/h
Effective air change rate Ambient nV,e	0,410	*(1-	0%	)*(1-	0,85	)+	0,042	=	0,104
Effective air change rate Ground nV,g	0,410	*	0%	*(1-	0,85	)		=	0,000

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation losses ambient Q_V	2199	*	0,104	*	0,33	*	85	=	6410	11,7
Ventilation losses ground $Q_{V,e}$	2199	*	0,000	*	0,33	*	53	=	0	0,0
Ventilation heat losses Q_V								Total	6410	11,7

		Q_T kWh/a		Q_V kWh/a		Reduction factor night/weekend saving		kWh/a	kWh/(m²a)
Total heat losses Q_L	(	22648	+	6410	) *	1,0	=	29058	52,9

Orientation of the area	Reduction factor See 'Windows' sheet		g-Value (perp. radiation)		Area m²		Global radiation kWh/(m²a)		kWh/a	kWh/(m²a)
North	0,22	*	0,50	*	10,8	*	136	=	162	
East	0,27	*	0,50	*	17,2	*	207	=	487	
South	0,63	*	0,50	*	150,1	*	346	=	16225	
West	0,24	*	0,50	*	6,0	*	240	=	176	
Horizontal	0,67	*	0,50	*	0,5	*	334	=	61	
Sum opaque areas									497	
Available solar heat gains Q_S								Total	17608	32,0

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal heat gains Q_I	0,024	*	212	*	2,8	*	549,8	=	7832	14,2

			kWh/a	kWh/(m²a)
Free heat Q_F	Q_S + Q_I	=	25440	46,3
Ratio free heat to losses	Q_F / Q_L	=	0,88	
Utilisation factor heat gains h_G		=	86%	
Heat gains Q_G	η_G * Q_F	=	21868	39,8
Annual heating demand Q_H	Q_L - Q_G	=	7190	13

	kWh/(m²*a)		(Yes/No)
Limiting value	15	Requirement met?	yes

Annex 29: *Heating Load Worksheet*

Passive House planning: **SPECIFIC SPACE HEATING LOAD**

Building: House of Trees Průhonice — Building type: Multifunctional building

Climate (HL): [CZ] - Praha — Treated floor area A_{TFA}: 549,8 m² — Interior temperature: 20 °C

	Design temperature		Radiation:	North	East	South	West	Horizontal	
Weather 1:	-10,6	°C		10	30	90	35	40	W/m²
Weather 2:	-1,2	°C		5	5	10	5	10	W/m²
Ground design temp.	9,6	°C							

	Building assembly	Temperature zone	Area		U-Value		Factor always 1 (except "X")		TempDiff 1		TempDiff 2		PT 1		PT 2
			m²		W/(m²K)				K		K		W		W
1.	Exterior wall - Ambient	A	364,8	*	0,102	*	1,00	*	30,6	or	21,2	=	1139	or	792
2.	Exterior wall - Ground	B		*		*	1,00	*	10,4	or	10,4	=		or	
3.	Roof/Ceiling - Ambient	A	655,3	*	0,083	*	1,00	*	30,6	or	21,2	=	1661	or	1155
4.	Floor slab / Basement ceiling	B	623,2	*	0,120	*	1,00	*	10,4	or	10,4	=	782	or	782
5.		A		*		*	1,00	*	30,6	or	21,2	=		or	
6.		A		*		*	1,00	*	30,6	or	21,2	=		or	
7.		X		*		*	0,75	*	30,6	or	21,2	=		or	
8.	Windows	A	184,7	*	0,691	*	1,00	*	30,6	or	21,2	=	3899	or	2711
9.	Exterior door	A		*		*	1,00	*	30,6	or	21,2	=		or	
10.	Exterior TB (length/m)	A		*		*	1,00	*	30,6	or	21,2	=		or	
11.	Perimeter TB (length/m)	P		*		*	1,00	*	10,4	or	10,4	=		or	
12.	Ground TB (length/m)	B		*		*	1,00	*	10,4	or	10,4	=		or	
13.	House/DU Partition Wall	I		*		*	1,00	*	3,0	or	3,0	=		or	

Transmission heat load P_T — Total = 7481 or 5439

Ventilation system:

	A_{TFA}		Clear room height		
	m²		m		m³
Effective air volume, V_V	549,8	*	4,00	=	2199

					η_{SHX} 1		η_{SHX} 2
Heat recovery efficiency of the heat exchanger η_{HR}	85%	Heat recovery efficiency SHX	0%	Efficiency SHX	0%	or	0%

	$n_{V,Res}$ (Heating Load)		$n_{V,system}$		Φ_{HP}		Φ_{HP}				
	1/h		1/h						1/h		1/h
Energetically effective air exchange n_V	0,105	+	0,410	*(1-	0,85	or	0,85	) =	0,167	or	0,167

Ventilation heat load P_V

V_V		n_V		n_V		c_{Air}		TempDiff 1		TempDiff 2		P_V 1		P_V 2
m³		1/h		1/h		Wh/(m³K)		K		K		W		W
2199,1	*	0,167	or	0,167	*	0,33	*	30,6	or	21,2	=	3697	or	2570

Total heating load P_L

		PL 1		PL 2
		W		W
$P_T + P_V$	=	11178	or	8010

	Orientation of the area	Area		g-Value (perp. radiation)		Reduction factor (see 'Windows' worksheet)		Radiation 1		Radiation 2		P_T 1		P_T 2
		m²						W/m²		W/m²		W		W
1.	North	10,8	*	0,5	*	0,22	*	11	or	5	=	13	or	6
2.	East	17,2	*	0,5	*	0,27	*	23	or	5	=	54	or	11
3.	South	150,1	*	0,5	*	0,63	*	80	or	8	=	3774	or	380
4.	West	6,0	*	0,5	*	0,24	*	37	or	5	=	27	or	4
5.	Horizontal	0,5	*	0,5	*	0,67	*	39	or	10	=	7	or	2

Solar heating power P_S — Total = 3875 or 402

Internal heating load P_I

Spec. power		A_{TFA}		P_I 1		P_I 2
W/m²		m²		W		W
1,6	*	550	=	880	or	880

Heating power (gains) P_G

		P_G 1		P_G 2
		W		W
$P_T + P_I$	=	4755	or	1282
$P_L - P_G$	=	6423	or	6728

Heating load P_H = 6728 W

Area specific space heating load P_H / A_{TFA} = 12,2 W/m²

					°C	°C
Input max. supply air temperature	40	°C				
Max. supply air temperature $\vartheta_{Supply,Max}$	40	°C	Supply air temperature without heating	$\vartheta_{Supply,Min}$	15,4	16,8

For comparison: heating load transportable by the supply Air $P_{Supply\ Air,Max}$ = 6899 W specific: 12,5 W/m²

Supply air heating: Sufficient? (Yes/No) yes

Annex 30: *SummVent Worksheet*

Passive House planning: **S U M M E R   V E N T I L A T I O N**

Building:	House of Trees Průhonice		Building type:	Multifunctional building	
Building volume:	2199	m³	Heat recovery η_{HRV}:	85%	
Max. indoor absolute humidity:	12	g/kg	Energy recovery η_{ER}:	0%	
Internal humidity sources:	2	g/(m²h)	Subsoil heat exchanger η^*_{SHX}:	0%	

Results passive cooling			**Results active cooling**		
Frequency of overheating:	**4,3%**	at the overheating limit ϑ_{max} = 26 °C	Useful cooling demand:	**2,1**	kWh/(m²a)
Frequency of exceeded humidity:			Dehumidification demand:	**0,0**	kWh/(m²a)
max. humidity:		g/kg			

Summer background ventilation to ensure adequate air quality

Air exchange via vent. system with supply air:	0,48	1/h	HRV/ERV in summer (check only one field)		
			None		
			automatic bypass, controlled by temperature difference	x	
			automatic bypass, controlled by enthalpy difference		
			always		
Air exchange via extract air system		1/h	Specific power consumption (for extract air system)		Wh/m³
Window ventilation air exchange		1/h			

effective air exchange

	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HP}		$n_{V,equi,fraction}$ 1/h
exterior $n_{V,e}$	0,480	*(1-	0%	)*(1-	0,85	) =	0,072
without HR	0,480	*(1-	0%	)		=	0,480
ground $n_{L,g}$	0,480	*	0%	*(1-	0,85	) =	0,000
without HR	0,480	*	0%			=	0,000

Ventilation conductance

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)			
exterior $H_{V,e}$	2199	*	0,072	*	0,33	=	52,4	W/K
without HR	2199	*	0,480	*	0,33	=	348,3	W/K
ground $H_{V,g}$	2199	*	0,000	*	0,33	=	0,0	W/K
without HR	2199	*	0,000	*	0,33	=	0,0	W/K
Infiltration, window, extract air system	2199	*	0,042	*	0,33	=	30,5	W/K

Additional Summer Ventilation for Cooling

Additional ventilation regulation

Minimum acceptable indoor temp. 22,0 °C

Type of additional ventilation

Window night ventilation, manual	Night ventilation value	0,00	1/h		
Mechanical, automatically controlled ventilation	Corresponding air change rate during operation, in addition to base air change	0,20	1/h	Controlled by (please cl	
				Temperature diff.	x
	Specific power consumption	0,45	Wh/m³	Humidity diff.	

Annex 31: *Summer Worksheet*

Passive House planning: **SUMMER: PASSIVE COOLING**

Climate:	[CZ] - Praha		Building type:	Multifunctional building
Building:	House of Trees Průhonice		Treated floor area A_{TFA}:	549,8 m²
Overtemperature limit:	26	°C	Building volume:	2199 m³
Nominal humidity:	12	g/kg	Internal humidity sources:	2,0 g/(m²h)
Spec. capacity:	132	Wh/(m²K)		

	Building assembly	Temperature zone	Area m²		U-Value W/(m²K)		Red. factor $f_{T,Summer}$		H_{Summer} heat conductance
1.	Exterior wall - Ambier	A	364,8	*	0,102	*	1,00	=	37,3
2.	Exterior wall - Grounc	B		*		*	1,00	=	
3.	Roof/Ceiling - Ambient	A	655,3	*	0,083	*	1,00	=	54,3
4.	Floor slab / Basement	B	623,2	*	0,120	*	1,00	=	74,9
5.		A		*		*	1,00	=	
6.		A		*		*	1,00	=	
7.		X		*		*	0,75	=	
8.	Windows	A	184,7	*	0,691	*	1,00	=	127,6
9.	Exterior door	A		*		*	1,00	=	
10.	Exterior TB (length/m)	A		*		*	1,00	=	
11.	Perimeter TB (length/m	P		*		*	1,00	=	
12.	Ground TB (length/m)	B		*		*	1,00	=	

Exterior thermal transmittance, $H_{T,e}$ 219,2 W/K

Ground thermal transmittance, $H_{T,g}$ 74,9 W/K

Summer ventilation from 'SummVent' worksheet

Ventilation unit conductance			Ventilation parameter		
exterior $H_{V,e}$	52,4	W/K	Temperature amplitude summer	0,0	K
without HR	348,3	W/K	Minimum acceptable indoor temperature	22,0	°C
ground $H_{V,g}$	0,0	W/K	Heat capacity air	0,33	Wh/(m³K)
without HR	0,0	W/K	Supply air exchange	0,48	1/h
Ventilation conductance, others			Ambient air exchange	0,04	1/h
exterior	30,5	W/K	Window night ventilation air exchange rate, manual @ 1K	0,00	1/h
			Air change rate due to mechanical, automatically controlled ventilation	0,20	1/h
			Specific power consumption for	0,45	Wh/m³
			η_{HR}	85%	
			η_{ERV}	0%	
			η^*_{SHX}	0%	

Summer ventilation regulation	HRV/ERV
None	
Controlled by temperature	x
Controlled by enthalpy	
Always	
	Additional ventilation
Controlled by temperature	x
Controlled by humidity	

	Orientation of the area	Angle factor Summer		Shading factor Summer		Loss-Dirt		g-Value (perp. radiation)		Area m²		Portion of glazing		Aperture m²
1.	North	0,9	*	0,29	*	0,95	*	0,50	*	10,8	*	62%	=	0,8
2.	East	0,9	*	0,33	*	0,95	*	0,50	*	17,2	*	71%	=	1,7
3.	South	0,9	*	0,67	*	0,95	*	0,50	*	150,1	*	95%	=	41,1
4.	West	0,9	*	0,33	*	0,95	*	0,50	*	6,0	*	66%	=	0,6
5.	Horizontal	0,9	*	0,97	*	0,95	*	0,50	*	0,5	*	87%	=	0,2
6.	Sum opaque areas													1,8

Solar aperture Total 46,2 — 0,08 m²/m²

	Specif. power q_I W/m²		A_{TFA} m²		W	W/m²
Internal heat gains Q_I	2,8	*	550	=	1539	2,8

Frequency of overheating $h_{\vartheta \geq \vartheta max}$ **4,3%** — **At the overheating limit ϑ_{max} = 26 °C**

If the "frequency over 25°C" exceeds 10%, additional measures to protect against the heat during the summer are necessary.

Daily internal temperature stroke

	Transmission kWh/d		Ventilation kWh/d		Solar load kWh/d		1/k		Spec. capacity Wh/(m²K)		A_{TFA} m²		
(	0,0	+	0,0	+	184,2	) *	1000	/ (	132	*	550	) =	**2,5** K

Passive House planning: **HEAT DISTRIBUTION AND DHW SYSTEM**

Building: House of Trees Průhonice

Interior temperature:	20	°C
Building type:	Multifunctional building	
Treated floor area A_{TFA}:	550	m²
Occupancy:	162,0	Pers
Number of dwelling units:	1	
Annual heating demand $q_{Heating}$	7190	kWh/a
Length of heating period:	217	d
Average heating load P_{ave}:	1,4	kW
Marginal utilisability of additional heat gains:	57%	

			Parts: Warm region	Cold region		Total		
			1	2	3			
Space heat distribution								
Length of distribution pipes	L_H *(Project)*		147,00				m	
Heat loss coefficient per m pipe	Ψ *(Project)*		0,890				W/(mK)	
Temp. of the room through which the pipes pass	ϑ_X *Mechanical Room*		20				°C	
Design flow temperature	ϑ_{dist} *Flow, Design Value*		40,0				°C	
Design system heating load	$P_{heating}$ *(exist./calc.)*		6,7				kW	
Flow temperature control (check)			x					
Design return temperature	ϑ_R	$=0.714^*(\vartheta_{dist}-20)+20$	34,3				°C	
Annual heat emission per m of plumbing	q^*_{HL}	$= \Psi\ (\vartheta_m-\vartheta_X)\ t_{Heating}{}^*0.024$	24				kWh/(m·a)	
Possible utilization factor of released heat	η_G		57%				-	
Annual losses	Q_{HL}	$= L_H \cdot q^*_{HL} \cdot (1-\eta_G)$	1541	0	0	**1541**	kWh/a	
Specif. losses	q_{HL}	$= \Sigma Q_{HL} / A_{TFA}$					kWh/(m²a)	**2,8**
Performance ratio of heat distribution	$ea_{,HL}$	$= (q_H + q_{HV}) / q_H$				**121%**	-	
DHW: Standard useful heat								
DHW consumption per person and day (60 °C)	V_{DHW} *(Project or average value 25 Litres/P/d)*					1,0	litre/person/d	
Average cold water temperature of the supply	ϑ_{DW} *Temperature of drinking water*					9,6	°C	
DHW non-electric wash and dish	*(Electricity worksheet)*					176	kWh/a	
Useful heat - DHW	Q_{DHW}					**3635**	kWh/a	
Specif. useful heat - DHW	q_{DHW}	$= Q_{DHW} / A_{TFA}$					kWh/(m²a)	**6,6**
DHW distribution and storage			Warm region	Cold Region		Total		
Length of circulation pipes (flow + return)	L_{HS} *(Project)*		60,0				m	
Heat loss coefficient per m pipe	Ψ *(Project)*		0,150				W/m/K	
Temp. of room through which the pipes pass	ϑ_X *Mechanical Room*		20				°C	
Design flow temperature	ϑ_{dist} *Flow, Design value*		55,0				°C	
Daily circulation period of operation.	td_{Circ} *(Project)*		9,0				h/d	
Design return temperature	ϑ_R	$=0.875^*(\vartheta_{dist}-20)+20$	51				°C	
Circulation period of operation per year	t_{Circ}	$= 365\ td_{Circ}$	3285				h/a	
Annual heat released per m of pipe	q^*_Z	$= \Psi\ (\vartheta_m-\vartheta_X)\ t_{Circ}$	16				kWh/m/a	
Possible utilization factor of released heat	η_{GDHW}	$=t_{heating}/365d * \eta_G$	34%				-	
Annual heat loss from circulation lines	QZ	$= L_{HS} \cdot q^*_Z \cdot (1-\eta_{GDHW})$	643			**643**	kWh/a	
Total length of individual pipes	L_U *(Project)*		6,00				m	
Exterior pipe diameter	d_{U_Pipe} *(Project)*		0,012				m	
Tap openings per person per day			1	1	1		-	
Utilisation days per year			300	300	300		d	
Heat loss per tap opening	$q_{Individual}$	$=(c_{pH2O}V_{H2O}+c_{pMat}V_{Mat})(\vartheta_{dist}-\vartheta_X)$	0,0188				kWh/tap opening	
Amount of tap openings per year	n_{Tap}	$= n_{Pers} \cdot n_{Tap} \cdot d / n_{WE}$	24300				tap openings per year	
Annual heat loss	q_U	$= n_{Tap} \cdot q_{Individual}$	457				kWh/a	
Possible utilization factor of released heat	η_{G_U}	$=t_{heating}/8760^*\eta_G$	34%				-	
Annual heat loss of individual pipes	Q_U	$= L_U \cdot q_U \cdot (1-\eta_{G\_U})$	303			**303**	kWh/a	
Average heat released from storage	P_S		43				W	
Possible utilization factor of released heat	η_{G_S}	$=t_{heating}/8760^*\eta_G$	34%					
Annual heat losses from storage	Q_S	$= P_S \cdot 8.760\ kh \cdot (1-_{\eta G\_S})$	250			**250**	kWh/a	
Total heat losses of the DHW system	Q_{WL}	$= Q_Z+Q_U+Q_S$				**1195**	kWh/a	
Specif. losses of the DHW system	q_{WL}	$= Q_{WL} / A_{TFA}$					kWh/(m²a)	**2,2**
Performance ratio DHW-distribution + storage	$e_{a,WL}$	$= (q_{TDHW} + q_{WV}) / q_{TDHW}$				**133%**	-	
Total heating demand of DHW system	Q_{gDHW}	$= Q_{DHW}+Q_{WL}$				**4830**	kWh/a	
Totalspec. heating demand of DHW system	q_{gDHW}	$= Q_{gDHW} / A_{TFA}$					kWh/(m²a)	**8,8**

Annex 33: *DHW + Distribution without Circulation Worksheet*

Passive House planning: **HEAT DISTRIBUTION AND DHW SYSTEM**

Building: House of Trees Průhonice

Interior temperature: 20 °C
Building type: Multifunctional building
Treated floor area A_{TFA}: 550 m²
Occupancy: 162,0 Pers
Number of dwelling units: 1
Annual heating demand $q_{Heating}$: 7190 kWh/a
Length of heating period: 217 d
Average heating load P_{ave}: 1,4 kW
Marginal utilisability of additional heat gains: 57%

			Parts: Warm region	Cold region		Total		
			1	2	3			
Space heat distribution								
Length of distribution pipes	L_H *(Project)*		147,00				m	
Heat loss coefficient per m pipe	Ψ *(Project)*		0,890				W/(mK)	
Temp. of the room through which the pipes pass	ϑ_X *Mechanical Room*		20				°C	
Design flow temperature	ϑ_{dist} *Flow, Design Value*		40,0				°C	
Design system heating load	$P_{heating}$ *(exist./calc.)*		6,7				kW	
Flow temperature control (check)			x					
Design return temperature	ϑ_R	$=0.714*(\vartheta_{dist}-20)+20$	34,3				°C	
Annual heat emission per m of plumbing	q^*_{HL}	$= \Psi\ (\vartheta_m-\vartheta_X)\ t_{Heating}*0.024$	24				kWh/(m·a)	
Possible utilization factor of released heat	η_G		57%				-	
Annual losses	Q_{HL}	$= L_H \cdot q^*_{HL} \cdot (1-\eta_G)$	1541	0	0	1541	kWh/a	
Specif. losses	q_{HL}	$= \Sigma Q_{HL} / A_{TFA}$					kWh/(m²a)	2,8
Performance ratio of heat distribution	$ea_{,HL}$	$= (q_H + q_{HV}) / q_H$				121%	-	
DHW: Standard useful heat								
DHW consumption per person and day (60 °C)	V_{DHW} *(Project or average value 25 Litres/P/d)*					1,0	litre/person/d	
Average cold water temperature of the supply	ϑ_{DW} *Temperature of drinking water*					9,6	°C	
DHW non-electric wash and dish	*(Electricity worksheet)*					176	kWh/a	
Useful heat - DHW	Q_{DHW}					3635	kWh/a	
Specif. useful heat - DHW	q_{DHW}	$= Q_{DHW} / A_{TFA}$					kWh/(m²a)	6,6

DHW distribution and storage			Warm region	Cold Region		Total		
Length of circulation pipes (flow + return)	L_{HS} *(Project)*						m	
Heat loss coefficient per m pipe	Ψ *(Project)*						W/m/K	
Temp. of room through which the pipes pass	ϑ_X *Mechanical Room*		20				°C	
Design flow temperature	ϑ_{dist} *Flow, Design value*		55,0				°C	
Daily circulation period of operation.	td_{Circ} *(Project)*						h/d	
Design return temperature	ϑ_R	$=0.875*(\vartheta_{dist}-20)+20$					°C	
Circulation period of operation per year	t_{Circ}	$= 365\ td_{Circ}$					h/a	
Annual heat released per m of pipe	q^*_Z	$= \Psi\ (\vartheta_m-\vartheta_X)\ t_{Circ}$					kWh/m/a	
Possible utilization factor of released heat	η_{GDHW}	$=t_{heating}/365d * \eta_G$					-	
Annual heat loss from circulation lines	QZ	$= L_{HS} \cdot q^*_Z \cdot (1-\eta_{GDHW})$				0	kWh/a	
Total length of individual pipes	L_U *(Project)*		6,00				m	
Exterior pipe diameter	d_{U_Pipe} *(Project)*		0,012				m	
Tap openings per person per day			1	1	1		-	
Utilisation days per year			300	300	300		d	
Heat loss per tap opening	$q_{Individual}$	$=(c_{pH2O}V_{H2O}+c_{pMat}V_{Mat})(\vartheta_{dist}-\vartheta_X)$	0,0188				kWh/tap opening	
Amount of tap openings per year	n_{Tap}	$= n_{Pers} \cdot n_{Tap} \cdot d / n_{WE}$	24300				tap openings per year	
Annual heat loss	q_U	$= n_{Tap} \cdot q_{Individual}$	457				kWh/a	
Possible utilization factor of released heat	η_{G_U}	$=t_{heating}/8760*\eta_G$	34%				-	
Annual heat loss of individual pipes	Q_U	$= L_U \cdot q_U \cdot (1-\eta_{G\_U})$	303			303	kWh/a	
Average heat released from storage	P_S		43				W	
Possible utilization factor of released heat	η_{G_S}	$=t_{heating}/8760*\eta_G$	34%					
Annual heat losses from storage	Q_S	$= P_S \cdot 8.760\ kh \cdot (1-\eta_{G\_S})$	250			250	kWh/a	
Total heat losses of the DHW system	Q_{WL}	$= Q_Z+Q_U+Q_S$				552	kWh/a	
Specif. losses of the DHW system	q_{WL}	$= Q_{WL} / A_{TFA}$					kWh/(m²a)	1,0
Performance ratio DHW-distribution + storage	$e_{a,WL}$	$= (q_{TDHW} + q_{WV}) / q_{TDHW}$				115%	-	
Total heating demand of DHW system	Q_{gDHW}	$= Q_{DHW}+Q_{WL}$				4187	kWh/a	
Totalspec. heating demand of DHW system	q_{gDHW}	$= Q_{gDHW} / A_{TFA}$					kWh/(m²a)	7,6

Annex 34: Comparison of *PVGis and PHPP Calculation*

PVGIS estimates of solar electricity generation

Location: 50°1'12" North, 14°26'59" East, Elevation: 297 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 9.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 8.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.2%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.4%

Fixed system: inclination=30°, orientation=-25°				
Month	E_d	E_m	H_d	H_m
Jan	7.14	221	0.97	30.0
Feb	13.50	379	1.83	51.4
Mar	24.20	749	3.36	104
Apr	33.80	1010	4.89	147
May	34.90	1080	5.19	161
Jun	36.10	1080	5.45	164
Jul	34.80	1080	5.31	165
Aug	32.40	1000	4.89	152
Sep	25.70	772	3.76	113
Oct	17.50	543	2.47	76.7
Nov	8.66	260	1.20	36.1
Dec	6.34	196	0.86	26.8
Yearly average	**23.0**	**699**	**3.36**	**102**
Total for year		**8390**		**1220**

The electricity production of 28 PV modules deviated 155° from north

PVGIS estimates of solar electricity generation

Location: 50°1'12" North, 14°26'59" East, Elevation: 297 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 19.2 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 8.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.1%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.4%

Fixed system: inclination=30°, orientation=-4°				
Month	E_d	E_m	H_d	H_m
Jan	16.00	496	1.01	31.2
Feb	30.00	841	1.89	53.0
Mar	53.00	1640	3.44	106
Apr	73.20	2200	4.95	148
May	75.10	2330	5.22	162
Jun	77.30	2320	5.46	164
Jul	74.70	2320	5.32	165
Aug	70.00	2170	4.94	153
Sep	56.20	1690	3.84	115
Oct	38.70	1200	2.55	78.9
Nov	19.40	583	1.25	37.5
Dec	14.30	443	0.90	28.0
Yearly average	**49.9**	**1520**	**3.40**	**103**
Total for year		**18200**		**1240**

The electricity production of 28 PV modules deviated 176° from north

PVGIS estimates of solar electricity generation

Location: 50°1'12" North, 14°26'59" East, Elevation: 297 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 9.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 8.1% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.1%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.4%

Fixed system: inclination=30°, orientation=17°				
Month	E_d	E_m	H_d	H_m
Jan	7.42	230	1.00	30.9
Feb	13.80	387	1.87	52.4
Mar	24.40	758	3.40	105
Apr	33.90	1020	4.92	148
May	34.90	1080	5.21	161
Jun	36.10	1080	5.45	164
Jul	34.80	1080	5.31	165
Aug	32.50	1010	4.91	152
Sep	26.00	779	3.80	114
Oct	17.80	551	2.51	77.9
Nov	9.00	270	1.24	37.2
Dec	6.62	205	0.90	27.8
Yearly average	**23.2**	**704**	**3.38**	**103**
Total for year		**8450**		**1240**

The electricity production of 28 PV modules deviated 197° from north

PVGIS estimates of solar electricity generation

Location: 50°1'12" North, 14°26'59" East, Elevation: 297 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 37.1 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 8.0% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.1%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 23.4%

Fixed system: inclination=30°, orientation=-4°				
Month	E_d	E_m	H_d	H_m
Jan	31.00	960	1.01	31.2
Feb	58.10	1630	1.89	53.0
Mar	102.00	3180	3.44	106
Apr	141.00	4240	4.95	148
May	145.00	4500	5.22	162
Jun	150.00	4490	5.46	164
Jul	144.00	4480	5.32	165
Aug	135.00	4200	4.94	153
Sep	109.00	3260	3.84	115
Oct	74.80	2320	2.55	78.9
Nov	37.50	1130	1.25	37.5
Dec	27.60	856	0.90	28.0
Yearly average	**96.5**	**2940**	**3.40**	**103**
Total for year		**35200**		**1240**

The electricity production of 116 PV modules deviated 176° from north

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

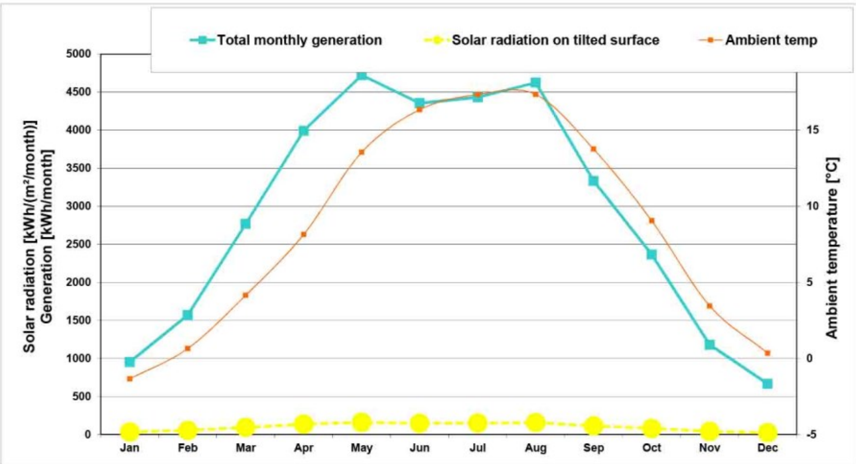
Information from the module data sheet

Mono-Si			
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K

Further specifications

Latitude:		50,1	°
Number of modules	n_M	116	
Deviation from North		176	°
Angle of inclination from horizontal		30,0	°
Height of module array		0,45	m
Height of horizon	h_{Hori}	0	m
Horizontal distance	a_{Hori}	3	m
Additional reduction factor shading	r_{other}	100%	
Efficiency of the inverter	η_{HRV}	96%	

Annual yield of the inverter	**34957**	kWh
Annual losses due to shading	**0**	kWh
PE value (non-renewable)	**0,420**	
CO_2-equivalent emission value	**63,1**	g/kWh



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Year	
Solar radiation on tilted surface	32	53	94	135	160	147	150	156	113	80	40	23	kWh/m²/Month	1184,0	kWh/m²/a
Ambient temp	-1	1	4	8	14	16	17	17	14	9	3	0	°C	8,6	°C
Total monthly generation	951	1570	2767	3991	4723	4355	4432	4626	3333	2365	1179	665	kWh/month	34957,0	kWh/a
Losses due to shading situation	0	0	0	0	0	0	0	0	0	0	0	0	kWh/month	0,0	kWh/a

Annex 35: *PV Worksheet*

PHOTOVOLTAIC SYSTEM

Building:	House of Trees Průhonice	Building type:	Multifunctional building
Climate:	[CZ] - Praha		

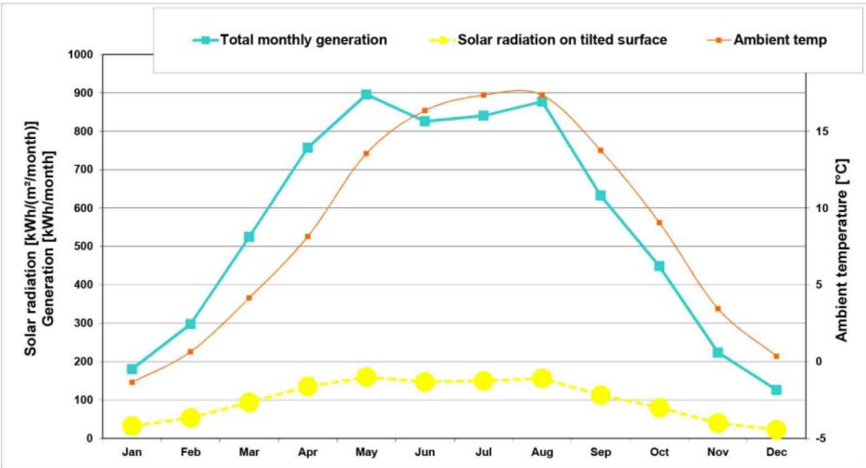
Information from the module data sheet

Technology	Mono-Si		
Nominal current	I_{MPP0}	9,53	A
Nominal voltage	U_{MPP0}	33,60	V
Nominal power	P_n	320	Wp
Temperature coefficient short-circuit current	α	0,038	%/K
Temperature coefficient open-circuit voltage	β	-0,039	%/K

Further specifications

Latitude:		50,1	°	*(Worksheet Climate)*
Number of modules	n_M	22		
Deviation from North		176	°	
Angle of inclination from horizontal		30	°	
Height of module array		0,45	m	
Height of horizon	h_{Hori}	0	m	
Horizontal distance	a_{Hori}	3	m	
Additional reduction factor shading	r_{other}	100%		
Efficiency of the inverter	η_{HRV}	96%		

Annual yield of the inverter	**6630**	kWh
Annual losses due to shading	**0**	kWh
PE value (non-renewable)	**0,4197**	
CO_2-equivalent emission value	**63,1**	g/kWh



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Year	
Solar radiation on tilted surface	32	53	94	135	160	147	150	156	113	80	40	23	kWh/m²/Month	1184,0	kWh/m²/a
Ambient temp	-1	1	4	8	14	16	17	17	14	9	3	0	°C	8,6	°C
Total monthly generation	180	298	525	757	896	826	841	877	632	449	224	126	kWh/month	6629,8	kWh/a
Losses due to shading situation	0	0	0	0	0	0	0	0	0	0	0	0	kWh/month	0,0	kWh/a

Annex 36*: Use Non-Res Worksheet*

Passive House planning: **U T I L I S A T I O N non-residential**

Building: House of Trees Průhonice

Latitude [°]: 50

	2	3 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	27
	Utilisation pattern	Periods of utilisation and operation	Begin utilisation [h]	End utilisation [h]	Daily utilisation hours [h/d]	Annual utilisation days [d/a]	Annual utilisation hours [h/a]	Annual utilisation hours during daytime [h/a]	Annual utilisation hours during nighttime [h/a]	Daily operating hours of heating	Daily operating hours of ventilation	Lighting	Illumination level [lux]	Height of utilisation level (0.8 or 0.0 m)	Height of utilisation level (0.8 or 0.0 m)	Relative absenteeism	Part use factor of building operating period for lighting	Average occupancy [m²/Pers.]
1	Office		10	18	9	300	2550	2365	185	11	11		500	0,8	0,8	0,00	0,7	5,0
2	Exposition hall		10	18	8	300	2250	2128	122	10	10		500	0,8	0,8	0,00	1,0	3,4
3	Indoor workshop		10	18	8	300	2250	2128	122	10	10		300	0,8	0,8	0,00	1,0	1,6
4	Computer room		10	18	8	300	2250	2128	122	10	10		300	0,8	0,8	0,00	0,7	3,3
5	WC, Sanitary		10	18	8	300	2400	2215	185	10	10		200	0,8	0,8	0,90	1,0	0,0
6	Entrance hall		10	18	8	300	2400	2215	185	10	10		200	0,8	0,8	0,90	1,0	0,0
7	Technical room		0	24	24	365	8760	4407	4353	26	26		100	0,8	0,8	0,98	1,0	0,0
8	Storage, Services		10	18	8	300	2400	2215	185	10	10		100	0,8	0,8	0,98	1,0	0,0
9	Lecture room		10	18	8	300	2400	2215	185	10	10		500	0,8	0,8	0,00	1,0	2,1
10	Snack bar/reception		10,0	18	8	300	2400	2215	185	10	10		300	0,8	0,8	0,00	1,0	2,5
11					0		0	0	0	2	2				0,8			
12					0		0	0	0	2	2				0,8			
13					0		0	0	0	2	2				0,8			
14					0		0	0	0	2	2				0,8			
15					0		0	0	0	2	2				0,8			
16					0		0	0	0	2	2				0,8			
17					0		0	0	0	2	2				0,8			
18					0		0	0	0	2	2				0,8			
19					0		0	0	0	2	2				0,8			
20					0		0	0	0	2	2				0,8			
21	Single office		7	18	11	250	2750	2543	207	13			500	0,8	0,8	0,30	0,70	10,00
22	Group office		7	18	11	250	2750	2543	207	13			500	0,8	0,8	0,30	0,70	
23	Open-plan office		7	18	11	250	2750	2543	207	13			500	0,8	0,8	0,00	1,00	15,00
24	Meeting		7	18	11	250	2750	2543	207	13			500	0,8	0,8	0,50	1,00	2,00
25	Counter area		7	18	11	250	2750	2543	207	13			200	0,8	0,8	0,00	1,00	
26	Retail		8	20	12	300	3600	2999	601	14			300	0,8	0,8	0,00	1,00	7,00
27	Classroom		8	15	7	200	1400	1398	2	9			300	0,8	0,8	0,25	0,90	2,00
28	University auditorium		8	18	10	150	1500	1409	91	12			500	0,8	0,8	0,25	0,70	0,75
29	Bedroom		0	24	24	365	8760	4407	4353	24			300	0,8	0,8	0,00	0,50	
30	Hotel room		21	8	11	365	4015	755	3260	24			200	0,8	0,8	0,25	0,30	
31	Canteen		8	15	7	250	1750	1748	2	9			200	0,8	0,8	0,00	1,00	
32	Restaurant		10	0	14	300	4200	2404	1796	16			200	0,8	0,8	0,00	1,00	1,50
33	Kitchen non-residential		10	23	13	300	3900	2404	1496	15			500	0,8	0,8	0,00	1,00	
34	Kitchen, Storage, Preparation		7	23	16	300	3900	2404	1496	15			300	0,8	0,8	0,50	1,00	
35	WC, Sanitary		7	18	11	250	2750	2543	207	13			200	0,8	0,8	0,90	1,00	
36	Other habitable rooms		7	18	11	250	2750	2543	207	13			300	0,8	0,8	0,50	1,00	
37	Secondary areas		7	18	11	250	2750	2543	207	13			100	0,8	0,8	0,90	1,00	
38	Circulation area		7	18	11	250	2750	2543	207	13			100	0,0	0,0	0,80	1,00	
39	Storage, Services		7	18	11	250	2750	2543	207	13			100	0,8	0,8	0,98	1,00	
40	Server room		0	24	24	365	8760	4407	4353	24			500	0,8	0,8	0,50	0,50	
41	Workshop		7	16	9	250	2250	2192	58	11			500	0,8	0,8	0,00	1,00	
42	Theatre auditorium		19	23	4	250	1001	55	946	6			200	0,8	0,8	0,00	1,00	
43	Theatre foyer		19	23	4	250	1001	55	946	6			300	0,8	0,8	0,50	1,00	
44	Theatre stage		13	23	10	250	2500	1253	1247	12			1000	0,8	0,8	0,00	0,60	
45	Fair, Congress		13	18	5	150	1350	1260	90	11			300	0,8	0,8	0,50	1,00	
46	Exhibition		10	18	8	250	2001	1850	151	24			200	0,8	0,8	0,00	1,00	
47	Library reading room		8	20	12	300	3600	2999	601	14			500	0,8	0,8	0,00	1,00	
48	Open access library		8	20	12	300	3600	2999	601	14			200	0,8	0,8	0,00	1,00	
49	Library repository		8	20	12	300	3600	2999	601	14			100	0,8	0,8	0,90	1,00	
50	Gymnasium		8	23	15	300	4500	3002	1498	17			300	0,8	0,8	0,30	1,00	
51	Parking garage		7	18	11	250	2750	2543	207	0			75	0,0	0,0	0,95	1,00	
52	Public parking garage		9	0	15	365	5475	3290	2185	0			75	0,0	0,0	0,80	1,00	

Annex 37: *Electricity Non-Res Worksheet*

Passive House planning: **ELECTRICITY DEMAND non-residential use**

Building: House of Trees Průhonice

Treated floor area A_{TFA}:	549,8	m²
Auxiliary electricity demand:	5037,5	kWh/a
Primary Energy factors:		
Electricity:	1,8	kWh/kWh
Natural gas:	1,1	kWh/kWh
Energy carrier for DHW:		kWh/kWh
Solar fraction of DHW	0%	
Marginal performance ratio DHW:		

Window properties (from Windows worksheet):

	Shading	Dirt factor	Non-perpendicular radiation	Glazing fraction
North	0,44	0,95	0,85	0,62
East	0,48			0,71
South	0,81			0,95
West	0,46			0,66

Lighting / non-residential	Percentage of treated floor area	Room category	Room category	Nominal illuminance level	Facade with windows: Deviation from North	Facade with windows: Orientation	Facade with windows: Light transmission glazing	Facade with windows: Existing window (1/0)	Room geometry (Input of a typical room or room by room): Room depth	Room width	Room height	Lintel height	Window width	Input warning	Daylight utilisation	User data: Installed lighting power	Installed lighting power (standard)	Lighting control	Motion detector with/without (1/0)	Lighting control	Utilisation hours per year [h/a]	User determined: Lighting full load hours	Full load hours of lighting	Electricity demand (kWh/a)	Spec. electricity demand (kWh/(m²a))	Primary energy demand (kWh/a)
Room / Zone				Lux	Degrees		-		m	m	m	m	m			W/m²	W/m²				h/a	h/a	h/a	kWh/a	kWh/(m²a)	kWh/a
			2	15																		9				
	2%	1	Office	500	0	North	69%	1	3,3	3,3	3,8	3,6	0,9		low	6	6,0	1	0	Manual Without motion	2550		1589,0	94,3	9,5	169,8
	38%	2	Exposition hall	500	191	South	69%	1	12,0	16,0	4,6	4,5	12,0		medium	6	6,0	1	0	Manual Without motion	2250		1741,3	2153,9	10,4	3877,1
	9%	3	Indoor workshop	300	6	North	69%	1	4,6	10,0	3,8	3,6	2,4		none	6	6,0	1	0	Manual Without motion	2250		2000,0	600,4	12,0	1080,6
	6%	4	Computer room	300	149	South	69%	1	8,0	4,1	4,6	4,5	3,0		good	5	5,0	1	0	Manual Without motion	2250		1022,0	168,6	5,1	303,4
	8%	5	WC, Sanitary	200	0	North		0	6,6	6,6	3,8			Contradiction: Check width and height inputs	none	5	5,0	1	0	Manual Without motion	2400		1740,0	373,1	8,7	671,5
	3%	6	Entrance hall	200	176	South	69%	1	2,8	10,4	4,6	4,5	8,0		good	4	4,0	1	0	Manual Without motion	2400		1140,0	80,2	4,6	144,4
	1%	7	Technical room	100	295	West	69%	1	3,5	3,1	3,8	2,0	0,8		none	3	3,0	1	0	Manual Without motion	8760		6880,0	147,5	20,6	265,5
	3%	8	Storage, Services	100	0	North		0	4,5	3,5				Contradiction: Check width and height inputs	none	3	3,0	1	0	Manual Without motion	2400		1680,0	94,2	5,0	169,6
	12%	9	Lecture room	500	0	North		0	6,8	8,2				Contradiction: Check width and height inputs	none	6	6,0	1	0	Manual Without motion	2400		2400,0	910,4	14,4	1638,8
	18%	10	Snack bar/reception	300	160	South	69%	1	7,2	14,0	4,6	4,5	9,8		good	5	5,0	1	0	Manual Without motion	2400		1570,0	794,1	7,9	1429,4

Office equipment	Room category	Room category	In the thermal envelope? (1/0)	Existing/Planned ? (1/0)	Quantity	Power rating (W)	Utilisation hours per year (h/a)	Relative absenteeism	Duration of utilisation in energy saving mode (h/a)	Useful energy (kWh/a)	Electricity demand (kWh/a)	Primary energy demand (kWh/a)
PC 1	1	Office	1	1	2	10	1785	0		36	35,7	64
PC in energy saving mode			1		2	2,0	1785	0		0	0,0	0
Monitor 1	1	Office	1	1	2	10	1785	0		36	35,7	64
Monitor in energy saving mode			1		2	2,0	1785	0		0	0,0	0
PC 2	4	Computer room	1	1	10	10	1575	0		158	157,5	284
PC in energy saving mode			1		10	2,0	1575	0		0	0,0	0
Monitor 2	4	Computer room	1	1	10	10	1575	0		158	157,5	284
Monitor in energy saving mode			1		10	2,0	1575	0		0	0,0	0
Copier	1	Office	1	1	1	400	2550		2295	102	102,0	184
Copier in energy saving mode			1		1	30	2295			69	68,9	124
Printer	1	Office	1	1	1	300	2550		2295	77	76,5	138
Printer in energy saving mode			1		1	2	2295			5	4,6	8
Server							0			0	0,0	0
Server in energy saving mode			0		0		8760		0	0	0,0	0
Telephone system							8760			0	0,0	0
										0	0,0	0
										0	0,0	0
										0	0,0	0
										0	0,0	0
										0	0,0	0

Kitchen / Aux. electricity	Room category	Predominant utilisation pattern of building	In the thermal envelope? (1/0)	Existing/Planned? (1/0)	Utilisation days per year (d/a)	Number of meals per utilisation day	Norm consumption	Useful energy (kWh/a)	Non-electric fraction	Electric fraction	Additional demand	Marginal performance ratio	Solar fraction	Other primary energy demand (kWh/a)	Electricity demand (kWh/a)	Primary energy demand (kWh/a)
Cooking	10	Snack bar/reception	1	1	300	10	0,25 kWh/Meal	750	100%	0%					0,0	0
Gas														750		825
Dishwashing			1	1	300	10	0,10 kWh/Cover	300		55%					165,0	297
DHW connection									45%		0,30	1,20	0,00	211		0
Refrigerating			1	1	365		0,70 kWh/d	256		100%					255,5	460
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
								0		100%					0,0	0
Total auxiliary electricity								5038							5037,5	9068

	Useful energy	Hot Water Non-Electric Dishwashing	Other primary energy demand	Electricity demand	Primary energy demand
Total	12398 kWh	176	961	11513 kWh/a	21549 kWh/a
Specific demand		0,3	1,7	21 kWh/(m²a)	39 kWh/(m²a)

Annex 38: *Aux. Electricity Worksheet – Space Heating and DHW Preparation by Biomass Boiler*

Passive House planning: **AUXILIARY ELECTRICITY**

Building: House of Trees Průhonice

Treated floor area	550	m²
Heating period	217	d
Air volume	2199	m³
Dwelling units	0	HH
Enclosed volume	3120	m³

Operation vent. system Winter	5,21	kh/a
Operation vent. system Summer	3,55	kh/a
Air change rate	0,41	h-1
Defrosting HX from		°C

Primary energy factor - Electricity	1,80	kWh/kWh
Annual space heating demand	13	kWh/(m²a)
Boiler rated power	15	kW
DHW system heating demand	4830	kWh/a
Design flow temperature	40	°C

Column nr.	1	2	3		4		5		6		7	8	9	10	11	12
Application	Used ? (1/0)	Within the thermal envelope? (1/0)	Norm demand		Utilization factor		Period of operation		Reference size		Electricity demand (kWh/a)	Available as interior heat	Used during time period (kh/a)	Internal heat source Winter (W)	Internal heat source Summer (W)	Primary energy demand (kWh/a)
Ventilation system																
Winter ventilation	1	1	0,42	Wh/m³	* 0,41	h⁻¹	* 5,2	kh/a	* 2199	m³	= 1973	considered in heat recovery efficiency				3551
Defroster HX	1	1	0	W	* 1,00		* 0,4	kh/a	* 1		= 0	* 1,0	/ 5,21	= 0		0
Summer ventilation	1	0,55	0,42	Wh/m³	* 0,48	h⁻¹	* 3,5	kh/a	* 2199	m³	= 1573	* 1,0	/ 3,55	=	244	2832
													Internal heat sources ' Additional summer ventilation'		65	
Additional vent. summer	1	0,55	0,45	Wh/m³	* 0,12	h⁻¹	* 3,5	kh/a	* 2199	m³	= 419	* 1,0	/ 3,55	=	65	754
Heating system					Controlled/UnControlled (1/0)											
Enter the rated power of the pump			100	W	1											
Circulation pump	1	1	100	W	* 0,7		* 5,2	kh/a	* 1		= 378	* 1,0	/ 5,21	= 73		681
Boiler electricity consumption at 30% load				W												
Aux. energy - Heat. boiler	0	0	55	W	* 1,00		* 0,00	kh/a	* 1		= 0	* 1,0	/ 5,21	= 0		0
Aux. energy - Wood fired/Pellet boiler	1	0	Data entries in Boiler worksheet. Aux. energy demand including possible drinking water produc.								439	* 1,0	/ 5,21	= 0		790
DHW system																
Enter average power consumption of pump				W												
Circulation Pump	1	1	34	W	* 1,00		* 6,6	kh/a	* 1		= 225	* 0,6	/ 8,76	= 15	15	404
Enter the rated power of the pump				W												
Storage load pump DHW	1	1	97	W	* 1,00		* 0,3	kh/a	* 1		= 31	* 1,0	/ 5,21	= 6	6	56
Boiler electricity consumption at 100% load				W												
DHW boiler aux. energy	1	0	165	W	* 1,00		* 0,0	kh/a	* 1		= 0	* 1,0	/ 5,21	= 0	0	0
Enter the rated power of the solar DHW pump				W												
Solar aux. electricity	0		75	W	* 1,00		* 1,8	kh/a	* 1		= 0	* 0,6	/ 8,76	= 0	0	0
Misc. aux. electricity																
Misc. aux. electricity				kWh/a	* 1,00		* 1,0		* 0	HH	= 0	* 1,0	/ 8,76	= 0	0	0
Total											5038			94	330	9068
Specific demand	kWh/(m²a)		divided by treated floor area:								9,2					16,5

Annex 39: *Aux. Electricity Worksheet – Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House planning: **AUXILIARY ELECTRICITY**

Building: House of Trees Průhonice

Treated floor area	550	m²
Heating period	217	d
Air volume	2199	m³
Dwelling units	0	HH
Enclosed volume	3120	m³

Operation vent. system Winter	5,21	kh/a
Operation vent. system Summer	3,55	kh/a
Air change rate	0,41	h-1
Defrosting HX from		°C

Primary energy factor - Electricity	2,60	kWh/kWh
Annual space heating demand	13	kWh/(m²a)
Boiler rated power	15	kW
DHW system heating demand	4830	kWh/a
Design flow temperature	40	°C

Column nr. / Application	1 Used ? (1/0)	2 Within the thermal envelope? (1/0)	3 Norm demand		4 Utilization factor		5 Period of operation		6 Reference size		7 Electricity demand (kWh/a)	8 Available as interior heat	9 Used during time period (kh/a)	10 Internal heat source Winter (W)	11 Internal heat source Summer (W)	12 Primary energy demand (kWh/a)
Ventilation system																
Winter ventilation	1	1	0,42	Wh/m³	0,41	h⁻¹	5,2	kh/a	2199	m³	1973	considered in heat recovery efficiency				5129
Defroster HX	1	1	0	W	1,00		0,4	kh/a	1		0	1,0	5,21	0		0
Summer ventilation	1	0,55	0,42	Wh/m³	0,48	h⁻¹	3,5	kh/a	2199	m³	1573	1,0	3,55		244	4091
Internal heat sources ' Additional summer ventilation'															65	
Additional vent. summer	1	0,55	0,45	Wh/m³	0,12	h⁻¹	3,5	kh/a	2199	m³	419	1,0	3,55		65	1089
Heating system					Controlled/UnControlled (1/0)											
Enter the rated power of the pump			100	W	1											
Circulation pump	1	1	100	W	0,7		5,2	kh/a	1		378	1,0	5,21	73		983
Boiler electricity consumption at 30% load				W												
Aux. energy - Heat. boiler	0	0	55	W	1,00		0,00	kh/a	1		0	1,0	5,21	0		0
Aux. energy - Wood fired/Pellet boiler	0	0	Data entries in Boiler worksheet. Aux. energy demand including possible drinking water produc.								0	1,0	5,21	0		0
DHW system																
Enter average power consumption of pump				W												
Circulation Pump	1	1	34	W	1,00		6,6	kh/a	1		225	0,6	8,76	15	15	584
Enter the rated power of the pump				W												
Storage load pump DHW	1	1	97	W	1,00		0,3	kh/a	1		31	1,0	5,21	6	6	81
Boiler electricity consumption at 100% load				W												
DHW boiler aux. energy	0	0	165	W	1,00		0,0	kh/a	1		0	1,0	5,21	0	0	0
Enter the rated power of the solar DHW pump				W												
Solar aux. electricity	0		75	W	1,00		1,8	kh/a	1		0	0,6	8,76	0	0	0
Misc. aux. electricity																
Misc. aux. electricity				kWh/a	1,00		1,0		0	HH	0	1,0	8,76	0	0	0
Total											4599			94	330	11957
Specific demand	kWh/(m²a)	divided by treated floor area:									8,4					21,7

Annex 40: *Aux. Electricity Worksheet – Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House planning: **AUXILIARY ELECTRICITY**

Building: House of Trees Průhonice

Treated floor area	550	m²
Heating period	217	d
Air volume	2199	m³
Dwelling units	0	HH
Enclosed volume	3120	m³

Operation vent. system Winter	5,21	kh/a
Operation vent. system Summer	3,55	kh/a
Air change rate	0,41	h-1
Defrosting HX from		°C

Primary energy factor - Electricity	2,60	kWh/kWh
Annual space heating demand	13	kWh/(m²a)
Boiler rated power	15	kW
DHW system heating demand	4011	kWh/a
Design flow temperature	40	°C

Column nr.	1	2	3	4	5	6	7	8	9	10	11	12
Application	Used ? (1/0)	Within the thermal envelope? (1/0)	Norm demand	Utilization factor	Period of operation	Reference size	Electricity demand (kWh/a)	Available as interior heat	Used during time period (kh/a)	Internal heat source Winter (W)	Internal heat source Summer (W)	Primary energy demand (kWh/a)
Ventilation system												
Winter ventilation	1	1	0,42 Wh/m³	0,41 h⁻¹	5,2 kh/a	2199 m³	1973	considered in heat recovery efficiency				5129
Defroster HX	1	1	0 W	1,00	0,4 kh/a	1	0	1,0	5,21	0		0
Summer ventilation	1	0,55	0,42 Wh/m³	0,48 h⁻¹	3,5 kh/a	2199 m³	1573	1,0	3,55		244	4091
								Internal heat sources ' Additional summer ventilation'			65	
Additional vent. summer	1	0,55	0,45 Wh/m³	0,12 h⁻¹	3,5 kh/a	2199 m³	419	1,0	3,55		72	1089
Heating system				Controlled/UnControlled (1/0)								
Enter the rated power of the pump			100 W	1								
Circulation pump	1	1	100 W	0,7	5,2 kh/a	1	378	1,0	5,21	73		983
Boiler electricity consumption at 30% load			W									
Aux. energy - Heat. boiler	0	0	55 W	1,00	0,00 kh/a	1	0	1,0	5,21	0		0
Aux. energy - Wood fired/Pellet boiler	0	0	Data entries in Boiler worksheet. Aux. energy demand including possible drinking water produc.				0	1,0	5,21	0		0
DHW system												
Enter average power consumption of pump			W									
Circulation Pump	0	1	34 W	1,00	6,6 kh/a	1	0	0,6	8,76	0	0	0
Enter the rated power of the pump			W									
Storage load pump DHW	1	1	97 W	1,00	0,0 kh/a	1	0	1,0	5,21	0	0	0
Boiler electricity consumption at 100% load			W									
DHW boiler aux. energy	0	0	165 W	1,00	0,0 kh/a	1	0	1,0	5,21	0	0	0
Enter the rated power of the solar DHW pump			W									
Solar aux. electricity	0		75 W	1,00	1,8 kh/a	1	0	0,6	8,76	0	0	0
Misc. aux. electricity												
Misc. aux. electricity			kWh/a	1,00	1,0	0 HH	0	1,0	8,76	0	0	0
Total							4343			73	316	11292
Specific demand	kWh/(m²a)		divided by treated floor area:				7,9					20,5

Annex 41: *HP worksheet: HP for space heating and DHW preparation*

Passive House planning: HEAT PUMP

Building:	House of Trees Průhonice	Building type:		Multifunctional building	
Climate:	[CZ] - Praha	Treated floor area A_{TFA}:		550	m²
Covered fraction of space heating demand			(PE Value worksheet)	100%	
Space heat demand + distribution losses		Q_H+Q_{HL}:	(DHW+Distribution)	8736	kWh/a
Solar fraction for space heat		$\eta_{Solar,H}$	(SolarDHW worksheet)	0%	
Effective annual heat demand		$Q_{H,Wi}=Q_H*(1-\eta_{Solar,H})$		**8736**	kWh/a
Covered fraction of DHW demand			(PE Value worksheet)	100%	
Total heat demand of DHW system		Q_{gDHW}	(DHW+Distribution)	4689	kWh/a
Solar fraction for DHW		$\eta_{Solar,DHW}$	(SolarDHW worksheet)	0%	
Effective DHW demand		$Q_{DHW,Wi}=Q_{DHW}*(1-\eta_{Solar,DHW})$		**4689**	kWh/a
Number of heat pumps in the system				1	
Functionality				Heating & DHW	
Heating					
Selection of HP:	Standard brine/water heat pump	Heat source:		Horizontal soil collectors	
Selection of distribution system				Supply air heating	
Design distribution temperature		θ_{design}	(DHW+Distribution)	55,00	°C
Nomimal power of distribution system		P_{nom}		6,73	kW
Distribution system (fulfilled from expert users only)					
Nomimal power of distribution system		P_{nom}			kW
Radiator exponent		n			
Heating storage				Yes	
Specific heat losses storage		$U * A_{Storage}$		1,8	W/K
Storage location in thermal envelope	Inside or outside of the thermal envelope			Inside	
Room temperature (storage location: outside of thermal envelope)			(DHW+Distribution)	4,11	°C
Sink temperature of heat pump for heating		θ_{snk}		56,50	°C
Entries in relation to the domestic hot water system					
Selection of HP:	Standard brine/water heat pump	Heat source:		Horizontal soil collectors	
DHW temperature			(DHW+Distribution)	55,00	°C
DHW storage location	Inside or outside of the thermal envelope			Inside	
Specific heat losses storage		$U * A_{Storage}$		1,3	W/K
Room temperature (storage location: outside of thermal envelope)			(DHW+Distribution)		°C
Type of backup heater				Continuous-flow heater, electrical	
Δθ of electric flow type heater				10,0	K
In case of one heat pump with functionality: Heating & DHW					
Same heat pump's sink temperature for Heating and for DHW				Yes	
Heat pump priority			(Manufacturer, Techn. Data)	Heating priority	
Control					
Control strategy				Ideal	
Heating					
Depth (horizontal / vertical) ground heat exchanger		z		1,5	m
Power of pump for ground heat exchanger		P_{pump}		0,10	kW

Passive House planning: **HEAT PUMP**

Heating

Heat pump: Standard brine/water heat pump

Source: Horizontal soil collectors

	θ_source °C	θ_sink °C	Heating capacity kW	COP
Test point 1	-5,0	35,0	5,3	3,7
Test point 2	0,0	35,0	6,0	4,3
Test point 3	5,0	35,0	6,7	4,9
Test point 4	-5,0	50,0	5,1	2,6
Test point 5	0,0	50,0	5,9	3,0
Test point 6	5,0	50,0	6,5	3,4
Test point 7				
Test point 8				
Test point 9				
Test point 10				
Test point 11				
Test point 12				
Test point 13				
Test point 14				
Test point 15				

Temperature difference in sink $\Delta\theta_{Sink}$ 5,0 K

DHW

Heat pump: Standard brine/water heat pump

Source: Horizontal soil collectors

	θ_source °C	θ_sink °C	Heating capacity kW	COP
Test point 1	-5,0	35,0	5,3	3,7
Test point 2	0,0	35,0	6,0	4,3
Test point 3	5,0	35,0	6,7	4,9
Test point 4	-5,0	50,0	5,1	2,6
Test point 5	0,0	50,0	5,9	3,0
Test point 6	5,0	50,0	6,5	3,4
Test point 7				
Test point 8				
Test point 9				
Test point 10				
Test point 11				
Test point 12				
Test point 13				
Test point 14				
Test point 15				

Temperature difference in sink $\Delta\theta_{Sink}$ 5,0 K

Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	208	kWh/a
Energy by direct electricity	$Q_{E,dir}$	886	kWh/a
Space heat supplied by HP	$Q_{HP,Heating}$	8652	kWh/a
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	1039	kWh/a
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	2763	kWh/a
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	8736	kWh/a
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	955	kWh/a
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	2563	kWh/a
Electrical consumption of HP	Qel_{HP}	4609	kWh/a

		1. HP: Heating or heating & DHW	2. HP: Domestic hot water
Seasonal performance factor of heat pump	SPF_{H-1}	2,59	
Seasonal performance factor of system	SPF_{H-3}	2,30	
Heat generation efficiency DHW & heating		43%	
		kWh/a	kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	5704	10,4
Annual primary energy demand		14829	27,0
		kg/a	kg/(m²a)
Annual CO_2-equivalent emissions		3878	7,1

Annex 42: *HP worksheet: HP used for space heating*

Passive House planning: HEAT PUMP

	Building:	House of Trees Průhonice	Building type:	Multifunctional building	
	Climate:	[CZ] - Praha	Treated floor area A_{TFA}:	550	m²
	Covered fraction of space heating demand		(PE Value worksheet)	100%	
	Space heat demand + distribution losses	Q_H+Q_{HL}:	(DHW+Distribution)	8736	kWh/a
	Solar fraction for space heat	$\eta_{Solar,H}$	(SolarDHW worksheet)	0%	
	Effective annual heat demand	$Q_{H,WI}=Q_H*(1-\eta_{Solar,H})$		**8736**	kWh/a
	Covered fraction of DHW demand		(PE Value worksheet)	0%	
	Total heat demand of DHW system	Q_{gDHW}	(DHW+Distribution)	3762	kWh/a
	Solar fraction for DHW	$\eta_{Solar,DHW}$	(SolarDHW worksheet)	0%	
	Effective DHW demand	$Q_{DHW,WI}=Q_{DHW}*(1-\eta_{Solar,DHW})$		**0**	kWh/a
	Number of heat pumps in the system			1	
	Functionality			Heating	
Heating					
	Selection of HP:	Standard brine/water heat pump	Heat source:	Horizontal soil collectors	
	Selection of distribution system			Supply air heating	
	Design distribution temperature	θ_{design}	(DHW+Distribution)	55,00	°C
	Nomimal power of distribution system	P_{nom}		6,73	kW
	Distribution system (fulfilled from expert users only)				
	Nomimal power of distribution system	P_{nom}			kW
	Radiator exponent	n			
	Heating storage			Yes	
	Specific heat losses storage	$U * A_{Storage}$		2,5	W/K
	Storage location in thermal envelope	Inside or outside of the thermal envelope		Inside	
	Room temperature (storage location: outside of thermal envelope)		(DHW+Distribution)	4,11	°C
	Sink temperature of heat pump for heating	θ_{snk}		56,50	°C
Entries in relation to the domestic hot water system					
	Selection of HP:	None	Heat source:		
	DHW temperature		(DHW+Distribution)	55,00	°C
	DHW storage location	Inside or outside of the thermal envelope		Inside	
	Specific heat losses storage	$U * A_{Storage}$			W/K
	Room temperature (storage location: outside of thermal envelope)		(DHW+Distribution)		°C
	Type of backup heater			Electr. immersion heater	
	Δθ of electric flow type heater			10,0	K
In case of one heat pump with functionality: Heating & DHW					
	Same heat pump's sink temperature for Heating and for DHW			No	
	Heat pump priority		(Manufacturer, Techn. Data)	Heating priority	
Control					
	Control strategy			Ideal	
Heating					
	Depth (horizontal / vertical) ground heat exchanger	z		1,5	m
	Power of pump for ground heat exchanger	P_{pump}		0,10	kW

Passive House planning: # HEAT PUMP

Heating

Heat pump: Standard brine/water heat pump

Source: Horizontal soil collectors

	θ_source °C	θ_sink °C	Heating capacity kW	COP
Test point 1	-5,0	35,0	5,3	3,7
Test point 2	0,0	35,0	6,0	4,3
Test point 3	5,0	35,0	6,7	4,9
Test point 4	-5,0	50,0	5,1	2,6
Test point 5	0,0	50,0	5,9	3,0
Test point 6	5,0	50,0	6,5	3,4
Test point 7				
Test point 8				
Test point 9				
Test point 10				
Test point 11				
Test point 12				
Test point 13				
Test point 14				
Test point 15				

Temperature difference in sink $\Delta\theta_{Sink}$ 5,0 K

DHW

Heat pump:

Source:

	θ_source °C	θ_sink °C	Heating capacity kW	COP
Test point 1				
Test point 2				
Test point 3				
Test point 4				
Test point 5				
Test point 6				
Test point 7				
Test point 8				
Test point 9				
Test point 10				
Test point 11				
Test point 12				
Test point 13				
Test point 14				
Test point 15				

Temperature difference in sink $\Delta\theta_{Sink}$ K

Electr. energy consumption pump (grnd. water / ground)	Q_{pump}	147	kWh/a
Energy by direct electricity	$Q_{E,dir}$	26	kWh/a
Space heat supplied by HP	$Q_{HP,Heating}$	8710	kWh/a
Winter DHW supplied by HP	$Q_{HP,DHW,Winter}$	0	kWh/a
Summer DHW supplied by HP	$Q_{HP,DHW,Summer}$	0	kWh/a
Space heating supplied by HP without storage losses	$Q_{HP,Heating}$	8710	kWh/a
Winter DHW supplied by HP without storage losses	$Q_{HP,DHW,Winter}$	0	kWh/a
Summer DHW supplied by HP without storage losses	$Q_{HP,DHW,Summer}$	0	kWh/a
Electrical consumption of HP	Qel_{HP}	3208	kWh/a

		1. HP: Heating or heating & DHW	2. HP: Domestic hot water
Seasonal performance factor of heat pump	SPF_{H-1}	2,60	
Seasonal performance factor of system	SPF_{H-3}	2,58	
Heat generation efficiency DHW & heating		39%	
		kWh/a	kWh/(m²a)
Final electrical energy demand heat generation	Q_{final}	3380	6,1
Annual primary energy demand		8788	16,0
		kg/a	kg/(m²a)
Annual CO_2-equivalent emissions		2299	4,2

Annex 43: *HP Ground Worksheet*

Ground collectors

Inner radius of pipe	r_i	0,020	m
Exterior pipe radius	r_a	0,023	m
Thermal conductivity of pipe	λ_r	0,350	W/(mK)
Pipe depth	z_{pipe}	1,5	m
Ground water depth	z_{gw}		m
Pipe spacing	D	0,9	m
Base area		421	m^2
Pipe outer surface		67,6	m^2
Pipe length	L	467,8	m

Brine

Brine (characteristics at 2 °C)	A	Ethylene glycol 25%	
Density of the brine	ρ_S	1052	kg/m³
dynamic viscosity of the brine	η_S	0,0052	kg/(ms)
Heat capacity brine	c_{pS}	3950	J/(kgK)
Thermal conductivity of brine	λ_S	0,48	W/(mK)
Brine - mass flow	m_S	1,0	kg/s
Specific heat extraction rate	q_{ex}	9,4	W/m^2
	U * A	**6900**	W/K

Climate

Period duration		365	d
Average ground surface temperature	T_{m0}	9,6	°C
Surface temperature amplitude	T_1	9,4	°C
Phase shifting surface	t_{02}	31	d

Annex 44: *Boiler Worksheet*

Passive House planning: **EFFICIENCY OF HEAT GENERATION (gas, oil & wood)**

Building:	House of Trees Průhonice		Building type:	Multifunctional building	
			Treated floor area A_{TFA}:	550	m²
Covered fraction of space heating demand		(PE Value worksheet)		100%	
Space heating demand + distribution losses	Q_H+Q_{HS}:	(DHW+Distribution)		8731	kWh
Solar contribution for space heaing	$\eta_{Solar,\ H}$	(SolarDHW worksheet)		0%	
Effective annual heating demand	$Q_{H,Wi}=Q_H*(1-\eta_{Solar,\ H})$			**8731**	kWh
Space heating demand without distribution losses	Q_H	(Verification sheet)		7190	kWh
Covered fraction of DHW demand		(PE Value worksheet)		100%	
Total heating demand of DHW system	Q_{gDHW}	(DHW+Distribution)		4830	kWh
Solar contribution for DHW	$\eta_{Solar,\ DHW}$	(SolarDHW worksheet)		0%	
Effective DHW demand	$Q_{DHW,Wi}=Q_{DHW}*(1-\eta_{Solar,\ DHW})$			**4830**	kWh

					Additional selection only in the case of g
Boiler type		(Project)	Wood pellet burning (direct and indirect release of heat)		Natural gas
Primary energy factor		(Data worksheet)	0,2	kWh/kWh	
CO_2-emissions factor (CO_2-equivalent)			26	g/kWh	
Useful heat provided	Q_{Use}		13561	kWh/a	
Max. heating power required for heating the building	P_{BH}	(Heating load worksheet)	6,73	kW	
Length of the heating period	t_{HP}		5211	h	
Length of DHW heating period	t_{DHW}		8760	h	

Use characteristic values entered (check if appropriate)? N

			Project data		Standard values		Input field	
Design output	P_{nom}	(Rating plate)	15	kW	15	kW		
Installation of boiler (Outdoor: 0, Indoor: 1)			0		0			
Input values (oil and gas boiler)			Project data		Standard values		Input field	
Boiler efficiency at 30% load	$\eta_{30\%}$	(Manufacturer)						
Boiler efficiency at nominal output	$\eta_{100\%}$	(Manufacturer)						
Standby heat loss boiler at 70 °C	$q_{B,70}$	(Manufacturer)						
Average return temperature measured at 30% load	$\vartheta_{30\%}$	(Manufacturer)		°C				
Input values (biomass heat generator)			Project data		Standard values		Input field	
Efficiency of heat generator in basic cycle	η_{GZ}	(Manufacturer)	72%		72%			
Efficiency of heat generator in constant operation	η_{SO}	(Manufacturer)	80%		80%			
Average fraction of heat output released to heating circuit	$z_{HC,m}$	(Manufacturer)	0,5		0,5			
Temperature difference betw. power-on and power-off	$\Delta\vartheta$	(Manufacturer)	10	K	10	K		
For interior installations: Area of mechanical room	$A_{install}$	(Project)	0	m²	0	m²		
Useful heat output per basic cycle	$Q_{N,GZ}$	(Manufacturer)	13,5	kWh	13,5	kWh		
Average power output of the heat generator	$Q_{N,m}$	(Manufacturer)	7,5	kW	7,5	kW		
Heat generator without pellets conveyor								
Unit with regulation (no fan / no starting aid)								
Heating energy demand for a basic machine cycle	$Q_{HE,GZ}$	(Manufacturer)	0,47	kWh	0,47	kWh		kWh
Power consumption in steady state operation	$P_{el,SB}$	(Manufacturer)	235	W	235	W		W

Utilisation factor heat generator heating run	$h_{H,g,K}=f_\varphi*\eta_{k*}$	**67%**	
Utilisation factor heat generator DHW run	$h_{TW,g,K}=\eta_{100\%}/f_{\varphi,TW}$	**50%**	
Utilisation factor heat generator DHW & heating	$h_{g,K}$	**60%**	
		kWh/a	kWh/(m²a)
Final energy demand space heating	$Q_{Final,\ HE}=Q_{H,wi}*e_{H,g,K}$	**12981**	
Final energy demand DHW	$Q_{Final,\ DHW}=Q_{DHW,wi}*e_{TW,g,K}$	**9706**	
Total final energy demand	$Q_{Final}=Q_{Final,DHW}+Q_{Final,HE}$	**22687**	**41,3**
Annual primary energy demand		**4537**	**8,3**
		kg/a	kg/(m²a)
Annual CO_2-equivalent emissions		**590**	**1,1**

Annex 45: *PE Value Worksheet - Space Heating and DHW Preparation by Biomass Boiler*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}: 550 m²

Space heating demand incl. distribution: 16 kWh/(m²a)

Useful cooling demand incl. dehumidification: kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	1,8	532
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	(DHW+Distribution, SolarDHW)	0,0	0,0	0,0
Electric post heating DHW wash&dish		(Electricity, SolarDHW)	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	(Electricity worksheet)	11,8	21,2	6,3
Electricity demand - Auxiliary electricity			9,2	16,5	4,9
Total electricity demand (without heat pump)			**20,9**	**37,7**	**11,1**

Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)		kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	1,8	532
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	(HP worksheet)			
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	(HP worksheet)			
Heat generation efficiency (excl. DHW wash&dish)		(HP worksheet)			
Heat generation efficiency (incl. DHW wash&dish)		(HP worksheet)			
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	(HP worksheet)	0,0	0,0	0,0
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		(HP worksheet)	**0,0**	**0,0**	**0,0**

Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	100%	0,2	26
Boiler type		(Boiler worksheet)	Wood pellet burning (direct and indirect release of he		
Performance ratio of heat generator		(Boiler worksheet)	167%		
Annual energy demand (without DHW wash&dish)		(Boiler worksheet)	40,9	8,2	1,1
Non-electric demand, DHW wash&dish		(Electricity worksheet)	0,4	0,1	0,0
Total heating oil/gas/wood			**41,3**	**8,3**	**1,1**

Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	0,2	55
Heat source		(Project)	Gas		
Performance ratio of heat generator		(Project)	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		(Electricity worksheet)	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		(Electricity worksheet)	1,4	1,5	0,1
Total - Other			**1,4**	**1,5**	**0,1**

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		63,6	47,4	12,3
Total PE Value	**47,4**	kWh/(m²a)		
Total emissions CO_2-Equivalent	**12,3**	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	**yes**

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		50,0	24,7	5,9
Specific PE demand - Mechanical system	**24,7**	kWh/(m²a)		
Total emissions CO_2-equivalent	**5,9**	kg/(m²a)		

Solar electricity			PE-Value (generation)	CO_2-emission factor
		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	(Worksheet PV)	6630	0,420	63
Specific demand		**12,1**	**5,1**	**0,8**
PE Value: Conservation by solar electricity	**16,6**	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	**5,7**	kg/(m²a)		

Annex 46: *PE Value Worksheet - Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type:	Multifunctional building
Treated floor area A_{TFA}:	550 m²
Space heating demand incl. distribution	16 kWh/(m²a)
Useful cooling demand incl. dehumidification:	kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	100%	2,6	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	(DHW+Distribution, SolarDHW)	7,3	19,0	5,0
Electric post heating DHW wash&dish		(Electricity, SolarDHW)	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	(Electricity worksheet)	12,0	31,3	8,2
Electricity demand - Auxiliary electricity			7,9	20,5	5,4
Total electricity demand (without heat pump)			27,2	70,8	18,5

			Final energy	Primary energy	Emissions
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	2,6	680
Energy carrier - Supplementary heating			Electricity	2,6	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	(HP worksheet)	2,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	(HP worksheet)			
Heat generation efficiency (excl. DHW wash&dish)		(HP worksheet)	0,39		
Heat generation efficiency (incl. DHW wash&dish)		(HP worksheet)	0,39		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	(HP worksheet)	6,1	16,0	4,2
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		(HP worksheet)	6,1	16,0	4,2

		Final energy	Primary energy	Emissions
Boiler			PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand	(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	(Project)	0%		250
Boiler type	(Boiler worksheet)			
Performance ratio of heat generator	(Boiler worksheet)	0%		
Annual energy demand (without DHW wash&dish)	(Boiler worksheet)	0,0	0,0	0,0
Non-electric demand, DHW wash&dish	(Electricity worksheet)	0,0	0,0	0,0
Total heating oil/gas/wood		0,0	0,0	0,0

		Final energy	Primary energy	Emissions
Other			PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand	(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	(Project)	0%	0,2	55
Heat source	(Project)	Wood		
Performance ratio of heat generator	(Project)	135%		
Annual energy demand, space heating		0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)		0,0	0,0	0,0
Non-electric demand, DHW wash&dish	(Electricity worksheet)	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)	(Electricity worksheet)	1,4	1,5	0,0
Total - Other		1,4	1,5	0,0

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		34,7	88,3	22,7
Total PE Value	88,3	kWh/(m²a)		
Total emissions CO_2-Equivalent	22,7	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		21,3	55,5	14,5
Specific PE demand - Mechanical system	55,5	kWh/(m²a)		
Total emissions CO_2-equivalent	14,5	kg/(m²a)		

Solar electricity			PE-Value (generation)	CO_2-emission factor
		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	(Worksheet PV)	6630	0,4	63
Specific demand		12,1	5,1	0,8
PE Value: Conservation by solar electricity	26,3	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	7,4	kg/(m²a)		

Annex 47: *PE Value Worksheet - Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²			
Space heating demand incl. distribution	16	kWh/(m²a)			
Useful cooling demand incl. dehumidification:		kWh/(m²a)			

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	2,6	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	0,0	0,0	0,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	11,8	30,6	8,0
Electricity demand - Auxiliary electricity			8,4	21,7	5,7
Total electricity demand (without heat pump)			20,1	52,4	13,7
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	2,6	680
Energy carrier - Supplementary heating			Electricity	2,6	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	2,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,43		
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,43		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	10,4	27,0	7,1
Non-electric demand, DHW wash&dish			0,1	0,2	0,1
Total electricity demand heat pump		*(HP worksheet)*	10,5	27,2	7,1
Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%		250
Boiler type		*(Boiler worksheet)*			
Performance ratio of heat generator		*(Boiler worksheet)*	0%		
Annual energy demand (without DHW wash&dish)		*(Boiler worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Total heating oil/gas/wood			0,0	0,0	0,0
Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	0,2	55
Heat source		*(Project)*	Wood		
Performance ratio of heat generator		*(Project)*	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		*(Electricity worksheet)*	1,4	1,5	0,1
Total - Other			1,4	1,5	0,1

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances			32,0	81,1	20,9
Total PE Value	81,1	kWh/(m²a)			
Total emissions CO_2-Equivalent	20,9	kg/(m²a)			(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)		yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)			18,7	48,7	12,7
Specific PE demand - Mechanical system	48,7	kWh/(m²a)			
Total emissions CO_2-equivalent	12,7	kg/(m²a)			

Solar electricity				PE-Value (generation)	CO_2-emission factor
			kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation		*(Worksheet PV)*	6630	0,4	63
Specific demand			12,1	5,1	0,8
PE Value: Conservation by solar electricity	26,3	kWh/(m²a)			
Saved CO_2 emissions through solar electricity	7,4	kg/(m²a)			

Annex 48: *PE Value Renewable Worksheet - Space Heating and DHW Preparation by Biomass Boiler*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type:	Multifunctional building	
Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	16	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,3	532
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	0,0	0,0	0,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	11,8	15,3	6,3
Electricity demand - Auxiliary electricity			9,2	11,9	4,9
Total electricity demand (without heat pump)			**20,9**	**27,2**	**11,1**
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*		kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	532
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*			
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*			
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*			
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		*(HP worksheet)*	**0,0**	**0,0**	**0,0**
Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	1,1	26
Boiler type		*(Boiler worksheet)*	Wood pellet burning (direct and indirect release of he		
Performance ratio of heat generator		*(Boiler worksheet)*	167%		
Annual energy demand (without DHW wash&dish)		*(Boiler worksheet)*	40,9	7,8	1,1
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,4	0,4	0,0
Total heating oil/gas/wood			**41,3**	**8,3**	**1,1**
Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	55
Heat source		*(Project)*	Gas		
Performance ratio of heat generator		*(Project)*	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		*(Electricity worksheet)*	1,4	1,5	0,1
Total - Other			**1,4**	**1,5**	**0,1**
Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances			**63,6**	**37,0**	**12,3**

Total PE Value	**37,0**	kWh/(m²a)		
Total emissions CO_2 Equivalent	**12,3**	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	**yes**

			Final energy	Primary energy	Emissions
Heating, DHW, auxiliary electricity (no lighting and electrical appliances)			**50,0**	**19,7**	**5,9**
Specific PE demand - Mechanical system	**19,7**	kWh/(m²a)			
Total emissions CO_2-equivalent	**5,9**	kg/(m²a)			

Solar electricity				PE-Value (generation)	CO_2-emission factor
			kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation		*(Worksheet PV)*	6630	0,420	63
Specific demand			**10,6**	**4,5**	**0,7**
PE Value: Conservation by solar electricity	**9,4**	kWh/(m²a)			
Saved CO_2 emissions through solar electricity	**5,0**	kg/(m²a)			

Annex 49: *PE Value Renewable Worksheet - Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice		Building type: Multifunctional building			
		Treated floor area A_{TFA}:	550	m²	
		Space heating demand incl. distribution	16	kWh/(m²a)	
		Useful cooling demand incl. dehumidification:		kWh/(m²a)	

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	1,3	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	7,3	9,5	5,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	12,0	15,6	8,2
Electricity demand - Auxiliary electricity			7,9	10,3	5,4
Total electricity demand (without heat pump)			27,2	35,4	18,5

				PE Value	CO_2-emissions factor (CO_2-equivalent)
Heat pump					
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	680
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	2,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,39		
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,39		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	6,1	11,1	4,2
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		*(HP worksheet)*	6,1	11,1	4,2

			PE Value	CO_2-emissions factor (CO_2-equivalent)
Boiler				
Covered fraction of space heating demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	0%		250
Boiler type	*(Boiler worksheet)*			
Performance ratio of heat generator	*(Boiler worksheet)*	0%		
Annual energy demand (without DHW wash&dish)	*(Boiler worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,0	0,0	0,0
Total heating oil/gas/wood		0,0	0,0	0,0

			PE Value	CO_2-emissions factor (CO_2-equivalent)
Other				
Covered fraction of space heating demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	0%	1,8	55
Heat source	*(Project)*	Gas		
Performance ratio of heat generator	*(Project)*	135%		
Annual energy demand, space heating		0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)		0,0	0,0	0,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)	*(Electricity worksheet)*	1,4	1,5	0,0
Total - Other		1,4	1,5	0,0

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		34,7	48,0	22,7
Total PE Value	48,0	kWh/(m²a)		
Total emissions CO_2-Equivalent	22,7	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		21,3	30,8	14,5
Specific PE demand - Mechanical system	30,8	kWh/(m²a)		
Total emissions CO_2-equivalent	14,5	kg/(m²a)		

			PE-Value (generation)	CO_2-emission factor
Solar electricity		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	*(Worksheet PV)*	6630	0,4	63
Specific demand		10,6	4,5	0,7
PE Value: Conservation by solar electricity	9,4	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	6,6	kg/(m²a)		

Annex 50: *PE Value Renewable Worksheet - Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	16	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

			Final energy kWh/(m²a)	Primary energy kWh/(m²a)	Emissions CO_2-equivalent kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,3	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	0,0	0,0	0,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	11,8	15,3	8,0
Electricity demand - Auxiliary electricity			8,4	10,9	5,7
Total electricity demand (without heat pump)			20,1	26,2	13,7
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	1,8	680
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	2,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,43		
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,43		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	10,4	18,7	7,1
Non-electric demand, DHW wash&dish			0,1	0,2	0,1
Total electricity demand heat pump		*(HP worksheet)*	10,5	18,8	7,1
Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%		250
Boiler type		*(Boiler worksheet)*			
Performance ratio of heat generator		*(Boiler worksheet)*	0%		
Annual energy demand (without DHW wash&dish)		*(Boiler worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Total heating oil/gas/wood			0,0	0,0	0,0
Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	55
Heat source		*(Project)*	Gas		
Performance ratio of heat generator		*(Project)*	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		*(Electricity worksheet)*	1,4	1,5	0,1
Total - Other			1,4	1,5	0,1

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		32,0	46,5	20,9	
Total PE Value	46,5	kWh/(m²a)			
Total emissions CO_2-Equivalent	20,9	kg/(m²a)		(Yes/No)	
Primary Energy Requirement		120	kWh/(m²a)	yes	

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		18,7	29,5	12,7
Specific PE demand - Mechanical system	29,5	kWh/(m²a)		
Total emissions CO_2-equivalent	12,7	kg/(m²a)		

			PE-Value (generation)	CO_2-emission factor
Solar electricity		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	*(Worksheet PV)*	6630	0,4	63
Specific demand		10,6	4,5	0,7
PE Value: Conservation by solar electricity	9,4	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	6,6	kg/(m²a)		

Annex 51: *Passive House Premium Heating Demand*

Passive House planning: **SPECIFIC ANNUAL HEATING DEMAND (monthly method)**

(This page displays the sums of the monthly method over the heating period)

Climate: [CZ] - Praha | Interior temperature: 20 °C

Building: House of Trees Průhonice | Building type: Multifunctional building

Spec. Capacity: 132 Wh/(m²K) | Treated floor area A_{TFA}: 549,8 m²

Building assembly	Temperature zone	Area m²		U-Value W/(m²K)		Month. red. fac.		G_t kKh/a		kWh/a	per m² treated floor area
Exterior wall - Ambient	A	364,8	*	0,088	*	1,00	*	85	=	2723	4,95
Exterior wall - Ground	B		*		*	1,00	*		=		
Roof/Ceiling - Ambient	A	655,3	*	0,073	*	1,00	*	85	=	4066	7,40
Floor slab / Basement ceiling	B	623,2	*	0,091	*	1,00	*	53	=	3022	5,50
	A		*		*	1,00	*		=		
	A		*		*	1,00	*		=		
	X		*		*	0,75	*		=		
Windows	A	184,7	*	0,691	*	1,00	*	85	=	10852	19,74
Exterior door	A		*		*	1,00	*		=		
Exterior TB (length/m)	A		*		*	1,00	*		=		0,00
Perimeter TB (length/m)	P		*		*	1,00	*		=		0,00
Ground TB (length/m)	B		*		*	1,00	*		=		0,00
											kWh/(m²a)
Transmission heat losses Q_T									Total	20663	37,6

	A_{TFA} m²		Clear room height m		m³
Effective air volume V_V	550	*	4,00	=	2199

	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HR}		$n_{V,Res}$ 1/h		$n_{V,equi,fraction}$ 1/h
Effective air change rate Ambient nV,e	0,410	*(1-	0%	)*(1-	0,85	)+	0,042	=	0,104
Effective air change rate Ground nV,g	0,410	*	0%	*(1-	0,85	)		=	0,000

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation losses ambient Q_V	2199	*	0,104	*	0,33	*	85	=	6402	11,6
Ventilation losses ground $Q_{V,e}$	2199	*	0,000	*	0,33	*	53	=	0	0,0
Ventilation heat losses Q_V								Total	6402	11,6

		Q_T kWh/a		Q_V kWh/a		Reduction factor night/weekend saving		kWh/a	kWh/(m²a)
Total heat losses Q_L	(	20663	+	6402	) *	1,0	=	27065	49,2

Orientation of the area	Reduction factor See 'Windows' sheet		g-Value (perp. radiation)		Area m²		Global radiation kWh/(m²a)		kWh/a	kWh/(m²a)
North	0,22	*	0,50	*	10,8	*	136	=	162	
East	0,27	*	0,50	*	17,2	*	207	=	487	
South	0,63	*	0,50	*	150,1	*	346	=	16225	
West	0,24	*	0,50	*	6,0	*	240	=	176	
Horizontal	0,67	*	0,50	*	0,5	*	334	=	61	
Sum opaque areas									434	
Available solar heat gains Q_S								Total	17545	31,9

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal heat gains Q_I	0,024	*	212	*	2,8	*	549,8	=	7832	14,2

				kWh/a	kWh/(m²a)
	Free heat Q_F	Q_S + Q_I	=	25378	46,2
	Ratio free heat to losses	Q_F / Q_L	=	0,94	
Utilisation factor heat gains h_G			=	83%	
Heat gains Q_G		η_G * Q_F	=	21160	38,5
Annual heating demand Q_H		Q_L - Q_G	=	5905	11

	kWh/(m²a)		(Yes/No)
Limiting value	15	Requirement met?	yes

Annex 52: *Passive House Premium Heating Load*

Passive House planning: **SPECIFIC SPACE HEATING LOAD**

Building:	House of Trees Průhonice	Building type:	Multifunctional building
Climate (HL):	[CZ] - Praha	Treated floor area A_{TFA}:	549,8 m²
		Interior temperature:	20 °C

	Design temperature		Radiation: North	East	South	West	Horizontal	
Weather 1:	-10,6	°C	10	30	90	35	40	W/m²
Weather 2:	-1,2	°C	5	5	10	5	10	W/m²
Ground design temp.	9,6	°C						

Building assembly	Temperature zone	Area m²		U-Value W/(m²K)		Factor always 1 (except "X")		TempDiff 1 K		TempDiff 2 K		PT 1 W		PT 2 W
1. Exterior wall - Ambient	A	364,8	*	0,088	*	1,00	*	30,6	or	21,2	=	978	or	680
2. Exterior wall - Ground	B		*		*	1,00	*	10,4	or	10,4	=		or	
3. Roof/Ceiling - Ambient	A	655,3	*	0,073	*	1,00	*	30,6	or	21,2	=	1461	or	1016
4. Floor slab / Basement ceiling	B	623,2	*	0,091	*	1,00	*	10,4	or	10,4	=	594	or	594
5.	A		*		*	1,00	*	30,6	or	21,2	=		or	
6.	A		*		*	1,00	*	30,6	or	21,2	=		or	
7.	X		*		*	0,75	*	30,6	or	21,2	=		or	
8. Windows	A	184,7	*	0,691	*	1,00	*	30,6	or	21,2	=	3899	or	2711
9. Exterior door	A		*		*	1,00	*	30,6	or	21,2	=		or	
10. Exterior TB (length/m)	A		*		*	1,00	*	30,6	or	21,2	=		or	
11. Perimeter TB (length/m)	P		*		*	1,00	*	10,4	or	10,4	=		or	
12. Ground TB (length/m)	B		*		*	1,00	*	10,4	or	10,4	=		or	
13. House/DU Partition Wall	I		*		*	1,00	*	3,0	or	3,0	=		or	

Transmission heat load P_T

Total	=	6932	or	5000

Ventilation system:

	A_{TFA} m²		Clear room height m		m³
Effective air volume, V_V	549,8	*	4,00	=	2199

						η_{SHX} 1		η_{SHX} 2
Heat recovery efficiency of the heat exchanger	η_{HR}	85%	Heat recovery efficiency SHX	0%	Efficiency SHX	0%	or	0%

	$n_{V,Res}$ (Heating Load) 1/h		$n_{V,system}$ 1/h		Φ_{HR}		Φ_{HR}		1/h		1/h
Energetically effective air exchange n_V	0,105	+	0,410	*(1-	0,85	or	0,85	) =	0,167	or	0,167

Ventilation heat load P_V

V_V m³		n_V 1/h		n_V 1/h		c_{Air} Wh/(m³K)		TempDiff 1 K		TempDiff 2 K		P_V 1 W		P_V 2 W
2199,1	*	0,167	or	0,167	*	0,33	*	30,6	or	21,2	=	3697	or	2570

Total heating load P_L

		PL 1 W		PL 2 W
$P_T + P_V$	=	10629	or	7571

Orientation of the area	Area m²		g-Value (perp. radiation)		Reduction factor (see 'Windows' worksheet)		Radiation 1 W/m²		Radiation 2 W/m²		P_T 1 W		P_T 2 W
1. North	10,8	*	0,5	*	0,22	*	11	or	5	=	13	or	6
2. East	17,2	*	0,5	*	0,27	*	23	or	5	=	54	or	11
3. South	150,1	*	0,5	*	0,63	*	80	or	8	=	3774	or	380
4. West	6,0	*	0,5	*	0,24	*	37	or	5	=	27	or	4
5. Horizontal	0,5	*	0,5	*	0,67	*	39	or	10	=	7	or	2

Solar heating power P_S

Total	=	3875	or	402

Internal heating load P_I

Spec. power W/m²		A_{TFA} m²		P_I 1 W		P_I 2 W
1,6	*	550	=	880	or	880

Heating power (gains) P_G

		P_G 1 W		P_G 2 W
$P_T + P_I$	=	4755	or	1282
$P_L - P_G$	=	5874	or	6289

Heating load P_H = **6289** **W**

Area specific space heating load P_H / A_{TFA} = **11,4** **W/m²**

					°C	°C
Input max. supply air temperature	38	°C				
Max. supply air temperature $\vartheta_{Supply,Max}$	38	°C	Supply air temperature without heating	$\vartheta_{Supply,Min}$	15,4	16,8

For comparison: heating load transportable by the supply Air $P_{Supply\ Air,Max}$ = 6305 W specific: 11,5 W/m²

Supply air heating: Sufficient? (Yes/No) **yes**

Annex 53: *PE Value Worksheet for PHP - Space Heating and DHW Preparation by Biomass Boiler*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	13	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	1,8	532
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	(DHW+Distribution, SolarDHW)	0,0	0,0	0,0
Electric post heating DHW wash&dish		(Electricity, SolarDHW)	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	(Electricity worksheet)	11,8	21,2	6,3
Electricity demand - Auxiliary electricity			9,2	16,6	4,9
Total electricity demand (without heat pump)			21,0	37,8	11,2

Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)		kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	1,8	532
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	(HP worksheet)			
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	(HP worksheet)			
Heat generation efficiency (excl. DHW wash&dish)		(HP worksheet)			
Heat generation efficiency (incl. DHW wash&dish)		(HP worksheet)			
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	(HP worksheet)	0,0	0,0	0,0
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		(HP worksheet)	0,0	0,0	0,0

Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	100%	0,2	26
Boiler type		(Boiler worksheet)	Wood pellet burning (direct and indirect release of he		
Performance ratio of heat generator		(Boiler worksheet)	170%		
Annual energy demand (without DHW wash&dish)		(Boiler worksheet)	37,5	7,5	1,0
Non-electric demand, DHW wash&dish		(Electricity worksheet)	0,4	0,1	0,0
Total heating oil/gas/wood			37,9	7,6	1,0

Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	0,2	55
Heat source		(Project)	Gas		
Performance ratio of heat generator		(Project)	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		(Electricity worksheet)	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		(Electricity worksheet)	1,4	1,5	0,1
Total - Other			1,4	1,5	0,1

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances			60,2	46,9	12,3
Total PE Value	46,9	kWh/(m²a)			
Total emissions CO_2 Equivalent	12,3	kg/(m²a)			(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)		yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)			46,7	24,1	5,9
Specific PE demand - Mechanical system	24,1	kWh/(m²a)			
Total emissions CO_2-equivalent	5,9	kg/(m²a)			

Solar electricity				PE-Value (generation)	CO_2-emission factor
			kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation		(Worksheet PV)	95859	0,501	75
Specific demand			174,4	87,4	13,1
PE Value: Conservation by solar electricity	226,4	kWh/(m²a)			
Saved CO_2 emissions through solar electricity	79,6	kg/(m²a)			

Annex 54: *PE Value Worksheet for PHP - Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²	
Space heating demand incl. distribution	13	kWh/(m²a)	
Useful cooling demand incl. dehumidification:		kWh/(m²a)	

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	2,6	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	7,4	19,1	5,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	12,0	31,3	8,2
Electricity demand - Auxiliary electricity			8,0	20,9	5,5
Total electricity demand (without heat pump)			27,4	71,3	18,6
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	2,6	680
Energy carrier - Supplementary heating			Electricity	2,6	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	3,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,28		
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,28		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	3,8	9,8	2,6
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		*(HP worksheet)*	3,8	9,8	2,6
Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%		250
Boiler type		*(Boiler worksheet)*			
Performance ratio of heat generator		*(Boiler worksheet)*	0%		
Annual energy demand (without DHW wash&dish)		*(Boiler worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Total heating oil/gas/wood			0,0	0,0	0,0
Other				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	0,2	55
Heat source		*(Project)*	Wood		
Performance ratio of heat generator		*(Project)*	135%		
Annual energy demand, space heating			0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)		*(Electricity worksheet)*	1,4	1,5	0,0
Total - Other			1,4	1,5	0,0

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		32,5	82,6	21,2
Total PE Value	82,6	kWh/(m²a)		
Total emissions CO_2-Equivalent	21,2	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		19,2	49,8	13,0
Specific PE demand - Mechanical system	49,8	kWh/(m²a)		
Total emissions CO_2-equivalent	13,0	kg/(m²a)		

Solar electricity			PE-Value (generation)	CO_2-emission factor
		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	*(Worksheet PV)*	95859	0,5	75
Specific demand		174,4	87,4	13,1
PE Value: Conservation by solar electricity	365,9	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	105,4	kg/(m²a)		

Annex 55: *PE Value Worksheet for PHP - Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:			550	m²		
Space heating demand incl. distribution			13	kWh/(m²a)		
Useful cooling demand incl. dehumidification:				kWh/(m²a)		
			Final energy	**Primary energy**	**Emissions CO_2-equivalent**	
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)	
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)	
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh	
Covered fraction of DHW demand		*(Project)*	0%	2,6	680	
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0	
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	0,0	0,0	0,0	
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0	
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	11,8	30,6	8,0	
Electricity demand - Auxiliary electricity			8,5	22,1	5,8	
Total electricity demand (without heat pump)			**20,3**	**52,7**	**13,8**	
Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)	
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh	
Covered fraction of DHW demand		*(Project)*	100%	2,6	680	
Energy carrier - Supplementary heating			Electricity	2,6	680	
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	2,6			
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*				
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,43			
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,42			
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	9,2	23,8	6,2	
Non-electric demand, DHW wash&dish			0,1	0,2	0,1	
Total electricity demand heat pump		*(HP worksheet)*	**9,2**	**24,0**	**6,3**	
Boiler				PE Value	CO_2-emissions factor (CO_2-equivalent)	
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh	
Covered fraction of DHW demand		*(Project)*	0%		250	
Boiler type		*(Boiler worksheet)*				
Performance ratio of heat generator		*(Boiler worksheet)*	0%			
Annual energy demand (without DHW wash&dish)		*(Boiler worksheet)*	0,0	0,0	0,0	
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0	
Total heating oil/gas/wood			**0,0**	**0,0**	**0,0**	
Other				PE Value	CO_2-emissions factor (CO_2-equivalent)	
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh	
Covered fraction of DHW demand		*(Project)*	0%	0,2	55	
Heat source		*(Project)*	Wood			
Performance ratio of heat generator		*(Project)*	135%			
Annual energy demand, space heating			0,0	0,0	0,0	
Annual energy demand, DHW (without DHW wash&dish)			0,0	0,0	0,0	
Non-electric demand, DHW wash&dish		*(Electricity worksheet)*	0,0	0,0	0,0	
Non-electric demand cooking/drying (gas)		*(Electricity worksheet)*	1,4	1,5	0,1	
Total - Other			**1,4**	**1,5**	**0,1**	
Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances			**30,9**	**78,3**	**20,2**	
Total PE Value		**78,3**	kWh/(m²a)			
Total emissions CO_2-Equivalent		**20,2**	kg/(m²a)			(Yes/No)
Primary Energy Requirement			120	kWh/(m²a)	**yes**	
Heating, DHW, auxiliary electricity (no lighting and electrical appliances)			**17,7**	**45,9**	**12,0**	
Specific PE demand - Mechanical system		**45,9**	kWh/(m²a)			
Total emissions CO_2-equivalent		**12,0**	kg/(m²a)			
Solar electricity				PE-Value (generation)	CO_2-emission factor	
			kWh/a	kWh/kWh	g/kWh	
Planned annual electricity generation		*(Worksheet PV)*	95859	0,5	75	
Specific demand			**174,4**	**87,4**	**13,1**	
PE Value: Conservation by solar electricity		**365,9**	kWh/(m²a)			
Saved CO_2 emissions through solar electricity		**105,4**	kg/(m²a)			

Annex 56: *PE Value Renewable Worksheet for PHP - Space Heating and DHW Preparation by Biomass Boiler*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	13	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

				Final energy	Primary energy	Emissions CO_2-equivalent
				kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)					PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*		0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*		0%	1,3	532
Direct electric heating	$Q_{H,de}$			0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*		0,0	0,0	0,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*		0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*		11,8	15,3	6,3
Electricity demand - Auxiliary electricity				9,2	12,0	4,9
Total electricity demand (without heat pump)				**21,0**	**27,3**	**11,2**

			Final energy	PE Value	CO_2-emissions factor (CO_2-equivalent)
Heat pump					
Covered fraction of space heating demand		*(Project)*		kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	532
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*			
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*			
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*			
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		*(HP worksheet)*	**0,0**	**0,0**	**0,0**

		Final energy	PE Value	CO_2-emissions factor (CO_2-equivalent)
Boiler				
Covered fraction of space heating demand	*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	100%	1,1	26
Boiler type	*(Boiler worksheet)*	Wood pellet burning (direct and indirect release of he		
Performance ratio of heat generator	*(Boiler worksheet)*	170%		
Annual energy demand (without DHW wash&dish)	*(Boiler worksheet)*	37,5	7,1	1,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,4	0,4	0,0
Total heating oil/gas/wood		**37,9**	**7,6**	**1,0**

		Final energy	PE Value	CO_2-emissions factor (CO_2-equivalent)
Other				
Covered fraction of space heating demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	0%	1,8	55
Heat source	*(Project)*	Gas		
Performance ratio of heat generator	*(Project)*	135%		
Annual energy demand, space heating		0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)		0,0	0,0	0,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)	*(Electricity worksheet)*	1,4	1,5	0,1
Total - Other		**1,4**	**1,5**	**0,1**

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		60,2	36,4	12,3
Total PE Value	**36,4**	kWh/(m²a)		
Total emissions CO_2 Equivalent	**12,3**	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	**yes**

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		46,7	19,1	5,9
Specific PE demand - Mechanical system	**19,1**	kWh/(m²a)		
Total emissions CO_2-equivalent	**5,9**	kg/(m²a)		

			PE-Value (generation)	CO_2-emission factor
Solar electricity		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	*(Worksheet PV)*	95859	0,501	75
Specific demand		153,6	77,0	11,6
PE Value: Conservation by solar electricity	**122,7**	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	**70,1**	kg/(m²a)		

Annex 57: *PE Value Renewable Worksheet for PHP - Heat Pump Space Heating and DHW Preparation by Electricity*

Passive House planning: **PRIMARY ENERGY VALUE**

Building: House of Trees Průhonice

Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	13	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	100%	1,3	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	*(DHW+Distribution, SolarDHW)*	7,4	9,6	5,0
Electric post heating DHW wash&dish		*(Electricity, SolarDHW)*	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	*(Electricity worksheet)*	12,0	15,6	8,2
Electricity demand - Auxiliary electricity			8,0	10,4	5,5
Total electricity demand (without heat pump)			27,4	35,6	18,6

				PE Value	CO_2-emissions factor (CO_2-equivalent)
Heat pump					
Covered fraction of space heating demand		*(Project)*	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		*(Project)*	0%	1,8	680
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	*(HP worksheet)*	3,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	*(HP worksheet)*			
Heat generation efficiency (excl. DHW wash&dish)		*(HP worksheet)*	0,28		
Heat generation efficiency (incl. DHW wash&dish)		*(HP worksheet)*	0,28		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	*(HP worksheet)*	3,8	6,8	2,6
Non-electric demand, DHW wash&dish			0,0	0,0	0,0
Total electricity demand heat pump		*(HP worksheet)*	3,8	6,8	2,6

			PE Value	CO_2-emissions factor (CO_2-equivalent)
Boiler				
Covered fraction of space heating demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	0%		250
Boiler type	*(Boiler worksheet)*			
Performance ratio of heat generator	*(Boiler worksheet)*	0%		
Annual energy demand (without DHW wash&dish)	*(Boiler worksheet)*	0,0	0,0	0,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,0	0,0	0,0
Total heating oil/gas/wood		0,0	0,0	0,0

			PE Value	CO_2-emissions factor (CO_2-equivalent)
Other				
Covered fraction of space heating demand	*(Project)*	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	*(Project)*	0%	1,8	55
Heat source	*(Project)*	Gas		
Performance ratio of heat generator	*(Project)*	135%		
Annual energy demand, space heating		0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)		0,0	0,0	0,0
Non-electric demand, DHW wash&dish	*(Electricity worksheet)*	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)	*(Electricity worksheet)*	1,4	1,5	0,0
Total - Other		1,4	1,5	0,0

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		32,5	43,9	21,2
Total PE Value	43,9	kWh/(m²a)		
Total emissions CO_2 Equivalent	21,2	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	yes

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		19,2	26,8	13,0
Specific PE demand - Mechanical system	26,8	kWh/(m²a)		
Total emissions CO_2-equivalent	13,0	kg/(m²a)		

			PE-Value (generation)	CO_2-emission factor
Solar electricity		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	*(Worksheet PV)*	95859	0,5	75
Specific demand		153,6	77,0	11,6
PE Value: Conservation by solar electricity	122,7	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	92,9	kg/(m²a)		

Annex 58: *PE Value Renewable Worksheet for PHP - Space Heating and DHW Preparation by Heat Pump with Ground Collectors*

Passive House planning: **P R I M A R Y   E N E R G Y   V A L U E**

Building: House of Trees Průhonice | Building type: Multifunctional building

Treated floor area A_{TFA}:	550	m²
Space heating demand incl. distribution	13	kWh/(m²a)
Useful cooling demand incl. dehumidification:		kWh/(m²a)

			Final energy	Primary energy	Emissions CO_2-equivalent
			kWh/(m²a)	kWh/(m²a)	kg/(m²a)
Electricity demand (without heat pump)				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	0%	1,3	680
Direct electric heating	$Q_{H,de}$		0,0	0,0	0,0
Hot water, direct electric (without DHW wash&dish)	$Q_{DHW,de}$	(DHW+Distribution, SolarDHW)	0,0	0,0	0,0
Electric post heating DHW wash&dish		(Electricity, SolarDHW)	0,0	0,0	0,0
Electricity demand lighting/auxiliary tools/kitchen	Q_{EHH}	(Electricity worksheet)	11,8	15,3	8,0
Electricity demand - Auxiliary electricity			8,5	11,1	5,8
Total electricity demand (without heat pump)			**20,3**	**26,4**	**13,8**

Heat pump				PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand		(Project)	100%	kWh/kWh	g/kWh
Covered fraction of DHW demand		(Project)	100%	1,8	680
Energy carrier - Supplementary heating			Electricity	1,8	680
Seasonal performance factor of heat pump 1 (heating / heating&D	SPF_{H-1}	(HP worksheet)	2,6		
Seasonal performance factor heat pump 2 (DHW)	SPF_{H-1}	(HP worksheet)			
Heat generation efficiency (excl. DHW wash&dish)		(HP worksheet)	0,43		
Heat generation efficiency (incl. DHW wash&dish)		(HP worksheet)	0,42		
Electricity demand heat pump (without DHW wash&dish)	Q_{HP}	(HP worksheet)	9,2	16,5	6,2
Non-electric demand, DHW wash&dish			0,1	0,2	0,1
Total electricity demand heat pump		(HP worksheet)	**9,2**	**16,6**	**6,3**

Boiler			PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand	(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	(Project)	0%		250
Boiler type	(Boiler worksheet)			
Performance ratio of heat generator	(Boiler worksheet)	0%		
Annual energy demand (without DHW wash&dish)	(Boiler worksheet)	0,0	0,0	0,0
Non-electric demand, DHW wash&dish	(Electricity worksheet)	0,0	0,0	0,0
Total heating oil/gas/wood		**0,0**	**0,0**	**0,0**

Other			PE Value	CO_2-emissions factor (CO_2-equivalent)
Covered fraction of space heating demand	(Project)	0%	kWh/kWh	g/kWh
Covered fraction of DHW demand	(Project)	0%	1,8	55
Heat source	(Project)	Gas		
Performance ratio of heat generator	(Project)	135%		
Annual energy demand, space heating		0,0	0,0	0,0
Annual energy demand, DHW (without DHW wash&dish)		0,0	0,0	0,0
Non-electric demand, DHW wash&dish	(Electricity worksheet)	0,0	0,0	0,0
Non-electric demand cooking/drying (gas)	(Electricity worksheet)	1,4	1,5	0,1
Total - Other		**1,4**	**1,5**	**0,1**

Heating, cooling, DHW, auxiliary electricity, lighting, electrical appliances		30,9	44,5	20,2
Total PE Value	**44,5**	kWh/(m²a)		
Total emissions CO_2 Equivalent	**20,2**	kg/(m²a)		(Yes/No)
Primary Energy Requirement		120	kWh/(m²a)	**yes**

Heating, DHW, auxiliary electricity (no lighting and electrical appliances)		17,7	27,5	12,0
Specific PE demand - Mechanical system	**27,5**	kWh/(m²a)		
Total emissions CO_2-equivalent	**12,0**	kg/(m²a)		

Solar electricity			PE-Value (generation)	CO_2-emission factor
		kWh/a	kWh/kWh	g/kWh
Planned annual electricity generation	(Worksheet PV)	95859	0,5	75
Specific demand		153,6	77,0	11,6
PE Value: Conservation by solar electricity	**122,7**	kWh/(m²a)		
Saved CO_2 emissions through solar electricity	**92,9**	kg/(m²a)		