University of Aveiro
2014

Department of Civil Engineering

Magdalena Dopierala

Heritage Buildings' retrofitting according to ENERPHIT requirements.

Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT.

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Master Thesis to submitted to the University of Aveiro to achieve the Master degree of Civil Engineering, conducted under the scientific guidance of Professor Maria Fernanda da Silva Rodrigues, Assistant Professor, Department of Civil Engineering, University of Aveiro, co-guidance of Professor Romeu da Silva Vicente, Assistant Professor, Department of Civil Engineering, University of Aveiro and Habilitated Doctor Dariusz Heim, Department of Process Engineering and Environmental Protection, Lodz University of Technology.

I dedicated this work to my mother.

Jury

President

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palavras-chave

Reabilitação energética, Passive House, requesitos EnerPHit

resumo

Esta dissertação versa sobre a aplicação do conceito da *Passive House* a um edifício com valor patrimonial do início do século XX, localizado na cidade de Jarocin, na Polónia, tendo como principal objetivo verificar a aplicabilidade dos requisitos de elevada eficiência energética estabelecidos pela *Passive House* à reabilitação de edifícios existentes, através do *standard EnerPhit.*

Para alcançar este objetivo, além da pesquisa bibliográfica, efetuou-se o balanço térmico do edifício objeto de estudo, segundo o *standard EnerHPit,* aplicando o *Passive House Planning Package* - PHPP8. Desenvolveram-se soluções construtivas com o intuito de efetuar a reabilitação do edifício antigo, situado num clima frio, para se obter um edifício passivo, com reduzida necessidade de energia para aquecimento, segundo os requisitos EnerPHit.

Em síntese esta dissertação apresenta a aplicação do conceito Passive House à reabilitação energética de edifícios, incidindo num edifício com valor patrimonial, localizado no centro da Polónia e concluiu-se que é viável a aplicação do *standard EnerPhit* nesta região climática, alcançando-se um consumo energético reduzido, qualidade do ar interior e conforto térmico.

Keywords: Energy Retrofit, Passive House, EnerPHit standard

Abstract:

This thesis refers to the applying of Passive house concept to a old building from the early twentieth century in Polish climate, focusing on city of Jarocin. All work is based on the EnerPHit requirements for buildings retrofitting (Certification thermomodernization with approved quality using quality components for passive construction - EnerPHit)

The aim of this study is to reach solutions to solve the problem of achiving low heating demand for old building in colder climate, according EnerPhit requirements.

The study began with the introduction to Passive House concepts for new and retrofitted buildings. Therefore, the examples of construction solutions, materials and the thermal performance comparison between them have been described.

The software "Passive House Planning Package" has been adopted for the thermal balance calculation.

Summarizing, this study presents the Passive House concept for building retrofitting, which focus on an historical old building, located in central of Poland, and conclude for the possible achivement of this standard requirements.

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1. Introduction

Passive house means - warm, comfortable, and inexpensive to maintain. Such features characterize this type of modern buildings. Their basic premise is to provide maximum comfort with minimum energy consumption. Its innovation is reflected in the fact that it focuses primarily on improving the performance of existing systems and components in each building rather than introducing additional solutions. Starting from the foundation to the roof, structural and no structural components must meet the requirements imposed by the applicable standards. In the aim of obtain thermal comfort it must be pad special attention to material's thermal conductivity coefficient - Λ (W/m·K), the heat transfer coefficient U ($W/m^2 \cdot K$), and to the total energy transmittance factor - for glazing area, g_{value}.
Passivhaus Institut was founded in 1996 by Dr. Wolfgang Feist, as an independent research facility in Darmstadt, Germany. That is - why he is considered the creator of the idea of passivity in the operation of buildings. Building energy efficient and passive performance has been prevalent from the beginning of a global concern about the negative effects of human activities on the environment. In those years, the discussions covered issues related with the development and impact of several economic sectors. Today it is known the strong and negative impact of the building sector in the environment especially due to the high energy consumption during life cycle, and consequently due of the greenhouse gas emissions. Views on climate change are divided. Some scientists believe that in the largest extent they are caused by human activities, and some are of the opinion that there is no change, or they are completely natural and unavoidable. People invented the fields of science as economics and logistics aimed of finding algorithms for ways to make better use of all resources, saving time, energy and money most of all. The same objective pushes to research on achievement, in the simplest way, the passive standards.

Nowadays, The Passive House became the internationally acknowledged standard for sustainable architecture. Scientists from whole world are working to invent new technologies, ideas, materials, solutions which enhance simplicity of build this type of buildings. The Passive House concept is relatively low-cost method to achieve these energy savings.

To spread knowledge throughout beyond select the group of specialists of professional building community is paramount importance. All new solutions and technology have supporters and opponents. However, lack of knowledge often causes drawing incorrect conclusions. Currently, important not only to build beautiful and impressive buildings, but building smart ones, for the benefit of themselves and the whole environment. End of construction spending is not the end, but the start time stage big disappoint for those who exploit it. Indeed also, there is a tendency, not only relating to the construction industry but also many issues, namely to desire to have things at a low cost As we know, this way of thinking often brings unsatisfactory results. Anyone who is planning to build a house must to consider the cost of expenses for heating, electricity, hot water, sewer, garbage and taxes. On these factors lots of particular components and elements have influence, such as: advanced materials solutions in construction of the building but also to the type of heat for central heating and domestic hot water .

In my thesis, I would like to present what have to be considered during the process of design to reach the Passive House standards. Interest in energy-saving and passive construction is increasing every year, which is associated with an increase ecological awareness in our society. Mainly I want to provide a framework for the high efficiency retrofitting of existing buildings, which, according to applicable standards must reach a heating demand not higher than 25 kWh/(m^2/year).

1.1. General characteristics of the building

The subject of discussion will be an existing detached building, which is located in the village of Jarocin in Wielkopolska voivodeship in Poland. Buildings has the basement under the entire residential part. The construction of the building consists of brick walls with ceramic brick and wooden ceiling in the span 3.9 m, 4.3 m.

It is a two-storey building: ground floor + attic over part of the building. It consists of a main section; above it is a gable roof and some parts that were added at a later date. One part is finished with a pitched roof, other with flat roof and a second one with terrace. The building has a driveway, with the appropriate declines, leading to the interior.

1.2 Historical overview

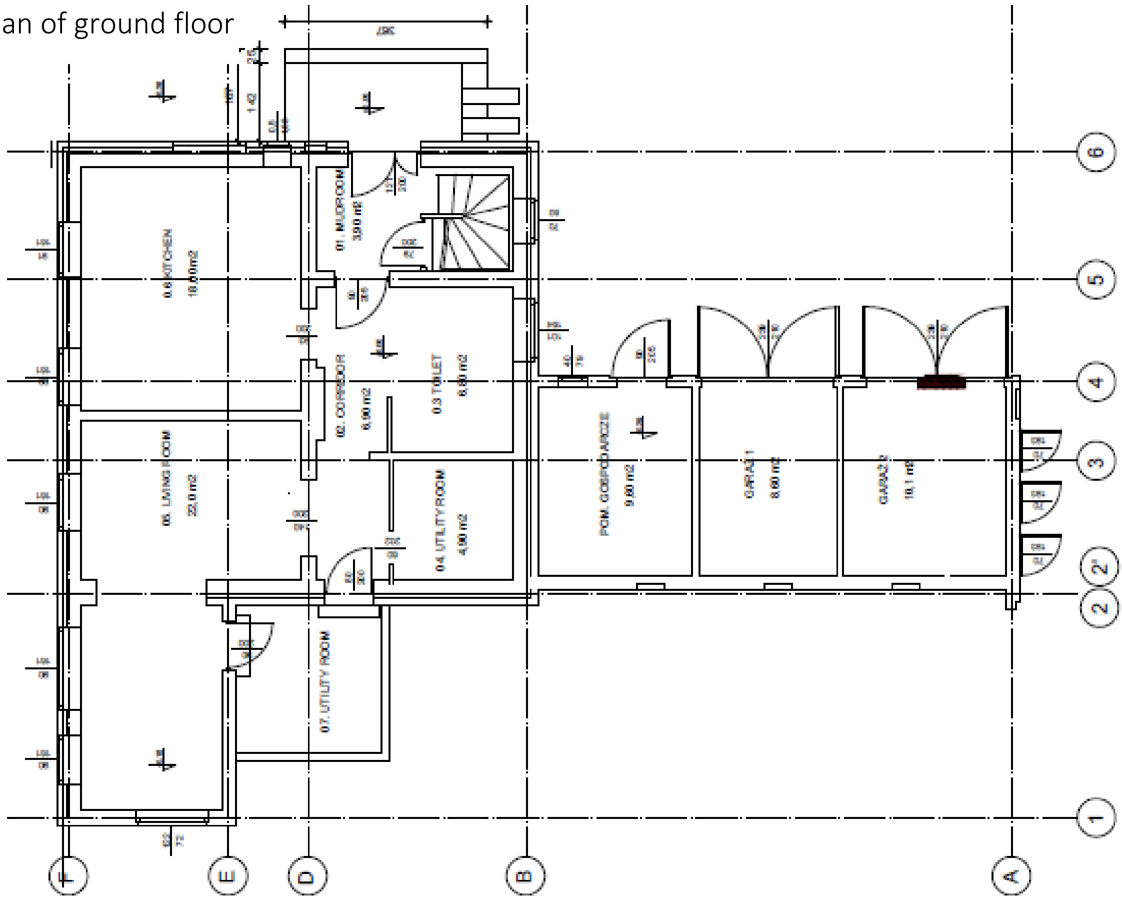
The building, which I will deal with, is located on the old, now inoperative, cemetery Evangelical-Augsburg. This cemetery is located in the western part of the city. It was founded in the second half of the nineteenth century by German settlers. It was designed on a square plan similar to a rectangle, with the main linden alley running from the corner to the door of the chapel. In the corner of the north-east is located the neo-Gothic gate. It was built with bricks. All objects in the cemetery have many decorative elements. The entire cemetery is overgrown with trees, with preserved fragments of tombstones. All facilities were built of solid brick grouted combined lime-sand mortar with the addition of cement. Some parts of the walls, such as cornices, pinnacles, etc. were plastered. Architectural details were made in cement mortar or in the form of castings made of artificial stone on the basis of cement mortar. Buildings do not currently have a secondary layers on the elevation. They were only slightly repainted.

1.3 Inventory, technical description and appraisal of the current state

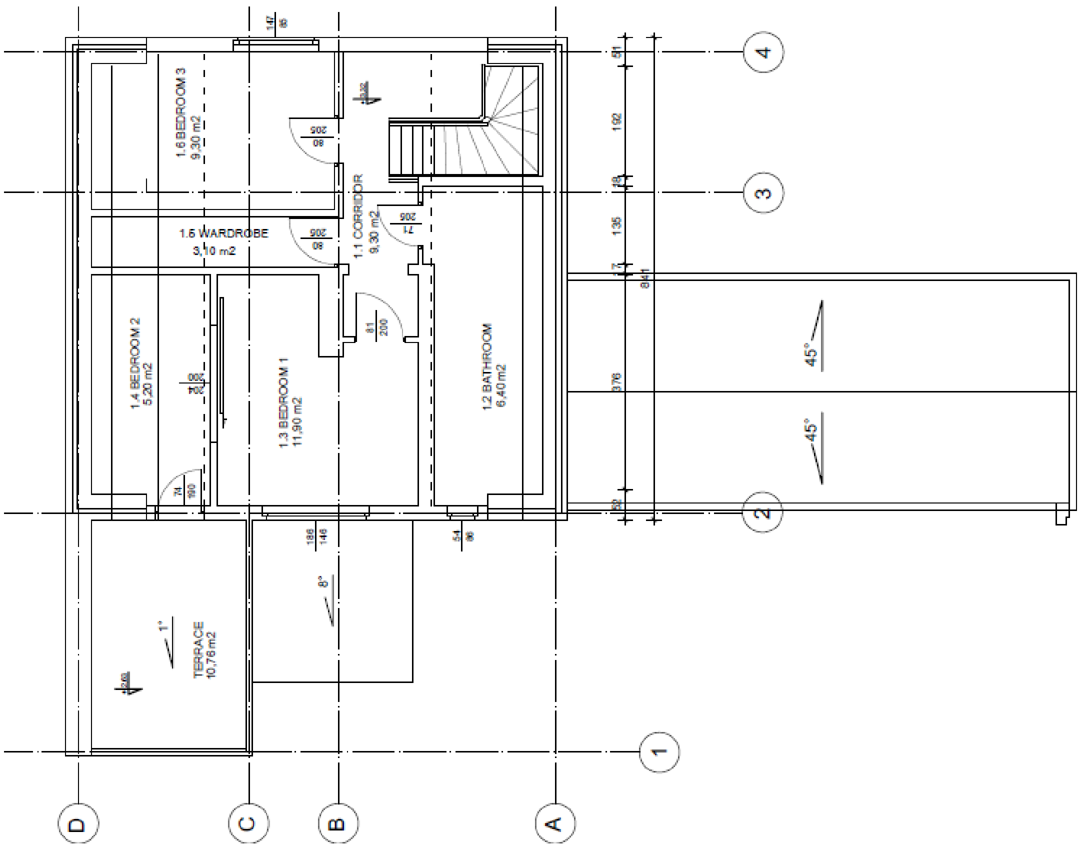
This part of my thesis is based on received inventory, the expertise of the building and the technical description.

1.3.1 Inventory drawings:

a) Plan of ground floor



b) Plan of first floor



- Gravedigger's house was built of brick. It was probably constructed at the same time with a chapel (about 1900). The main part of the building is designed on a square plan, two-storey - with loft, currently usable, covered with a pitched roof. From the south-east has a rectangular wing adjacent to the building. This ranch wing is also covered with a gable roof with ridge perpendicular to the main ridge. From the south-west there are two outbuildings with flat roofs, which are currently used as a terrace.
- The external walls were built of ceramic bricks on lime-cement mortar. They are placed on a ring fenced from the face of the wall brick foundation, brick topped with a roller projecting from the face of the wall. Decorative elements in the form of lintels, cornices were made of brick.
- Internal walls covered with plaster, and partly covered with ceramic tiles. The building has been remodeled inside with adjusting to the new use requirements. Some of the walls were demolished, and raised new partitions. Some parts of the internal walls are not plastered.
- Ceiling - wooden floor above the ground floor pelted the mat of reeds. Above residential part on ground floor, there are wooden floors with wooden beams.
- Rafter framing in the residential part is not available because of the way management of attic. On the surface of interior walls of attic, columns and struts hidden wooden structure are clearly visible. The roof in utility part of attic was made of wooden rafters.

- The roof of a residential building with utility wing is covered with ceramic plain tiles, which are arranged in a double ichthyosis. The ridge is covered by ridge tile.
- The floors in the living areas of the ground floor and of attic are useful wooden shuttering partially covered with linoleum. In one room on the ground floor of the original floor was replaced with wood-paneling. In hygiene and sanitation areas are placed secondary tiles.
- External stairs at the main entrance to the building are preceded by a low brick low wall with visible traces of plaster with no hand rails. The landing and steps are covered with slabs of granite.
- Window openings are preserved in the original version, in the shape of rectangles. Partially preserved original wooden window closed straight, double. Narrower window in the front elevation is a double, three-level, closed straight.
- Exterior door openings are in rectangles shape, closed straight. They are filled with wooden doors. In rooms inside the building there are no-preserved original woodwork doors. The main exterior doors are double. The decorative handles have been preserved as a original appearance of doors. Above the door there is a glazed, three-pole fanlight.

2. Passive Houses Principles

The need to amend habits and change the way of thinking regarding the environment is gaining momentum in recent years. People slowly become aware of the negative effect of their actions in the era of technological industrial development. Cases that have determined these changes are largely political reasons, economic and pressure from international organizations which deal with the ecology in the broadest sense of the word.

Thus this building technique confirm following arguments:

- international action against climate change and to reduce energy demand,
- aware that buildings with less power consumption interact to a lesser extent on the environment,
- the fact that this type of buildings have lower life-cycle cost with taking into account the currently existing high energy prices,
- the need to meet international commitments of our country.

Action against climate change and reducing energy demand.

Directive of the European Parliament and of the Council 2010/31/EU of 19 May 2010 on the energy performance of buildings requires Member States to bring about a situation in which until 2020 all newly created buildings have become the objects of very low energy demand. This document shows the European Union quest reduce energy consumption until 2020 by 20% [1]. The Polish government has prepared a priority program entitled "Efficient use of energy", in which the third part refers to subsidies to loans for the construction of passive houses and energy-efficient.

The entire program is planned for the years 2013-2018. It ranges subsidies to credit. It has to adapt to the requirements of the Directive of all entities taking part in the construction process, including construction materials producers. It is anticipated that subsidy will enable the execution approximately 12,000 houses and apartments in multifamily buildings. The entire budget of the program amounts to 300 million Polish zlotys.[2] It is also constitute incentive to build a well-balanced buildings on Polish territory. It has also bring financial benefits to the beneficiaries, as well as effectively influence public education. The program introduces two standards that distinguish the amount the grant, namely the standard NF40 and NF15. NF40 applies to low-energy buildings, where the demand for primary energy is not more than 40 kWh (m^2·year), while NF15 refers to passive buildings, where the value does not exceed 15 kWh (m^2·year). The National Fund for Environmental Protection and Water Management has published detailed guidelines relating to the achievement of these standards SF40 and SF15 energy, methods of design verification and checking finished buildings. For example, according to these guidelines for climatic zones I, II and III, a detached building NF15, limit the value of heat transfer coefficient of the outer wall is 0.10 W/m^2K and for external doors, garage doors, this value does not exceed 0.8 W/m^2K. [3] These requirements apply to both the building structure and the mechanical ventilation systems and systems heating and domestic hot water systems. Accordingly, the division of these standards and the type of building (single family houses and apartments in multifamily buildings) is selected amount of funding. Single-family homes in the case of low-energy NF40 amounts to 30 000 Polish zlotys gross. [4]

In summary, all of these activities is expected to bring benefits to households in the form of subsidies to loans which cover a large part of the investment costs, reducing the operating costs of the building and enhance the value of the building. Both the investors, by financial benefits, the State in fulfillment of European Union Directive whereby plan to cut energy demand will decrease and our environment will benefit in the form of reduced greenhouse gas pollution. Thanks to this type of initiative from the state each party gains.

EnerPHit performance criteria

Benefits of Passivhaus refurbishment are as fallows: increased insulation and airtightness to improve thermal comfort and reduce risk of surface condensation and mould growth, by increasing surface temperatures and controlling moisture. "Quality-Approved Energy Retrofit with Passive House Components" Certificate this is the main purpose of hole action plan upgrading of existing buildings according the Passive House Institute. The goal was to create a standard for an economically and ecologically optimal energy retrofit, for old buildings that cannot achieve Passive House Standard due to reasonable effort.

The table below shows the differences between performance criteria for new and retrofit buildings (Table 2.1). Next one (Table 2.2) presents coefficients values for buildings component.

Table 2.1 EnerPHit performance criteria

Criteria	New build	Retrofit
Q_H Specific Space heat demand.	max. 15 kWh/(m^{2}a)	max. 25 kWh/(m^{2}a)
Pressurisation test result n_{50}	max. 0.6 h^{-1}	max. 1.0 h^{-1}
Q_P Entire Specific Energy Demand	max. 120 kWh/(m^{2}a)	max. 120 kWh/(m^{2}a) = ((Q_H – 15 120 kWh/(m^{2}a) · 1,2)
Frequency of overheating (over degress)	max. 10 %	max. 10 %
Water activity of interior surface a_w		max. 80 %

Source: *Melisa Taylor, Passivehaus Trust, EnerPHit – The ner Passivhaus referbishemnt standard from the Passivehaus Institute, The Uk Passive House Organisation Passivehouse Trust, March 2011*

Table 2.2 EnerPHit component criteria

Building Component	Retrofit criteria
Externall Wall	External insulation U ≤ 0.150 W/(m$^{2\cdot}$K) Internal insulation U≤0.350 W/(m^{2}K)
Roof or top floor ceiling	U ≤ 0.120 W/(m^{2}K)
Windows	$U_{W\ installed}$ ≤ 0.85 W/(m^2·K) g- 1,6 W/(m^{2}K) ≤ U_g
External door	$U_{D\ installed}$ 0.80 W/(m^{2}K)
Thermal bridges	No linear thermal bridges with Ψ > + 0.01 W/(m^{2}K) Or punctiform thermal Bridges with χ > + 0.04 W/(m^{2}K)
Ventilation Electrical efficiency of ventilation system	$\eta_{HR,eff}$ ≥ 75 % ≤ 0.45 Wh/m^3

Source: *Melisa Taylor, Passivehaus Trust, EnerPHit – The ner Passivhaus referbishemnt standard from the Passivehaus Institute, The Uk Passive House Organisation Passivehouse Trust, March 2011*

The standard heating system in Central Europe is a central water heating with radiators, installations, central oil, gas, or coal furnaces. Typically, existing buildings have heat demand on the level of 100W/m2. This number means the need to provide 10kw of energy to heat 100 m2 apartment. The main idea of Passive Houses is reduction of heat loss to the extent that a separate heating system The heat demand is met by pre-heating the air which is ventilated house. When the need for this purpose only surface 10W/m2 year we can so we can call a passive object. With such demand for energy object does not need any additional active heating system and uses a passive thermal energy contained in the air, the earth, solar and users apartments. Consequently attention is directed at high efficiency of energy use. The next priority is using the passive techniques such as solar gains. After high efficiency has been obtained with all forms of energy use in the building, on-site renewable energy sources can be applied to meet the highly reduced demand for the operation.

We can distinguish few different factors to restrict the energy consumption such as:

1. The architectural design (the solar exposition and geographical conditions);
2. The insulation;
   a) having the most inferior K factor ;
   b) being airtightness;
   c) avoiding thermal bridges – temperature differences which could come from a weakness point in the insulation;
3. The characteristics of used materials and properties of components of windows and doors;
4. The mechanical ventilation with air exchanger;
5. Using of solar energy by means photopiles and thermopiles;
6. The user's behavior;

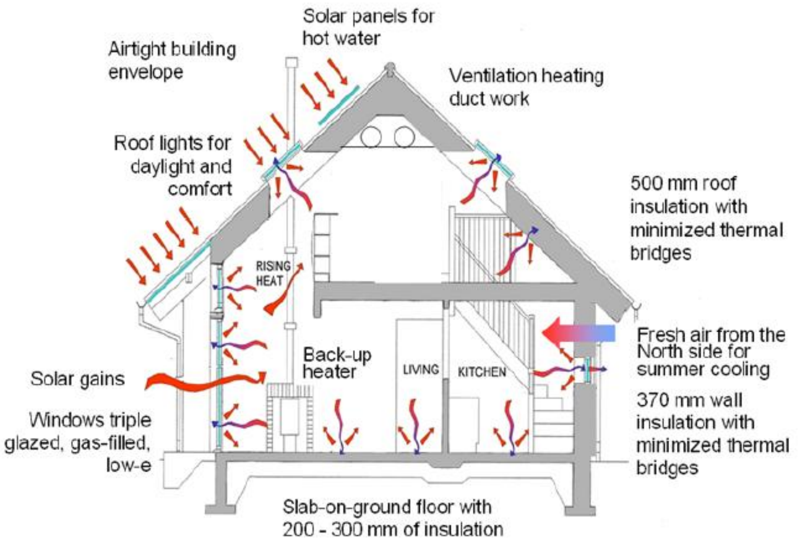


Figure 2.1 Optimizing-performance conditions

Source: Luca Merciadri, "Passive house can be the solution to our energy problems, and particularly with solar energy?", Lieege, Belgium, April 2009

This will provide a broad overview of the required solutions, the aspects that need attention, and approaches that can be employed to reach the Passive House standard. More detailed information regarding the Passive House solutions applied has been included in following chapters.

2.1 Architectural arrangement

In connection with this we must take care about architecture design of this type of building. There are many international and national definitions concerning the standards to be met by low-energy buildings. But the goal is a project which, through applying the structural solutions should lead to a reduction in energy consumption. Its features are:

- Energy efficient windows facing south in order to use the heat gains from the sun
- Compact shape of building

Regarding the shape of the building must take into account the fact that the greatest heat loss are located in the corners and bends of envelope. These places are very unfavorable. Therefore, the most effective is the shape of a sphere, which is difficult to implement. Because of this shape, the number of kinks solids can be reduced to a minimum in an unusual way, building a house on the circle (Fig. 2.2).

Figure 2.2 Design of houses in the village Pszczyna shape of the house cube. (Poland, Silesia, project of Robert Konieczny)
Source: http://projektowaniewnetrz.eu/akademia2 /wp-content/uploads/2012/04/indywidualny-dom-typowy-1.jpg

An unfavorable phenomenon is the design of dormers and bay windows. However, if such they are, should be designed detailed implementing solutions in the project which minimize the effect of thermal bridges. Another neuralgic place is the combination of the balcony slab of the wall. If possible, should be organize a replacement space in the form of terraces, balconies on a separate structure or isolation balcony from wreaths with special structural elements. In result it leads to to practical eliminate of thermal bridges. To providing to residents comfort such as natural lighting of rooms must be planned accordingly arrange window which will have increased thermal performance. Orientation the elevation with the highest number of glazing also influences on in obtaining free heat. All clear that it should be arranged on the south side while it is reduced to a minimum on the north side. What is more, it is advantageous location of windows and elements so-called winter gardens on south site of building (Fig. 2.4) Greenhouse effect makes by the action of the sun the outer wall surface area has a higher temperature as a result the heat penetrates into outside.

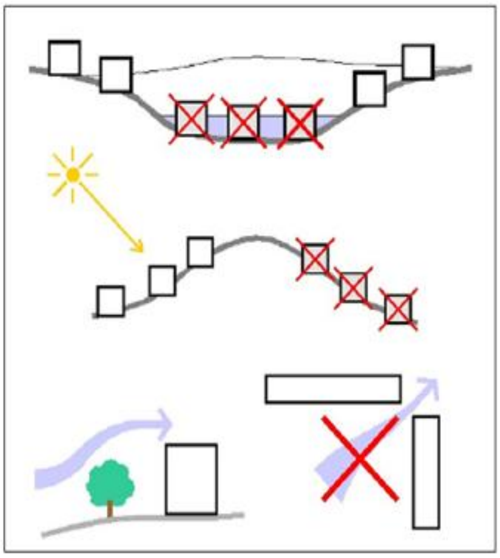


Figure 2.3 Different localization of the building
Source: http://projektowaniewnetrz.eu

One of the problems of placement of windows on the south side is the ability to feeling of too high temperature inside the building by the residents during the summer. The appropriate shading of southern elevation in the concept of Passive House and energy-efficient is actually an autonomous system whose task is, on the one hand, provide shade,

Figure 2.4 Shading elements on the south facade
Source: http://projektowaniewnetrz.eu

the other admitting the maximum amount of sunlight into the building, depending on seasonal needs.

The fulfillment of these two seemingly mutually exclusive demands, brings with it several design problems. It should first be to ensure the proper fastening of shading elements. It is necessary to avoid thermal bridges at the same time. Problematic is also the fastening of any elements to walls with tens of centimeters insulation layer.

Another of the main factors influencing the reduction in heating costs is to design homes with at least two floors. It will have about a dozen percent less demand in comparison with single-storey house. It should be take into account ratio area and volume A/V to guarantee more properly architecture of building. Regarding the placement of rooms and each wall is not accidental. They should be divided and grouped according to their thermo spikes needs. The "residential zone" consists of living room, dining room, kitchen, sanitary facilities should be situated from the south (Fig. 2.5). These places require a higher temperature in the range 20-23°C. Lack of separating walls the kitchen from the dining room or living room conducive to uniform the heat transfer in these areas. The system the location of bathroom on southern side is the most suitable due to the fact that they require high temperatures. The rooms with lower temperature, such as a utility room, pantry, storage, or garage situates from the north and east.

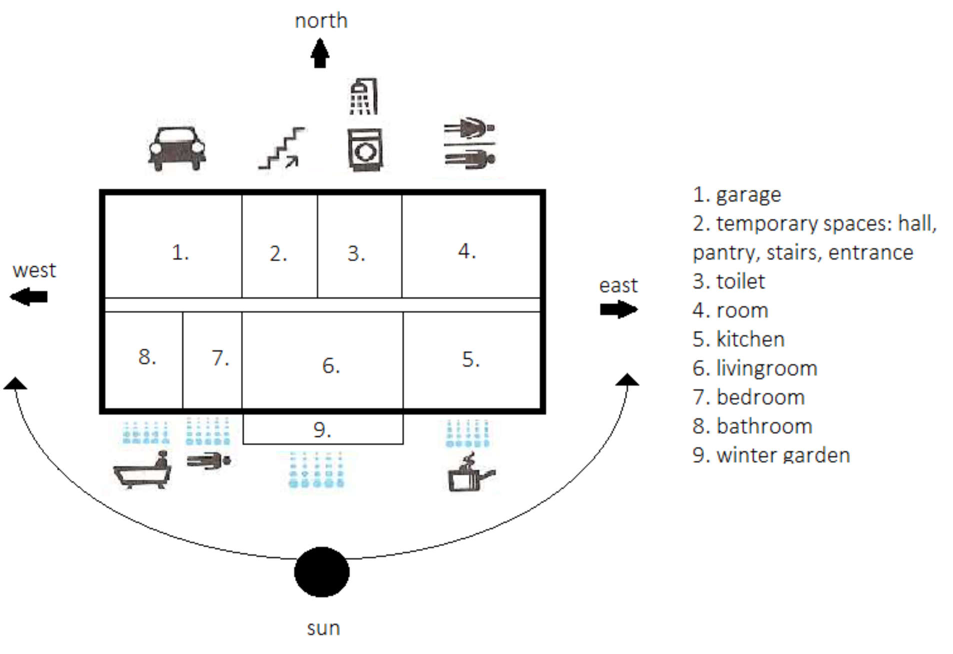


Figure 2.5 Principles of bioclimatical architecture

Source: http://projektowaniewnetrz.eu

Each external partition is treated as an air escape route from the interior of building. A buffer zones are designed in passive and low-energy houses to prevent of this effect. This zone may be created a group of cooler areas designed on the north side of building, ie: garage, storage room or out of use. This part of the house can have its own independent system installation and should be insulated from both sides. An example of a building presented below (Fig. 2.6) well illustrates the principle of buffer zones. In the accommodation such as bedrooms, kitchen, bathroom provided the temperature at the level of 18-22°C. However, in the garage is expected only 4-8°C. In the case of immediate vicinity of these zones, the wall between them have to characterize the heat transfer coefficient U at the level of 0.3 or 0.2 W/(m2·K). The expected temperature in utility room is 12-15°C. Due to the additional separation buffer zone can be used typical partition wall in these areas. Profit from this arrangement is dual – areas are not heated where the high temperature is not, and the residential zone has additional protection against the cold. This zone may be an attic wasteland also. The space between the ceiling and the roof, where the temperature is low during the winter, but temperature is higher on outside gives another isolation of the heated interior.

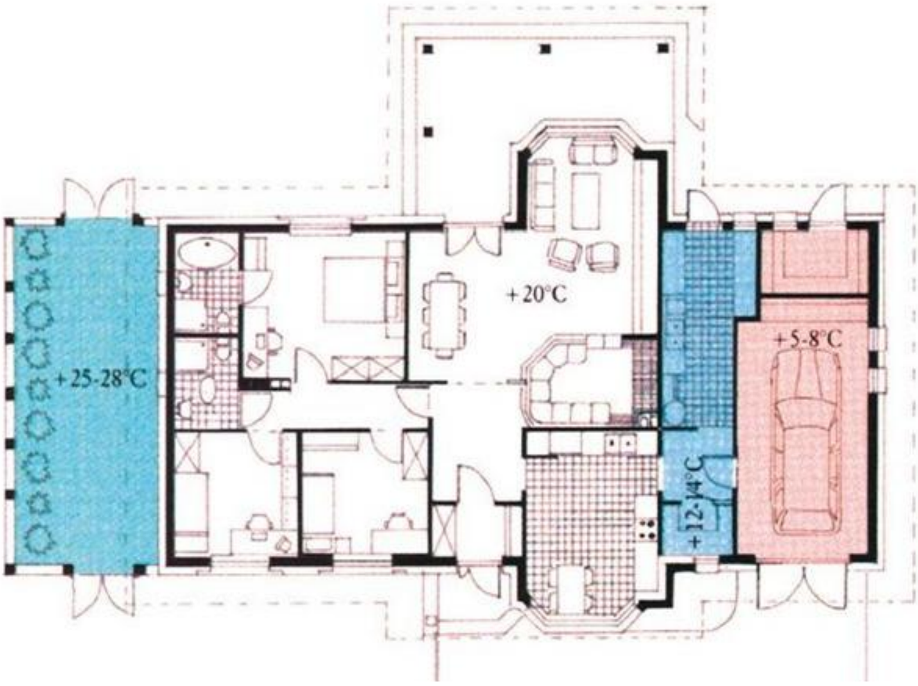


Figure 2.6 Plan of building explaining the rules of the buffer zones. Color indicates the computing temperature of the rooms.

Source: http://www.nportal.pl

2.2 Building envelop insulations

Many building methods can be used in the construction of a passive house, including masonry, lightweight frames (timber and steel), prefabricated elements, insulated concrete formwork, straw bale and combinations of the above. Continuous insulation of the entire thermal envelope of a building is the most effective measure to reduce heat losses in order to meet the Passivhaus Standard.

A thermographic image is used to illustrate the difference between the well and poorly insulation levels in a house. Heat loss through the building envelope is highlighted by the green, yellow and red colouring. The amount of radiation emitted increases with temperature, therefore warm objects stand out well against cooler backgrounds. In the passive house some heat is lost through windows but heat lost through the external wall is very low. In the conventional building, on the other hand, there is heat loss from the entire building envelope, especially through windows

Insulation of the building envelope can be divided into four distinct areas: external wall, floor, roof and windows. Existing passive houses in Central and Northern European countries have U-values for walls, floors and roofs ranging from 0.09 to 0.15 W/(m2K). As it was mentioned before the value of this coefficient for retrofitted building is requires on the level between 0.12 to 0.15 W/(m2K). The average U-value for windows including glazing and window frames in the region of 0.60 to 0.80 W/(m2K) for new building and the U-value for process of upgrading is less than 0.85 W/(m2K). [5]

The insulation and airtightness are very important to prevent from heat losses. Every layer of the house must be isolated, so as the insulation will not be discontinued. Some layers of the house require more isolation than others. For instance, the floor must be less isolated than the roof, because the floor is always warmer than the roof, even in winter.

There are several different methods and materials available to upgrade the performance of the building envelope in dwellings to the Passivhaus Standard. Continuous insulation of the entire thermal envelope is the most effective measure to reduce heat losses in order to meet the Passivhaus Standard. Although achieving this in a retrofit situation is more challenging than for a new-build. Passive house need to be very airtight, even hermetic, all the connections between the parts of the building such as connections between: window and wall, wall and ceiling, etc. should be very well sealed. Which in turn requires the design of a great supply and exhaust running system ventilation. Insulation of: frames, windows, floor, roof, walls and of the plumbing such as water, heating valves, vent pipes. Furthermore, sewage and water lines must be short too. Insulation must prevent sewer and cold water lines from condensation and freezing.

In addition to the appropriate insulation, the building envelope is surrounded by one continuous airtight layer with all components and connections fitted in an airtight manner. Air-tightness tapes and seals are applied around all areas where components meet, with special attention paid to the installation of electrical and mechanical services. Air-tightness in a Passive House is verified by conducting a pressure test (blowerdoor test) to measure the amount of air changes the building experiences within one hour. It will be decried in one of next part of the my work.

In accordance with the recommendations of the Passivhaus Institut wall passive should have a high thermal inertia, which allows for temperature stability in the interior. In contrast, the heat transfer coefficient of the external walls not to exceed the value of 0.15 W/(m2K), which corresponds to the thickness of the insulation layer in the range of 30 centimeters. To execute such warming can be applied technology jointless insulation system. This joinery is fixed to the wall on the three-layer system, which comprises:

• insulating material - lining formatted discs of polystyrene or mineral wool (glass or rock), or other materials with the required thickness,

- the reinforcing layer system, for example, flexible glass fiber mesh,
- outer layer or thin layer plaster and paint of facade

Required thickness of insulation materials and mechanical fasteners of appropriate length can be purchased on the Polish market. They are offered by most manufacturers of insulation materials or companies providing insulation systems. In the case of using the mineral wool insulation, insulation thickness can exceed 40 cm. Then the thermal insulation of buildings with thick layers of insulation can be used light-dry method. During the construction of passive houses are also used unconventional solutions in the form of such prefabricated façade elements. In this case, insulation is fixed to the external walls of the light components where windows have already been installed. [7]

2.3 Passive solar gain

How to extract energy from the sun?

Energy can be obtained from various sources, coal, wood or oil. The abundance and availability of these sources is becoming more and more extensive, which affects the development of civilization. In the era of progress, there are new ways of generating energy, which are often more friendly to the environment of the most popular. The man began to look for new, beneficial energy sources, because exhaustion of fossil fuels is inevitable in the future. So far we use are largely from non-renewable sources. Nonrenewable energy resources will decrease, and the demand for it our civilization, which needs it to grow still growing. The sudden lack of energy is equally dangerous to humanity, what the effects of global warming. Although opinion on the existence of this process are divided. You can not underestimate it. Between these two processes, there is a clear correlation. Pay attention to the problems of climate change, which according to some scholars are the result of emissions of greenhouse gases emitted mainly by the burning of fossil fuels.

The sun emits a tremendous amount of energy through nuclear fusion, which is estimated at around 1023 kW. [8] To the earth's surface reaches only a small part of it. To the limits of the Earth's atmosphere about 28% is reflected and scattered, and the rest is absorbed by the biosphere. The amount of energy reaching the surface of our planet than 10 000 times the current demand for energy and humanity is 30 000 times greater than the amount of energy produced in all the earth. Therefore, solar energy have extremely high potential in the production of energy needed to meet our needs and to further the development of civilization. Most importantly - allows the extraction of energy without causing any effects in the form of emissions or depletion of natural resources.
Solar energy can be used to produce:

- thermal energy which is sourced in the photothermal conversion process of solar collectors,
- electricity produced in the photovoltaic conversion process

The photovoltaic effect consists in the formation of the electromotive force of homogeneous structure due to solar radiation.

The house passive solar energy can and should be used effectively. A very important issue determining obtaining energy from solar radiation is adequately positioning the house relative to sites of the world. Important is also the distance from the neighboring buildings and the use of vegetation and topography to raise natural energy and reducing heat losses.

The most advantageous orientation is the positioning of the longest wall of the building on the east-west axis, which is on the south side. In many cases, this is not quite possible. However, deviation from the axis by 15 ° did not significantly affect the amount of heat acquired by the glazing to the building. In Poland, the maximum deviation from this axis is 20 ° to the east and 35 ° to the west. [9]

In the case of a situation where the east-west axis is perpendicular to the street. To avoid in casement the building by other objects should be a significant distance with regard to the length of the shadow cast by the house with a height of 5 meters on a day when the sun is lowest in the winter solstice, which is 19 meters

Setting the windows at the correct angle provides reach sunlight into the house. Heat supplied by a window with an area of 30% to 40% of the western facade provide sufficient heat to ensure a comfortable temperature in the room, even in winter when the sun is shining. Therefore, it is very important to distribute largest number of windows on the south side. You should also take care of the angle at which the sun shines on a given area - the angle is greater the more rays penetrates the substrate. Figure 2.7 shows the difference angle of sunlight depending on the time of year.

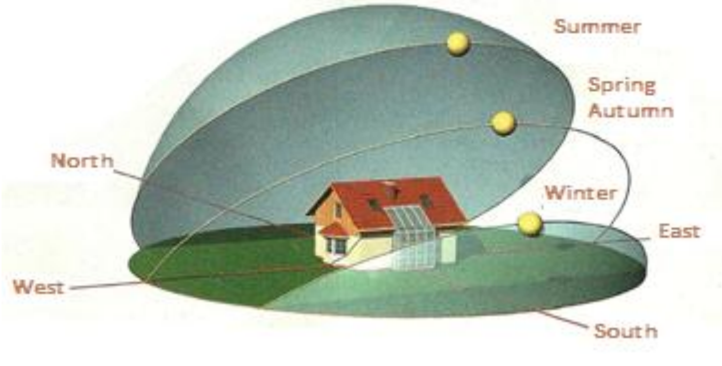


Figure 2.7 The difference angle of the sun, depending on the season.

Source: Murator – building jurnal, number 2/2012, str. 16

In winter, the sun falls at a smaller angle than in the summer, so that heat gains were felt should be put windows on the facade, to which the rays come in winter too. Such a situation is possible for the location of the wall of a building with more glazing towards the south. Is most preferred that from the viewpoint of obtaining solar energy windows should be located as high as possible. Should pay attention also that this window was not too high. There should begin just above the floor, as it may turn out that the heat gains from the lower part of the window does not compensate our losses that we incur in the winter as a result of penetration by a larger glass area.

When it comes to provide the best illumination of rooms with daylight best solution is to located the windows on both tracts of the roof, which will provide lighting inside the house all day. (Fig. 2.8)

Figure 2.8 The prederred arragement of windows on tracts of the roof.

Source: Murator magazine , no 2/2012, page 16

Should be remembered that a large amount of glazing in the summer can cause excessive heat gains called overheating. To avoid this situation is used shading in the form of various types of roller shutters, awnings or appropriate width of the eave. Wide eaves (Fig. 2.9) makes it difficult to reach sunlight into the house through the windows, which cannot be used the free solar energy for space heating as well as their natural light. On the other hand brings advantages in the summer when the sun is above the horizon, and the windows faster heat. (Fig. 2.10)

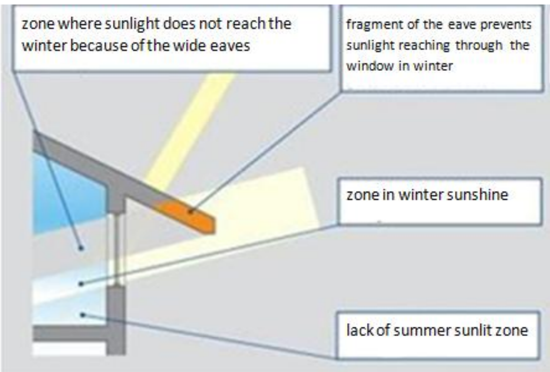


Figure 2.9 Wide eaves

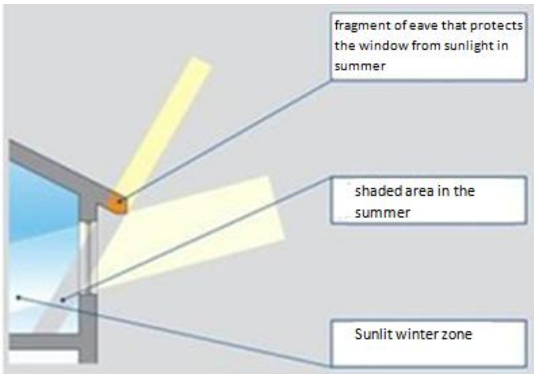


Figure 2.10 Short eaves

Source: http://muratordom.pl/budowa/dachy-i-stropy/okap-a-energooszczednosc,17_3141.html

Accumulation is a word often occur in descriptions and articles relating to the passive and low-energy construction. Elements of accumulating heat is crucial in the process of building heating thanks to solar radiation. During cloudy days or after sunset in the building takes place cooling, in the case of the sunny day. Therefore, the key task is to design element such as a wall, which will radiate stored heat when the sun's rays will cease to penetrate into the interior of building. In brick houses such elements are walls, floors and ceilings. Designing the front wall of windows facing south with materials such as solid brick, concrete or stone will give noticeable benefits. Wall accumulation should have a thickness of 20-45mm. Besides the well walls will store energy stone or ceramic casing of the fireplace located in front of the window.

The color of the walls is signify also. Black wall will have a better ability to store heat as much as 75% compared with the white walls. Other wall surfaces should be as the brightest to bounce and disperse light.

2.4 Thermal bridging

Not only is the proper selection of thermal insulation meets specified requirements to ensure the building limit heat losses through the walls, roof or floor on the ground. A very important thing is the proper its execution to avoid appears of so-called thermal bridges. Practically it is not possible not to break the continuity of the insulation on the surface of the building. Windows and doors are also of this type, in which heat can escape to the outside.

Increased heat dissipation increases the demand for heating energy. That's because more energy. It is estimated that the thermal bridges may result in a loss of about one third of thermal energy. It is these places cause unwanted efflorescence. They are the result of exceeding the dew point by temperature drop on the inner surface of the partition. As a consequence of this process may occur condensation the water vapor for example on the window and around it. Humid places also easily collects dust which is beyond the aesthetic values in the form of dark spots, its giving space for the development of mites and fungi.

The compact body of the building is necessary to achieve passive standards. However, despite the limited number of kinks are still many critical places, where the heat escapes. Such places can be balcony slabs, the gap between the plates of mineral wool or polystyrene, single basement walls or foundations, cavity windows and doors. We are dealing with bridges when elements such as railings or awnings are fastened to the wall but not to the outer layer of insulation.

It should be understood that the essential part is carefully performing different works related to the laying insulation of partitions. Insulation except gaps between each plates must also eliminate the possibility of filter of heat.

.

1) Places around windows

To well-performed place around windows and doors , you can use ready-made solutions in the form of anchors in casings with low thermal conductivity. Insulation should overlap about 2-3 cm windows frame and balcony doors, thus forming a so-called jamb. Figure 2.11-12 shows the wrong way layer thermal insulation. Warming face of the wall ends in the frame of the window or door. In the case where reinforced concrete lintel is formed along its entire length linear thermal bridge. As a result, on the wall in the room can appear dew, hot stains or even fungus. The figure on the right shows how to properly insulate the window. Extension of the insulation layer of 2-3 cm will suffice to stop the air escaping outside.

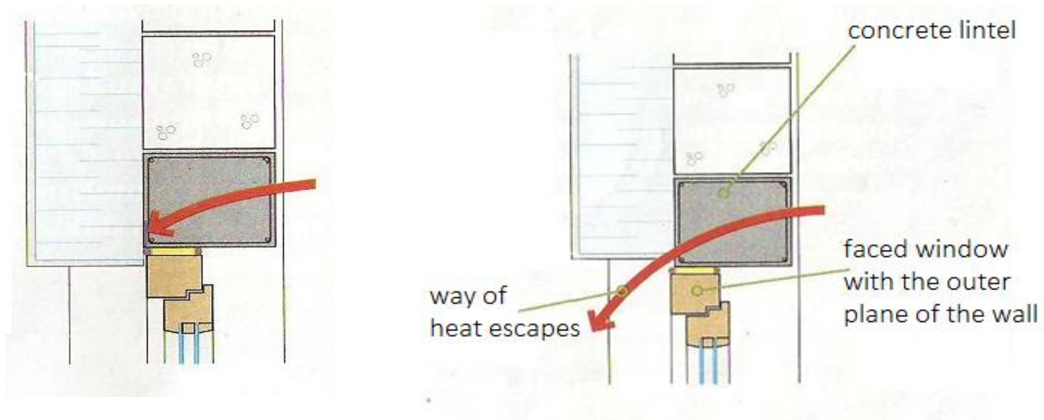


Figure 2.11 Incorrectly *executed insulation around the window*
The Figure 2.12 Applications windows jamb edge
Source: Murator. Materials and technology, issue of February 2012, page 78

2) Concrete balconies

At the interface between of the balcony slab or loggia of the structural part of the building is the possibility of using the system fasteners balcony. They are made neopor - polystyrene containing small particles of graphite. Which has better insulating properties than a normal polystyrene and concrete insets to ensure adequate strength of the composite. Such factors also have reinforcing bars thanks to which it is possible to connect the reinforcement rod and the balcony slab.

3) Connection between foundation wall with the wall of the building or floor and the basement

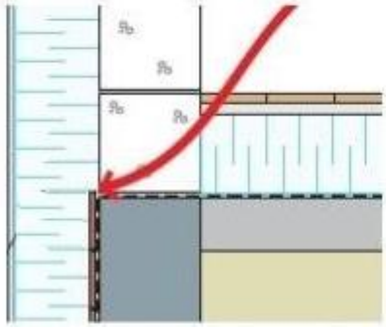


Figure 2.13 The place the occurrence thermal bridge in place of connection foundation wall with the wall of building.
Source: Murator. Materials and technology, issue of February

To reduce the thermal bridge at this place are used hollow insulating boards. The skeleton is made of lightweight concrete with high compressive strength of glass fiber reinforced shaped enhancer and its resistance to load. A typical solution is insulation the floor on the ground in case of a building without basement or floor above the basement. However, it is the foundation walls are the place where the heat escapes from the ground floor rooms. It is necessary to adhere to one of the rules:

- The layer insulation of the foundation walls should extend 1 m below the ground surface. Heat insulation in this case may have the same thickness as or thinner walls insulation. Then the walls of the ground floor creates a "drip" - protects against moisture from the base of rainwater reflecting off the surface of the ground. It also undercut the forces on the flowing water from the walls of the building before the grains fall of the wall. (Fig. 2.13)

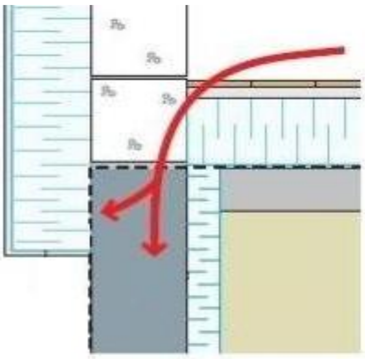


Figure 2.14 The proper insulated connection of foundation wall with the exterior wall of building.
Source: Murator. Materials and technology, issue of February

- The insulating outer layer and internal of foundation walls occur at the same time over a length of at least 50 cm. When so much is extended insulation of building walls, the road to escape the heat becomes longer and starts to become less noticeable for residents. (Fig. 2.14)

The PassivHaus Standard for linear thermal transmittance should not exceed 0.01 W/(m2K). This requires the building designer to identify and locate all potential thermal bridging in the construction. Applying careful specification and detailing of those elements providing where is possible a continuing layer of insulation, as well as taking care to execute those elements on site as particular details. The impact of thermal bridging can be tested and verified in the PHPP software. The examples below (Fig. 2.4.15-16) presents the importance of properly execute of details in connecting places such as connection between window and external wall to provide airtightness and eliminate thermal bridges..

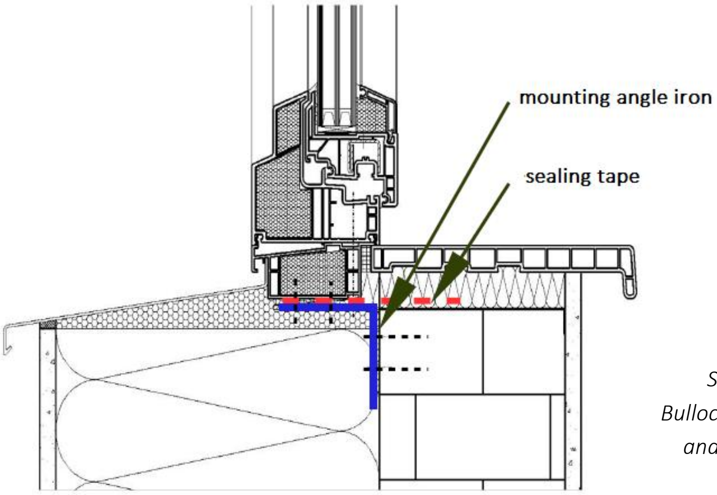


Figure 2.15 Detail of proper window installation

Source: C. Sankowski, Passive house in Bullocks near Warsaw - modern installation and construction solutions, Polish Passive House Institute, Gdańsk 2012

Figure 2.16 Mounting angle iron (on the left) and sealing tape(on the right)
Source: C. Sankowski, Passive house in Bullocks near Warsaw - modern installation and construction solutions, Polish Passive House Institute, Gdańsk 2012

The way how we montage of window on the "size" of thermal bridge have huge influence. The left figure (Fig. 2.17) below show improperly montage of window to external wall. This conventional assembly gives the values of the coefficients Ψ at the level of 0,15 W/(m·K) and value of $U_{w,eff}$ equal 1,19 W/(m·K). The second one (Fig. 2.18) on the right presents recommended way to solve such a combination in which the coefficient Ψ can be achieved at 0.005 W/(m·K) and the value of $U_{w,eff}$ at 0.78 W/(m·K). The value of coefficient B reached a value of about 30 times smaller than the previous one. [19]

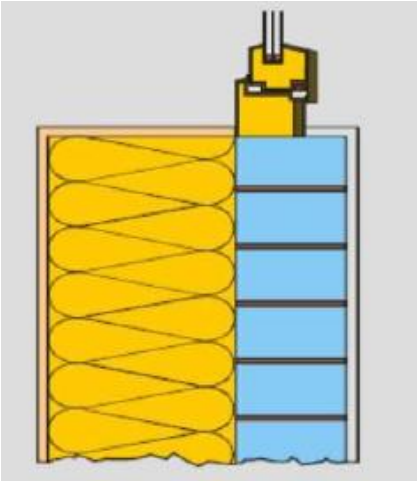


Figure 2.17 The conventional installation of window

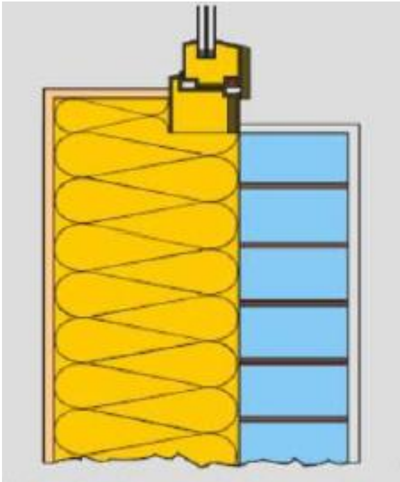


Figure 2.18 Installation of the window in a passive building

2.5 Internal heat gains

Energy gains means the energy that is supplied to the system. There are three primary sources of heat for passive building: internal heat gains, heat gains from solar radiation which was mentioned in the previous section and the heat supplied central heating system.

In order to reduce heat losses in a building passive is to reduce the energy demand for heating and reduce losses related to the use of mechanical ventilation. Passive house standard is determined by its seasonal heat demand for heating specified E ratio - the amount of heat calculated on unit area. This unit specifies the need to heat the building during the whole year is kWh/m2 per year.

The value of this ratio allows to specifying the passive house standard and the entire heating system. The algorithm for estimate these values have been described in the Polish standard PN-/B-02020. Calculations by this standard, the imposing building division into zones: heated and unheated. The balance of the profit and loss is calculated for each month of the heating season separately. Then the calculated heat demand for heating the building during the month, taking into account the utilization factor of heat gains. The sum of the total energy demand for heating of the building is formed by summing up the requirement for heat in the subsequent months of the heating season. E ratio is calculated by dividing the total demand and the heated surface. For passive building the value of this coefficient determines the relationship:

$$\mathbf{E \leq 40\ kWh/m^2\ year}\ [10]$$

The indicator - E allows the assessment of building energy standard and the total heat loss. Another indicator E_o describes the amount of additional heat necessary to heat the unit area - in the building. It determines the quality and standard of building energy (of external partitions) [1]. For passive building the value of this coefficient determines the relationship:

$$E_o \leq 15\ kWh/m^2\ year.$$ [10]

The following table (Tab. 2.3) illustrates the reduced value of the Coefficient depending on the period in which the building was constructed.

Table 2.3 Summary index of seasonal heat demand of the building depending on the year of construction

Single-family houses built different periods	Seasonal demand E_0 for heat for heating [kWh/m² year]
Until 1966	350
1967 - 1985	260
1986 – 1992	200
1993 – 1997	160
1998 - 2007	120

Source: Zurwski, J., Energy efficiency in buildings Part II - energy consumption, insulation 2/2008

It is also possible to classify buildings because of the value of seasonal coefficient of heat demand (Tab. 2.4). E0 index enables an estimation how much energy must be used annually for heating calculated on square meter of its area or cubic meter of its volume. On the basis of this index, fuel calorific values and their prices can be estimated annual cost of home heating. (Tab. 2.5)

Table 2.4 Building type depending on the values of the seasonal heat demand of the building

Seasonal demand E_0 for heating [kWh/m² year]	Type of building
Max. 70	energy-efficient
Max. 15	passive
0	zero energy

Source: Regulation of the Minister of Infrastructure of 6 November 2008 amending Regulation on technical conditions which should be met by buildings and their location.

Table 2.5 Summary of the cost for heating the building depending on the year of construction and the type of building which has been calculated using index of seasonal heat demand (in euro).

Single-family houses built different periods or type of building	Seasonal demand E_0 for heat for heating [kWh/m^2 year]	The unit price of heat obtained from the gas boiler [€/kWh]	apartment area [m^2]	Monthly heating costs [€/m^2]	Annual heating costs [€]
Until 1966	350	0,04	47	1,12	626,00
1967 - 1985	260	0,04	47	0,83	465,52
1986 – 1992	200	0,04	47	0,64	358,10
1993 – 1997	160	0,04	47	0,50	1203,20
1998 - 2007	120	0,04	47	0,38	286,43
Max. 70	80	0,04	47	0,26	143,24
Max. 15	45	0,04	47	0,14	80,57
0	15	0,04	47	0,05	26,86

Source: Zurwski, J., Energy efficiency in buildings Part II - energy consumption, insulation 2/2008

A passive house is very efficient at utilising "free" internal heat gains from domestic household appliances, kitchen and utility equipment, electronic equipment, artificial lighting, and occupants. Heat losses from stoves or boilers also contribute towards the overall space heating requirement as long as they are positioned within the building envelope. Occupants of the building also contribute to meeting the heat load. A typical adult human continuously emits 100W of heat when stationary. A family of five persons, therefore, can emit up to 0.5 kW of heat. This may seem like a small amount but it equates to approximately two thirds of the total space heat load.

How to get the heat for building with passive standards for free or almost for free?

- Through the so-called. external gains such as heat, which produces and gives man himself
- Through the heat generated while cooking
- Through the heat, which emit light bulbs, television, computers and other appliances
- Through passive heat generated by large tracts of windows facing south

Passive house has a very high comfort for the residents and users with very low energy consumption. This object is achieved by a so-called passive components, e.g.

special windows, insulation thickness. Each building passive an active contribution to environmental protection, and thus improve the quality of life of every human being.

2. 6 Passive House Building System

Passive house does not need a conventional space heating system of radiators or underfloor heating to maintain a comfortable indoor climate. Instead, due to the small space heating requirement involved, the following building systems are sufficient in a passive house:

- Mechanical ventilation system with heat recovery which provides most of the space heat requirement.
- Back-up system capable of heating the air passing through the dwelling via mechanical ventilation to meet any auxiliary space heating needs, expected to be small. Typical fuel sources for the back-up system include biomass, heat pump, gas, and in some instances electricity for example 'green electricity' from renewable sources). The back-up system is also used to provide hot water, either throughout the year or during winter if a solar water heating system is used during summer.

An airtight house requires a well designed mechanical ventilation system to provide good indoor air quality. A passive house is ventilated using a mechanical system which incorporates air to air heat recovery (mechanical heat recovery ventilation, or MHRV). Exhaust air is extracted from rooms that typically produce heat, moisture and unwanted smells such as kitchens and bathrooms. Before this air is expelled to the outside it passes through a heat exchanger here the heat is transferred to the separate stream of incoming fresh air, thereby eliminating the need to completely heat the fresh air as it enters the building.

It is important to paid attention to regular replacement of air-filters for both incoming and exhaust air. Filters are used not only to provide clean air for the occupants but also to ensure that the heat exchanger is not clogged with dust and other objects. If the filters are not regularly replaced (for example every six to twelve months) and become clogged with dirt the MHRV will have to work harder to provide the same volume of air to the house, thereby increasing the speeds of the fans and, ultimately, using more energy. A retrofitting a dwelling includes Mechanical Heat Recovery Ventilation System. Unfortunately, occupants very often don't have any experience of the maintenance requirements involved with this system.

During process of design a passive and low-energy buildings, designers tend to a situation in which each of elements of building such as windows, doors or walls with coefficients make the building very well-air-tight. The disadvantage of this is the lack of an adequate exchange of stale air. Therefore, to maintain thermal comfort is used mechanical supply – exhaust ventilation system . Most preferred is a combination of the devices which recover heat from the exhaust air.

One such way is to equip the house with a heat recovery system, or central ventilation, which recovers heat from the exhaust air. The illustration below (Fig.2.19) shows a scheme the ventilation in an exemplary building

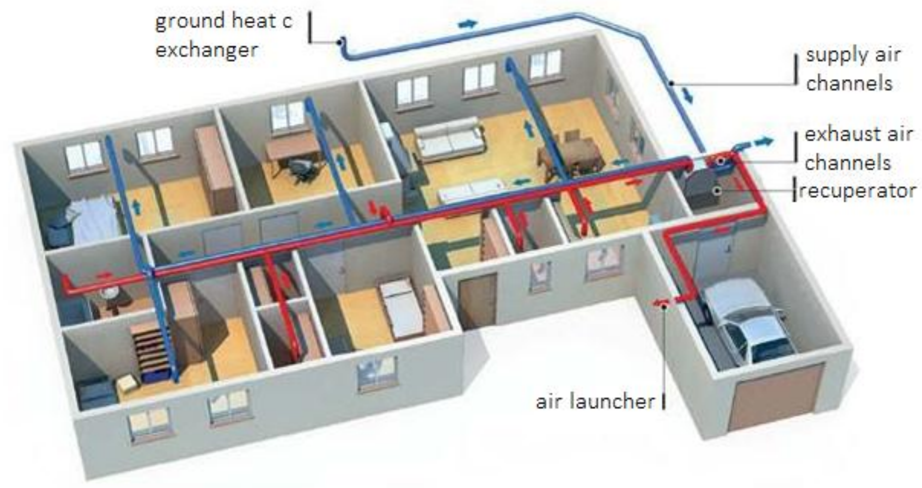


Figure 2.19 Arrangement diagram the various elements of the mechanical ventilation system
Source: http://www.climrem.com.pl/rekuperatory.php

Air intake and exhaust vents

Intake and exhaust vents is placed in the wall of the house or in the garden where it is combined with the most ground heat exchanger which is designed to cool the incoming air in the summer and warm it in the winter. The tasks is to get fresh air from outside. It must be remembered to put it further on the north side of the building, away from the street with heavy traffic. The exhaust air outlet while removing exhaust air from inside the house. It is usually placed on the roof as a finished chimney or directly on gable wall of the building.

Ventilation

Their role in the whole the ventilation system is to supply and removal of air from the premises. They are made aluminum wires, insulated with mineral wool or with a more rigid type of Spiro. This insulation will prevent the cooling of the air in the ducts that pass through unheated areas. This method avoids cooling of the air flowing through them, but also the condensation of water on their surfaces. At the ends of each channel diffusers and exhaust air elements are mounted.

The recover

It is an essential element of the mechanical ventilation system. The principle of its operation is very simple. It consists of two channels adjacent to each other. Through one of them warm and worn air flows, while through the second cool fresh flows. The entire air circulation in the force two fans which are installed inside. Similarly, one of them is the supply fan and the other is the exhaust fan. The heat penetrates through the wall of the tubular heat exchanger, thereby the cooler air is warming up.

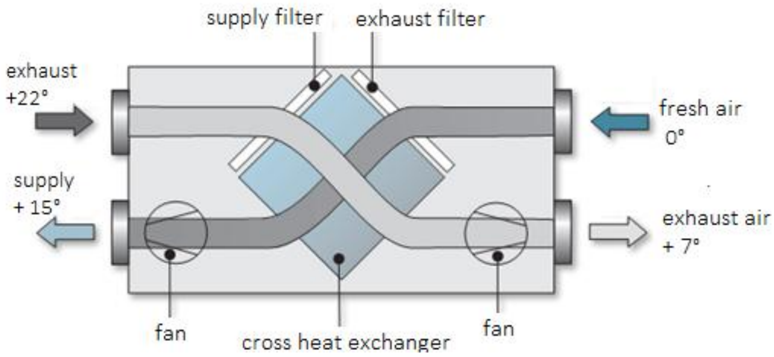


Figure 2.20 Functional diagram of recover with the plate heat exchanger production of Mistral PRO-VENT Company
Source: Website of Pro-Vent Company http://www.pro-vent.pl/budowa-rekuperatora-mistral,0.html

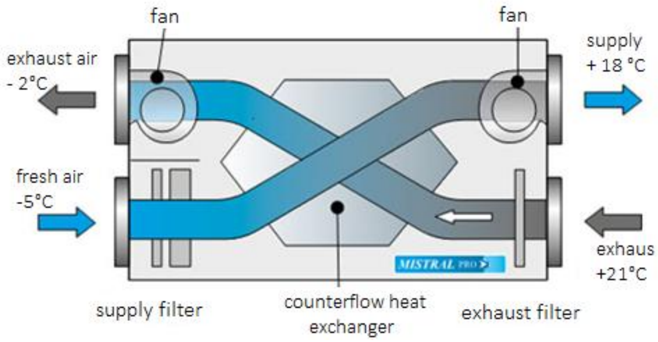


Figure 2.21 Functional diagram of recover with the counterflow exchanger production of Mistral PRO-VENT company
Source: Website of Pro-Vent Company http://www.pro-vent.pl/budowa-rekuperatora-mistral,0.html

Most are commercially available heat recovery units with plate heat exchanger - the so-called cross recuperators and counter-called counterflow heat recovery units. These second devices are more effective because their efficiency is about 92%. For comparison, the efficiency of the cross recuperator is on the level of 60%. [11]

For every home heating costs affect the parameters of individual partitions affecting the amount of losses and heat gains. Back-up system capable of heating the air passing through the dwelling via mechanical ventilation. It is also used to hot water production, either throughout the year or during winter if a solar water heating system is used during summer. Now there is a tendency for equipping homes with devices that utilize renewable energy sources. However, around investors there is a popular misconception of the belief that an investment of modern technologies can cause exceed the planned budget. People who cannot afford to solutions such as heat pumps, ground heat exchanger, solar panels, photovoltaic cells, all units, ending up controlling the whole system through the so-called intelligent, not should bear the losses by investing in these solutions. Not always, however, the cost of installation of such solutions can turn back quickly. When deciding on the cheapest, classical solutions such as boiler and central heating installation should pay attention to individual parameters of components.

The costs of heating and DHW heating is about 70 to 80% of the total annual costs of operating the building. In modern times, in which the resources of fossil fuels such as natural gas and coal are decreasing, we are forced to pay more for their delivery. Cost-effective investment is the purchase of a condensing gas boiler or low temperature. In the event of such a decision, it should be of higher efficiency, which consumes about 10 to 15% less fuel than the normal. The chart below (Chart 2.1) shows the differences in the prices of various energy sources in the years 2002 – 2011.

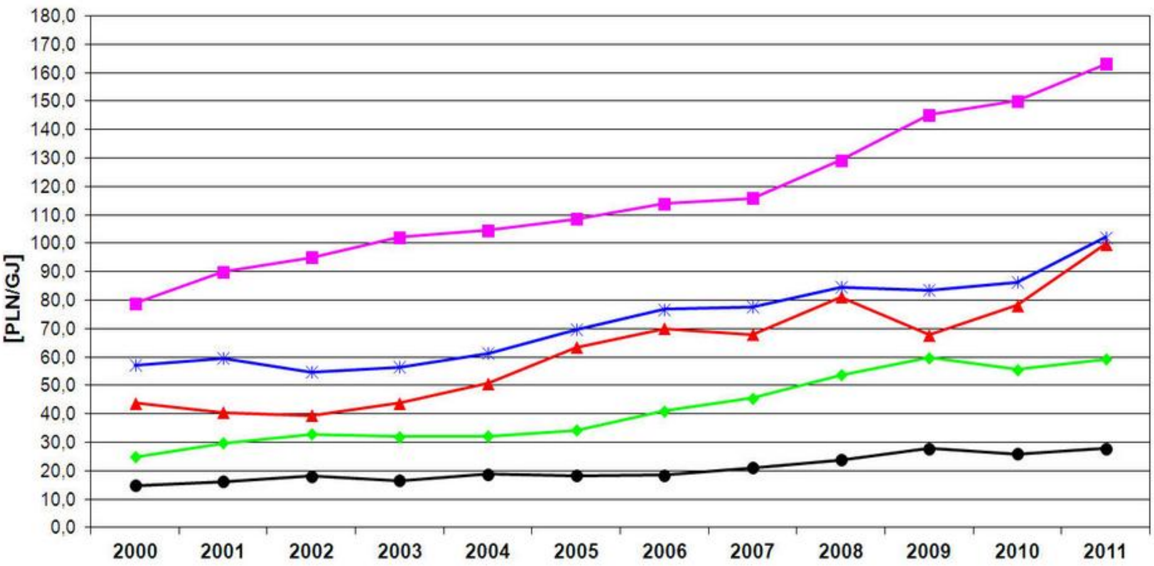


Chart 2.1 Prices of selected energy for households in PLN / GJ

The chart above shows the price of natural gas, electricity, fuel oil, coal and propane-butane gas for households. These are average prices denominated in PLN / u. for the years 2000-2011. Prices include VAT, which was 22% in 2000-2010 and 23% in 2011, and excise taxes unless valid for the energy carrier.

Prices of propane-butane gas relate to wireless cylinder, for which the excise tax is not applicable. Excise duty is also included in the price: electricity and light fuel oil. The conversion price of natural gas for PLN / GJ made using the heat of combustion, while the conversion prices of other media used currently in force net calorific values (in the absence of such data for 2011, the assumed value of 2010).

Source: Polish Energy Market Agency

What happens in the event of a power failure?

If there is a loss of electricity (and the dwelling has no back-up generator) the ventilation system will stop working and the supply of fresh air will be cut off. If power is lost for a short while (for example a few hours), then there is likely to be no noticeable difference in indoor air quality. However, if the loss of power is prolonged, the simple solution is to open the windows and to create natural cross flow ventilation through the building.

Modern condensing boilers compared to standard energy sources could achieve savings in annual fuel demand of 30%. The combination of these boilers with a solar thermal system to heat the domestic hot water, but also to support the entire central heating system of the building.

For single-family homes just application of solar collectors with an area of about 11 m2 to have met the demand for energy at and hot domestic water . Another advantageous idea is combination of fuel oil and solar power. The use of solar energy installations based on lowering the cost of home heating because oil is more expensive than natural gas. Another aspect enforce for this type of solution is to extend the subsidy from the state for the solar panels. It entered into force in 2010 at the initiative of the National Fund for Environmental Protection and Water Management. It aims to support the purchase and installation of solar and directed to owners of single-family homes and residential communities, with the exception of those objects that are connected to heating networks. The program's budget dedicating amount of EUR 300 million to encompass subsidies in the period 2010-2014 in the amount of up to 45% bank loan for the project. [12]

2.7 Domestic hot water production

As in any type of dwelling, the passive house requires a system that provides domestic hot water (DHW). As with space heating, it is important that the system is energy efficient, well controlled and has an adequate capacity to meet demand. Generally the DHW system in a passive house is combined with a heat source such as a wood stove, solar thermal collector, compact unit or heat pump for pace heating. Most passive house examples encountered have utilised solar thermal collectors as they reduce the use of primary energy and CO_2 emissions.

Savings achieved through proper insulation of pipes supplying hot water circulating pump control using time programmers, sealed thermostatically controlled valves. Heat losses can also be partially eliminated in the installation of cold water. Cold water flowing into the building usually has a temperature no higher than 10°C. It then heated to in the pipes and other accumulator in the building for example in the toilet flushing chamber.

This causes a loss of energy, because the passive construction pays special attention to limiting the length of the installation of cold water, good insulation and its economical fittings. Are also used the apparatus using the "gray water" for flushing the toilet bowl and an apparatus for heat recovery from waste water discharged from the building. The term "gray water" refers to the European Standard 12056-1 defines gray water as free from fecal contaminated water. In practice, this is a non-industrial waste water produced during domestic work such as washing dishes, bathing or washing, suitable to a limited extent for reuse.

The energy demand for heating of the passive house is much smaller than the energy demand for heating domestic hot water, which anyway has to be water delivered. Heating of the home is a byproduct relative to the necessary heating water. Systems, domestic hot water, we can divide them into connected to a ventilation system or operating separately. The second option is often found in older buildings passive. Currently, however, the aim is to integrate the two systems, since it allows for better use of energy. When combined ventilation and hot water for domestic hot water is possible, inter alia, the use of waste energy from the exhaust air from the building. In contrast, the heat from the solar collectors can be used to heat the air supply, which would not be possible in a non-integrated system. As a source of heat in the integrated systems typically are used a small heat pumps. Depending on the type of device it can derive energy from the outside air or exhaust air from the building. To generate energy, instead of the heat pump is also used equipment supplied fuel oil, natural gas, biomass, etc. Often the main supporting power source is used as an additional source are solar collectors. [7]

The solar collector

> "The solar collector is a device for obtaining heat from solar radiation. Occurs in the conversion of solar radiation into heat. The sun's rays are absorbed by the absorber. Acquired thermal energy is received and transmitted outside the collector through the liquid which is an energy carrier." [14]

So if an investor decides to invest in solar panels for hot water needs of utility models, should ensure that the installation was done properly. This will ensure its full utilization and an appropriate amount of free heat. In terms of specifying a solar collector system, the following outline guidance should be considered:

- The optimal orientation is due south and deviation from this will reduce the contribution of the collectors to DHW production. In places where there is no south facing roof, then expected orientation losses can be overcome by increasing the collector area.

- The optimal tilt of the solar panels for DHW is approximately 45 degrees. In a pitch that is greater than 45 degrees the potential annual output is compromised somewhat.

- There are two main types of solar collectors typically used, namely flat plate panels and vacuum panels (Fig.2.7.22-23). The former is characterized by a high price and high efficiency, even at low temperatures. Flat-plate collectors are cheaper but less efficient.

Figure 2.22 Flat plate panels
Source: http://www.budynkipasywne.pl/

Figure 2.23 Vacuum tube collector
Source: http://www.einsiedler-solar.at

3. Typical Phrases of Retrofitting

In one of the previous chapters have been presented national and international regulations imposing changes in the design process of buildings, as well as investments in the modernization of existing as well. The EU Directive from 19 May 2010 on the energy performance of buildings requires that all homes built in the member States of the European Union after December 31, 2020 were characterized by a nearly zero-energy consumption. The government now wants to prepare investors, designers and manufacturers of building materials, contractors to the requirements of this Directive.
Money from these funds are intended to provide market stimulus to change the way construction of buildings in Poland and in addition to the financial benefits bring significant educational effect on society. Greening modifications to be made also for the renovation and retrofitting elements of existing buildings.

Thus, when designing a new building or renovating an existing one, should be well prepared for future requirements of energy efficiency. The role of science centers will be educated in the field of knowledge, popularization and development of low-energy techniques and technologies. At the same time education of specialists of the construction sector will be aimed at creating a model of an integrated energy design.
From the point of view of energy saving, modernization of existing buildings have the greatest potential in the building sector. However, at the same time, from a technical point of view, it is one of the most challenging task. It is not possible to increase the energy efficiency of all existing buildings to passive house standard, because these investments don't make economic sense. Because every home is different, every project overhaul of the energy must be carefully planned, taking into account the specific needs of each home.

3.1 Changes in layout and design

In some cases, it might be possible to alter the dwelling layout and/or arrangement of glazing in order to increase overall energy efficiency. Given that the existing building is already modelled in the PHPP. Any changes have been considered for the building regarding with its shape and orientation of glazing, as well as the risk of overheating can be tested during the design process regarding the effect on energy performance. The overheating might arise if a dwelling has an excess of south-facing glazing without a screen to keep the high summer sun out.

> Passive House design and certification relies on a proprietary software system produced by PHI. It is dubbed "Passive House Planning Package" or PHPP. The models and calculates building energy loads through the entire design process in sorftware ensuring that certification standards will be met before

construction begins. In the interest of creating a worldwide, unified program, the 2012 version of the PHPP is communicated in metric terms, but includes a calculator to easily convert metric to imperial standards. [15]

When designing a new building was a building or upgrading existing, and before making decision of spending should be carried out workmanlike calculation of costs. In taking such decisions, it is worth remembering that the heat "escapes" from home most often by:

- The roof - from 15% to 25%,
- Walls - from 20% to 35%,
- Ventilation - from 10% to 40%,
- The window - from 15% to 25%,
- The floor - from 5% to 10%. [16]

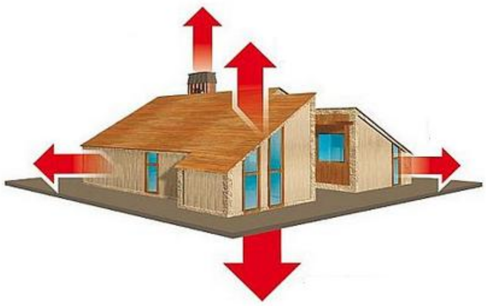


Figure3.1 Heat loss in the house

Source: Retrofitting of a building", 06.2010,

Outlays associated with the operation of buildings in Poland are much higher than in most European Union countries. This is due to both the high prices of electricity and heat, as well as the energy loss due to the fact that improperly designed and badly constructed buildings erected especially during the 70-80's. These buildings require high energy inputs for exploitation. Their technical condition is not responsible in any way the current requirements.

In years when energy was cheap it was not a big problem. At present, while the costs associated with the normal operation of buildings constitutes a big load. I mean first of all the processes connected with central heating and providing hot water.

Energy losses are the result of a large extent to the fact that most of the buildings are incorrectly or insufficiently protected against escape of heat from the premises. In this case, the heat (energy) are lost mainly by large surfaces are not properly insulated or insulated exterior walls, foundations, basements, attics and roofs, as well as the abnormal (low quality thermal), or improperly secured and leaky doors and windows.

We cannot forget the thermal losses arising as a result of faulty ventilation systems, as well as losses caused by the outdated and low capacity heating systems. The only legitimate way to solve the problem of the reduction of the costs incurred, as well as eliminating the problems associated with excessive energy consumption and at the same time reduce the emission of harmful substances into the environment and water consumption is correct overall upgrading existing of buildings. [17]

Elaborating on a major retrofit project, the owners might also consider using the opportunity to extend their home or to modify the internal layout or arrangement of rooms. In such cases, it should be remembered that bigger houses undoubtedly consume more energy than smaller houses with similar specification. Minimising the area of extended floor space will reduce build cost and perhaps leave additional funds for enhancing the overall retrofit specification.

If it is proposed to change the overall form of the dwelling, care should be taken to bear in mind the important principles of achieving compactness, namely reducing the surface to volume ratio. Very important is also maximizing the proportion of exposed glazing to the south, east and west, and avoiding unnecessary recesses and projections that might cause unwanted shading. An retrofitting process should be established between the architectural redesign of the dwelling and cross-checking the overall energy performance in the PHPP. For instance, existing windows to the south, east and west of the building could possibly be enlarged in order to increase solar gain and thereby reduce the space heating requirement.

3.2. Insulation

Survey

A detailed survey of the building to be retrofitted is an important basis for a good low-energy design. The existing build-up (in terms of materials, performance and dimensions) of the different elements of the thermal envelope and details of connections, possible thermal bridges, windows and doors have to be accurately recorded. In many cases, the precise build-up of the envelope will not be known to the owner of the dwelling. They don't know whether external walls are of cavity block, hollow block or solid block. In these situations it will be necessary to make inspection for describing the construction of building.

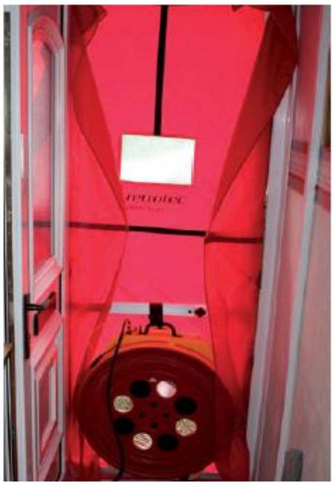


Figure 3.2 Blower door airtghtness test Source: https://encrypted-tbn2.gstatic.com

Details of the heating and domestic hot water system as well as data on energy consumption over a few years period are also critically important as a means of verifying the thermal performance of the existing building fabric. In parallel with this, it is also important to consider the comfort levels experienced by the owners of buildings and flats. Low energy bills could be faulty interpreted as a effect of an sparing operation of dwelling when in fact the occupants might live in some considerable discomfort during the heating season. Maybe due to lack of resources or malfunctioning heating systems.

A "blower door" test would be helpful to ascertain the current level of airtightness and to identify where cold air may infiltrate the building fabric in the heating season. The Passivhaus Standa rd requires the target value of airtightness of 0.6 air changes per hour for new buildings and value of 1.0 for retrofitted measured at 50 Pascal pressure and the majority of older dwellings will perform considerably poorer than this.

> "If a value of 0.6 h-1 is exceeded, comprehensive leak detection must be carried out within the framework of a pressure test during which individual leaks that can cause building damage or impair comfort are sealed. This must be confirmed in writing and signed by the authorized person." [18]

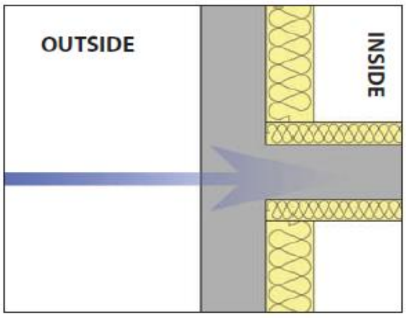


Figure 3.3 External insulation
Source: Sustainable Energy Ireland, Retrofitted Passive Homes – Guidelines upgrading existing dwellings in Ireland to the Passive Standard, SEI Renewable Energy Information Office and MosArt Architecture, Ireland, 2009

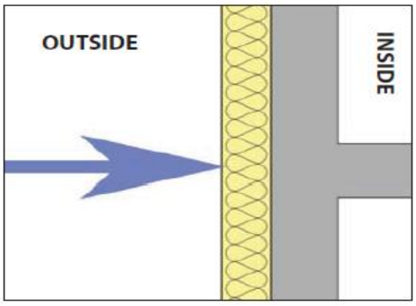


Figure 3.4 Internal insulation
Source: Sustainable Energy Ireland, Retrofitted Passive Homes – Guidelines upgrading existing dwellings in Ireland to the Passive Standard, SEI Renewable Energy Information Office and MosArt Architecture, Ireland, 2009

The use of a thermal imaging camera can also be very helpful in locating weak points in the thermal envelope but such a procedure is not necessarily mandatory especially if the survey and assessment is being undertaken by someone with experience in retrofitting.

Building insulation is added to an existing wall of the additional layer of material with high insulation properties. Insulation reduces heat loss and also increase the temperature on the inner wall surface. This brings with it a positive effect on comfort and eliminates the possibility of condensation and mold formation. The degree of thermal insulation of the walls is characterized by a heat transfer coefficient U. The smaller the ratio is, the lower the "escape" of heat through the wall.

Ideally, the insulation layer should be continuous on all around the building without any breaks. However, to avoiding breaks in the insulation layer is more challenging in the case of retrofitting. The location of insulation relative to the structural envelope can have a significant influence on thermal bridges. External insulation, for example, is typically the most effective in reducing thermal bridges, whereas internal insulation would be the least effective. The figure below shows the risk of creating a thermal bridge. This effect, as we can see, Is greatly reduced using external insulation.

Each kind of insulation of internally insulating the building have advantages as well as disadvantages which need to be considered at an early stage of the retrofitting strategy. In terms of advantages of external insulation can be distinguish:

- The external facade of the building will remain untouched by the upgrading works which would be beneficial when dealing with certain external finishes which homeowners might be reluctant to cover with external insulation, such as traditional brick, or natural stone in old buildings.
- Internal insulation may be cheaper when compared to external insulation. In this case there are certain savings, such as not having to use scaffolding and not being dependent on weather to carry out the works.
- In terms of thermal comfort, a room internally insulated will heat up much quicker due to the avoidance of having to heat up massive external walls.

Considering disadvantages can be mentions about:

- Internal insulation will reduce the usable net floor area of rooms with external walls
- Inevitably thermal bridges will be created for example in place of connection of exterior and interior walls or exterior wall and ceiling. As a result of this, additional insulation may be necessary along internal elements such as walls and ceilings to reduce the effect of the thermal bridges (Fig. 3.5-6).

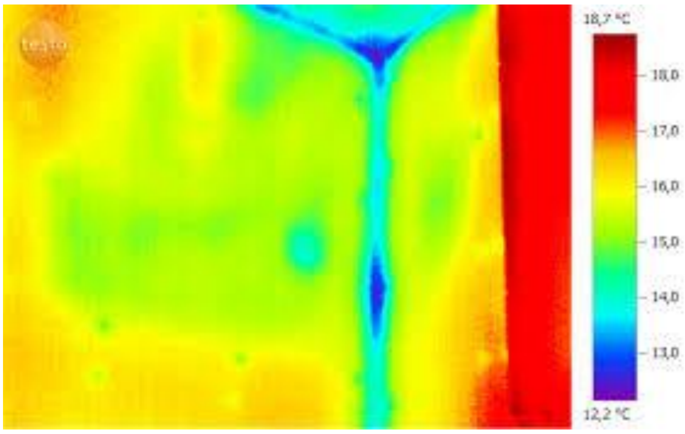


Figure 3.5 Thermal bridges in the corner of the room overhead

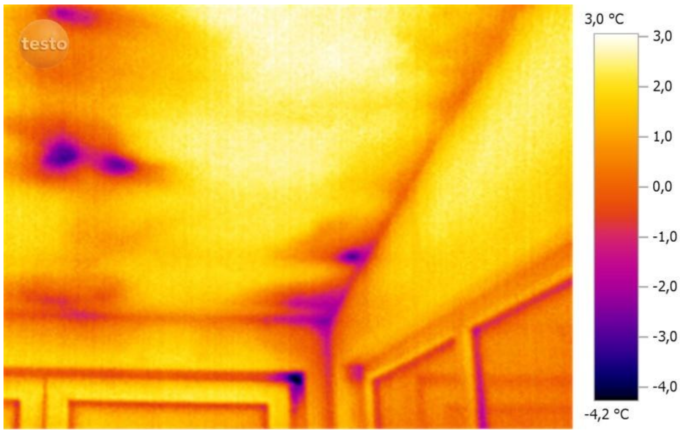


Figure 3.6 Thermal bridges on the ceiling

Source: Sustainable Energy Ireland, Retrofitted Passive Homes – Guidelines upgrading existing dwellings in Ireland to the Passive Standard, SEI Renewable Energy Information Office and MosArt Architecture, Ireland, 2009

External insulation is typically used with masonry construction types but might also be considered as an option for upgrading timber frame dwellings. The key principle behind this insulation method is to completely wrap around the entire structural building envelope thereby significantly reducing thermal bridges which can otherwise arise where external walls and foundations connect o internal walls and the floor slab.

3.3 Upgrading of Typical Construction Types

3.3.1 Wall insulation

The wall of older buildings are usually poorly insulated. The temperatures of the interior surfaces and humidity rises. It can often lead to occur of mould. Good insulation on the exterior can prevent this from happening. The walls of the buildings built several decades ago have U has a value of about 1 W/(m2K). Certification according to "EnerPHit and EnerPHit+i - Certification Criteria for Energy Retrofits with Passive House Components requires the achievement of this coefficient for opaque building envelope at the level of:

For exterior insulation: f_t - U ≤ 0.15 W/(m2K)

For interior insulation4: f_t . U ≤ 0.35 W/(m2K)

With temperature factor f_t:

in contact with the outdoor air: f_t = 1

in contact with the ground: "ground reduction factor " from the PHPP "Ground" Sheet [18]

For the our weather condition in Poland Polish Passive House Institute and Renewable Energy in criteria for Energy Retrofit House recommends the following values of the coefficients U:

For external walls: U <0.1 W/m2K [19]

Insulation can be accomplished in many ways. The basic division of these methods is insulation from the inside and from the outside of the building. Insulation from the outside is by far the most effective and convenient in implementation in comparision with wall's insulation from the inside. It must be competently planned and carried out properly. In contrast to external insulation, there are many problems associated with interior insulation. It must be performed sealed and airtight inside every room and all thermal bridges must be reduced as much as possible in the order to eliminate of cold areas that could lead to occur of moisture.

Begs the question: if the insulation will change the appearance of home? Applying insulation to the external walls increases their thickness. When additional insulation is applied to an existing facade, the design options are almost limitless. For ornate 19th - century facades or valuable brickwork facades it may be better to apply insulation on the inside. One of the key challenges in upgrading overall level of insulation in dwellings is to choose appropriate one from the wide variety of materials available on the marketplace. Above all, the insulation has to be appropriate to its application. Some insulation products are suited to use for fill in cavity walls, for example, whereas others are not. Some are load-bearing for use under concrete floors whereas others are 'soft' and better suited to fitting in the attic space. Some products have very low thermal conductivity values lambda values.

Different thicknesses and thermal conductivities of insulation products can easily be tested in the U-value sheet in the PHPP software. Dependent on the overall retrofit strategy, the additional insulation might divided depends on location of insulation:

- can be placed on the outside of the structural building shell and sometimes it is referred to as "outsulation",
- can be placed in the inside of the building and it is so-called "dry-lining",
- and/or within the construction envelope, for example filling the cavity space created by two leaves of external and internal blockwork or in the case of timber frame between the wall studs.

The figure below (Figure 3.7) shows the critical space each building, over which need to pay special attention.

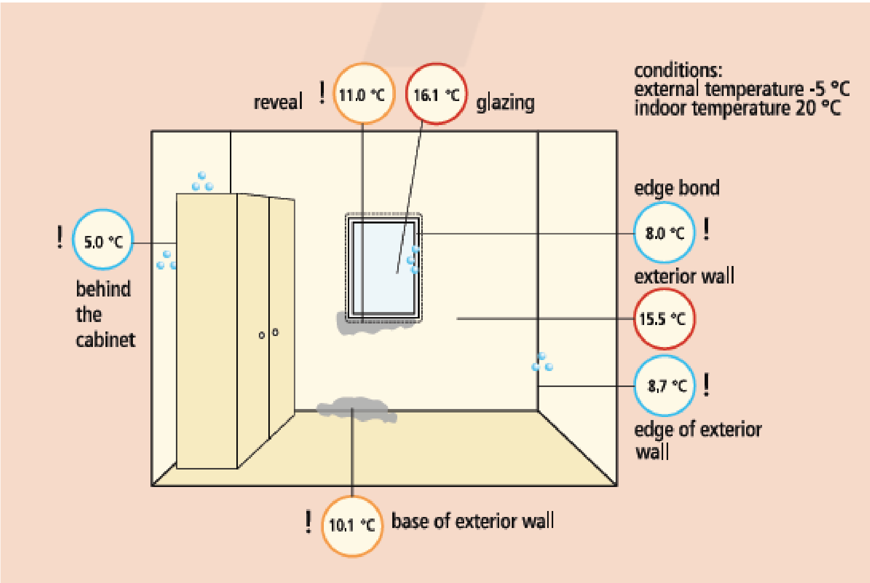


Figure 3.7 Old situation: Cold surface temperatures can lead to humidity-related damage.

Source: International Passive House Association, Active for more comfort: The Passive House – information for property developers, contractors and clients., Darmstadt 2010

On the other hand the figure (Figure 3.8) presents the same living room after modernisation with adding 200 minimeters of insulation on the external walls and new Passive House windows. Almost all the surface temperatures are above 16°C – even at the skirting board and the corner behind the cabinet. The moisture level remains low and there is no risk of mould. [21]

There are two options of external wall insulation, as follows:

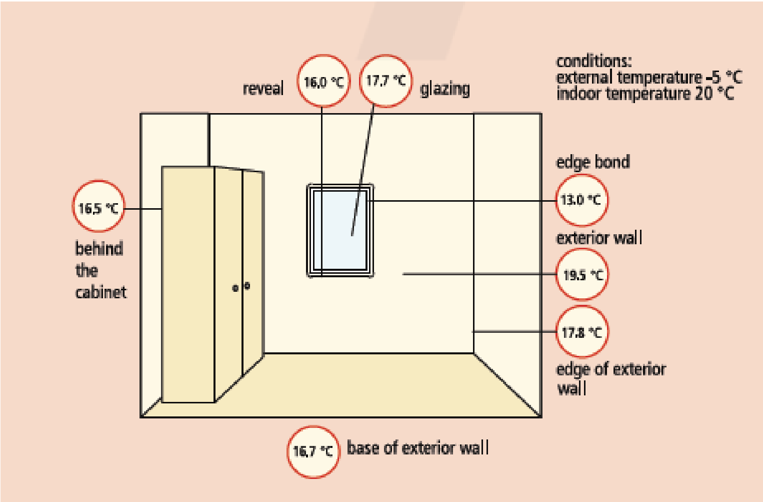


Figure 3.8 New situation: Refurbished with Passive House components

Source: International Passive House Association, Active for more comfort: The Passive House – information for property developers, contractors and clients., Darmstadt 2010

- This is so-called 'composite system' or 'single-skin system'. This type of insulation is either stuck or mechanically fixed directly to the external face of masonry wall, reinforced with for example a plastic or glass fibre mesh and then rendered. This composite system is used widely on Continental Europe as a technique to upgrade existing buildings to the Passivhaus Standard.
- The second system is where instead of the above single-skin system a ventilated cavity is created between the external cladding and the insulation.
  When considering insulating the roof space, the first decision to make is to determine the position of the thermal envelope of the dwelling. In most homes, the thermal envelope will be on the horizontal and just above the plastered ceiling comprising of insulation rolled out between the roof joists. In other situations, such as where there is a vaulted ceiling for example, the thermal envelope will be within the sloping roof comprising of insulation fitted between the roof trusses.

3.3.2 The floor slab on the ground

The traditional way of building foundation consists in making concrete continuous footings, mortaring foundation walls, insulation then and laying damp-proof barrier or water-proof course. Separate structural components are exterior walls of ground floor which can be one-, two-or three-layered like in typical buildings. In energy efficient and passive homes, the exteror walls on the ground floor should always be insulated independently of whether the space is heated or not. The contact of construction elements must be designed and manufactured to provide connections free from thermal bridges. This means that the thermal insulation of the foundation walls must be connected to the warming external walls. This allows for continuity of insulation.

Polish Passive House Institute and Renewable Energy in criteria for Energy Retrofit House recommends the values of the coefficients U for floor slab on the ground on the level of:

$$f * U \leq 0{,}150\ W/(m^2K)$$

"For the Polish conditions this coefficient is equal $U \leq 0.12\ W/(m^2K)$ where f is a 'reduction factor for the land' from the sheet PHPP "Grunt". Since the foundation slab insulation is internal warming, check whether its construction there will be no problem of moisture." [19]

The exception to this requirement is the situation in which it is possible to heat the foundation slab with the desired heat transfer coefficient with using conventional thermal insulation materials with a coefficient of thermal conductivity $\lambda \leq 0.032\ W/(m\cdot K)$ for reasons such as ceiling height and frame door. In such case, the thickness of the insulation can be reduced to acceptable levels. With the heat transfer coefficient $U \geq 0.300\ W/(m^2K)$ should be used maximum possible thickness of the insulation materials characterized by the coefficient of thermal conductivity with a value of $\lambda \leq 0.025\ W/(m\cdot K)$ or $\lambda \leq 0.022\ W/(m\cdot K)$. Of course, if the market offers products suitable for just such a use. In this case, check the insulation in addition coat surrounding the entire floor slab or relatively to perform it. To ensure the fulfillment of the conditions of thermal comfort temperatures prevailing on the internal surfaces of the floor space located on the ground floor have while keeping the design at least 17° C. [19]

To externally insulate a slab of ground floor, completely removing the existing concrete slab will be required. Before placing of hardening concrete a damp-proof membrane should be applied, a layer of insulation and a new floor screed. If will be decided a decision to not removing a slab to provide a new insulation layer, some it will be partly provided by externally insulating the external walls down as far as the foundation. The insulation of exterior walls down to the foundation will marginally reduce the heat loss from internal floors as well as marginally will reduce thermal bridges emanating from the rising walls. [22]

3.4 Windows and doors

3.4.1 Windows

As mentioned at the beginning, passive house characterized by a large amount of glazing on the south wall of the building. As we know, the windows have inferior thermal performance than the wall. However, not only should we pay attention on heat transfer coefficient of the window but also other parameters, in order to most effectively utilize the heat from solar radiation.

Criteria EnerPHit recommends the upgrade window frames with usng the window frames holding a certificate "component suitable for passive house" and triple glazing. If this recommendation is not followed, preservation, provide conditions for thermal comfort should be fulfilled with according to DIN EN ISO 7730 standard form is the Polish equivalent of the PN - EN ISO 7730:2006 "Ergonomics of the thermal environment -

Analytical determination and interpretation of thermal comfort with using calculation of the PMV and PPD indicators and local thermal comfort criteria,". [19]

Undoubtedly the most important parameter for the window parameter is U - the Heat Transfer Coefficient. It describes us quantity of heat which penetrates within a second of a construction element with an area of 1m2. The difference on both sides of the wall is equal to 1°C. The lower it is the better it protects against heat loss in winter and in summer the heat. In a passive way, we obtain the energy, if we choose the window with the appropriate g-factor of the total energy transmittance. In addition to directing the windows in the direction of corresponding side of the world, very important is degree of shading, the state of pollution of the glass, as well as part of the frame and divisions in a total area of the window.

The value of Heat Transfer Coefficient according Certification Criteria for Energy Retrofits with Passive House Components is required on the level of:

For the window as a whole: $U_{W,installed} \leq 0.85\ W/(m^2K)$

for g and U_g-value of glazing: $g \cdot 1.6\ W/(m^2K) \geq U_g$ [18]

The "g" coefficient refers to which part of the solar radiation reaches through the window into the house. Its value depends primarily on the type of glazing (Tab. 3.1).

Table 3.1 Total energy permeability coefficient of for a set of glazing.

Type of glazing	"g" Total Energy Permeability coefficient of for a set of glazing.
single glazing	0,85
double glazing	0,75
Double glazing with selective coating	0,67
triple-glazed	0,7
triple glazed with selective coating	0,5
double window	0,75

Source: *The legal basis: Official Gazette item. 926 of 08.13.2013, the [Regulation of the Minister of Transport, Construction and Maritime Economy on 5 July 2013 amending Regulation on technical conditions to be met by buildings and their location]*

Also belong to remember that the value of this coefficient should not be too high, as may occur during the summer overheating. In particular, for windows oriented from the south or south-west. For optimum energy efficient windows g-value is at least 50%. The most effective factor is the ratio of the two U-value no greater than 0.85 W/(m2·K), and the ratio of "g" not less than 45%. [20] The windows of such parameters are often referred to as active because they have a lower heat loss, a higher profit. On the overall heat transfer coefficient is influenced by the proportion of the window frame surface and the surface of the glazing. It is important for large windows, in which the proportion of glazing area is approximately 80%, which largely affects the U window. The desire to get better and better insulation performance of windows meant that they are becoming tighter - practically eliminating the inflow of fresh air from the outside. The presence of an efficient mechanical ventilation system eliminates the possibility of the appearance of moisture in the building.

In the group efficient windows with Passive Energy Standard is a two-chamber windowpane packet achieves heat transfer coefficient Ug =0,5 W/(m2·K). This windowpane packet consists of three glass thickness from 3 to 6 mm, separated distance frame. Practically the entire space is filled noble gas-argon or krypton. Both of these gases are much heavier than air which causes a lesser extent are convection movement, and thus decreases heat loss. Once the windowpane packet is filled with argon gas, is then separated distance frame thickness of 14 to 15 mm. This creates a relatively thick insulating glass unit and consequently causes the extension of the window's frame. Krypton is two times heavier than argon, so circulation of this gas is slower. In results the less energy is lossed and the acoustics properties of the windows are improved.

3.4.2 Doors

The selection of external door to the passive house besides the safety, it is necessary to pay attention to their insulating properties. To achieve the parameters, they should be filled with a thermally insulating material. To improve the stability and security of the door is placed in a space intended for thermal insulation, metal reinforcement. This type of task significantly impairs the heat transfer coefficient U.

The value of Heat Transfer Coefficient for external doors according Certification Criteria for Energy Retrofits with Passive House Components is required on the level of:

" ft · $U_{D,installed} \leq 0.80$ W/(m^2K)

with temperature factor f_t:

in contact with the outdoor air: $f_t = 1$

in contact with the unheated basement: f_t = "ground reduction factor " from

the PHPP

"Ground" Sheet." [18]

On the market today can be purchased doors with U-values of less than 0.8 W/(m2·K). More and more companies are committed to expand their offer by introducing doors with better insulation properties. To achieve this level of insulation is needed good materials such as polyurethane foam, polystyrene or mineral wool. Wooden doors are made of laminated wood, and filling their by plates are made of wood or wood-based materials. Warm wooden doors are therefore relatively heavy, and the thickness thereof reaches up to 10 cm. When it comes to doors, aluminum or plastic, thermal insulation in them is usually polyurethane foam. The steel doors are the most difficult to warming.

3.5 Airtightness

An airtight building envelope prevents from warm air escaping and stopping cold air from entering which also protects the building from damage. If warm, damp indoor air flow into the walls or roof through cracks, it condenses on the colder, more external building layers, causing mould and structural damage. Every refurbishment should, however, also include the installation of a ventilation system to prevent excessive moisture accumulation in the air and on the surfaces of building elements. Building structures that are not airtight always end up being more expensive than using proper construction methods from the beginning. Having to repair any damage or improve the building envelope at a later stage is more complex and ultimately leads to higher costs.

The PassivHaus Standard requires a maximum hourly air change rate of 0.6 at an under and under pressure of 50 Pascal. That means value of the entire air changes through gaps, cracks and other openings in the building is equal 0.6 times in one hour at an air pressure of 50 Pascal.

The airtight membrane or layer should always be located on the warm side of the insulation and should be continuous located around the building envelop without any break. In masonry buildings, the plastered internal face of walls is regarded as the 'airtight' layer, whereas a separate membrane would be required if the wall construction is comprised of timber or steel frame.

Different construction configurations will require different strategies with regards to protection from the dangers of interstitial condensation. For example, in certain instances a vapor check membrane with a relatively low resistance factor might be sufficient (i.e., allowing some moisture to pass through the wall), whereas in other situations, a complete vapor barrier might be required which totally prevents any moisture entering the construction. There are currently vapor membranes available on the market which are so called 'intelligent' in so far as their vapor resistance can change depending on the relative difference in vapor pressure between internal and external environments. Membrane works as the airtight layer and must be treated with great care during the construction process.

The timing of carrying out an "blower door" test is very important in the overall retrofit procedure. It is important to carry out the test prior to the completion of final finishes so that if the test fails then any gaps or cracks in the airtight layer can be precisely located and accessed for repairs. The test should ideally be carried out once the airtight layer has been completed but while it is still exposed, including most especially the taped joints between the windows and doors to the building envelope as well as joints between different elements of the dwelling such as ceiling, walls and floors.

3.6 Thermal bridges

As was described in previous chapter , the thermal bridge is a piece of the building envelope is characterized by a significantly poorer thermal insulation than the adjacent building elements . Thermal bridges in the walls can raise as much as 20 % requirement for heat , or increase the cost of home heating . The cause of such places are mostly design and manufacturing errors . Thermal bridges cause large heat loss , as they lead to hypothermia point of building partitions . This can result in condensation of water vapor in these places and humidity insulation materials and construction , and even the development of fungi and molds. Places of thermal bridges are located in design nodes, in any connection of external elements made of different materials. It is necessary to pay special attention on these places in building, which is upgraded . These sites are most common:

- connection between ground floor and foundation wall,
- connection between baseplate and external wall,
- anchoring seat of windows and doors,
- connection between roof and knee wall,
- balcony slabs,
- beams protruding from the exterior walls,
- supporting structures such as the places of fastening the steel railings, brackets, satellite dishes and even aluminum slats startup are used in light-wet method;

Small and middle-sized Passive Houses must be free from thermal bridges. Certified building products already come with exact illustrations of the most important details. In large-volume buildings, achieving a thermal tightness for load-bearing construction elements can be very complex task, so specified level of thermal bridges effect is acceptable. Somewhat better insulation in of other building parts can make up for influence of thermal bridges and allow to improve a good energy balance, because these buildings have a favorable surface-to-volume ratio (A/V ratio). Many sources describe the profitability of the investment, consisting in the reduction of thermal bridges.

> Thermal building envelope may show linear thermal bridges worth $\psi > 0.01$ W/(m·K) or point thermal bridges worth $\chi > 0.04$ W/(m·K).

These requirements poses for Polish conditions - Polish Passive House Institute and Renewable Energy as one of the criterion standard EnerPHit for retrofitting buildings. The exception is the situation when the limit value refers to the thermal bridges are part of regular structural element (eg, significant from the point of view of static mounts insulation made light-wet method). [19]

How to recognize thermal bridges?

The simplest method of identification weak thermal spots is water vapor condensation and mold growing. The most effective way to identify bridges in an existing building is to take thermovision pictures of facade. On the thermograms, places with different temperatures are color coded respectively from blue (coldest places), through red, to white (the place with the highest temperatures). Bridges, as a place of increased external temperature will therefore be on the pictures clearly visible as white areas. Professional thermal imaging study should be accompanied by a report containing specific recommendations on the elimination of thermal bridges. This should be done in view of the large temperature difference between the internal and external environment. This is the period of late autumn or winter.

How can you eliminate the existing thermal bridges?

Elimination of existing thermal bridges, which consists in supplementing the continuity of thermal insulation of the building this is not a simple task. Each case must be examined separately, very important is also an appropriate choice of components. What materials would be best to complete the insulation of each envelope is one of the most important question.

Should be consider modernization such action such as:

- installation of windows and doors in the wall's insulation layer in this way to prevent overlapping of insulation on window's and door's frames;
- insulate the basement walls from the inside and outside, so that the basement insulation combined with external wall's and ceiling's insulation;
- interior wall should be insulated with using layer insulation with a height of 50-100 cm, connected to a ceiling insulation;
- resignation from traditional balconies and replacing them by self-supporting or hanging balconies;
- supplementing the insulation of ceilings, roofs and ceilings;
- eliminate cracks and large cracks on the façade;
- the continuity of insulation on all the partitions;

Polish Passive House and the Renewable Energy Institute and criteria EnerPhit give a additional information regarding thermal bridges in construction, which are uneconomic or impossible for technical reasons. This kind of thermal bridge should be considered in consultation with the authorized person as possible to reduce its influence. However requirement for protection against moisture must be always met. [19]

3.7 Upgrade of ventilation system

The upgrading of the ventilation and heating system is the second step in retrofitting dwellings to the Passivhaus Standard. Mechanical ventilation is essential element to modernize the house. A comfortable ventilation according to standard EnerPHit must met the condition η_{OC},eff ≥ 75%. In addition, the electrical efficiency of the ventilation device cannot be less than 0.45 Wh/m^3. The basic principle is that all premises within the heated volume of the building must be vented. Value of coefficient η_{OC},eff addition to meeting the criterion of "Component suitable for passive house" must refer to the entire ventilation system, which means that it must also be included heat losses from warm air through ducts in cold part of the building.

3.7.1 Ventilation System

The retrofitted dwelling can be ventilated in a number of ways, including through controlled means by extract fans, vents in the wall and openable windows or by simply by uncontrolled leaky in thermal envelop. As highlighted in one of the previous chapter, however, it is vital for the Passivhaus Standard regarding with very high level of airtightness is achieved in order to minimise heat loss. Airtight construction, in turn, is accompanied in the Passivhaus Standard with mechanical heat recovery ventilation systems. This next section of the guidelines will provide an outline of considerations necessary in planning such a system in the context of retrofitting a dwelling.

3.7.2 Recommended Ventilation Rate

According to the Passivhaus Institut, the appropriate air change rate for dwellings is between 0.3 and 0.4 times the volume of the building per hour at normal pressure, with a general recommendation of leaning toward the lower rate. This maintains high indoor air quality while ensuring a comfortable level of humidity and maximizing energy savings.

Increasing the effectiveness of the ventilation system can be achieved using ground heat exchanger. Most ground heat exchanger is a plastic or ceramic tube placed in the ground below the frost line. Ground heat exchanger is used for preheating ventilation air supplied to the recuperator in the winter and cooling it in summer.

3.7.3 Mechanical Heat Recovery Ventilation System

The efficiency of the heat exchanger in the Mechanical Heat Recovery Ventilation (MHRV) determines the amount of heat that can be recovered from the exhaust air and, therefore, has a very significant influence on the additional space heating that may be required in a passive house. The efficiency of sensible heat recovery should exceed 75% for the nominal range of flow rates specified for the unit when measured in terms of the supply-air side temperature ratio. Specifiers and designers should be wary of products claiming extraordinary efficiency rates of 95% or higher. The safest route is to install equipment that has been independently tested and verified by such bodies as the Passivhaus Institut.

The Passivhaus Standard can be achieved without a heat recovery system as well. However, when eliminating the MHRV system the savings foregone in recovering the thermal energy have to be compensated by other measures such as additional insulation of the thermal envelope. [21]

3.7.4 Insulation and Positioning of Duct Work and Vents

It is very important to adequately insulate the air ducts so that will occur a minimal losses of temperature in delivering warm air into house. The thickness of insulation generally used in passive houses is between 6 cm and 10 cm for ductwork. It is also preferable to locate the ducts within the thermal envelope and to keep pipes runs as short as possible by ideally positioning the MHRV unit in the centre of the house.

Vents are usually placed in the ceiling but can also be placed in the wall if it is necessary. The air inlets are typically designed to spread the air horizontally across the ceiling and minimising downward draughts. A gap of 10mm should be either under or over the door of each room. It enable the easy movement of air from one room to the next. There are a number of MHRV products available on the market that have been specifically developed for retrofitting to the Passivhaus Standard.

3.8 Heating system

With a small demand for building passive heat does not have to be equipped with a conventional heating system. To maintain a comfortable indoor temperature, even during the harsh winter, should be enough only heating the fresh supply air by mechanical ventilation. Heat to heat the supply air can come from heating system domestic hot water. The heat source can also be connected systems using condensing boiler and heat pump assisted solar collectors used simultaneously for heating, domestic hot water production and ventilation. Ventilation systems in passive houses are characterized by high efficiencies and quality. This is necessary due to the very high energy requirements placed on these solutions. In addition, the criterion to reduce the total primary energy consumption by building forcing investors and designers to use solutions with low power consumption. Especially for passive houses are offered compact central heating, which in one case are hidden all the necessary heating and ventilation.

The basic criteria for determining the selection of additional heat sources are:

- primary energy consumption,
- energy costs in the local market, because of the very small heat consumption much more importance to the amount of fixed fees and subscription,

- additional investment cost of the heat source for example chimney,
- limitations associated with the necessity of placement of additional installations such as air supply, flue gases, water system
- exploitation - for example supplying fuel to the boiler, cleaning

  Fulfilling one of the basic criteria - the heating load at 25W/m2. This allows the use of a common system of air as ventilation and heating system.

The most common method of 'heating' in a passive house is by post-heating the fresh air after it has already been warmed by the exhaust air in the MHRV. There are a number of ways in which the temperature of the air can be raised, including those distinguished below:

- water to air heat exchanger;
- compact unit with electrical heat pump;
- wood pellet/wood log boiler.

It may well be possible to continue to use the existing heating system in the building. hanging the oil boiler with radiators can be unnecessary but in many cases it might not be an efficient way to heating and might be at or near the end of its useful life. In addition, the design output of the heating system is likely to be too large for the retrofitted building. Another strategy would be to retain the pipes and radiators already existing in the building but to replace the older larger boiler with a smaller and more efficient one that can serve not only space heat requirements but also domestic hot water production.

One advantage of keeping the radiators results in the homeowner being able to control individual room temperatures by adjusting the valves manually to suit their needs or using Thermostatic Radiator Valves to set the room temperatures. Even if the original radiators are being retained as the primary heating system, there will still be a need for a Mechanical Heat Recovery Ventilation system. It will now not only supply fresh pre-heated air to the dwelling but will also distribute the heat generated by the radiators throughout the house. A further issue to consider in whether or not to retain the original radiators is the fact that they will probably have to be moved if internal insulation will be designed for the building. Therefore, a detailed plan for the modernization of the heating system for the building is necessary. This will allow for proper planning of the work, the need to reorganize any other building components. This will help you predict the budget for the investment.

3.8.1 Ground heat exchanger

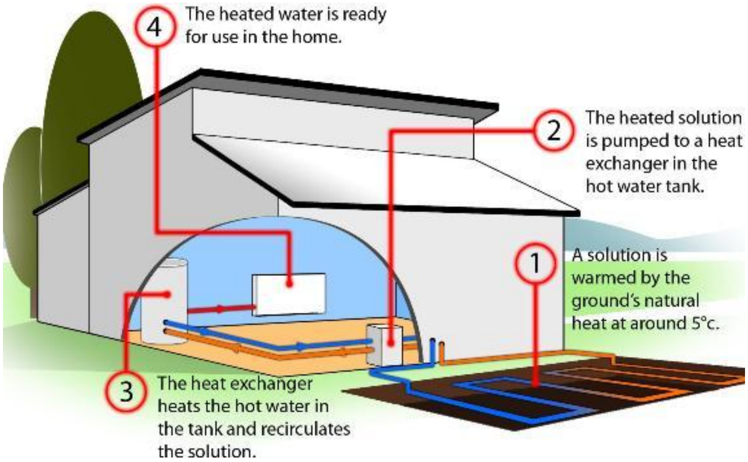


Figure 3.9 Functional diagram of installation using ground heat exchanger

Source: http://www.simonlawrencebuilders.co.uk

Ground source heat, is heat contained in the ground derived from solar energy. The heat from the sun's rays are absorbed into the ground. This free heat source can then be extracted by means of burying a coil of plastic pipe below ground at a minimum depth of a meter (Fig. 3.9). The pipe is then connected to a heat source pump and manifold, the system is then filled with a mixture of water and a solution to prevent freezing. The pump takes the warm water and compresses it and feeds it into a heat exchanger then to the hot water tank.

In Polish climatic zone at a depth of 1 ÷ 4 m throughout the year there is a constant temperature of 10 ° C and ranges between + / -1.5 ° C. Practically gravel in GWC is located very shallow, sometimes even above the ground, which is above the ground water level. However, thanks to good thermal insulation localized an cover bed of ground heat exchanger, the designers decide to placing it at a depth of 5 ÷ 6 m below the surface. This mechanism was invented in order to use the power of the land. At least a few thousand employed in Poland GWC confirms that the outside air flowing through the gravel fixed to the bed depth of the peaks heated in winter about 20 ° C and cools down in the summer of about +30 ° C to +20 ° C. The figure above show the one of example of exchanger's construction.

Figure 3.10 Ground Sorce Heating Pipes
Source: http:///www.simonlawrencebuilders.co.uk

The design of the heat exchanger is designed as a natural gravel bed of clean, washed, placed in the ground. Air flow through the gravel, depending on the time of year, summer is cooled and dehumidified, heated and humidified in the winter and throughout the year filtered from pollen and bacteria. Direct contact of the bed with the surrounding native soil facilitates the rapid regeneration of the bed temperature.

3.8.2 Electrical heat pump

The heat pump is a device, which pumping the heat from an area of low temperature to a home heating system, in which the temperature factor is higher. The name is similar to the usual water pump, which draws water from the place at low altitude and forces it higher, or increases its pressure. The heat pump heats up the heat to facilitate its use for heating. This allows us to draw heat from the ground, air or water, and then use it to heat our house.

The heat pump takes 1 kWh of electricity guves to the environment 1-4 kWh of heat and then a total of 2-5 kWh transmit the heat to the environment. The heat pump delivers more heat than it consumes power and is cheap to operate, which has a high coefficient of performance. Therefore, it is considered that the pump is a renewable source of energy - a significant portion of the heat supplied to the building is taken from the environment. [22]

On the Polish market offers three types of heat pumps: brine-water (BW), water-water (WW) and air-water (AW). So-called lower environmental heat source or a heat pump which draws heat energy are as follows: saline, water and air. "Brine" means that the heat pump receives the heat energy from the ground. Soil heat energy first heats the liquid circulating in the pipes in the ground, from which heat is then received already in the heat pump. In the second type (WW) heat is taken directly from the water, and the type AW draws heat from the air. The simplest installation is certainly a heat pump type AW.

The biggest disadvantage of the use of heat pumps AW is the variable temperature of the heat source. This is due to the fact that the temperature and varies greatly throughout the year. In winter when there is a need to heat the most heat in the building, air temperatures are lowest. In the summer, the situation is reversed. The heat pump WW requires a more complicated installation. It is necessary to perform the supply wells and wells of discharge. The advantage of this solution is the constant temperature of the brine or water. The fact should not be overlooked, however, that the water to the heat pump to bring the water pump, which also consumes energy. WW heat pumps are usually used in large systems where the amount of electricity consumed by the water pump is relatively small compared to the electric power efficiency and the heat pump itself. The third variation of the heat pump is a pump - type BW. Heat source can be either horizontal collector or vertical probe. The area that will take ground collector depends largely on the efficiency of the heat, and hence, the type of soil in which it is planned to location of ground collector. Soil heat capacity ranging between 10 and 30 W/m^2. The land is more hydrated, the greater the thermal efficiency. When using probes, soil thermal efficiency is taken in the range of 20 to 70 W/m.

In conclusion, the most powerful and stable heat source is a vertical probe. Immediately afterwards properly made horizontal ground probe. The disadvantage of this solution is to deal with a large surface area. The air-water heat pump is the cheapest to install, but for obvious reasons do not guarantee the stable performance of the heat source and good efficiency. Regardless of the choice of the type of heat pump, each of which, if it is properly chosen, can be successfully applied in Polish climatic conditions.

4. Assessment and improving the technical condition elements of the building

How to measure the strength of brick and mortar and how to strengthen the brickwork without affecting its appearance?

In the old renovated buildings very often we are faced with the problem of adapting the building to for instance new building's functions or new loads. Increased loads require checking bearing capacity of walls. This situation causes for example necessary replacing of light floor by more massive, superstructure of additional stories or the demolition of part of the wall.

This is one of the main problems during overhauls of old buildings. The second problem is very often necessary to repair cracked walls, so as not to damage the historic character of the building. Also, it is important to immediately after completion of the work to strengthen co-operated with the wall without the need of preliminary deformation, which cause microcracks along old cracks occurring before the renovation. How can test the strength of bricks and mortar and how to strengthen the walls without interfering in their appearance?

The wall is a structure composed of two very differing from each other elements: bricks and mortar masonry connecting elements as well as improving the shortcomings of ceramic components - especially in the field of geometric imperfections. Strength test can be performed on wall elements in accordance with rules and standard PN-70/B-1201. However, it is connected with fairly extensive damage of the wall in order to take some samples- whole bricks. This task is feasible, although rarely used. In addition, one test does not guarantee that such on other floors there are the same brick.

Strength tests of the mortar are even more problematic. Taking sample of mortar from the wall is virtually impossible. Because of this, it is required to be tested a sample with area of 4 x 4 cm and the thickness of the mortar between the bricks is only 1.5 cm. Chemical analysis of the composition of the mortar is so inaccurate and it is comparable with the intuitive assessment. Useful methods included a ultrasound test. Thus before restoration work is needed technical evaluation particular elements of their construction. The further in this subsection, examples of the method of walls strengthening have been described. [24]

4.1 Expertise of existing state of the building

In my work I draw upon from received data object from inventory, the technical description and expertise from one of the student of Technology University of Poznan - Joanna Pawlak.

4.1.1 Technical expertise condition of the structure of the existing building.

The absence of any cracks on the walls shows good condition of foundations. The area around the brick wall of the building is dirty, and the joints between the bricks are destroyed - crumbled or dirty and overgrown with algae.

4.1.2Residential building (gravedigger's house)

The general condition of the building is good. In the corner room (north-west) can see traces of moisture. As part of the utility part is possible to notice loosening of single roof tiles.
The floor above the ground floor in a residential part requires repair. In some places the plaster fell off and can see a bit corroded beams. Assessment of the roof structure must be made during the works. Joinery, external doors and windows in good condition. Walls in good condition. There are only local defects bricks in the wall south-west.

4.1.3 Planned restoration and building work

4.1.3.1 General restoration recommendations

Should be checked the efficiency of isolation from groundwater and drainage for drainage water to soakaways. Finally after the discovery of foundations construction manager may waive the performance drainage. It may turn out that the moisture in the interior comes exclusively from unprotected window openings.

If it is technically possible, use the same roof tiles, complementing the missing tile, and lay the foil vapor permeable cover. General exchange of all roof tiles is not recommended. Perform a new flashings. If during the execution of the works turns out that some element of the roof structure corroded should be replaced or strengthen – it is depends and should be assess by the construction manager.

4.1.3.2 Renovation of brick wall

Old buildings made of brick are usually exposed, to a large extent, to getting damp due to lack of appropriate damp-courses. After the reasons for dampness have been eliminated and the walls have been dehumidified we often face a problem of their restoration and adjustment to new loads or to new tasks to be performed in the building.

There occur questions regarding the strength of brick and mortar which constitutes the basis for determining the load capacity of the walls and quite often it is also necessary to bond the cracked walls without affecting the historic qualities of the building.

4.1.3.2.1 Removing old layers from the brick

The brick wall should be clean up with cold water or hot water under pressure 125 bars. Places on the so called. black build ups, which are indelible with water should be remove with using a special chemical preparations, for example: hydrofluoric acid or 1% solution of acid ammonium fluoride. When the first of these preparations will be used before starting cleaning, the test is essential to carry out. Because on some types of bricks can cause surface damage or white aggregations of silica. In the case of these defects can also use a 1% solution of this acid, and repeat this cleaning.. Time of the preparation for the brick cannot exceed 20 minutes. After this period, the wall should be washed off with water.

When working in the winter, with freezing air temperatures must be used a dry cleaning method - through attrition by using a stream of pressurized air. Depending on the type and condition of surface should be used abrasives with different hardness and shape of the grains: quartz sand, glass microspheres, marble dust, ground nut shells, microcrystalline powders of sodium carbonate, etc. The intensity of the cleaning should be regulated by air pressure.

4.1.3.2.2 Desalination the walls by compress method

It is best to use a mixture of bentonite and sand in the ratio of 1:6 and water. Alternatively, a mixture of kaolinite with sand in the ratio 1:5 can be used. However, these compresses are more difficult method to remove greasinesses and they can leave white footprints on bricks. It is also possible the use conventional compresses in the form of paper pulp. In the case of facade cleaning by dry desalination may be unnecessary.

4.1.3.2.3 Destruction of microorganisms

For the control of microorganisms and security of buildings against their invasion is proposed to use for example a 1,5% solution of the preparation *Lichenichida 246* Bresciani production in ethanol or acetone.

4.1.3.2.4. Supplementing defects in the wall by inserting bricks with dimensions such as those used primarily.

It will be necessary to reconstruct the correct thread. Bricks used should be properly matched for color and texture, and to hold a appropriate quality. Mechanical strength of mortar must be selected to the hardness of details that will not cause the formation of mechanical stress.

4.2 Details architectural - constructional and existing state description of the building.

Figure 4. 1 The front façade
Source: Own

4.2.1 Appearance of particular elevations of the building.

4.2.1.1 The north elevation

Figure 4.2 The north elevation
Source: Own

Figures 4.3 Photos of north elevation
Source: Own

4.2.1.2 The west elevation

Figure 4.4 The west elevation
Source: Own

Figures 4.5 Photos of west façade

Source: Own

4.2.1.3 The south facade

Figure 4.6 The south elevation

Source: Own

Figures 4.7 Photos of south façade

Source: Own

4.2.1. 4 The east facade

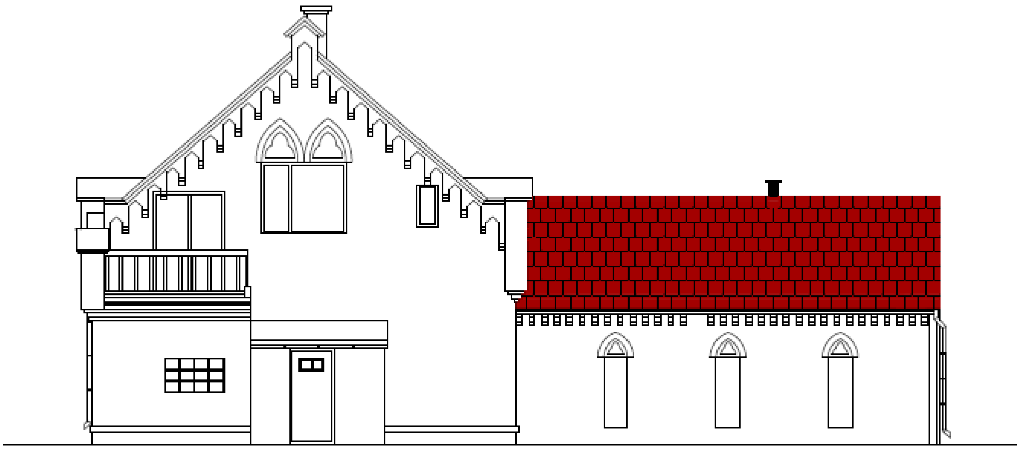


Figure 4.8 The east elevation

Source: Own

Figures 4.9 Photos of east façade
Source: Own

Figures 4.10 Photo of east elevation
Source: Own

4.2.2 Rooms inside the considered building under - current state

4.2.2.1 Kitchen

Figures 4.11 The interior of the kitchen
Source: Own

4.2.2.2 Hall

Figures 4.12 Photos of hall
Source: Own

4.2.2.3 Bedroom 2 on the ground floor

Figures 4.13 The interior of the bedroom 2 on the ground floor
Source: Own

4.2.2.4 Bedroom 1 on the ground floor

Figures 4.14 Photos of bedroom 1on the ground floor
Source: Own

4.2.2.5 Bottom of the floor above ground floor (main part of the building)

Figures 4.15 Photos of bottom of the floor above ground floor (main part of the building)
Source: Own

4.2.2.6 The interior utility rooms in other parts of the building - basement


Figures 4.16 Photos of basement
Source: Own

4. 3. Techniques repairing of brick walls

4.3.1 Cracks on the walls

In the case of cracks occurring in the walls is necessary to take action to remove them. The technical literature describes several methods of strengthening the walls. Apply a variety of ways of getting separated parts of the wall using for example turnbuckles, tie roods, anchoring in ceilings, etc. The effectiveness of these methods can be assessed in two ways. In general, when it comes to the safety of the entire building is the solution passes the test. On a smaller scale after the repair, smaller cracks may appear at place of occurrence the old cracks. This is due to the fact that before tie rod or clamp begins to cooperate with the wall, there are some deformation – sufficient hairlike cracks occur in the weakest point - old break. For some time, there are special items to repair damage-cracks on the market. These elements are helically twisted steel rods made of austenitic, stainless steel (Fig 4.17).

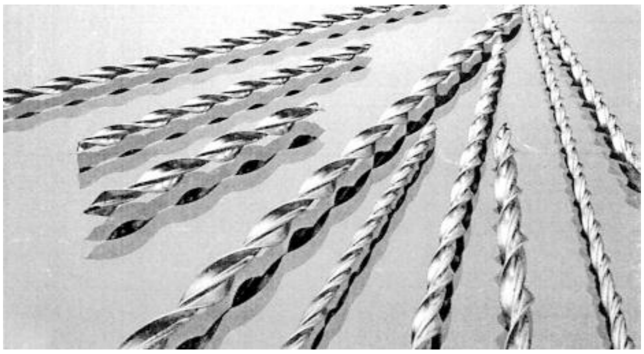


Figure 4.17 Spiral rods used to repair cracked masonry walls.

Source: http://www.twistfix.co.uk/images/pictures/products/structural/crack-repair/helical-bars-5-9mm-(page-picture-large).jpg

In order to restore the continuity of the walls, the helical rods with diameters from 4.5 to 8 mm should be arranged in a purified from mortar to a depth of 6 cm from the surface, the horizontal joints, in every 5-6 joint. The length of the bars should provide a achievement the distance at least 50 cm from crack to the end of bar. The bars can be folded along the wall at the site of corners closer than 50 cm from crack. After inserting the bars, joints should be filled, forced, non-shrinking, thixotropic resin or cement mortar.

It is also recommended way to reinforce strongly cracked walls with raw brick. (Figure 4.18). Spiral steel bars can also reinforce the wall. After drilling the bores, bars are glued with using for example a polyester resin. To drill bores diagonally to cracks (Fig. 4.19-20) can consume less bars. Anchoring bar outside of a crack can be much shorter for example: 10 cm, 15 cm. It depends on the strength of the materials combined.

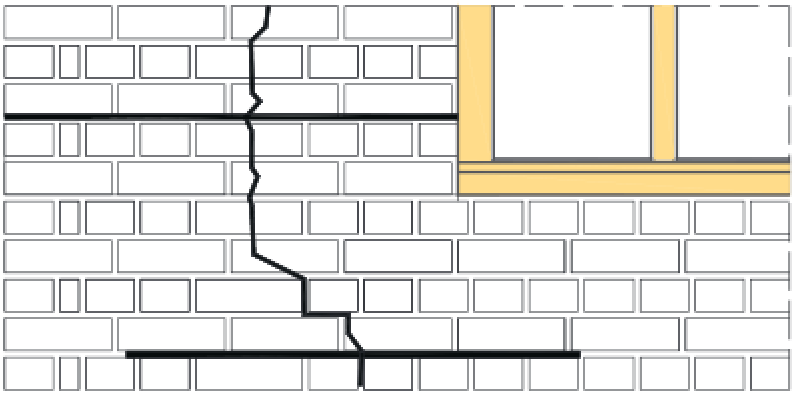


Figure 4.18 Repairing the walls with vertical and diagonal cracks.

Source: Dr. Ing. Elizabeth groceries, "Causes damage and a repair of a historic building in the floodplain Gubin", University of Zielona Gora, Review of Building 3/2013, Renovations 2013

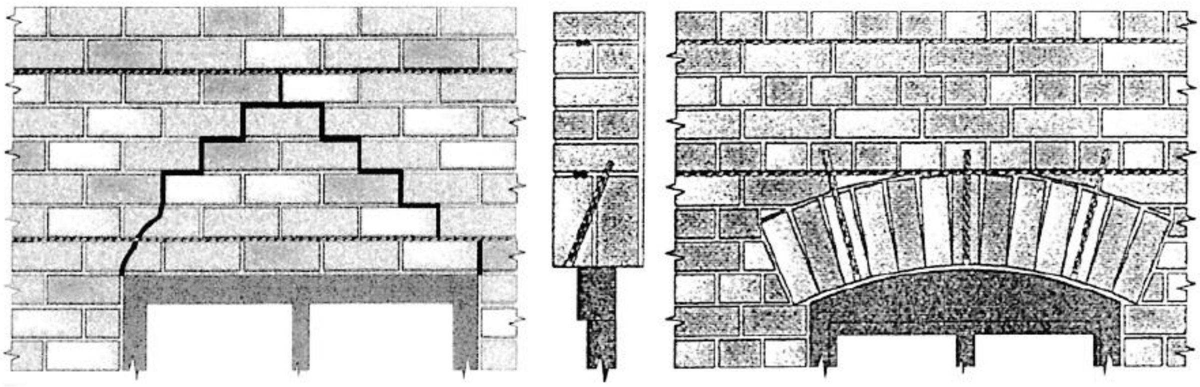


Figure 4.19 Possible ways of strengthening the lintels

Source: Thiery J, ZALESKI S., Restoration of buildings and reinforcing the structure. Arcade Publishing, Warsaw 1982.

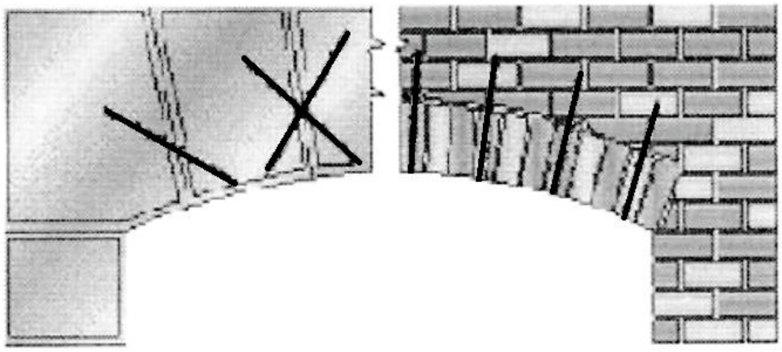


Figure 4.20 Reinforcing bars lintels implemented diagonally to lintels

Source: Thiery J, ZALESKI S., Restoration of buildings and reinforcing the structure Arcade Publishing, Warsaw 1982..

Listed test methods and properties of the walls of bricks and mortar, as well as new ways to strengthen the cracked show that the problem of maintenance, repair or renewal of old buildings with masonry walls may be well and quickly resolved.

4.3.2 Mortars for renovation the historic walls

Facing walls are perhaps the most exposed to the effects of weather conditions. That is why it is important to choose the appropriate mortar during renovation. Renovation mortars must on the one hand take into account the characteristics and features of the surviving original materials, and on the other to ensure durability, while drawing influence of various external loads. During the renovation of brick or stone facade addition, we are dealing with a diverse range of works. In the first place to be ready for injection slots later to reconstruct the face bricks until the grouting. It is important, therefore, that at these specific tasks use various mortars depending on the type of load, even within the same type of work.

Other mechanical and capillary must have a joints to the face of the bricks, and a completely different joints and mortar on crowns. Finally, the maintenance of face brick is also aesthetic arrangement of large areas. For this reason, very important is the right choice of color and texture visible mortar grouting or additions bricks.

4.3.3 Bricklaying, grouting and reprofiling

Mortars in a historic brick wall have several functions. On the one hand, it was combining construction material, on the other it also protected them. Mortars and grooving usually have in fact much higher porosity, quicker hauled water, and were much weaker mechanically than bricks. As a result, followed by the free migration of water vapor, or excess moisture out of the wall, and possible destructive processes taking place just in the mortar, which could always be replaced. New mortar facing implement during renovations should therefore meet these requirements mainly depending on the parameters of the brick or stone. However, in today's acidic environment should not be significantly more resistant than the original mortar.

Frequent white patches on the walls are the effects of an aggressive environment (eg. acids from the air) to unbound lime. Thanks to the silica contained in trass, "free lime" (calcium hydroxide) is bound in the mortar and converted into highly resistant silicate. In this way, main cause of poor immunity lime is eliminated . Both the mortar for bricklaying or pointing and reconstruction of brick addition to the standard properties of the rapid transport of water, optimum strength, trass additives may be prepared taking into account the characteristics of the object and in the right color for him and aggregate fractions. All also have appropriate usable features - adhesion, plasticity allowing for safe and work easier. The various range mortars there are also special products and additives for mortars assumed in areas exposed to constant contact with water or residual snow. In those parts of the wall such as crown, base, joints must be not only waterproof but also flexible to be resistant to temperature fluctuations. This modified mortar allows for permanent renovation of the most loaded places (Figure 4.21-23). [25]

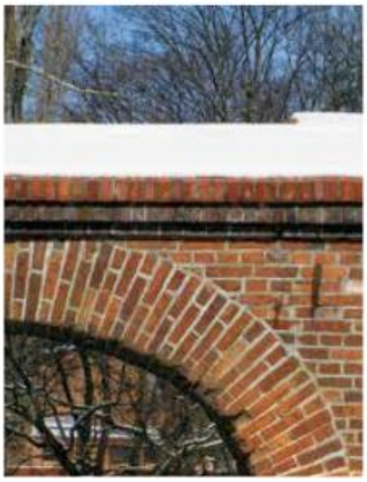


Figure 4.21 Crown of walls require special mortars (on the left)

Figure 4.22Example of reconstruction of brick

Source: "Conservation of monuments and renovation of old buildings" - Renovations, Sto-ispo Sp. z o.o , Build consciously, Warsaw, August 2013, www.sto.pl

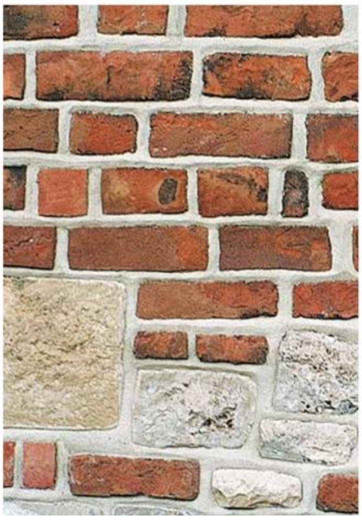


Figure 4.23 Mortar with additive of trass prevent efflorescence of lime.

Source: "Conservation of monuments and renovation of old buildings" - Renovations, Sto-ispo Sp. z o.o , Build consciously, Warsaw, August 2013, www.sto.pl

4.4. Proposed insulating materials and finishes

4.4.1 The exterior walls

In my work, I considered only part of the building, which will be residential part of the building. In this part will be installed mechanical ventilation. For the sake of conservation reasons it is necessary to use insulation on the inside of the building so as not to violate the XX-century original appearance of the building.

Thermal insulation of buildings from the inside always aroused controversy. In certain situations, but nevertheless this is the only possible and reasonable solution. Modern insulation materials facilitate the thermal modernization in this way. Insulation from the inside involves risk, when inside the building there is high humidity, and ventilation is not running smoothly. There is the risk that the wall under the insulation will be so cold that moisture starts to condense at this site. Ensure proper ventilation eliminates this problem. This type of problems related with excessive moisture from the inside in general is not occur in modern construction, in which the principles of efficiency require the use of mechanical ventilation with heat recovery.

Instead of the question "whether in such a situation it is worth to insulate from the inside", designers and investors must answer on another question that necessarily should be considered precisely, namely-"what material will be the best" to get the maximum effect. The first step is to find out as the most precisely as it is possible everything about construction of walls. How to insulate the walls from the inside, depends on what material is used for this purpose. In another way, you need to go by when the walls are made of stone or clinker bricks, and otherwise in the case wooden logs, timber-framed or clay. It is necessary to take into account the vapor permeability of the wall. Different ways of isolating partitions are presented in chapter 2 (section 2.2) and chapter 3 (section 3.2) of my work. The external walls of the building are considered part of the brick and have a thickness of 25 cm or 54 cm. Thinner wall is present only in the part of the building. The following figures (Fig. 4.24-25) illustrate the plan of walls on the ground floor and first floor.

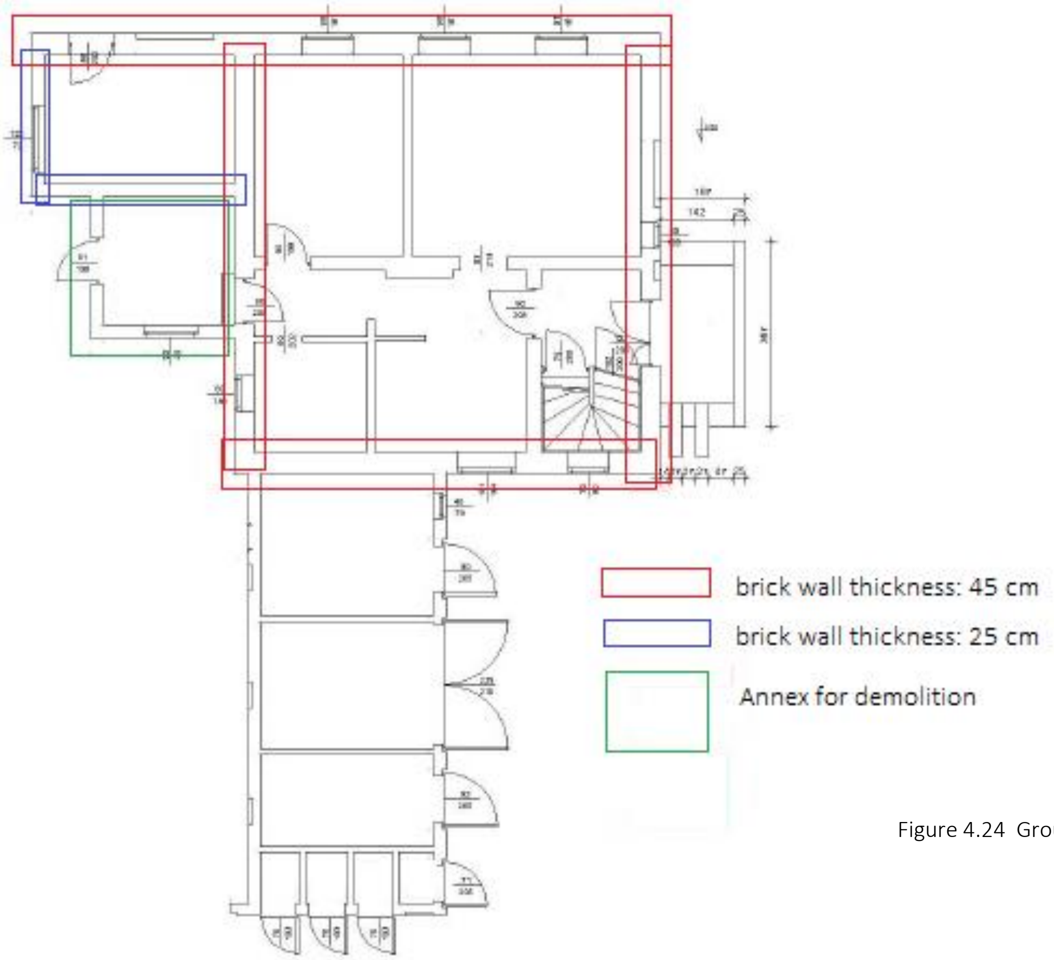


Figure 4.24 Ground floor plan

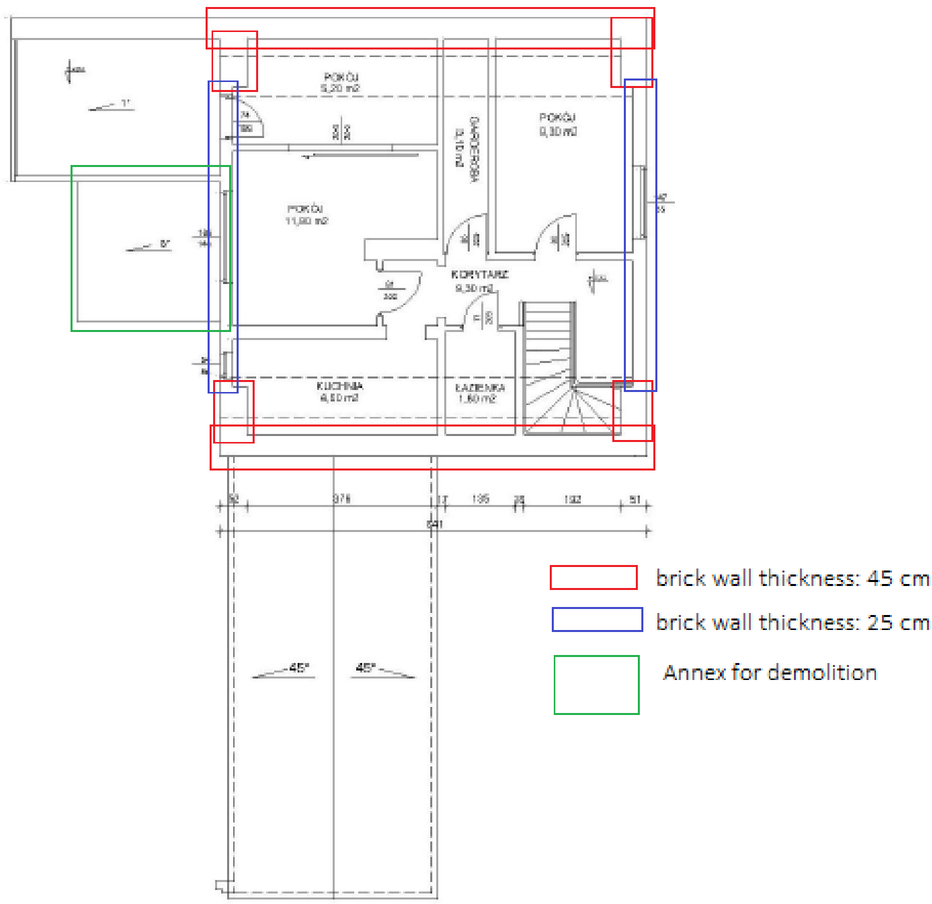


Figure 4.25 First floor plan

The greater part of the outer walls as shown above is constructed with a wall thickness of 45 cm. It consists of parallel layers: a brick with a thickness of 12 cm, a ventilation gap with a thickness of 8 cm and 25 cm thick layer of bricks. The wall cross section is shown in figure 4.26. This is called a diaphragm wall. A cavity wall or otherwise known as double wall have been popular since the early twentieth century in Poland. This is the traditional method of erecting exterior walls, which giving unprecedented opportunities to shape the facade. [26]

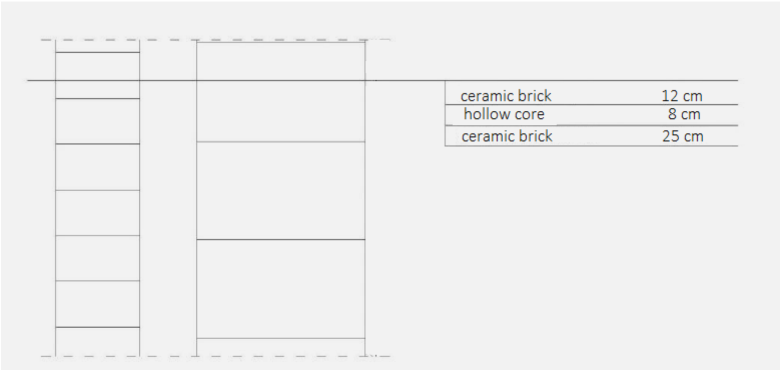


Figure 4.26 Cross-section of cavity wall
Source: Own

The principle of a cavity wall (except for the differences associated with wall thicknesses and widths of the slots) are based on the following assumptions:

1. Brick exterior wall made of half of brick
2. Air gap
3. Interior wall made of half of brick or other masonry material
4. Interior plaster

A cavity wall aims to prevent moisture transmission to internal wall.
In general it may be concluded that:
- exterior walls protect against external moisture
- the cavity is a partition capillary
- Interior walls and plaster provides airtightness

Should be take into account the fact that in case of lashing rains, after a certain period of time, depending on the capillarity of the exterior brick, water flowing down from the outer wall gets into to the air gap. This water must be drained out so as to prevent its penetration into the inner layers. It is not possible to guarantee 100% of tightness in case if:

- the interior wall can easily air permeable, so-called. "can easily breathable", for example in the case of large thickness of mortar
- exterior wall was built of impermeable materials
- air gap is too narrow

The gap should be additionally ventilated. The additional ventilation occurs in the case if open gaps are left on the bottom and the top. They are spaced one meter. The all exterior wall is being performed as a connection the interior and exterior layer of brick which are combined with special anchors.

4.4.1.1 Thermal insulation from the inside

During matching suitable materials for these walls insulation, at the same time, achievement appropriate level of U-values should be taken into account, All requirements posed for residential buildings undergoing retrofit to the Polish climatic conditions have been specified in the documentation of the Polish Passivhaus Institut and Renewable Energy. The part of this document below describes requirements for exterior wall and floor storey down in contact with the outside air.

> „External insulation: U ≤ 0.150 W/(m² K) - the value for the Polish U ≤ 0.10 W/(m² K)
> The internal insulation: U ≤ 0.350 W/(m² K) - the value for the Polish U ≤ 0.20 W/(m² K)
> Thermal insulation of exterior walls must be applied to at least 75% of the external surface of the building. Internal insulation installed on 25% of the inner surface of the building is permitted only when external thermal insulation is not possible due to technical reasons, it is not permitted or it is clearly uneconomic. ." [27]

Due to the occurrence of a ventilation gap between the two layers of bricks, the best solution is the application in its place polyurethane foam, crylamin foam, granules of expanded polystyrene or granules of wool fibers. Foams are swelling materials and they are capable of adapt to the shape of the surface and accurately fill it after application. For the implementation of insulation, small holes are drilled in the wall. Their quantity depends on the construction of the wall. The material is supplied under the pressure, which ensures the granules reaching every corner in the walls of the air gap. This method ensures accurate filling voids and consequently effective insulation. After completion of insulation, the holes are stick down with using frost resistant glue. On the photo below (Fig. 4.27) application method of insulating material is shown.

Figure 4.27 Insufflation of insulation material.

Source: "Thermal insulation of buildings - cavity walls," INSULATOR - Thermal insulation of buildings, website: http://www.ocieplaniebudynkow.pl/docieplaniebudynkow.html

Lambda-values for the proposed materials to the fill the air gap:

- The granulate of expanded polystyrene - 0.043 W/(m·K)
- The granulate of cellulose wool - 0.042-0.037 W/(m·K) (Hydro - Clean)
- Polyurethane foam - 0.023 W/(m·K)
- Crylamin foam - the density of 50 kg/m^2 is about 0.045 W/(m·K)

The granulate expanded polystyrene is a popular material for the performance of thermal insulation. It is most commonly used to the thermal insulation of buildings – cavity and layered walls. This material is very light. Thanks to its structure tightly fills all the empty spaces. Its advantage is competitive price with high insulation properties. Insulation made with using granule of expanded polystyrene is durable and effective. Styrofoam, or expanded polystyrene, is composed of balls, each containing tens of thousands of closed cells filled with air (Fig. 4.28). In each cell, there is no possibility to air movement. As a result, this material has very good thermal insulation. The granulate of expanded polystyrene is in the form of loose granules. Application of the method of insufflation provides taking to every nook and cranny on the roof, cavity wall and other hard to reach places that require thermal modernization. Properties granulate of expanded polystyrene are: thermal insulation (low thermal conductivity), lifetime (resistance to aging), resistance to bacteria, biological and chemical resistance (rodents, fungi and insects) and the possibility of self-extinguishing.

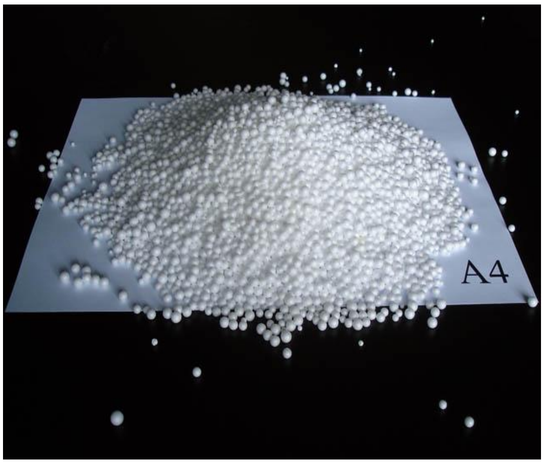


Figure 4.28 The granulate of styrofoam

Source: "Styrofoam the granulate" INSULATOR - Thermal insulation of buildings, website: http://www.ocieplaniebudynkow.pl/styropiangranulat.html

Worth recommending is thermal insulation material made of wool of the granulate of cellulose (Fig. 4.29). The beginnings of the use of impregnated cellulose date back to the First World War. Precursors of this method were engineers from the U.S. and Canada. They began in the period just before World War II industrial application of this technology. Then this technology was started to use in Scandinavian countries, and in the 80's was appreciated in the German

Figure 4.29 The granulate of cellulose

Source: "Retrofitting performed by insufflation of loose insulation materials", official website of HYDRO CLEAN: http://hydro-clean.pl/termomodernizacja.html construction industry. Cellulose can be used for buildings with different designs among others: concrete, ceramic, wood and skeletal. The granulate is insufflated with using specialized equipment for insufflation by dry method in vertical walls, that is - the material is blown in under pressure in closed bareness of the walls through the technical holes. In this case of roof surfaces. The material is insufflate on dry in the pocket of roof – they are formed between the rafters. In this way the material precisely fills these spaces.

Characteristics of insulation made of cellulose:

- continuity of insulation during installation of any thickness of insulation thanks to the method of insufflation.
- high protection against temperature fluctuations due to the fibrous structure, ie during winter insulation "heats", the summer "cool",
- It allows the diffusion of gases “ BREATHABLE "isolation,
- good protection against fire - flame retardant material,
- excellent thermal properties,
- It does not contain formaldehyde, it is completely safe for health and does not cause allergies, because it is formed from renewing itself raw material. It provides a quick drying when using moist wood. This allows for the resignation from chemical wood protection.
- Thanks to the use boron salts of cellulose impregnation, chemical wood protection is not necessary. The same situation occurs in the case of protection against insects and fungi.
- Protection against water condensation greatly reduces the cost of heating in winter and air conditioning costs in the summer. Besides this is a good acoustic insulator.

Cellulose insulation despite fluctuations in humidity and temperature outside, retains its insulating properties, until the moisture content of 12%. Coefficient of thermal conductivity λ for cellulose is 0,042-0,037 W/(m·K). The density of the material, depending on the application is an average of 25-64 kg/m3. The chart below (Chart 4.1)shows the change in the heat transfer coefficient U by example a different thicknesses of cellulose insulation. [28]

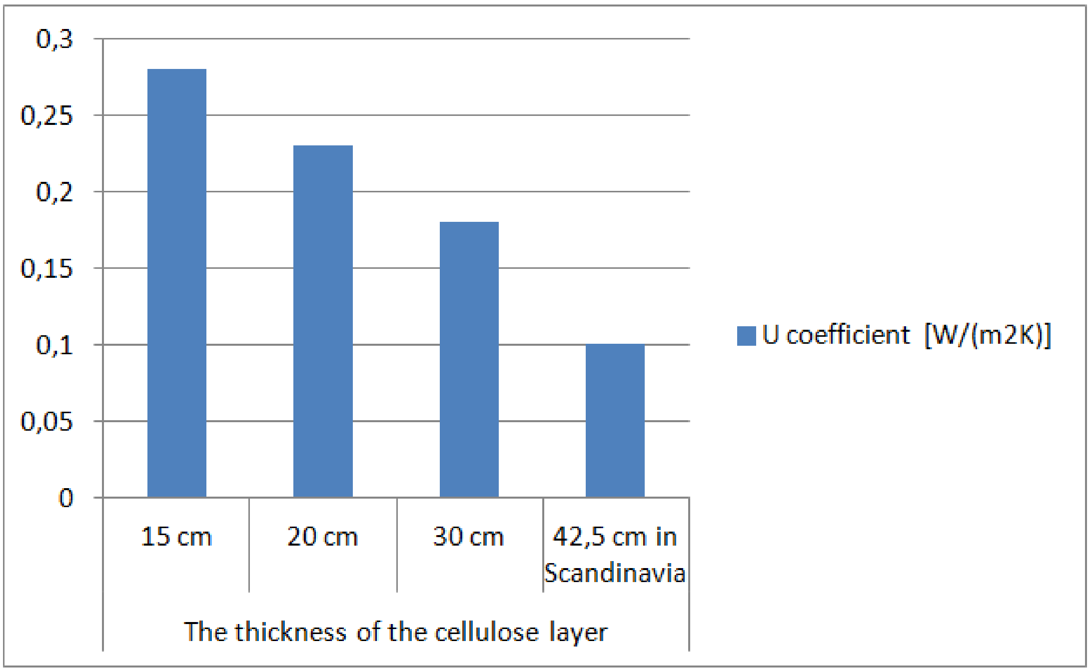


Chart 4.1 Value of heat transfer coefficient U for different thickness of cellulose layer.

Source: "Retrofitting performed by insufflation of loose insulation materials.", Official website of HYDRO CLEAN, http://hydro-clean.pl/termomodernizacja.html

The crylamin foam belongs to the group of urea materials. In addition to thermal insulation, its properties include sound absorption, low hygroscopicity, non-flammability and fire resistance. Apparent density of this material is 5-25 kg/m. Thermal conductivity varies from 0.026 to 0.038 W/m·K depending on the density and temperature.

On the other hand closed-cell rigid polyurethane foam as compared to other well known insulating materials, has the lowest coefficient of thermal conductivity. It reaches a value of 0,019-0,022 W/(m·K). A rigid foam layer with a thickness of 1 cm is equivalent to the insulation layer of 1.6 cm of expanded polystyrene, about 1.7 cm of crylamin, 1.8 cm of mineral wool and 6 cm of wood. This is a closed cell material. The content of these cells is about 95%. Polyurethane foam is formed by mixing two liquid components in a 1:1 ratio hereinafter abbreviated as MDI: polyol and isocyanate. Upon mixing, the reaction mixture is formed. Then the gassing process occurs. It takes about 10 seconds. Accordingly, mixture is froths (releasing heat) and hardens to give a hard, closed-cell structure. Applied by hydrodynamic , high-pressure spray with using a special gun. It creates a durable and resistant to external agents coating with excellent thermal and waterproofing. The components included in ingredients of this foam contain organic foaming agents, which do not destroy the earth's ozone layer. Polyurethane foam is a ecological and safe material. Foamed polyurethane is a compound physiologically inert. Closed cell polyurethane foam has a higher density compared with open cell foam. This density is in the range of 30 - 60 kg/m^3 and more. Open cell foam has a density in the range from 6 to 35 kg/m^3. Thermal conductivity of the closed cell polyurethane foam is in the range

0.018 - 0.028 W/(m·K). The crosslinked nature of the rigid foams makes them resistant to many organic solvents used in construction. Is not observed here the typical of expanded polystyrene effect of "disappearance" under the influence of lacquer solvents. Resistance to these substances allows the use of solvent-based adhesives to joining foam with linings (the preparation of sandwich panels) or a thermally insulated construction. Rigid polyurethane foam during the process of creating shows excellent adhesion to many construction materials such as sheet steel, wood, plasterboard, laminates made of unsaturated polyester resins and epoxy resins, etc. This property is used in manufacture of building panels in rigid cladding (metal sheet - foam - sheet) and flexible (foil - foam - foil). Application of this foam is low laborious. One team within 1 day can insulate around 1000 m2 of roof. An additional advantage of rigid polyurethane foam is relatively high permeability to water vapor in diffusion process. This allows to spray foam on incompletely dry substrate. [29]

So to sum up the most important characteristics of polyurethane foam are:

- the best commercially available thermal insulating material with high thermal resistance,
- homogeneous layer, without technological seams and joints with extremely high tightness,
- monolithic layer without thermal bridges,
- thermo and hydro-insulation during one the application process, obtained by closed cell structure provides gas-tight in cold and storage rooms
- very good adhesion to various surfaces,
- cohesive structure - does not slip and does not felting,
- limits the diffusion of water vapor and prevents moisture condensation
- durable and unscented, physiologically inert,
- applied to the wood does not cause rot,
- resistant to fungi, bacteria and insects that feed on wood,
- strengthens, stiffens and dampens frame constructions,
- resistant to high and low temperatures from -60 ° C to +130 ° C,
- has a certified hygienic and technical approval;

To fill the ventilation gap I decided in the first instance to adopt a polyurethane foam for the calculation. I justified this choice that this material has the best thermal conductivity - in the case of a building under consideration is one of the most important and critical factors. Made of polyurethane foam layer has a high tightness and eco-friendly foaming agent is used to its application.

To achieve U external walls of ≤ 0.20 W/(m^{2}K) (values for Polish conditions) and to reduce influence of thermal bridge, an additional layer of insulation is necessary. With the help of the passive House Planning Package counted that in the locations shown in figures 4.4.1.2, extra 15 cm of polyurethane foam should be applied. This can be done in two ways: with using plasterboards or wooden or aluminum shell. Walls made of plasterboards must be mounted at a distance of 15 centimeters from the surface to the inner surface of bricks. Then proceed to drill technical holes in these boards. Through these holes, a polyurethane foam should apply under pressure. However, to ensure the proper distance of 15 cm over the entire surface of the walls can bring big problems. On the other hand, the use of a material other than polyurethane foam insulation thickness increases, whilst also reducing cubic capacity of the room. But is the case of building considered it is unavoidable. What in regards to the whole building can significantly reduce the usable space.

Second way is using a wooden or aluminum shell. The first step is to install wood beams or aluminum profiles with appropriate thickness that after filling the space between them gave the expected polyurethane foam insulation layer thickness. The figure number 4.30-31 presents these steps.

Figure 4.30-31 Filling the space between profiles by polyurethane foam.

Source: http://www.poli-pur.pl/

After the application, the excess foam should be cutted with using a suitable device. The surface of the insulation, must be finished with lining of plasterboard.

Therefore, a good solution is to use ready-made solutions available in the market such as polyurethane panels with lining of plasterboards. This gives additional benefit of the surface, almost ready for painting, wallpapering, tiling and ceramic or adapted for mounting items. Unfortunately, this kind of insulation materials are available only with thickness around 100 mm.

The figures below (Fig. 4..32) show the part of the wall (before and after) which was performed as described above insulation in two layers (wall thickness of 45 cm - see figure 4.24 and 4.25 throw the walls of the ground and first floor, divided into different wall thickness).

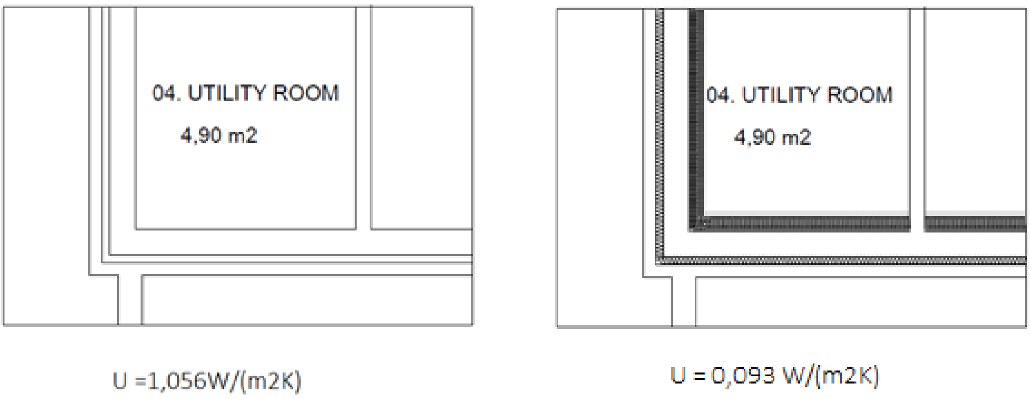


Figure 4.32 Part plan of corner of north and east exterior wall before (on the left) and after (on the right) termomodernization.

In the building there are places where the exterior wall differs in construction. In some places in the cavity walls, window openings are bricked up by the previous owners. Drawing and photograph below show these places (Fig. 4.33-34). The problem in the wall consisted in the fact that a bricked up window opening exists in a place of the eight-centimeter air gap and layer of bricks with a thickness of 12 centimeters. This change in layer arrangement and no air gap worsened U-value of the wall (in its original form - without insulation) of 0.481 W/(m^{2}K). This change is due to the fact that air has some insulating properties. Thermal conductivity of air is ʎ = 0.270 W/(m·K).

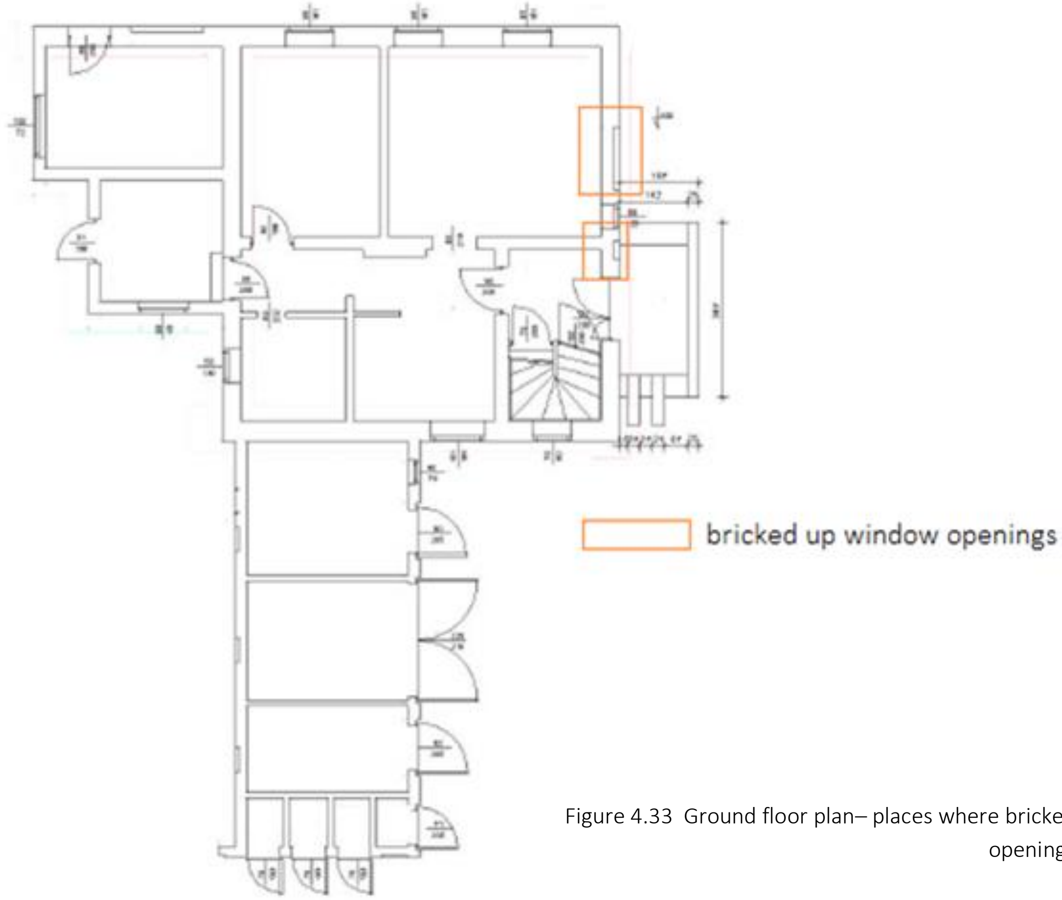


Figure 4.33 Ground floor plan– places where bricked up window openings are placed.

Figure 4.34 Building facade - bricked up window openings.

Assumed wall insulation from the inside has thickness of 15 cm. This insulation is proper in this places as well. The same thickness was used on the whole surface of this wall on ground floor. Although on other places it is not necessary. Figure 4.35 shows the wall before and after thermo-modernization.

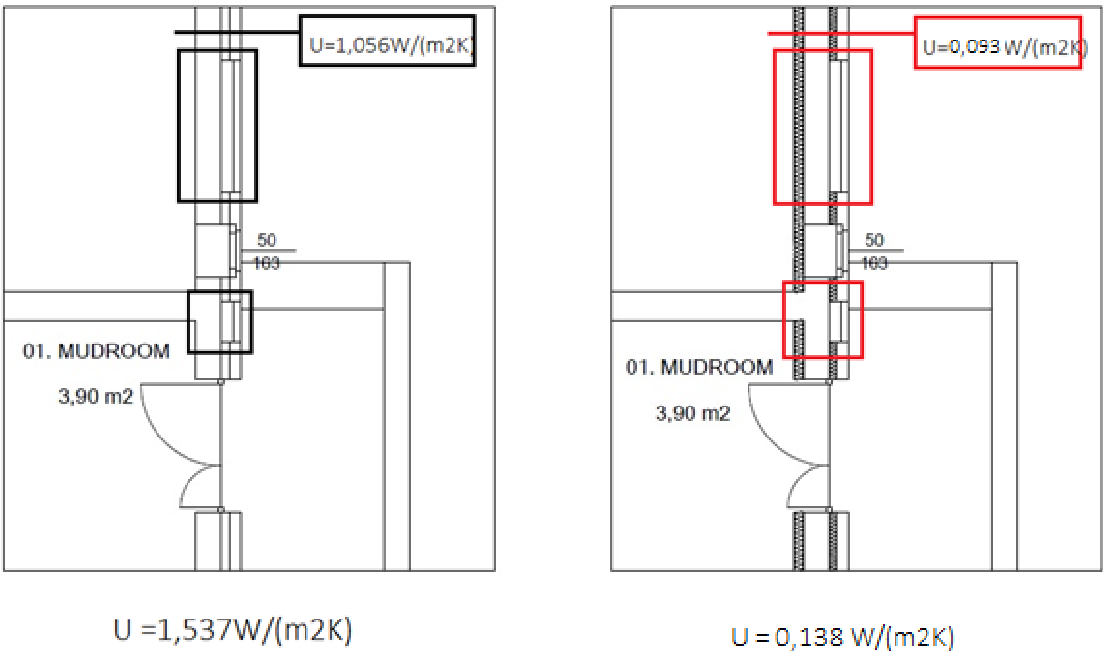


Figure 4.35 Part plan of west exterior wall before (on the left) and after (on the right) termomodernisation.

The third type of exterior wall is single-layered wall. It consists of a 25 cm thick layer of brick (Fig. 4.36-37). U coefficient has reached the required level of less than 0.2 $W/(m^2K)$ the best solution is 12 centimeter isolation from the inside also using polyurethane foam. Here also, by analogy adopted board EUROTHANE G. The assumption a 10 centimeter insulation results in exceeding value of 0.2 for the U-coefficient. Figure (Fig. 4.38) below show this wall after modernization.

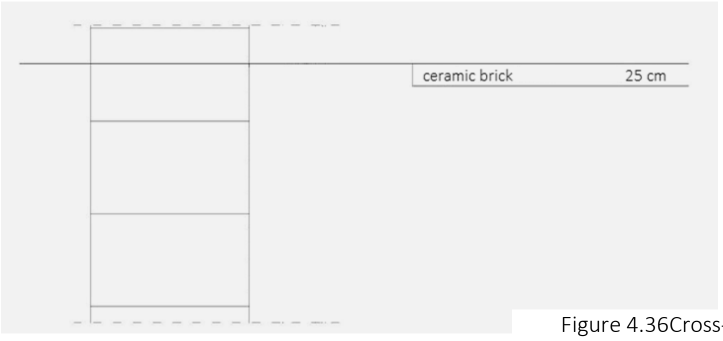
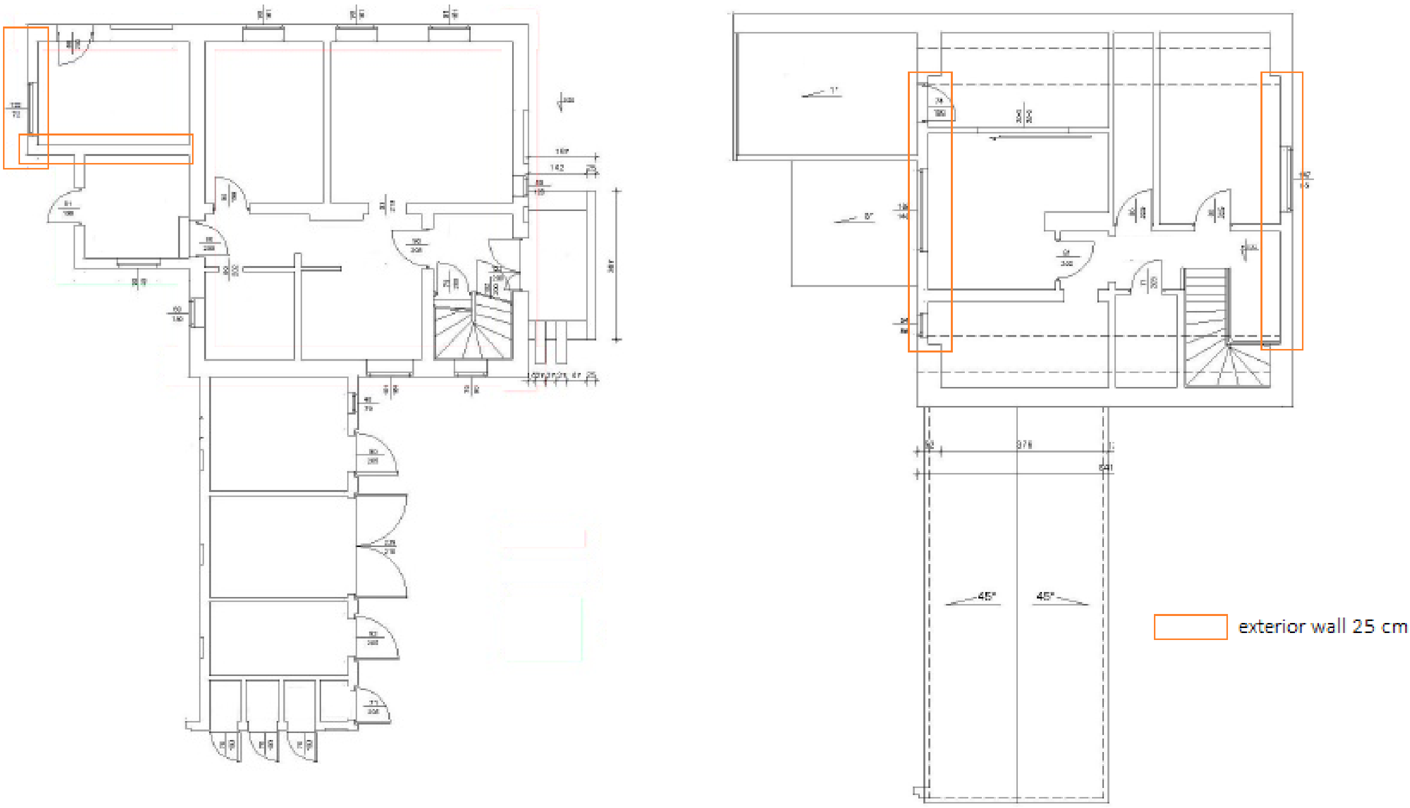


Figure 4.36Cross-section o f brick wall with thickness of 25 cm



4.37 Location of single-layered walls in the building on the ground floor (on the left) and first floor (on the right

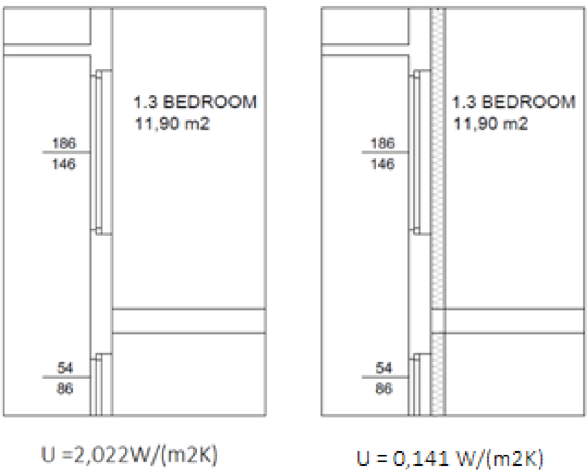


Figure 4.38 A single-layered wall after modernization

The last elements to be included in the calculation are the decorative elements of the facade. We are talking about concrete finishing space between the arc lintels and the upper edge of the windows or doors. Photo (Fig. 4.39) shows exactly which elements are taken into account. However, there was no need to change the thickness of the insulation in these places. In PHPP program has been defined only concrete layer with respective thicknesses which correspond to the actual state.

Figure 4.39 Decorative elements of the façade.
Source: Own

The necessary elements that need to be taken into account in the calculations are all kinds of reinforced beams in the wall like a the lintels or ring beams. In the analyzed building, ring beam is placed along the wall of axis A 0.2-4 and D-4 of 0.2. It provides a at the same time support for wall plate. At this place the same insulation as in the whole wall has been applied. There was no need to increase the thickness of the insulation. Heat transfer coefficient after appropriate insulate reached a value of 0,095W/(m^{2}K). Drawings below show change of U-value after modernization (Fig 4.40)

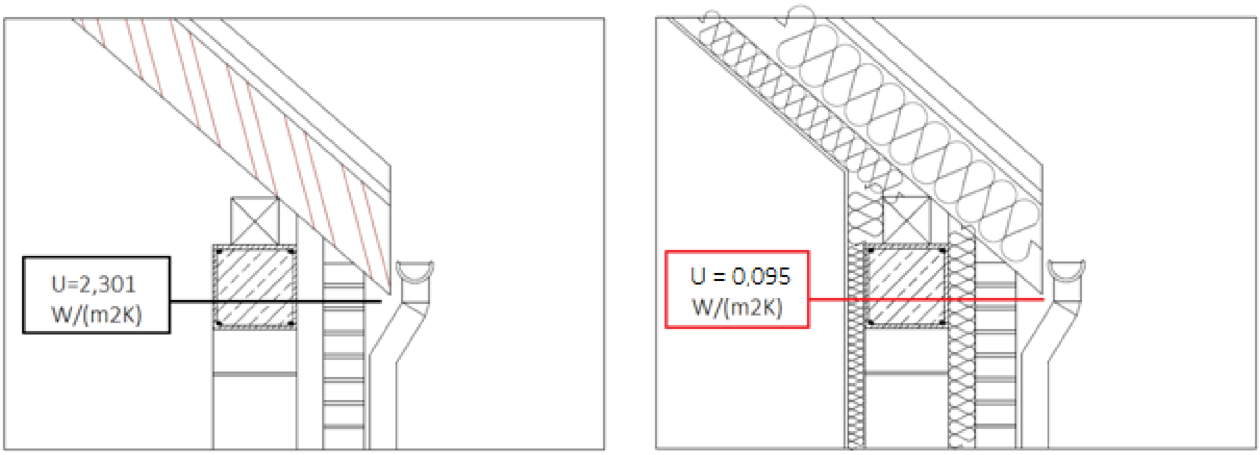
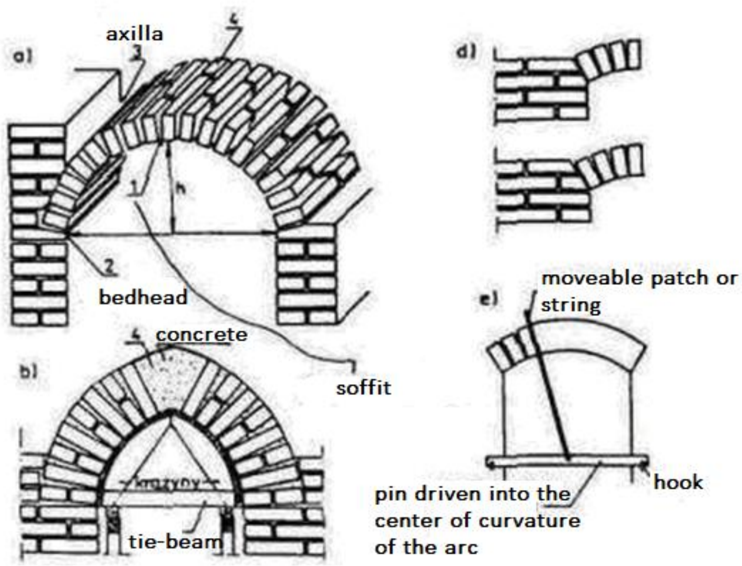


Figure 4.40. Cross section at the place of backrest wall plate on the ting beam.

To achieve the best results for the calculation of demand for energy retrofit buildings should take care of the details. Therefore the issue of lintels above openings in the wall cannot be ignored. In a modern construction industry can meet several ways to overlap window and door openings. As a rule, they are made of lintel beam elements. Depending on the construction of the building - traditional (brick) or prefabricated (industrialized) - lintel may occur as a short beam, designed exclusively for overlaping the hole in the wall, or as a continuous coronary beam stiffening building in horizontal and lateral plane. It plays a role of lintels on those sections where it runs above openings. Lintel of window and door openings in brick walls present in the following varieties: brick flat with reinforced joints, with I-shaped steel girders, filled with brick, concrete made on wet and reinforced precast concrete (L19).

Figure 4.41 Lintels in considered building
Source: Own

From the point of view of geometry, brick lintels can generally be divided into flat and curved. Among the flat lintels distinguish between two types due to way of arranging of bricks. The first is the lintel elements arranged horizontally. Emphasizing the lintels and separate them from the rest of brick wall arrangement – this is a second kind of lintels. That is lintel made of bricks arranged vertically. Arched lintels can be divided into full (semicircle shaped), segmental (arc constitutes any part of the district - smaller than a semicircle), and pointed arch. (Fig. 4.42) These latter is used in contemporary architecture extremely rare and normally they are reserved for sacred architecture. This is probably due a very strong association of this element with Gothic architecture. In general, arched lintels forms reminiscent of historic architectural styles - gothic whether with aforementioned pointed arches, roman architecture, romanesque and renaissance arches in the case of full or bourgeois architecture of the nineteenth century, for which such a segmental lintels were characteristic. [30]



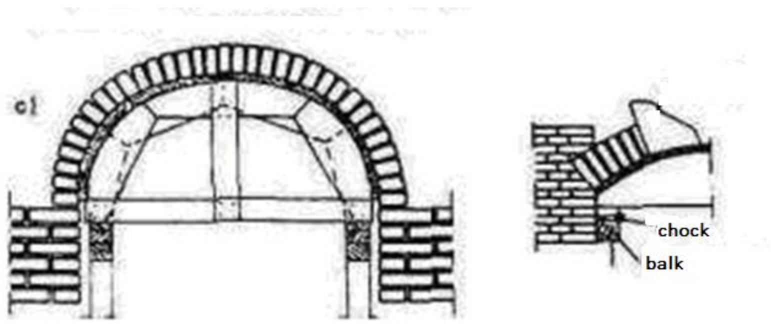


Figure 4.42 Types of arch lintels: a. - segments, b. – pointed arch, c - basket, d - method for battress bricks of arch, e. - verify the position of bricks in the arch, 1 - soffit, 2 - bedhead, 3 -axilla,
Source: R. Nowak, R. Orłowicz, "Failure mechanisms of brick arc lintels", XIII Scientific - Technical Conference REMO, Wrocław 2009.

If arch lintel is made of brick, the connection chocking is obtained by thickening of the upper part of the joints between the bricks. Brick lintels are used depending on the span of the opening. In a single family home they are used to span 2.25 m with brick lintels achieved a uniform look whole brick wall. In the case of the analyzed building, we have to deal with pointed-arch lintels. Because they are made of the same material as the wall-brick, it is not necessary to define them separately.

4.4.2 The pitched roof

The roof of the building analyzed is a gable roof (Fig. 4.43). I have not received the documentation which would include informations about original material of roof insulation. It can be supposed that it is a reed placed between the rafters. In Poland in the prewar or war years were used only natural materials such as reed. Layout of the original aqueous layer is shown in figure 4.44.

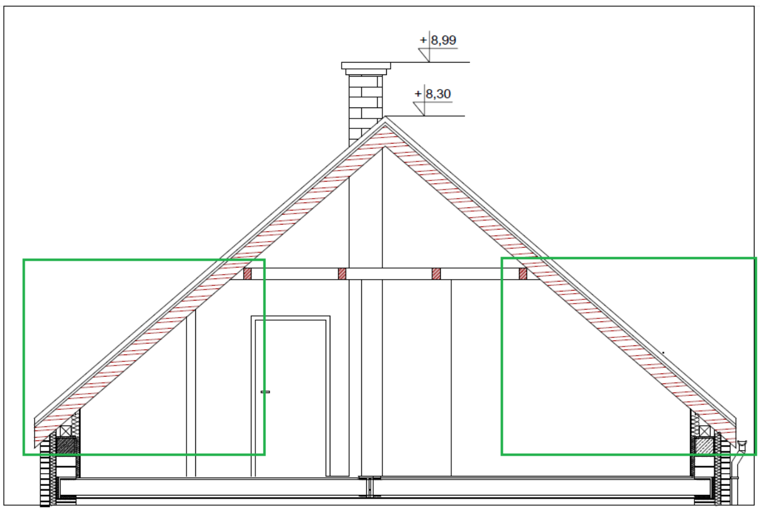


Figure 4.43 . Cross-section of gable roof in the building

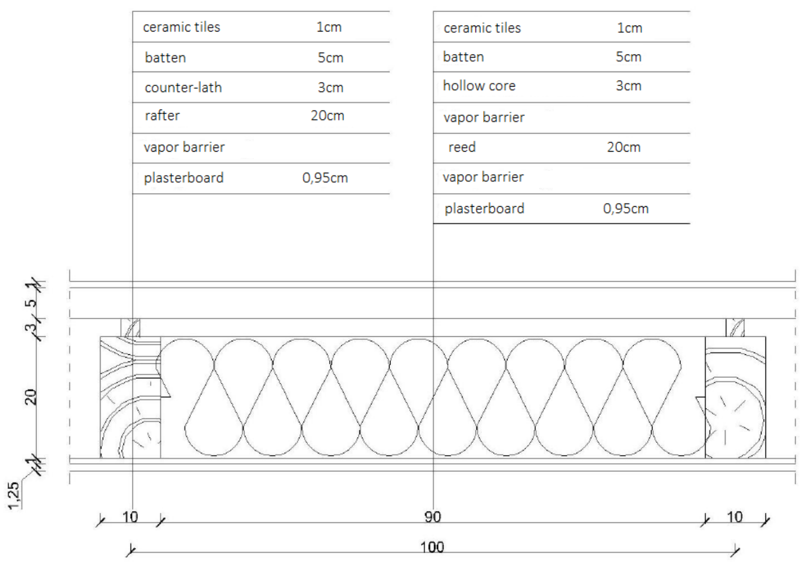


Figure 4.44. Arrangement of layers on the pitched roof In the building

The insulation properties of reed

The roof insulation perhaps has been completely made of reed, which has a very high thermal insulation properties. It is a kind of thermos. In the winter it keeps the heat and in the summer gives coolness. In connection with this isolation reed in the last century has been felicitous and solutions which giving lots of benefits. Water reed is characterized by a very high thermal insulation. According to Western studies the heat transfer coefficient U layer of reed is at a level 0.35 W/m2K. The roof of reed with a thickness of 30 cm corresponds to 100mm mineral wool insulation laid under the traditional roofing. [31]

Here should be emphasized that natural materials such as straw or reed have comparatively very low thermal conductivity coefficient of any known insulating materials. This is possible because stem is filled by air, which has one of the smallest heat conductivity coefficient $\lambda = 0.024$ W/m·K. For comparison, this coefficient for ceramic brick is equal 0.8 W/mK which is 33 times higher, for concrete 1.5 - 1.7 W/m·K (62-71 times), for copper sheet this coefficient is on the level of 400 W/m·K, i.e. until 16 666 times. more. [32]

A solution that has been proposed by me involves removing layers of reeds, and in its place performance 20 cm layer of polyurethane foam insulation by spraying it under the pressure. In addition, the extra layer of insulation is necessary to meet the requirements relating to the value of thermal conductivity for the roof according to the 2.3 point of "Requirements posed residential buildings undergoing retrofit the Polish climatic conditions developed by the Polish Institute of Passive and Renewable Energy, namely:

"$U \leq 0.12$ W / (m² K) - for Polish conditions $U \leq 0.09$ W / (m² K)" [27]

It was necessary to add another layer of 10 cm of polyurethane foam insulation. Because of the thickness of this layer spraying a appropriate foam layer would be laborious. Therefore, for implementation this additional insulation the material worthy of command is as EUROTHANE G of manufacturer Recticel. Technical Data Sheet of this product is attached to the end of the paper in the Annex 3.3. According to the manufacturer in the technical documentation EUROTHANE G is free of chlorofluorocarbons. These are hard polyurethane panels, single coated of plasterboard. Between the layer of polyurethane and plaster there is a layer a vapor barrier. With this solution, you can avoid the laborious performing of three separate layers - insulation, vapor barrier and sheathing of plasterboard. Disappears also the risk of error during the work and significantly reduces material consumption. Their thermal conductivity lambda (λ) is perfect and is only 0.023 W/(m·K) - for mineral wool and polystyrene can be considered as very good thermal insulation, the ratio is about 0.04 W/(m K). The boards EUROTHANE G have been adopted. The figure 4.45-47 below shows the designed arrangement of the layers in the PHPP. Thermal conductivity coefficient U reached 0.088 W/(m2K), and he has reached the required value.

Assembly No. 3 | Building assembly description: Roof | Interior insulation?

Heat transfer resistance [m²K/W]: interior Rsi: 0,10; exterior Rse: 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.	Batten	0,160					50
2.	Hollow core	0,270			Counter-lath	0,160	30
3.	Polystyrene Foam	0,023	Rafter	0,160			200
4.	Polystyrene Foam	0,023					100
5.	Plasterboard	0,160					10
6.							
7.							
8.							
			Percentage of Sec. 2	10,0%	Percentage of Sec. 3	3,0%	Total 39,0 cm

U-Value: 0,088 W/(m²K)

Figure 4.45 New arrangement of roof layers

Source: Screenshot from U-values worksheet - PHPP

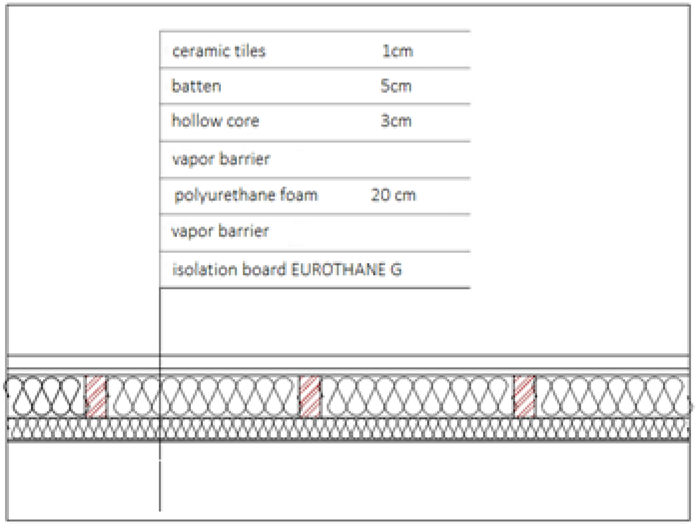
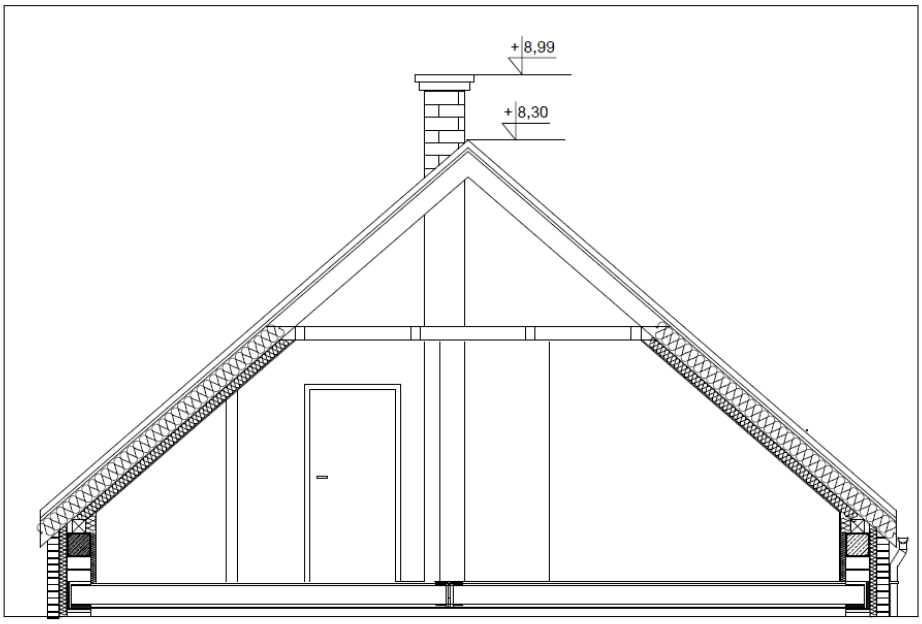


Figure 4.46 New layers of roof – cross section



U =0,088 W/(m2K)

Figure 4.47 Gamble roof of the building after modernization

4.4.2.1 The adopted solutions and materials

Polyurethane foam

The seamless shell made of rigid polyurethane foam seals and insulates very well surfaces which are covered. In order to protect against solar radiation rigid polyurethane foam is covered with a suitable protective coating. Is irreplaceable method in the performance of the insulation of flat roofs and all elements of small architecture of this type of structures (fireplaces, walls, etc.). The injection density of about 60 kg/m^3 foam causes the roof covering is made very light.

One square meter of roof insulated polyurethane foam weighs about 2.5 kg. Mechanical strength of material is sufficient to keep a roof conservation treatments. During the thermal renovation of the old roof should not make special preparations - it is enough thoroughly clean the roof and make the necessary flashings. Much better is spraying foam on the existing roof than to attach to the roof structure expanded polystyrene or mineral wool and an additional layer of roofing felt. Because of it, that by its application by spraying it adheres perfectly to the hard to reach places for other insulating materials. The reason for this is the expansion (increase the volume), and creating a uniform joint it practically it eliminates the possibility of appearance of thermal bridges. Isolation of the polyurethane foam (PU foam) to minimize air infiltration which can lead to condensation or condensation. Just 20 mm thick layer of spray polyurethane foam is able to eliminate condensation or water condensation, which can lead to growth of mold and fungi. Disregard fungi and molds can expose the wood to rotting. Figure 4.48 below shows spraying layer of foam between rafters. [32]

Figure 4.48 Spraying of polyurethane foam between the structural elements of the roof

Source: http://forum.muratordom.pl

EUROTHANE G boards

As it was mentioned earlier boards EUROTHANE G are quicker solution. These boards can also be fixed against the inner side of a sloping roof. But wooden slats must be used for this. In the case of the attachment to the inner side of a sloping roof a trellis must be provided to support the EUROTHANE G boards. This trellis must be attached as flat as possible to the wooden structure of the roof truss. The EUROTHANE G boards are also attached to these trellis with screws. Figure 4.48 below presents how arrangement of layers with using these boards looks like.

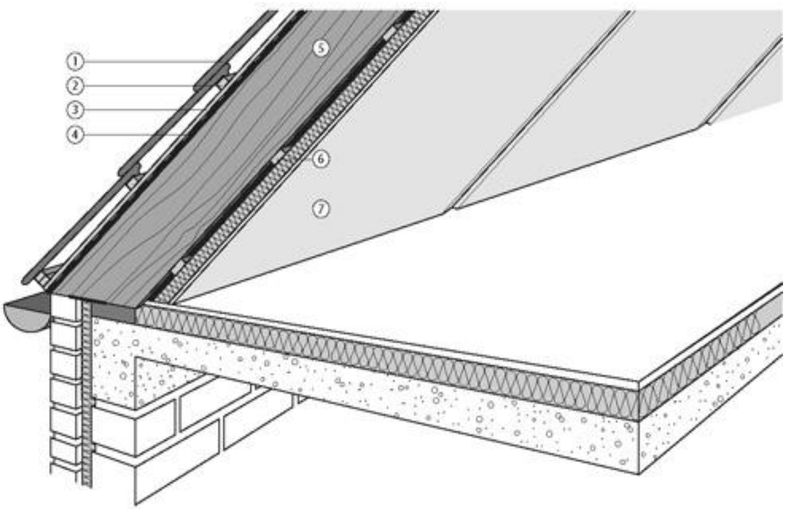


Figure 4.49 Arrangement of roof layers

1.Roof covering
2. Batten
3. Batten strip
4. Roof underlay foil
5. Truss
6. Wooden trellis
7. EUROTHANE G board

Source: Internal roof insulation, official website Recticel Company http://www.recticelinsulation.be

4.4.3 The floor above first floor

Above the usable attic there is wooden floor. This is the so-called naked wooden floor. From top covered with wooden boards. The figure 4.50 below shows the element that will now be considered (surrounded by a green frame).

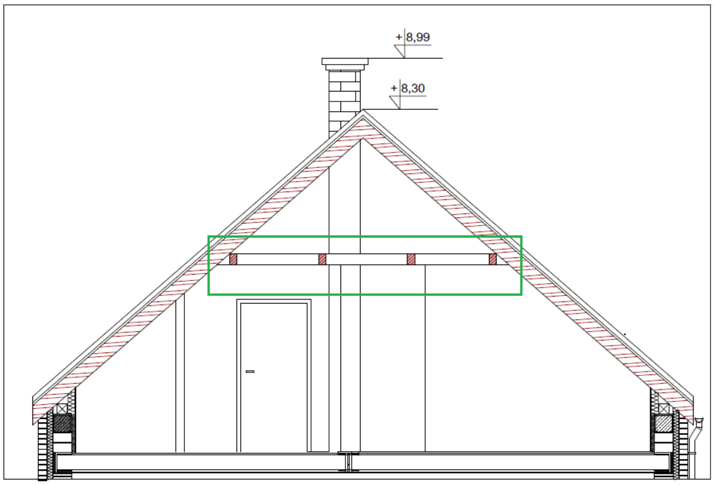


Figure 4.50 The cross section of firs floor.

The solution that has been proposed involves spraying of polyurethane foam with a total thickness of 30 cm. This layer of insulation fulfills the condition relating to the value of thermal conductivity for the last floor according to. the 2.3 "Requirements posed residential buildings undergoing retrofit for Polish climatic conditions developed by the Polish Institute of Passive and Renewable Energy:

"U ≤ 0.12 W / (m² K) - for Polish conditions U ≤ 0.09 W / (m² K)" [5]

One method of how layer of insulation like this can be performed is to first create a "form" to later fill it with foam. This can be done by mounting the plasterboard for example with a thickness of 12.5 mm from the top and bottom (Fig. 4.50). Then, technical holes must be drilled in the bottom plate. Through these holes the pressurized foam is injected. Due to the fact that its volume is increasing rapidly, it fills the whole space of "form". With this method, the surface prepared for painting from the bottom is made at the same time.

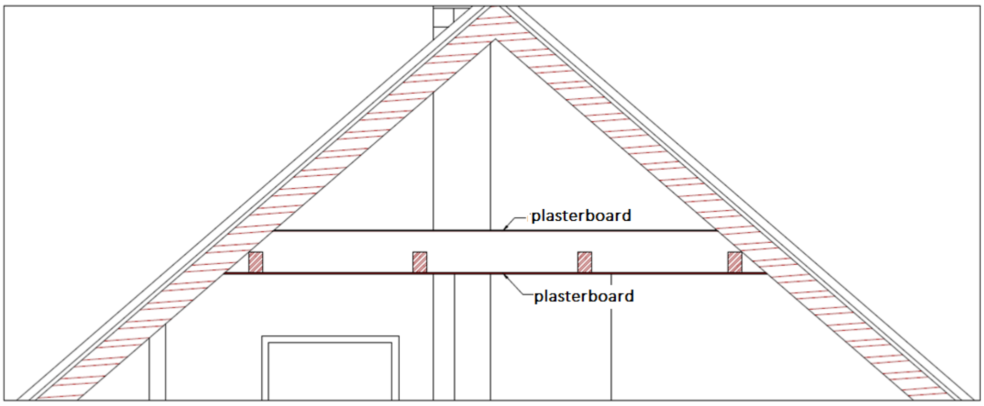


Figure 4.51Preparing special form for fulfilling by foam.

In case of application another material than polyurethane foam it is at the same time necessary to increase the thickness and weight of the insulation layer. In case of using expanded polystyrene or rockwool with a coefficient λ about 0.042 W/(mK), the thickness of layer required would achieve 500 mm. Thus, application of polyurethane foam at this point is justified.

4.4.4 The floor above basement

The each action during the modernization of the historic building should include identification of its nature, age and technological engineering solutions. A conservation protection should also be subjected to construction solutions. This analysis is especially difficult in the case of flat floors. The similarity in assumptions and ignorance of historical materials and technology can lead to wrong conclusions. Both as regards the originality and authenticity of the solutions, and as a consequence lead to adverse reactions from conservation point of view. Commonly there is a perception that in the past people used only the simplest materials and technology. However, in the light of contemporary theory of conservation, as protection of monuments or buildings are treated also from the first half the XX century, and in part even post-war buildings. This considered building was built probably in the early twentieth century. It is a period in which the buildings were erected very intensively with using majority of solutions and materials which are also used today. This means that in the maintenance process should take into account the possibility or the need to maintain eventually recreate these technical solutions used today. The modernized building, the basement there is a basement ceiling brick supported on the steel girders (Fig. 4.52)

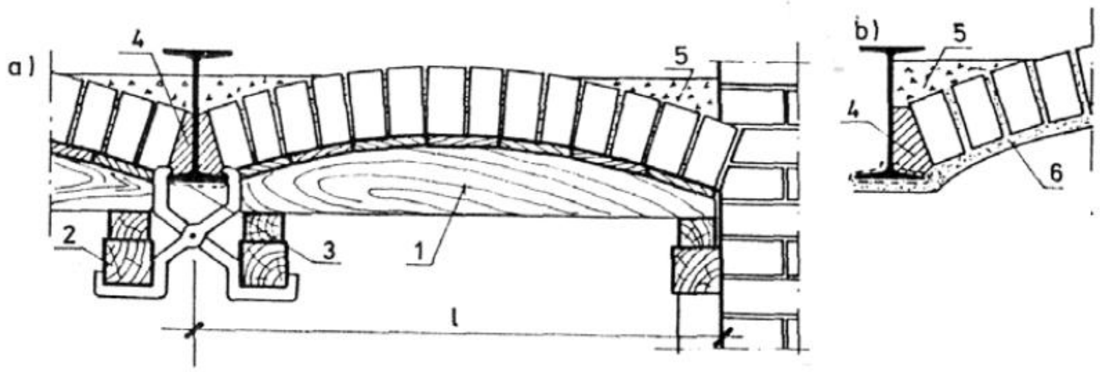


Fig. 4.52 Cross sections of segment floor: a) during execution, b) detail of the groin, c) tie rods connecting the steel beams. 1 - cradling, 2 - balk 12 x 12 cm (suspended on a steel scissor keeper), 3 - mesh, 4 - concrete, 5 - rubble, 6 -, plaster, 7 - tie stee

Source: "Floors on steel beams" Agnieszka Kulczycka, page 23 "Project co-financed by the European Social Fund", Department of Metal Structures Technical University of Wroclaw, official website: www.metale.pwr.wroc.pl

The segment floor in the previous century had a wide range of application. Thus, they are often identified during maintenance work on historic buildings. The I-steel beams are anchored in load-bearing walls. Between them there is arched ceiling, which was made of solid or porous ceramic bricks.[33]

The slabs of this type on steel beams have been widely used for the forties of the last century in Poland. Currently, this solution design is rarely used. Only this type of floors can be found in the modernization and reconstruction of buildings. [34]
In the current state of this floor in the building looks from the outside as it is shown on the photograph below. (Fig. 4.53)

Figure 4.53 Floor above the basement.
Source: Own

The basement in the considered building will be located in an unheated area. Thus, the floor must be appropriately insulated. For the Polish climatic conditions, the heat transfer coefficient for unheated basement floor must be less than or equal to 0.12 W/(m²K). [27]

The first issue you need to consider is where to put the best warming. From the bottom we have to deal with vaulted ceiling shape, and also materials such as wool or polystyrene are not suitable for a tight insulation. Next, you need to ask ourselves whether it is worthwhile to cover the curved shapes layer warming? Therefore, the amount of space of the ground floor is not sufficient to place the whole on top of the roof insulation. Curved shape also makes the correct definition of the layers in this type of ceiling the problem. Because of this, two cross sections have been defined in the PHHP. One was carried out by a cross-section through the center of the arc and the second one by a steel I-beam in the groin (Fig. 4.54). The layers are defined respectively for each section are shown below. (Fig. 4.55-56).

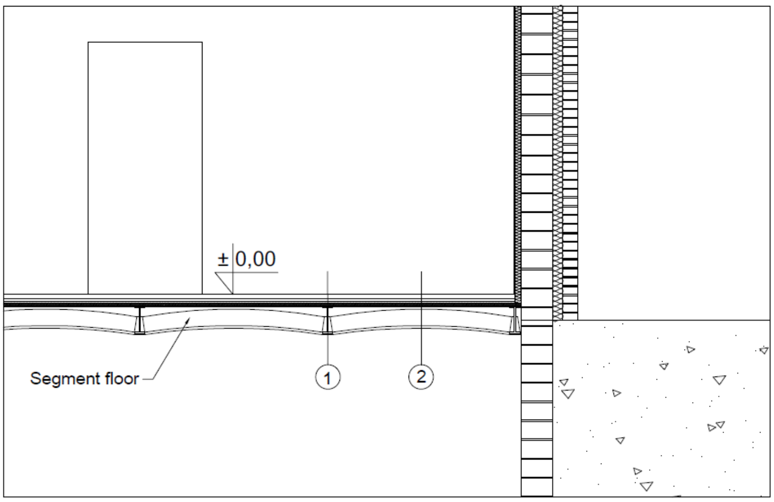


Figure 4.54 Defined sections in PHPP

Assembly No.	Building assembly description					Interior insulation?
4	Floor under residential part of the building (with basement) - cross-section of bricks					

Heat transfer resistance [m²K/W]	
interior Rsi :	0,17
exterior R_{se} :	0,10

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Wooden boards	0,160					32
2.	Self-leveling Screed	1,700					25
3.	Base screed	1,700					50
4.	Polystyrene Foam	0,023					250
5.	Concrete Screed	1,700					100
6.	Brick	0,770					130
7.	polystyrene Foam	0,023					100
8.							
			Percentage of Sec. 2		Percentage of Sec. 3		Total 68,7 cm

U-Value: 0,063 W/(m²K)

Figure 4.55 First section – center of the arc

Source: Screenshot of U-values worksheet – PHPP

Assembly No.	Building assembly description					Interior insulation?
5	Floor under residential part of the building (with basement) - cross-section of I-beam					

Heat transfer resistance [m²K/W]	
interior Rsi :	0,17
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.	Wooden boards	0,160					32
2.	Self-leveling Screed	1,700					25
3.	Base screed	1,700					50
4.	Polystyrene Foam	0,023					250
5.	Concrete Screed	1,700					100
6.	steel I-beam 180	50,000					200
7.	polystyrene Foam	0,023					100
8.							
			Percentage of Sec. 2		Percentage of Sec. 3		Total 75,7 cm

U-Value: 0,064 W/(m²K)

Figure 4.56 Second section – center of steel I-beam.

Source: Screenshot of U-values worksheet - PHPP

Polyurethane foam insulation layer has been used for the calculations, because the smallest thermal conductivity Λ is necessary here. For the foam this value is at the level 0.023 W/(m·K). However, the layer is required as many as 18 cm to the U-value was less than 0.12 W/(m^{2}K). One way to achieve this insulation type is spraying foam under the pressure or using polyurethane insulation boards. Here I can suggest a solution from the same manufacturer, which have been proposed for the walls. They are called EUROFLOOR. These are hard boards made of the foam PIR and claddings vapor laminate. Boards are also free of freons. Lining consists of kraft paper and aluminum foil. They are produced in thicknesses from 20 to 120 mm. To achieve the thickness used in the calculation should be connect the two thickness of these boards. Below is the proposed solution manufacturer Recticel (Fig. 4.57). [35]

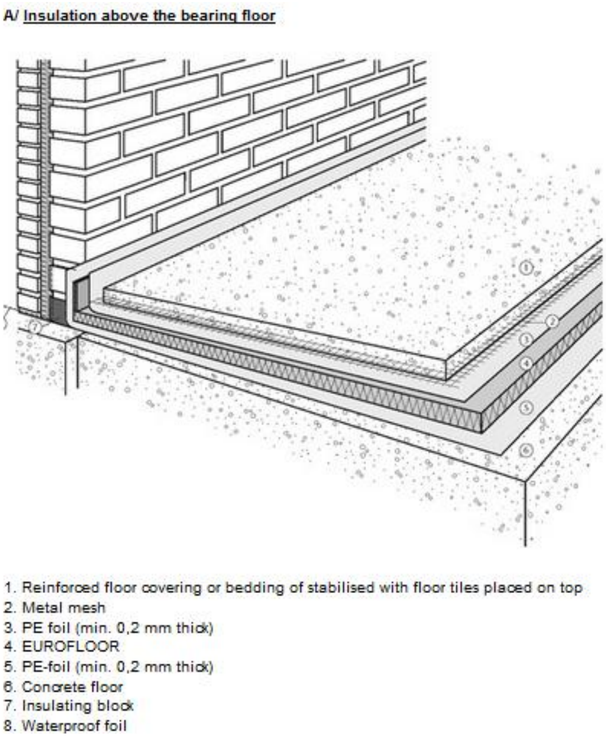


Figure 4.57 Insulation of floor above the basement

Source: Technical data sheet Eurofloor, website Recticel Insulation company: http://www.recticelinsulation.be

Designed insulation greatly improved insulating properties of the floor. But due to influence of thermal bridges it was necessary to design extra layer of insulation. In connection of exterior wall and floor of the basement, as well as interior wall and floor of the basement. All of crucial connections have been described in following part about thermal bridges. The drawings below represent the situation before (Fig 4.58)and after (Fig 4.59) thermomodernisation.

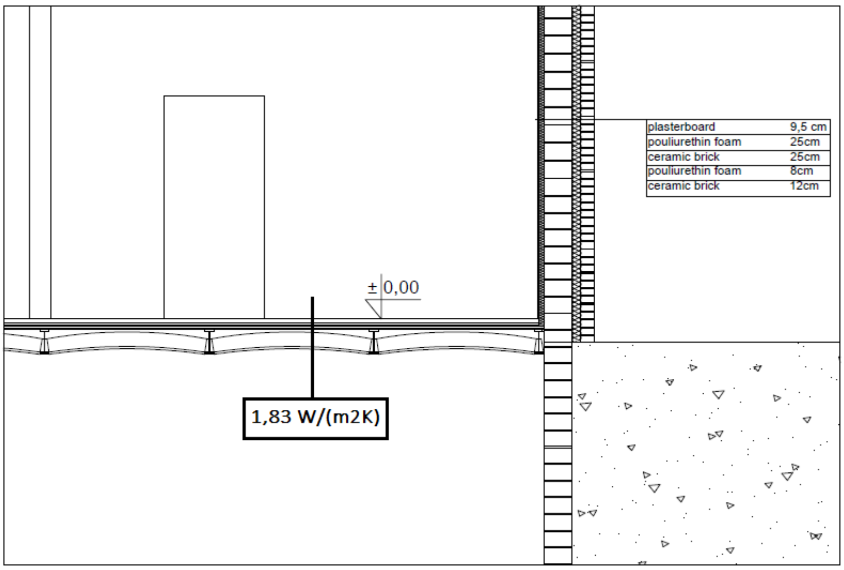


Figure 4.58 Floor above basement before modernization

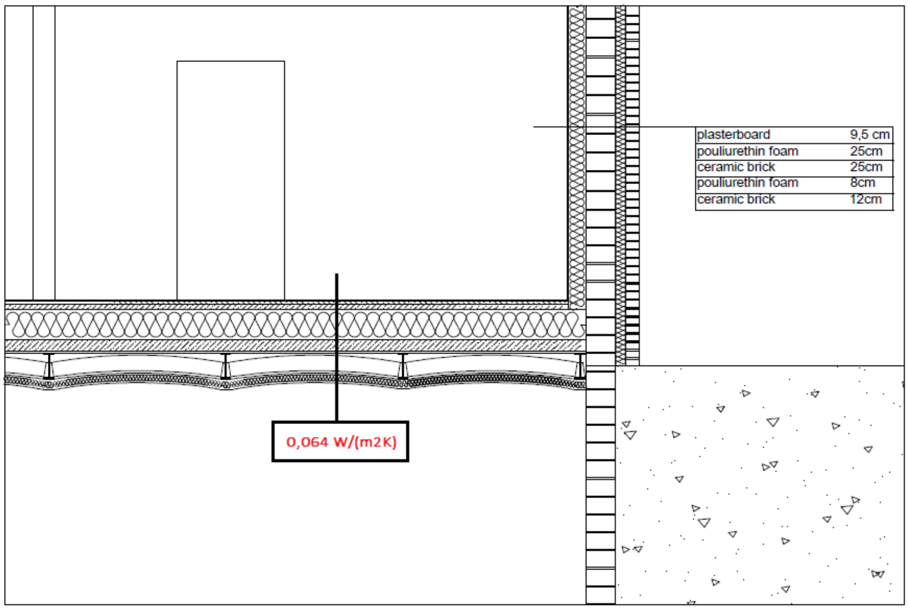


Figure 4.59 Floor above basement after modernization

4.4.5 Horizontal damp insulation in the historical building.

During execution the renovation works can often be faced with a situation of moisture the lower parts of the building. This is due to the fact that old buildings do not have a damp-proof course or the old insulation has lost its protective properties. To perform a robust insulation shall primarily be remove moisture and fungus from the walls, which caused by rainwater and groundwater. It is necessary to performing secondary horizontal insulation commonly called horizontal or hydrophobic membrane. Most often refers to a very old houses, in which the horizontal damp-proof course has been destroyed or never have been made. To reduce the risk of damage to the house structure it is necessary to re-execution of this insulation.

The construction work, which the end result will be stopping penetration of moisture into the structure of the walls, which is a difficult and laborious process. This task requiring the contractor with a large knowledge and experience. Before starting the repair works in damp basement rooms, technical condition assessment of the building should be made. In one of the previous chapters reasons of mechanical destruction such as crack on the walls have been described. Determine the condition and causes of potential moisture can be investigated by a thorough analysis of the problems observed during an inspection. Only after defining the causes of moisture can make decisions how to conduct repair work. In particular this concerns on performing a vertical and horizontal insulation of basement walls, dry and antifungal treatment of entire building. The next step is to perform surrounding drainage around the building. . This will lead to appropriate ventilation of basement rooms and carry reprofiling declines of land surrounding the building. An extremely important element of the renovation is the use of appropriate materials.

Ranging from renovation plastering , which are intended for application to saline substrates through joint mortars, sealants to fill cavities in brick to the preparations for waterproofing surfaces. Described range renovation work, which has been described above is illustrated in figure 4.60, which has been described as an example of brick and stone wall.

The task of secondary horizontal insulation is to create a layer inside the wall, which prevents capillary moisture transport and cut off the possibility of penetration of moisture in parts of the wall located above the horizontal barrier. The most common method of implementation of horizontal insulation in existing walls is a method of mechanical and chemical injections.

1. Cement mortar
2. Bituminous seal coat
3. Extruded polystyrene
4. Screed concrete
5. Bituminous seal coat
6. Extruded polystyrene
7. Cement screed
8. Horizontal barriers
9. Mortar for voids in the stone
10. Joint mortar
11. Renovation plastering

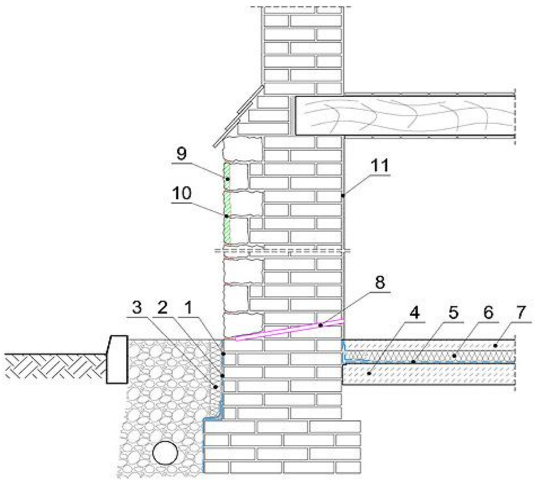


Figure 4.60. Example of renovation works of brick-stone wall
Source: http://www.renowacjeizabytki.pl

Making new vertical insulation in the existing home is relatively easy because it is done on the walls. In contrast, reconstruction horizontal insulation is difficult, because it requires interference with the construction of the walls. Mechanical methods generally rely on the incorporation of the structure of the wall a thin layer of material, which crosses the capillary action. The most effective and most commonly used are mechanical methods: segmental undercutting the walls after which the insulating layer is inserted in the slot. It should be mentioned materials such as bitumen sheeting, films and laminates, plastic and stainless steel sheets. Another way is driving steel, chrome-nickel corrugated sheets into the wall.

In the first method the wall is undercut by segments with length of 1-1.5 m with using electric saw (Fig. 4.61). After cutting the slots with a thickness of 14 mm, it is blown by compressed air, for example with using a reciprocating compressor. Then, the insulating material is tightly applied. However, there is

Figure 4.61 Propelled Platform electric saw used to walls undercut
Source: article „New insulations in old buildings", website; HW Pantienter System : http://www.hwizolan.republika.pl

a large interference in the construction of the walls. More recommended method is driving sheets into the wall.

Chemical injections rely on leading of chemicals in the structure of the building material. This substance vaulting capillary or giving hydrophobic properties of capillary surfaces. Thanks to this, capillary transport of water in the higher parts of the building is prevented. The Frequently applied chemicals resulting in vaulting of capillaries are produced on the basis of silicates while chemicals used for waterproofing are made based on silicone or siloxane microemulsion. The illustration below gives an example of the application of such preparation (Fig. 4.62).

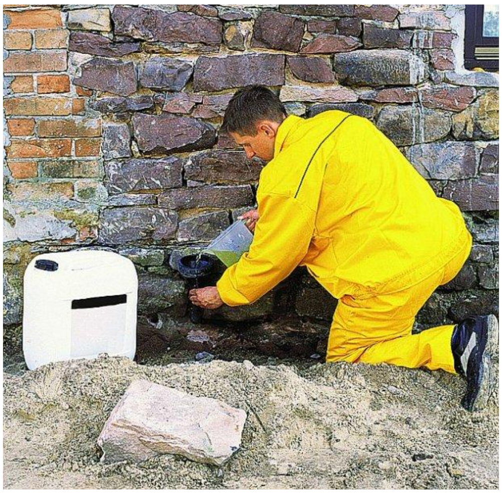


Figure 4.62 Example of the application of preparation
Source: *article „New insulations in old buildings", website; HW Pantienter System : http://www.hwizolan.republika.pl*

Before the performing chemical injection, contractors usually make quick measurements of moisture in the wall with using electronic gauges. These devices allow only to determination the content of moisture in wall mass. The implementation of effective horizontal insulation by chemical injection requires investigation of an additional parameter known as capillary degree of moisture soak. Knowledge of this degree allows to select a suitable chemical preparation of the, as well as methods of its injection. At the chosen method of injection may also affect the type of material of which the wall was bricked up, the technical condition of the baffle, its homogeneity, the occurrence of scratches, cracks, voids, as well as multi-layered structure of the wall.

4.5. Replacement of windows and doors in historic buildings

Replacement of windows only after consultation with the conservator

One of the major problem next to insulation issue of historic buildings is replacement windows and doors. The need for applying modern solutions in the old buildings, in an era of rising energy bills is becoming a key for the owners and the new owners of such buildings. From this point of view of the historic nature of the architectural assumptions, the problem is theoretically simple replacement of windows and doors, becoming one of the most difficult task - both in terms of the problems with the development roads the proceedings as well as the roads the enforcement these solutions.

Replacement of windows and doors in historic buildings qualify as a renovation. Minor repairs or painting does not include this repair work. In relation to historic buildings, which are a whole architectural, they consist of, among others, special building material, finishes, colors, decoration of the facade, layout, size and shape of windows, panes of glass breaks and all kinds of details etc. In principle, all construction activities associated with interference in the building, causing a greater or lesser extent, a change of this object are understood as a whole. Replacement of windows is therefore a renovation of the building within the meaning of Art. 3 Section 8 of the Act of 7 July 1994 - Construction Law (consolidated text.: Journal of Laws of 2010 No. 243, item 1623 as amended) - on construction law, and in the case of buildings entered in the register of monuments is required to obtain permission to build. In addition, the replacement of window can only take place after consultation with the conservator. [36]

Point 1.10 EnerPHit criteria for the windows in the building certified describes the suggested solution:

> "It is recommended to use the standard window frame that has a certificate" component suitable for passive house "and triple glazing thermal insulation (or equivalent) with the provisions on recommendation for installation the Passivhaus Institut (PHI). If this recommendation is not respected it is necessary to provide a confirmation a preservation conditions for thermal comfort according to DIN EN ISO 7730 [Polish equivalent: BS EN ISO 7730:2006 "Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria, "or equalize drops of temperature in the areas of windows by installing heating surfaces. [5]

In the calculations, window frames and glazing type was adopted from the catalog of certified components "component suitable for passive house". This catalog is available on the official website of the Passive House Institute in Darmstadt. Besides, the institute gives requirements assigned to specific regions of the world. The map below presents this division (Fig. 4.63), and the table below gives the recommended glazing assigned to particular regions (Tab. 4.1).

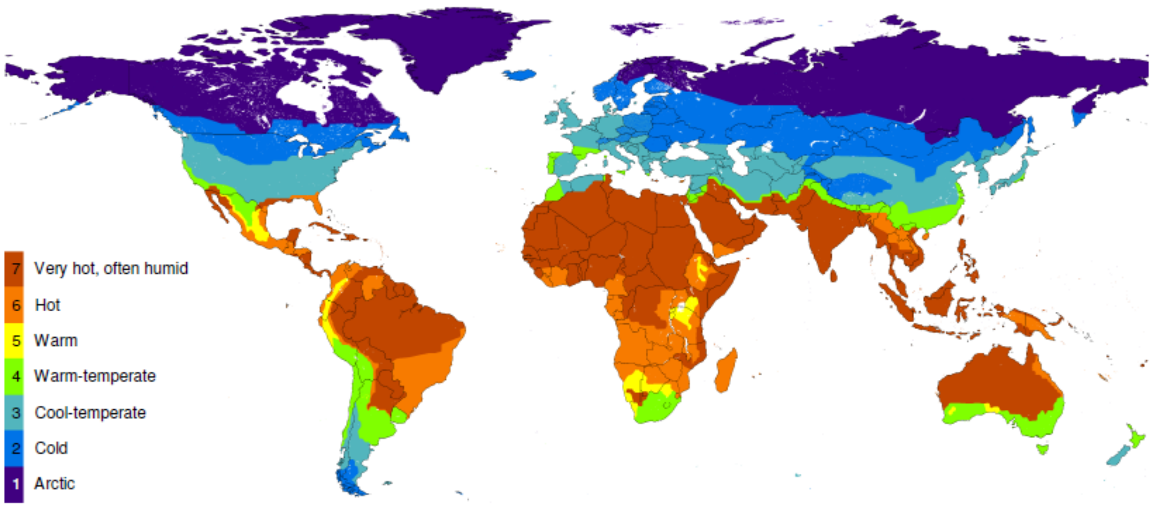


Figure 4.63 Classification of regions with equivalent requirements for Certifies Passive House Gazing and Transparent Components.

Source: "Certificatio Certification criteria for Certified Passive House: Glazings and Transparent Components", Passive Hous Institute. Version 2.0 E. June 2012. Darmstadt. Germanv

Table 4.1 Example cities in each regions and recommended glazing.

Region No.	Name	Cities	Recommended glazing
1	Arctic	Tromso, Murmansk, Novosibirsk, Magadan	Vacuum low-e
2	Cold	Anchorage, Calggary, Regina, Winnipeg, Quebec, Halifax, Reykjavik, Oslo, Stockholm, Warswa, Kiev, Moscow, Ekaterinburg, Urumqi, Yinchuan, Harbin, Ushuaia (AR)	Quadruple glazed low-e
3	Cool-temperate	Vancouver, Seattle, Portland, Salt Lake City, Kansas City, Memphis, Ottawa, Montreal, Portland, New York, Washington, London, Paris, Berlin, Vienna, Rome, Zagreb, Budapest, Sofia, Istanbul, Erzurum, Groznyy,Teheran, Beyneu, Muynak, Tokmok, Mazari Sharif, Chengdu, Wuhan, Shanghai, Beijing, Seoul, Tokio, Christchurch (NZ South Island), Comooro Rivadavia AR, Rio Grande (AR), Conchi (CL)	Triple glazed low-e
4	Warm-temperate	San Francisco, Los Angeles, Albuquerque, Juarez, Chihuahua, Casablanca, Lisbon, Porto, Bilbao, Toulouse, Marseilles, Corsica, Sardinia, Sicily, Aqaba, Gaza, Kathmandu, Guilin, Quanzhou, Elizabeth, Melbourne (Southern Australia), Wellington (NZ Northern Island), Santiago (CL), Antofagosta (CL), Buenos Aires(AR) , Vecina (AR), Cape Town (ZA), Post Elizabeth, Quthing	Double glazed low-e
5	Warm	Campala (Lake Victoria), Hawassa (ET), Johannesburg, Hawaii, Mexico City, Zcatecas, Torreon, Monclova, Quito, Trujillo	Double glazed
6	Hot	Matamoros (MX), Veracruz (Mx), Palm Bay, Maiami, Homestead, Havana, Caparazon (VZ), Salvador (BR), Rio de Janeiro (BR), Florianopolis (BR), Windhoek, Huambo, Boma, Libreville, Port Harcourt Nigeria, Maputo, Beira, North Vietnam, Las, Burma, Papua New Guinea (not Southern part)	Double glazed anti-sun
7	Extremly hot, often humid	Southern California, Corpus Christi, Houston, New Orleans, Talahassee, Amazonas, Santa Cruz de la Sierra, Sahara, Central Africa, Mbandaka, Basako, Mdagascar, Saudi Arabia, Yemen, UAE, India, Sri Lanka, Bangladesh, Burma, Cambodia, Indonesia, Philippines, Northern Parts of Australia	Triple glazed anti-sun

Source: "Certification criteria for Certified Passive House: Glazings and Transparent Components", Passivhaus Institute, Version 2.0 E, June 2012, Darmstadt, Germany

As shown in the table and map, Poland is among the cold climate region. The recommended glazing is quadruple glazed low-emission. However, the German institute is not listed glazing certified for cold climate. For the calculation of PHPP program has been adopted already defined glazing for "Passive House Window Frame (Preliminary Design Stage): PRE Passive house frame; good thermal quality ". Using this type is justified when a fictional window frame is adopted for the calculation of the early design phrase, when actual windows frame is still unknown.

If the house is best to accept this type of frame, because, as already mentioned, is required consultation with the conservator. Thus, the selection of an appropriate framework will be held later. By selecting this framework, the requirements for the maximum value, ie: U_f value, frame dimensions and thermal coefficients Bridges have been imposed. Below parameters of the selected frames are shown (Tab. 4.2).

Table 4.2 Properties of selected frame: *frame with good thermal quality*

<table>
<tr><th colspan="4">PRE Passive House frame; good thermal quality</th></tr>
<tr><th>U_f-Value</th><th>Frame Dimensions</th><th colspan="2">Thermal bridges</th></tr>
<tr><td rowspan="2">Frame: left, right, bottom, top</td><td rowspan="2">Width for left, right, below, above frame</td><td>Glazing edge thermal bridge</td><td>Installation thermal bridge</td></tr>
<tr><td>For left, right, bottom and top edge</td><td>For left, right, bottom and top insulation</td></tr>
<tr><td>W/(m²K)</td><td>m</td><td>W/(mK)</td><td>W/(mK)</td></tr>
<tr><td>0,82 (bottom)
0,84 (site/top)</td><td>0,138 (bottom)
0,120 (site/top)</td><td>0,022(bottom)
0,023 (site/top)</td><td>0,002 (site,top)
0,006 (bottom)</td></tr>
</table>

When it comes to glazing of windows has been proposed only triple glazing for reasons of lack of data for a low-emission quadruple glazing. The values for the defined "custom glazing are as follows:

g value = 0,49
U_g value = 0,64 W/(m²K)
For any door entrance assumed U-value equal to: 0,80 W/(m²K).

Technical data sheets for assumed glazing and frame have been attached in annex 3.1 and 3.2.

In the one of previous chapter (Chapter 2, point 4) of my work concerning on thermal bridges in the building. There, the correct method of installation of windows and doors which lead to the elimination of thermal bridges can be found.

4.6 Mechanical ventilation

4.6.1 Selection of the main unit

The "Ventilation" in the part program PHPP worksheet requires input data on the main unit of mechanical ventilation. During the designing this type of installation should be taken into account, such as: the location of the main unit, the type and the ability to work with ground heat exchanger. Polish Standard for the ventilation in residential buildings provides the information:

> "any mechanical exhaust ventilation equipment in residential buildings shall meet the requirements according to PN-80/B-03433" [37]

An important issue to consider is the possibility of air dryness during the winter. This situation can be avoided by equipping the ventilation in enthalpy heat exchanger. For this building, the main unit has been adopted for the from the catalogue Zenhder company. Products of this manufacturer are certified by the Pasivhaus Institute. This unit is named ComfortAir 200 (Fig.4.64). It is a ventilation unit designed for single-and multi-family buildings both new and retrofit. It is equipped with cross-counterflow heat exchanger. His efficiency $\eta_{HR,eff}$ was calculated for the designed location intake and exhaust vent (Fig. 4.65) and amounted to 90.5%.

Below details of the selected ventilation units are given

1. Efficiency of the device 200m^3/h at 200Pa;
2. Automatic bypass (100%), depending on the comfort temperature;
3. System antifreeze;
4. Pre-heater as standard (VV);
5. Chimney security;

6. Filters G4 (EU4) standard or F7 (F7) as an option;
7. Efficient fans on the direct current (power 9 - 143W), adjustable smoothly and independently;
8. The volume of the device 30 - 73dB;
9. For mounting on a wall or ceiling (weight 30kg);
10. Control:
    - CC Ease
    - Wireless RFZ (optional)
    - The CO2 sensor (optional)
    - Bathroom switch (optional)

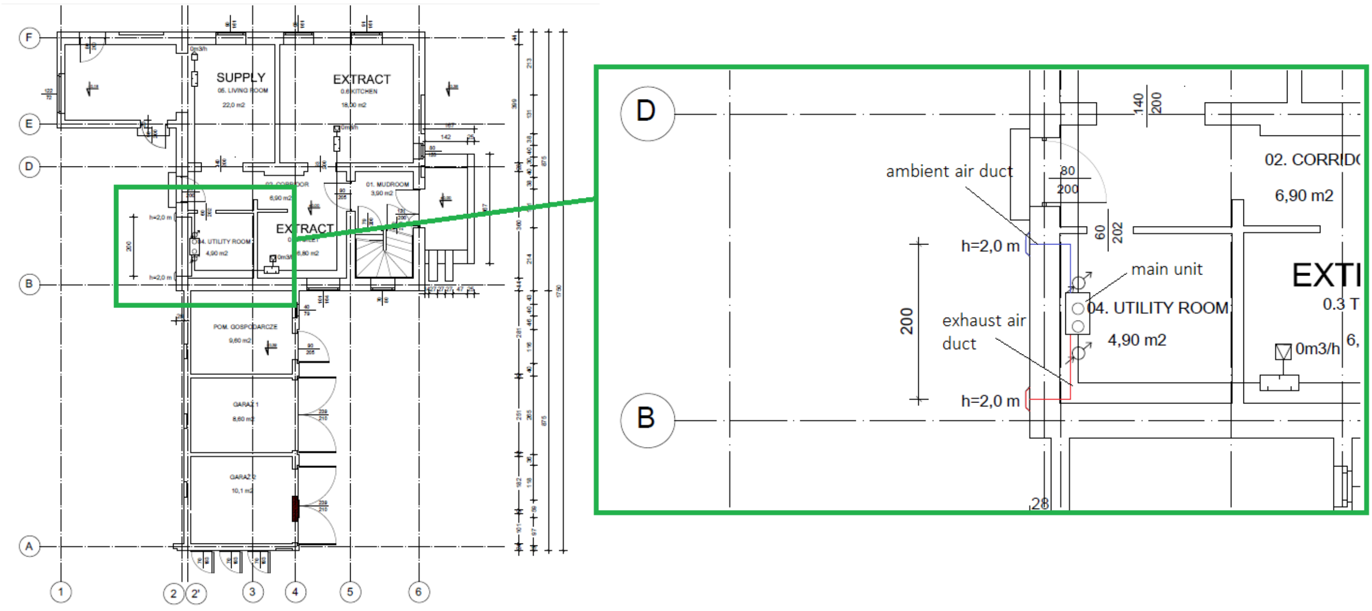


Figure.4.64 Drawings present location of main unit, ambient (blue color) and exhaust (red color) air ducts

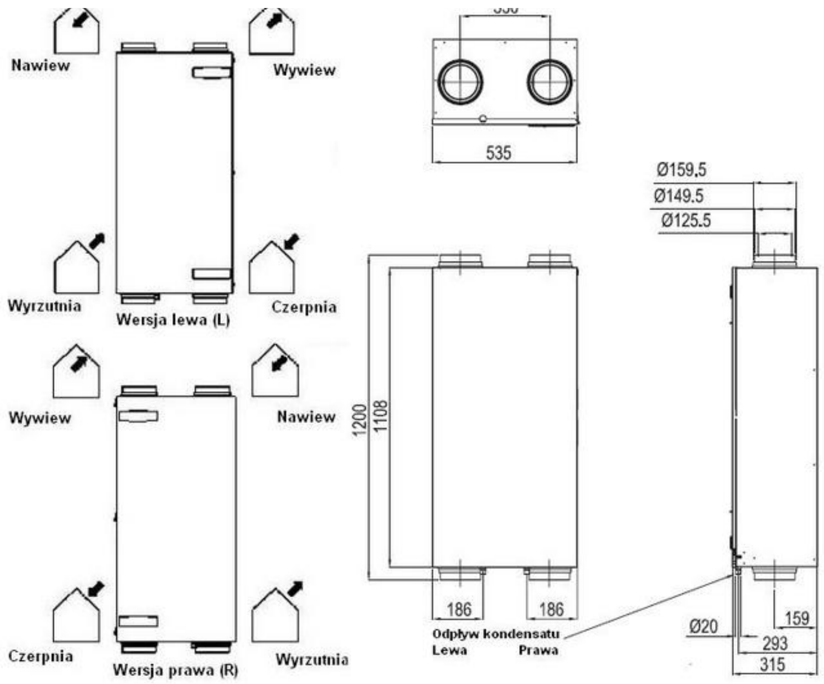


Figure 4.65 Dimensions of main unit Zenhder ComfoAir 200

Source: Technical details of the ventilation unit ComfoAir 200 manufacturer Zenher http://www.zehnder.pl/

The choosing unit with higher flow rate, eg ComfoAir 350 Lux makes the same assumptions, the efficiency (ηHR, eff) this recovery unit was equal to 82.6%. What is more disadvantageous because in this situation Annual Heating Demand raises by 2 kWh/(m2·s). In the case of this building, where the achievement of the required value of 25kWh/(m2·a) is difficult, this change constitutes a big difference. However, the selection of this unit makes it possible to apply enthalpy exchanger as an option. The unit with the number 200 gives also possible for it. After consulting this issue with Service Coordinator Zehnder Poland registered office in Wroclaw - Mr. Eng Sławomir Duda, it was given me information that the cost of installing the enthalpy exchanger is much higher than for installation of this exchanger to recovering of humidity in the unit ComfoAir 300.

Enthalpy heat exchanger optimizes the level of air moisture. It prevents air drying during the winter and also protects against freezing in the case of extremely low temperatures outside. Relative humidity of indoor air depends on the amount of fresh air entering the building and the amount of water vapor that is produced inside the building by activities such as: laundry, cooking, use of bathrooms, plants, etc. The higher the supply of outdoor air is in winter, the more decreases the relative humidity is inside the building. [38]

Enthalpy exchanger may transfer moisture from one air stream to another. This exchanger transfers moisture as steam of by diffusion from the high partial pressure of steam to the site with low pressure. At the same time prevents the passage of gases, smells and pollution. Up to 65% moisture is returned to the supply air, which means much more comfortable during the winter. Another advantage is that there is no necessity to remove the condensate: before a condense of moisture. All moisture that would normally be removed is transferred to the supply air. [39]

Figure 4.66 The enthalpy Exchange
Source: www. Zenhder.com

On the manufacturer's website Zenhder can be find the answer to the question whether the unit ventilation can cause dryness the air in the winter? Well, as a producer explained in the winter due to rooms cold air passes from the outside and warm to room temperature - then that the relative humidity falls. The air is felt as dry. This problem affects of all ventilations kinds, natural ventilation through windows also. In case of a system with an enthalpy heat exchanger, heat recovery is provided, and additionally moisture from the air discharged. In this way, the problem of dry air in the rooms is resolved. [40]

Let us not forget that comfortable conditions for the development of all kinds of mites, when through trough the air is also too much moisture. However this type of recovery system eliminates this problem and has no relation to recovery of moisture to the enthalpy heat exchanger - of mold formation is automatically prevented. The appearance on the surface of the mold is a serious problem that can be caused by constant too high humidity (Fig. 4.66). Filamentous fungus not only looks nice but also spreads the smell of musty, while it negatively affects the health and can damage the building. High humidity only improves living conditions mites, which are situated eg. in upholstered furniture and mattresses. Allergy also these "house mites" are dangerous. Ventilation units, such as the company Zenhder Comfosystems remove excessive humidity from the air and the used air is replaced with fresh.

Figure 4.67 Fungus in the corner of the wall, which is the result of too high air humidity
Source: article J.E. Stork, „Zehnder – Rekuperation"- ttp://www.hbr.olsztyn.pl

Furthermore, a significant reduction in energy requirements will be achieved by the using of an enthalpy exchanger. This combination would be more favorable compared with the system: recuperator with a normal exchanger and a humidifier. Mention may be made here, the principle of operation of air conditioners, that this devices moisturizers for the purpose of air cooling . It is used in these devices reduce the effect of wind chill temperature in the room with strong air moisture. It turns out that for better indoor climate comfort in order to moisten the air warm and dry, usually have to pick up energy from it. This energy is absorbed by water vapor, which usually has a much lower temperature. By incorporating the cooler of air is not cooled, but only increases its moisture, resulting in a momentary feeling of coolness. Often, however, this does not cause a significant change in the room temperature. The recuperator heat exchanger, as a result of condensation of moisture, there is a significant dryness of the air entering to the building. The effect of condensation increases the efficiency of each heat. However, this happens at the expense of dryness of air. For interior of rooms, relatively warm air is Supply, but it is very dry, which is not always pleasant, as has already been described above. To humidify the air used are temporary limitations of ventilation during the winter, or a humidifier. This lowers the temperature appreciably - analogous to the cooler, which was mentioned earlier.

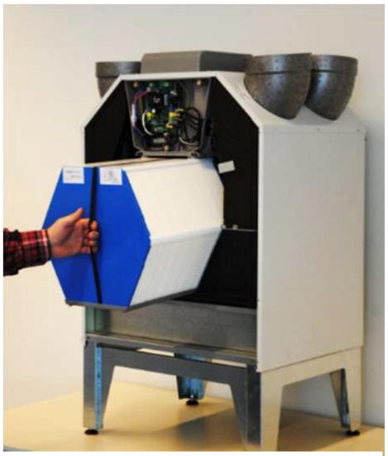


Figure 4.68 Interior of the recuperator - AERIS with an enthalpy exchanger. This heat exchanger has a blue cover and this differentiates it from the normal recuperator without moisture recovery.
Source: The article "The whole truth about the enthalpy exchanger", website: www.rekuperatory.pl

The real efficiency of such a system (recuperator + humidifier) (Fig. 4.68) providing better comfort at the expense of lowering the temperature, because the temperature will be lower than the enthalpy exchanger. The enthalpy exchanger, the air is moistened with water vapor containing the heat of the premises, which has a temperature higher than the temperature of the supply air. Hence, in the energy balance, and above all in the sense of climate comfort, the enthalpy exchanger dominates over cross flow exchanger, and even over the counterflow exchanger.

Proper location of the main unit is important due to maintenance work or any repairs. It must therefore be located in such a place that it was possible to free access. Furthermore, should there be a temperature above 0 ° C. If this condition is not fulfilled, the main unit may be damaged. The device can be located in the basement or in the garage. In both cases, should be placed on a platform or suspended under the ceiling. If in the house there is no a basement, the main unit can be mounted on the ground floor, for example, in place of the boiler or other utility room. As well recuperator will check on the attic. Furthermore the unit should be placed on a platform or hung on the wall at a height that allows free flow of condensate. When choosing a place for this unit , should be noted that the outgoing ventilation ducts from recuperator. These ducts should be perfectly straight on the section min. 80 cm - only then can be refracted by the using of the knees.

4.6.2 Location of air ducts, intake exhaust vent.

General requirements for the ventilation ducts are contained in the Regulation of the Minister of Infrastructure dated 12 April 2002 on the technical conditions to be met by buildings and their location. Specific requirements determine the many standards. The basic norm is PN-83/B-03430/Az3: 2000 "Ventilation in residential, collective home, public and buildings. - Requirements (including the change Az3: 2000). All requirements for ventilation duct are used for safety and health of the users. After years of neglect in the field of ventilation, the regulations governing these important issues begin to formed and applicable.

Cross-section of the ducts in mechanical ventilation must be due to air flow calculations. Each vent pipe must be fitted with a special a moulding, which enable its inspection and cleaning. Ventilation ducts in residential construction must also meet the requirements for tightness: should be ducts of class A (normal tightness). Tightness indicators for this class are specified in PN-B-76001: 1996 (this involves ducts of mechanical ventilation).

Number of a passing air depends on the purpose of the room and it is defined in the standard: PN-83/B-03430/Az3: 2000) and in technical conditions to be met by buildings and their location. The figure 4.69 and 4.70 show the distribution of the planned rooms for supply and exhaust air. Appendix 3 shows a larger-scale drawings the arrangement of ventilation ducts.

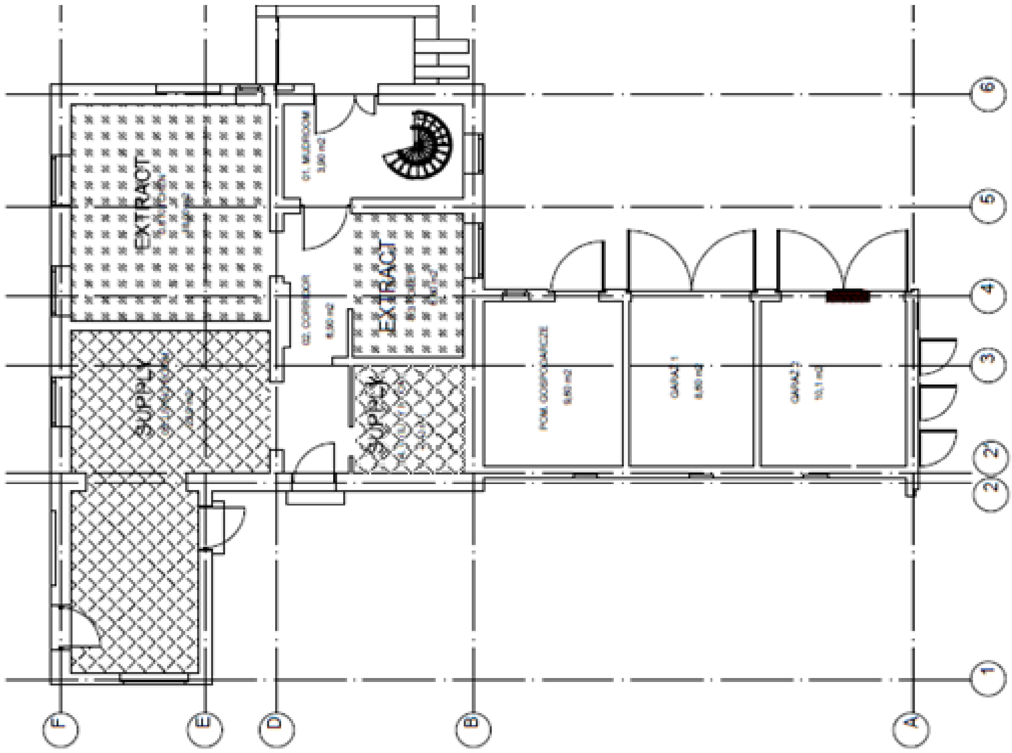


Figure 4.69 Air flow-   ground floor

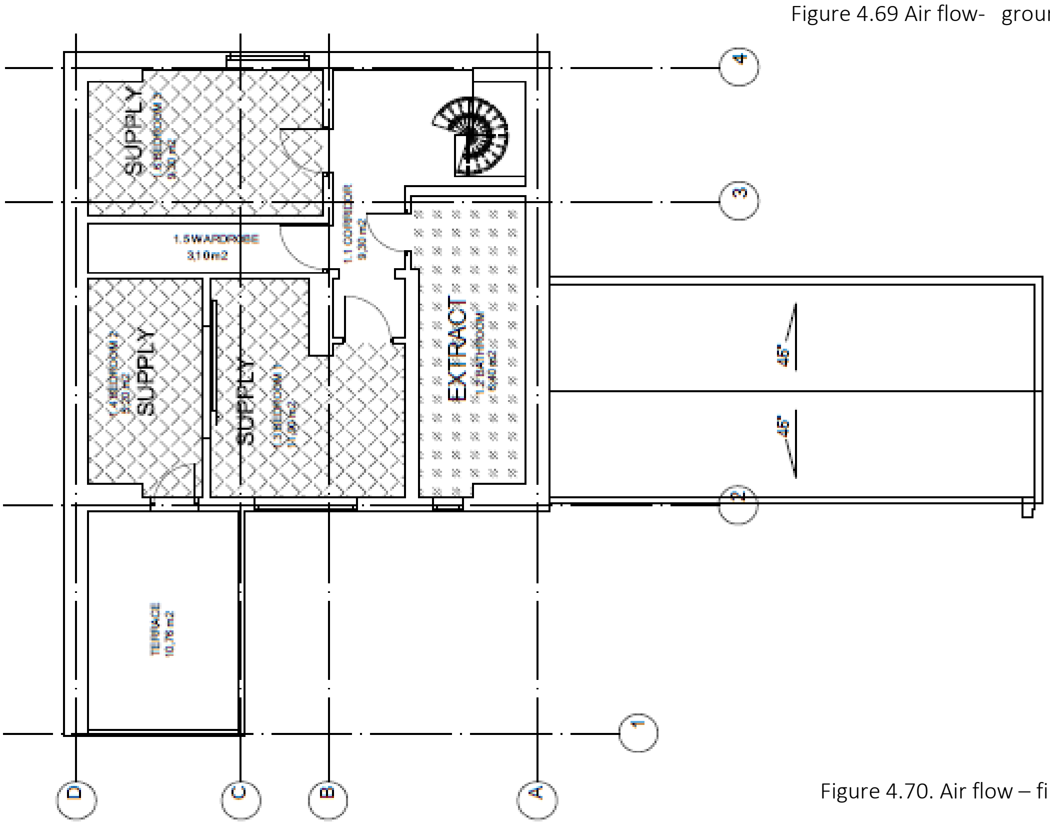


Figure 4.70. Air flow – first floor

The mechanical ventilation system, air is intake through the air intake in the wall (recommended) or in the roof. After passing through the duct comes to the main unit and the exchange of energy occurs in the heat exchanger. Next, a fan placed in the recuperator pumps it through the supply-air ducts (blue) to the living areas. Air diffusers are usually placed on the opposite side of the front door of the room, which allows for proper ventilation of the entire volume. The holes or slots in the bottom of the door allows to air flow between rooms. The hygienic and sanitary rooms and ancillary takes place receiving the air which carries moisture and impurities. Location extracts in the upper zone allows for efficient receiving air from rooms. Then, the air goes to the recuperator by extraction ducts (red), where it gives off its heat energy. Sometimes in high-tech headquarters moisture thanks to connected enthalpy heating exchanger. The fan removes the air from the building by so called. exhaust vent located in the wall or on the roof. So in short it looks effects of mechanical ventilation of the building. To everything worked fine set each of the element respectively, arranged in a building. Intake and exhaust components in its design should be able to allow achievement of the proper values of the air flow.

Depending on what type of ducts used in mechanical ventilation systems, their diameter, soundness of connections performing and insulation, and their route depends on the efficiency of the entire system. Channels should be made of material not undergoing abrasion, which does not change its properties over time and those that after a few years it will can be mechanically cleaned. Regarding the location of the air intake vent should be some basic rules to follow. Intake duct combines air intake vent air intake recuperator. It transports the outside air to the recuperator where it in subject to heat and qualitative treatment. Air intake vent is a "hole" in the exterior wall or roof, whose task is to take the fresh air of the highest possible purity. It must be adequately protected against the ingress of any undesirable elements from the outside.

4.6.3 Location of intake and exhaust vent in the building

Location intake and exhaust vent must conform to the Journal of Laws No. 75 of the Minister of Infrastructure on the technical conditions to be met by buildings and their location, dated 12.02.2002 as amended in Journal of Laws No. 56 dated March 12, 2009, Chapter 6 "Ventilation and Air Conditioning". Intake vents of air in ventilation and air-conditioning should be protected from rain and wind, and be located so as to receive air in given conditions as the purest as possible and the coolest air in the summer. Air intake vents should not be located in areas where there is danger of inflow exhaust air from the exhaust vent.

Air Intake vents are placed at ground floor or on the wall of the lowest two stories above ground building. They should be located at least 8 m on horizontal plan from the streets and grouping of parking spaces for more than 20 cars, places of solid waste collection, sewer grates and other sources of air pollution. In contrast, the exhaust vent is a hole in an exterior wall of a building or roof, whose task is to dispose used air.. It must be adequately protected against the ingress of any undesirable elements from the outside as well. Below are presented the principles that should be followed when location of the intake and exhaust vent of the wall is choosing, according to Regulation of the Minister of Infrastructure. general principles.

Paragraph § 152 points. 9 is allowed to locate exhaust vent in the wall of the building, provided that the exhaust air does not contain unpleasant odors and pollutants harmful to health, and when the opposite wall of a neighboring building with windows located at a minimum distance of 10 m or this wall has no windows at the distance of at least 8 m. The figure below illustrates on a plan of the building requirements for the appropriate location of these elements (Fig. 4.71) . [41]

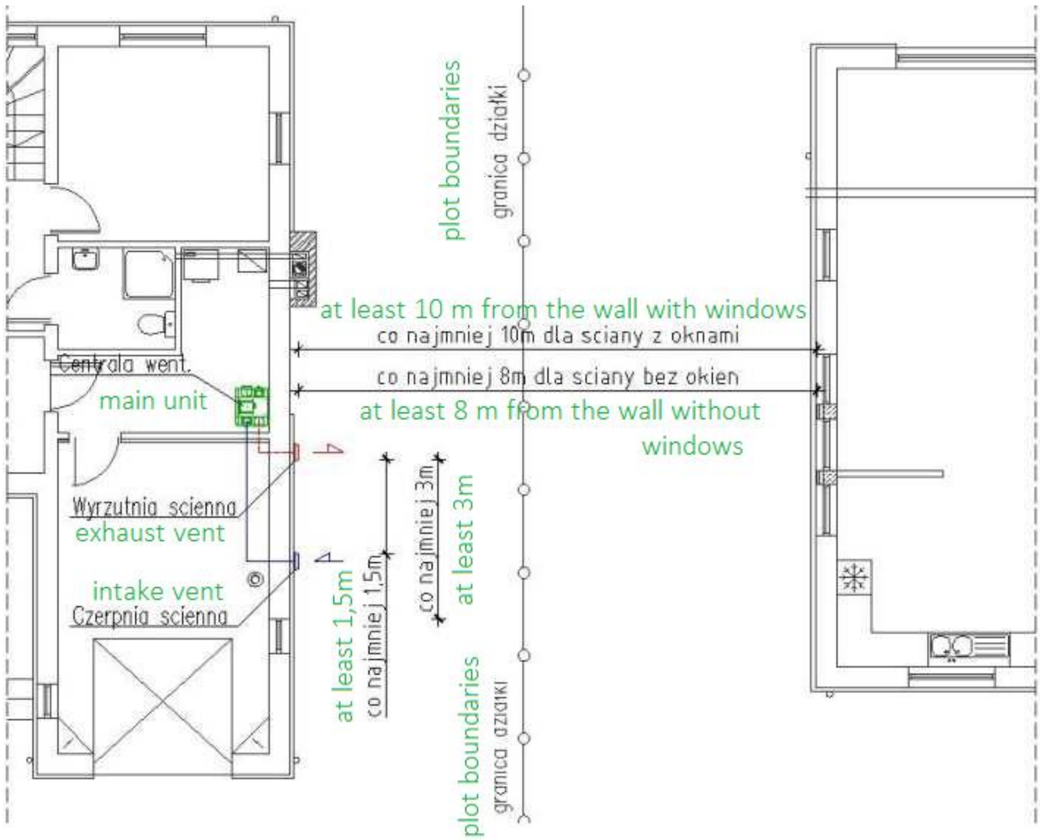


Figure 4.71 Location of intake and Exhaust vent - mandatory minimum distances.

Source: "Recuperation - mechanical ventilation with heat recovery as a logical alternative to natural ventilation. Guidebook for designers. - Based on many years of experience of engineers Rekuperatory.pl

The appropriate arrangement placed on the wall of exhaust vent are imposing restrictions on also Paragraph § 152 points. 9. It allows to locate the exhaust air vent on building wall, provided that the windows located on the same wall are spaced horizontally from the exhaust vent of at least 3 m, and below or above exhaust vent - at least 2 m (Fig. 4.72). Paragraph § 152 points. 3 - refers to the restrictions for intake vent. It specifies that

"(...) Distance the bottom edge of the inlet of intake vent from the ground level should be at least 2 m" (Fig. 4.73). [20]

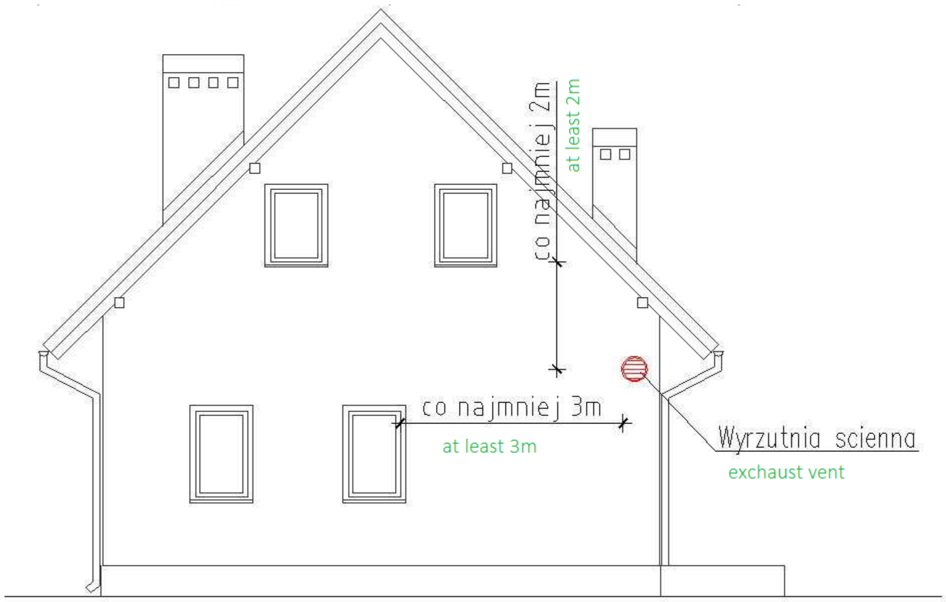


Fig. 4.72 Location of exhaust vent - mandatory minimum distances.
Source: "Recuperation - mechanical ventilation with heat recovery as a logical alternative to natural ventilation. Guidebook for designers. - Based on many years of experience of engineers Rekuperatory.pl

Figure 4.73 Location of intake vent - mandatory minimum distance from the ground level.
Source: "Recuperation - mechanical ventilation with heat recovery as a logical alternative to natural ventilation. Guidebook for designers. - Based on many years of experience of engineers Rekuperatory.pl

The illustration below (Figure 4.74) shows a fragment of the ground floor plan of the considered building. It presents the location of the intake and exhaust vent. The distance between the centers of these elements at least 2 meters and 1.9 meters between the edges They are placed at a height of 2 m from the lower edge of elements to ground level. East elevation drawing shows the distance, specified by standards for intake and the exhaust vent. (Fig. 4.75)

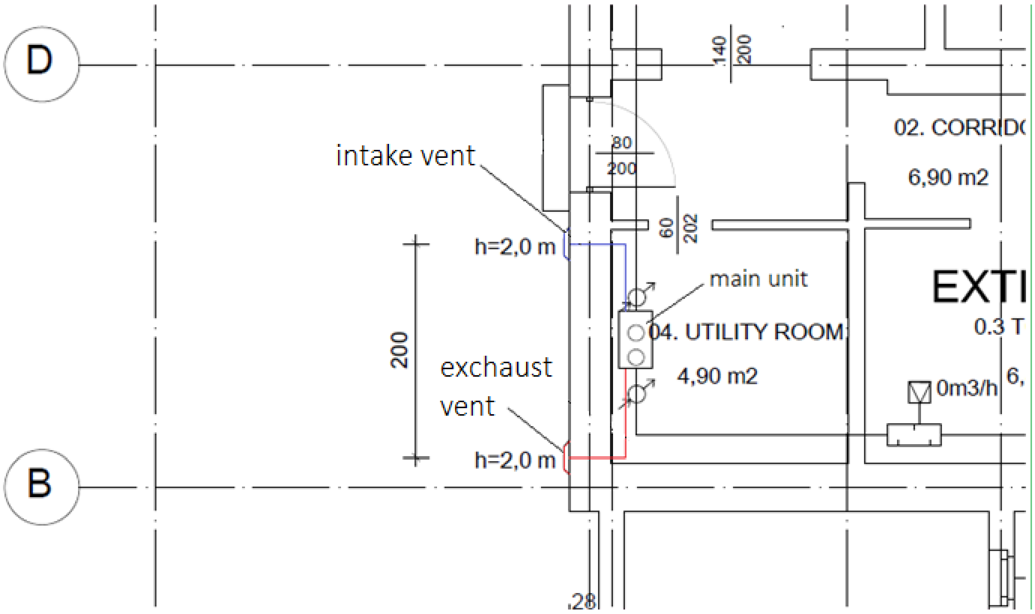


Fig. 4.74 Part of ground floor plan – location of exhaust and intake vent.

Figure 4.75 Part of the eastern elevation of the building – location of exhaust and inlet vent.

4.6.4 Arrangement of ducts in the building

We can distinguish two types of ducts: ducts leading from the to the recuperator to ventilation elements in a residential area which transport air, which already been heated - supply air ducts. They are also exhaust ducts that lead from exhaust elements located in bathrooms and utility rooms to the recuperator. They transport a air used, which carries the moisture and impurities. Ventilation ducts - should be conducted, as far as possible, through rooms heated or room insulated. This insulation should provide the difference in temperature inside the building and temperature of transported air cannot differ more than 12 ° C. Conducting the ventilation ducts through rooms with a much higher temperature difference may be also provided by designing adequately thickness channels insulation.

Figure 4.76 shows how the channels are conducted, namely in the housing of plasterboards. It also presents location of the installation – horizontal, supply and exhaust ducts in the space between the floor and suspended ceilings. Annexes 4.5 and 4.6 show more precisely how ducts are routed to the plans of ground floors and first floor.

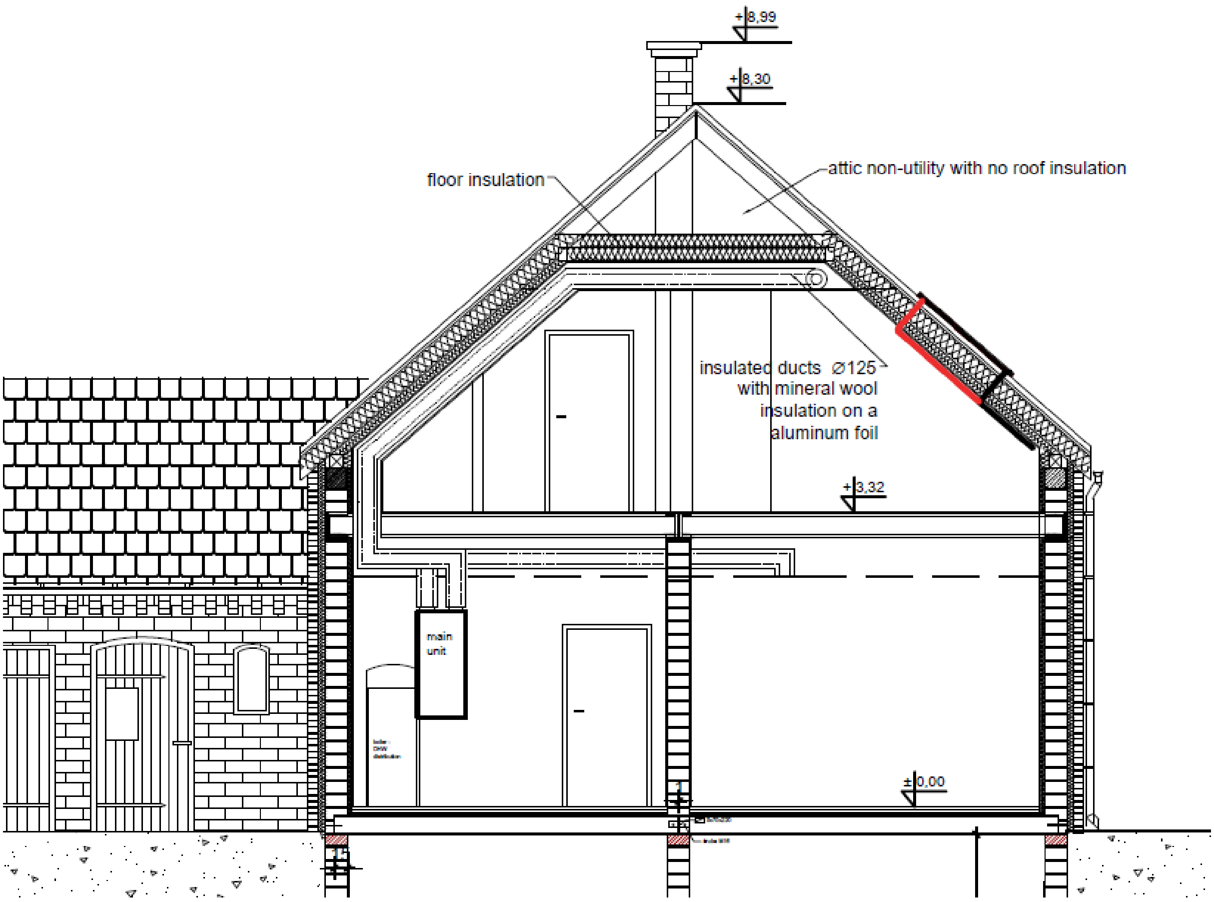


Figure 4.76 Ventilation ducts routed in space of ceiling with floor insulated - between the first floor and the unheated space.

4.6.5 Arrangement of air inlets

Air intakes are designed so that their arrangement provide for ventilation of the rooms in their entire cubic capacity. Diffusers and outlet grilles have been arranged as far as possible from the door of the rooms. Air supply will be implemented from the ceiling or wall level. If their planning as part of the supply elements of installation in the form of a outlet nozzle is possible to install them at the front door to the room. Location of supply air outlets also depends on whether we are dealing with a room on the ground floor or first floor. On the higher floors, different ceiling heights, such as inclinations may occur. In such cases, it is recommended to mount the exhaust outlets at the highest point. [42]

Extract is also planned from the upper zone of rooms - wall or ceiling. This arrangement of this elements allow for good air circulation in the room. In general, the wrong location or the using of incorrect elements can cause lack of proper air flow in ventilated areas. Figure 4.77-78 illustrate the arrangement of this ducts on each floor of the building.

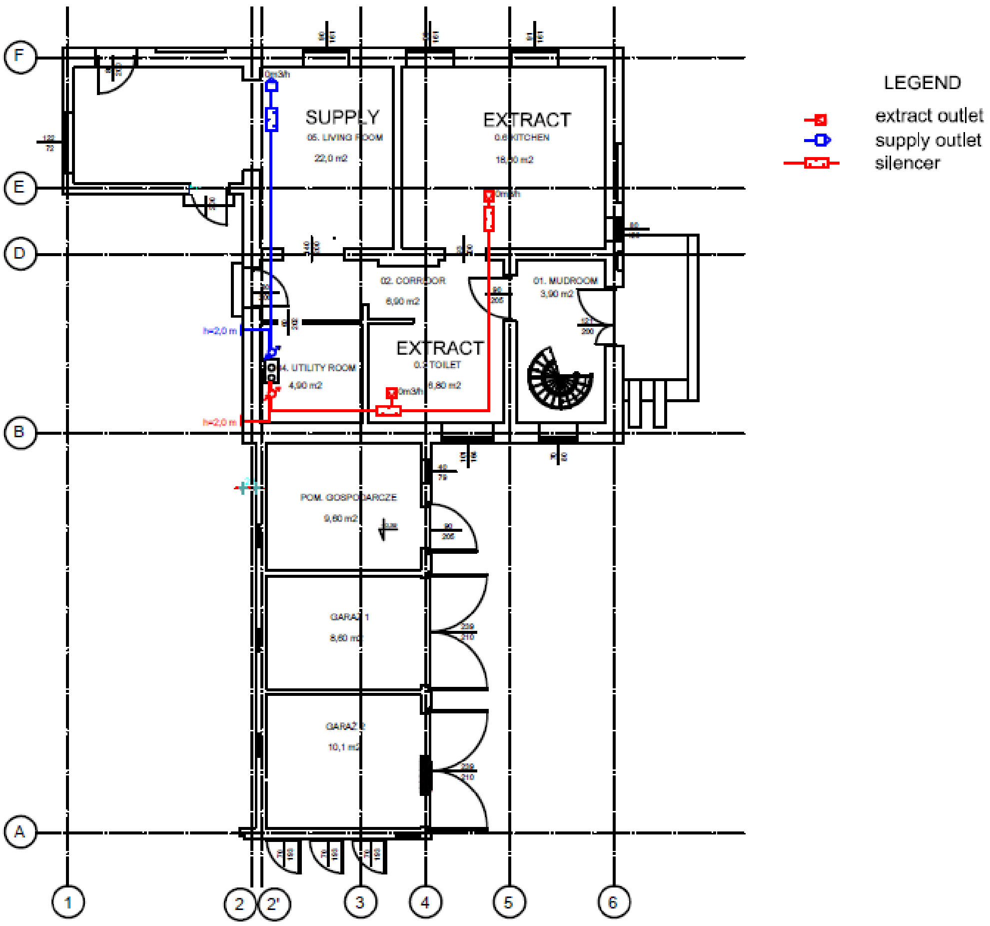


Figure 4.77 The arrangement of this ducts on the ground floor

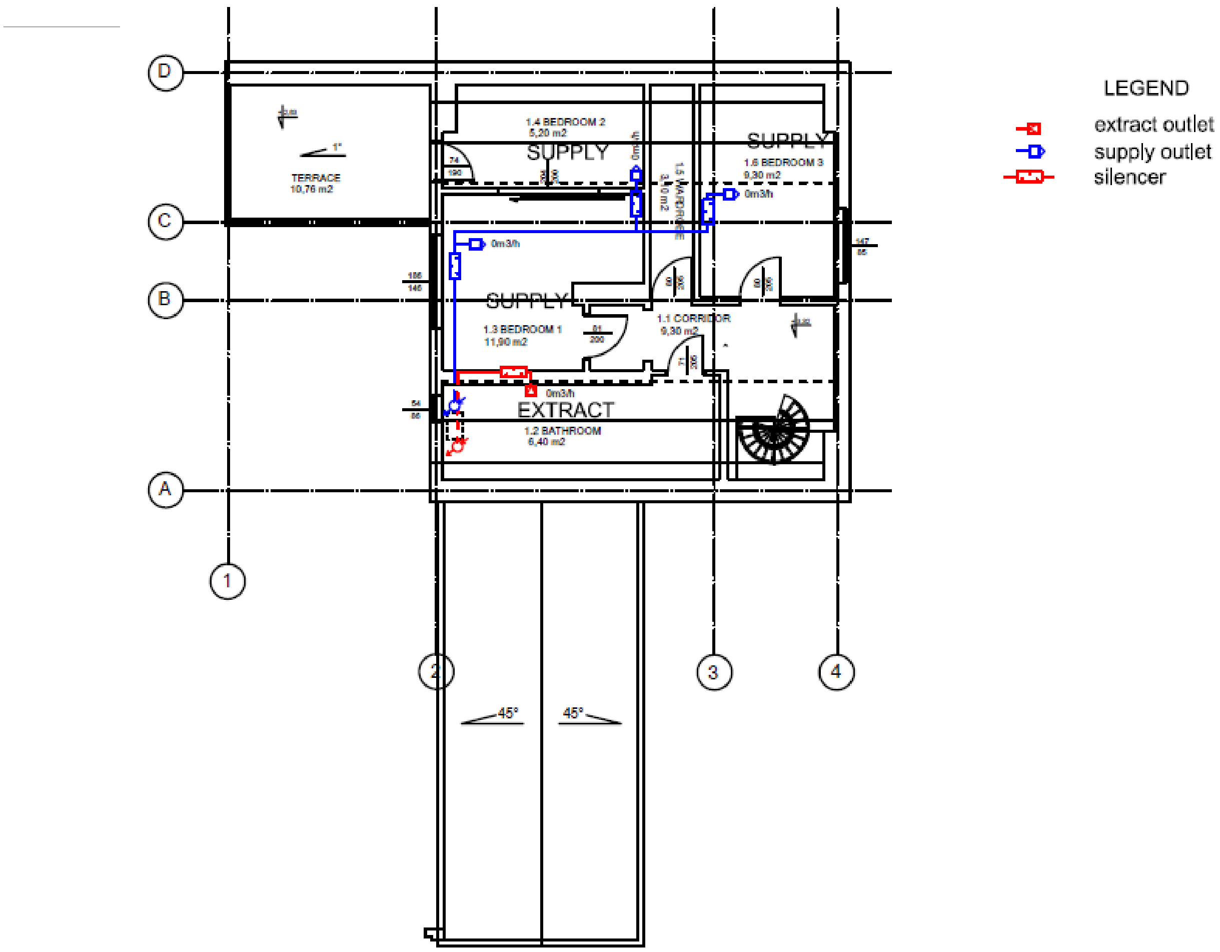


Figure 4.78 The arrangement of this ducts on the first floor

4.6.6 Insulation of ventilation duct

Another issue that had to be considered besides the length of ducts is the thermal insulation of ducts. In the "DHW + Distribution worksheet, entering data of " Heat Loss Coefficient per m in pipe "Ψ is required. This worksheet also allows the calculation of this value of thanks to additional field to fill (Fig. 4.79). The diameters of ducts, which are used in this recovery systems: 80, 100, 125, 160, 200, 250, 315 mm. [43] For the calculations in the PHPP nominal diameter of ventilation ducts assumed equal to 125 mm. Ventilation ducts run in the building must be mandatory insulated. Mineral wool as thermal insulation has been designed. It has a thickness of 50 mm and has a protective coat of aluminum foil as a reflective material. Coefficient of Ψ factor was 0.364 W/(m·K).

Secondary Calculation: Ψ-Values of Plumbing

Nominal Width	**125**	mm
Insulation Thickness:	**50**	mm
Reflective? Please mark with an "x"!		
x Yes		
No		
Thermal Conductivity	**0,04**	W/(mK)
Δϑ	30	K
Interior Pipe Diameter:	0,12500	m
Exterior Pipe Diameter	0,12725	m
Exterior Pipe Diameter	0,22725	m
α–Surface	3,21	W/(m²K)
Ψ-Value	**0,364**	**W/(mK)**
Surface Temperature Difference	4,777	K

Figure. 4.79 Secondary Calculation Ψ-values of plumbing.

Thus it is important to choose the appropriate thickness of insulation of these ducts. The entire ventilation system with heat recovery system in a single family home is not only a way to proper ventilation of rooms but also on energy savings. Insulation is important and necessary for the protection against condensation of water vapor on both their internal and external surfaces. They are used to protect against fire or soundproof against the noise in the accompanying of air flow. Conditions of use of insulation are defined in the Regulation of the Minister of Infrastructure "on the technical conditions to be met by buildings and their location." Official Gazette dated 08.201.1238. According to this of the Regulation, in the case when ventilation system runs through unheated rooms or in any other way it is exposed to the energy losses, should be protected by insulation. Table 4.3 shows the minimum insulation thickness for different diameters and ducts.. The other hand the recommended thickness of insulation for each ducts and various temperatures illustrates Table 4.4.

Type of duct or component	Min. thickness of thermal insulation
Inner diameter to 22 mm	20 mm
Inner diameter 22 mm to 35 mm	30 mm
Inner diameter 35 mm to 100 mm	equal to the inner diameter of pipe
Inner diameter at more than 100 mm	100 mm
Ducts and fittings by 1-4 passing through walls, floors	½ required from pos. 1-4
Ducts of central heating systems arranged in building components between heated rooms of different users	½ required from pos. 1-4
Ducts (6) arranged in floor	6 mm
Ducts of air heating (arranged inside the thermal insulation of building	40 mm
Ducts of air heating (arranged outside the thermal insulation of building	80 mm
Pipe of ice water system arranged inside the building ²	50% required from pos 1-4
Pipe of ice water system arranged outside the building ²	100% required from pos 1-4

Table 4.3: Requirements for thermal insulation of ducts and components according to Regulation of the Minister of Infrastructure "on the technical conditions to be met by buildings and their location." Journal of Laws dated 08.201.1238

Source: Regulation of the Minister of Infrastructure "on the technical conditions to be met by buildings and their location." Journal of Laws dated 08.201.1238

Table 4.4 Insulation for ducts of mechanical ventilation

	Surrounding temperature		
	from +20°C to +15°C	from +14°C to +1°C	from 0°C to -20°C
	Thickness of insulation for each temperature range		
Ducts:	[mm]	[mm]	[mm]
Intake	20	50	20+(200)*
Exhaust	20	50	20+(200)
Intake vent	50	50	20
Exhaust vent	20-30	20	20+(200)*

* insulation rock wool with thickness of 20 mm, covered onsite aluminium foil + minimum 200 mm rock wool as lag of ducts uninsulated of the attic.

Source: "Guidelines for the ventilation system with heat recovery system (recovery system in single-family homes), Gregory Grygier, Paul Szyperski, Association of Polish Ventilation WW/1.2011, Standards for ventilation, Warsaw 2011, edition I, ISBN 978-83-9349410-1-8

Due to the differences of temperatures between the air ducts and the rooms where they take placed on the surface of ducts often comes to condensation. Required insulation prevents this phenomenon. The effectiveness of this type of insulation determines the proper selection of the thickness of the insulating jacket. Another factor in determining its correct operation is appropriate installation. Insulation should be tight. For the installation of insulation against condensation are self-adhesive and for welding nails. Part of the insulation has an adhesive surface and can be glued directly to the duct.

The movement of air in ducts or fan operation cause noise and vibration. In addition, acoustic effects created in the case of air flow in the ducts bends and tees. To limit the acoustic effects, silencers are used. They are mounted on the inner surface of ventilation ducts: supply air, exhaust air and the exhaust vent. The construction of silencers based on the mantle in the form of the air duct inside the noise absorbing material is placed - it is mostly stone wool. Besides this, Polish standard PN-B-03430 83 "Ventilation in dwelling and public buildings. Specifications "specifies that in order to reduce the noise and vibration caused by operation of ventilation equipment is also used insulations of passageway of ducts through the partitions. Insulation thickness of 50 mm is used for this purpose. (Fig. 4.80)

Figure 4.80 Insulated internal ducts and fittings of ventilation system.

4.6.6.1 Insulation materials

An additional element that must be taken into account when fitting the ventilation system is appropriate fire protection. The requirements for fire resistance of ducts clarifies the Regulation of Minister of Infrastructure on the technical conditions to be met by buildings and their location. From the records of this the Regulation, it follows that the smoke exhaust ventilation systems should meet at least fire resistance class of floor.

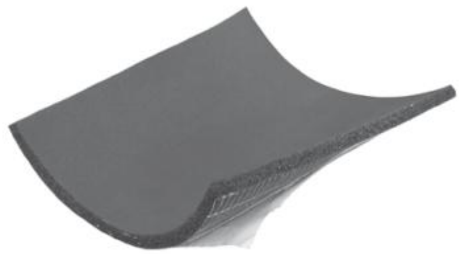


Figure 4.81 Mats made of rubber.

Choosing insulation should be guided by parameters such as: low thermal conductivity, non-flammability, high coefficient of fire reaction - which means low level emission of smoke and flaming droplets during the fire. Due to the diversity of requirements for insulation, there are several types of insulation materials. The basic material is wool - rock or glass. For insulation of ventilation systems are used also mats and of rubber cover. This type of insulation is made of a synthetic rubber. Rubber mats are present in the variant of with an adhesive layer, which facilitates and speeds up the assembly process. Because of its flexibility, the insulation made of rubber can be matched to almost any shape of the insulated ducts or fittings. Rubber provides protection against condensation and well dampens vibrations and noises. Rubber mats, due to the low thermal conductivity factor, increase the energy efficiency of the installation.

In the case of ducts between the main unit and exhaust vent , there these ducts shall be not insulated. However, this is only acceptable only when the temperature difference between the air transmitted and the air surrounding the ventilation ducts never exceed the level of 4 ° C. The minimum thickness of the applied insulation of mineral wool should be at least 20 mm.

Caring for insulation of installation translates into a higher degree of energy efficiency of system as a whole. In some sections it also protects the system against the formation of moisture on the surface. Ventilation ducts shall be fastened to the partitions of the house at a minimum distance of 100 mm. This will enable the tightness of execution of cross connections tight. Passageways of ducts through the partitions must be performed in the openings, whose dimensions are from 50 to 100 mm larger than the external dimensions of ducts or ducts with insulation.

According to the Polish standard PN-B-03430 83 "Ventilation in dwelling and public buildings. Specifications "It must also be ensure proper air flow from the living areas to the corridor, sanitary rooms and auxiliary. The inner door should be equipmented in the slot, which will be located at the lower part. In the considered buildings in accordance with the drawings in annex 4.5 i 4.6 (the partition of the building into different zones of air flow).

The surface of this slot in the door of residential rooms and ancillary should be at least 80 cm2. In the case of width of the door of 80 cm should be performed undercut with a width of 1 cm. The area of this slot for sanitary rooms should be at least 200 cm2.
Here is the list of the requirements posed by the Polish standard PN-B-03430 83 "Ventilation in dwelling and public buildings. Specifications " for mechanical ventilation:

1. Mechanical exhaust ventilation equipment in residential buildings shall meet the requirements by PN-80/B-03433,
2. Other mechanical ventilation devices should be designed based on the general principles of ventilation technology, including the requirements for PN-73/B-03431,
3. The arrangement of exhaust air ducts should be designed in such a way that during the period of breaks, these ducts acted partly in as natural ventilation in fan operation,
4. Heat recovery: devices intake is recommended to use the heat contained in the exhaust air to heat the outside air,
5. Acoustic requirements: mechanical ventilation devices should not cause exceeding the maximum permissible sound level of noise specified in the applicable standards and regulations;

4.7. The solar installation

4.7.1 Type and localization

Solar collectors should be designed and constructed in accordance with Art. 3 point 3 of the Directive of the European Parliament and of the Council of Europe 97/23/EC of 29 May 1997 concerning the pressure equipment, which has been implemented into Polish law by the Regulation of the Minister of Economy of 21 December 2005 on essential requirements for pressure equipment and pressure equipment units (Journal of Laws No. 263, item. 2200). This is to guarantee the safe operation of the collector that through the proceedings in accordance with the good, acknowledged engineering practices. Solar Keymark is a quality mark for solar products confirming the compliance of the products with the requirements of the European standards EN 12975 and EN 12976. He was introduced with a view to highlight the producers of solar panels and solar systems, which in its activities are guided by compliance with applicable European standards. Information released by the European Solar Thermal Industry Federation (www.estif.org) describes that the basis of the certification program is to control products based on compliance with applicable European standards and quality control according to ISO 9000. The task of the Solar Keymark is to support customers when choosing of solar panels and solar systems that meet the requirements of the relevant European standards. The institution, which deals with the granting of this designation is, among other things, the company DIN

CERTCO from Berlin. The company receives the authority to certify after it will have been considered to be neutral, independent and competent certifying authority. Solar Keymark can also be achieved in other institutions appointed by the above-mentioned association - European Solar Thermal Industry Federation, such as: CERTIF (Portugal), ICIM (Italy), ELOT (Greece), KIWA (Netherlands) and SP (Sweden). To get the Solar Keymark is necessary to perform a full set of tests according to standards required in research institution accredited by the DIN CERTCO. A list of these institutions is listed on the website www.dincertco.de.

In considered building, because of the fact it is a historic building, for the calculations in the PHPP, the flat plate collectors have been adopted. Because the collector in such buildings should not significantly distinguish themselves and interfere with the original design of the roof. PHPP program gives the opportunity to choose from a list of the collector. From this such list "Improved Flat Plate Collector" has been selected. In the table below the parameters of these collectors are collated (Table 4.5).

Table 4.5 „Selection list of solar panels" from PHPP program

	η_0 = FR*(ta)	K1	K2	C	Kdir(50°)	Kdfu	Output	Module Area (Aperture)	VTC/FPC
	-	W/(m²K)	W/(m²K)	kJ/(m²K)	-	-	kWh/(m²a)	m²	please enter
Standard Flat Plate Collector	0,77	3,5	0,02	6,4	0,9	0,8	300	2	FPC
Improved Flat Plate Collector	0,854	3,37	0,0104	4,7	0,97	0,94	546	2,6	FPC
Vacuum Tube Collector	0,62	0,395	0,02	11,53	0,95	0,9	487	1,2	VTC

VTC - Vacuum Tube Collector
FPC - Flat Plate Collector

Source: PHPP

In order to minimize interference in appearance the building and its original appearance, construction fittings have been proposed. Thanks to them, it is possible to fixing collector in parallel to the roof surface (Fig. 4.82). These types of fittings are designed exclusively for installation of flat solar panels. The surface of collectors is an integral part of the roof slope and at the same time it replaces the roof tile. This type of fixing option is used mainly in new buildings or the case of roof renovation. Manufacturers recommend this type of fittings for practical reasons. This solution can only be used for roofs with a slope greater than 30 ° covered with ceramic tiles. In this

Figure 4.82 Flat roof collector in the fitting.

Source: Catalogue of products 2013 - "Solar technology" of Hewalex company, Page 39 modernized building inclination is 41°. Figure 4.83-84 shows the proposed location of the panels on the roof.

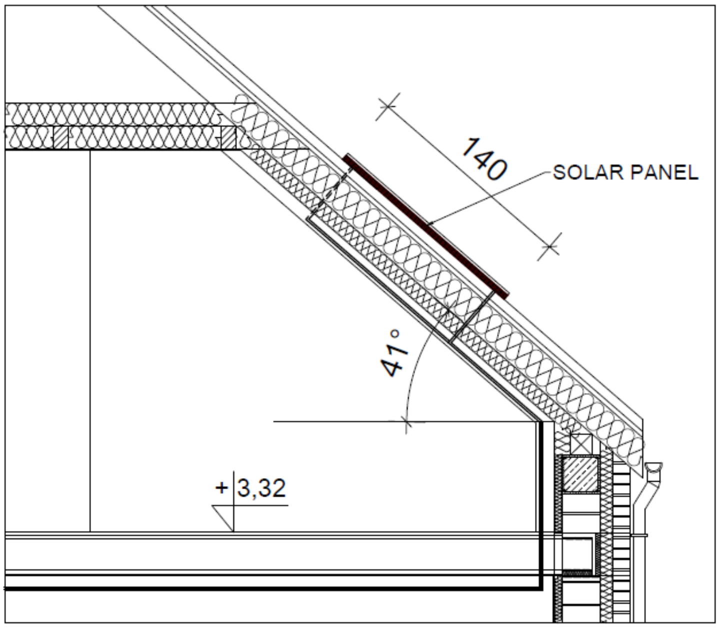


Figure 4.83 Part of cross section of the building with solar panels location.

Figure 4.84 Location of solar panel on roof slope.

4.7.2 Slope angle of solar panels.

Apart from the effect of the characteristics of the collector itself, the output of the solar system is dependent on the inclination angle of the collector to the sun. The largest yield is obtained when the collector is always orientated perpendicular to the sun. However, the optimal tilt angle for the collectors varies according to the season, as the sun is higher in the sky in summer than in winter. As a general rule, the optimum angle of tilt is equal to the degree of latitude of the site . But the minimum angle of the collector should be 15 degree to assist the thermosyphon effect. The following table (Tab. 4.6) shows optimum tilt angles of different latitudes and seasons.

Table 4.6 Tilt angle for different latitudes and seasons

Latitude [degree]	**Best collector tilt in:**					
	June	Orientation	**Sept./March**	Orientation	**December**	Orientation
50 N	26.5	S	50	S	73.5	S
40 N	16.5	S	40	S	63.5	S
30 N	6.5	S	30	S	53.5	S
20 N	3.5	N	20	S	43.5	S
15 N	8.5	N	15	S	38.5	S
10 N	13.5	N	10	S	33.5	S
Equator = 0	**23.5**	**N**	**0**	**-**	**23.5**	**S**
10 S	33.5	N	10	N	13.5	S
15 S	38.5	N	15	N	8.5	S
20 S	43.5	N	20	N	3.5	S
30 S	53.5	N	30	N	6.5	N
40 S	63.5	N	40	N	16.5	N
50 S	73.5	N	50	N	26.5	N

Source: "Dimensioning and Design of Solar Thermal Systems", AEE – Institute for Sustainable Technologies, Gleisdorf, Austria

Figure 4.85 Location of Jarocin on maps of Poland

Modernized building is located in Poland, namely in Jarocin (Fig. 4.85). The coordinates of the city are as follows: 51 ° 58'N 17 ° 30'E. Thus, according to this table of collectors tilt. Their slope should reach about 74 degrees. However, as was described earlier, the flat plate collectors are designed which adhered closely to the roof. Well throughout the year they will be inclined only 49 ° from the vertical on the south side of the building.

A well-designed solar installation should provide to 40 ÷ 60% of the heat required during the year for Domestic Hot Water heating. For this purpose, can be taken the following proportion, which is given by the Manual of PHPP program: 1m^2 per one person. In addition, when determining the storage tank capacity should be taken a standard rate of daily consumption of hot water of 70 to 100 liters per one person. According to the data entered at the beginning, the building will stay about 3 people, so that the total daily consumption may be about 210 to 300 liters.

4.8 Domestic hot water systems with forced circulation

In Central and Northern European climatic conditions, double-circuit systems with forced circulation are almost exclusively used. The collector circuit is driven by a circulation pump. Characteristic to this system is the separation of the collector and the tank as the collectors are usually mounted on the roof and the tank is installed in the cellar of the house. During summer in Europe the energy supplied by the sun is sufficient to cover between 80% and 95% of the hot water demand, depending on the dimensioning of the system. If the hot water consumption is matched with the solar radiation profile, it is possible to omit all other forms of energy during the summer months.

During the interseasons and winter months, the solar energy supply is still sufficient to pre-heat the domestic water, i.e. the temperature of the inlet water has to be raised only by a small amount by the heating boiler or electric heating element (Fig. 4.86). During the cold winter months, water temperatures between 30 and 50°C can still be reached on sunny days. Thus, the energy saving effect in winter may be still considerable.

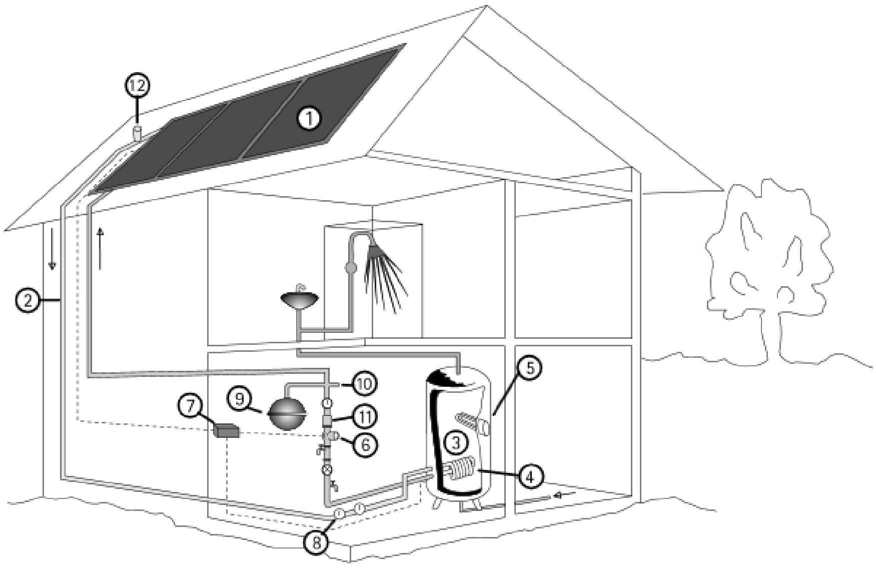


Figure 4.87 Solar hot water system with forced circulation

Source: SOLAR THERMAL SYSTEMS AND COMPONENTS AEE - Institute for Sustainable Technologies

The incoming solar radiation is converted into heat by the collector (1). This heat is transported by a heat transfer medium (water/anti-freeze mixture) in pipes (2) to a storage tank (3). There, the heat is transferred through a heat exchanger (4) to the domestic water and thus becomes utilisable. The storage tank should be dimensioned in such a way that its volume corresponds to the hot water demand of one to two days. The installation of an additional (e.g. electric) heater (5) ensures that sufficient amounts of hot water are available even during long and continuous periods of overcast weather.

The water, which has been cooled in the heat exchanger, then flows back to the collector. The heat transfer medium is circulated by a circulation pump (6). An electronic control (7) ensures that the pump is only turned on when an energy gain from the solar collector is expected, i.e. when the medium in the collector is warmer than the domestic hot water in the tank. Both the storage tank and the pipes are well insulated to avoid unnecessary losses.

Additionally, thermometers (8) in the inlet- and outlet pipes belong to the basic equipment of the system. They are preferably installed close to the storage tank. Temperature dependent volume changes in the fluid are compensated by the expansion tank (9), keeping the operating pressure in the system constant. The gravity brake (11) prevents the heat from flowing back to the top if a standstill in the system occurs. A pressure relief valve (10) allows fluid to escape if the system pressure becomes too high. An air escape valve (12) is installed at the highest point, allowing air in the piping to escape. Inlet and outlet taps complete the system. In general, the auxiliary heating of the domestic hot water is performed with a second heat exchanger by a boiler instead of, or in addition to, the electrical auxiliary heating device.

This type of system was designed in my modernized building. Because according results of calculation Solar radiation can cover only 46% for Domestic Hot Water production. It is necessary to designed extra electric boiler for fulfilled heat demand (Fig. 88). [44]

Occupancy	3,0	Persons		
Specific Collector Area	1,1	m²/Pers		
Estimated Solar Fraction of DHW Production	**46%**			
Solar Contribution to Useful Heat	**1231**	kWh/a	**12**	kWh/(m²a)

Figure 4.87 Results of calculation in PHPP program

4.8.1 Ducts of the solar system

The ducts in the solar system are designed to allow circulation of the heating medium (glycol) between the heat source - solar collectors, and the place heat collection - such as coil of DHW cylinder . A large spread of temperature and pressure of work, put for ducts of solar installation very high technical requirements. Regarding the type of ducts is recommended to use copper conductors in the solar system. There are several reasons for using this material, for example copper they do not cause a conflicts of materials - if only because the ducts in solar collectors are made of copper. Another advantage stems from the fact that copper has a high resistance to high and low temperatures, and corrosion resistance and has a relatively low thermal expansion (at 100 K increases by 1.7 mm).

Selection of the diameter of ducts is to determine unitary the flow rate of the heating medium through the solar collector and the total for the whole of the solar system. There are two types of the flow rate, namely: High-Flow - and standard intensity of solar plants with a small flow rate, called Low-Flow. The second is a reduced intensity and occurs in large solar installations. Appropriate selection of size of the flow rate It allows to removal of heat from the collectors, at the same time the lowest consumption of electricity by the circulating pump. Depending on the manufacturer, the required flow rate for flat collectors is usually lower than the vacuum tube collectors. After calculating the flow rate, the appropriate diameter of the duct should be adopted. Below are presented examples of the calculated flow rates for particular collectors (Figure 4.88).

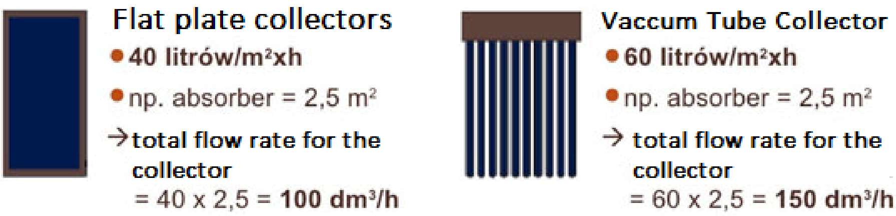


Figure 4.88 Example of calculation of flow rate

Source: http://www.4budowlani.pl/strefa-wykonawcy/produkty-i-technologie/beton-i-cement/320-miedz-w-budownictwie/instalacje-z-miedzi/7780-jak-dobrac-srednice-przewodow-w-instalacji-solarnej

In this building, flat plate collectors with an area of 3.4 m2 has been designed. For the calculation of the diameter of ducts, It has been assumed:

- 40 liter/m²xh
- The area of collectors = 3,4 m²
- The total flow rate for installation: 40x3,4=136 dm³/h = 0,0136 m3/h

<u>According to Table 4.7 size recommended for ducts is 12X1 mm.</u>

Natężenie przepływu		Prędkość przepływu, m/s						
		Rozmiar rury miedzianej						
m³/h	l/min	12x1	15x1	18x1	22x1	28x1,5	35x1,5	42x1,5
0,125	2.08	0.44	0,26	0,17	0,11	0,07	0,04	0,03
0,15	2,50	0.53	0,31	0,21	0,13	0,08	0,05	0,03
0,175	2,92	0,62	0,37	0,24	0,15	0,10	0,05	0,04
0,2	3,33	0,70	0,42	0,28	0,18	0,11	0,06	0,05
0,25	4,17	0,88	0,52	0,35	0,22	0,14	0,08	0,06
0,3	5,00	1,05	0,63	0,41	0,27	0,17	0,09	0,07
0,35	5,83	1,23	0,73	0,48	0,31	0,20	0,11	0,08
0,4	6,67	1,41	0,84	0,55	0,35	0,23	0,13	0,09
0,45	7,50	1,58	0,94	0,62	0,40	0,25	0,14	0,10
0,5	8,33	1,76	1,04	0,69	0,44	0,28	0,16	0,12
0,6	10,00	2,11	1,25	0,83	0,53	0,34	0,19	0,14
0,7	11,67	2,46	1,46	0,97	0,62	0,40	0,22	0,16
0,8	13,33	2,81	1,67	1,11	0,71	0,45	0,25	0,19
0,9	15,00	3,16	1,88	1,24	0,80	0,51	0,28	0,21
1,0	16,67	3,52	2,09	1,38	0,88	0,57	0,31	0,23
1,5	25,00	5.27	3.13	2,07	1.33	0.85	0.47	0.35
2,0	33,33	7,03	4,18	2,76	1,77	1,13	0,63	0,46
2,5	41,66	8,79	5,22	3,45	2,21	1,41	0,79	0,58
3,0	50	10,55	6,27	4,15	2,65	1,70	0,94	0,70

Table 4.7 The table allows to choose the right a diameter of ducts in the system

Source: http://www.4budowlani.pl/

Moreover, it should be noted to prevent the accumulation of air bubbles in the upper part of the solar system, the flow rate of glycol should be higher than 0.4 m/s The recommended range is 0.5 m/s to 0.7 m/s is especially important is speed of flow in the vertical outlet from the solar collectors. Too low a speed can cause "build-up" of air bubbles in solar collectors. This means no floating of bubbles with heating medium downwards the installation. In this municipal air separator is installed. [45]

4.8.2 Storage tank

The "SolarDHW - Solar Hot Water Generation" worksheet, besides giving the type, area, location and of the collectors asks for the type of DHW storage. It is possible to select from among 15 tanks already defined in the program. Solar storage. However, there is the possibility to enter of its own data, and create an additional tank on the list. Table 4.8 shows the parameters of each tank. For the calculation as you can see in the screenshot of the program PHPP, "Solar stratified storage" has been chosen (Fig. 4.89).

Secondary Calculation of Storage Losses

Selection of DHW storage from list (see below):	10	Selection:	10 Stratified Solar Storage
Total Storage Volume	313	litre	
Volume Standby Part (above)	94	litre	
Volume Solar Part (below)	219	litre	
Specific Heat Losses Storage (total)	2,6	W/K	
Typical Temperature DHW	60	°C	
Room Temperature	20	°C	
Storage Heat Losses (Standby Part Only)	**26**	W	
Total Storage Heat Losses	**104**	W	

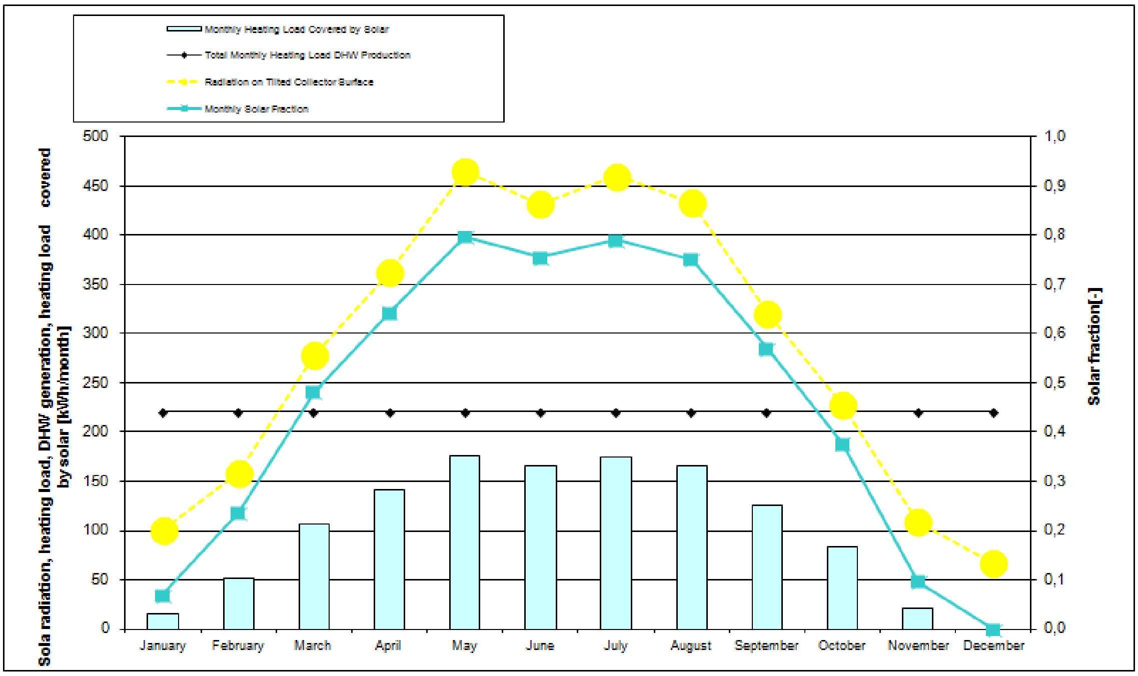
Figure 4.89 The screenshot of „ Solar DHW" worksheet from the PHPP program - storage tank assumed.

Table 4.8 A summary table of properties of storage tanks – data form PHPP program

Description	Total Storage Volume	Volume Standby Part (above)	Volume Smolar Part (below)	Losse Stanby Part Only	Losses Standby Part Only	Total losses	Vs aux/ V Total
	litre	Vs, aux ltr.	Vs,sol ltr.	kWh/d	W/K	W/K	-
Simple Solar Storage	200	60	140	0,78	0,65	3,00	0,30
Simple Solar Storage	300	90	210	0,78	0,65	2,80	0,30
Simple Solar Storage	400	120	280	0,82	0,69	3,20	0,30
Simple Solar Storage	500	150	350	0,90	0,75	3,60	0,30
Stratified Solar Storage	313	94	219	0,78	0,65	2,59	0,30
Stratified Solar Storage	391	117	274	0,82	0,69	2,88	0,30
Stratified Solar Storage	490	147	343	1,01	0,84	3,29	0,30
Stratified Solar Storage	755	227	529	1,23	1,03	4,38	0,30
Stratified Solar Storage with DHW Heat Exchanger	490	147	343	0,71	0,59	2,00	0,30
Stratified Solar Storage with DHW Heat Exchanger	550	165	385	0,60	0,50	2,00	0,30
Stratified Solar Storage with DHW Heat Exchanger	800	240	560	0,96	0,80	2,50	0,30
Stratified Solar Storage with DHW Heat Exchanger	1000	300	700	1,08	0,90	3,10	0,30
Stratified Solar Storage with DHW Heat Exchanger	2000	600	1400	1,44	1,20	4,50	0,30
Combined Solar Storage (Tank-in-Tank)	698	209	489	1,01	0,84	3,16	0,30
Combined Solar Storage (Tank-in-Tank)	982	295	687	1,23	1,03	3,98	0,30

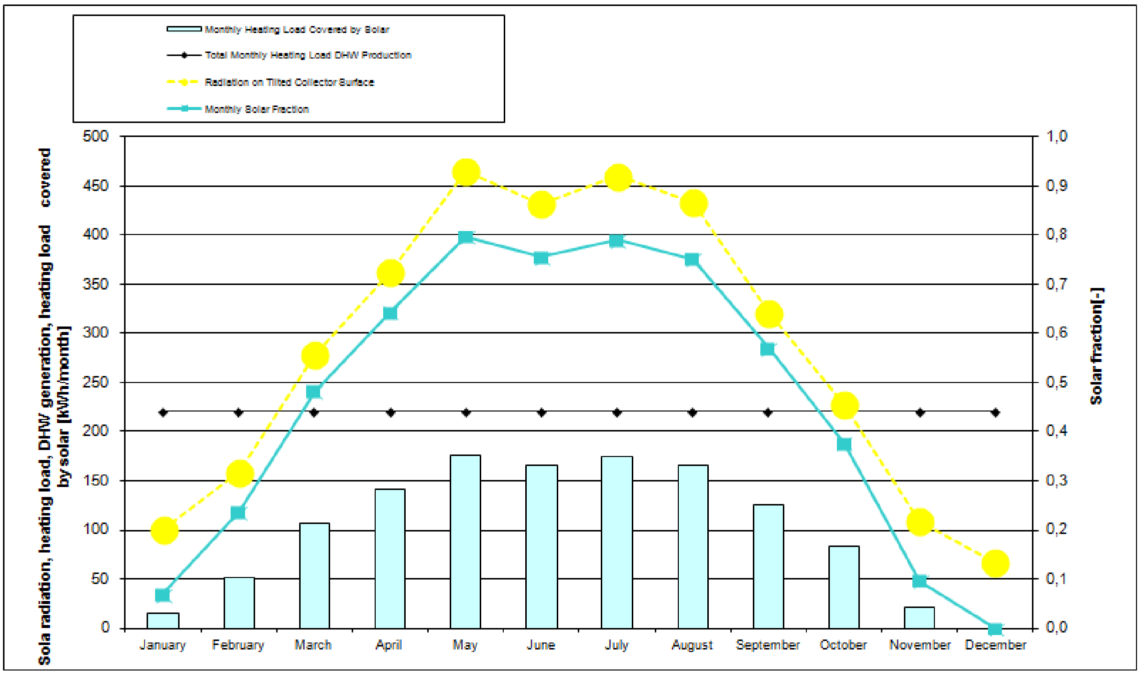
4.8.3 A comparison between different types and areas of collectors

The tables and graphs (Figures 4.90-92) below show the graphical and tabular collected data from the program PHPP for different types and areas of panels. All values have been calculated for considered building.



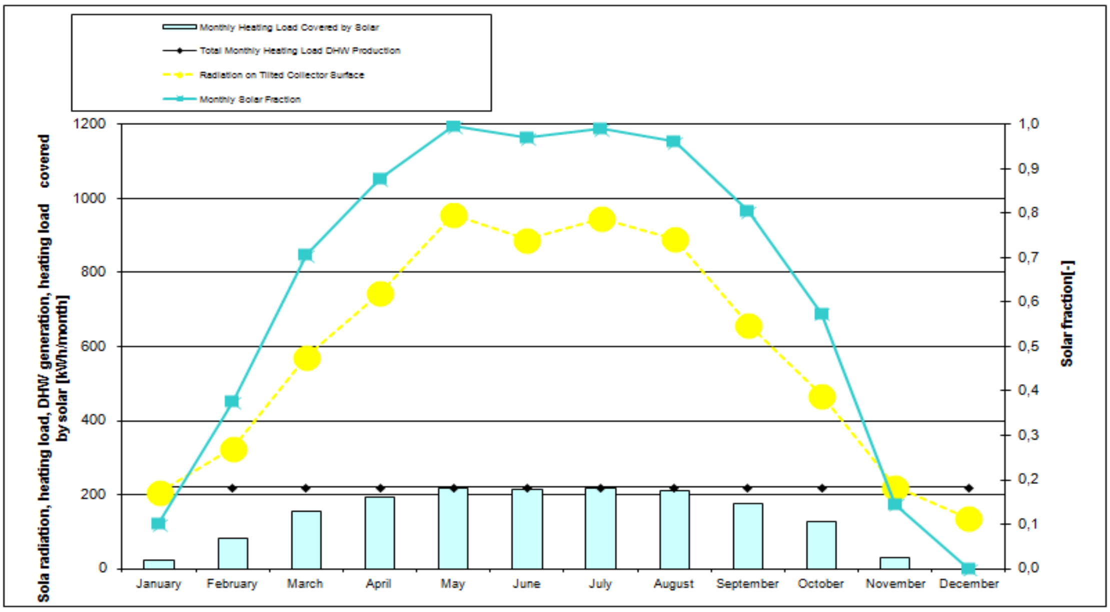
Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	101	159	278	362	464	432	460	433	321	228	108	66	kWh/Month
Monthly Solar Fraction	0,07	0,24	0,48	0,64	0,80	0,76	0,79	0,75	0,57	0,38	0,10	0,00	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	kWh/Month
Monthly Heating Load Covered by Solar	15	52	106	142	176	167	175	166	126	83	21	0	kWh/Month

Fig 4.90 Values for *Improved Flat Plate Collector* with area of 3,4 m^2



Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	148	234	409	533	683	635	676	637	472	335	159	98	kWh/Month
Monthly Solar Fraction	0,08	0,31	0,61	0,79	0,94	0,90	0,93	0,89	0,71	0,48	0,12	0,00	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	kWh/Month
Monthly Heating Load Covered by Solar	18	67	134	173	207	198	205	197	156	106	26	0	kWh/Month

Figure 4.91 Values for *Improved Flat Plate Collector* with area of 5,0 m^2



Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	207	327	573	746	956	889	947	891	661	470	223	137	kWh/ Month
Monthly Solar Fraction	0,10	0,38	0,71	0,88	1,00	0,97	0,99	0,96	0,81	0,58	0,15	0,00	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	kWh/ Month
Monthly Heating Load Covered by Solar	22	83	156	194	220	214	219	212	178	127	32	0	kWh/ Month

Fig 4.92. Values for *Improved Flat Plate Collector* with area of 7,0 m^2

The chart below (chart 4.8.3.1) shows the variation of demand coverage of heating for hot water for particular variants of solar panels. What is more, differences in covering the demand for DHW production for different collector area do not cause the change in the Annual Heating Demand even by a 1 kWh/(m^2a).

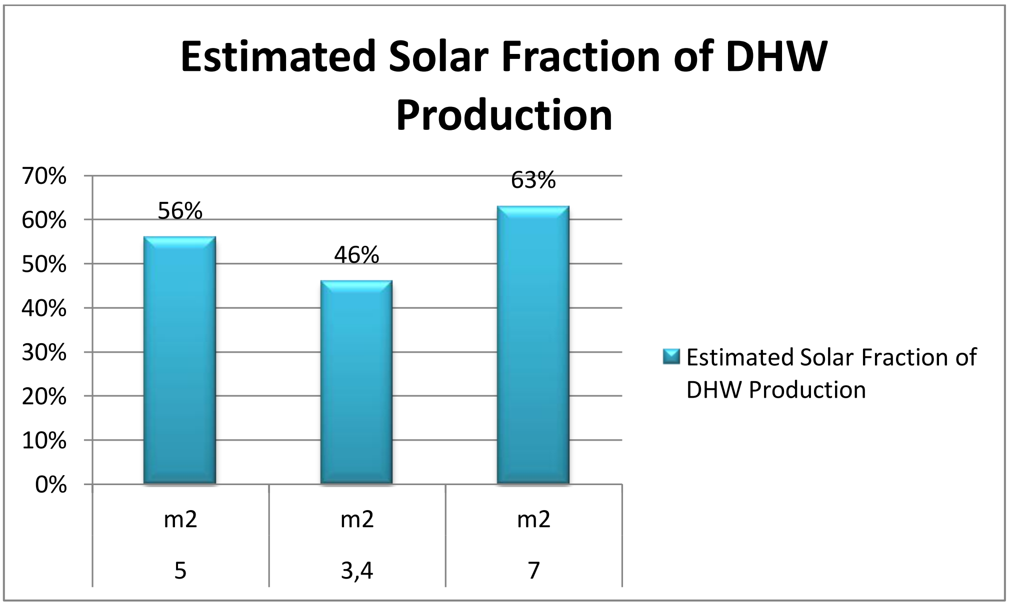


Chart 4.2 Estimate solar fraction of Domestic Hot Water Production – dates calculated with using PHPP program

To show the properties of assumed collectors, few charts have been prepared. On these on graph (Chart 4.2), the relationship between the type of collector and monthly heating load has been illustrated. Adopted collector surface area is 3.4 m2. Collectors, which were taken from the account are: Standard Flat Plate Collector, Flat Plate Collector Improved and Vacuum Tube Collector. They are collectors suggested by the PHPP. Individual their parameters are compiled from the tables below (Table 4.9-11).

Table 4.9 Data for Standard Flat Plate Collector with area of 3,4 m^2

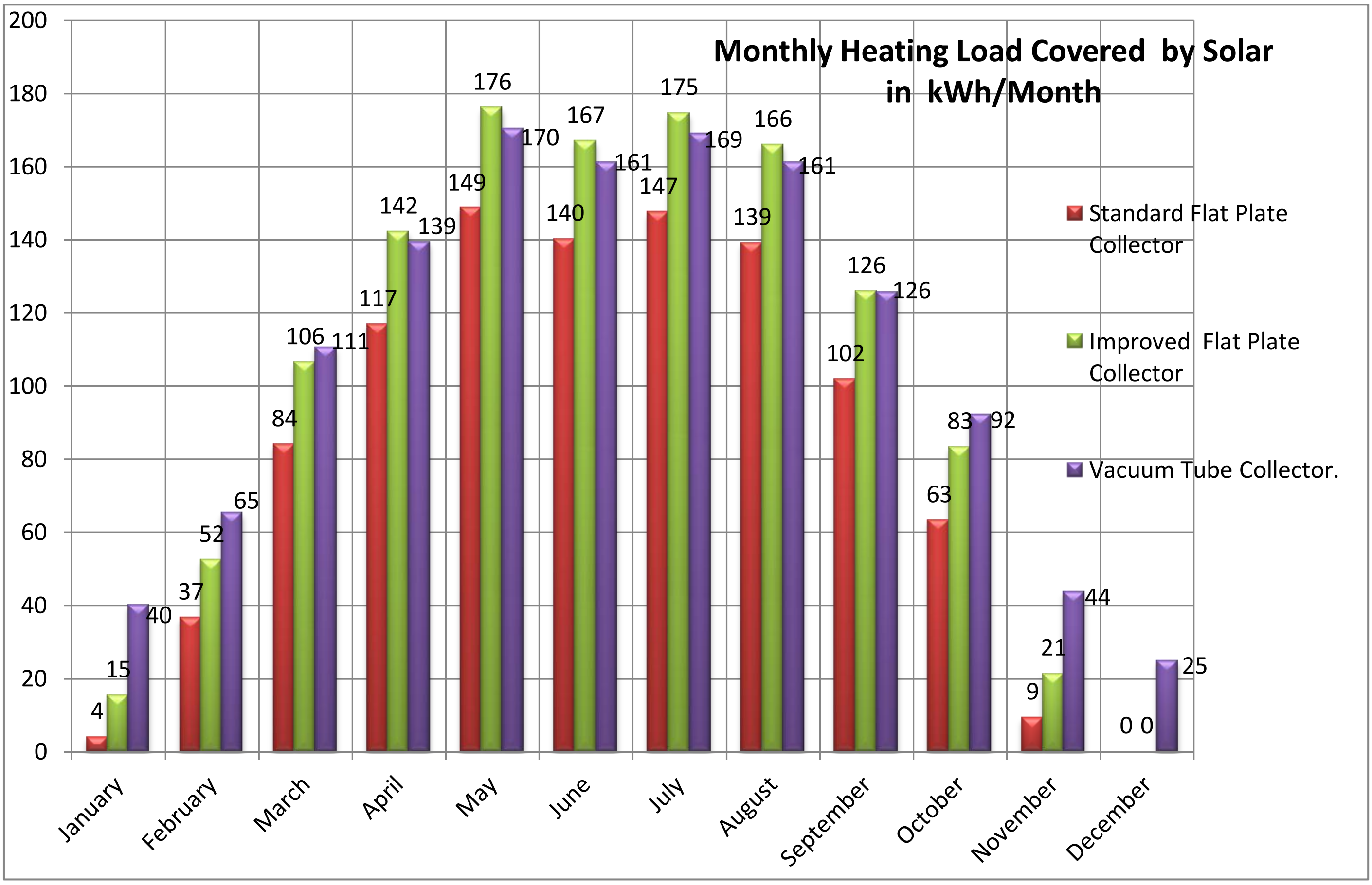
Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	101	159	278	362	464	432	460	433	321	228	108	66	kWh/Month
Monthly Solar Fraction	0,02	0,17	0,38	0,53	0,67	0,63	0,67	0,63	0,46	0,29	0,04	0,00	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	kWh/Month
Monthly Heating Load Covered by Solar	4	37	84	117	149	140	147	139	102	63	9	0	kWh/Month

Table 4.10 Data for Improved Flat Plate Collector with area of 3,4 m^2

Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	101	159	278	362	464	432	460	433	321	228	108	66	kWh/Month
Monthly Solar Fraction	0,07	0,24	0,48	0,64	0,80	0,76	0,79	0,75	0,57	0,38	0,10	0,00	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	kWh/Month
Monthly Heating Load Covered by Solar	15	52	106	142	176	167	175	166	126	83	21	0	kWh/Month

Table 4.11 Data for Improved Vacuum Tube Collector with area of 3,4 m^2

Monthly Solar Fraction	anuary	ebruary	Aarch	April	May	June	July	ugust	eptember	Dctober	lovember	ecember	
Radiation on Tilted Collector Surface	101	159	278	362	464	432	460	433	321	228	108	66	Wh/Month
Monthly Solar Fraction	0,18	0,30	0,50	0,63	0,77	0,73	0,77	0,73	0,57	0,42	0,20	0,11	-
Total Monthly Heating Load DHW Production	221	221	221	221	221	221	221	221	221	221	221	221	Wh/Month
Monthly Heating Load Covered by Solar	40	65	111	139	170	161	169	161	126	92	44	25	Wh/Month



Charts 4.3 Monthly Heating Load Covered by Solar with using variety kind of solar panels.

As is apparent from this chart (Chart 4.3) the smallest covering the heat demand by the sun we achieve by applying standard plate solar panels. The difference between the Improved Flat Plate Collector and Vacuum Tube Collector lies in the fact that they are more efficient in other months of the year. Improved Flat Plate Collector from April to August cover more demand for heat than the Vacuum Tube Collectors. However, these second one compensate gains in September. From this month until March will see a significant advantage in the production of hot water for this collectors. Vacuum Tube Collector, as the only one obtains a heat to Domestic Hot Water in December

4.9. Thermal bridges

The conductivities of thermal bridges have been calculated in software Therm 7.2. After preliminary calculations, it turned out that the influence of thermal bridges at the annual heat demand is quite high. Therefore, after the execution and implementation of the results to the program PHPP, annual heating demand increased by about 10 kWh/(m2a). For this reason I decided to increase the thickness of exterior wall insulation of about 10 cm. Additionally, in some places I made the decision to secure the connection of the internal wall with exterior using the polyurethane boards with a thickness of 5 cm on the surface of the adjacent exterior walls.

However, the achievement the required for value of the coefficient less than or equal to 0.1 W/(m·K) wasn't be possible. In refurbishments of existing buildings, it is not always possible to largely eliminate thermal bridge effects with justifiable effort as is necessary for Passive House new builds. Nevertheless, thermal bridge effects must always be avoided or minimised as much as possible while ensuring cost-effectiveness. In the considered building, I had a deal only with insulation on the inner side walls. This meant that the first coefficient of thermal bridges significantly exceed the maxim value by as much as 4-5 times. Such a situation like this occurred in the building. In some places, I made the decision to stay with the obtained values, because a value of annual heating demand reached a value of 25kW/(m2a).

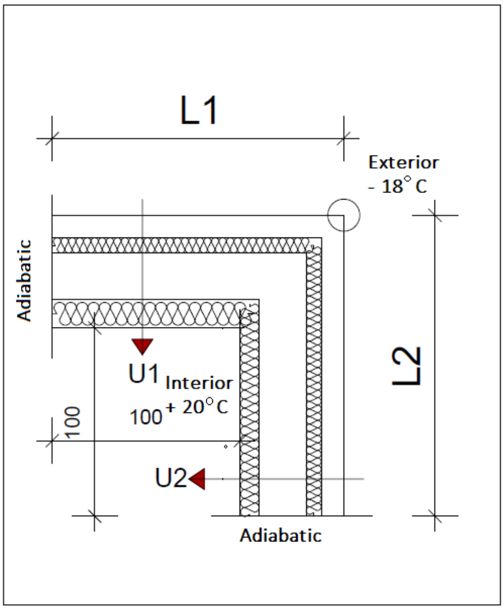
That's why every sensitive spot in the building has been considered separately. The tables below (Tab.12) show a list of all pending thermal bridges together those obtained values of heat flow and thermal bridge coefficient.

Method of determining the linear heat transfer coefficient Ψ for external and internal system for a selected thermal bridge has been presented below. This analogy of calculating has been adopted during computed for each of bridges listed below (Tab. 4.13).

In practical calculations, the linear thermal transmittance - Ψ [W/(m·K)] is used. It is obtained as a result of numerical calculations of individual properties of each thermal bridge. Coefficient Ψ defines the additional value of heat flux caused by thermal bridge and given to 1 of linear meter its length. The value of Ψ affects the entire additional loss over the bridge, which means in case of such losses through the corner of the two branches (the surface of the 2d - in both directions from the inner corner - Figure 4.93-97).

On the basis of the following formula from EN ISO 10211 calculations have been carried out.

$$\Psi = \frac{\phi}{\Delta t} - (U_1 \cdot L_1 + U_1 \cdot L_1)$$



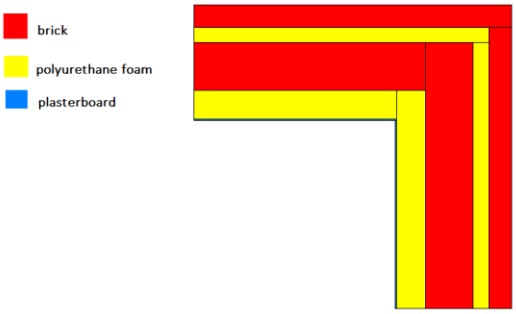


Figure 4.93-94 An example of a thermal bridge: a combination of external walls - corner
scheme assumed for calculation (1) computational model (2)

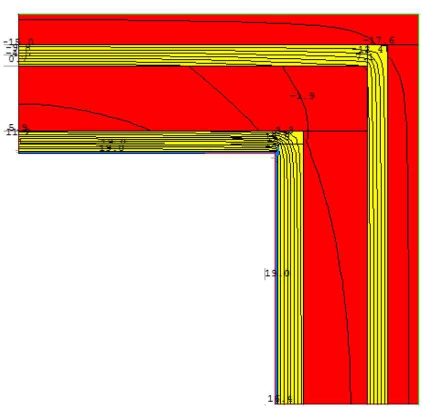


Figure 4.95The temperature distribution - isoterms

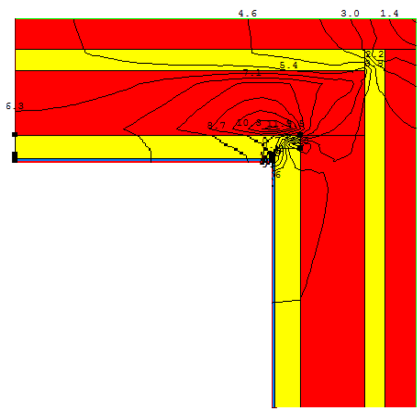


Figure 4.96 The heat flux

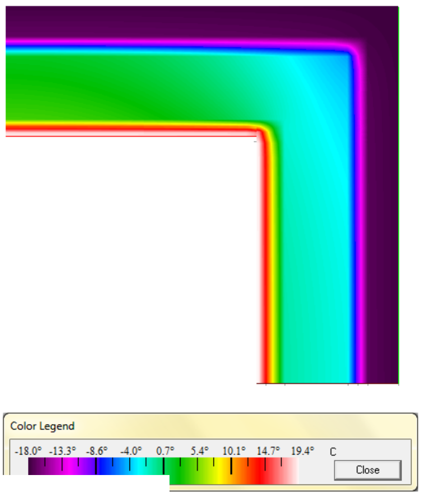
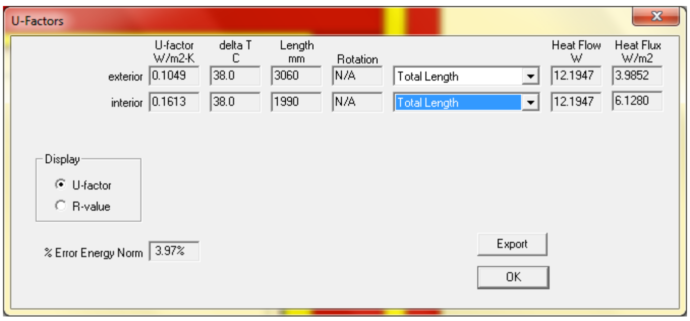
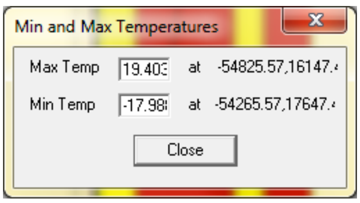


Figure 4.97 Temperature distribution





$$\Psi = \frac{\phi}{\Delta t} - (U_1 \cdot L_1 + U_1 \cdot L_1)$$

$$\Psi = \frac{12{,}19747}{38} - (0{,}093 \cdot 1{,}56 + 0{,}093 \cdot 1{,}56)$$

$$\underline{\Psi = 0{,}038 < 0{,}1}$$

Table 4.12 List of thermal bridges in building considered (results from Therm 7.2).

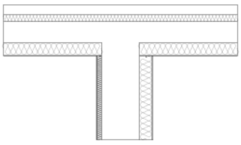
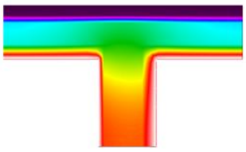
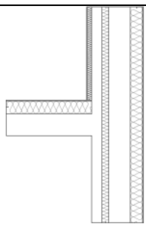
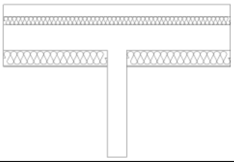
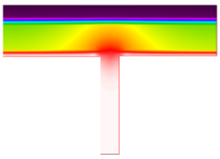
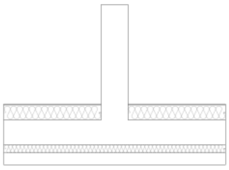
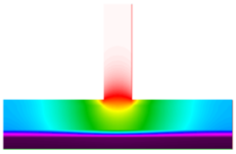
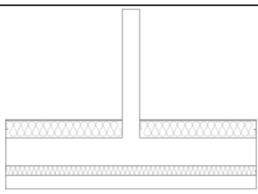
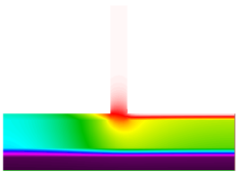
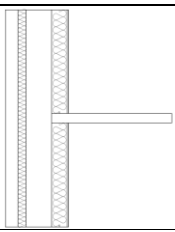
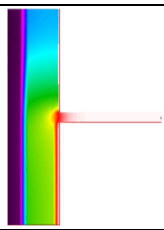
No.	Type		Arrangement of temperature	Heat Flow [W]	Thermal Bridge Coefficient
1.	exterior+interior wall ground floor			12,435	0,071133
2.	exterior+interior wall ground floor			13,6372	0,067203
3.	exterior+interior wall ground floor			15,0637	0,192743
4.	exterior+interior wall ground floor			10,783	0,071723
5.	exterior+interior wall ground floor			12,095	0,106249
6.	exterior+interior wall ground floor			11,225	0,101025

Table 4.9.1 List of thermal bridges in building considered (results from Therm 7.2) -continuation

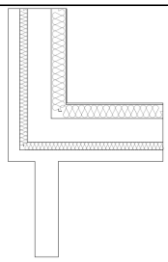
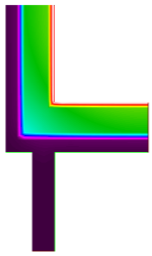
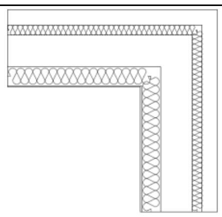
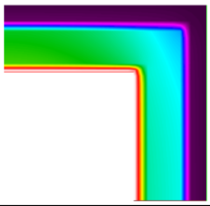
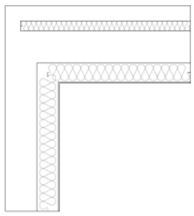
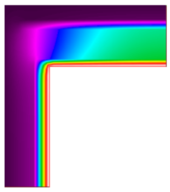
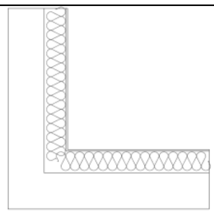
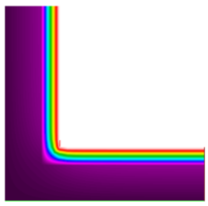
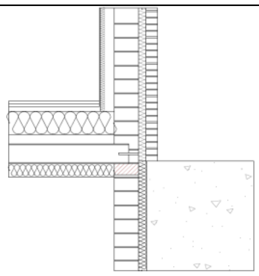
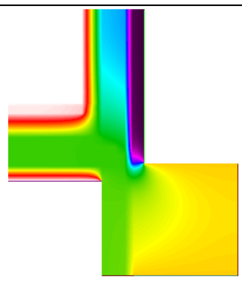
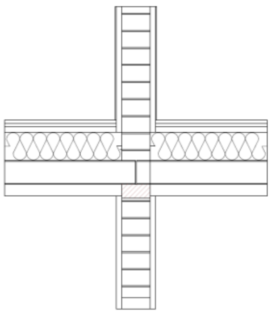
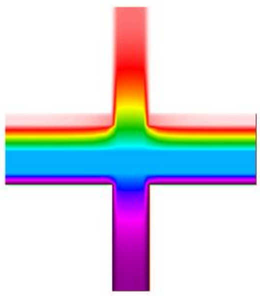
No.	Type		Arrangement of temperature	Heat Flow [W]	Thermal Bridge Coefficient
8.	exterior + interior wall ground floor			13,9562	0,086408
9.	corner of walls ground floor			12,1947	0,037833
10.	corner of walls ground floor			16,0225	0,131155
11.	corner of walls - ground floor			13,6073	0,060007
12.	floor above basement + exterior wall			4,0166	0,022415
13.	floor above basement + int. wall			4.338	0.138

Table 4.9.1 List of thermal bridges in building considered (results from Therm 7.2) -continuation

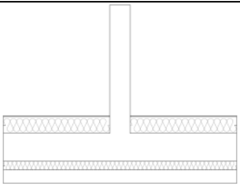
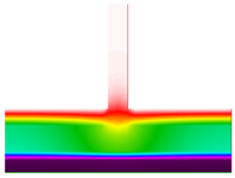
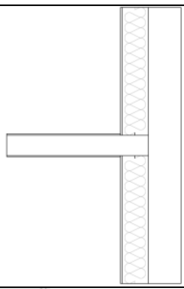
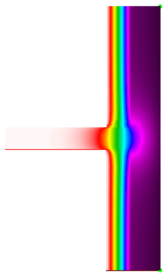
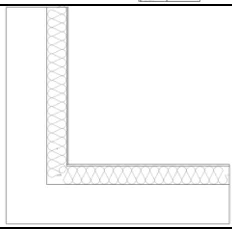
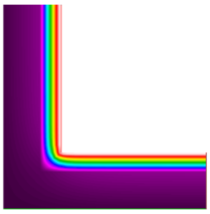
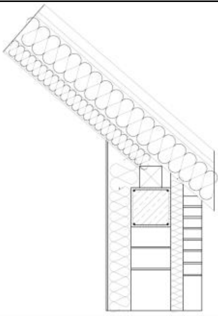
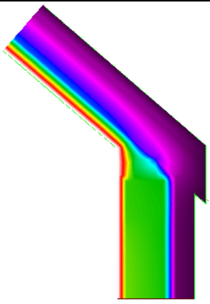
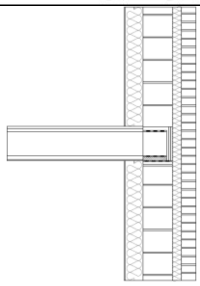
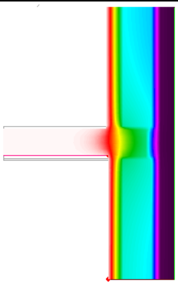
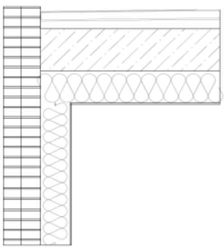
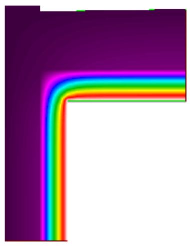
No.	Type		Arrangement of temperature	Heat Flow [W]	Thermal Bridge Coefficient
15.	exterior + interior wall first floor			11,638	0,061031
17.	exterior + interior wall first floor			18,798	0,190124
18.	corner of exterior walls first floor			13,1874	0,090357
19.	exterior wall + roof			12,5592	0,080485
20.	floor above the ground floor + exterior wall			9,3222	0,032677
21.	flat roof + exterior wall			7,8411	-0,07971

Table 4.13 List of thermal bridges in building considered (results from Therm 7.2)

List of thermal bridges									
		ϕ	Δt	$\phi/\Delta t$	L_1	L_1	U_2	L_2	Ψ
No.	Name	W/m	°C	W/(m·°C)	W/(m·°C)	m	W/(m·°C)	m	W/(m·°C)
GROUND FLOOR									
1.	exterior + interior wall 1	12,435	38	0,327237	0,093	1,38	0,093	1,38	0,071
2.	exterior + interior wall 2	13,6372	38	0,358874	0,093	1,38	0,108	1,51	0,067
3.	exterior + interior wall 3	15,0637	38	0,396413	0,093	1,095	0,093	1,10	0,193
4.	exterior + interior wall 4	10,783	38	0,283763	0,093	1,14	0,093	1,14	0,072
5.	exterior + interior wall 5	12,095	38	0,318289	0,093	1,075	0,093	1,075	0,106
6.	exterior + interior wall 6	11,225	38	0,295395	0,093	1,05	0,093	1,05	0,101
7.	exterior + interior wall 7	15,1948	38	0,399863	0,138	1,14	0,093	1,14	0,137
8.	corner of walls	13,9562	38	0,367268	0,093	1,51	0,093	1,51	0,086
9.	corner of walls	12,1947	38	0,320913	0,093	1,56	0,093	1,50	0,038
10.	corner of walls	16,0225	38	0,421645	0,108	1,51	0,093	1,37	0,131
11.	corner of walls	13,6073	38	0,358087	0,108	1,38	0,108	1,38	0,060
12.	a) floor above basement + ext. wall	4,0166	38	0,1057	0,064	1,45	0,093	1,64	-0,140
	b) floor above basement + ext. wall	4,0166	15	0,267773	0,064	1,45	0,093	1,64	0,022
	c) floor above basement + ext. wall	4,0166	27,7	0,145004	0,064	1,45	0,093	1,64	-0,100
13.	floor above basement + int. wall	4,338	15	0,2892	0,064	1,18	0,064	1,18	0,138
FIRST FLOOR									
14.	exterior + interior wall 8	14,2909	38	0,376076	0,093	1,06	0,093	1,06	0,179
15.	exterior + interior wall 9	11,638	38	0,306263	0,093	1,32	0,093	1,32	0,061
16.	exterior + interior wall 10	17,177	38	0,452026	0,141	1,06	0,141	1,06	0,153
17.	exterior + interior wall 11	18,798	38	0,494684	0,141	1,08	0,141	1,08	0,190
18.	corner of walls	13,1874	38	0,347037	0,093	1,38	0,093	1,38	0,090
19.	roof + exterior wall	12,5592	38	0,330505	0,088	1,33	0,122	1,09	0,080
20.	floor above ground floor + ext. wall	9,3222	38	0,245321	0,093	1,14	0,093	1,14	0,033
21.	Roof - terrace + exterior wall	7,8411	38	0,206345	0,084	1,31	0,108	1,63	-0,080

5 . Conclucions

5.1 General conclusion

The aim of my work was the refurbishment of a heritage building according to EnerPHit standard requirements of Passivhaus Institute.

From the beginning of my work on this project I was struggling with a number of problems and inconsistencies regarding the building itself because of the lack of precise drawings and technical description. I devoted a lot of time to find accurate data on the components of the building. Subsequently, the decision to adopt appropriate data, conditions, assumptions and specific solutions to calculations required a sizeable amount of work. These decisions required adequate knowledge of the buildings erected in the early twentieth century in Poland. In the case of buildings subjected to conservator of monuments supervision, should be paid special attention to preserve the original appearance of the building and its individual elements, doing the least interference on it.

According these principles insulation only can be applied by the inside of the facades as well as between the individual layers of bricks in cavity walls. The insulation by inside reduces the usable area of the house and its interior volume. After performing the insulation with a thickness of 15 cm by the inside of the walls, usable area decreased from 121.43 m^2 to 103.85 m^2. The most important questions waiting to answer were: which material would be better to minimize the thickness of the insulation layer? How this layer should be performed? Chapter 4 is dedicated to the description of the different variants of the materials and methods of its implementation.

Adequate insulation of the old building and the elimination of thermal bridges is a tough task. For the Polish climatic conditions and retrofit buildings, heat transfer coefficient for the exterior wall with internal insulation equals U ≤ 0.2 W/(m^2K). In the first version assumptions has been taken into consideration this condition. The coefficients for the exterior walls has been adopted from 0.120 W/(m^2K) to 0.196 W/(m^2K). However, because of the huge influence of linear thermal bridges, which coefficient was more than 1.0 W/(m·°C) or sometimes 2.0 W/(m°C) lead to the reduction of the U-values. This situation occurred when the insulation with thickness from 5 to 10 cm has been assumed. So I decided to increase the thickness of insulation. Without this, the achievement of the passive house standard would be impossible. It results from the fact that after entering the values of the thermal bridges coefficients, the level of energy demand for the building amounted to 33.06 kWh/(m^2a). Unfortunately, this value significantly exceeded the Passive House limit of 25 kWh/(m^2a). The use of thicker insulation from the inside considerably reduced the loss by the influence of thermal bridges. New U-values for the insulation of the same material gave a value from 0.088 to 0.196 W/(m^2K). It caused decrease of Thermal Bridge Heat Losses from 6.2 kWh/(m^2a) to 2,7 kWh/(m^2a).

The table 5.1 and the chart 5.1 depict data and values for annual heating demand, heat load and primary energy for space heating and dehumidification, cooling, household electricity for the insulation versions considered, getting clear the differences on energy demand, or the impact of the insulation on the results we get. It shows that with proper building insulation the value of annual heating demand has decreased by more than 12 times, and the demand for primary energy has decreased 4 times.

Table 5.1 Comparison between different versions of assumed insulations for considered building

	without insulation	1st version	2sd version
Insulation			
1)Exterior wall 1 45 cm [U [W/(m^{2}K)]	1.402	0.157	0.093
2)Exterior wall 2 25 cm [U [W/(m^{2}K)]	1.795	0.173	0.141
3)Exterior wall 3.1 [U [W/(m^{2}K)]	1.409	0.169	0.138
4)Wall - substantial thermal bridges [U [W/(m^{2}K)]	2.025	0.120	0.095
5)Exterior wall 3.2 [U [W/(m^{2}K)]	0.092	0.154	0.092
6)Exterior wall 4.1 [U [W/(m^{2}K)]	1.177	0.155	0.092
7)Exterior wall 4.2 [U [W/(m^{2}K)]	1.222	0.154	0.092
8)Exterior wall 4.3 [U [W/(m^{2}K)]	1.329	0.196	0.196
9)Floor above residential part of the building [U [W/(m^{2}K)]	1.641	0,086	0.064
10)Terrace [U [W/(m^{2}K)]	0.985	0.084	0.084
11)Roof [U [W/(m^{2}K)]	1.601	0.088	0.088
12) Floor above I storey [U [W/(m^{2}K)]	0.451	0.073	0.073
MRV – Zenhder 200			
Solar installation: Solar panels (3,4m^2) – Improved Flat Plate Collector + Stratified Solar Storage			
Annual heating demand [kWh/(m2a)]	297.18	33.06	**24.1**
Heating Load [W/m^2]	101	19	**16**
Primary energy [kWh/(m^{2}a)] Space heating and dehumidification, cooling, household electricity.	432	108	**100**
The coefficients for thermal bridges haven't been changed			

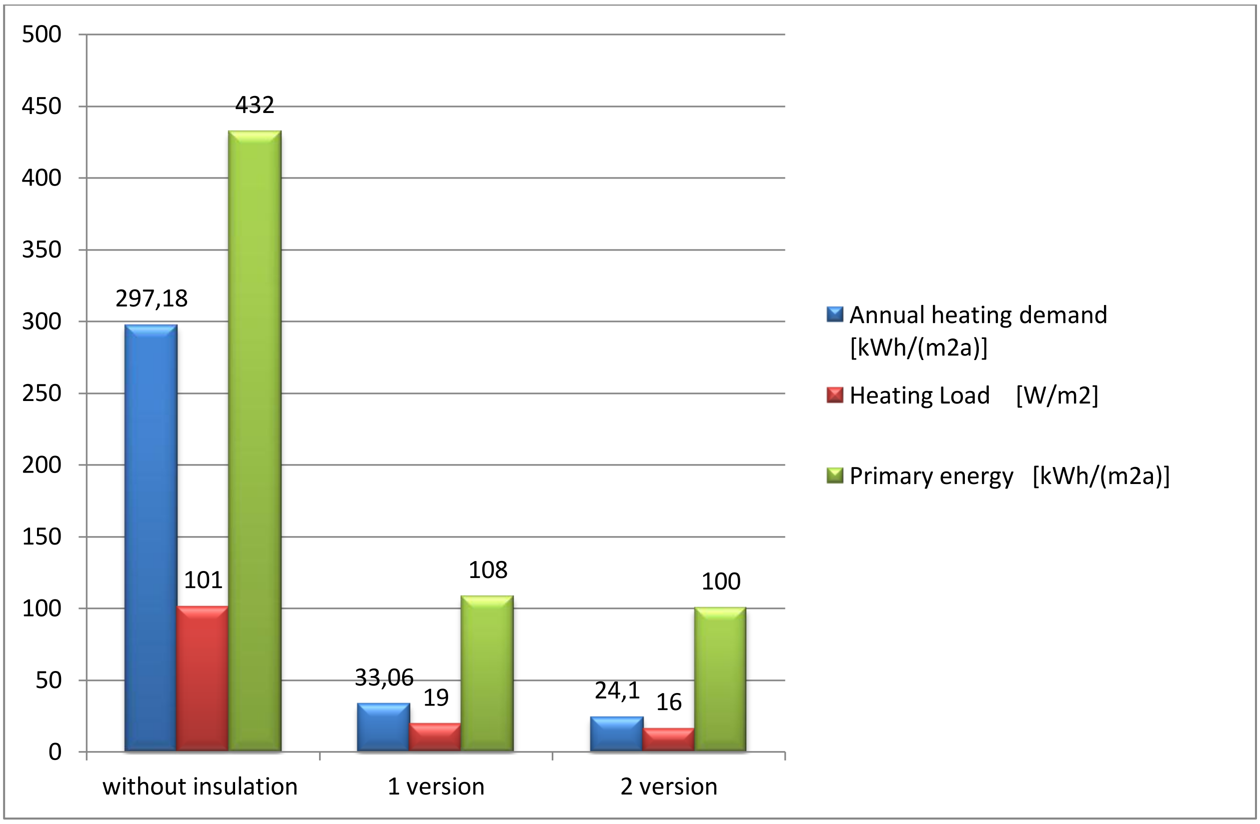


Chart 5.1 Comparison of different version of assumed insulation– annual heating demand, heating load, primary energy

So, I have achieved the goal of my work. This retrofitted house, which I was working on, meets the requirements according to passive house (EnerPHit) standard. Therefore, to achieve this purpose have been used components, materials and equipments with very good thermal performance. Renovation of this kind of old and often neglected buildings is associated with a high number of repairs and renovations of individual components. However, restoring the glamour of this type of buildings gives a lot of satisfaction and a beautiful effect. Moreover, in accordance with European Union directives should be invested a great effort in existing buildings retrofitting, upgrading them, preserving its patrimonial value.

4.10.2 Future perspective

After finishing this work, retrofitting of a old house in Polish climatic conditions, the question of development more precise requirements for the individual parameters for building elements such as insulation, glazing comes to mind. In colder regions of the world and especially in the case of old buildings insulated only from the inside, the impact of thermal bridges is so significant that it should push institutions involved in the development of new solutions, to focus on this problem of heat losses in these crucial areas.

In particular, the focus should be on the proposed solutions and requirements for colder climates, in which the passive house standard is not entirely justified economically because of the high cost of investment in the construction or refurbishment. Today, in the era of rising prices of fuel, and the need to get energy from renewable sources, people are indirectly forced to improve the energy performance of their homes. That is a reality. In order to encourage greater number of people to take the opportunities to get cheaper operation during the life cycle of buildings, the retrofitting with efficient passive measures must be incentivized. As, the lack of knowledge determines the human aversion to new ideas and solutions, the knowledge to achieve high efficient building with almost passive solutions must be spread.

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Annex 1

Energy calculation according to Passive House Planning Package (PHPP)

PHPP program is a tool for the design of passive houses. It can also be used for design energy-efficient buildings and thermal upgrading. The calculations obtained in this program are the basis for the certification of passive houses.
PHPP is the Microsoft Excel document which combines different worksheets responsible for specific calculations and results. It allows to take into account, inter alia, such factors as, inter alia: building envelope, linear thermal bridges, the type of window frames, the parameters of mechanical ventilation, the tightness of the building, use regime of the building, or to estimate the heat from internal gains from people, devices, and solar radiation. With this tool can be easily obtain such data as the demand for thermal power, seasonal heat demand, the demand for primary energy, heat losses for central heating and domestic hot water It is also possible to check how the building behaves during the summer, as often there is a risk of overheating. The software also allows you to calculate the planned cost of heating the building - operation.

Figure 1 present the flow chart of sequence of entries for respective worksheets according to PHPP.

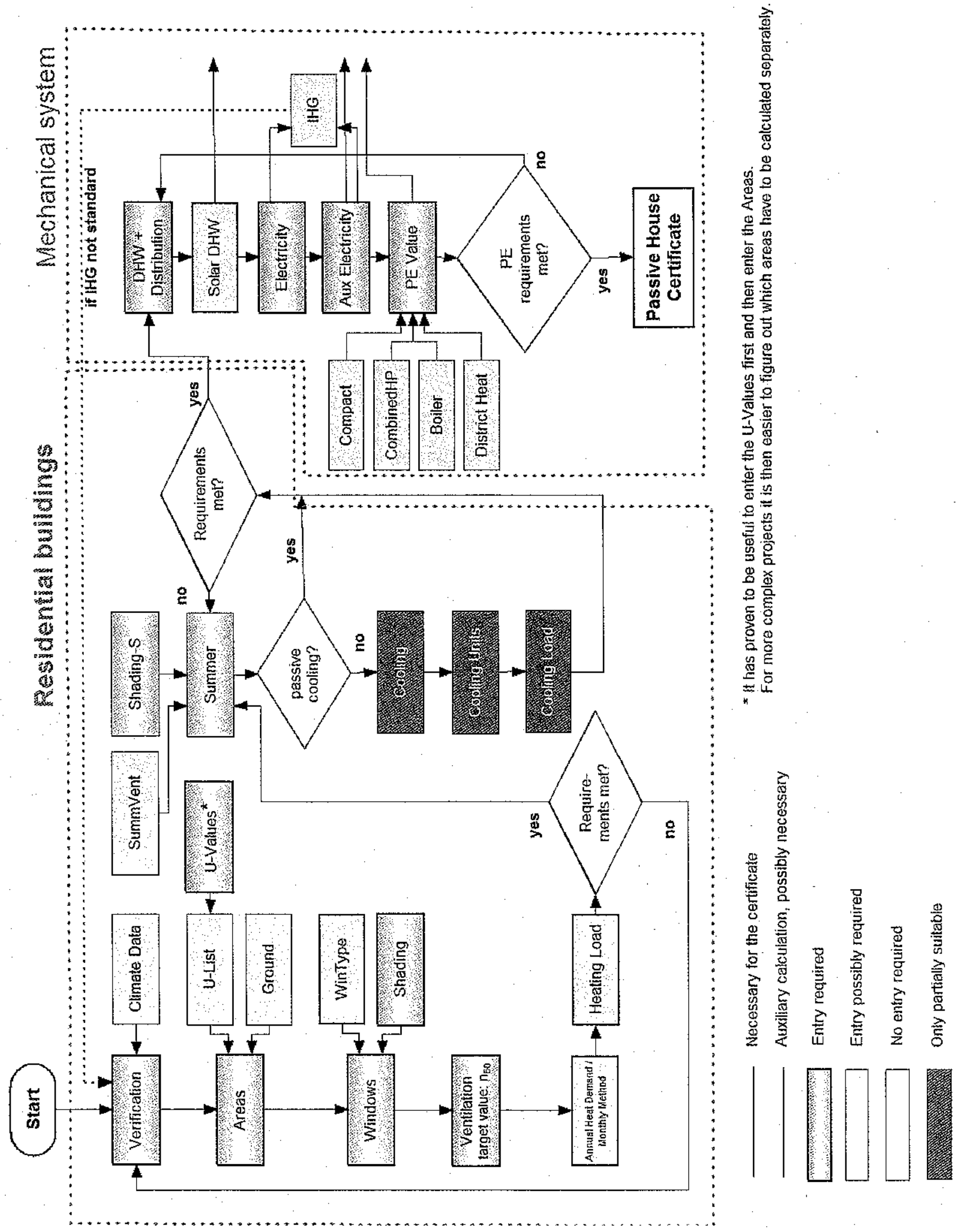


Figure 1 Flow chart of sequence of entries according to PHPP

Source: Manual Passive House Planning Package 7, PassivHause Institute, Germany

1. Structure of PHPP worksheets

All of these worksheets can be found in Annex 2.

1.1 "Brief Instructions" Worksheet

General overview and instructions on the work in worksheets listed below.

1.2 "Verifications" Worksheet

Every import and initial data of the building must be entered in this worksheet. Any energy values such as: Specific building demands with reference to the treated floor area can be found there. The most important data given are listed below (Tab. 1.2.1):

Table 1.2 1. Data and results from Verificaton worksheet (PHPP)

Year of Construction	1910
Building type	Residental Building
Utilisation pattern	Dwelling
Number of Dwelling Units	1
Enclosed Volume V_e	366,0 m^3
Number of Occupants	3,0 (planned number of occupants – verification)
Interior Temperature	20°C
Certification type	EnerPHit Building retrofit (acc. to heating demand)
Internal Heat Gains	2,1 W/m^2
Annual heating demand	24,04 $kWh/(m^2a)$
Heating load	16 W/m^2
Frequency of overheating (>25°C)	1,9 %
Pressurization test result n_{50}	0,6 1/h

Screenshots from this worksheet can be found in Annex 2 point 1.

1.3 „Areas" Worksheet

Summary list of areas with issuing to them of the appropriate U-values, the balance of radiation and thermal bridges.

Screenshots from this worksheet can be found in Annex 2 point 2.

1.4 "U- List" Worksheet

List of building elements with appropriate U-values and thickness, such as: exterior walls, floors, roof is given in the end after fulfillment U-Values worksheet.

Screenshots from this worksheet can be found in Annex 2 point 3.

1.5 "U- Values" Worksheet

The calculation of the U opaque envelope: according to PHPP calculation based on the standard EN 6946 [Polish equivalent: BS EN ISO 6946:2008 - Building components and building elements. Thermal resistance and heat transfer coefficients. Calculation Method], the measured values coefficients of thermal conductivity according to national standards, or on the basis of the authorization building inspection.

Screenshots from this worksheet can be found in Annex 2 point 4.

1.6 "Ground" Worksheet

The calculation of the round reduction factor (for Annual Hating Demand sheet), monthly average ground temperatures (for Monthly Method sheet), design ground temperature (for Heating and Cooling Load sheets). The results are listed below (Tab. 1.6.1,2). Only the case of unheated basement was considered.

Table 1.6.1 Results from Ground worksheet (PHPP)

Ground reduction factor	0,58
Design ground temperature for Heating Load sheet	9,5
Design ground temperature for Cooling Load sheet	13,4

Table 1.6.2 Results from Ground worksheet (PHPP)

Monthly Average Ground Temperatures													
Month	1	2	3	4	5	6	7	8	9	10	11	12	Average values
Winter	9,7	9,5	9,7	10,3	11,1	11,9	12,5	12,8	12,5	11,9	11,1	10,3	11,1
Summer	10,3	10,2	10,3	10,9	11,8	12,6	13,2	13,4	13,2	12,6	11,8	10,9	11,8

Screenshots from this worksheet can be found in Annex 2 point 5.

1.7 "Windows" Worksheet

The data, such as: heat transfer coefficient of windows, installation and frame thermal bridges are linked automatically with the "WinType" worksheet. The most important results is annual transmission losses through the windows and heat gains from solar radiation. They are presented in a table below (Tab. 1.7.1):

Table 1.7.1 Results from Windows worksheet (PHPP)

Window area orientation	Tansmission losses	Heat gains solar radiation
	kWh/a	kWh/a
North	178	45
East	492	321
South	652	805
West	157	71
Total Value for all windows	1479	1242

Screenshots from this worksheet can be found in Annex 2 point 6.

1.8 "WinType" Worksheet

List of windows and glazing used with their properties assumed.

Types of glazing and window frame were chosen from Database of Certified Passive House Components (Tab. 1.8.1). Table 1.8.2 presents particular values for all window based on data from technical data sheets, which are attached in Annex 4.

Table 1.8.1 Type of glazing and frame assumed to calculation in PHPP.

Glazing	Category: Manufacturer: Product name: U_w : g (PHPP): U_g (PHPP):	Fixed glazing POL-SKONE Sp. z o. o. Poland EC90 PLUS ALU EFFECT Fix 0,79 W/(m^{2}K) ≤ 0,80 W/(m^{2}K) 0,49 0,64 W/(m^{2}K)
Frame	Category: Manufacturer: Product name: U_w :	Window Frame Green Building Store United Kingdom Ecocontract ULTRA 0,80 W/(m^{2}K) ≤ 0,80 W/(m^{2}K)

Table 1.8.2 Particular values for windows assumed for calculation in PHPP.

PRE Passive House frame; good thermal quality			
Uf-Value	Frame Dimensions	Thermal bridges	
Frame: left, right, bottom, top	Width for left, right, below, above frame	Glazing edge thermal bridge	Installation thermal bridge
		For left, right, bottom and top edge	For left, right, bottom and top insulation
W/(m²K)	m	W/(mK)	W/(mK)
0,72	0,140	0,028	0,002

Screenshots from this worksheet can be found in Annex 2 point 7.

1.9 „Shading" Worksheet

The calculation of the reduction factor for shading (Tab.1.9.1).
In this worksheet none shading objects were assumed, because it is detached house next to cemetery. In the surrounding area there are any building that could cause shading of the building considered.

Table 1.9.1 Values of reduction factor from Shading worksheet (PHPP)

Orientation	Glazing area m^2	Reduction factor r_s
North	1,54	76 %
East	4,84	75 %
South	6,28	77 %
West	1,11	73 %

Screenshots from this worksheet can be found in Annex 2 point 8.

1.10 „Ventilation" Worksheet

Calculation of ventilation airflow, the efficiency of the device and the evaluation of the leak test.

Description of particular device, ducts have been described in previous second chapter Chapter 2, point 4 "Mechanical Ventilation). Table below (Tab. 1.10.1) presents the most important values, which have been obtained in this sheet.

Table 1.10.1 Results from Ventilation sheet (PHPP)

Design air flow rate (maximum)	120 (m^3/h)
Average air flow rate	92 (m^3/h)
Average air change rate	0,35 (1/h)
Effective heat recovery efficiency $H_{HR,eff}$	90,7 %
Specific power input	0,42 Wh/m^3

Screenshots from this worksheet can be found in Annex 2 point 9.

1.11 "Annual Heating Demand" Worksheet

Parameters evaluation of the heat demand for space heating according to PHPP - Annual method. This worksheet sums up all of the heat losses and heat gains. In this worksheet no data is required. Below (Tab. 1.11.1) are presented a results of total annual heat losses and heat gains:

Table 1.11.1 Results from Annual Heating Demand sheet (PHPP)

Transmission Heat Losses (Q_T)	Q_T=39,8 kWh/(m^2a)
Transmission Heat Losses (Q_T)	Q_T=40,5 kWh/(m^2a)
Ventilation Heat Losses (Q_V)	Q_V=6,0 kWh/(m^2a)
Available Solar Heat Gains (Q_S)	Q_S =11,8 kWh/(m^2a)
Tptal Heat Losses (Q_L)	Q_L=46,5 kWh/(m^2a)
Internal Heat Gains (QI)	QI = 10,9 kWh/(m^2a)
Heat Gains (Q_G)	Q_G = 22,4 kWh/(m^2a)
Annual Heating Demand (Q_H)	Q_H = **24,08** kWh/(m^2a)

Screenshots from this worksheet can be found in Annex 2 point 10.

1.12 "Monthly Method" Worksheet

Parameters evaluation the heat demand for heating in the method monthly. In this worksheet no data is required as well. Below (Tab. 1.12.1) are presented a results of total annual heat losses and heat gains:

Table 1.12.1 Results from Monthly Method sheet (PHPP)

Transmission Heat Losses (Q_T)	Q_T=39,8 kWh/(m^2a)
Ventilation Heat Losses (Q_V)	Q_V=5,9 kWh/(m^2a)
Available Solar Heat Gains (Q_S)	Q_S =11,6 kWh/(m^2a)
Tptal Heat Losses (Q_L)	Q_L=45,6 kWh/(m^2a)

Table 1.12.1 Results from Monthly Method sheet (PHPP) - continuation

Internal Heat Gains (QI)	QI = 10,7kWh/(m^2a)
Heat Gains (Q_G)	Q_G = 22,1kWh/(m^2a)
Annual Heating Demand (Q_H)	Q_H = **23,54** kWh/(m^2a)

The difference in the result between annual and monthly method is only 0,54 kWh/(m^2a).

Screenshots from this worksheet can be found in Annex 2 point 11.

1.13 "Heating Load" Worksheet

Evaluation of heating power according to PHPP. It is based on the results of dynamic building simulations. According to this way of calculation, the maximum heating load may occur in two situations depending on the weather conditions: cold but sunny winter day with a cloudless sky or a moderately cold overcast day with minimal solar radiation. Table below presents results of calculations (Tab.1.13.1)

Table 1.13.1 Results from Head Load sheet (PHPP)

	Situation 1	Situation 2
Transmission Heat Losses P_T	1477 W	1195 W
Ventilatioeating Load P_V	449W	361W
Total Heating Load P_L $P_L = P_T + P_V$	1926 W	1556 W
Solar heating power P_S	89 W	39 W
Internal heating power P_I	169 W	169 W
Heating power (gains) P_G $P_S + P_I$ $P_L - P_G$	 257 W 1669 W	 208 W 1348 W
Heating Load P_H	1669W	
Specific Heating Load P_H/A_{TFA}	15,8 W/m^2	
Heating Load Transported by Supply Air $P_{Sypply\ Air,\ MAx}$	1369 W	

The condition for using fresh air as a heat source is:

$$P_H \leq P_{Sypply\ Air,\ Max}$$

1669 ≥ 1369 W

An extra auxiliary heat source has been assumed in "PE" worksheet.

Screenshots from this worksheet can be found in Annex 2 point 12.

1.14 "Summer" Worksheet

Calculation of the incidence of excessive temperatures in the summer. In the certified buildings assessment of summer comfort must be carried. Calculations in PHPP to assess the overheating of the building in the summer reflect average values for the whole building. This assessment shows if the additional window measures are necessary.

Data has been entered:

- "Specific Capacity" – the effective thermal storage capacity of the building; Value assumed: 132 Wh/K pro m^2TFA
- "Overheating limit" – the maximum temperature for an indoor comfort; Value assumed: 25°C
- Summer Ventilation
  Air Change Rate by Natural (Windows & Leakages) or Exhaust-Only Mechanical Ventilation, Summer: 0,27 (1/h) – values taken from "Summer Ventilation" sheet.
- Mechanical Ventilation Summer: 0,30 (1/h)
- Additional Summer Ventilation for Cooling:
  Selected: Window Night Ventilation, Manual
  Corresponding Air Change Rate: 0,11 (1/h)
  Minimum Acceptable Indoor Temperature: 22°C

In the result the frequency of Overheating amounted: **1,9%.** In the case when "frequency over 25°C" exceeds 10%, additional measures to protect against summer heat waves are necessary.

Screenshots from this worksheet can be found in Annex 2 point 13.

1.15 "Shading-S" Worksheet

Calculation of the correction factor for shading in the summer. Most of the data is transferred to this table from the "Shading" worksheet. But two columns had to be fulfilled, namely:

- "Additional Shading Reduction Factor (Summer)" r_{other}:
  value has been assumed the same as in Shading worksheet: 80%
- "Reduction factor z for temporary sun protection" z:
- value entered based on equation below:

$$z_{effective}=0,3+0,7\cdot z$$

z- reduction factor for temporary shading devices
value for blinds, vertical lamellas in interior position: 0,7 (values form table number 5 in Manual.

$$z_{effective}=0,3+0,7\cdot 0,7=0,79$$

This values was assumed only for windows orientated on the south.

Results of shading factor are listed below (Tab. 1.15.1).

Table 1.15.1 Results from Shading-S sheet (PHPP)

Orientation	Glazing area	Summer shading factor
	m²	r_S
North	1,54	76%
East	4,84	78%
South	6,28	60%
West	1,11	77%

Screenshots from this worksheet can be found in Annex 2 point 14.

1.16 "SummVent" Worksheet

Estimating the size of the vent stream in summer. Results from this sheet have been transferred into Summer worksheet.

Screenshots from this worksheet can be found in Annex 2 point 15.

1.17 „Cooling" Worksheet

The calculation of the annual cooling demand, if used for active cooling system.

In this case there is no need to use mechanical cooling system, due to the climate and weather conditions during the summer.

Screenshots from this worksheet can be found in Annex 2 point 16.

1.18 „Cooling Units" Worksheet

The calculation of the energy demand for cooling devices, if it has been applied.
This does not apply.

1.19 "Cooling Load" Worksheet

Calculation daily average cooling load if the system of active cooling was used.

Its main objective is to calculate the cooling load during the summer design day. In order to do this, firstly ventilation and transmission heat losses are calculated. Then, solar and internal heat loads are generated. In the end of calculation, the difference between heat losses and heat gains determines the specific maximum cooling load.

In the result for this considered house, the value of Specific Maximum Cooling Load is 10,5 W/m^2. In the end of this worksheet the values of Daly Temperature Swing due to Solar Load is given. Its value should be less than 3K. For this case this value has been obtained on the level of 1.5K. Requirement has been met.

Screenshots from this worksheet can be found in Annex 2 point 17.

1.20 "DHW + Distribution" Worksheet

Calculation of heat loss through the distribution (Domestic Hot Water and Heating.
Any assumption have been described in Chapter number 2 (point 4). Below are presented particular values for calculation and results (Tab. 1.20.1,2,3,4).

Table 1.20.1 Data entered and results of Space Heat Distribution from DHW + Distribution sheet (PHPP)

Space Heat Distribution		
Length of Distribution Pipes	L_H	40,8 m
Heat Loss Coefficient per Pipe	Ψ	0,364 W/(mK)
Temperature of the Room Through Which the Pipes	ϑ x	20°C
Design Flow Temperature	ϑ dist	55°C
Design System heating load	$P_{heating}$	1,65 kW
Design Return Temperature =0.714*(ϑ dist-20)+20	ϑ R	45 °C
Annual Heat Emission per m of Plumbing = Ψ (ϑ m- ϑ x) $t_{Heating}$*0.024	q^*_{HL}	22 kWh/(m·a)
Possible Utilization Factor of Released Heat	η_G	93%
Annual Losses $Q_{HL} = L_H \cdot q^*_{HL} \cdot (1-\eta_G)$	**Q_{HL}**	**66 kWh/a**
Specif. Losses = $\sum Q_{HL} / A_{TFA}$	**q_{HL}**	**0,6 kWh/(m²a)**
Performance ratio of heat distribution = $(q_H + q_{HL}) / q_H$	**$E_{a,HL}$**	**103%**

Table 1.20.2 Data entered and results of DHW: Standard Useful Heat from DHW + Distribution sheet (PHPP)

DHW: Standard Useful Heat		
DHW Consumption per Person and Day (60 °C)	V_{DHW}	25,0 Litre/Person/d
Average Cold Water Temperature of the Supply	ϑ_{DW}	9,7 °C
DHW Non-Electric Wash and Dish	Q_{DHW}	229 kWh/a
Useful Heat - DHW	q_{DHW}	**1830 kWh/a**
Specif. Useful Heat – DHW = Q_{DHW} / A_{TFA}	$P_{heating}$	**17,4 kWh/(m²a)**

Table 1.20.3 Data entered and results of DHW Distribution and Storage from DHW + Distribution sheet (PHPP)

DHW Distribution and Storage		
Length of Circulation Pipes (Flow + Return)	L_H	31,4 m
Heat Loss Coefficient per m Pipe	Ψ	0,171 W/m/K
Temperature of the Room Through Which the Pipes	ϑ x	20°C
Design Flow Temperature	ϑ dist	60°C
Daily circulation period of operation	t_{Circ}	18 h/d
Design Return Temperature =0.875*(ϑ dist-20)+20	ϑ R	55 °C
Circulation period of operation per year = 365 td_{Circ}	t_{Circ}	6570 h/a
Annual Heat Released per m of Pipe = Ψ (ϑ m- ϑ x) t_{circ}	q^*_{HL}	42kWh/m/a
Possible Utilization Factor of Released Heat =$t_{heating}$/365d * η_G	η_{GDHW}	55%
Annual Heat Loss from Circulation Lines = $Ls_H \cdot q^*z \cdot (1-\eta_{GDHW})$	Q_Z	**593kWh/a**
Total Length of Individual Pipes	L_U	29,10 m
Exterior Pipe Diameter	d_{U_Pipe}	0,012 m
Heat loss per tap opening =$(c_{pH2O}V_{H2O}+c_{pMat}V_{Mat})(\vartheta_{dist}-\vartheta x)$	$q_{individual}$	0,1042 kWh/tap opening
Amount of tap openings per year =n_{Pers} . 3 . 365 / n_{LU}	n_{Tap}	3295 Tap openings per year
Annual Heat Loss = n_{Tap} . $q_{Individual}$	q_U	343 kWh/a
Possible Utilization Factor of Released Heat =$t_{heating}$/8760*n_G	η_{G_U}	55%
Annual Heat Loss of Individual Pipes = $q_U \cdot (1- n_{G\_U})$	Q_U	**154 kWh/a**
Average Heat Released From Storage	P_S	26 W
Possible Utilization Factor of Released Heat =$t_{heating}$/8760* n_G	η_{G_U}	55 %
Annual Heat Losses from Storage = $P_S \cdot 8.760$ kh$\cdot(1-n_{G_S})$	Q_S	**102 kWh/a**

Table 1.20.4 Results from DHW + Distribution sheet (PHPP)

Total Heat Losses of the DHW System	Q_{WL}	853kWh/a
Specif. Losses of the DHW System	q_{WL}	8,1 kWh/(m²a)
Performance ratio DHW-distribution + storage	$e_{a,WL}$	146,4%
Total Heating Demand of DHW system	Q_{gDHW}	2680 kWh/a
Total Spec. Heating Demand of DHW System	q_{gDHW}	25,4 kWh/(m²a)

Screenshots from this worksheet can be found in Annex 2 point 18.

1.21 „Solar DHW" Worksheet

When using the solar system, the calculation of the degree of coverage of the heat demand for domestic hot water through the solar system.

In Chapter 2 (point 5. The solar installation), all assumptions and results have been described precisely.

Screenshots from this worksheet can be found in Annex 2 point 19.

1.22 "Electricity" Worksheet

This worksheet summarizes the electricity energy demand of all electricity appliances in the building (excluded services for DHW and heat pumps). The calculation of electricity may be provided in two ways. Firstly using the value of planned number of occupants as a basis and secondly using the Treated Floor Area value. Generally, the maximum recommended electricity demand for a Primary Energy demand is 50. The value for considered building reached a value of 45,8 kWh/(m^2a). Electricity Demand amounted to 15,3 kWh/(m^2a), and maximum value is equal 18 kWh/(m^2a).

Screenshots from this worksheet can be found in Annex 2 point 20.

1.23 „Auxiliary Electricity" Worksheet

The calculation of electricity demand by operation unit of the following systems: heating, ventilation, solar thermal systems and DHW. it was assumed that auxiliary electricity will be spent on:
winter and summer ventilation systems, heat exchanger defroster, circulation pump and storage load pump, boiler as a auxiliary energy for DHW system and solar auxiliary electricity systems. The results of the calculations are as follows:

Total Electricity Demand: 668 kWh/a
Specific Electricity Demand: 6,3 kWh/m^2a (divide by Living Area)
Total Primary Energy Demand: 1737kWh/a
Specific Primary Energy Demand: 16,5 kWh/m^2a (divide by Living Area)

Screenshots from this worksheet can be found in Annex 2 point 21.

1.24 ”PE Value” Worksheet

The calculation of primary energy demand.

In this worksheet it is needed to assume how space heating and Domestic Hot Water production are covered. Program PHPP gives a list of different source of energy, such as: heat pumps, compact heat pump unit, boilers, district heating and another combinations. This sheet gives a possibility to combine different way of heating and DHW production. But in this case the percentage of coverage fraction of each should be entered. Otherwise, in the end of primary energy result, the equivalent total annual emission of carbon dioxide is presented. For the considered house it was decided that DHW demand will be fully satisfied by boiler. The results have been listed below:

<u>Heating, Cooling, DHW, Auxiliary and Household Electricity</u>

Total PE Value: 99,5 kWh/(m^2a)

Total Emission CO_2 – Equivalent: 27,0 kg/(m^2a)

<u>Heating, DHW, Auxiliary Electricity (No Household Applications)</u>

Specific PE Demand – Mechanical System: 67,7 kWh/(m^2a)

Total Emissions CO_2 – Equivalent: 18,7 kg/(m^2a)

Screenshots from this worksheet can be found in Annex 2 point 22.

1.25 “Boiler” Worksheet

Selection of the boiler as auxiliary equipment to cover fraction of Space Heating Demand and DHW Demand.

The Low Temperature Boiler Gas has been chosen from the default list in the program PHPP.

Screenshots from this worksheet can be found in Annex 2 point 23.

1.26 „Climate Data” Worksheet

Wybór regionu klimatycznego, jeżeli nie jest standardowy

.

Selection of climatic region. In the sheet is possible to select a region with a defined list, or if it is not standard, there is a possibility to define a new as a "User Data". In this case “Regional climate data” option was chosen from the first list, “N-Europe” region was chosen from the second list, and finally “PL-Strefa 2 (Poznan/Pila) was chosen as a regional climate. No more additional entries are needed in this worksheet.

Screenshots from this worksheet can be found in Annex 2 point 24.

1.27 “Internal Heat Gains” Worksheet

Screenshots from this worksheet can be found in Annex 2 point 25.

Annex 2

Worksheets from Passive House Planning Package program

1. "Verifications" Worksheet

EnerPHit verification

Building:	Home
Street:	
Postcode/City:	Jarocin
Country:	Poland
Building Type:	Detached house
Climate:	PL - Strefa II (Poznan/Pila)
Home Owner(s) / Client(s):	Technical University of Lodz
Street:	Aleja Politechniki 6
Postcode/City:	Lodz
Architect:	Magdalena Dopierala
Street:	Poznanska 237
Postcode/City:	88-100 Inowroclaw
Mechanical System:	yes
Street:	
Postcode/City:	

Year of Construction:	1910	Interior Temperature:	20,0	°C
Number of Dwelling Units:	1	Internal Heat Gains:	2,1	W/m²
Enclosed Volume V_e:	366,0			
Number of Occupants:	3,0			

Specific building demands with reference to the treated floor area — use: Monthly method

				Requirements	Fulfilled?*
	Treated floor area	105,3	m²		
Space heating	Annual heating demand	**24,10**	**kWh/(m²a)**	25 kWh/(m²a)	**yes**
	Heating load	**16**	**W/m²**	-	**-**
Space cooling	Overall specific space cooling demand		**kWh/(m²a)**	-	**-**
	Cooling load		**W/m²**	-	**-**
	Frequency of overheating (> 25 °C)	1,9	%	-	-
Primary Energy	Space heating and cooling, dehumidification, household electricity.	**100**	**kWh/(m²a)**	131 kWh/(m²a)	**yes**
	DHW, space heating and auxiliary electricity	68	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
Airtightness	Pressurization test result n_{50}	**0,6**	**1/h**	1 1/h	**yes**

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

Calculation electricity / internal heat gains

Building type: Residential building

Internal heat gains

Utilisation pattern: Dwelling

Type of values used: Standard

Planned number of occupants

Verification

Verification Monthly method

Specific space heating demand, annual method:	24,1	kWh/(m²a)
Specific space heating demand, monthly Method:	23,5	kWh/(m²a)

Certification type EnerPHit building retrofit (acc. to heating demand)

Hide the result cells for the requirements of EnerPHit - according to component quality (retrofit) through the activation of the grouping (left). For this deactivate worksheet protection and then hide the additional lines through the grouping sign.
Activate worksheet protection again.

2. „Areas" Worksheet

EnerPHit verification

A R E A S   D E T E R M I N A T I O N

Building: Home Heating demand: 24 kWh/(m²a)

Group Nr.	Area group	Temp. zone	Area	Unit	Comments	Building element overview	Average U-Value [W/(m²K)]
	Summary						
1	Treated Floor Area		105,33	m²	*Living area or useful area within the thermal envelope*		
2	North Windows	A	2,51	m²	Results are from the Windows worksheet.	North Windows	0,791
3	East Windows	A	7,16	m²		East Windows	0,768
4	South Windows	A	9,41	m²		South Windows	0,773
5	West Windows	A	2,10	m²		West Windows	0,824
6	Horizontal Windows	A	0,00	m²		Horizontal Windows	
7	Exterior Door	A	8,30	m²	*Please subtract area of door from respective building element*	Exterior Door	0,800
8	Exterior Wall - Ambient	A	122,14	m²	*Window areas are subtracted from the individual areas specified in the "Windows" worksheet.*	Exterior Wall - Ambient	0,107
9	Exterior Wall - Ground	B	0,00	m²	*Temperature Zone "A" is ambient air.*	Exterior Wall - Ground	
10	Roof/Ceiling - Ambient	A	87,98	m²	*Temperature zone "B" is the ground.*	Roof/Ceiling - Ambient	0,084
11	Floor slab / basement ceiling	B	66,99	m²		Floor slab / basement ceiling	0,063
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 < f, < 1):* 50%		
						Thermal Bridge Overview	Ψ [W/mK]
15	Thermal Bridges Ambient	A	100,93	m	*Units in m*	Thermal Bridges Ambient	0,033
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 Floor Slab	B	0,00	m	*Units in m*	Thermal Bridges Floor Slab	
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		306,59	m²		Average Therm. Envelope	0,167

Area input

Area Nr.	Building element 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 the corresponding building element assembly	Nr.	U-Value [W/(m²K)]
	Treated Floor Area	1	Treated Floor Area	1	x (		x		+	105,33	-	0,00			) =	105,3			
	North Windows	2	North Windows	Please complete in Windows worksheet only!												2,5	From Windows sheet		0,791
	East Windows	3	East Windows													7,2	From Windows sheet		0,768
	South Windows	4	South Windows													9,4	From Windows sheet		0,773
	West Windows	5	West Windows													2,1	From Windows sheet		0,824
	Horizontal Windows	6	Horizontal Windows													0,0	From Windows sheet		0,000
	Exterior Door	7	Exterior Door	1	x (		x		+	8,30	-		) -		=	8,3	U-Value Exterior Door		0,80
1	Exterior wall south	8	Exterior Wall - Ambient	1	x (		x		+	37,08	-		) -	9,4	=	27,7	Exterior wall 1 45 cm	1	0,093
2	Exterior wall north 1	8	Exterior Wall - Ambient	1	x (		x		+	26,29	-		) -	2,5	=	23,8	Exterior wall 1 45 cm	1	0,093
3	Exterior wall north 2	8	Exterior Wall - Ambient	1	x (		x		+	3,75	-		) -	0,0	=	3,8	Exterior wall 2 25 cm	2	0,141
4	Exterior wall west 1	8	Exterior Wall - Ambient	1	x (		x		+	0,98	-		) -	0,0	=	1,0	Exterior wall 1 45 cm	1	0,093
5	Exterior wall west 2	8	Exterior Wall - Ambient	1	x (		x		+	15,30	-		) -	4,3	=	11,0	Exterior wall 2 25 cm	2	0,141
6	Exterior wall west 3	8	Exterior Wall - Ambient	1	x (		x		+	3,86	-		) -	0,0	=	3,9	Exterior wall 3.1 (ala okna)	7	0,138
7	Exterior wall west 4	8	Exterior Wall - Ambient	1	x (		x		+	11,98	-		) -	0,8	=	11,1	Exterior wall 3.2 (brick 45 e	11	0,092
8	Exterior wall east 1	8	Exterior Wall - Ambient	1	x (		x		+	16,45	-		) -	0,0	=	16,5	Exterior wall 1 45 cm	1	0,093
9	Exterior wall east 2	8	Exterior Wall - Ambient	1	x (		x		+	16,25	-		) -	4,1	=	12,1	Exterior wall 2 25 cm	2	0,141
10	Terrace	10	Roof/Ceiling - Ambient	1	x (	3,75	x	2,55	+		-		) -	0,0	=	9,6	Terrace	6	0,084
11	Basement floor slab 1st crosssec.	11	Floor slab / basement ceiling	1	x (		x		+	61,92	-		) -	0,0	=	61,9	Floor under residential part c	4	0,063
12	Basement floor slab 2st crosssec.	11	Floor slab / basement ceiling	1	x (		x		+	5,07	-		) -	0,0	=	5,1	Floor under residential part c	5	0,064
13	Floor above first store	10	Roof/Ceiling - Ambient	1	x (	2,92	x	7,36	+		-		) -	0,0	=	21,5	Floor above I Store	8	0,073
14	Roof	10	Roof/Ceiling - Ambient	1	x (		x		+	56,93	-		) -	0,0	=	56,9	Roof	3	0,088
15	Thermal bridge:spine beam	8	Exterior Wall - Ambient	1	x (	18,81	x	0,25	+		-		) -	0,0	=	4,7	Wall substandal thermal bric	9	0,095
16	Element od ext. wall S	8	Exterior Wall - Ambient	1	x (		x		+	1,05	-		) -	0,0	=	1,1	Exterior wall 4.1 (concrete el	12	0,092
17	Element od ext. wall W	8	Exterior Wall - Ambient	1	x (		x		+	2,10	-		) -	0,0	=	2,1	Exterior wall 4.3(concrete ele	14	0,196
18	Element od ext. wall W	8	Exterior Wall - Ambient	1	x (		x		+	0,20	-		) -	0,0	=	0,2	Exterior wall 4.2(concrete ele	13	0,092
19	Element od ext. wall S	8	Exterior Wall - Ambient	1	x (		x		+	3,32	-		) -	0,0	=	3,3	Exterior wall 4.1 (concrete el	12	0,092
20					x (		x		+		-		) -	0,0	=				

Thermal Bridge Inputs

No.	Thermal bridge description	Group Nr.	Assigned to group	Quantity	x (	User determined length [m]	-	Subtraction user-determined length [m]	)=	Length l [m]	Input of thermal bridge heat loss coefficient W/(mK)	Ψ W/(mK)
1	exterior+interior wall 1	15	Thermal Bridges Ambient	1	x (	1,52	-		) =	1,52	exterior+interior wall 1	0,071
2	exterior+interior wall 2	15	Thermal Bridges Ambient	1	x (	1,52	-		) =	1,52	exterior+interior wall 2	0,067
3	exterior+interior wall 3	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	exterior+interior wall 3	0,193
4	exterior+interior wall 4	15	Thermal Bridges Ambient	1	x (	6,06	-		) =	6,06	exterior+interior wall 4	0,072
5	exterior+interior wall 5	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	exterior+interior wall 5	0,106
6	exterior+interior wall 6	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	exterior+interior wall 6	0,101
7	exterior+interior wall 7	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	exterior+interior wall 7	0,137
8	corner of walls 1	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	corner of walls 1	0,086
9	corner of walls 2	15	Thermal Bridges Ambient	1	x (	6,06	-		) =	6,06	corner of walls 2	0,038
10	corner of walls 3	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	corner of walls 3	0,131
11	corner of walls 4	15	Thermal Bridges Ambient	1	x (	3,03	-		) =	3,03	corner of walls 4	0,060
12	floor slab + exterior walls	15	Thermal Bridges Ambient	1	x (	18,85	-		) =	18,85	floor slab + exterior walls	-0,139
13	floor slab + interior walls	15	Thermal Bridges Ambient	1	x (	7,36	-		) =	7,36	floor slab + interior walls	0,022
14	exterior+interior wall 8	15	Thermal Bridges Ambient	1	x (	1,60	-		) =	1,60	exterior+interior wall 8	0,179
15	exterior+interior wall 9	15	Thermal Bridges Ambient	1	x (	1,60	-		) =	1,60	exterior+interior wall 9	0,061
16	exterior+interior wall 10	15	Thermal Bridges Ambient	1	x (	5,00	-		) =	5,00	exterior+interior wall 10	0,153
17	exterior+interior wall 11	15	Thermal Bridges Ambient	1	x (	2,50	-		) =	2,50	exterior+interior wall 11	0,190
18	corner of walls 5	15	Thermal Bridges Ambient	1	x (	3,20	-		) =	3,20	corner of walls 5	0,090
19	roof + exterior wall	15	Thermal Bridges Ambient	1	x (	7,41	-		) =	7,41	roof + exterior wall	0,080
20	floor above gr floor+wall	15	Thermal Bridges Ambient	1	x (	7,41	-		) =	7,41	floor above gr floor+wall	0,092
21	roof terrace +ext wall	15	Thermal Bridges Ambient	1	x (	9,64	-		) =	9,64	roof terrace +ext wall	-0,079
22					x (		-		) =			

3. “U- List” Worksheet

EnerPHit verification

U - LIST

Compilation of the building elements calculated in the U-Values worksheet and other construction types from databases.

Assembly No.	Type Assembly description	Total thickness	U-Value
		m	W/(m²K)
1	Exterior wall 1 45 cm	0,610	0,093
2	Exterior wall 2 25 cm	0,410	0,141
3	Roof	0,390	0,088
4	Floor under residential part of the building (with basement) - cross	0,687	0,063
5	Floor under residential part of the building (with basement) - cross-	0,757	0,064
6	Terrace	0,924	0,084
7	Exterior wall 3.1 (ala okna)	0,530	0,138
8	Floor above I Store	0,632	0,073
9	Wall substancial thermal bridges 1 spine beam	0,610	0,095
10			
11	Exterior wall 3.2 (brick 45 extra 5 cm ins)	0,610	0,092
12	Exterior wall 4.1 (concrete elemets above windows - brick 45 normal)	0,605	0,092
13	Exterior wall 4.2(concrete elements above windows brick 45 + 5 extra	0,610	0,092
14	Exterior wall 4.3(concrete elements above "doors" W-site brick 45 + 5	0,440	0,196
15	basement wall	0,320	0,354

4. "U- Values" Worksheet

EnerPHit verification

U-VALUES OF BUILDING ELEMENTS

Building: Home

Wedge shaped building element layers and still air spaces -> Secondary calculation to the right

Assembly No. 1 — Building assembly description: Exterior wall 1 45 cm — Interior insulation? x

Heat transfer resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	ceramic brick	0,770					250
4.	Polyurethane foam	0,023					80
5.	ceramic brick	0,770					120
6.							
7.							
8.							

Percentage of Sec. 2 — Percentage of Sec. 3 — Total 61,0 cm

U-Value: 0,093 W/(m²K)

Assembly No. 2 — Building assembly description: Exterior wall 2 25 cm — Interior insulation? x

Heat transfer resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	Ceramic brick	0,770					250
4.							
5.							
6.							
7.							
8.							

Percentage of Sec. 2 — Percentage of Sec. 3 — Total 41,0 cm

U-Value: 0,141 W/(m²K)

Assembly No. 3 — Building assembly description: Roof

Interior insulation?

Heat transfer resistance [m²K/W] — interior Rsi: 0,10; exterior Rse: 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.	Batten	0,160					50
2.	Hollow core	0,270			Counter-lath	0,160	30
3.	Polystyrene Foam	0,023	Rafter	0,160			200
4.	Polystyrene Foam	0,023					100
5.	Plasterboard	0,160					10
6.							
7.							
8.					1 -		

Percentage of Sec. 2: 10,0%

Percentage of Sec. 3: 3,0%

Total: 39,0 cm

U-Value: 0,088 W/(m²K)

Assembly No. 4 — Building assembly description: Floor under residential part of the building (with basement) - cross-section of bricks

Interior insulation?

Heat transfer resistance [m²K/W] — interior Rsi: 0,17; exterior R_{se}: 0,10

	Area section 1	λ [W/(mK)]	Area section 2 (optional)	λ [W/(mK)]	Area section 3 (optional)	λ [W/(mK)]	Thickness [mm]
1.	Wooden boards	0,160					32
2.	Self-leveling Screed	1,700					25
3.	Base screed	1,700					50
4.	Polystyrene Foam	0,023					250
5.	Concrete Screed	1,700					100
6.	Brick	0,770					130
7.	polystyrene Foam	0,023					100
8.							

Percentage of Sec. 2:

Percentage of Sec. 3:

Total: 68,7 cm

U-Value: 0,063 W/(m²K)

Assembly No. 5 — Building assembly description: Floor under residential part of the building (with basement) - cross-section of I-beam

Interior insulation?

Heat transfer resistance [m²K/W] — interior Rsi: 0,17; 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.	Wooden boards	0,160					32
2.	Self-leveling Screed	1,700					25
3.	Base screed	1,700					50
4.	Polystyrene Foam	0,023					250
5.	Concrete Screed	1,700					100
6.	steel I-beam 180	50,000					200
7.	polystyrene Foam	0,023					100
8.							

Percentage of Sec. 2:

Percentage of Sec. 3:

Total: 75,7 cm

U-Value: 0,064 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
6	Terrace	

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.	Plasterboard	0,160					10
2.	Polystyrene Foam	0,023					250
3.	Concrete-bearing lay	1,700					300
4.	Slope layer 1%	0,500					284
5.	water barier layer	0,700					20
6.	Concrete Screed	1,700					50
7.	mebrane	0,500					5
8.	Tiles	1,300					5

Percentage of Sec. 2: — Percentage of Sec. 3: — Total: 92,4 cm

U-Value: 0,084 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
7	Exterior wall 3.1 (windows)	x

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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	ceramic brick	0,770					250
4.	ceramic brick	0,770					120
5.							
6.							
7.							
8.							

Percentage of Sec. 2: — Percentage of Sec. 3: — Total: 53,0 cm

U-Value: 0,138 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
8	Floor above I Store	

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.	Polyurethane foam	0,023					150
2.	Polyurethane foam	0,023	wood beam	0,160			150
3.	Plasterboard	0,160					10
4.	Hollowe core	0,160					310
5.	Plasterboard	0,160					13
6.							
7.							
8.							

Percentage of Sec. 2: 10,0% — Percentage of Sec. 3: — Total: 63,2 cm

U-Value: 0,073 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
9	Wall substancial thermal bridges 1 spine beam	x

Heat transfer resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	Reinforced-concrete	2,300					250
4.	Polyurethane foam	0,023					80
5.	ceramic brick	0,770					120
6.							
7.							
8.							

Percentage of Sec. 2 | Percentage of Sec. 3 | Total 61,0 cm

U-Value: 0,095 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
11	Exterior wall 3.2 (brick 45 extra 5 cm ins)	x

Heat transfer resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	ceramic brick	0,770					250
4.	Polyurethane foam	0,023					80
5.	ceramic brick	0,410					120
6.							
7.							
8.							

Percentage of Sec. 2 | Percentage of Sec. 3 | Total 61,0 cm

U-Value: 0,092 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
12	Exterior wall 4.1 (concrete elemets above windows - brick 45 normal)	x

Heat transfer resistance [m²K/W] interior Rsi : 0,13 exterior Rse : 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.	Plasterboard	0,160					5
2.	Polyurethane foam (g	0,023					150
3.	ceramic brick	0,770					250
4.	Polyurethane foam	0,023					80
5.	concrete	0,410					120
6.							
7.							
8.							

Percentage of Sec. 2 | Percentage of Sec. 3 | Total 60,5 cm

U-Value: 0,092 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
13	Exterior wall 4.2(concrete elements above windows brick 45 + 5 extra ins)	x

Heat transfer resistance [m²K/W] interior Rsi : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					150
3.	ceramic brick	0,770					250
4.	Polyurethane foam	0,023					80
5.	concrete	0,410					120
6.							
7.							
8.							
				Percentage of Sec. 2		Percentage of Sec. 3	Total
							61,0 cm

U-Value: 0,092 W/(m²K)

Assembly No.	Building assembly description	Interior insulation?
14	Exterior wall 4.3(concrete elements above "doors" W-site brick 45 + 5 extra in	x

Heat transfer resistance [m²K/W] interior Rsi : 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.	Plasterboard	0,160					10
2.	Polyurethane foam	0,023					100
3.	ceramic brick	0,770					250
4.	concrete	0,410					80
5.							
6.							
7.							
8.							
				Percentage of Sec. 2		Percentage of Sec. 3	Total
							44,0 cm

U-Value: 0,196 W/(m²K)

5. “Ground” Worksheet

EnerPHit verification

HEAT LOSSES VIA THE GROUND

Ground Characteristics				Climate Data			
Thermal Conductivity	λ	2,0	W/(mK)	Av. Indoor Temp. Winter	T_i	20,0	°C
Heat Capacity	ρc	2,0	MJ/(m³K)	Av. Indoor Temp. Summer	T_i	25,0	°C
Periodic Penetration Depth	δ	3,17	m	Average Ground Surface Temperatu	$T_{g,ave}$	9,7	°C
				Amplitude of $T_{g,ave}$	$T_{g,\wedge}$	10,0	°C
				Length of the Heating Period	n	7,1	months
				Heating Degree Hours - Exterior	G_t	86,4	kKh/a

Building Data							
				U-value floor slab/basement ceiling	U_f	0,064	W/(m²K)
Floor Slab Area	A	62,8	m²	Thermal bridges floor slab/basemer	$\Psi_B{}^{*}l$	0,00	W/K
Floor Slab Perimeter	P	36,9	m	U-value floor slab/basement ceiling	$U_f{}'$	0,064	W/(m²K)
Charact. Dimension of Floor Slab	B'	3,41	m	Eq. Thickness Floor	d_t	31,25	m

Floor Slab Type (select only one)			
	Heated Basement or Underground Floor Slab	x	Unheated basement
	Slab on Grade		Suspended Floor

For Basement or Underground Floor Slab							
Basement Depth	z	2,50	m	U-Value Belowground Wall	U_{wB}	0,138	W/(m²K)
Additionally for Unheated Basements				Height Aboveground Wall	h		m
Air Change Unheated Basement	n	0,20	h⁻¹	U-Value Aboveground Wall	U_W		W/(m²K)
Basement Volume	V	177	m³	U-Value Basement Floor Slab	U_{fB}	0,064	W/(m²K)

For Perimeter Insulation for Slab on Grade				For Suspended Floor			
Perimeter Insulation Width/Depth	D		m	U-Value Crawl Space	U_{Crawl}		W/(m²K)
Perimeter Insulation Thickness	d_n		m	Height of Crawl Space Wall	h		m
Conductivity Perimeter Insulation	λ_n		W/(mK)	U-Value Crawl Space Wall	U_W		W/(m²K)
				Area of Ventilation Openings	εP		m²
Orientation of the Perimeter Ins.	horizontal			Wind Velocity at 10 m Height	v	4,0	m/s
(check only one field)	vertical			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	1,00	months	Harmonic Fraction	$\Psi_{P,harm}{}^{*}l$	0,000	W/K

Groundwater Correction							
Depth of the Groundwater Table	z_W	3,0	m	Transm. Belowground El. (w/o Ground)	L_{reg}	16,76	W/K
Groundwater Flow Rate	q_W	0,05	m/d	Relative Insulation Standard	d_t/B'	2,20	-
				Relative Groundwater Depth	z_W/B'	0,88	-
Groundwater Correction Factor	G_W	1,0009509	-	Relative Groundwater Velocity	l/B'	0,24	-

Interim Results							
Phase Shift	β	1,00	months	Steady-State Heat Flow	Φ_{stat}	35,7	W
Steady-State Transmittance	L_S	3,48	W/K	Periodic Heat Flow	Φ_{harm}	3,0	W
Exterior Periodic Transmittance	L_{pe}	0,66	W/K	Heat Losses During Heating Period	Q_{tot}	201	kWh

Ground reduction factor for "Annual Heating Demand" she **0,58**

Monthly Average Ground Temperatures for Monthly Method

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Value
Winter	8,7	8,6	8,7	10,3	11,1	11,9	12,6	12,8	12,6	11,9	11,1	10,3	11,1
Summer	10,3	10,1	10,3	10,9	11,8	12,8	13,2	13,4	13,2	12,8	11,8	10,9	11,8

Design Ground Temperature for Heating Load Shee 8,6   for Cooling Load Sheet 13,4

6. "Windows" Worksheet

EnerPHit verification

REDUCTION FACTOR SOLAR RADIATION, WINDOW U-VALUE

Building: Home — Annual heating demand: 24 kWh/(m²a) — Heating degree hours: 88,4

Climate: PL - Strefa II (Poznan/Pila)

Window area orientation	Global radiation (cardinal points)	Shading	Dirt	Non-perpendicular incident radiation	Glazing fraction	g-Value	Reduction factor for solar radiation	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	97	0,76	0,95	0,85	0,615	0,49	0,38	2,51	0,79	1,5	97	171	45
East	223	0,75	0,95	0,85	0,676	0,49	0,41	7,16	0,77	4,8	223	475	321
South	420	0,77	0,95	0,85	0,667	0,49	0,42	9,41	0,77	6,3	420	628	805
West	223	0,73	0,95	0,85	0,530	0,49	0,31	2,10	0,82	1,1	223	149	71
Horizontal	334	1,00	0,95	0,85	0,000	0,00	0,00	0,00	0,00	0,0	334	0	0
Total or Average Value for All Windows.						0,49	0,40	21,18	0,78	13,8		1424	1242

					Window rough openings		Installed		Glazing		Frame		g-Value	U-Value		Ψ-Spacer
Quantity	Description	Deviation from north	Angle of inclination from the horizontal	Orientation	Width	Height	in Area in the Areas worksheet	Nr.	Select glazing from the WinType worksheet	Nr.	Select window from the WinType worksheet	Nr.	Perpendicular Radiation	Glazing	Frames (centre)	Ψ_{spacer} (centre)
		Degrees	Degrees		m	m	Select:		Select:		Select:		-	W/(m²K)	W/(m²K)	W/(mK)
4	South	180	90	South	1,020	1,610	Exterior wall south	1	Individual custom frame	1	Custom frame	1	0,49	0,64	0,84	0,028
1	South	180	90	South	1,520	1,870	Exterior wall south	1	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	East	90	90	East	1,860	1,460	Exterior wall east 2	9	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	East	90	90	East	1,340	0,720	Exterior wall east 2	9	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	East	90	90	East	0,540	0,860	Exterior wall east 2	9	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	East	90	90	East	1,470	2,050	Exterior wall west 2	5	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	West	270	90	West	0,520	1,630	Exterior wall west 4	7	Individual custom frame	1	Custom frame	1	0,49	0,64	0,84	0,028
1	West	270	90	West	1,470	0,850	Exterior wall west 2	5	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	North	0	90	North	0,820	0,800	Exterior wall north 1	2	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028
1	North	0	90	North	1,130	1,640	Exterior wall north 1	2	Individual custom frame	1	Custom frame	1	0,49	0,64	0,83	0,028

7. “WinType” Worksheet

Quan-tity	Description	Installation									Results (unhide cells to make U- & Ψ-values from WinType worksheet visible)				Frame-U-values from WinTpye worksheet			
		Left 1/0	Right 1/0	Bottom 1/0	Top 1/0	$\Psi_{installation}$ left	$\Psi_{installation}$ right	$\Psi_{installation}$ bottom	$\Psi_{installation}$ top	$\Psi_{installation}$ Average value	Window Area	Glazing Area	U-Value Window	Glazed Fraction per Window	Frame left	Frame right	Frame bottom	Frame top
						W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	m²	m²	W/(m²K)	%	W/(m²K)	W/(m²K)	W/(m²K)	W/(m²K)
4	South	1	1	1	1	0,000	0,000	0,000	0,000	0,000	6,6	4,22	0,78	64%	0,84	0,84	0,82	0,84
1	South	1	1	1	1	0,000	0,000	0,000	0,000	0,000	2,8	2,06	0,75	73%	0,84	0,84	0,82	0,84
1	East	1	1	1	1	0,000	0,000	0,000	0,000	0,000	2,7	1,95	0,75	72%	0,84	0,84	0,82	0,84
1	East	1	1	1	1	0,000	0,000	0,000	0,000	0,000	1,0	0,51	0,82	53%	0,84	0,84	0,82	0,84
1	East	1	1	1	1	0,000	0,000	0,000	0,000	0,000	0,5	0,18	0,87	39%	0,84	0,84	0,82	0,84
1	East	1	1	1	1	0,000	0,000	0,000	0,000	0,000	3,0	2,20	0,75	73%	0,84	0,84	0,82	0,84
1	West	1	1	1	1	0,000	0,000	0,000	0,000	0,000	0,8	0,38	0,86	45%	0,84	0,84	0,82	0,84
1	West	1	1	1	1	0,000	0,000	0,000	0,000	0,000	1,2	0,73	0,80	58%	0,84	0,84	0,82	0,84
1	North	1	1	1	1	0,000	0,000	0,000	0,000	0,000	0,7	0,31	0,84	48%	0,84	0,84	0,82	0,84
1	North	1	1	1	1	0,000	0,000	0,000	0,000	0,000	1,9	1,23	0,77	66%	0,84	0,84	0,82	0,84

Frame measures from WinType worksheet																			Thermal bridges									Installation length	
Width - Left	Width - Right	Width - Below	Width - Above	Area left	Area right	Area bottom	Area top	Total area	Glazing edge length left	Glazing edge length right	Glazing edge length bottom	Glazing edge length top	Total glazing edge length	Installation length left	Installation length right	Installation length bottom	Installation length top	Total installation length	$\Psi_{glazing\ edge}$ 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	Descrip-tion	Glazing	Frames
m	m	m	m	m²	m²	m²	m²	m²	m	m	m	m	m	m	m	m	m	m	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)		m	m
0,12	0,12	0,14	0,12	0,16	0,16	0,14	0,12	0,59	1,35	1,35	0,78	0,78	4,26	1,61	1,61	1,02	1,02	5,26	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	South	17,1	21,0
0,12	0,12	0,14	0,12	0,19	0,19	0,21	0,18	0,78	1,61	1,61	1,28	1,28	5,78	1,87	1,87	1,52	1,52	6,78	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	South	5,8	6,8
0,12	0,12	0,14	0,12	0,14	0,14	0,26	0,22	0,77	1,20	1,20	1,62	1,62	5,64	1,46	1,46	1,86	1,86	6,64	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	East	5,6	6,6
0,12	0,12	0,14	0,12	0,06	0,06	0,18	0,16	0,46	0,46	0,46	1,10	1,10	3,12	0,72	0,72	1,34	1,34	4,12	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	East	3,1	4,1
0,12	0,12	0,14	0,12	0,07	0,07	0,07	0,06	0,28	0,60	0,60	0,30	0,30	1,80	0,86	0,86	0,54	0,54	2,80	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	East	1,8	2,8
0,12	0,12	0,14	0,12	0,22	0,22	0,20	0,18	0,81	1,79	1,79	1,23	1,23	6,04	2,05	2,05	1,47	1,47	7,04	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	East	6,0	7,0
0,12	0,12	0,14	0,12	0,16	0,16	0,07	0,06	0,46	1,37	1,37	0,28	0,28	3,30	1,63	1,63	0,52	0,52	4,30	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	West	3,3	4,3
0,12	0,12	0,14	0,12	0,07	0,07	0,20	0,18	0,52	0,59	0,59	1,23	1,23	3,64	0,85	0,85	1,47	1,47	4,64	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	West	3,6	4,6
0,12	0,12	0,14	0,12	0,07	0,07	0,11	0,10	0,34	0,54	0,54	0,58	0,58	2,24	0,80	0,80	0,82	0,82	3,24	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	North	2,2	3,2
0,12	0,12	0,14	0,12	0,17	0,17	0,16	0,14	0,62	1,38	1,38	0,89	0,89	4,54	1,64	1,64	1,13	1,13	5,54	0,028	0,028	0,028	0,028	0,000	0,000	0,000	0,000	North	4,5	5,5

EnerPHit verification

GLAZING ACCORDING TO CERTIFICATION

Go to curtain wall facades / window frames from line 99 onwards

Assem-bly No.	Type Glazing	g-Value	U_g-Value
			W/(m²K)
1	Individual custom frame	0,49	0,64
2			

CURTAIN WALL FACADE / WINDOW FRAME AS PER CERTIFICATE

Go to glazing from line 2 onwards

Assem-bly No.	Type	U_f-Value				Frame Dimensions			
	Window frame	Frame left	Frame right	Frame bottom	Frame top	Width - Left	Width - Right	Width - Below	Width - Above
	Curtain wall facade	Post left	Post right	Beam bottom	Beam top	Post left	Post right	Beam bottom	Beam top
		W/(m²K)	W/(m²K)	W/(m²K)	W/(m²K)	m	m	m	m
1	Custom frame	0,84	0,84	0,82	0,84	0,120	0,120	0,138	0,120
2									

Thermal bridges								
Glazing edge thermal bridge				Installation thermal bridge				Curtain wall facades:
$\Psi_{Glazing\ edge}$ 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/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/(mK)	W/K
0,028	0,028	0,028	0,028	0,002	0,002	0,006	0,023	

8. „Shading" Worksheet

EnerPHit verification

CALCULATING SHADING FACTORS

Climate: PL - Strefa II (Poznan/Pila)

Building: Home

Latitude: 52,42 °

Orientation	Glazing area m²	Reduction factor r_S
North	1,54	76%
East	4,84	75%
South	6,28	77%
West	1,11	73%
Horizontal	0,00	100%

Quantity	Description	Deviation from North	Angle of Inclination from the Horizontal	Orientation	Glazing width	Glazing height	Glazing area	Height of the shading object	Horizontal distance	Window reveal depth	Distance from glazing edge to reveal	Overhang depth	Distance from upper glazing edge to overhang	Additional shading reduction factor	Horizontal shading reduction factor	Reveal Shading Reduction Factor	Overhang shading reduction factor	Total shading reduction factor
		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}	r_H	r_R	r_O	r_S
4	South	180	90	South	0,78	1,35	4,2	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	96%	100%	77%
1	South	180	90	South	1,28	1,61	2,1	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	97%	100%	78%
1	East	90	90	East	1,62	1,20	1,9	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	95%	100%	76%
1	East	90	90	East	1,10	0,46	0,5	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	94%	100%	75%
1	East	90	90	East	0,30	0,60	0,2	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	85%	100%	68%
1	East	90	90	East	1,23	1,79	2,2	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	94%	100%	75%
1	West	270	90	West	0,28	1,37	0,4	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	84%	100%	67%
1	West	270	90	West	1,23	0,59	0,7	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	94%	100%	75%
1	North	0	90	North	0,58	0,54	0,3	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	93%	100%	74%
1	North	0	90	North	0,89	1,38	1,2	0,00	0,00	0,10	0,120	0,00	0,00	80%	100%	95%	100%	76%

9. „Ventilation" Worksheet

EnerPHit verification

VENTILATION DATA

Building: Home

Treated floor area A_{TFA}	m²	105	(Areas worksheet)
Room height h	m	2,5	(Annual Heating Demand worksheet)
Room ventilation volume (A_{TFA}*h) = V_V	m³	263	(Annual Heating Demand worksheet)

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	322	m³	0,63	m³/(hm²)

			for Annual Demand:	for Heating Load:
Excess extract air		1/h	0,00	0,00
Infiltration air change rate	$n_{V,Res}$	1/h	0,051	0,128

Selection of ventilation data input - Results

Ventilation unit / Heat recovery efficiency design

- x Sheet Ventilation (Standard design) *(Sheet Ventilation see below)*
- Sheet Extended ventilation *(Sheet Additional Vent)*

(Multiple ventilation units, non-residential buildings)

Mean Air exchange m³/h	Mean Air Change Rate 1/h	Extract air excess Extract air system 1/h	Effective heat recovery efficiency Unit [-]	Specific power input Wh/m³	Heat recovery efficiency SHX
92	0,35	0,00	90,7%	0,42	0,0%

SHX efficiency η^*_{SHX} 0%

STANDARD INPUT FOR BALANCED VENTILATION

Ventilation dimensioning for systems with one ventilation unit

Occupancy	m²/P	35				
Number of occupants	P	3,0				
Supply air per person	m³/(P*h)	30				
Supply air requirement	m³/h	90				
Extract air rooms		Kitchen	Bathroom	Bathroom (shower only)	WC	other
Quantity		1	1	0	1	1
Extract air requirement per room	m³/h	50	30	20	30	10
Total Extract Air Requirement	m³/h	120				
Design air flow rate (maximum)	m³/h	120				

Average air change rate calculation

Type of operation	Daily operation duration h/d	Factors referenced to maximum	Air flow rate m³/h	Air change rate 1/h
Maximum		1,00	120	0,46
Standard	24,0	0,77	92	0,35
Basic		0,54	65	0,25
Minimum		0,40	48	0,18
	Average value	0,77	Average air flow rate (m³/h) 92	Average air change rate (1/h) 0,35

Selection of ventilation unit with heat recovery

x	Central unit within the thermal envelope.
	Central unit outside of the thermal envelope.

	Heat recovery efficiency Unit η_{HR}	Specific power input [Wh/m³]	Application range [m³/h]	Frost protection required	Unit noise level < 35dB(A)
Ventilation unit selection: ComfoAir 200 - Zehnder	0,92	0,42	60 - 150	yes	no

Conductance value of outdoor air du Ψ	W/(mK)	0,183	See calculation below
Length of outdoor air duct	m	1	
Conductance value of exhaust air dı Ψ	W/(mK)	0,224	See calculation below
Length of exhaust air duct	m	1,2	
Temperature of mechanical services room	°C		
(Enter only if the central unit is outside of the thermal envelope.)			

Room Temperature (°C)	20
Av. Ambient Temp. Heating P. (°C	3,9
Av. Ground Temp (°C)	9,7

Effective heat recovery efficiency $\eta_{HR,eff}$ **90,7%**

Effective heat recovery efficiency subsoil heat exchanger

SHX efficiency	η^*_{SHX}	0%
Heat recovery efficiency SHX	η_{SHX}	0%

Secondary calculation

Ψ-value supply or ambient air duct

Nominal width:	125	mm
Insul. Thicknes	150	mm
Reflective? Please mark with an "x"!		
Yes	x	
No		
Thermal conductivity	0,04	W/(mK)
Nominal air flow rate	92	m³/h
Δϑ	16	K
Exterior duct diameter	0,125	m
Exterior diameter	0,425	m
α-Interior	10,54	W/(m²K)
α-Surface	2,12	W/(m²K)
Ψ-value	**0,183**	**W/(mK)**
Surface temperature difference	1,041	K

Secondary calculation

Ψ-value extract or exhaust air duct

Nominal width:	125	mm
Insul. Thickness:	100	mm
Reflective? Please mark with an "x"!		
Yes	x	
No		
Thermal conductivity	0,04	W/(mK)
Nominal air flow rate	92	m³/h
Δϑ	16	K
Exterior duct diameter	0,125	m
Exterior diameter	0,325	m
α-Interior	10,54	W/(m²K)
α-Surface	2,34	W/(m²K)
Ψ-value	**0,224**	**W/(mK)**
Surface temperature difference	1,511	K

10. "Annual Heating Demand" Worksheet

EnerPHit verification

SPECIFIC ANNUAL HEATING DEMAND

Climate:	PL - Strefa II (Poznan/Pila)	Interior Temperature:	20,0 °C
Building:	Home	Building Type/Use:	Detached house
		Treated Floor Area A_{TFA}:	105,3 m²

Building Element	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	122,1	*	0,107	*	1,00	*	86,4	=	1129	10,72
Exterior Wall - Ground	B		*		*	0,58	*		=		
Roof/Ceiling - Ambient	A	88,0	*	0,084	*	1,00	*	86,4	=	641	6,08
Floor slab / basement ceiling	B	67,0	*	0,063	*	0,58	*	86,4	=	210	2,00
	A		*		*	1,00	*		=		
	A		*		*	1,00	*		=		
	X		*		*	0,50	*		=		
Windows	A	21,2	*	0,778	*	1,00	*	86,4	=	1424	13,52
Exterior Door	A	8,3	*	0,800	*	1,00	*	86,4	=	574	5,45
Exterior TB (length/m)	A	100,9	*	0,033	*	1,00	*	86,4	=	286	2,71
Perimeter TB (length/m)	P		*		*	0,58	*		=		0,00
Ground TB (length/m)	B		*		*	0,58	*		=		
Total of All Building Envelope Areas		306,6									kWh/(m²a)
Transmission Heat Losses Q_T									Total	4264	40,5

Ventilation System:

			A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V			105,3	*	2,50	=	263,3

Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	91%
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 n_V	0,453	* (1 -	0,91	) +	0,051	=	0,092

Ventilation Heat Losses Q_V

V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
263	*	0,092	*	0,33	*	86,4	=	692	6,6

Total Heat Losses Q_L

	Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
(	4264	+	692	)	1,0	=	4955	47,0

Available Solar Heat Gains Q_S

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a
1.	North	0,38	*	0,49	*	2,51	*	97	=	45
2.	East	0,41	*	0,49	*	7,16	*	223	=	321
3.	South	0,42	*	0,49	*	9,41	*	420	=	805
4.	West	0,31	*	0,49	*	2,10	*	223	=	71
5.	Horizontal	0,00	*	0,00	*	0,00	*	334	=	0

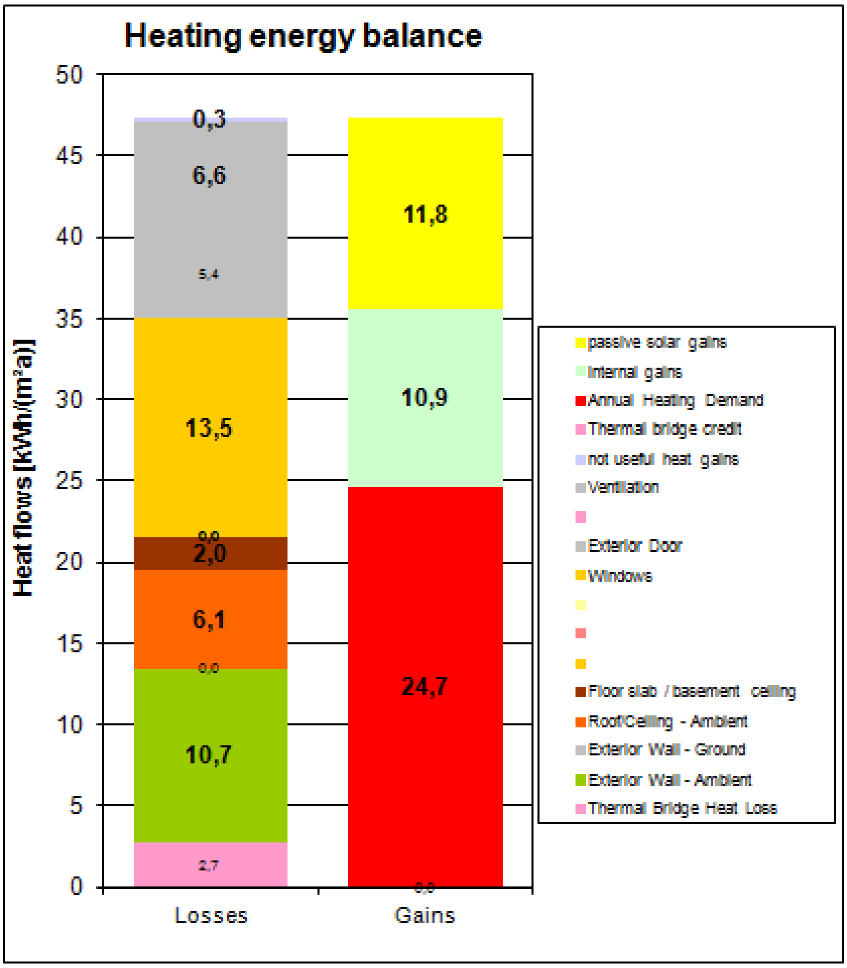
Total 1242 kWh/a; 11,8 kWh/(m²a)

Internal Heat Gains Q_I

kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
0,024	*	217	*	2,10	*	105,3	=	1150	10,9

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	2392	22,7
Ratio of Free Heat to Losses	Q_F / Q_L	=	0,48	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	99%	
Heat Gains Q_G	$\eta_G * Q_F$	=	2359	22,4
Annual Heating Demand QH	$Q_L - Q_G$	=	2596	**24,65**

Limiting Value 25 kWh/(m²a) — Requirement met? (Yes/No): **yes**



11. "Monthly Method" Worksheet

EnerPHit verification

SPECIFIC ANNUAL HEATING DEMAND MONTHLY METHOD

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

Climate:	PL - Strefa II (Poznan/Pila)	Interior Temperature:	20 °C
Building:	Home	Building Type/Use:	Detached house
Spec. Capacity:	132 Wh/(m²K) (Enter in "Summer" worksheet.)	Treated Floor Area A_{TFA}:	105,3 m²

Building Element	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	122,1	*	0,107	*	1,00	*	85	=	1109	
Exterior Wall - Ground	B		*		*	1,00	*		=		
Roof/Ceiling - Ambient	A	88,0	*	0,084	*	1,00	*	85	=	629	
Floor slab / basement ceiling	B	67,0	*	0,063	*	1,00	*	49	=	206	
	A		*		*	1,00	*		=		
	A		*		*	1,00	*		=		
	X		*		*	0,50	*		=		
Windows	A	21,2	*	0,778	*	1,00	*	85	=	1399	
Exterior Door	A	8,3	*	0,800	*	1,00	*	85	=	564	
Exterior TB (length/m)	A	100,9	*	0,033	*	1,00	*	85	=	281	
Perimeter TB (length/m)	P		*		*	1,00	*		=		
Ground TB (length/m)	B		*		*	1,00	*		=		
Transmission Heat Losses Q_T									Total	4188	39,8 kWh/(m²a)

			A_{TFA} m²		Clear Room Height m		m³
	Effective Air Volume V_{RAX}		105	*	2,50	=	263

	$n_{V,system}$ 1/h		η^*_{SHX}		η_{HR}		$n_{V,Res}$ 1/h		$n_{V,equi,fraction}$ 1/h
Effective Air Change Rate Ambient $n_{V,a}$	0,453	*(1-	0%	)*(1-	0,91	)+	0,051	=	0,092
Effective Air Change Rate Ground $n_{V,g}$	0,453	*	0%	*(1-	0,91	)		=	0,000

	V_{RAX} m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Losses Ambient Q_V	263	*	0,092	*	0,33	*	85	=	680	6,5
Ventilation Losses Ground $Q_{V,e}$	263	*	0,000	*	0,33	*	52	=	0	0,0
Ventilation Heat Losses Q_V								Total	680	6,5

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	4188	+	680	)	1,0	=	4868	46,2

Orientation of the Area	Reduction Factor See Windows worksheet		g-Value (perp. radiation)		Area m²		Global Radiation kWh/(m²a)		kWh/a	kWh/(m²a)
North	0,38	*	0,49	*	2,5	*	94	=	43	
East	0,41	*	0,49	*	7,2	*	216	=	312	
South	0,42	*	0,49	*	9,4	*	416	=	798	
West	0,31	*	0,49	*	2,1	*	217	=	69	
Horizontal	0,00	*	0,00	*	0,0	*	323	=	0	
Sum Opaque Areas									0	
Available Solar Heat Gains Q_S								Total	1222	11,6

	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	*	2,1	*	105,3	=	1125	10,7

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	2347	22,3
Ratio Free Heat to Losses	Q_F / Q_L	=	0,48	
Utilisation Factor Heat Gains η_G		=	99%	
Heat Gains Q_G	η_G * Q_F	=	2330	22,1
Annual Heating Demand QH	Q_L - Q_G	=	2538	24,10

	kWh/(m²a)		(Yes/No)
Limiting Value	25	**Requirement met?**	yes

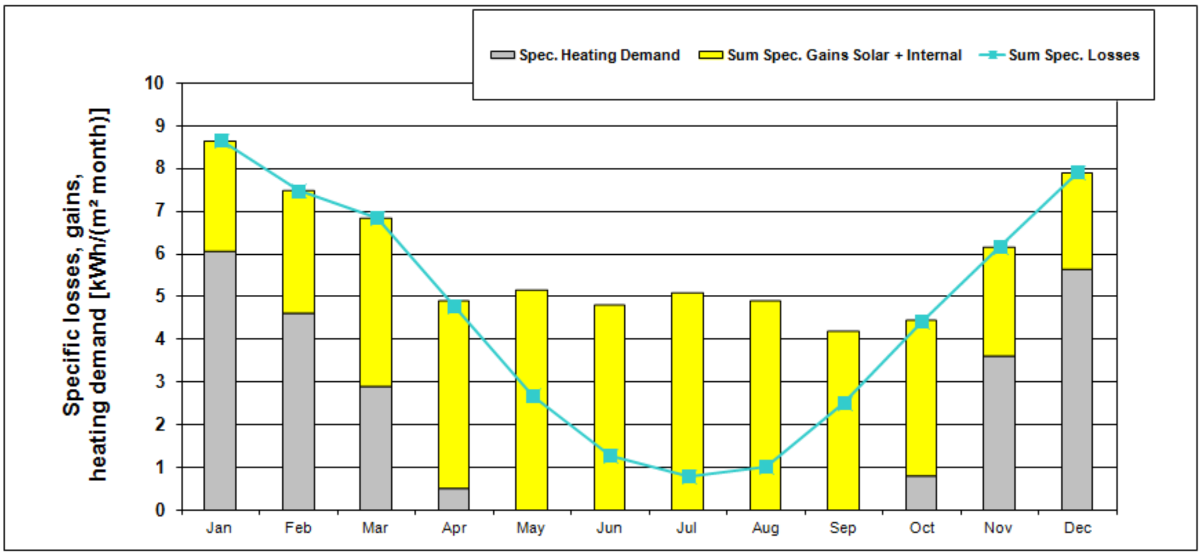
EnerPHit verification

SPECIFIC ANNUAL HEAT DEMAND MONTHLY METHOD

Climate: PL - Strefa II (Poznan/Pila)
Building: Home

Interior Temperature: 20 °C
Building Type/Use: Detached house
Treated Floor Area A_{TFA}: 105 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	16,0	13,8	12,5	8,6	4,6	2,0	1,1	1,6	4,4	8,0	11,3	14,6	99	kKh
Heating Degree Hours - G	7,7	7,1	7,7	7,0	6,6	5,3	5,1	4,9	5,4	6,0	6,4	7,2	76	kKh
Losses - Exterior	880	758	688	472	255	112	63	87	243	439	622	802	5422	kWh
Losses - Ground	32	30	32	29	28	22	21	21	23	25	27	30	321	kWh
Sum Spec. Losses	8,7	7,5	6,8	4,8	2,7	1,3	0,8	1,0	2,5	4,4	6,2	7,9	54,5	kWh/m²
Solar Gains - North	3	5	9	14	20	22	22	17	11	7	4	2	134	kWh
Solar Gains - East	19	35	69	101	140	127	136	117	82	50	23	14	913	kWh
Solar Gains - South	82	105	159	169	192	169	184	192	173	150	79	54	1707	kWh
Solar Gains - West	5	8	15	22	29	30	31	28	18	12	5	3	204	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Internal Heat Gains	165	149	165	159	165	159	165	165	159	165	159	165	1938	kWh
Sum Spec. Gains Solar +	2,6	2,9	4,0	4,4	5,2	4,8	5,1	4,9	4,2	3,6	2,6	2,3	46,5	kWh/m²
Utilisation Factor	100%	100%	100%	97%	52%	27%	16%	21%	60%	99%	100%	100%	65%	
Annual Heating Demand	639	486	304	51	0	0	0	0	0	84	380	595	2538	kWh
Spec. Heating Demand	**6,1**	**4,6**	**2,9**	**0,5**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,8**	**3,6**	**5,6**	**24,1**	kWh/m²



Annual Heating Demand: Comparison

EN 13790 Monthly Method	2538	kWh/a	24,1	**kWh/(m²a) Reference to habitable area**
PHPP, Heating Period Method	2596	kWh/a	24,7	**kWh/(m²a) Reference to habitable area**

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total	Heating Period Method
Days	31	28	31	30	31	30	31	31	30	31	30	31	365	217
Ambient Temp.	-1,54	-0,54	3,16	8,06	13,76	17,16	18,46	17,86	13,86	9,26	4,26	0,36	8,7	3,4
North Radiation	6,0	11,0	19,0	30,0	43,0	48,0	47,0	36,0	23,0	15,0	8,0	5,0	291	97
East Radiation	13,0	24,0	48,0	70,0	97,0	88,0	94,0	81,0	57,0	35,0	16,0	10,0	633	223
South Radiation	43,0	55,0	83,0	88,0	100,0	88,0	96,0	100,0	90,0	78,0	41,0	28,0	890	420
West Radiation	15,0	24,0	47,0	68,0	90,0	95,0	96,0	87,0	55,0	38,0	15,0	10,0	640	223
Hori. Radiation	19,0	36,0	71,0	109,0	156,0	155,0	160,0	136,0	86,0	52,0	23,0	13,0	1016	334
Tsky	-16,11	-14,50	-9,30	-3,12	2,56	7,16	8,61	8,04	3,41	-3,26	-8,95	-12,84	-3,1	
Ground Temp	9,67	9,45	9,67	10,28	11,10	12,60	13,20	13,42	12,53	11,93	11,10	10,28	11,3	10,4

12. "Heating Load" Worksheet

EnerPHit verification

SPECIFIC SPACE HEATING LOAD

Building:	Home	Building Type/Use:	Detached house
Climate (HL):	PL - Strefa II (Poznan/Pila)	Treated Floor Area A_{TFA}:	105,3 m²
		Interior Temperature:	20 °C

	Design Temperature		Radiation:	North	East	South	West	Horizontal	
Weather Condition 1:	-10,5	°C		10	15	30	15	25	W/m²
Weather Condition 2:	-4,5	°C		5	10	10	10	10	W/m²
Ground Design Temp.	9,5	°C							

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Factor Always 1 (except "X")		TempDiff 1 K		TempDiff 2 K		P_T 1 W		P_T 2 W
1.	Exterior Wall - Ambient	A	122,1	*	0,107	*	1,00	*	30,5	or	24,5	=	399	or	321
2.	Exterior Wall - Ground	B		*		*	1,00	*	10,5	or	10,5	=		or	
3.	Roof/Ceiling - Ambient	A	88,0	*	0,084	*	1,00	*	30,5	or	24,5	=	226	or	182
4.	Floor slab / basement ceiling	B	67,0	*	0,063	*	1,00	*	10,5	or	10,5	=	44	or	44
5.		A		*		*	1,00	*	30,5	or	24,5	=		or	
6.		A		*		*	1,00	*	30,5	or	24,5	=		or	
7.		X		*		*	0,50	*	30,5	or	24,5	=		or	
8.	Windows	A	21,2	*	0,778	*	1,00	*	30,5	or	24,5	=	503	or	404
9.	Exterior Door	A	8,3	*	0,800	*	1,00	*	30,5	or	24,5	=	203	or	163
10.	Exterior TB (length/m)	A	100,9	*	0,033	*	1,00	*	30,5	or	24,5	=	101	or	81
11.	Perimeter TB (length/m)	P		*		*	1,00	*	10,5	or	10,5	=		or	
12.	Ground TB (length/m)	B		*		*	1,00	*	10,5	or	10,5	=		or	
13.	House/DU Partition Wall	I		*		*	1,00	*	3,0	or	3,0	=		or	

Transmission Heat Losses P_T

Total = 1477 or 1195

Ventilation system:

	A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V	105,3	*	2,50	=	263

					η_{SHX} 1		η_{SHX} 2
Efficiency of Heat Recovery of the Heat Exchanger	η_{HR} 91%	Heat Recovery Efficiency SHX	0%	Efficiency SHX	0%	or	0%

	1/h		1/h						1/h		1/h
Energetically Effective Air Exchange n_V	0,128	+	0,453	*(1-	0,91	or	0,91	)=	0,169	or	0,169

Ventilation Heating Load P_V

V_L m³		n_L 1/h		n_L 1/h		c_{Air} Wh/(m³K)		TempDiff 1 K		TempDiff 2 K		P_V 1 W		P_V 2 W
263,3	*	0,169	or	0,169	*	0,33	*	30,5	or	24,5	=	449	or	361

Total Heating Load P_L

		P_L 1 W		P_L 2 W
$P_T + P_V$	=	1926	or	1556

	Orientation the Area	Area m²		g-Value (perp. radiation)		Reduction Factor (see Windows worksheet)		Radiation 1 W/m²		Radiation 2 W/m²		P_S 1 W		P_S 2 W
1.	North	2,5	*	0,5	*	0,4	*	10	or	5	=	5	or	2
2.	East	7,2	*	0,5	*	0,4	*	15	or	10	=	22	or	14
3.	South	9,4	*	0,5	*	0,4	*	30	or	10	=	58	or	19
4.	West	2,1	*	0,5	*	0,3	*	15	or	10	=	5	or	3
5.	Horizontal	0,0	*	0,0	*	0,4	*	25	or	10	=	0	or	0

Solar heating power P_S

Total = 89 or 39

Internal heating power P_I

Spec. Power W/m²		A_{TFA} m²		P_I 1 W		P_I 2 W
1,6	*	105	=	169	or	169

			P_G 1		P_G 2	
			W		W	
Heating power (gains) P_G	$P_S + P_I$	=	257	or	208	
	$P_L - P_G$	=	1669	or	1348	
Heating Load P_H		=		1669		W
Specific Heating Load P_H / A_{TFA}		=		15,8		W/m²

Input Max. Supply Air Temperature	52	°C		°C		°C
Max. Supply Air Temperature $\vartheta_{Supply,Max}$	52	°C	Supply Air Temperature Without Heating $\vartheta_{Supply,Min}$	17,3		17,8

For Comparison: Heating Load Transportable by Supply Air. $P_{Supply\ Air,Max}$	=	1369	W specific:	13,0	W/m²
			Supply Air Heating Sufficient? (Yes/No)	No	

13. "Summer" Worksheet

EnerPHit verification

S U M M E R

Climate:	PL - Strefa II (Poznan/Pila)	Interior Temperature:	20 °C
Building:	Home	Building Type/Use:	Detached house
		Treated Floor Area A_{TFA}:	105,3 m²

Spec. Capacity: 132 Wh/K pro m² TFA

Overheating limit: 25 °C

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Red. Factor $f_{T,Summer}$		H_{Summer} Heat Conductance
1.	Exterior Wall - Ambi	A	122,1	*	0,107	*	1,00	=	13,1
2.	Exterior Wall - Grou	B		*		*	1,00	=	
3.	Roof/Ceiling - Ambie	A	88,0	*	0,084	*	1,00	=	7,4
4.	Floor slab / basemen	B	67,0	*	0,063	*	1,00	=	4,2
5.		A		*		*	1,00	=	
6.		A		*		*	1,00	=	
7.		X		*		*	0,50	=	
8.	Windows	A	21,2	*	0,778	*	1,00	=	16,5
9.	Exterior Door	A	8,3	*	0,800	*	1,00	=	6,6
10.	Exterior TB (length/	A	100,9	*	0,033	*	1,00	=	3,3
11.	Perimeter TB (length	P		*		*	1,00	=	
12.	Ground TB (length/m)	B		*		*	1,00	=	

Exterior Thermal Transmittance, $H_{T,e}$	46,9	W/K
Ground Thermal Transmittance, $H_{T,g}$	4,2	W/K

				A_{TFA}		Clear Room Height		
				m²		m		m³
Heat Recovery Efficiency	η_{HR}	91%	Effective Air Volume V_V	105,3	*	2,50	=	263
SHX Efficiency	η^*_{SHX}	0%						

Summer Ventilation continuous ventilation to provide sufficient indoor air quality

Air Change Rate by Natural (Windows & Leakages) or Exhaust-Only Mechanical Ventilation, Summer: 0,27 1/h

Mechanical Ventilation Summer: 0,30 1/h — [ ] with HR (check if applicable)

	$n_{L,rest}$ (1/h)		$n_{V,system}$ (1/h)		Φ_{HR}		$n_{V,Rest}$ (1/h)		1/h
Energetically Effective Airchange Rate n_V	0,267	+	0,300	* (1 -	0,000	) +	0,000	=	0,567

	V_V (m³)		$n_{V,equi,fraction}$ (1/h)		c_{Air} (Wh/(m³K))			
Ventilation Transm. Ambient $H_{V,e}$	263	*	0,567	*	0,33	=	49,3	W/K
Ventilation Transm. Ground $H_{V,g}$	263	*	0,000	*	0,33	=	0,0	W/K

Additional Summer Ventilation for Cooling — Temperature amplitude summer 10,6 K

Select: [x] Window Night Ventilation, Manual
[ ] Mechanical, Automatically Controlled Ventilation

Corresponding Air Change Rate 0,11 1/h
(for window ventilation: at 1 K temperature difference indoor - outdoor)

Minimum Acceptable Indoor Temperature 22,0 °C

	Orientation of the Area	Angle Factor summer		Shading Factor summer		Dirt		g-Value (perp. radiation)		Area m²		Portion of Glazing		Aperture m²
1.	North	0,9	*	0,76	*	0,95	*	0,49	*	2,5	*	62%	=	0,5
2.	East	0,9	*	0,78	*	0,95	*	0,49	*	7,2	*	68%	=	1,6
3.	South	0,9	*	0,60	*	0,95	*	0,49	*	9,4	*	67%	=	1,6
4.	West	0,9	*	0,77	*	0,95	*	0,49	*	2,1	*	53%	=	0,4
5.	Horizontal	0,9	*	1,00	*	0,95	*	0,00	*	0,0	*	0%	=	0,0
6.	Sum Opaque Areas													0,0

Solar Aperture — Total 4,0 m² — 0,04 m²/m²

	Specif. Power q_I (W/m²)		A_{TFA} (m²)		W	W/m²
Internal Heat Gains Q_I	2,10	*	105	=	221	2,1

Frequency of Overheating $h_{\vartheta \geq \vartheta_{max}}$ **1,9%** **at the overheating limit ϑ_{max} = 25 °C**

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

	Solar Load (kWh/d)		1/k		Spec. Capacity (Wh/(m²K))		A_{TFA} (m²)		
Daily Temperature Swing due to Solar Load	20,3	*	1000	/ (	132	*	105	) =	1,5 K

14. "Shading-S" Worksheet

EnerPHit verification

CALCULATING SUMMER SHADING FACTORS

Climate: PL - Strefa II (Poznan/Pila)

Building: Home

Latitude: 52,42

Summer

Orientation	Glazing area	Summer shading factor
	m²	r_S
North	1,54	76%
East	4,84	78%
South	6,28	60%
West	1,11	77%
Horizontal	0,00	100%

Results from the Summer worksheet:
Frequency of Overheating $h_{\vartheta \geq \vartheta max}$ **1,9%**

Quantity	Description:	Deviation from North	Angle of Inclination from the Horizontal	Orientation	Glazing Width	Glazing Height	Glazing Area	Height of the Shading Object	Horizontal Distance	Window Reveal Depth	Distance from Glazing Edge to Reveal	Overhang Depth	Distance from Upper Glazing Edge to Overhang	Additional Shading Reduction Factor (Summer) (Input Field: Summer)	Reduction factor z for temporary sun protection (Input Field: Summer)	Horizontal Shading Reduction Factor (Summer)	Reveal Shading Reduction Factor (Summer)	Overhang Shading Reduction Factor (Summer)	Total Summe Shading Reduction Factor
		Degrees	Degrees			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}	z	r_H	r_R	r_O	r_S
4	South	180	90	South	0,78	1,35	4,2	0,00	0,00	0,10	0,12	0,00	0,00	80%	79%	100%	95%	100%	60%
1	South	180	90	South	1,28	1,61	2,1	0,00	0,00	0,10	0,12	0,00	0,00	80%	79%	100%	96%	100%	61%
1	East	90	90	East	1,62	1,20	1,9	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	98%	100%	79%
1	East	90	90	East	1,10	0,46	0,5	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	98%	100%	78%
1	East	90	90	East	0,30	0,60	0,2	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	94%	100%	75%
1	East	90	90	East	1,23	1,79	2,2	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	98%	100%	78%
1	West	270	90	West	0,28	1,37	0,4	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	94%	100%	75%
1	West	270	90	West	1,23	0,59	0,7	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	98%	100%	78%
1	North	0	90	North	0,58	0,54	0,3	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	94%	100%	75%
1	North	0	90	North	0,89	1,38	1,2	0,00	0,00	0,10	0,12	0,00	0,00	80%		100%	95%	100%	76%

15. "SummVent" Worksheet

EnerPHit verification

SUMMER VENTILATION

Building: Home

Building Type/Use: Detached house

Building Volume: 263 m³

Description	South W/1	West W/1	South W/1	Night	Night	Night	
Fraction of Opening Duration	50%	50%	50%	70%	70%	70%	
Climate Boundary Conditions							
Temperature Diff Interior - Exterior	4	4	4	1	1	1	K
Wind Velocity	1	1	1	0	0	0	m/s

Note: for summer night ventilation please set a temperature difference of 1 K and a wind velocity of 0 m/s otherwise the cooling effects of the night ventilation will be overestimated!

Window Group 1							
Quantity	3	1	1	1	1	1	
Clear Width	0,90	1,22	0,80	0,74	1,86	1,47	m
Clear Height	1,60	0,72	2,00	1,90	1,46	0,85	m
Tilting Windows?	x	x	x	x	x	x	
Opening Width (for tilting windows)	0,050	0,050	0,050	0,050	0,050	0,050	m
Window Group 2 (Cross Ventilation)							
Quantity							
Clear Width							m
Clear Height							m
Tilting Windows?							
Opening Width (for Tilting Windows)							m
Difference in Height to Window 1							m

Single-Sided Ventilation 1 - Airflow Volume	90	13	37	17	16	7	m³/h
Single-Sided Ventilation 2 - Airflow Volume	0	0	0	0	0	0	m³/h
Cross Ventilation Airflow Volume	90	13	37	17	16	7	m³/h
Contribution to Air Change Rate	0,17	0,03	0,07	0,04	0,04	0,02	1/h

Summary of Summer Ventilation Distribution

Description Ventilation Type	Daily Average Air Change Rate	
Night time Window Ventilation (@1K)	0,11	1/h
Daytime Window Ventilation	0,27	1/h
		1/h

16. „Cooling" Worksheet

EnerPHit verification

SPECIFIC USEFUL COOLING DEMAND
MONTHLY METHOD

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

Climate: PL - Strefa II (Posnan/Pila) | Interior Temperature Summer: 25 °C

Building: Home | Building Type/Use: Detached house

Spec. Capacity: 132 Wh/(m²K) (Enter in Summer worksheet.) | Treated Floor Area A_{TFA}: 105,3 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Mon. Red. Fac.		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	122,1	*	0,107	*	1,00	*	21	=	274	
2.	Exterior Wall - Ground	B		*		*	1,00	*		=		
3.	Roof/Ceiling - Ambient	A	88,0	*	0,084	*	1,00	*	21	=	155	
4.	Floor slab / basement ceil	B	67,0	*	0,063	*	1,00	*	33	=	137	
5.		A		*		*	1,00	*		=		
6.		A		*		*	1,00	*		=		
7.		X		*		*	0,50	*		=		
8.	Windows	A	21,2	*	0,778	*	1,00	*	21	=	346	
9.	Exterior Door	A	8,3	*	0,800	*	1,00	*	21	=	139	
10.	Exterior TB (length/m)	A	100,9	*	0,033	*	1,00	*	21	=	69	
11.	Perimeter TB (length/m)	P		*		*	1,00	*		=		
12.	Ground TB (length/m)	B		*		*	1,00	*		=		

Transmission Losses Q_T (Negative: Heat Loads) — Total: 1121 kWh/a | 10,6 kWh/(m²a)

	A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume V_V	105	*	2,50	=	263

	Heat Transfer Coe W/K		G_t kKh/a		kWh/a	kWh/(m²a)
Exterior	49,3	*	21	=	1034	9,8
Ground	0,0	*	40	=	0	0,0

Additional Summer Ventilation

Select:
- x — Window Night Ventilation, Manual
- Mechanical, Automatically Controlled Ventilation

Corresponding Air Change Rate: 0,11 1/h
(for window ventilation: at 1 K temperature difference indoor - outdoor)
Minimum Acceptable Indoor Temperat: 22,0 °C

Heat Losses Summer Ventilation — 616 kWh/a | 5,8 kWh/(m²a)

	$Q_{L,ext}$ kWh/a		$Q_{L,ground}$ kWh/a		$Q_{L,summer}$ kWh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	1034	+	0	+	616	=	1650	15,7

	Q_T kWh/a		Q_V kWh/a		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	1121	+	1650	=	2771	26,3

Orientation of the Area	Reduction Factor		g-Value (perp. radiation)		Area m²		Global Radiation kWh/(m²a)		kWh/a
1. North	0,40	*	0,49	*	2,5	*	160	=	78
2. East	0,45	*	0,49	*	7,2	*	332	=	528
3. South	0,34	*	0,49	*	9,4	*	354	=	560
4. West	0,35	*	0,49	*	2,1	*	338	=	121
5. Horizontal	0,40	*	0,00	*	0,0	*	554	=	0
6. Sum Opaque Areas									0

Available Solar Heat Gains Q_S — Total: 1288 kWh/a; 12,2 kWh/(m²a)

Internal Heat Gains Q_I — 0,024 kh/d * 109 d/a (Length Heat. Period) * 2,1 W/m² (Spec. Power q_I) * 105,3 m² (A_{TFA}) = 579 kWh/a; 5,5 kWh/(m²a)

Sum Heat Loads Q_F — $Q_S + Q_I$ = 1867 kWh/a; 17,7 kWh/(m²a)

Ratio of Losses to Free Heat Gains — Q_L / Q_F = 1,48

Utilisation Factor Heat Losses η_G = 63%

Useful Heat Losses $Q_{V,n}$ — $\eta_G * Q_L$ = 1751 kWh/a; 16,6 kWh/(m²a)

Useful Cooling Demand Q_K — $Q_F - Q_{V,n}$ = 115 kWh/a; **1** kWh/(m²a)

Limiting Value — 15 kWh/(m²a) — **Requirement met?** (Yes/No): -

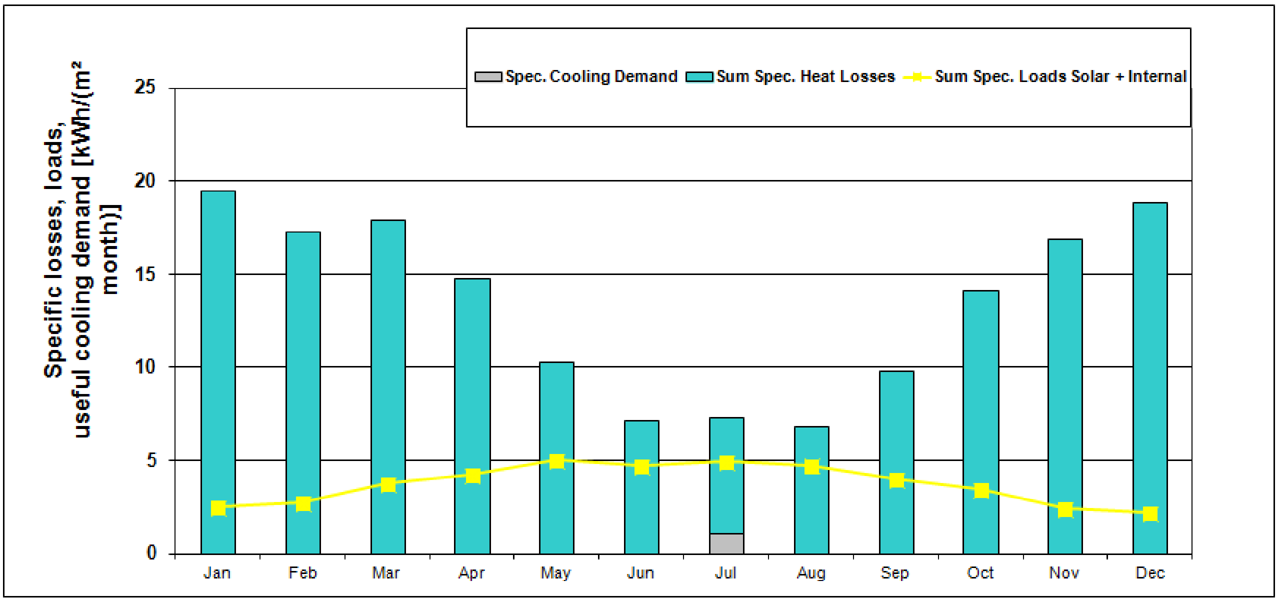
EnerPHit verification

SPECIFIC USEFUL COOLING DEMAND MONTHLY METHOD

Climate: PL - Strefa II (Poznan/Pila)
Building: Home

Interior Temperature: 25 °C
Building Type/Use: Detached house
Treated Floor Area A_{TFA}: 105 m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	19,7	17,2	16,2	12,2	8,4	5,6	4,9	5,3	8,0	11,7	14,9	18,3	143	kKh
Heating Degree Hours - G	11,4	10,4	11,4	10,6	10,3	8,9	8,8	8,6	9,0	9,7	10,0	11,0	120	kKh
Losses - Exterior	1900	1651	1563	1173	804	543	468	511	772	1127	1437	1764	13713	kWh
Losses - Ground	48	44	48	45	43	38	37	36	38	41	42	46	505	kWh
Losses Summer Ventilati	102	124	270	335	232	165	151	159	222	321	300	170	2551	kWh
Sum Spec. Heat Losses	19,5	17,3	17,9	14,7	10,2	7,1	6,2	6,7	9,8	14,1	16,9	18,8	159,2	kWh/m²
Solar Load North	3	5	9	15	21	24	23	18	11	7	4	2	143	kWh
Solar Load East	21	38	76	111	154	140	149	129	90	56	25	16	1005	kWh
Solar Load South	68	87	131	139	158	139	152	158	143	124	65	44	1410	kWh
Solar Load West	5	9	17	24	32	34	35	31	20	14	5	4	230	kWh
Solar Load Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Load Opaque	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Internal Heat Gains	165	149	165	159	165	159	165	165	159	165	159	165	1938	kWh
Sum Spec. Loads Solar +	2,5	2,7	3,8	4,3	5,0	4,7	5,0	4,8	4,0	3,5	2,5	2,2	44,9	kWh/m²
Utilisation Factor Losses	13%	16%	21%	29%	49%	66%	64%	70%	41%	24%	15%	12%	28%	
Useful Cooling Energy De	0	0	0	0	0	3	106	5	0	0	0	0	115	kWh
Spec. Cooling Demand	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**1,0**	**0,1**	**0,0**	**0,0**	**0,0**	**0,0**	**1,1**	kWh/m²



Temperature Amplitude Summer 10,6 K

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total
Days	31	28	31	30	31	30	31	31	30	31	30	31	365
Ambient Temp.	-1,54	-0,54	3,16	8,06	13,76	17,16	18,46	17,86	13,86	9,26	4,26	0,36	8,7
North Radiation	6,0	11,0	19,0	30,0	43,0	48,0	47,0	36,0	23,0	15,0	8,0	5,0	291
East Radiation	13,0	24,0	48,0	70,0	97,0	88,0	94,0	81,0	57,0	35,0	16,0	10,0	633
South Radiation	43,0	55,0	83,0	88,0	100,0	88,0	96,0	100,0	90,0	78,0	41,0	28,0	890
West Radiation	15,0	24,0	47,0	68,0	90,0	95,0	96,0	87,0	55,0	38,0	15,0	10,0	640
Hori. Radiation	19,0	36,0	71,0	109,0	156,0	155,0	160,0	136,0	86,0	52,0	23,0	13,0	1016
Tsky	-16,11	-14,50	-9,30	-3,12	2,56	7,16	8,61	8,04	3,41	-3,26	-8,95	-12,84	-3,1
Ground Temp	9,67	9,45	9,67	10,28	11,10	12,60	13,20	13,42	12,53	11,93	11,10	10,28	11,3

17. "Cooling Load" Worksheet

EnerPHit verification

COOLING LOAD

Building:	Home	Building Type/Use:	Detached house	Interior Temperature:	25 °C
Spec. Capacity:	132 Wh/(m²K) (Enter in "Summer" worksheet.)	Treated Floor Area A_{TFA}:	105,3 m²		
		Climate (Cooling Load):	PL - Strefa II (Poznan/Pila)		

	Ambient Air	Sky	Ground	Radiation:	North	East	South	West	Horizontal	
Design Temperature:	25,5 °C	16,3 °C	13,4 °C		110	230	220	220	350	W/m²

	Building Elements	Temperature Zone	Area m²		U-Value W/(m²K)		Factor Always 1 (except "X")		TempDiff K		W
1.	Exterior Wall - Ambie	A	122,1	*	0,107	*	1,00	*	0,5	=	6
2.	Exterior Wall - Groun	B		*		*	1,00	*	-11,6	=	
3.	Roof/Ceiling - Ambien	A	88,0	*	0,084	*	1,00	*	0,5	=	3
4.	Floor slab / basement	B	67,0	*	0,063	*	1,00	*	-11,6	=	-49
5.		A		*		*	1,00	*	0,5	=	
6.		A		*		*	1,00	*	0,5	=	
7.		X		*		*	0,50	*	0,5	=	
8.	Windows	A	21,2	*	0,778	*	1,00	*	0,5	=	8
9.	Exterior Door	A	8,3	*	0,800	*	1,00	*	0,5	=	3
10.	Exterior TB (length/m)	A	100,9	*	0,033	*	1,00	*	0,5	=	2
11.	Perimeter TB (length/m)	P		*		*	1,00	*	-11,6	=	
12.	Ground TB (length/m)	B		*		*	1,00	*	-11,6	=	
13.	House/DU Partition Wall	I		*		*	1,00	*	3,0	=	
			$L_{ambient}$ W/K		TempDiff K		L_{Sky} W/K		TempDiff K		
14.	Radiation Correction		0,0	*	0,5	+	0,0	*	-8,7	=	0
	Transmission Heat Losses P_T								Total	=	-27

Ventilation System:

	A_{TFA} m²		Clear Room Height m		m²
Effective Air Volume, V_V	105,3	*	2,50	=	263

	Vent. Transm. W/K		TempDiff K		W
Exterior	49,3	*	0,5	=	23
Ground	0,0	*	-11,6	=	0

Additional Summer Ventilation:

x	Window Night Ventilation, Manual	Corresponding Air Change Rate	0,11	1/h
	Mechanical, Automatically Controlled Ventilation	Minimum Indoor Temperature	22,0	°C

		kWh/d		kh/d		W
Heat Removal Cooling Design Day	Window Ventilation	-1,6	/	0,024	=	-66
(from Cooling worksheet)	Automatic Night Ventilation	0,0	/	0,024	=	0

Ventilation Heat Load P_V

Total = -43 W

	Orientation of the Area	Area m²		g-Value (perp. radiation)		Reduction Factor		Radiation W/m²		P_S W
1.	North	2,5	*	0,5	*	0,40	*	110	=	54
2.	East	7,2	*	0,5	*	0,45	*	230	=	365
3.	South	9,4	*	0,5	*	0,34	*	220	=	349
4.	West	2,1	*	0,5	*	0,35	*	220	=	79
5.	Horizontal	0,0	*	0,0	*	0,40	*	350	=	0
6.	Sum Opaque Areas									0

Heat Gain - Solar Heat Load, P_S

Total = 847

	Spec. Power W/m²		A_{TFA} m²		P_I W
Internal Heat Load P_I	3,1	*	105	=	327

Cooling Load P_C $P_T + P_V + P_S + P_I$ = **1103** W

Specific Maximum Cooling Load P_C / A_{EB} = **10,5** W/m²

Minimal supply air temperature 4 °C Supply air temperature without cooling $\vartheta_{Supply,Min}$ 25,5 °C

Cooling capacity that is transportable through the supply air $P_{SupplyAir,Max}$ = 547 W

specific = 5,2 W/m²

Air conditioning over the supply air possible? (yes/no) **no**

	Solar Load W		Time h/d		Spec. Capacity Wh/(m²K)		A_{TFA} m²		
Daily Temperature Swing due to Solar Load	846,7	*	24	/ (	132	*	105	) =	1,5 K

18. "DHW + Distribution" Worksheet

EnerPHit verification

HEAT DISTRIBUTION AND DHW SYSTEM

Building:	Home	
Interior Temperature:	20	°C
Building Type/Use:	Detached house	
Treated Floor Area A_{TFA}:	105	m²
Occupancy:	3,0	Pers
Number of Residences:	1	
Annual Heating Demand qHeating	2479	kWh/a
Length of Heating Period:	217	d
Average heating load Pave:	0,5	kW
Marginal Utilisability of Additional Heat Gains:	93%	

			Parts: Warm Region 1	Parts: Cold Region 2	Parts: Cold Region 3	Total	Unit	
Space Heat Distribution								
Length of Distribution Pipes	L_H (Project)		40,80				m	
Heat Loss Coefficient per m Pipe	Ψ (Project)		0,364				W/(mK)	
Temperature of the Room Through Which the Pipe	ϑ_X Mechanical Room		20				°C	
Design Flow Temperature	ϑ_{dist} Flow, Design Value		55,0				°C	
Design System heating load	$P_{heating}$ (exist./calc.)		1,65				kW	
Flow Temperature Control (check)			x					
Design Return Temperature	ϑ_R	$=0.714*(\vartheta_{dist}-20)+20$	45,0				°C	
Annual Heat Emission per m of Plumbing	q^*_{HL}	$= \Psi\,(\vartheta_m-\vartheta_X)\,t_{Heating}*0.024$	22			Total 1,2,3	kWh/(m·a)	
Possible Utilization Factor of Released Heat	η_G		93%				-	
Annual Losses	Q_{HL}	$= L_H \cdot q^*_{HL} \cdot (1-\eta_G)$	68	0	0	**68**	kWh/a	
Specif. Losses	q_{HL}	$= \Sigma Q_{HL} / A_{TFA}$					kWh/(m²a)	**0,6**
Performance ratio of heat distribution	$e_{a,HL}$	$= (q_H + q_{HL}) / q_H$				**103%**	-	

			Value	Unit	
DHW: Standard Useful Heat					
DHW Consumption per Person and Day (60 °C)	V_{DHW}	(Project or Average Value 25 Litres/P/d)	25,0	Litre/Person/d	
Average Cold Water Temperature of the Supply	ϑ_{DW}	Temperature of Drinking Water (10°)	9,7	°C	
DHW Non-Electric Wash and Dish		(Electricity worksheet)	229	kWh/a	
Useful Heat - DHW	Q_{DHW}		**1830**	kWh/a	
Specif. Useful Heat - DHW	q_{DHW}	$= Q_{DHW} / A_{TFA}$		kWh/(m²a)	**17,4**

			Warm Region	Cold Region	Cold Region	Total	Unit	
DHW Distribution and Storage								
Length of Circulation Pipes (Flow + Return)	L_{HS} (Project)		31,4				m	
Heat Loss Coefficient per m Pipe	Ψ (Project)		0,171				W/m/K	
Temperature of the Room Through Which the Pipe	ϑ_X Mechanical Room		20				°C	
Design Flow Temperature	ϑ_{dist} Flow, Design Value		60,0				°C	
Daily circulation period of operation.	td_{Circ} (Project)		18,0				h/d	
Design Return Temperature	ϑ_R	$=0.875*(\vartheta_{dist}-20)+20$	55				°C	
Circulation period of operation per year	t_{Circ}	$= 365\ td_{Circ}$	6570				h/a	
Annual Heat Released per m of Pipe	q^*_Z	$= \Psi\,(\vartheta_m-\vartheta_X)\,t_{Circ}$	42				kWh/m/a	
Possible Utilization Factor of Released Heat	$\eta_{G,DHW}$	$=t_{heating}/365d * \eta_G$	55%				-	
Annual Heat Loss from Circulation Lines	Q_Z	$= L_{HS} \cdot q^*_Z \cdot (1-\eta_{G,DHW})$	596			**596**	kWh/a	
Total Length of Individual Pipes	L_U (Project)		29,10				m	
Exterior Pipe Diameter	d_{U_Pipe} (Project)		0,012				m	
Heat loss per tap opening	$q_{individual}$	$=(c_{pH2O}V_{H2O}+c_{pMat}V_{Mat})(\vartheta_{dist}\text{-}\vartheta$	0,1042				kWh/tap opening	
Amount of tap openings per year	n_{Tap}	$= n_{Pers} \cdot 3 \cdot 365 / n_{LU}$	3295				Tap openings per year	
Annual Heat Loss	q_U	$= n_{Tap} \cdot q_{individual}$	343				kWh/a	
Possible Utilization Factor of Released Heat	η_{G_U}	$=t_{heating}/8760*\eta_G$	55%				-	
Annual Heat Loss of Individual Pipes	Q_U	$= q_U \cdot (1-\eta_{G\_U})$	155			**155**	kWh/a	
						Total 1,2,3		
Average Heat Released From Storage	P_S		26				W	
Possible Utilization Factor of Released Heat	η_{G_S}	$=t_{heating}/8760*\eta_G$	55%					
Annual Heat Losses from Storage	Q_S	$= P_S \cdot 8.760\ kh \cdot (1-\eta_{G\_S})$	103			**103**	kWh/a	
						Total 1,2,3		
Total Heat Losses of the DHW System	Q_{WL}	$= Q_Z+Q_U+Q_S$				**853**	kWh/a	
Specif. Losses of the DHW System	q_{WL}	$= Q_{WL} / A_{TFA}$					kWh/(m²a)	**8,1**
Performance ratio DHW-distribution + storage	$e_{a,WL}$	$= (q_{TWW} + q_{WV}) / q_{TWW}$				**146,6%**	-	
Total Heating Demand of DHW system	Q_{gDHW}	$= Q_{DHW}+Q_{WL}$				**2684**	kWh/a	
Total Spec. Heating Demand of DHW System	q_{gDHW}	$= Q_{gDHW} / A_{TFA}$					kWh/(m²a)	**25,5**

Secondary Calculation Storage Losses

Specific Heat Losses Storage (total)	3,0	W/K
Typical Temperature DHW	60	°C
Room Temperature	20	°C
Total Storage Heat Losses	120	W

19. „Solar DHW" Worksheet

EnerPHit verification

SOLAR HOT WATER GENERATION

Building: Home

Building Type/Use: Detached house

Treated Floor Area A_{TFA}: 105,3 m²

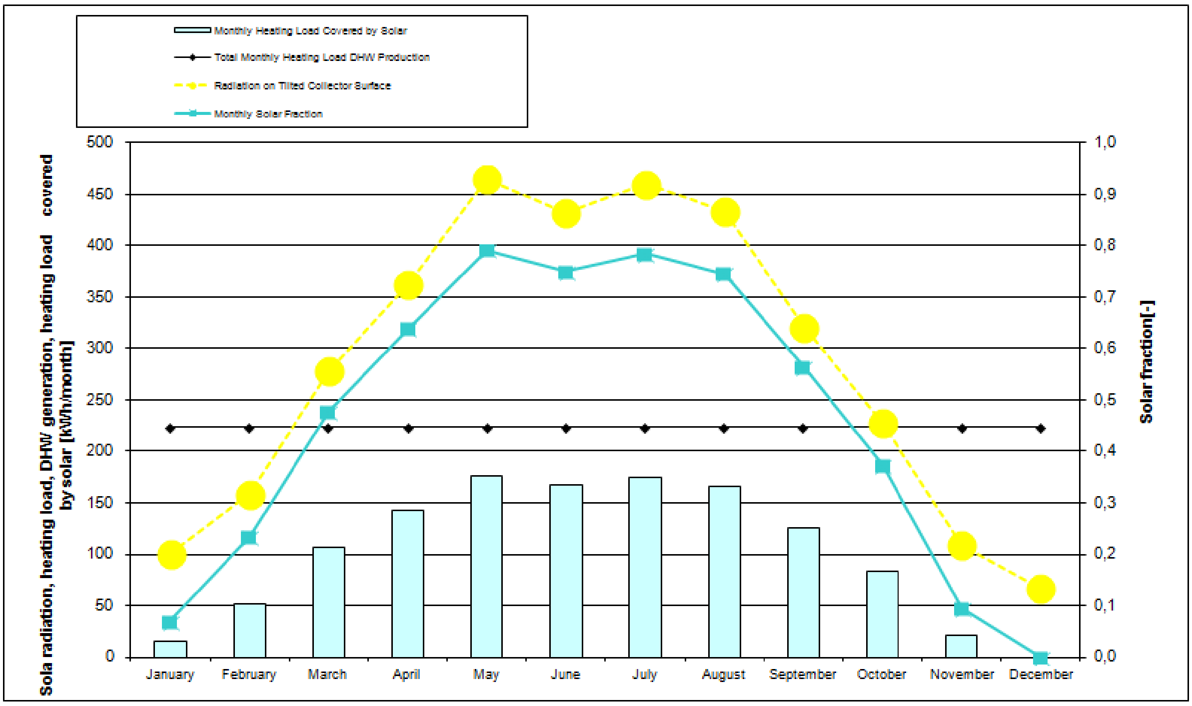
Solar Fraction with DHW demand including washing and dish-washing

Heating Demand DHW	q_{gDHW}	2684	kWh/a	from DHW+Distribution worksheet
Latitude:		52,4	°	from Climate Data worksheet
Selection of collector from list (see below):		7	Selection:	7 Improved Flat Plate Collector
Solar Collector Area		3,40	m²	
Deviation from North		180	°	
Angle of Inclination from the Horizontal		41	°	
Height of the Collector Field		1,4	m	
Height of Horizon	h_{Hori}		m	
Horizontal Distance	a_{Hori}		m	
Additional Reduction Factor Shading	r_{other}	80%	%	
Occupancy		3,0	Persons	
Specific Collector Area		1,1	m²/Pers	

Estimated Solar Fraction of DHW Production	46%			
Solar Contribution to Useful Heat	1235	kWh/a	12	kWh/(m²a)

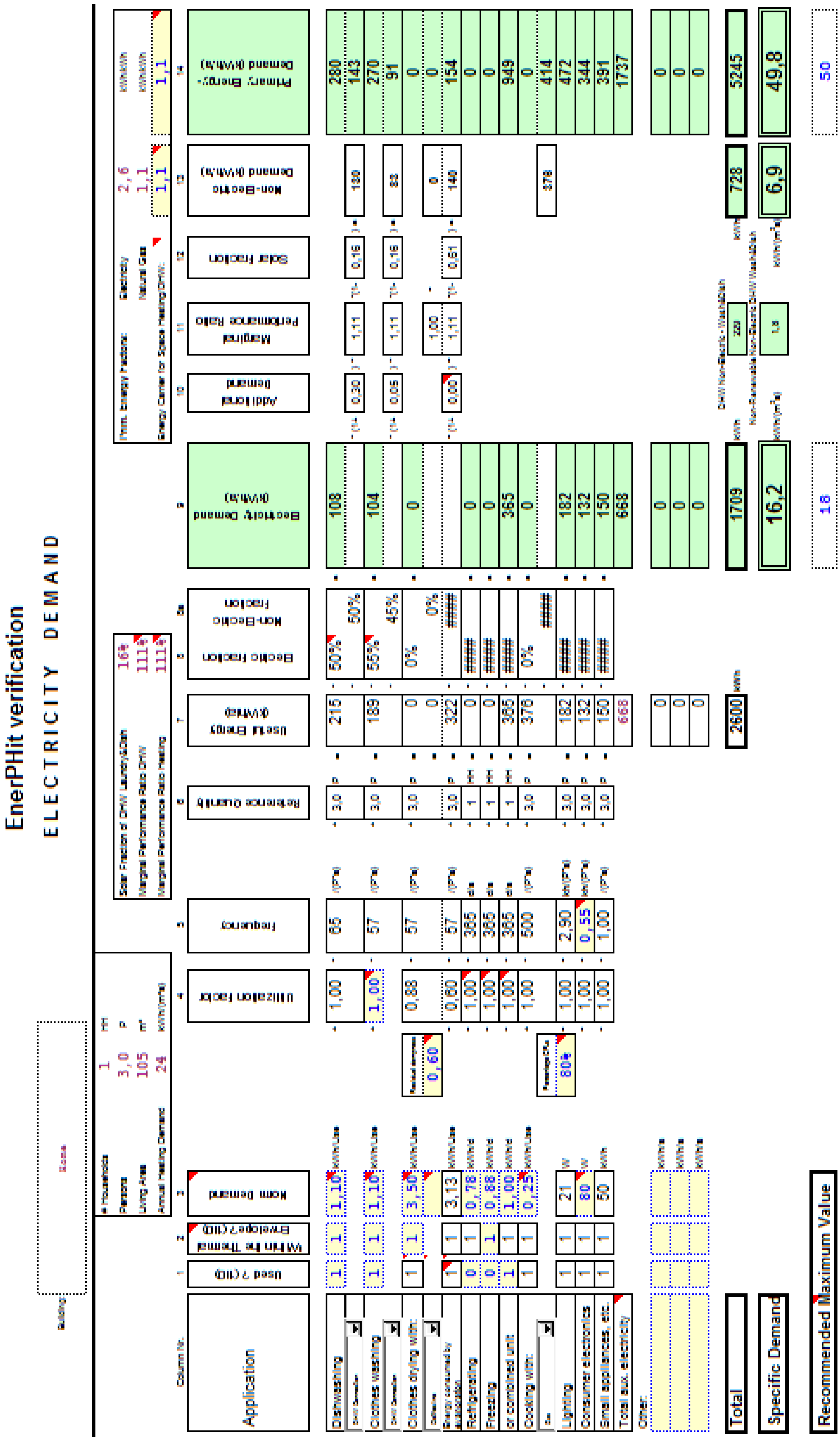
Secondary Calculation of Storage Losses

Selection of DHW storage from list (see below):	10	Selection:	10 Stratified Solar Storage
Total Storage Volume	313	litre	
Volume Standby Part (above)	94	litre	
Volume Solar Part (below)	219	litre	
Specific Heat Losses Storage (total)	2,6	W/K	
Typical Temperature DHW	60	°C	
Room Temperature	20	°C	
Storage Heat Losses (Standby Part Only)	26	W	
Total Storage Heat Losses	104	W	



Monthly Solar Fraction	January	February	March	April	May	June	July	August	September	October	November	December	
Radiation on Tilted Collector Surface	101	159	278	362	464	432	460	433	321	228	108	66	kWh/Month
Monthly Solar Fraction	0,07	0,23	0,48	0,64	0,79	0,75	0,78	0,75	0,56	0,37	0,10	0,00	-
Total Monthly Heating Load DHW Production	224	224	224	224	224	224	224	224	224	224	224	224	kWh/Month
Monthly Heating Load Covered by Solar	15	52	107	143	177	168	176	167	126	84	21	0	kWh/Month

20. "Electricity" Worksheet



EnerPHit verification

ELECTRICITY DEMAND

Building: Home

# Households	1	HH
Persons	3,0	P
Living Area	105	m²
Annual Heating Demand	24	kWh/(m²a)

Solar Fraction of DHW Laundry&Dish	16%
Marginal Performance Ratio DHW	111%
Marginal Performance Ratio Heating	111%

Prim. Energy Factors:	Electricity	2,6	kWh/kWh
	Natural Gas	1,1	kWh/kWh
Energy Carrier for Space Heating/DHW:		1,1	1,1

Column Nr. / Application	1 Used ? (1/0)	2 Within the Thermal Envelope? (1/0)	3 Norm Demand		4 Utilization factor	5 Frequency		6 Reference Quantity		7 Useful Energy (kWh/a)	8 Electric fraction	8a Non-Electric fraction	9 Electricity Demand (kWh/a)	10 Additional Demand	11 Marginal Performance Ratio	12 Solar fraction	13 Non-Electric Demand (kWh/a)	14 Primary Energy-Demand (kWh/a)
Dishwashing	1	1	1,10	kWh/Use	1,00	65	/(P*a)	3,0	P	215	50%		108					280
[illegible]												50%		0,30	1,11	0,16	130	143
Clothes washing	1	1	1,10	kWh/Use	1,00	57	/(P*a)	3,0	P	189	55%		104					270
[illegible]												45%		0,05	1,11	0,16	83	91
Clothes drying with:	1	1	3,50	kWh/Use	0,88	57	/(P*a)	3,0	P	0	0%		0					0
[illegible]										0		0%			1,00		0	0
Energy consumed by evaporation	1	1	3,13	kWh/Use	0,60	57	/(P*a)	3,0	P	322		####		0,00	1,11	0,61	140	154
Refrigerating	0	1	0,78	kWh/d	1,00	365	d/a	1	HH	0	####		0					0
Freezing	0	1	0,88	kWh/d	1,00	365	d/a	1	HH	0	####		0					0
or combined unit	1	1	1,00	kWh/d	1,00	365	d/a	1	HH	365	####		365					949
Cooking with:	1	1	0,25	kWh/Use	1,00	500	/(P*a)	3,0	P	376	0%		0					0
[illegible]												####					378	414
Lighting	1	1	21	W	1,00	2,90	kh/(P*a)	3,0	P	182	####		182					472
Consumer electronics	1	1	80	W	1,00	0,55	kh/(P*a)	3,0	P	132	####		132					344
Small appliances, etc.	1	1	50	kWh	1,00	1,00	/(P*a)	3,0	P	150	####		150					391
Total aux. electricity										668			668					1737
Other:																		
				kWh/a						0			0					0
				kWh/a						0			0					0
				kWh/a						0			0					0
Total										2600 kWh			1709 kWh	DHW Non-Electric - Wash&Dish	229	kWh	728	5245
Specific Demand													16,2 kWh/(m²a)	Non-Renewable Non-Electric DHW Wash&Dish	1,8	kWh/(m²a)	6,9	49,8
Recommended Maximum Value													18					50

Additional input boxes	
Residual dampness	0,60
Percentage CFLs	80%

21. „Auxiliary Electricity" Worksheet

EnerPHit verification

AUXILIARY ELECTRICITY

Building: Rome

1	Living Area	105	m²
2	Heating Period	217	d
3	Air Volume	263	m³
4	Dwelling Units	1	HH
5	Enclosed Volume	366	m³

Operation Vent. System Winter	5,20	kh/a
Operation Vent. System Summer	3,56	kh/a
Air Change Rate	0,45	h^{-1}
Defrosting HX from	-2,0	°C

Primary Energy Factor - Electricity	2,6	kWh/kWh
Annual Space Heating Demand	24	kWh/(m²a)
Boiler Rated Power	15	kW
DHW System Heating Demand	2690	kWh/a
Design Flow Temperature	55	°C

Column Nr.	1	2	3		4		5		6		7	8	9	10	11
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 Internal Heat	Used During Time Period (kh/a)	Internal Heat Source (W)	Primary Energy Demand (kWh/a)
Ventilation System															
Winter Ventilation	1	1	0,42	Wh/m³	0,45	h^{-1}	5,2	kh/a	263,325	m³	261	considered in heat recovery efficiency			677
Summer Ventilation	1	1	0,42	Wh/m³	0,30	h^{-1}	3,6	kh/a	263,325	m³	118	no summer contribution to IHG			307
Defroster HX	1	0	350	W	1,00		0,1	kh/a	1		47	1,0	5,20	0	122
Heating System					Controlled/Uncontrolled (1/0)										
Enter the Rated Power of the Pump			20	W	0										
Circulation Pump	0	1	20	W	1,0		5,2	kh/a	1		0	1,0	5,20	0	0
Boiler Electricity Consumption at 30% Load				W											
Aux. Energy - Heat. Boiler	1	0	55	W	1,00		0,58	kh/a	1		32	1,0	5,20	0	83
Aux. Energy - Wood fired/pellet boiler	0	0	Data entries in worksheet Boiler. Auxiliary energy demand including possible drinking water prod								0	1,0	5,20	0	0
DHW system															
Enter Average Power Consumption of Pump			28	W											
Circulation Pump	1	1	28	W	1,00		4,4	kh/a	1		123	0,6	8,76	8	319
Enter the Rated Power of the Pump			52	W											
Storage Load Pump DHW	1	1	52	W	1,00		0,2	kh/a	1		9	1,0	5,20	2	24
Boiler Electricity Consumption at 100% Load				W											
DHW Boiler Aux. Energy	1	0	165	W	1,00		0,1	kh/a	1		16	1,0	5,20	0	41
Enter the Rated Power of the Solar DHW Pump				W											
Solar Aux Electricity	1	1	36	W	1,00		1,8	kh/a	1		63	0,6	8,76	4	163
Misc. Aux. Electricity															
Misc. Aux. Electricity	0	0		kWh/a	1,00		1,0		1	HH	0	1,0	8,76	0	0
Total											668			15	1737
Specific Demand kWh/(m²a)			Divide by Living Area								6,3				16,5

22. "PE Value" Worksheet

EnerPHit verification

PRIMARY ENERGY VALUE

Building: Home

Building Type/Use:	Detached house
Treated Floor Area A_{TFA}:	105 m²
Space Heating Demand incl. Distribution	25 kWh/(m²a)
Useful Cooling Demand:	0 kWh/(m²a)

		Final Energy kWh/(m²a)	Primary Energy kWh/(m²a)	Emissions CO_2-Equivalent kg/(m²a)
Boiler			PE Value	CO_2-Emission 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	310
Boiler Type	*(Boiler worksheet)*	Low Temperature Boiler Oil		
Performance Ratio of Heat Generator	*(Boiler worksheet)*	126%		
Annual Energy Demand (without DHW Wash&Dish)	*(Boiler worksheet)*	46,5	51,2	14,4
Non-Electric Demand, DHW Wash&Dish	*(Electricity worksheet)*	2,0	2,2	0,6
Total Heating Oil/Gas/Wood		**48,6**	**53,4**	**15,1**

23. "Boiler" Worksheet

EnerPHit verification

EFFICIENCY OF HEAT GENERATION (GAS, OIL, WOOD)

Building: Home

Building Type/Use:	Detached house
Treated Floor Area A_{TFA}:	105 m²

			Value	Unit
Covered Fraction of Space Heating Demand		*(PE Value worksheet)*	100%	
Space Heating Demand + Distribution Losses	Q_H+Q_{HS}	*(DHW+Distribution)*	2604	kWh
Solar Fraction for Space Heat	$\eta_{Solar,\ H}$	*(Separate Calculation)*	0%	
Effective Annual Heating Demand	$Q_{H,WI}=Q_H*(1-\eta_{Solar,\ H})$		**2604**	kWh
Space Heating Demand without Distribution Losses	Q_H	*(Verification sheet)*	2538	kWh
Covered Fraction of DHW Demand		*(PE Value worksheet)*	100%	
Total Heating Demand of DHW system	Q_{gDHW}	*(DHW+Distribution)*	2680	kWh
Solar Fraction for DHW	$\eta_{Solar,\ DHW}$	*(SolarDHW worksheet)*	46%	
Effective DHW Demand	$Q_{DHW,WI}=Q_{DHW}*(1-\eta_{Solar,\ DHW})$		**1445**	kWh

Effective DHW Demand	$Q_{DHW,wi}=Q_{DHW}*(1-\eta_{Solar,DHW})$	**1445**	kWh			
Boiler Type	*(Project)*	Low Temperature Boiler Oil				
Primary Energy Factor	*(Data worksheet)*	1,1	kWh/kWh			
CO_2-Emissions Factor (CO_2-Equivalent)		310	g/kWh			
Useful Heat Provided	Q_{Use}	4049	kWh/a			
Max. Heating Power Required for Heating the Building	P_{BH} *(Heating Load worksheet)*	1,67	kW			
Length of the Heating Period	t_{HP}	5198	h			
Length of DHW Heating Period	t_{DHW}	8760	h			
Use characteristic values entered (check if appropriate)?						
		Project Data		Standard Values		Input field
Design Output	$P_{nominal}$ *(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)*	91%		91%		
Boiler Efficiency at Nominal Output	$\eta_{100\%}$ *(Manufacturer)*	90%		90%		
Standby Heat Loss Boiler at 70 °C	$q_{B,70}$ *(Manufacturer)*	1,4%		1,4%		
Average Return Temperature Measured at 30% Load	$\vartheta_{30\%}$ *(Manufacturer)*	40	°C	40		

Utilisation Factor Heat Generator Heating Run	$h_{H,g,K}=f_0*\eta_K$	**80%**	
Utilisation Factor Heat Generator DHW Run	$h_{TW,g,K}=\eta_{100\%}/f_{0,TW}$	**78%**	
Utilisation Factor Heat Generator DHW & Heating	$h_{g,K}$	**79%**	
		kWh/a	kWh/(m²a)
Final Energy Demand Space Heating	$Q_{Final,HE}=Q_{H,wi}*e_{H,g,K}$	**3259**	
Final Energy Demand DHW	$Q_{Final,DHW}=Q_{WW,wi}*e_{TW,g,K}$	**1856**	
Total Final Energy Demand	$Q_{Final}=Q_{Final,DHW}+Q_{Final,HE}$	**5115**	**48,6**
Annual Primary Energy Demand		**5627**	**53,4**
		kg/a	kg/(m²a)
Annual CO_2-Equivalent Emissions		**1586**	**15,1**

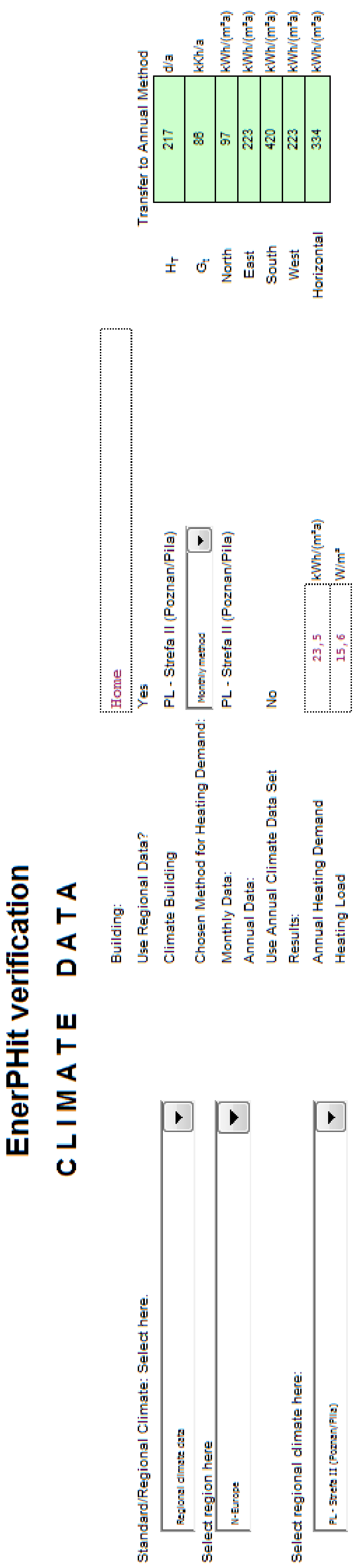
Secondary Calculation: Efficiency of the Oil and Gas Boiler:

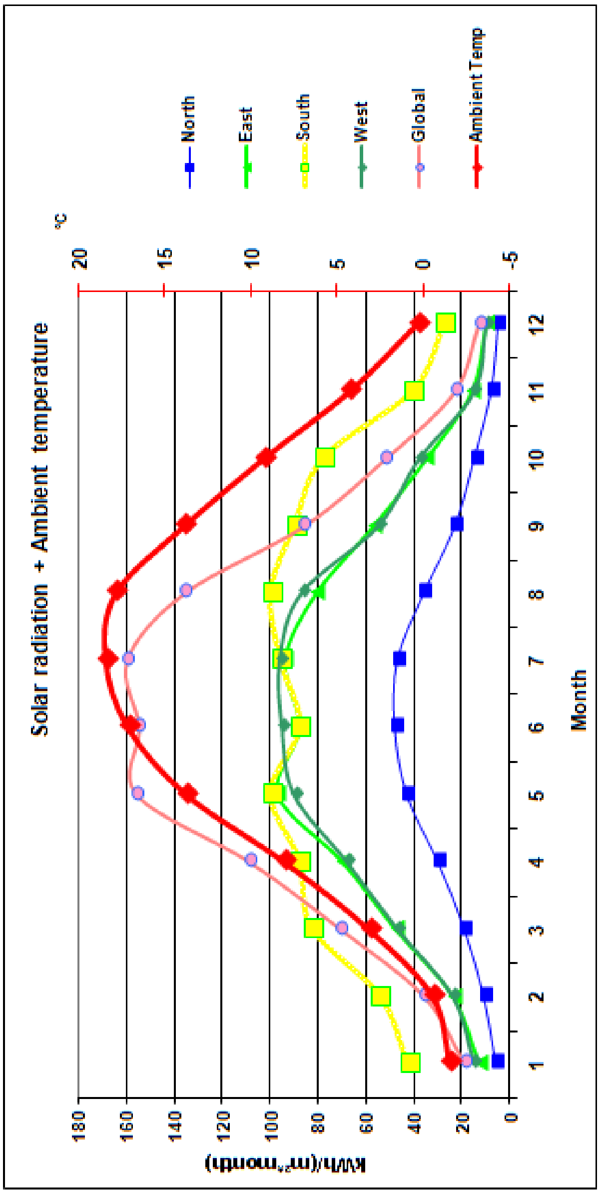
Design Flow Temperature	ϑ_{flow} (DHW+Distribution)	55	°C
Average Boiler Temperature Space Heating	ϑ_{ba} (Table values)	38	°C
Average Boiler Temperature (Summer) DHW	$\vartheta_{ba,DHW}$ $=35+0.002*A_{TFA}$	35,2	°C
Standby Heat Loss at Average Boiler Temperature Heating	$q_{B,\vartheta}$ $=q_{B,70}*(\vartheta_{ba}-20)/(70-20)$	0,52%	
Standby Heat Loss at Average Boiler Temperature DHW	$q_{B,\vartheta,DHW}$ $=q_{B,70}*(\vartheta_{km,DHW}-20)/(70-20)$	0,44%	
Average Useful Heating Load, DHW	P_{DHW} $= Q_{WW,wi}/t_{TW}$	0,165	kW
Load Fraction Boiler Heating	φ_H $= Q_{H,wi}/(P_{Nenn}*t_{HZ})$	3,3%	
Load Fraction Boiler DHW	φ_{DW} $= P_{DW}/P_{nominal}$	1,1%	
Heat Loss Factor Heating (Interior / Exterior Installation)	f_c $=25*\theta_{B,\vartheta}$ or 1	1,000	
Boiler Efficiency Heating (Interior/Exterior Correction)	η_K $=\eta_{30\%}+q_{B,\vartheta}*(1-f_c)/\varphi_H$	90,8%	
Load Factor Boiler (Use and Operating Temp.)	f_e $=(1+(1/0.3-1)*q_{B,\vartheta}) / (1+(1/\varphi_H-1)*q_{B,\vartheta})$	0,880	
Boiler Efficiency Heating (Condensation Allowance)	$\eta_{K'}$ $=\eta_K+0.003*(\vartheta_{30\%}-\vartheta_{km}))$	90,8%	
Fraction of Standby Losses Outside of the Heating Period	f_{DW} $=1-t_{HP}/t_{DHW}$	0,407	
Load Factor Boiler DHW	$f_{e,DW}$ $=1+(1/\varphi_{DHW}-1)*q_{B,\vartheta DHW}*f_{DHW}$	1,160	
Performance Ratio of Heat Generator Space Heat Run	$e_{H,g,K}$ $=1/(f_e*\eta_{K'})$	125%	
Performance Ratio of Heat Generator DHW Run	$e_{DW,g,K}$ $=f_{e,DHW}/\eta_{100\%}$	128%	

Standard Values LT and Condensing Boiler

	Improved gas condensing bo	Improved oil condensing b	Condensing boiler gas	Condensing boiler oil	Low Temperature	Low Temperature Boiler Oil	
$\eta_{30\%}$	104,2%	99,2%	99,2%	94,5%	90,8%	90,8%	
$\eta_{100\%}$	95,2%	95,2%	93,2%	93,2%	90,3%	90,3%	
Condensing?	x	x	x	x			
System Design	Average Boiler Temperature [°C]						System Design
70 °C / 55 °C	41	41	41	41	46	46	70 °C / 55 °C
55 °C / 45 °C	35	35	35	35	38	38	55 °C / 45 °C
35 °C / 28 °C	24	24	24	24	26	26	35 °C / 28 °C
Av. Boiler Temp During Test	30	30	30	30	40	40	

24. „Climate Data" Worksheet





Parameters for PHPP Calculated Ground Temperatures:

Phase Shift Months	2,00
Damping	-1,05
Depth m	3,32
Shift of Average Temperature K	1,60

Month	1	2	3	4	5	6
Days	31	28	31	30	31	30
PL - Strefa II (Poznan/Pila)	Latitude:	52,4	Longitude ° East	16,9	Altitude m	97
Ambient Temp	-1,5	-0,5	3,2	8,1	13,8	17,2
North	6	11	19	30	43	48
East	13	24	48	70	97	88
South	43	55	83	88	100	88
West	15	24	47	68	90	95
Global	19	36	71	109	156	155
Dew Point	-3,8	-3,2	-0,5	2,6	6,6	10,4
Sky Temp	-16,1	-14,5	-9,3	-3,1	2,6	7,2
Ground Temp	9,7	9,5	9,7	10,3	11,1	12,6

Month	7	8	9	10	11	12	Heating Load		Cooling Load
Days	31	31	30	31	30	31	Weather 1	Weather 2	Radiation
	20	Daily Temperature Swing Summer (K)		10,6	Radiation Data:	kWh/(m²*month)	Radiation: W/m²		W/m²
Ambient Temp	18,5	17,9	13,9	9,3	4,3	0,4	-10,5	-4,5	25,5
North	47	36	23	15	8	5	10	5	110
East	94	81	57	35	16	10	15	10	230
South	96	100	90	78	41	28	30	10	220
West	96	87	55	38	15	10	15	10	220
Global	160	136	86	52	23	13	25	10	350
Dew Point	11,7	11,7	9,1	5,8	1,4	-1,8			
Sky Temp	8,6	8,0	3,4	-3,3	-9,0	-12,8			16,3
Ground Temp	13,2	13,4	12,5	11,9	11,1	10,3	9,5	9,5	13,4

25. “Internal Heat Gains” Worksheet

EnerPHit verification

INTERNAL HEAT GAINS

Building: Home

Utilisation Pattern: Dwelling | 2,10 W/m²

Type of Values Used: Standard | No entry required W/m²

Calculation Internal Heat Household

Persons 3,0 P | Living Area 105 m²

Heating Demand 24 kWh/(m²a) | Heating Period 217 d/a

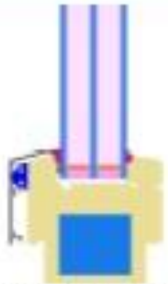
Application (Column Nr.)	1 Existing (1/0), or number of people	2 In the Thermal Envelope (1/0)	3 Norm Consumption		4 Utilization Factor	5 Frequency		6 Useful Energy (kWh/a)	7 Included in Electricity Balance?	8 Availability	9 Used During Time Period (kh/a)	10 Internal Heat Source (W)
Dishwashing	1	1	1,1	kWh/Use	1,00	65	/(P*a)	215	*	0,30 /	8,76 =	7
Clothes Washing	1	1	1,1	kWh/Use	1,00	57	/(P*a)	189	*	0,30 /	8,76 =	6
Clothes drying with:	1	1	3,5	kWh/Use	0,88	57	/(P*a)	0	*	1,00 /	8,76 =	0
Clothesline		1	0,0					0		0,80		
Energy consumed by evaporation	1	1	-3,1	kWh/Use	0,60	57	/(P*a)	-322	* (1- 0) *	1,00 /	8,76 =	-37
Refrigerating	0	1	0,8	kWh/d	1,00	365	d/a	0	*	1,00 /	8,76 =	0
Freezing	0	1	0,9	kWh/d	1,00	365	d/a	0	*	1,00 /	8,76 =	0
or Combination	1	1	1,0	kWh/d	1,00	365	d/a	365	*	1,00 /	8,76 =	42
Cooking	1	1	0,3	kWh/Use	1,00	500	/(P*a)	376	*	0,50 /	8,76 =	21
Lighting	1	1	20,8	W	1,00	2,9	kh/(P*a)	182	*	1,00 /	8,76 =	21
Consumer Electronics	1	1	80,0	W	1,00	0,55	kh/(P*a)	132	*	1,00 /	8,76 =	15
Household Appliances/Other	1	1	50,0	kWh	1,00	1,0	/(P*a)	150	*	1,00 /	8,76 =	17
Auxiliary Appliances (cf. Aux Electricity Sheet)											=	15
Other Applications (cf. Electricity Sheet)	0	0,0						0	*	0 /	8,76 =	0
Persons	3	1	80,0	W/P	1,00	8,76	kh/a	2109	*	0,55 /	8,76 =	132
Cold Water	3	1	-5,0	W/P	1,00	8,76	kh/a				=	-15
Evaporation	3	1	-25,0	W/P	1,00	8,76	kh/a	-659	*	1,00 /	8,76 =	-75
Total											W	**150**
Specific Demand											W/m²	**1,43**
Heat Available From Internal Sources									217 d/a		kWh/(m²a)	**7,4**

Certificate

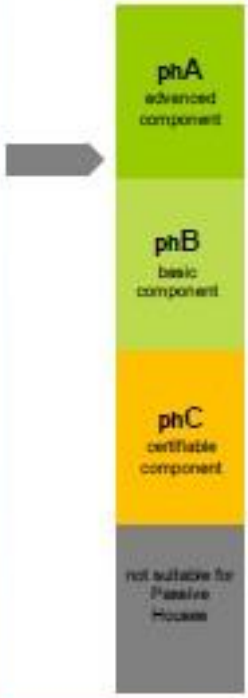
Certified Passive House Component
for cool, temperate climates; valid until 31.12.2014

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
GERMANY

Category:	**Fixed glazing**
Manufacturer:	**POL-SKONE Sp. z o. o.** **20-328 LUBLIN, POLAND**
Product name:	**EC90 PLUS ALU EFFECT Fix**



Passive House Efficiency Class



This certificate was awarded based on the following criteria:

Given a Ug value of 0.70 W/(m²K) and a window size of 1.23 m by 1.48 m,

U_W = 0.79 W/(m²K) ≤ 0.80 W/(m²K)

Taking into account the installation based thermal bridges and provided that the installation is, with regard to the thermal bridges, equal or better than shown in the data sheet, the window meets the following criterion.

$U_{W,Installed}$ ≤ 0.85 W/(m²K)

Thermal data

	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.25}$ [-]
Spacer			Swisspacer V*	
Bottom	0.83	93	0.028	0.72
Side/top	0.78	93	0.028	

*Spacers of lower thermal quality, especially those made of aluminium, lead to significantly higher thermal losses and lower temperature factors.

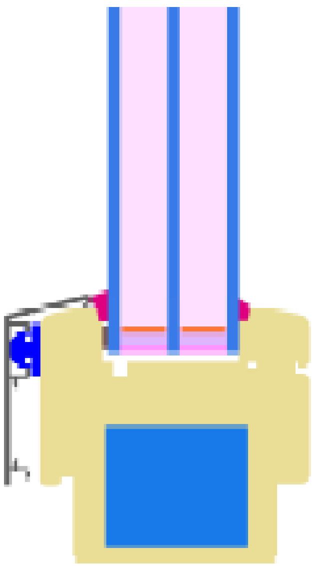
For further information, please see the data sheet

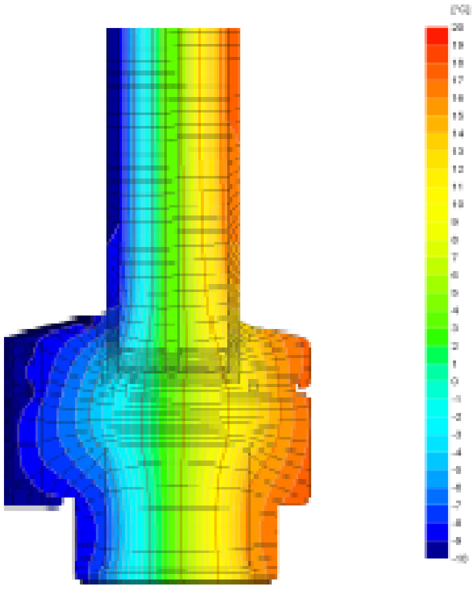
phA CERTIFIED COMPONENT Passive House Institute

www.passivehouse.com **0530fx03**

Data Sheet POL-SKONE Sp. z o. o., EC90 PLUS ALU EFFECT Fix

Manufacturer POL-SKONE Sp. z o. o.
ul. Lucyny Herc 8, 20-328 LUBLIN, POLAND
Tel.: 0048817443011
Email: poczta@pol-skone.eu, www.pol-skone.eu


Bottom section

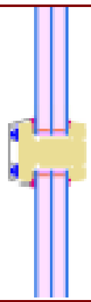

Isothermal

Description

Windowframe without opening sash of timber with facing shell of aluminium and insulation of polyurethane. Pane thickness: 44 mm (4/16/4/16/4), Rebate depth: 18 mm.

Thermal data for the window frame

	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.25}$ [-]
Spacer			Swisspacer V*	
Bottom	0.83	93	0.028	0.72
Side/Top	0.78	93	0.028	
Flying Mullion	0.98	89	0.027	0.72


Mullion

* Spacers of lower thermal quality lead to higher thermal losses and lower glass edge temperatures.

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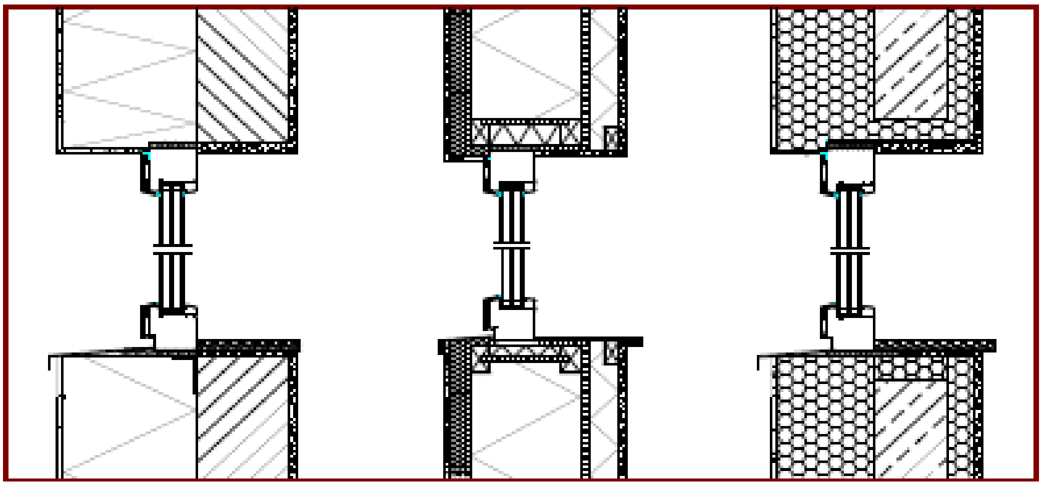
Data Sheet POL-SKONE Sp. z o. o., EC90 PLUS ALU EFFECT Fix

Installation



Installation based thermal bridge $\Psi_{install}$ in Passive House suitable walls

Position		EIFS	Timber construction wall	Insulated formwork blocks
Bottom	[W/(mK)]	0.024	0.024	0.019
Side/Top	[W/(mK)]	0.016	0.017	0.016
$U_{W,instal.}$	[W/(m²K)]	0.85	0.85	0.84

Explanatory notes

The window U-values were calculated based on a 1.23 m by 1.48 m window U_g = 0.70 W/(m²K).
If better glazing is used, the window U-values decrease as follows:

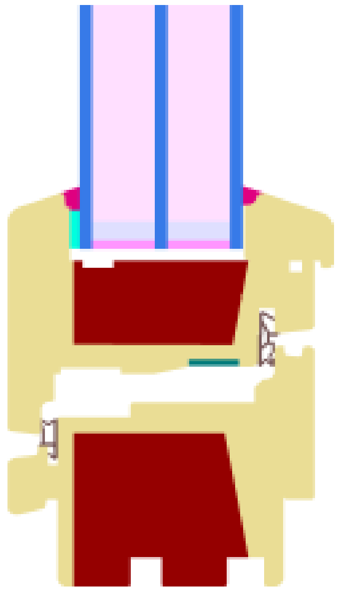
U Glazing	U_g [W/(m²K)]	0.64	0.58	0.54
U Window	U_W [W/(m²K)]	0.75	0.70	0.68

Depending on the thermal losses through opaque elements, transparent components are categorised according to efficency classes. These thermal losses include the losses through the frame, the frame width, the thermal bridge at the glass edge as well as the length of the glass edge. Certificates for arctic regions are too valid vor cold, certificates for cold regions are too valid for cool, temperate zones.
Please ask the manufacturer for a detailed report containing all calculations and results.
For further information, please visit www.passivehouse.com or www.passipedia.org.

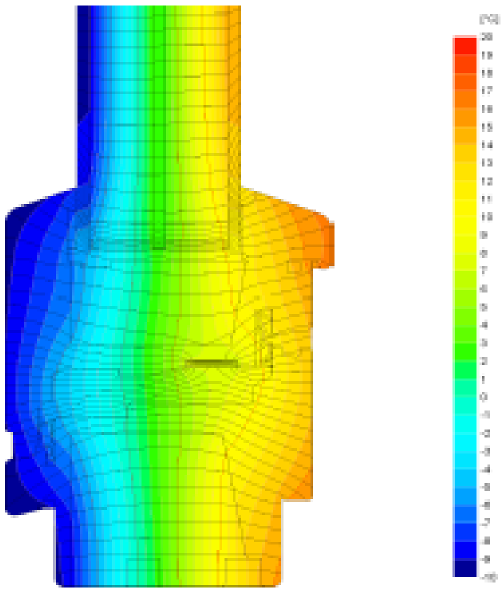
www.passivehouse.com Passive House Institute Page 2/2

Data Sheet Green Building Store, Ecocontract ULTRA

Manufacturer Green Building Store
Heath House Mill, Heath House Lane, Golcar, HD7 4JW Huddersfield, UK
Tel.: +44 (0)1484 461 705
Email: info@greenbuildingstore.co.uk, www.greenbuildingstore.co.uk



Bottom section



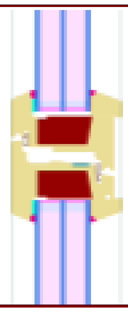
Isothermal

Description

Outside opening timber window frame (0,13 W/(mK)), insulated by CF 200 (0,046 W/(mK)). Pane thickness: 52 mm (4/20/4/20/4), Rebate depth: 19 mm.

Thermal data for the window frame

	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.25}$ [-]
Spacer			Swisspacer Ultimate*	
Bottom	0.82	138	0.022	0.75
Side/Top	0.84	120	0.023	
Flying Mullion	0.84	136	0.023	0.75



Flying Mullion

* Spacers of lower thermal quality lead to higher thermal losses and lower glass edge temperatures.

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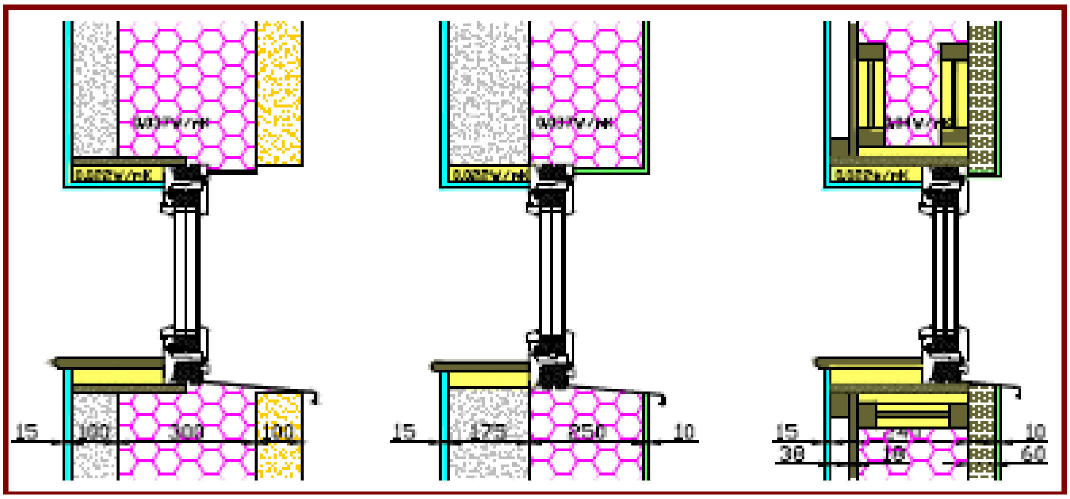
Data Sheet Green Building Store, Ecocontract ULTRA

Installation



Installation based thermal bridge $\Psi_{install}$ in Passive House suitable walls

Position		EIFS	Timber construction wall	Cavity wall
Bottom	[W/(mK)]	0.023	0.009	0.006
Side/Top	[W/(mK)]	0.009	0.005	0.002
$U_{W,install}$	[W/(m²K)]	0.84	0.81	0.81

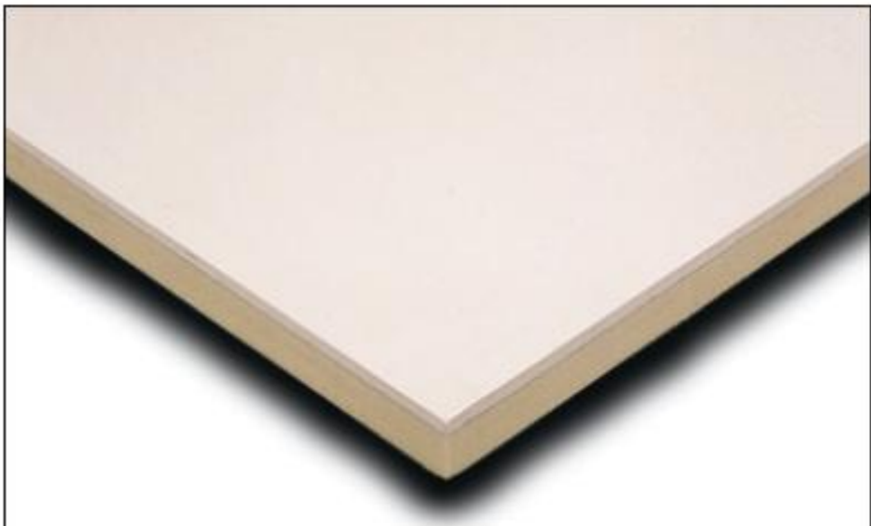
Explanatory notes

The window U-values were calculated based on a 1.23 m by 1.48 m window U_g = 0.70 W/(m²K).
If better glazing is used, the window U-values decrease as follows:

U Glazing	U_g [W/(m²K)]	0.64	0.58	0.54
U Window	U_W [W/(m²K)]	0.76	0.72	0.69

Depending on the thermal losses through opaque elements, transparent components are categorised according to efficency classes. These thermal losses include the losses through the frame, the frame width, the thermal bridge at the glass edge as well as the length of the glass edge. Certificates for arctic regions are too valid vor cold, certificates for cold regions are too valid for cool, temperate zones.
Please ask the manufacturer for a detailed report containing all calculations and results.
For further information, please visit www.passivehouse.com or www.passipedia.org.

www.passivehouse.com Passive House Institute Page 2/2



EUROTHANE® G

DESCRIPTION

EUROTHANE G is an insulation board with a core of rigid polyurethane foam covered on one side with a plasterboard.

TECHNICAL FEATURES

- **Thermal conductivity λ_D-value** according to EN 12667: **0,023 W/mK**
- **Core volume weight** **± 30 kg/m³**
- **Vapour diffusion resistance number μ of the PUR *foam*: 50-100**
- **Facing**
  - Covered plasterboard thickness 9,5 mm with bevelled longitudinal edges
  - Vapour barrier between plaster and PUR.
- **Fire behaviour**
  - A1 according to RD 19/12/1997
  - Class 1 according to BS 476 part 7
  - Euroclass F according to EN 13501-1

DIMENSIONS

- Width: 1200 mm
- Length: 2600 mm
- Thicknesses PUR *foam*: 20 mm ➡ 80 mm 100 mm on request

APPLICATIONS

- Internal lining of walls and ceilings
- Attic insulation

CERTIFICATES

ATG/H707

001-BK-514-0004-0006-W012

STANDARDS

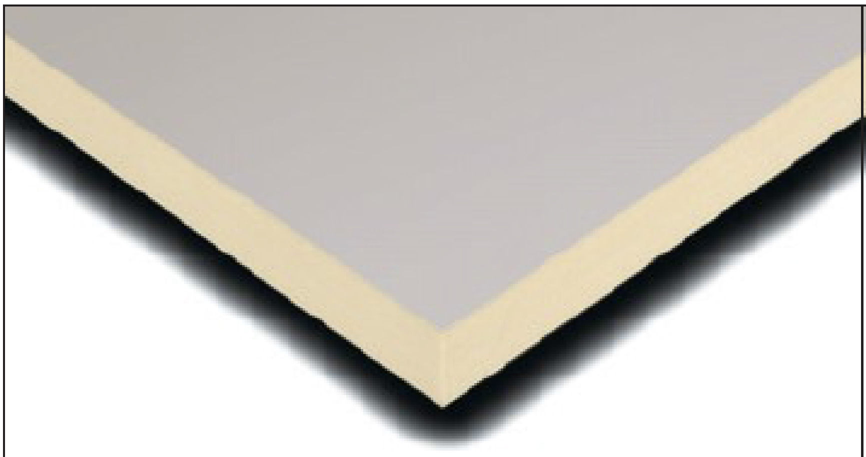
- EN 13165
- The production of these insulation boards is certified according to ISO 9001:2000

RECTICEL insulation

Tramstraat 6 - 8560 WEVELGEM - Belgium
Tel. +32 (0)56 43 89 43 - Fax +32 (0)56 43 89 29
www.recticelinsulation.com

RECTICEL insulation

09-2010



EUROFLOOR

DESCRIPTION

EUROFLOOR is an insulation board with a core of rigid polyurethane foam faced on both sides with a flat grey, gastight and multi-layered complex of kraft and metal foil.

TECHNICAL FEATURES

- **Thermal conductivity λ_D-value** according to EN 12667: **0,023 W/mK**
- **Core volume weight** $\pm$ **30 kg/m³**
- **Mechanical performance**
  - Compressive strength with 10% deformation: **CS(10/Y)120** according to EN 826 ≥120 kPa (1,2 kg/cm²)
  - Transformation under the influence of a load: **DLT(2)5** according to EN 1605: 40 kPa, at 70°C during 168 hours: ≤ 5%
- **Vapour diffusion resistance number** μ of the PUR *foam*: **50-100**
- **Facing**
  Flat grey, gastight and multi-layered complex of kraft and metal foil
- **Long-term water absorption: WL(T)2** according to EN 12087: <2%
- **Fire behaviour**
  - A1 according to RD 19/12/1997
  - Class 1 according to BS 476 Part 7
  - Euroclass F according to EN13501
- **Dimensional stability**
  DS(TH)4 according to EN 1604
  - Humidity test 48-hours: 70°C, 90% RH
  - Change in length: ≤ 3%
  - Change in width: ≤ 3%
  - Change in thickness: ≤ 8%

DIMENSIONS

- Width: 1200 mm
- Length: 2500 mm
- Thicknesses: 20 mm ➞ 60 mm on stock
- Thicknesses: 70 mm ➞ 100 mm on request

FINISHING

Straight edges

APPLICATIONS

Floor insulation

CERTIFICATES

ATG/H707

001-BK-514-0004-0018-W012

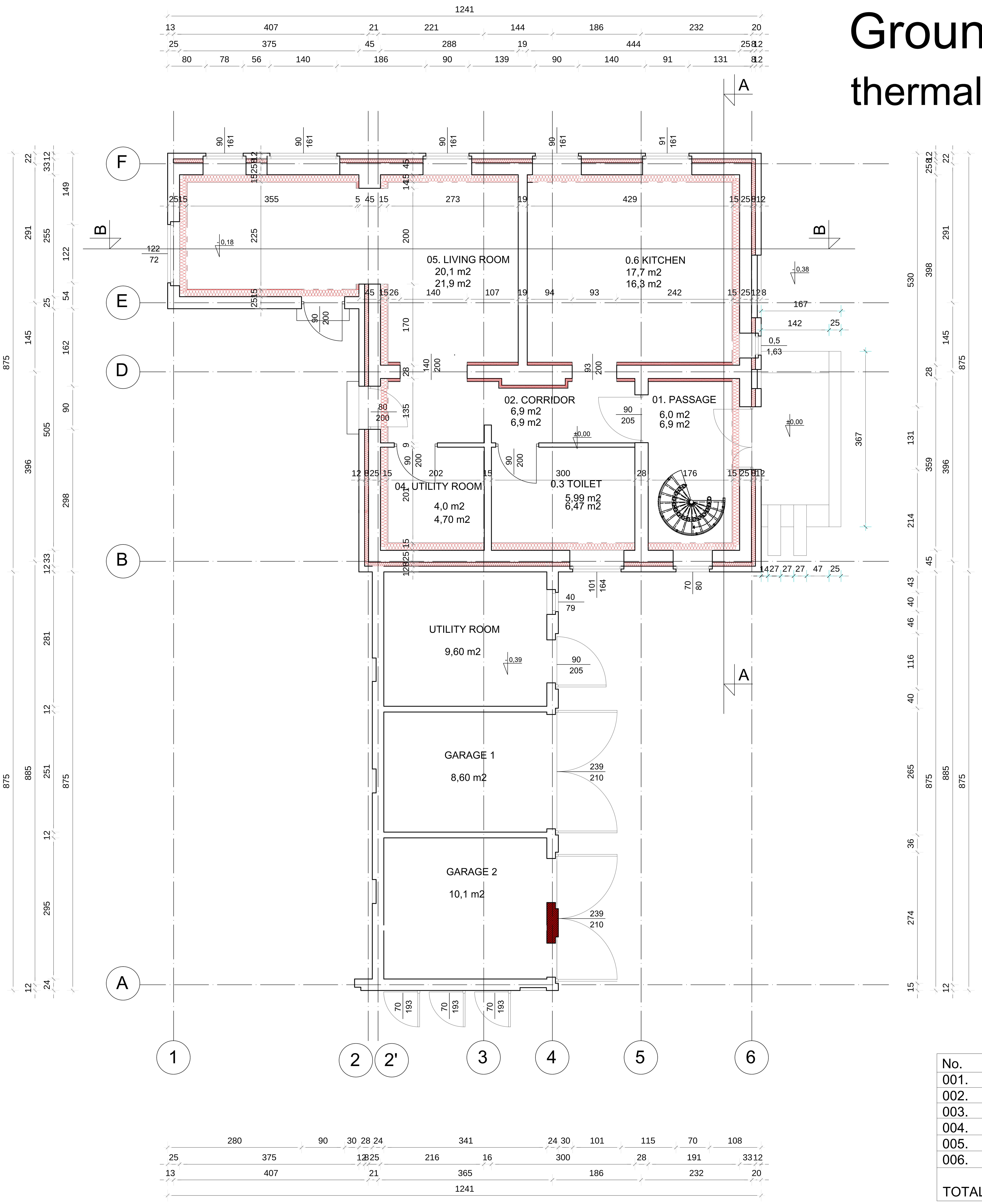
STANDARDS

- EN 13165
- The production of these insulation boards is certified according to ISO 9001:2000

RECTICEL

Tramstraat 6 - 8560 WEVELGEM-Belgium
Tel. +32 (0)56 43 89 43 - Fax +32 (0)56 43 89 29
www.recticelinsulation.com

Ground Floor Plan
thermal envelop



No.	Typ2	Area
001.	Passage	6,00 m2
002.	Corridor	6,90 m2
003.	Toilet	5,99 m2
004.	Utility room	4,00 m2
005.	Living room	21,0 m2
006.	Kitchen	17,7 m2
TOTAL:		51,59 m2

LEGEND

01. PASSAGE - name of particular room
6,0 m2 - surface area after performing the interior insulation
6,9 m2 - surface area before performing the interior insulation

Subject: Annex 4.1
"Ground Floor Plan - thermal envelop"
University of Aveiro

Drawing number: 1
Scale: 1:50
Date: 30.06.2014

Project:
Master Thesis:
" Heritage Building's retrofitting according to ENERPHIT requirements."
"Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."

Drawn by: Magdalena Dopierala

UTWORZONY PRZEZ PROGRAM EDUKACYJNY FIRMY AUTODESK
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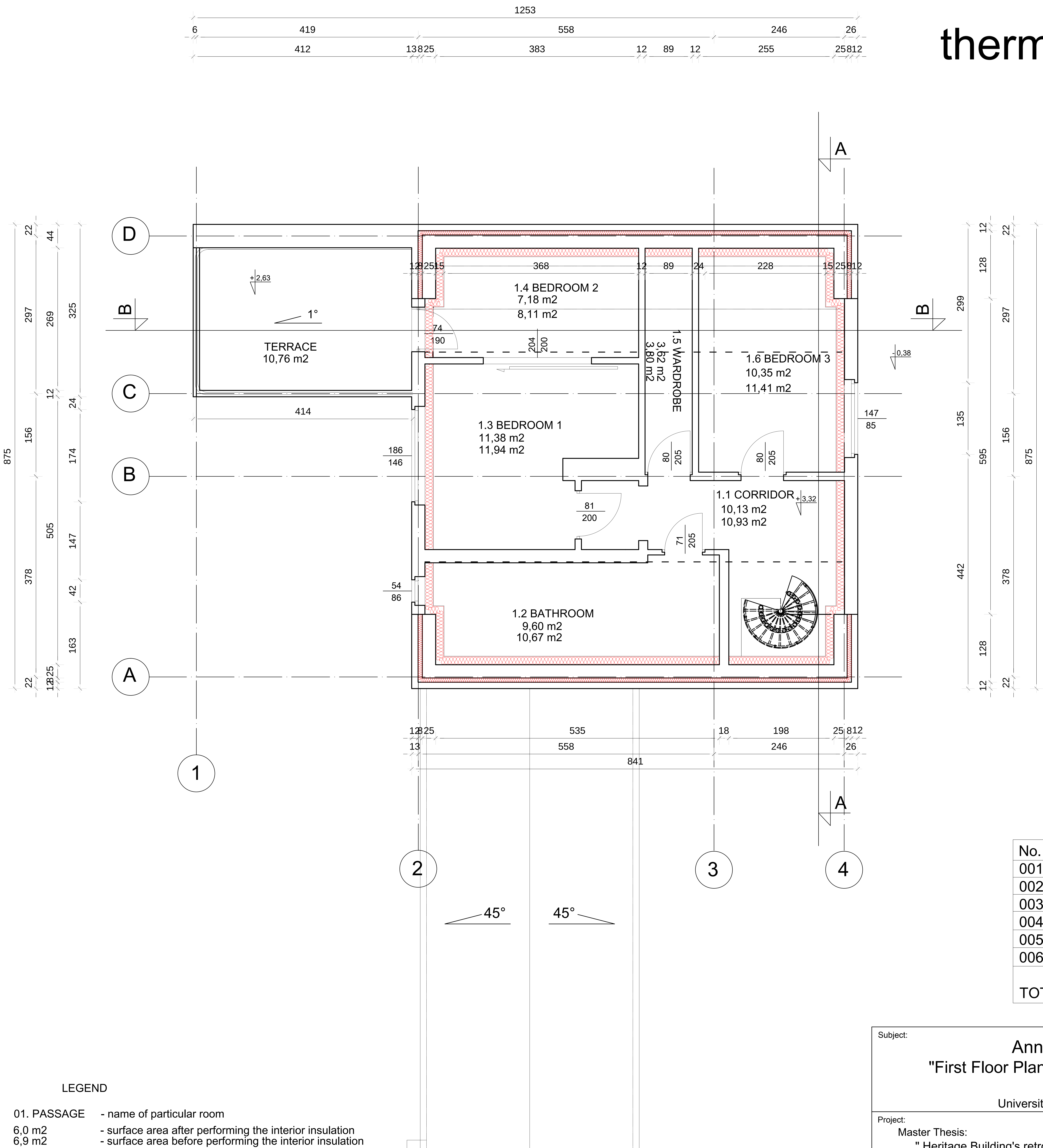
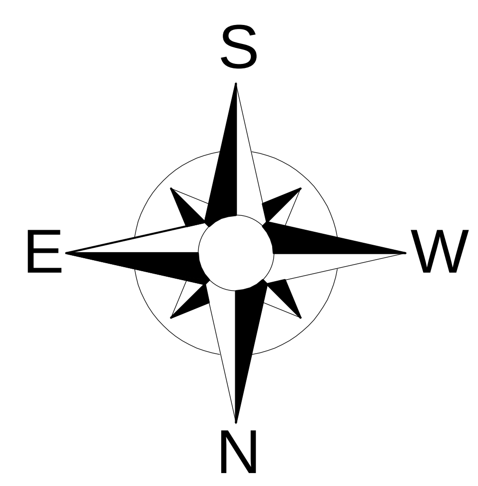
First Floor Plan
thermal envelop





No.	Typ2	Area
001.	Corridor	10,13 m2
002.	Bathroom	9,60 m2
003.	Bedroom 1	11,38 m2
004.	Bedroom 2	7,18 m2
005.	Wardrobe	3,62 m2
006.	Bedroom 3	10,35 m2
TOTAL:		52,26 m2

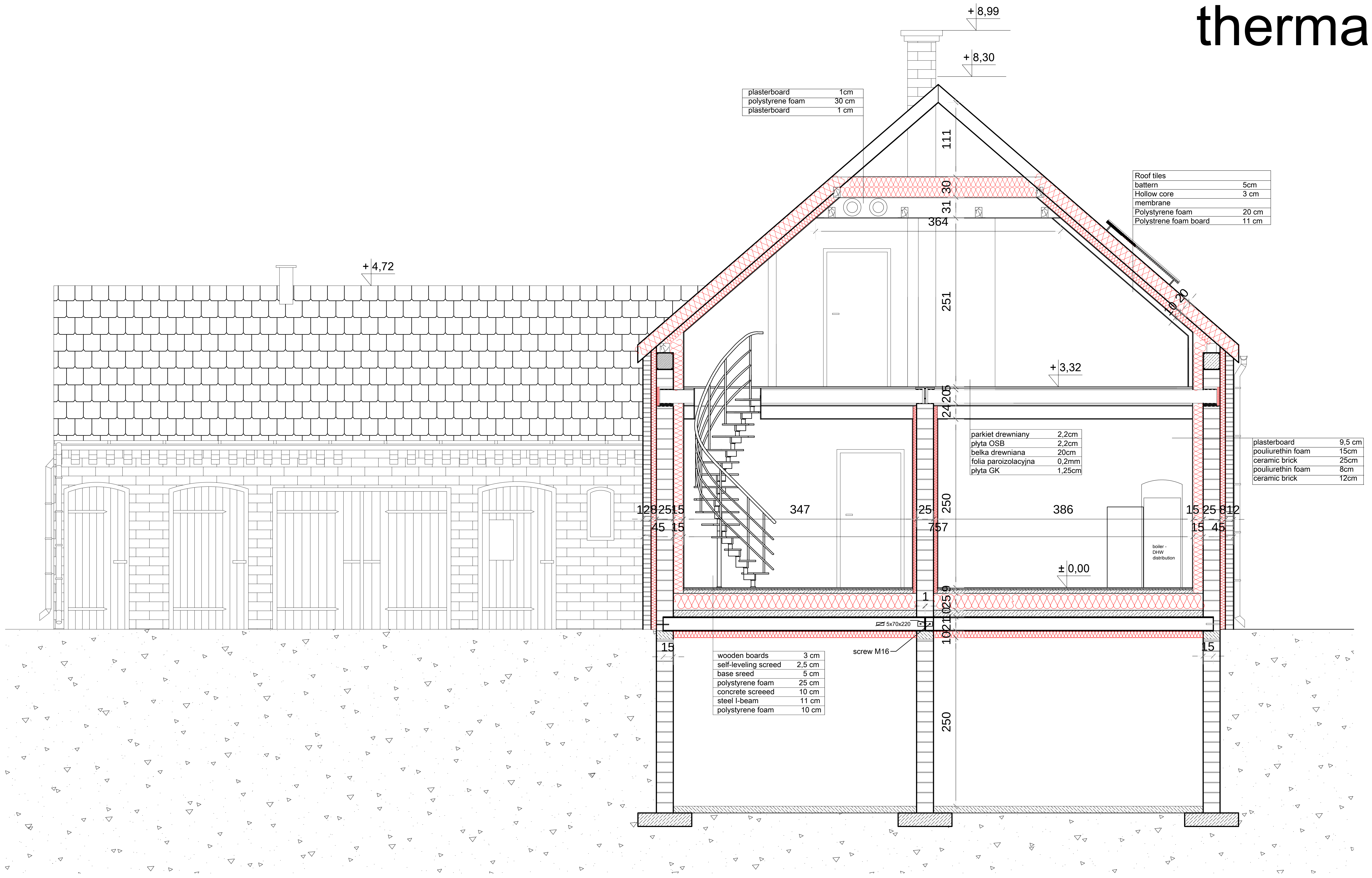
LEGEND

01. PASSAGE - name of particular room
6,0 m2 - surface area after performing the interior insulation
6,9 m2 - surface area before performing the interior insulation

Subject: Annex 4.2 "First Floor Plan - thermal envelop" University of Aveiro	Drawing number: 2
	Scale: 1:50
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014
	Drawn by: Magdalena Dopierala

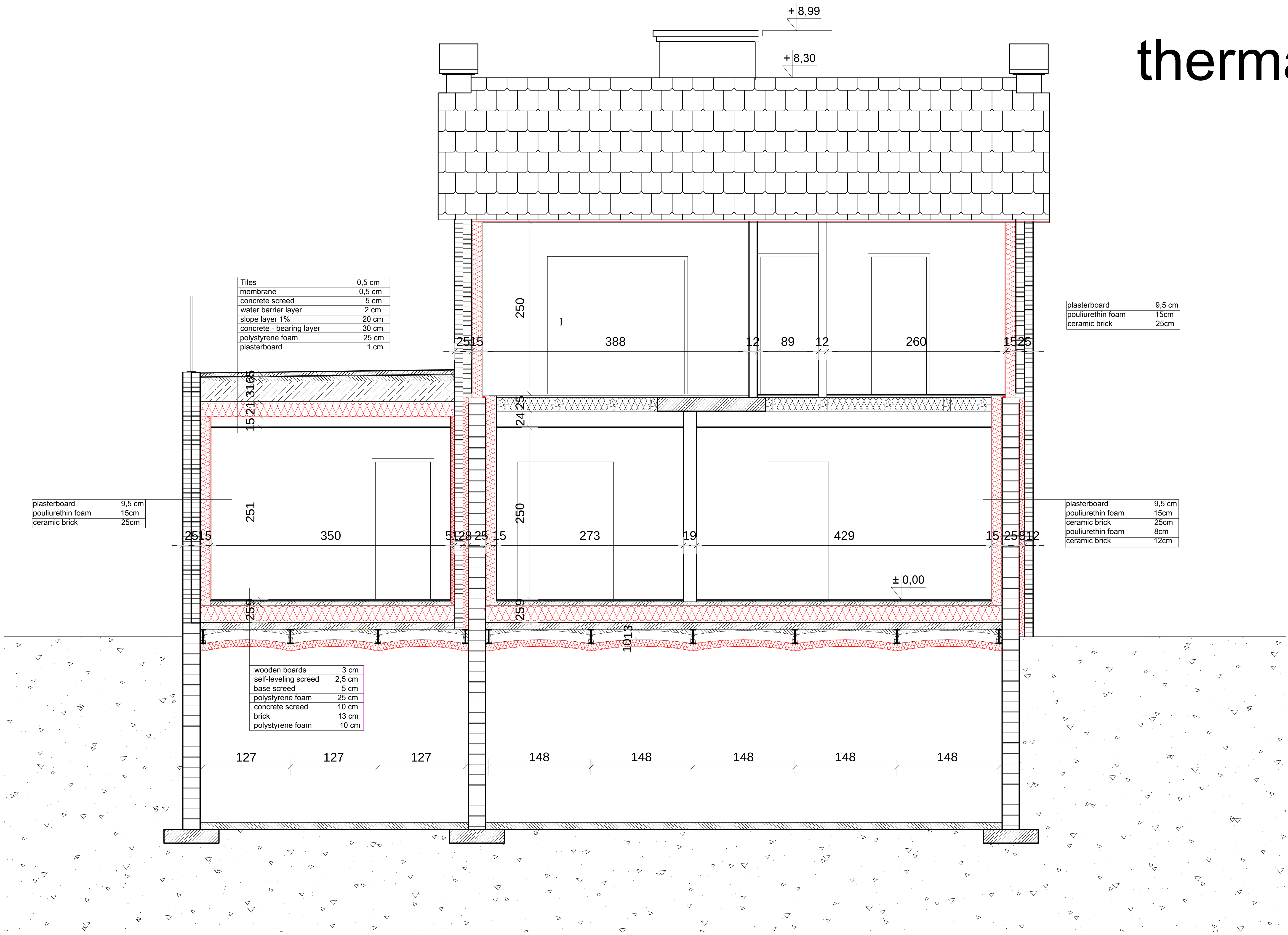
Cross-section A-A

thermal envelop



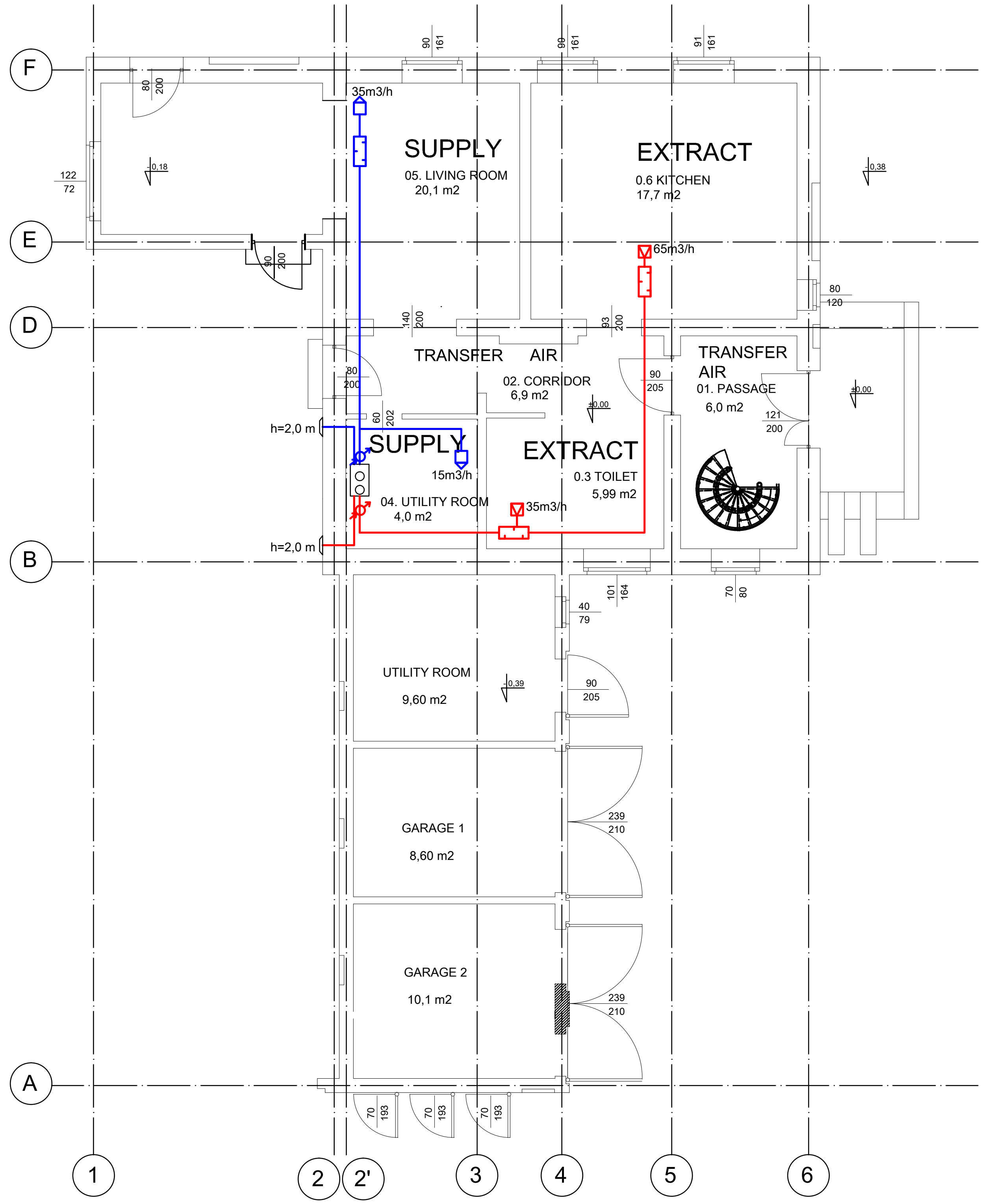
Subject: Annex 4.3 "Cross-secton A-A - thermal envelop" University of Aveiro	Drawing number: 3
	Scale: 1:50
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014
	Drawn by: Magdalena Dopierala

Cross-section B-B
thermal envelop



Subject: Annex 4.4 "Cross-secton B-B - thermal envelop" University of Aveiro	Drawing number: 4
	Scale: 1:50
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014
	Drawn by: Magdalena Dopierala

Ground Floor Plan
ventilation



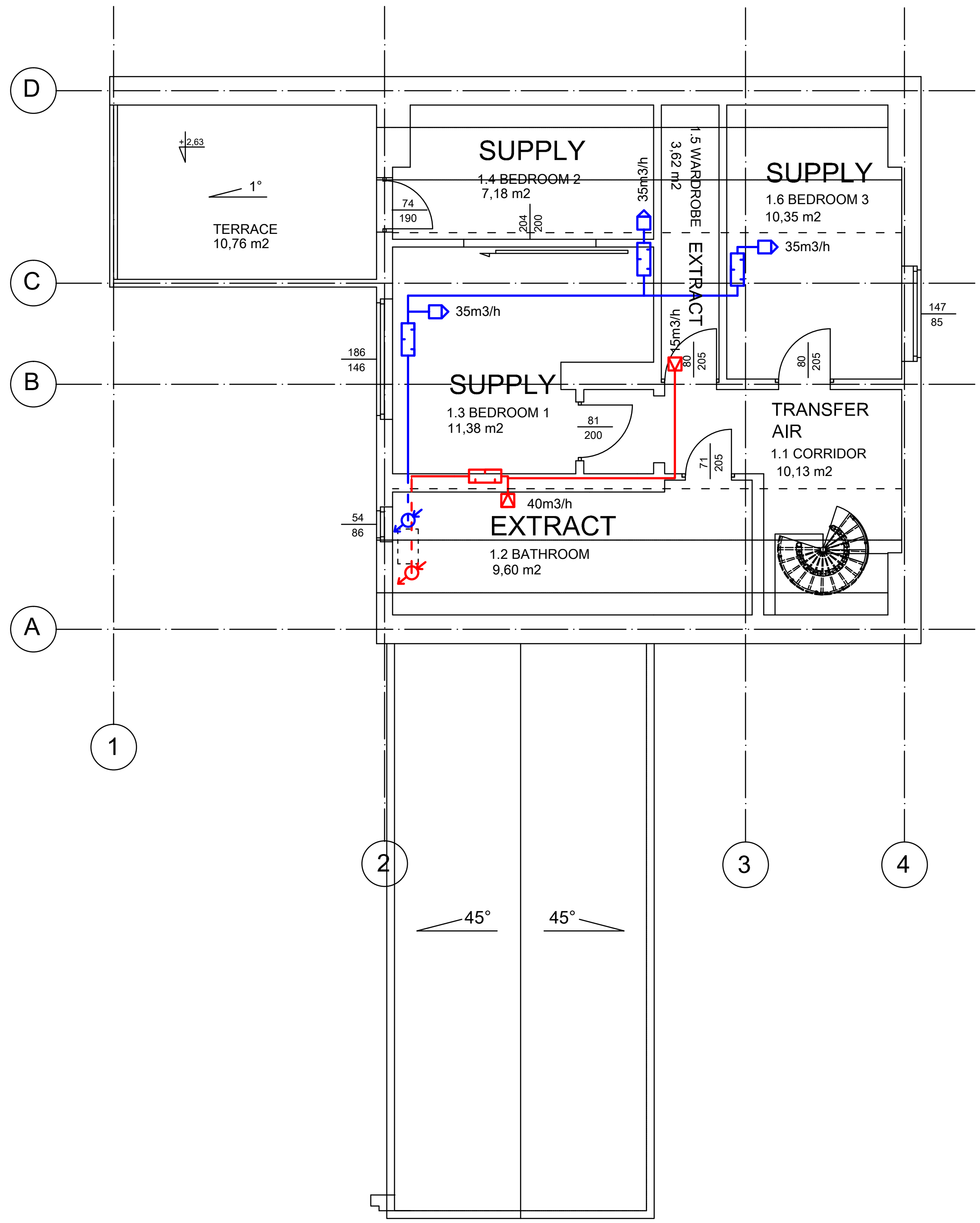
Lp.	Type of room	quantity of supply air	quantity of exhaust air
		[m3/h]	[m3/h]
	GROUND FLOOR		
0.1	PASSAGE		
0.2	CORRIDOR		
0.3	TOILET		35
0.4	UTILITY ROOM	15	
0.5	LIVING ROOM	35	
0.6	KITCHEN		65
	FIRST FLOOR		
1.1	CORRIDOR		
1.2	BATHROOM		40
1.3	BEDROOM 1	35	
1.4	BEDROOM 2	35	
1.5	WARDROBE		15
1.6	BEDROOM 3	35	
	SUM UP	**155**	**155**

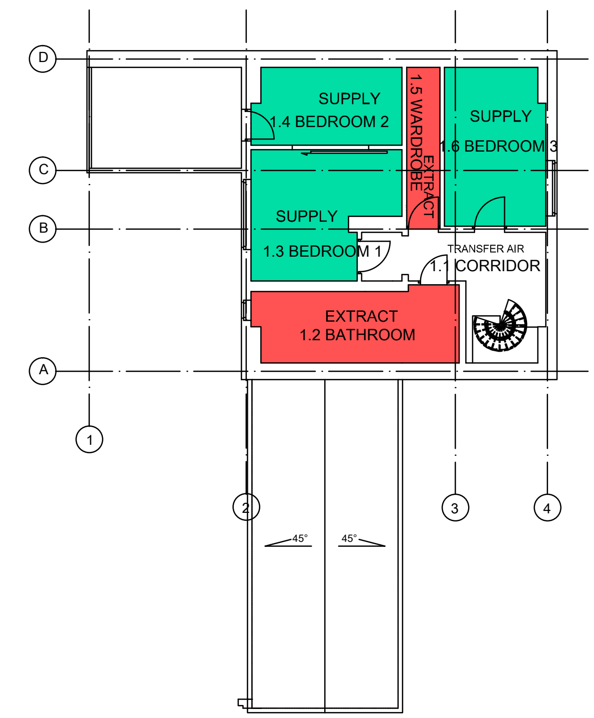
LEGEND

- extract outlet
- supply outlet
- silencer

Subject: Annex 4.5 "Ground Floor Plan - ventilation" University of Aveiro	Drawing number: 5
	Scale: 1:100
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014
	Drawn by: Magdalena Dopierala

First Floor Plan
ventilation





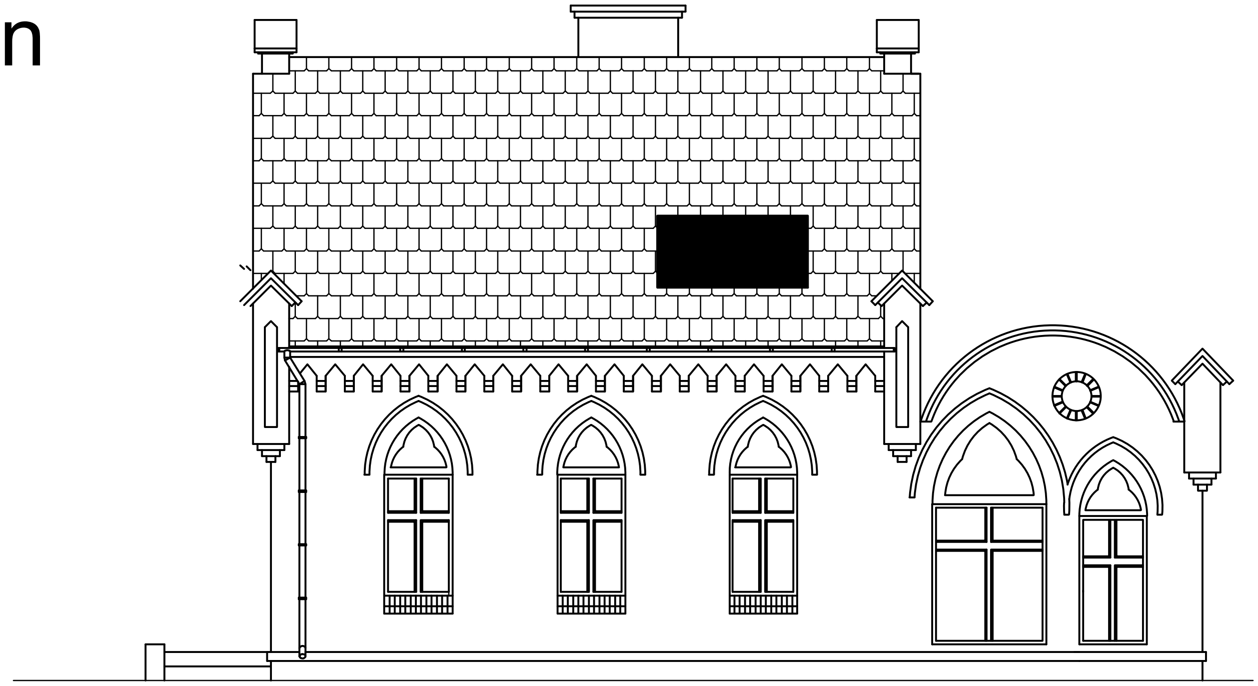
Lp.	Type of room	quantity of supply air [m3/h]	quantity of exhaust air [m3/h]
	GROUND FLOOR		
0.1	PASSAGE		
0.2	CORRIDOR		
0.3	TOILET		35
0.4	UTILITY ROOM	15	
0.5	LIVING ROOM	35	
0.6	KITCHEN		65
	FIRST FLOOR		
1.1	CORRIDOR		
1.2	BATHROOM		40
1.3	BEDROOM 1	35	
1.4	BEDROOM 2	35	
1.5	WARDROBE		15
1.6	BEDROOM 3	35	
	SUM UP	**155**	**155**

LEGEND

- extract outlet
- supply outlet
- silencer

Subject:	Drawing number:
Annex 4.6 "First Floor Plan - ventilation" University of Aveiro	6
	Scale: 1:100
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014
	Drawn by: Magdalena Dopierala

South elevation



North elevation

Subject:

Annex 4.7
"South and north elevation"

University of Aveiro

Drawing number: 7

Scale: 1:100

Project:
Master Thesis:
" Heritage Building's retrofitting according to ENERPHIT requirements."
"Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."

Date: 30.06.2014

Drawn by: Magdalena Dopierala

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West elevation

East elevation

Subject: Annex 4.8 "South and north elevation" University of Aveiro	Drawing number: 8 Scale: 1:100
Project: Master Thesis: " Heritage Building's retrofitting according to ENERPHIT requirements." "Reabilitação de edifícios antigos de acordo com os requisitos ENERPHIT."	Date: 30.06.2014 Drawn by: Magdalena Dopierala

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