ДГКМ
ДРУШТВО НА ГРАДЕЖНИТЕ КОНСТРУКТОРИ НА МАКЕДОНИЈА

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ENVELOPE OF BUILDING AND ENERGY DEMAND FOR ACHIEVING PASSIVE HOUSE STANDARD

SUMMARY

The building orientation and the thickness of the thermal isolation of the building envelope are one of the factors affecting the achievement of the Passive House standard. Other important factors are the windows. For the windows the three basic parameters that influence the achievement of the Passive House standard are: the size of the windows in facade elements, the type of the glass and the type of the window frames. Analysis based on variations of all these parameters give a clear picture of the impact of each of these parameters as well as of their combination on the energy needs of the Passive House. The calculations presented in this paper were based on the methods of thermodynamics, using MKS EN and DIN standards, and the program packages PHPP 2007, HEAT2 and NOVOLIT.

Keywords: passive house, energy demand, thermal insulation, energy efficient windows, solar factor

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ОБВИВКА НА ЗГРАДА И ЕНЕРГЕТСКО БАРАЊЕ ЗА ПОСТИГНУВАЊЕ СТАНДАРД НА ПАСИВНА КУЌА

РЕЗИМЕ

Ориентацијата на зградатаи дебелината на топлинската изолација на обвивката на објектот се еден од факторите кои влијаат на остварувањето на стандардот на пасивна куќа. Други важни фактори се прозорците. Кај прозорците три основни параметри влијаат на остварувањето на стандардите за пасивна куќа: големината на прозорците во фасадните елементи, видот на стаклото и видот на прозорецот-рамки. Анализа направена врз основа на варијанти на сите овие параметри дава јасна слика за влијанието на секој од овие параметри, како и на нивната комбинација на енергетските потреби на пасивна куќа. Пресметките презентирани во оваа студија беа врз основа на методите на термодинамиката, употребувајќи МКС ЕН и DIN стандардите, и програмските пакети PHPP 2007, HEAT2 и NOVOLIT.

Клучни зборови: пасивна куќа, енергија, топлинска изолација, енергетски ефикасни прозорци

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1. INTRODUCTION

Nearly 40% of the total energy consumption in Europe is consumed in buildings, 67% of it in residential buildings and only 33% in commercial buildings. Hence, this paper refers to the analysis of residential buildings under Macedonian climate conditions.Passive buildings represent the highest standard in the energy efficiency of buildings [1,2,3,4,5]. They guarantee extremely low energy needs, which can be fully meet with relatively small alternative energy sources (sun, water, wind, waste, etc..). It will help to decrease the environmental impact of the building sector, in same time it gives opportunity for full independence from the most exploited sources of energy that are used so far and hence, the concentration of CO_2 in atmosphere could be reduced drastically.

Up to 90 million tons of CO_2 emissions could be saved annually by 2020 if all Europe’s buildings were fitted with double-glazed Low-E insulating glass units (i.e. all existing and new, residential and non-residential buildings). Up to 97 million tons of CO_2 emissions could be cut if, in addition to retrofitting existing buildings with Low-E double-glazing, greater use were made of triple-glazed Low-E units for new buildings, where appropriate (i.e. in cooler northern regions). This is good news because the EU has committed to cutting around 300 million tons of needless CO_2 emissions annually.

2. BASIC FACTORS FOR ACHIEVING THE PASSIVE HOUSE STANDARD

2.1. Micro and macro location

The location is an important factor for calculation of the energy demand of the building, either for heating or cooling, due to the angle at which the sun rays fall on the ground in summer or winter. Shadings over the buildings that are coming from the nearby mountains, hills, buildings, plants, from the structural elements of the building and even from the position of the windows in the wall, have a major influence on energy demands too.

2.2. Architecture

The layout of the rooms, the disposition, design and especially the compactness of the façade have a huge influence on energy demands of the buildings and therefore the ratio between the surface of the building envelope and the building volume (A/V) should be approximately 0.7 m^2/m^3.

The south side shall be assigned to the rooms for longer stay (living room, dining room, study room, etc.). The north side shall be assigned to the bedrooms, if the building is at the ground level. If the building has more floors, the bedrooms shall be on the south side.

The recommendation for the toilets, staircases, storage rooms and other ancillary facilities is always to be oriented on the north side, or in exceptional situations on east or west.

On the south facade windows should occupy 25% to 30% of the area and should have shading blinds or louvers with such an angle that allows the winter sun to shine the windows, but disables the summer sun. The windows on the north side should be reduced to the minimum possible architectural standards. It is essential to avoid windows on the east and west side of the building. If it is still necessary they should be of the smallest possible size and well shaded.

2.3. Building envelope

For the walls, roof and ground floor the thermal insulation thickness should satisfy the requirement $U \leq 0.15$ W/(m^2K). It is commonly achieved by the insulation thickness of 250 mm, 300 mm, up to 400 mm, depending on climate conditions. Glazing is mostly with three-layer low emission glass with $U \leq 0.80$ W/(m^2K), but for the build in windows the U-factor has to be $U \leq 0.85$ W/(m^2K). The general light transmittance (solar factor) has to be $g \geq 50\%$. Nowadays, we have glazing with $U = 0.51$ W/(m^2K) and $g \geq 62$. The same criteria are applicable to the doors. For the entrance doors the certificate for the highest climate test E (extreme) is required and the U factor has to fit the value $U \leq 0.80$ W/(m^2K). In case of Passive House the heat losses through thermal bridges are strictly limited to total $U \leq 0.01$ W/(m^2K).

2.4. Air impermeability

Air impermeability is one of the criteria for evaluation and certification of passive houses and limit value is $n_{50} \leq 0.6\ h^{-1}$, where n_{50} is the ratio between the volume of the scavenging air at a pressure of 50 Pa and the total volume of the building. It is recommended this value to be reduced as much as possible, even under 0.3 h^{-1}. The air impermeability is measured through the air exchange with 50 Pa difference in pressure.

2.5. Ventilation

Replacement of the used with fresh air and delivery of the required amount of heat to the building are made by the ventilation. Thus, humidity and air quality are controlled. The amount of fresh air needed for passive houses is only 20 to 30 m^3/person which shall be taken into account while sizing of the system for ventilation. For gyms or rooms for smoking the required quantity is 50 to 60 m^3/person. The criteria that the ventilation system shall meet are the following: recuperator with thermal efficiency $\eta \geq 75\%$, high efficiency of fans and controller (CRC ≤ 0.45 Wh/m^3); air temperature after the recuperator ≥ 16.5°C at -10°C, normal operation of the system up to -15°C, high quality air filters (F7 minimum standard for entry, G4 for output); air speed in ducts ≤ 2m/sec.

2.6. Heating

An extremely low energy demand for heating enables the heat to be delivered through the ventilation system. The air is heated with electric heaters after the recuperator, or with thermal pumps. When the air is heated by the the sanitary hot water the most economical solutions are obtained. The required energy for hot sanitary water is dominant in the total energy demand and reaches up to 35kWh/(m^2a), therefore it is an important factor in choosing the right heating system for hot sanitary water.

2.7. Frequency of overheating

The frequency of overheating during summer period is an important criterion in the evaluation of passive houses and the value should not be more than 10% of the period in use. Projected summer temperature in the building is 25°C, and frequency of overheating is acceptable only up to 26°C.

2.8. Additional energy for heating

The additional energy required for heating is another assessment criteria for certification of the Passive Houses and must not exceed 15 kWh/(m^2a). Distribution of the energy losses and gains and the additional energy requirements are presented in Figure 1.

2.9. Gross energy requirement

The gross energy requirement, or so-called initial energy, is one of the assessment criteria for passive houses. The maximum allowable total energy consumption for passive house is 120 kWh/(m^2a).

3. CALCULATION METHODOLOGY

Appropriate planning, anticipation of all the steps and taking into account the exact entry parameters is an extremely important during the design and the calculation procedure of the passive houses. The entry data that has to be defined as first are: type and purpose of the building; internal design temperature (20°C); number of inhabitants; calculation method (monthly or annual method); location (climate conditions);existence of surrounding buildings (Feist, 1993). The next step is determination of: areas and their functions; U-values of the different parts of the building envelope; emission balances, thermal bridges; as well as energy demands for heating and cooling (Bisanz, 1999).

The basic assessment criteriawhether the building meets the standard “passive house” or not, are as follows: specific energy demands for heating/cooling (QSH/QSC) [≤ 15kWh/(m^2a)],or alternative: heating/cooling load (HL)/(CL)[≤ 10W/m^2];air impermeability [$\eta_{50} \leq 0.6h^{-1}$]; specific primary energy demand (QSP) [≤ 120 kWh/(m^2a)] (Feist, 1994).In addition to these basic criteria, there are several criteria which are also important, especially from the economical aspect and the exploitation costs of the building, such as: frequency of overheating of the building (hφ)[≤ 10%];the ability of the ventilation system to distribute the required quantity of heat (PH) and the emission of CO_2.

This paper deals with the influence of some of the basic parameters on the evaluation criteria for Passive House standard. The orientation of the passive house and the thickness of the thermal insulationof the roof, ground and in façade walls were varied and the influence of these four parameters was analyzed. In order to obtaincomplete analysis there is a need to track and vary some more parameters, as: percentage and position of the glazed surfaces on the facade; the type of the window glass; the type of the window frames; the position of the windows in the wall; shading from structural elements;an additional shading in summer; the size and number of solar panels for hot water; the technical solutions for the use of sanitary hot water. All these parameters were subject of the complete research (Andreev, 2013), but the results are not presented in this paper.The calculations are based on the methods of thermodynamics, using Macedonian MKS EN and DIN standards, and program packages PHPP 2007, HEAT2 and NOVOLIT.

3.1. Basic data on the analyzed passive house

The macro location of the analyzed passive house was taken to be in the eastern part of Macedonia. It was located on plateau, at altitude of 600 m. The front facade of the building was completely orientated on south, and the entrance was on the north side. The architecture was taken to be the same as for the famous house of Franz Freundorfer (Figure 2). The building was located in "ideal" conditions in order to enable variations of all mentioned parameters and additionally to enable parametric analysis. The building consisted of ground-floor, first floor and under roof space. The ground floor was allocated to daily living, while the first floor was designed for sleeping and resting. The under roof space was designed to accommodate technical equipment.

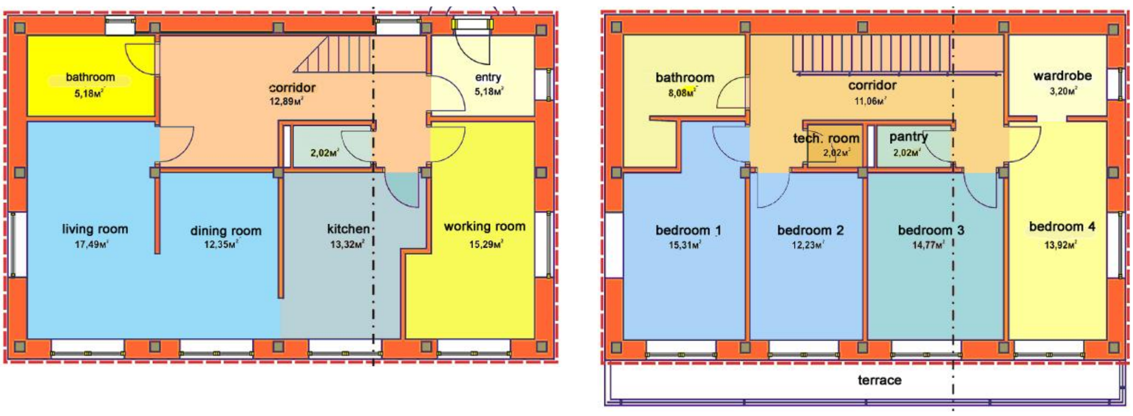

Figure 1. Passive house designed by Franz Freundorfer –
Ground and first floor of the analyzed building

The construction materials used in this study were different from the ones in the original building because they were adapted to the construction market in Macedonia. Façade walls were the same on all four sides of the building with a thickness of 50 cm and the composition was: plasterboard 12.5 mm on metal sub-construction; rock wool 50 mm with λ = 0.045 W/(mK), gypsum mortar 17 mm with λ = 0.510 W/(mK), masonry blocks from "Ytong" 250 mm with λ = 0.16 W/(mK), gypsum-lime mortar 17 mm with λ = 0.70 W/(mK), 5 mm glue for thermal insulation, 150 mm styrofoam as thermal insulation with λ = 0.024 W/(mK), 5mm glue and smoothing mass, 3mm final mortar.

The gable roof was made of reinforced concrete slab MB30 with shelters on all four sides of the building. The composition of the roof was: 12.5 mm plasterboard on metal sub construction; 50 mm rock wool with λ = 0.045 W/(mK), 100 mm reinforced concrete slab MB30 with λ = 2.30 W/(mK), 150 mm thermal insulation with λ = 0.024 W/(mK), 22 mm wooden revetment with λ = 0.024 W/(mK); 3mm vapor barrier, two layers of wood laths and roof tiles.

The ground floor was placed directly on earth and around the building a route horizontal intermediate plate from extruded polystyrene was set. The composition of the floor was: floating floor base 30 mm, rock wool 20 mm with λ=0.038 W/(mK), 350 mm reinforced concrete slab MB30 with λ = 2.3 W/(mK), 340 mm thermal insulation with λ = 0.038 W/(mK), 8 mm waterproofing layer with λ = 1.2 W/(mK), concrete foundation 100 mm.

The windows were selected from the list of certified passive house windows, as follows:

- Frame W Internorm - passiv Fixverglasung - with distancer 'Thermix',
- Glass INTERPANE - iplus 3E (4:/14/4/14/:4 Argon 90%)

During the process of defining the parameters, the following values and information were defined, too: thermal envelope (line of balance); Treated Floor Area- TFA.

The calculation of the areas covered: all net living areas with heights over 2m, areas with heights from 1m to 2m were calculated with 50%, non leaving areas (basement, machine rooms and storage) with height above 2m, were calculated with 60%.

4. ANALYSIS OF THE CALCULATION RESULTS

The calculation of the passive house was made with the software package PHPP 2007. Dimensions of the insulation, windows and all other elements were defined to meet the criteria for a passive house and in same time to be as close as possible to the limit values for the Passive House (PH) standard. In such a way by variations of the above mentioned parameters the influence of each parameter on achievement the Passive House standard could be defined.

The indoor temperature in summer was taken to be 25^0C while in winter to be 20^0C. According to the calculation results the ventilation system could not deliver the needed quantity of heat, so there was a need somewhere in the house a supplementary heating device to be placed. This device should supply an additional 171 W. During the summer period there was no need of cooling system, but opening of the windows was required at nights. Emission of carbon dioxide caused by the heating was 9 kg/(m^2a), while the emission caused by the total consumed energy was 19 kg/(m^2a). Comparison of the final calculation results with the maximum values defined by the Passive House standard is presented in Table 1.

Table 1. Comparison of calculation results and standard values

Criteria	Symbol	Unites	Design value	Max. value (standard)	Are criteria satisfied?
Specific space heating demand	Q_{SH}	kWh/(m^2a)	14	15	Yes
Specific primary energy demand	Q_{SP}	kWh/(m^2a)	78	120	Yes
Heating load	HL	W/m^2	10	0	Yes
Cooling load	CL	W/m^2	7	10	Yes
Frequency of overheating	h_ϕ	%	4	10	Yes

4.1. Influence of the orientation of the building on achievement the PH standard

The orientation of the building plays an extremely important role in the final balance of energy gains and losses, because windows with south orientation contribute to reduction of the energy demand for heating, while windows on the north side have no contribution to gains, but in opposite - the losses are increased. However, during summer, the southern windows contribute to overheating of the building and hence to energy demands for cooling the building. To prevent overheating there are effective and relatively inexpensive measures for summer shading.

The windows on the east and west sides of the building make significant contribution to the needs for heating of the building in winter, but they are unsuitable for use in the summer because seriously contribute to overheating. The measures for their shading are either extremely expensive or not effective. The orientation of the walls has no impact on energy balance, due to the large thickness of insulation in them. The influence of orientation of the house, presented in this paper, is based on analysis of several parameters. For that purpose the initial orientation of the house was rotated by steps of 30° clockwise and the results of PHPP 2007 for each of the defined positions of the house are presented in the Table 2.

Table 2. Influence of orientation of the building on achievement the Passive House standard

Description	Specific energy demands			Load		Frequency	CO_2emision	
	heating	cooling	primary energy	heating	cooling	of overheating	Without equipment	Total
Symbol	Q_{SH}	Q_{CS}	Q_{SP}	HL	CL	h_ϕ	CO_2^{Qsh}	CO_2^{Qsp}
Unites	kWh/(m^{2}a)			W/m^2		%	kg/(m^{2}a)	
Prescribed values	15		120	10	10	10	/	/
Design values	13.93	9.36	77.74	10.06	6.76	3.62	8.88	19.35
Rotation 30^o	14.57	11.22	78.33	10.22	7.87	6.11	9.01	19.49
Rotation 60^o	16.34	14.93	79.96	10.46	8.56	12.97	9.39	19.86
Rotation 90^o	18.26	17.20	81.78	10.65	10.03	11.90	9.80	20.28
Rotation 120^o	20.02	16.68	83.47	10.75	8.96	9.89	10.19	20.66
Rotation 150^o	21.41	14.99	84.84	10.78	7.55	4.10	10.51	20.97
Rotation 180^o	22.92	13.85	86.36	10.94	6.61	1.83	10.85	21.32

4.2. Influence of the thickness of the thermal insulation on achievement the PH standard

For the purposes of this analysis, the thickness of the insulation in all elements first was increased by 25% from the initial design value until doubling the thickness was reached, and then decreased by 25% until complete elimination of insulation was reached. The results of PHPP 2007 for each variation are sorted and presented in Table 3. The calculations were also made for individual variations, as well as with the same ratio of increase and decrease of the insulation (25%) (facade walls, floor and roof). The results for façade walls are presented in Table 4.

The influence of the variation of the thermal insulation thickness on specific energy demand for heating is presented in Figure 2 and the influence of the variation of the thermal insulation thickness on specific primary energy demand is presented in Figure 3.

Table 3. Influence of thickness of thermal isolation in building envelope on achievement the PH standard

Description	Specific energy demands			Load		Frequency	CO_2emision	
	heating	cooling	primary energy	heating	cooling	of overheating	Without equipment	Total
Symbol	Q_{SH}	Q_{CS}	Q_{SP}	HL	CL	h_ϕ	CO_2^{Qsh}	CO_2^{Qsp}
Unites	kWh/(m^{2}a)			W/m^2		%	kg/(m^{2}a)	
Prescribed values	15		120	10	10	10	/	/
Design values	13.93	9.36	77.74	10.06	6.76	3.62	8.88	19.35
No isolation	310.67	0.00	415.63	97.44	0.00	0.00	86.08	96.54
Decreased 75%	57.55	12.27	125.62	24.04	5.13	0.00	19.83	30.29
Decreased 50%	30.27	12.03	95.04	15.58	6.19	0.62	12.84	23.30
Decreased 25%	19.48	10.63	83.43	12.04	6.57	2.15	10.18	20.65
Increased 25%	10.67	8.33	74.56	8.80	6.87	4.54	8.15	18.63
Increased 50%	8.59	7.53	72.62	7.92	6.95	5.20	7.70	18.18
Increased 75%	7.17	6.90	71.35	7.28	7.00	5.81	7.41	17.89
Increased 100%	6.16	6.40	70.47	6.78	7.05	6.96	7.21	17.69

Table 4. Influence of thickness of thermal isolation in facade walls on achievement the PH standard

Description	Specific energy demands			Load		Frequency of overheating	CO_2emision	
	heating	cooling	primary energy	heating	cooling		without equipment	Total
Symbol	Q_{SH}	Q_{CS}	Q_{SP}	HL	CL	h_{ϕ}	CO_2^{Qsh}	CO_2^{Qsp}
Unites	kWh/(m^{2}a)			W/m^2		%	kg/(m^{2}a)	
Prescribed values		15	120	10	10	10	/	/
Design values	13.93	9.36	77.74	10.06	6.76	3.62	8.88	19.35
No isolation	59.35	16.35	127.71	25.30	6.97	0.53	20.30	30.77
Isolation 50mm	29.91	13.02	94.67	15.70	6.84	1.43	12.75	23.22
Isolation 100mm	20.73	11.21	84.75	12.56	6.79	2.56	10.48	20.95
Isolation 150mm	16.40	10.10	80.24	11.00	6.77	3.21	9.45	19.92
Isolation 250mm	12.35	8.83	76.18	9.44	6.75	3.90	8.52	19.00
Isolation 300mm	11.26	8.44	75.12	9.00	6.74	4.11	8.28	18.75
Isolation 350mm	10.47	8.14	74.36	8.66	6.74	4.27	8.10	18.58
Isolation 400mm	9.86	7.90	73.79	8.40	6.73	4.40	7.97	18.45

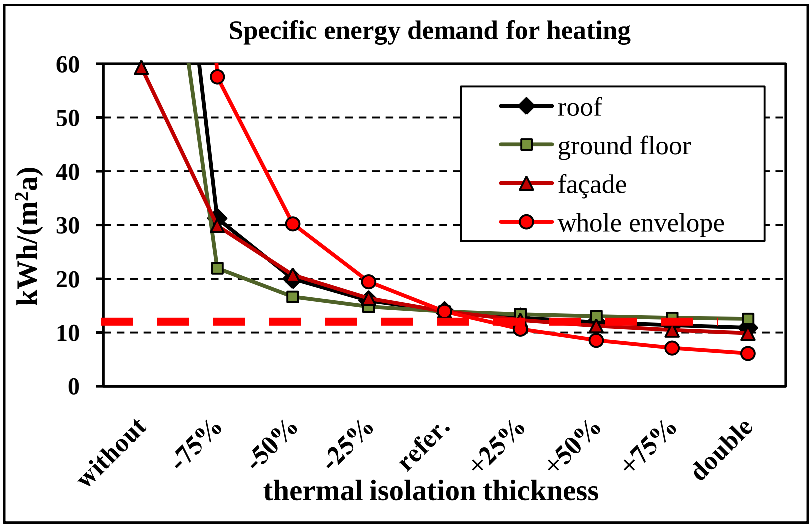

Figure 2. Influence of variation of thermal insulation thickness on specific energy demand for heating

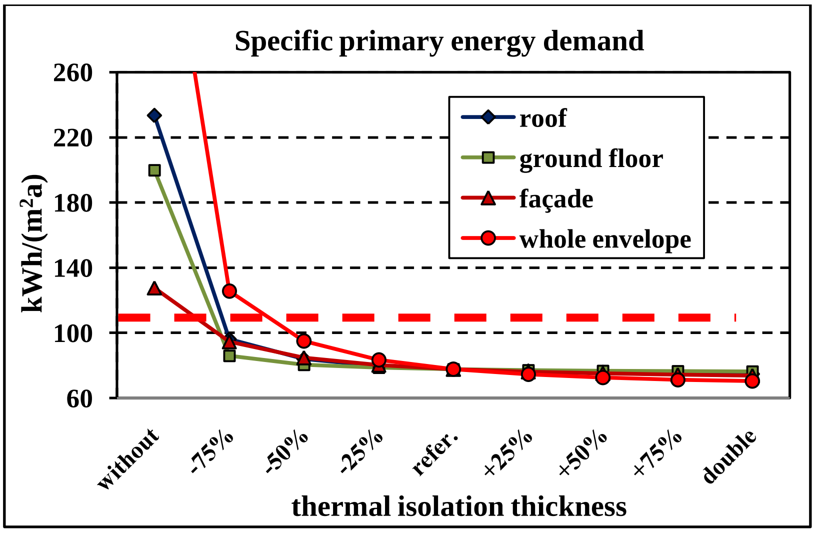

Figure 3. Influence of variation of thermal insulation thickness on specific primary energy demand

4.3. The impact of windows on achieving the passive house standard

The windows are part of the thermal envelope of the building and therefore their impact on total energy demand is high. It is even more apparent in case of passive houses, because despite the need for good heat insulation properties, the use of energy from the sun in winter is of exceptional importance. To provide the necessary solar gains in house, the solar factor or permeability of the light glazing becomes crucial for overall energy needs, but also the risk of overheating is high in summer. Because of these facts, the windows are a key element in achieving the passive house standard.

For the purposes of this paper and for more detailed analysis of the impact of the glazed surfaces on the energy demands of the building, variations in percentage of the window area separately on each facade and on the whole building were made. According to the design data, on the south side of the building the total window area is 26,63 m^2, on the north side it is 3,46 m^2, on the east side it is 8,21 m^2 and on the west side it is 6,55 m^2. The total design window area for the entire building is 44,85 m^2.

For the purposes of this analysis, the window area on each façade separately and on the whole building first was increased by step of 25 % up to 100% and then decreased by step of 25 % up to complete elimination of the windows. In all these cases the following parameters were analyzed: specific energy demand for heating (Q_{SH}), specific energy demand for cooling (Q_{SC}), specific energy demand for primary energy (Q_{SP}), heating load (HL), cooling load (CL), thermal energy to be submitted through the ventilation system (PH), the frequency of overheating (h_{φ}) and the emission of carbon dioxide (CO_2).

For each of the analyzed variations the calculation results obtained by the computer program PHPP 2007 are presented in: Table 5 for south orientation of the windows, Table 6 for north orientation of the windows, Table 7 for east orientation of the windows, Table 8 for west orientation of the windows and Table 9 for the whole building.

Table 5. Effects of variations in window area on the south facade

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_{φ}	CO_2^{QSH}	CO_2^{QSP}
	kWh/(m^2a)	kWh/(m^2a)	kWh/(m^2a)	W/m^2	W/m^2	W	%	kg/(m^2a)	kg/(m^2a)
Prescribed value	15		120	10	10	/	10	/	/
Designed area	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Without windows	18,41	6,58	81,16	8,90	3,18	1348,34	0	9,67	20,13
75% less	21,88	6,96	84,95	10,03	3,19	1519,50	0	10,53	21,00
50% less	19,45	8,09	82,64	10,12	4,21	1532,60	0	10,00	20,47
25% less	16,54	8,94	79,99	10,10	5,46	1530,02	0,62	9,40	19,87
25% more	11,74	9,47	75,94	10,02	8,08	1517,52	8,83	8,46	18,94
50% more	10,05	9,39	74,61	9,97	9,32	1510,72	12,61	8,16	18,64
75% more	8,51	9,22	73,41	9,92	10,74	1502,51	14,12	7,88	17,80
100% more	7,35	9,01	72,53	9,86	12,08	1494,67	15,40	7,68	18,16

Table 6. Effects of variations in window area on the north facade

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_{φ}	CO_2^{QSH}	CO_2^{QSP}
	kWh/(m^2a)	kWh/(m^2a)	kWh/(m^2a)	W/m^2	W/m^2	W	%	kg/(m^2a)	kg/(m^2a)
Prescribed value	15		120	10	10	/	10	/	/
Designed area	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Without windows	13,40	8,65	77,18	9,86	6,36	1493,99	2,41	8,75	19,22
75% less	13,76	8,81	77,54	10,00	6,40	1515,15	2,47	8,83	19,31
50% less	13,84	9,02	77,63	10,03	6,53	1519,52	2,93	8,85	19,33
25% less	13,91	9,24	77,71	10,05	6,68	1523,11	3,39	8,87	19,35
25% more	14,03	9,69	77,86	10,10	6,97	1529,88	4,19	8,91	19,38
50% more	14,10	9,92	77,94	10,12	7,12	1533,20	4,55	8,92	19,40
75% more	14,16	10,15	78,01	10,14	7,27	1536,49	4,89	8,94	19,41
100% more	14,22	10,38	78,09	10,16	7,42	1539,77	5,20	8,96	19,43

Table 7. Effects of variations in window area on the east facade

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_φ	CO_2^{QSH}	CO_2^{QSP}
	kWh/ (m^2a)	kWh/ (m^2a)	kWh/ (m^2a)	W/m^2	W/m^2	W	%	kg/(m^2a)	kg/(m^2a)
Prescribed value	15		120	10	10	/	10	/	/
Designed area	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Without windows	13,98	6,57	77,58	9,77	4,59	1480,67	0	8,84	19,32
75% less	14,63	7,00	78,25	10,04	4,80	1521,37	0	9,00	19,47
50% less	14,45	7,81	78,13	10,06	5,44	1524,62	0,41	8,97	19,44
25% less	14,19	8,59	77,94	10,06	6,09	1524,84	1,16	8,92	19,40
25% more	13,67	10,09	77,55	10,06	7,42	1523,56	5,51	8,83	19,31
50% more	13,42	10,80	77,37	10,05	8,08	1522,64	11,97	8,79	19,27
75% more	13,18	11,48	77,19	10,04	8,75	1521,65	13,21	8,75	19,23
100% more	12,94	12,14	77,02	10,04	9,41	1520,61	12,98	8,71	19,19

Table 8. Effects of variations in window area on the west facade

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_φ	CO_2^{QSH}	CO_2^{QSP}
	kWh/ (m^2a)	kWh/ (m^2a)	kWh/ (m^2a)	W/m^2	W/m^2	W	%	kg/(m^2a)	kg/(m^2a)
Prescribed value	15		120	10	10	/	10	/	/
Designed area	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Without windows	14,16	9,62	77,77	9,74	6,62	1476,15	3,61	8,89	19,36
75% less	14,58	9,73	78,22	9,94	6,63	1506,62	3,54	8,99	19,46
50% less	14,39	9,62	78,09	9,99	6,67	1513,48	3,56	8,96	19,43
25% less	14,16	9,49	77,92	10,03	6,72	1519,06	3,59	8,92	19,39
25% more	13,70	9,23	77,57	10,09	6,80	1529,50	3,65	8,84	19,31
50% more	13,48	9,10	77,41	10,13	6,84	1534,61	3,68	8,80	19,28
75% more	13,26	8,98	77,25	10,16	6,88	1539,68	3,71	8,76	19,24
100% more	13,05	8,86	77,10	10,20	6,92	1544,73	3,73	8,73	19,21

Table 9. Effects of variations in window area on all four facades of the house

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_φ	CO_2^{QSH}	CO_2^{QSP}
	kWh/ (m^2a)	kWh/ (m^2a)	kWh/ (m^2a)	W/m^2	W/m^2	W	%	kg/(m^2a)	kg/(m^2a)
Prescribed value	15		120	10	10	/	10	/	/
Designed area	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Without windows	18,97	1,13	81,31	9,74	0,48	1225,84	0	9,70	20,17
75% less	23,78	1,92	86,77	9,94	0,80	1496,48	0	10,95	21,41
50% less	20,92	5,39	83,94	9,99	2,58	1517,21	0	10,30	20,77
25% less	17,16	7,97	80,49	10,06	4,67	1524,02	0	9,51	19,98
25% more	11,48	10,25	75,82	10,08	9,00	1527,44	12,74	8,43	18,91
50% more	9,70	10,67	74,47	10,09	11,09	1528,15	14,48	8,12	18,60
75% more	8,21	10,89	73,35	10,08	13,37	1527,31	22,67	7,86	18,35
100% more	7,15	11,05	72,57	10,08	15,57	1526,77	26,79	7,68	18,17

The calculation results showed that the energy demand for heating is most sensitive to changes in the percentage of window area on the south facade. When the window area on the south facade is increased, the Specific energy demand for heating is reduced and opposite. All other facades have negligible effect and the north facade has negligible, but opposite effect (Figure 4). The energy demand for cooling is most sensitive to changes in the percentage of window area on the east facade. When the window area on the east facade is decreased, the Specific energy demand for cooling is reduced and opposite. All other facades have less, but not negligible effect (Figure 5).

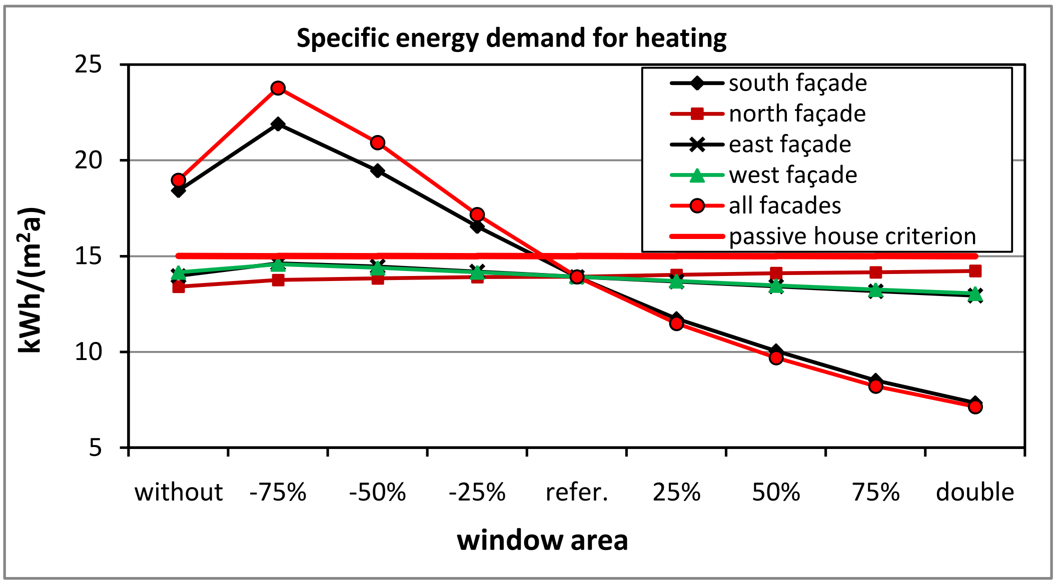

Figure 4. Effects of window area variations on Specific energy demand for heating

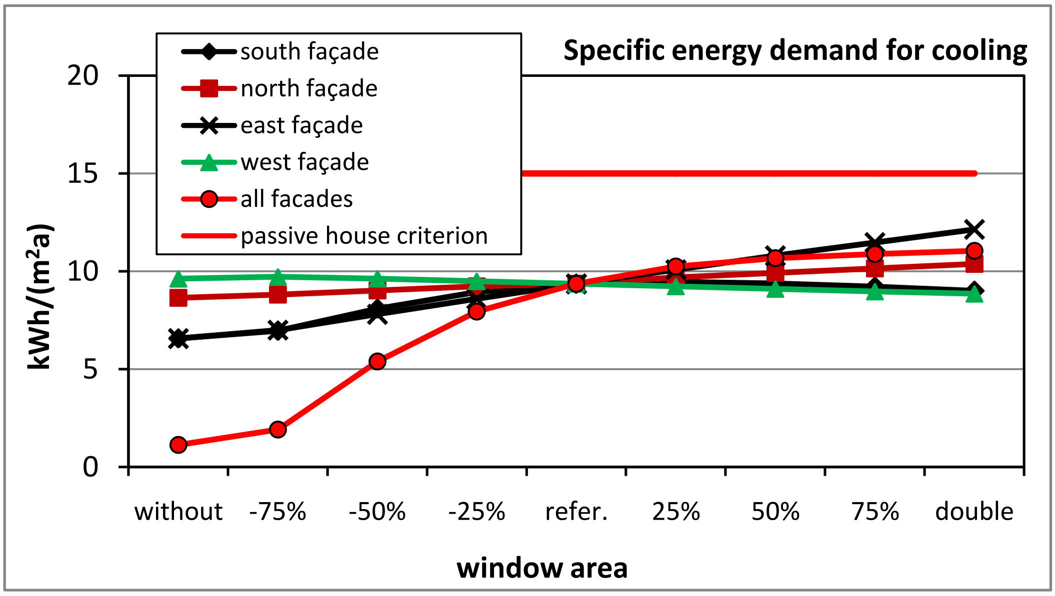

Figure 5. Effects of window area variations on Specific energy demand for cooling

4.4. Influence of the type of window frame and type of glass

In addition to variations of window area on different facades of the building, the type of glass and the type of the frame were varied and the results of the analysis are presented in this paper. For that purpose combinations of frames and glass which are characteristic for the building tradition in Macedonia were used. It was assumed that the built in windows were made identically as for windows of passive house, which means thermal bridges were eliminated.

The following combinations were analyzed: 1) Windows with wooden frame d = 48 mm (U_f=2,50 W/m^{2}K), glazed with single glass (U_g=5,80 W/m^{2}K and g=0,87) ; 2) PVC frame windows with d=72 mm (U_f=2,20 W/m^{2}K), with double glazed glass 4+12 (air) +4 (U_g=2,90 W/m^{2}K and g=0,77) 3.) PVC frame windows with d=98 mm (U_f=1,60 W/m^{2}K), with double glazed glass 4+16 (90 % argon)+4, PVC spacer with thermal bridges factor ψ=0,05 W/(mK) (U_g=1,20 W/(m^{2}K) and g=0,60).

For that purpose the computer program PHPP 2007 was used and the calculation results are presented in Table 10.

Table 10. Influence of the type of window frame and type of glass

Criteria	Q_{SH}	Q_{SC}	Q_{SP}	HL	CL	P_H	h_φ	CO_2^{QSH}	CO_2^{QSP}
	kWh/ (m^2a)	kWh/ (m^2a)	kWh/ (m^2a)	W/m^2	W/m^2	W	%	$kg/(m^2a)$	$kg/(m^2a)$
Prescribed values	15		120	10	10	/	10	/	/
Design values	13,93	9,36	77,74	10,06	6,76	1524,34	3,62	8,88	19,35
Single glass with wooden frame	91,62	23,63	164,64	37,38	9,46	5663,01	1,56	28,74	39,21
PVC frame with double glazed glass	53,29	18,51	120,98	24,35	8,46	3689,98	1,52	18,77	29,23
PVC frame with double glazed glass with argon	30,58	12,82	95,37	15,81	6,63	2394,82	0,92	12,91	23,38

5. CONCLUSION

With the radical changes in urban development, i.e. the way the buildings are designed, constructed and renovated, significant impact can be made in the reduction of energy needs and the use of renewable energies, and thus in creating a sustainable future for the buildings and cities.

The orientation of the building has direct impact on the energy balance of the passive building. The results show that the building orientation of ± 30° has minimal impact on the demand for energy for heating or the most up to 5%. Further rotation of the building shows far greater impact on energy demand for heating with a growth of about 7% for every additional 30° rotation. The reason for this change is to reduce the exposure of the windows to the southern sun rays, thus reducing solar heat gains.

The orientation of the building has a great impact on energy demand for cooling. The reason for this is the exposure of significant area of windows on the south side to the sun rays, when it is rotated by more than ± 30°. Accordingly, the extended rotation to the north side, i.e. for rotations of more than ± 120° a decrease of energy demand for cooling appears. The rotation of the building to ± 30° from the north-south orientation makes small and insignificant impacts on energy demand for cooling, and thus over the necessary financial means to achieve the Passive House standard. Larger deviations have a serious impact on energy demand for cooling. Good insulation in walls doesn’t allow cooling of the building during the night but therefore requires more energy to cool the building.

The orientation itself has a profound effect on overheating the building. Unlike the energy needs for heating and cooling, even the slightest deviation on axis from north-south, the increase in overheating is high. For deviations up to ± 30 °, an increase in the frequency of overheating is even 50%. Maximum frequency of overheating is reached when deviations from the north-south axis are between ± 60 ° and ± 90° and can reach overheating of 2.2 times greater than projected ones. Therefore, it is necessary to apply measures for summer shading on windows (eaves that protect from the summer sun and allow winter sun lighting, various blinds and even deciduous trees).The emission of CO_2 is proportional to the increase in energy consumption for heating / cooling and total primary energy. The CO_2 emissions can vary due to the orientation of the building up to 22% (out of the energy consumed without household appliances) or up to 10% (of total energy consumed).

In order to better understand the influence of the changes in the thickness of the insulation, many combinations have been analyzed in this paper, such as different thickness of the thermal isolation in the roof; to the ground, in the façade walls and in the whole envelope. By analyzing the results it is obvious that the slightest impact on energy demand for heating has insulation in the floor slab, and the most effective is the insulation of the facade. Increasing the thickness of the insulation more than it is recommended (i.e. an increase of the U-value of elements) has no major contribution to the reducing of the energy demands and represents an economically non profitable investment. In opposite, the reduction of the insulation of the elements drastically affects energy demand for heating, so that the least cuts in insulation within any of the building elements will pass the limit 15 kWh/(m^2a). Opposite of the energy demands for heating, the thermal insulation of the building envelope has insignificant impact on energy demand for cooling. The thermal insulation of the building envelope makes almost no impact on energy demand for cooling.

Contrary to expectations, the overheating decreases with decreasing the insulation and increases with increasing the insulation. This is due to the fact that with reduction of the insulation, the thermal capacity of the elements is proportionally decreased and in case of less insulation the cooling of the building grows faster during the nights. And vice versa the greater insulation prevents nighttime cooling of the building, which contributes to higher overheating. The emission of CO_2 is proportional to the increase of energy consumption for heating / cooling.

The orientation of the building plays an extremely important role in the final balance of profit and loss, because the southern orientation of windows contribute to reducing energy demand for heating, while windows on the north side have no contribution to gains, but the opposite - the losses are increased. The analysis confirmed that the greatest impact on the energy demand for heating has the window area located on the south side of the building. It appears that the design should anticipate as large window area with this orientation as it is possible. However, during summer, the southern windows contribute to overheating of the building and hence the energy demand for cooling increases. To prevent overheating there are effective and relatively inexpensive measures for summer shading.

The windows on the east and west sides of the building make significant contribution to the needs for heating of the building in winter, but they are unsuitable for use in the summer because seriously contribute to over-heating. The measures for their shading are either expensive or not effective. The orientation and the size of the windows have impact on energy balance, of the building that very seriously should be taken for consideration at the planning and design stage of the building.

The frequency of overheating mostly depends on the type of glazing of the windows. By reducing the solar factor the overheating is reduced, but the energy demand for heating is increased and vice versa.

From the analysis results it could be concluded that windows are one of the most important elements in achieving the Passive House standard. The choice of glazing is extremely important and it should satisfy all the prescribed criteria for glass for passive house.

Emission of carbon dioxide (CO_2) is proportional to the increase in energy consumption for heating / cooling and total primary energy.

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