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CONTENT

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Influence of building envelope on building energy consumption

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Abstract *The query of energy stability has become the key query of the world economic and social system in the last few years. In addition to its high development and evolution of its relationship to energy security, the EU also faces with the problem of environmental pollution, global warming and climate changes. For several decades, it has been recognized that renewable energy sources are the main support of the energy independence of the world in the future.*

Extensive efforts have been made to reduce CO2 emissions generated by the intensive combustion of fossil fuels, to meet the growing energy needs of humanity. Continuous adoption of numerous directives in EU countries leads to the reduction of existing environmental imbalances on Earth, as well as greater energy efficiency.

The building envelope is a critical component for energy losses and heating energy consumption. So it is very it is important to design energy efficient buildings or implement the principles for improvement energy efficiency of already existing buildings. Paper shows the real consumption of primary and final energy in Serbian building, with variable thermal insulation thickness and different windows . A comparative analysis has showed that the improvement of the building envelope can greatly contribute to the improvement of building energy efficiency and reduction of energy consumption. The investigated building was located in Kragujevac, Serbia. The building is simulated in software EnergyPlus, while Open Studio plug-in Google SketchUp was used for building design. The paper also shows the buliding energy rate, depending on the thermal insulation thickness.

Keywords *building, thermal insulation, window, simulation, energy efficiency*

1. INTRODUCTION

Energy resources and their utilization relate to sustainable development. In attaining sustainable development, increasing the energy efficiencies of processes utilizing sustainable energy resources plays an important role. Humanity is in constant researching of new energy sources that would cover the growing energy needs. Many sources indicate that the construction sector has a high level of energy consumption, which is 20-40% of total energy consumption, which means that we have a high level of CO2 emissions of about 36%. Therefore, we should strive to improve the energy efficiency of the building. The EU obliges its members to continuously increase energy efficiency by adopting numerous directives in order to achieve greater energy efficiency and reduce existing environmental imbalances on Earth.

In Serbia, the building sector consumes more than 50% of the total energy consumption [1]. Heating systems in Serbia consume 60% of total energy consumption [2]. The main reason for this is a large number of energy inefficient buildings in Serbia. For this reason, it is necessary to explore all aspects of energy consumption. The building envelope is one of the critical components for energy losses and heating energy consumption. So it is very it is important to design energy efficient buildings or implement the principles for improvement energy efficiency of already existing buildings.

The paper represents an energy analysis of a single - family residential building for three cases, with a small thickness of the insulation layer and ordinary single glazed windows, with a larger thickness of the insulation layer and with the use of higher quality windows (double and triple glazing) on facades with greater insulation thickness and their impact on heating energy consumption in typical residential buildings in Serbia. Heating system operated from October 15th to April14th next year. The investigated building is located in the city of Kragujevac, Serbia. The building is simulated in software EnergyPlus, while Open Studio plug-in Google SketchUp was used for building design[3-6]. Obtained results show the real consumption of final and primary energy for heating. The paper also shows the building energy rate depending on the thermal insulation thickness, according to the Serbian standards. This very useful knowledge is also needed for identifying energy efficiency and energy conservation opportunities, as well as for dictating the right energy management strategies of a country.

2. MODEL OF ANALYZED BUILDING

The modeled residential building is shown in Figure 1. It is one-store building and it contains from 6 conditioned zones (living room, kitchen, hall, bathroom and two bedrooms). The total floor area of the building is 81 m2. The windows are double glazed. The concrete building envelope, roof, and the floor were thermally insulated by polystyrene. In this investigation, the polystyrene thickness varied (0.05 m, 0.1 m and 0.15 m).

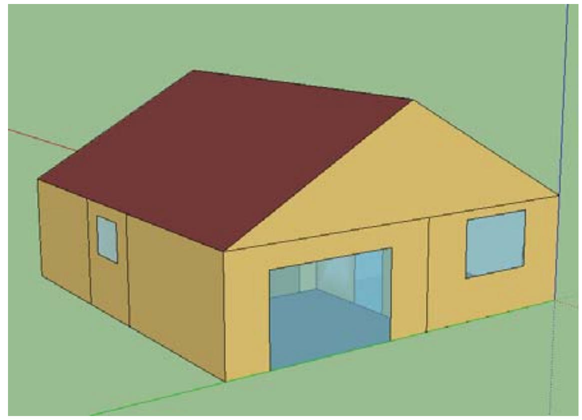

Figure. 1. Modeled building in EnergyPlus - south facade

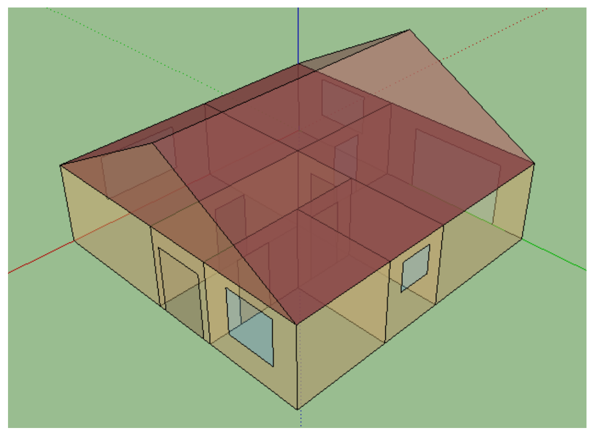

Figure. 2. Modelled building in EnergyPlus - X ray view

Generally, electricity in building is consumed for lighting, domestic hot water (DHW) and appliances. It is analyzed real heating energy consumption (final and primary energy) in the residential building. First, it will be given the required heating energy for the modeled building (obtained with simulation in EnergyPlus software), for different thermal insulation thickness, then real energy consumption and building energy rate.

3. REQUIRED HEATING ENERGY

The amount of required heating energy Q_h in the analyzed residential building is obtained by simulations in software package EnergyPlus (Table 1). The heating energy is independent of the heating system. The results below show the amount of heating energy Q_h, as well as the total final energy consumption Q_f (annually), in the case of different thermal insulation thickness: 0.05 m, 0.1 m and 0.15 m.

Table 1. Building final energy consumption for different thermal insulation thickness

Energy consumption, GJ	**Case 1**
Heating (Qh)	32.73
Lighting	0.5
Electric equipment	8.91
Total energy consumption	42.14
Energy consumption, GJ	**Case 2**
Heating (Qh)	23.66
Lighting	0.5
Electric equipment	8.91
Total energy consumption	33.07
Energy consumption, GJ	**Case 3**
Heating (Qh)	22.29
Lighting	0.5
Electric equipment	8.91
Total energy consumption	31.7

Based on Table 1 it can be concluded that the consumption of heating energy depends on the thickness of the thermal insulation. Heating energy consumption is the lowest in case of maximum thermal insulation thickness. Figure 2 shows a comparison of the energy consumption in the building, depending on the insulation thickness.

In the further investigations, it will be discuss the case of building with 0.15 m thermal insulation thickness, becouse it is the most favorable case from the aspect of energy efficiency. In this case, the required heating energy has the lowest value; heating losses are the smallest, as the U value through the building envelope. By implementation of some other principles of energy efficiency, building energy consumption could be reduce even more. Also, incorporation of renewable energy sources has a significant role in the reduction of total building energy consumption.

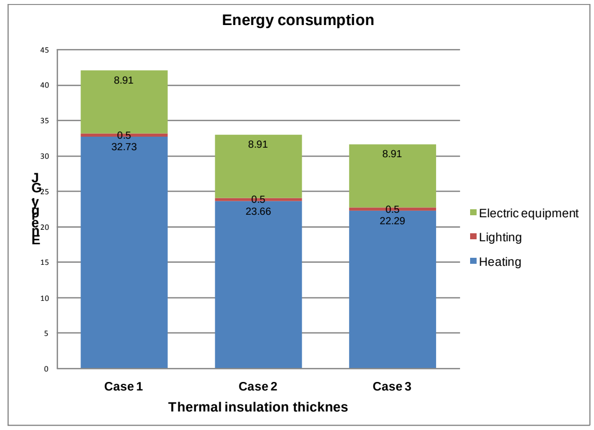

Figure 2. Structure of energy consumption in modeled building

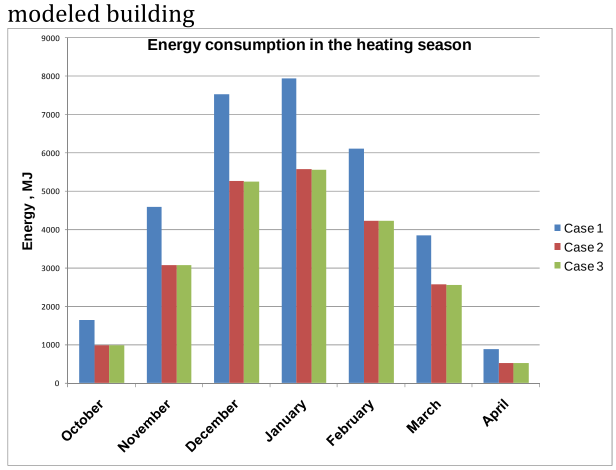

Figure 3. Energy consumption in the heating season for case 1,2,3

Table 2 shows a comparison of the U values for exterior wall, interior wall and roof in the buildings with different thermal insulation thickness. With increasing of thermal insulation thicknes (which is placed at exterior walls), U values decreasing through the building envelope. By implementation of some other principles of energy efficiency, building heating energy consumption could be reduce even more.

Table 2. U values for exterior walls, interior walls and roof, in the cases of the building with different thermal insulation thickness

U [W/m2-K]	**Case 1**
Exterior wall	0.429
Interior wall	0.490
Roof	1.138

U [W/m2-K]	Case 2
Exterior wall	0.250
Interior wall	0.490
Roof	1.138
U [W/m2-K]	**Case 3**
Exterior wall	0.177
Interior wall	0.490
Roof	1.138

4. REAL HEATING ENERGY CONSUMPTION

The amount of real heating energy consumption (Qfin) depends of different values of some efficiency coefficients. These coefficients are related to base board efficiency, boiler efficiency, pump efficiency and heat exchanger efficiency. Some of these coefficients figure in terms of real energy consumption calculating, and they are different for different space heating system, like equiation for real energy consumption [7, 8].

4.1 Real final heating energy for analyzed building and electric space heating

Real energy consumption for electric space heating in building is given in equation (1):

$$Q_{fin} = \frac{Q_h}{\eta_{er}} \tag{1}$$

where ηer stands for efficiency of convective electric baseboard (η_{er}=0.95, [9]).

4.2 Real consumption of final and primary heating energy

According to the above coefficients and equation 1, real consumption of final heating energy consumption (Q_{fin}) for analyzed electric space heating system in modelled building can be calculated. Primary heating energy consumption (Q_{prim}) is calculated by multiplying the real final heating energy consumption with the corresponding primary conversion multiplier. For Serbia, primary conversion multiplier for for electricity is 3.04 [1].

Next table (Table 3) shows results for real consumption of final and primary heating energy, for analyzed heating system in the modelled building. It is also presented the specific heating energy consumption in analyzed buildings (real final heating energy per conditioned area).

Table 3. Building real final and primary heating energy consumption (kWh)

Insulation thickness	Case 1
Required heating energy (Q_h)	9091.65
Real final heating energy (Q_{fin})	9570.157
Heating energy/area (Q_{fin}/A)	112.25
Primary heating energy (Q_{prim})	35586.011
Insulation thickness	**Case 2**
Required heating energy (Q_h)	6572.222
Real final heating energy (Q_{fin})	6918.128
Heating energy/area (Q_{fin}/A)	81.14
Primary heating energy (Q_{prim})	27925
Insulation thickness	**Case 3**
Required heating energy (Q_h)	6191.666
Real final heating energy (Q_{fin})	6517.543
Heating energy/area (Q_{fin}/A)	76.45
Primary heating energy (Q_{prim})	26769.444

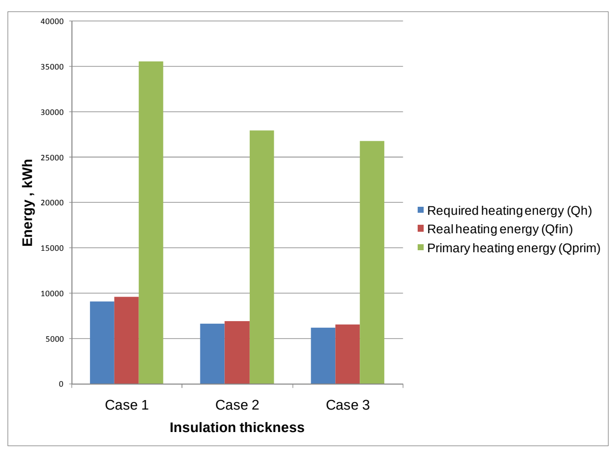

Figure 4. Required heating energy, final and primary heating energy consumption in modeled building for different thermal insulation thickness

Figure 4 shows the graphical presentation of obtained results for required, real final and primary heating energy for three different cases – thermal insulation of 0.05 m, 0.1 m and 0.15 m. It can be concluded that real annual final heating energy consumption in the building with the 0.1 m of thermal insulation is lower by 22%, compared to the building with smallest insulation of 0.05m. In the case of thermal insulation of 0.15 m - real annual final heating energy consumption is lower by 25%, compared to the building with smallest insulation of 0.05 m. The percentage of the annual primary energy saving is the same as in case of real final energy saving.

5. BUILDING ENERGY RATE

A Building Energy Rating or BER is an energy label with accompanying advisory report for buildings. The building rating is a simple A to G scale. A-rated buildings are the most energy-efficient and will tend to have the lowest energy bills. The Advisory Report identifies potential energy performance improvements that could lead to better comfort levels, reduced energy use and costs. A BER is valid for up to 10 years provided that there is no material change to the home that could affect the energy performance.

A BER in the EU is based on the calculated energy performance and associated carbon dioxide emissions for the provision of space heating, ventilation, water heating and lighting under standardised operating conditions. The characteristics of the major components of the home including dimensions, orientation, insulation, and space and hot water system efficiencies are used in the calculation. The energy performance is expressed as:

(a) Annual primary energy use per unit floor area (kWh/m2) represented on an A to G scale; and

(b) Associated annual Carbon Dioxide (CO2) emissions in kgCO2/m2.

A BER is only an indication of the energy performance of a home, it does not include electricity used for purposes other than heating, lighting, pumps and fans. Therefore the energy used for electrical appliances such as cookers, fridges, washing machines and TVs is excluded.
The standards and rules for building energy rating are different in different countries. In Serbia, building energy rate is determined only on the basis of annual building energy consumption for heating per m2 of heated space [11]. Analyzed building belongs to the group of typical Serbian buildings which are built in 1970 i 1980s. These buildings are energy-inefficient buildings, so that is the main reason for the great values of energy consumption for heating and specific heating energy consumption (per m^2 of heating area). This building is classified at D-rate, becouse in modeled cases 2 and 3, the specific energy consumption was in range of 70 -105 kWh/m^2 (Table 4).

Table 4. Building energy rate in Serbia

		New building	*Old building*
Building Energy Rate	QH,nd,rel [%]	QH,nd [kWh/(m^{2}a)]	QH,nd [kWh/(m^{2}a)]
A+	≤ 15	≤ 9	≤ 10
A	≤ 25	≤ 15	≤ 18
B	≤ 50	≤ 30	≤ 35
C	≤ 100	≤ 60	≤ 70
D	≤ 150	≤ 90	≤ 105
E	≤ 200	≤ 120	≤ 140
F	≤ 250	≤ 150	≤ 175
G	> 250	> 150	> 175

6. CONCLUSION

The paper represents an energy analysis of a single - family residential building for three cases, with a small thickness of the insulation layer and ordinary single glazed windows, with a larger thickness of the insulation layer and with the use of higher quality windows (double and triple glazing) on facades with greater insulation thickness and their impact on heating energy consumption in typical residential buildings in Serbia.

Software EnergyPlus was used for simulating of building energy behaviour, while building design was condusted in Open Studio plug-in for Google SketchUp software.
Three cases of the thermal insulation thickness at the same building, with electric space heating system are investigated – 0.05 m, 0.1 m and 0.15 m. It was calculated required heating energy consumption, real final and primary heating energy consumption and specific energy consumption.
Obtained results showed that real annual final heating energy consumption in the building with the 0.15 m of thermal insulation and with

the use of higher quality windows is lower by 25%, compared to the building with smallest insulation of 0.05 m and ordinary single glazed windows.

In accordance with Building Energy Rating in Serbia, this building is classified at D-rate, becouse in modeled cases 2 and 3, the specific energy consumption was in range of 70-105 kWh/m^2.

This fact means that the energy efficiency of the analyzed building can be significantly improved by thermal insulation on the external walls and by installing high quality windows as an integral part of the facade. By taking further measures to improve energy efficiency, financial savings can be increased at a very high level.

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