UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

5th INTERNATIONAL SCIENTIFIC CONFERENCE

COMETa 2020

„Conference on Mechanical Engineering Technologies and Applications“

PROCEEDINGS

26th-28th November

East Sarajevo, RS, B&H

ZBORNIK RADOVA

PROCEEDINGS

Istočno Sarajevo, BiH, RS
26 - 28. novembar 2020.

East Sarajevo, B&H, RS
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COMETa2020, Istočno Sarajevo, 2020.

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COMETa2020, East Sarajevo, 2020

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PREFACE

Faculty of Mechanical Engineering of the University of East Sarajevo is organizing the 5th International Scientific Conference COMETa 2020 – "Conference on Mechanical Engineering Technologies and Applications“ in specific circumstances. Namely, faced with numerous challenges due to the pandemic caused by the spread of COVID-19 virus on a global level, the Organizing Committee decided to hold the Conference COMETa 2020 virtually, in order to ensure the safety of participants and the entire community. Also, the continuity of the event was a significant reason for the establishment of the online model, especially considering the fact that the conference COMETa has been categorized by the relevant Ministry as an international scientific conference of the first category.

The main goal of the conference is to contribute to increasing the competitiveness of national business entities through the presentation and implementation of new scientific achievements in the field of mechanical engineering. In addition, the conference will provide additional support to researchers in the presentation of their results, as well as establishing a higher level of cooperation with leading national and international scientific institutions, universities, public companies and partners from industry.

The program of the conference COMETa 2020 consists of the following thematic areas:

- Manufacturing technologies and advanced materials,
- Applied mechanics and mechatronics,
- Machine design, simulation and modeling,
- Product development and mechanical systems,
- Energy and thermotechnic,
- Renewable energy and environmental,
- Maintenance and technical diagnostics,
- Quality, management and organization.

A total of 193 authors and co-authors from 12 countries are participating in the 5th International Scientific Conference COMETa 2020 where 70 papers have been accepted, including 5 plenary lectures. Round table on the very actual topic “Challenges in the education during COVID-19 pandemic – Online as a solution ...“ is planned to be held.

The participation of a significant number of domestic and foreign scientists and researchers strengthens our conviction that the online format of the conference will not diminish its importance. On the contrary, we are sure that together we will gain new experiences, which will further enable us better and more meaningful cooperation in the near future by generating new ideas and establishing modern approaches to solving complex issues in mechanical engineering in the context of challenges that are present in the technical and technological development of an advanced society in the 21st century. In that sense, we want to emphasize that each of your proposals is welcome and will be carefully considered from the aspect of organizing the next conferences.

On behalf of the Organizing and Scientific Committee of the conference COMETa 2020, we would like to express our gratitude to all authors, reviewers, universities, business entities, and national and international institutions and organizations that supported the organization of the conference. We would like to express special gratitude to the Ministry of Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska, the City of East Sarajevo and local communities.

In the hope that our joint efforts will meet the expectations of the scientific and professional public, the organizer of the Conference, Faculty of Mechanical Engineering, University of East Sarajevo, wishes all participants successful work. Welcome to the online conference COMETa 2020.

East Sarajevo, November 23rd, 2020.

President of the Scientific Committee
PhD Nebojša Radić, Full Professor

President of the Organizing Committee
PhD Milija Kraišnik, Associate Professor

C O N T E N T

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MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS

APPLIED MECHANICS AND MECHATRONICS

MACHINE DESIGN, SIMULATION AND MODELING

PRODUCT DEVELOPMENT AND MECHANICAL SYSTEMS

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INFLUENCE OF THERMAL INSULATION THICKNESS ON HEATING ENERGY CONSUMPTION

Jasmina Skerlić[1], Danijela Nikolić[2], Ana Radojević[3], Milan Đorđević[4]

Abstract: The problem of energy stability in the last few decades has become the most important problem of the world economy and the social system. Extensive efforts have been undertaken to alleviate global warming of the earth caused by emission of CO_2 in atmosphere. These emissions are generated by intensive burning of fossil fuels to satisfy the growing energy needs of humanity. 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.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. This paper shows the real consumption of energy for heating in tipicaly Serbian building, with variable thermal insulation thickness. The investigated building is located in Kragujevac, Serbia. The building is simulated in software EnergyPlus, while Open Studio plug-in for Google SketchUp was used for building design. The paper also shows the buliding energy rate, depending on the thermal insulation thickness.

Key words: heating energy, thermal insulation, building, simulation

1 INTRODUCTION

The problem of energy stability in the last few decades has become the most important problem of the world economy and the social system. Humanity is in constant researching of new energy sources that would cover the growing energy needs.

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. From many sources it can be concluded

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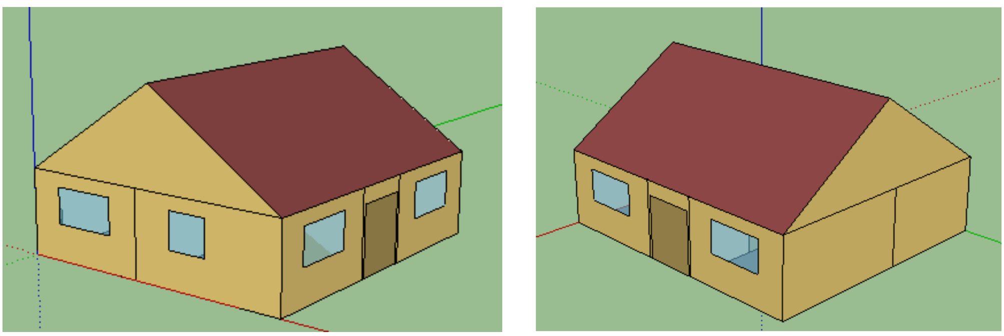
that the building sector has energy consumption of around 20-40% of total energy consumption and CO_2 emissions around 36% Therefore, we should strive to improve the energy efficiency of the building, which implies the continuous application of a wide range of activities with the ultimate goal of reducing the consumption of all types of energy with better or equal conditions in the building. In Serbia, the building sector consumes more than 50% of the total energy consumption [1]. As the buildings consume a significant part of energy, it is necessary to investigate all aspects of energy consumption in order to minimize the total final and primary energy consumption. In developed countries heating systems consume around a third of the total building energy consumption, while in Serbia it is at the level of even 60 %[2].The main reason for this is a large number of energy inefficient buildings in Serbia, with annual energy consumption of 220 kWh/m^2, while the European average energy consumption is 60 kWh/m^2 [2]. 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.

This paper represents the influence of thermal insulation thickness to the building heating energy. 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 in tipicaly Serbian building, with variable thermal insulation thickness. The paper also shows the building energy rate depending on the thermal insulation thickness, according to the Serbian standards.

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, hall, bathroom and three bedrooms). The total floor area of the building is 120.17 m^2. 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). These building materials and constructions are usual in Serbian buildings and correspond to typical Serbian construction materials (Cementmortar, Polystyrene, Clay block, Lime mortar, Cement,Glass wool, Monta block,Sand).It was assumed that these rooms would have almost the same occupancy, lighting, and small power schedule. The heating and cooling are assumed to operate according to the schedules, during the entire year, to meet the temperature heating and cooling setpoints.



a) b)

Fig. 1 *Modeled building in EnergyPlus (a – south facade; b – north facade)*

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 E_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 E_h, as well as the total final energy consumption E_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	Energy consumption (kWh)		
	0.05 m	0.1 m	0.15 m
Required heating energy (E_h)	12224	11645	11392
Lighting	158.5	158.5	158.5
Electric equipment	1345.5	1345.5	1345.5
Total energy consumption	13728	13149	12896

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 of 0.15 m. Figure 2 shows a comparison of the energy consumption in the buildings, depending on the thermal insulation thickness. Energy consumption for lighting and electric equipment is the same in all three cases, 158.5 kWh and 1345.5 kWh, respectively. The highest annual required heating energy consumption has building with the lowest thermal insulation thickness 0.05 m – 12224 kWh, then building with 0.1 m of thermal insulation thickness – 11645 kWh, while the lowest required heating energy consumption has building with the higher thermal insulation thicknes of 0.15 m – 11392 kWh.

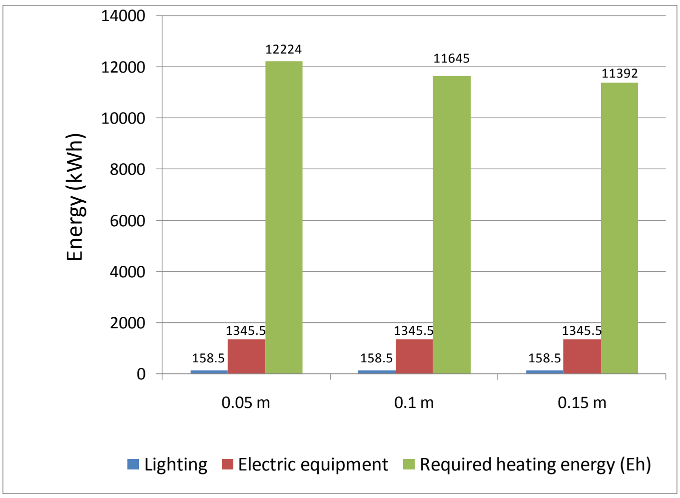


Figure 2. *Schematics of building energy consumption for the building with SDHWS (left) and reference building without SDHWS (right)*

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/m^2-K]		
	0.05 m	0.1 m	0.15 m
Exterior wall	0.429	0.250	0.177
Interior wall	0.490	0.490	0.490
Roof	1.138	1.138	1.138

4 REAL HEATING ENERGY

The amount of real heating energy consumption (E_{fin}) 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 district heating system

Real energy consumption for district heating system in building is given in equation (1):

$$E_{fin} = \frac{E_h}{\eta_{raz}\eta_{cm}\eta_a} + \frac{E_p}{\eta_p} \quad (1)$$

where

- η_{raz} stands for heat exchanger efficiency (η_{raz} =0.84) [9],
- η_{cm} stands for pipeline efficiency (η_{cm} =0.95) [9],
- ηa stands for fittings efficiency (η_a=0.95) [9],
- E_p stands for electricity for circulation pump and
- η_p stands for circulation pump efficiency (η_p=0.87), [10].

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 (E_{fin}) for analyzed district heating system in modelled building can be calculated. Primary heating energy consumption (E_{prim}) is calculated by multiplying the real final heating energy consumption with the corresponding primary conversion multiplier. For Serbia, primary conversion multiplier for district heating is 2.03 [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) for district heating system*

Insulation thickness	*0.05 m*	*0.1 m*	*0.15 m*
Required heating energy (E_h)	12224	11645	11392
Real final heating energy (E_{fin})	16,377.40	15,613.64	15,279.91
Heating energy/area (E_{fin}/A)	136,48	130,11	127,33
Primary heating energy (E_{prim})	33,246.11	31,695.70	31,018.23

Figure 3 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 763.76 kWh, i.e. 4,7%, 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 1097.49 kWh, i.e. 6,7%, 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.

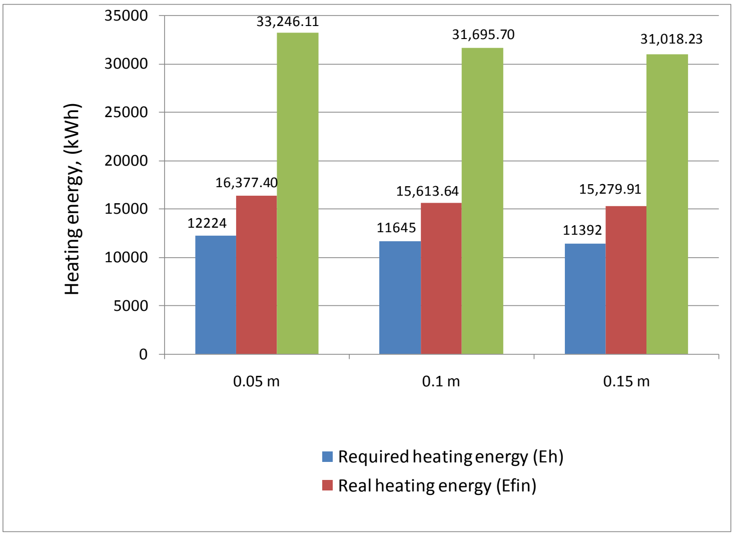


Figure 3. *Required heating energy, final and primary heating energy consumption in modeled building for different thermal insulation thickness*

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/m^2) represented on an A to G scale; and

(b) Associated annual Carbon Dioxide (CO_2) emissions in $kgCO_2/m^2$.

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 m^2 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 E-rate, becouse in all modeled cases, the specific energy consumption was in range of 105 -140 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/(m²a)]	QH,nd [kWh/(m²a)]
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

This paper represents the investigation on influence of thermal insulation thickness to heating energy consumption in typical residential building 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 district 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 (kWh) 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 is lower by 1097.49 kWh, i.e. 6,7%, compared to the building with smallest insulation of 0.05 m.

In accordance with Building Energy Rating in Serbia, this building is classified at E-rate, becouse in all modeled cases, the specific energy consumption was in range of 105 -140 kWh/m^2.

This fact means that energy efficiency of analyzed building can not be significantly improved only with thermal insulation on exterior walls. Some other measures have to be conducted for better improving of energy efficiency and financial saving.

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