COMETa 2018
4th INTERNATIONAL SCIENTIFIC CONFERENCE
27th - 30th November 2018
Jahorina, Republic of Srpska, B&H
University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

ENERGY CONSUMPTION AND ECONOMIC ANALYSIS OF DIFFERENT HEATING SYSTEMS IN SERBIAN BUILDING

Danijela Nikolić[1], Jasmina Skerlić[2], Blaža Stojanović[3], Radoslav Tomović[4], Dragan Cvetković[5], Saša Jovanović[6]

Abstract: Energy consumption in buildings at the global level is 20 - 40% of total energy consumption, while in Serbia it is at the level even of 50 %. This consumption is related to the exploitation conditions of buildings, where the largest consumer is heating system with ratio of 50 - 60 %. This paper represents the investigations in simulation of different heating systems in typical Serbian building. It is analyzed the electric space heating, district heating, gas heating and coal central heating, for typical Serbian building with variable thermal insulation thickness. 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. Paper shows the real consumption of primary and final energy in Serbian building. Finally, the economic analysis was performed for different heating systems, which shown that the gas heating system is the most effective heating systems for the Serbian building – it has a small primary energy consumption and it is cost effective.

Key words: Building, Heating, EnergyPlus, Energy consumption, Economic analysis

1 INTRODUCTION

In recent years, question of energy security and stability has become the cardinal question of the entire world economy, economic and social system. The rapid population growth on Earth causes a steady increase of energy needs. Therefore, humanity is in constant researching of new energy sources that would cover the growing energy needs. The world currently covered their energy needs with conventional energy sources, mainly fossil - nonrenewable energy sources, which have a large number of negative impacts, especially on the environment.

[1] Ph. D. Danijela Nikolić, Faculty of Engineering University of Kragujevac, Serbia, danijelan@kg.ac.rs
[2] Ph. D. Jasmina Skerlic, Faculty of Engineering University of Kragujevac, Serbia, jskerlic@gmail.com
[3] Ph. D. Blaža Stojanovic, Faculty of Engineering University of Kragujevac, Serbia, blaza@kg.ac.rs
[4] Ph. D. Radoslav Tomović, Faculty of Mechanical Engineering, University of Montenegro, Podgorica, Montenegro, radoslav@ac.me
[5] Ph. D. Dragan Cvetković, Faculty of Engineering University of Kragujevac, Serbia, dragan.cvetkovic83@gmail.com
[6] Ph. D. Saša Jovanović, Faculty of Engineering University of Kragujevac, Serbia, dviks@kg.ac.rs

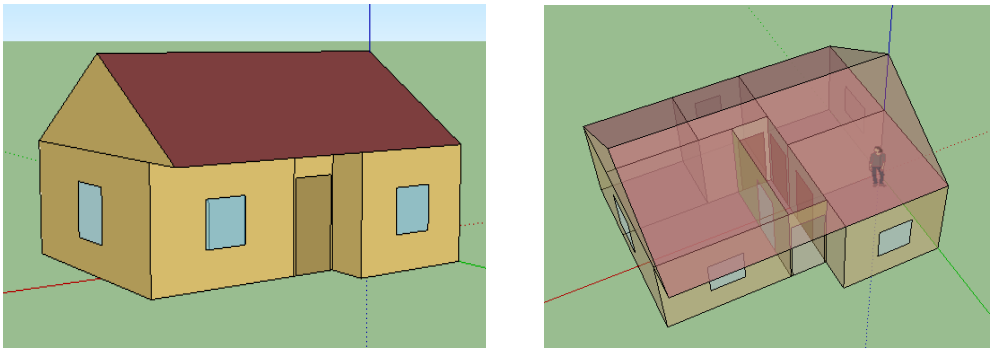
In Serbia, the building sector consumes more than 50% of the total energy consumption [1]. As the buildings consume a significant part of energy, it is necessary to investigate all aspects of energy consumption in order to minimize the total final and primary energy consumption. In developed countries 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 rest part of energy consumption is related to the ventilation, lighting and electrical appliances. The main reason for this is a great 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. The building envelope is a critical component for the energy losses and heating energy consumption. So it is very important to design energy efficient buildings or implement the principles for improving energy efficiency of already existing buildings.

This paper presents the investigations of the possibilities to decrease primary energy consumption of Serbian residential buildings with different heating systems, through the variation of thermal insulation thickness and implementation of real parameters in calculation of total energy consumption. It is analyzed four type of heating system. Also, an economic analysis was performed.

The investigated building was located in Kragujevac, Serbia. Heating system operated from October 15th to April14th next year. In this paper, the EnergyPlus software was used for building energy simulation [3], while Open Studio plug-in in Google SketchUp [4] was used for building design.

2 MODEL OF ANALYZED BUILDING

The modeled residential building is shown in Figure 1. The building is one-store building and it contains from 5 conditioned zones (living room, hall, bathroom and two bedrooms). The total floor area of the building is 98.8 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).



a) b)

Figure 1. *Modeled building in EnergyPlus (a – north facade; b – X ray mode view)*

Generally, electricity is consumed for lighting, domestic hot water (DHW) and appliances. It is analyzed the electric space heating, gas heating, coal central heating and district heating, and also real energy consumption (final and primary energy) in the residential building. First, it will be given the required heating energy for the modeled building, in the cases of different thermal insulation thickness.

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*
Heating (Eh)	*7180.88*	*6503.32*	*6206.15*
Lighting	*593.19*	*593.19*	*593.19*
Electric equipment	*1552.76*	*1552.76*	*1552.76*
Water heating	*2384.62*	*2384.62*	*2384.62*
Total energy consumption	*11711.45*	*11.033.89*	*10736.72*

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.

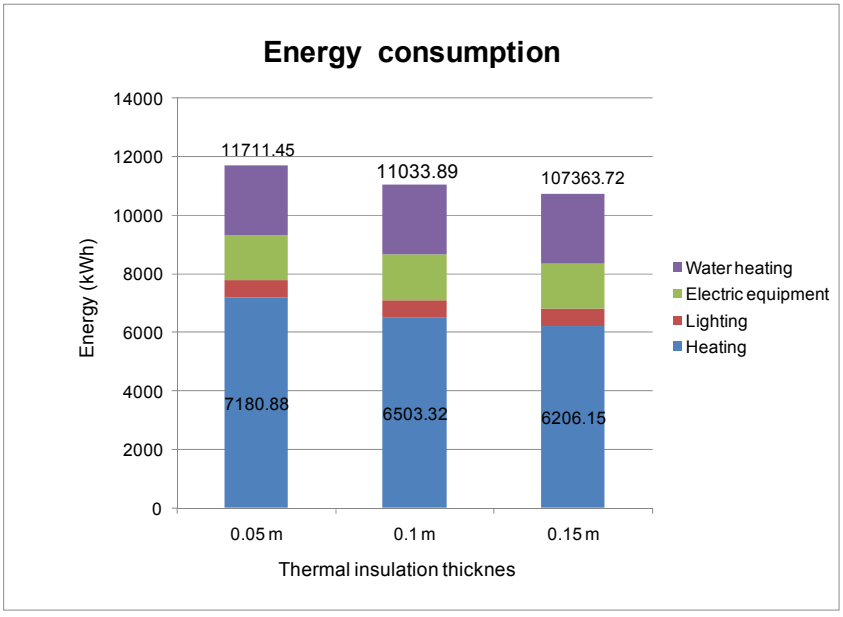


Figure 2. *Structure of energy consumption in modeled building*

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.

4 REAL HEATING ENERGY CONSUMPTION

The amount of real heating energy consumption (E_{fin}) depends of different values of some efficiency coefficients. These coefficients are related to baseboard 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 [5, 6] .

4.1 Electric space heating (EH)

Electric space heating means convective electric baseboard in every conditioned zone (room). Real consumption of electric energy for heating, in electric space heating system is:

$$E_{fin} = \frac{E_h}{\eta_{er}} \tag{1}$$

where η_{er} stands for efficiency of convective electric baseboard (η_{er}=0.95, [7]).

4.2 Gas heating system (GH)

Real energy consumption in gas heating system (with gas boiler in the building) is given in next equation:

$$E_{fin} = \frac{E_h}{\eta_{kpg}} + \frac{E_p}{\eta_p} \tag{2}$$

where E_p stands for electricity for circulation pump, η_{kpg} stands for efficiency of gas boiler (η_{kpg}=0.85, [8]) and η_p stands for circulation pump efficiency (η_p=0.87, [9]).

4.3 Coal central heating (CH)

Real energy consumption in coal central heating system (with coal boiler) is given in equation (3):

$$E_{fin} = \frac{E_h}{\eta_{ku}} + \frac{E_p}{\eta_p} \tag{3}$$

where η_{ku} stands for efficiency of coal boiler (η_{ku}=0.68, [8]).

4.4 District heating (DH)

Real energy consumption for district heating system in building is given in equation (4):

$$E_{fin} = \frac{E_h}{\eta_{raz} \cdot \eta_{cm} \cdot \eta_a} + \frac{E_p}{\eta_p} \tag{4}$$

where η_{raz} stands for heat exchanger efficiency (η_{raz} =0.84), η_{cm} stands for pipeline efficiency (η_{cm} =0.95) and η_a stands for fittings efficiency (η_a=0.95) [8].

4.5 Real consumption of final and primary heating energy

According to the above coefficients and equations, it can be calculated real final heating energy consumption (E_{fin}) for all analyzed heating system in modelled building. 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 electricity is 3.04, for district heating it is 2.03, for coal heating it is 1.3 and for gas it is 1.1 [10].

Next table (Table 2) shows the results for real consumption of final and primary heating energy, for all types of analyzed heating systems in the modelled building.

Table 2. *Building real final and primary heating energy consumption for different heating systems*

	Energy consumption (kWh)			
	EH	*DH*	*CH*	*GH*
Heating energy (Eh)	*6206.15*	*6206.15*	*6206.15*	*6206.15*
Real final heating energy (Efin)	*6532.78*	*8187.42*	*9148.12*	*7322.79*
Primary heating energy (Eprim)	*19859.68*	*16642.12*	*11929.87*	*8096.65*

Graphical presentation of results for building energy consumption in cases of different heating systems is presented on Figure 3.

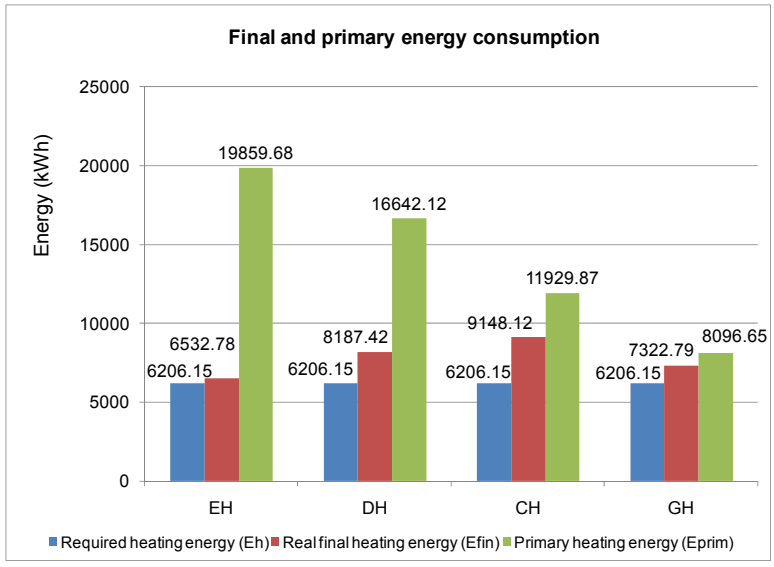


Figure 3. *Required heating energy, final and primary heating energy consumption in modeled building for different heating systems*

Primary energy consumption is influenced by the efficiency of devices that transform the final energy form into a useful energy form, and the final energy conversion multiplier in the primary energy.

From Table 2 and Figure 2, it can be concluded that the real final heating energy consumption has the highest value for coal heating, becouse of the low value of the coal boiler efficiency. Also, real final heating energy consumption is lowest for electric space heating. Primary energy consumption is the greatest for electric space heating (primary conversion multiplier has the highest value for electricity, 3.04), and it is lowest for gas heating (primary conversion multiplier has the value only 1.1). From the aspect of energy efficiency, according to the primary energy consumption, gas heating is the most advantageous heating system, which, also, have the smallest influence to the environment and greenhouse gas emission.

5 ECONOMIC ANALYSIS

For the economic analysis of energy consumption and the final price paid for heating during the heating season in a modelled house, real energy prices in Serbia were used. The price of electricity of the single-tariff meter in the blue zone in Serbia is 7.658 din/kWh [11]. The amount of natural gas, as well as the coal required for heating the object, is calculated according to the procedures described in [5] and [6]. Taking into account that the price of natural gas for category 1 (p < 6 bar) is 32.28 din/m^3 [12], and the price of dark coal to which the corresponding lower thermal power is 14.000 din/t [13], the heating price for modelled house is given below (Table 3). The price of district heating is given on the basis of the average price of district heating in the city of Kragujevac, for a building area of 100 m^2.

Table 3. *Total cost for building heating for different heating systems*

Heating system	*Efin*	*Required amount*	*Unit price*	*Total cost (din)*
Electric heating (electricity)	*6532.78*	*6532.78 kWh*	*7.658 din/kWh*	*50029*
Gas heating (gas)	*7322.79*	*796,51 m^3*	*32.38 din/m^3*	*25791*
Coal heating (coal)	*9148.12*	*1.830 t*	*14 000 din/t*	*25620*
District heating	*8187.42*	*8187.42*	*-*	*54795*

Economic analysis shows that the most economical heating systems are coal heating and gas heating, while currently, the district and electric heating are more expensive heating systems in Serbia. District heating and electric heating have approximately the same price, but this price is significantly higher than the cost of gas and coal heating. When choosing a heating system, it should taking into account the pollution of the environment, which is the biggest with fossil fuels combustion (e.g. coal). Coal heating is very difficult as well as the process of its servicing, so it should be considered too. It should not always look only the price, but consider all the other factors in choosing a proper heating system.

At the end, it can be concluded that the gas heating system is favourable and the most economic heating system in Serbia – it is the cheap and clear and it has a smallest primary energy consumption.

Figure 4 represent graphically the total cost for heating energy in the analyzed building, for different heating system.

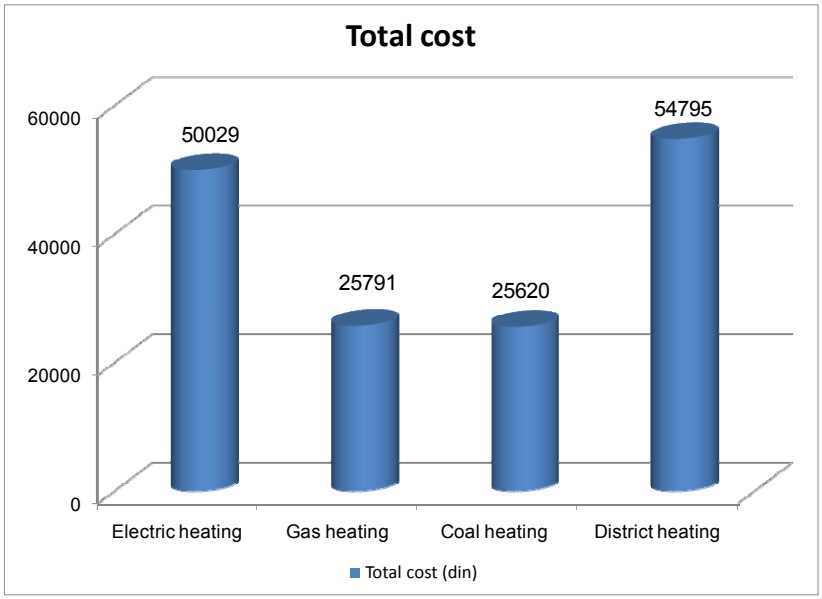


Figure 4. *Total cost for heating energy for different heating systems*

6 CONCLUSION

This paper represents investigation of real final and primary energy consumption for residential Serbian building. First, required heating energy (final energy) was obtained by EnergyPlus software for analyzed building. Then, real heating energy consumption was calculated, taking into account different values of some efficiency coefficients which refer to heating system installation. Obtained results showed that the real final heating energy consumption has the highest value for coal heating and it is lowest for electric space heating. Primary energy consumption is the greatest for electric space heating and it is lowest for gas heating (primary conversion multiplier has the value only 1.1).

After energy analyses, the economic analyses was made, which showed that for analyzed Serbian building, the most economical heating systems are coal heating and gas heating system.

According to all these facts, the conclusion is that the best solution for heating in Serbian building is gas heating which is very cheap, clear and very convenient to the environment. It also has a lowest primary energy consumption.

ACKNOWLEDGMENT

This investigation is part of the project TR 33015 of Technological Development of the Republic of Serbia. We would like to thank to the Ministry of Education and Science of Republic of Serbia for the financial support during this investigation.

NOMENCLATURE

E energy, kWh

p pressure, bar

Greek symbols

η	efficiency

Subscripts and superscripts

a	fittings
cm	pipeline
er	electric baseboard
f	final energy
fin	real final heating energy
h	heating
kpg	gas boiler
ku	coal boiler
p	pump
prim	primary heating energy
raz	heat exchanger

REFERENCES

[1] Bojić M., Nikolić N., Nikolić D., Skerlić J., Miletić I., (2011). A simulation appraisal of performance of different hvac systems in an office building, *Energy and Buildings*, 43/6, p. p. 2407-241.

[2] Nikolic D., Skerlic J., Radulovic J., (2017). Energy efficient buildings – legislation and design, *2nd International Conference on Quality of Life*, Kragujevac, Conference Proceedings, p. 55-60.

[3] Anonymous, (2009). ENERGYPLUS, Input Output Reference - *The Encyclopedic Reference to EnergyPlus Input and Output*, University of Illinois & Ernest Orlando Lawrence Berkeley National Laboratory

[4] Bojić M., Skerlić J., Nikolić D., Cvetković D., Miletić M, (2012). Toward future: positive net-energy buildings, *Proceedings 4th IEEE International Symposium on Exploitation of Renewable Energy Sources, EXPRES 2012*, Subotica, Serbia, p. 49-54

[5] Zrnić, S., Ćulum, Ž., (1966). *Grejanje i klimatizacija sa primenom solarne energije*, Naučna knjiga, Beograd

[6] Todorović, B. (2005). *Projektovanje postrojenja za centralno grejanje*, Mašinski fakultet Univerziteta u Beogradu,.Beograd

[7] NOBO, http://norveski-radijatori.com/gclid=CLK964-n6c8CFcQV0wods0cETQ, (accessed 18.09.2018.)

[8] Inzenjerska komora Srbije, http://www.ingkomora.org.rs/,(accessed 18.09.2018.)

[9] Uredjaji i oprema sistema centralnog grejanja, http://aliquantum.rs/wp-content/uploads/2011/12/04-Predavanje-Ure%C4%91aji-i-oprema-sistema-grejanja.pdf, (accessed 20.09.2018.)

[10] Nikolic, D. (2015). Energetsko-eksergetska optimizacija velicina fotonaponskih panela il solarnih kolektora kod kuca neto-nulte potrosnje energije, *Doktorska disertacija*, Fakultet inzenjerskih nauka Univerziteta u Kragujevcu, Kragujevac
http://www.nrel.gov/docs/fy13osti/56487.pdf, (accessed 20.09.2018.)

[11] ServisInfo, http://www.servisinfo.com/cena-struje, (accessed 20.09.2018.)

[12] Srbijagas, http://www.srbijagas.com/sr_rs/, (accessed 20.09.2018.)

[13] TROPIKAL,http://ugalj.rs/opis.php?naziv=Banovi%C4%87i%20-%20mrki%20-%20kocka&gclid=CNqt24jzk9ACFRPjGwodog8MFg , (accessed 20.09.2018.)