POTENCIJAL UŠTEDE TOPLOTNE ENERGIJE U VRTIĆU SA PRIPREMNIM PREDŠKOLSKIM GRUPAMA – STUDIJA SLUČAJA KRAGUJEVAC

POTENTIAL FOR HEATING ENERGY SAVINGS IN A KINDERGARTEN WITH PREPARATORY PRESCHOOL GROUPS – CASE STUDY KRAGUJEVAC

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U ovom radu izvršena je procena potencijalne uštede energije za grejanje u slučaju jednog vrtića u Kragujevcu pomoću simulacionog softvera „EnergyPlus". Cilj rada je odrediti količinu energije za grejanje koja se može uštedeti ako se vrtić razdvoji na dva dela i ukoliko se primene različiti rasporedi uključenja sistema grejanja određeni prema prisustvu dece u odgovarajućim grejanim zonama tokom različitih vremenskih intervala. Ovaj rad ukazuje na problem neracionalne upotrebe energije tokom boravka malog broja ljudi u zgradi sa velikim brojem grejanih prostorija. Osnovni razlog za razdvajanje vrtića u dva odeljka su njegove celodnevne i poludnevne grupe dece. Celodnevne grupe prisutne su u oba odeljka analiziranog vrtića od 8 do 15^h, dok su poludnevne grupe (pripremne predškolske grupe) prisutne samo u jednom odeljku vrtića ukupno četiri sata (16^h-20^h). Prema rezultatima simulacija, 13,2% (7277.5 kWh) toplotne energije bi bilo moguće uštedeti ukoliko bi se temperatura uključenja sistema grejanja tokom vikenda (kada nema prisustva dece) smanjila za sve grejane zone sa 20°C na 12°C. S druge strane, ukoliko bi se uz smanjenje pomenute temperature aktivacije sistema grejanja tokom vikenda, zagrevao samo deo objekta u kome su prisutna deca (pripremne predškolske grupe) tokom radnih dana, uštede energije za grejanje vrtića bi iznosile 24,84% (13700 kWh).

Ključne reči: *grejanje; ušteda energije; EnergyPlus; vrtić; predškolska grupa*

In this paper the potential of heating energy savings in the case of one kindergarten in the city of Kragujevac by using "EnergyPlus" simulation software was evaluated. The main objective of the paper is to determine the amount of heating energy that can be saved if kindergarten is separated into two sections and if different schedules for heating system activation defined according to the presence of children in respective heated zones during different intervals are applied. This paper points out the problem of irrational use of energy during the presence of a small number of people in a building with a large number of heated rooms. The main reason for separating the kindergarten into two sections are its full-day and half-day groups of children. The full-day groups are present in both sections of the analysed kindergarten from 8^h to 15^h, while the half-day groups (preparatory preschool groups) are present only in one section of the kindergarten for a total time of four hours (16^h-20^h). According to the simulation results, 13.2% (7277.5 kWh) of heating energy could be saved if the temperature of the heating system activation during weekends (when there is no presence of children) is decreased for all heated zones from 20°C to 12ºC. On the other side, if with the decrease of the mentioned temperature of the heating system activation during the weekend, only the part of the building where children are present (preparatory preschool groups) would be heated during weekdays, the heating energy savings for the kindergarten would amount to 24.84% (13700 kWh).

Key words: *heating; energy savings; EnergyPlus; kindergarten; preschool group*

1 Introduction

Buildings consume more than 40% of primary energy in Europe, which makes them one of the largest end-use consumer sector in Europe. Also, non-residential buildings make up 25% of the existing buildings in Europe [1]. For example, more than a third of EU's buildings are more than 50 years old [2], and only 1-3% of buildings are renovated annually [3], which makes them perfect for energy-saving policy. According to the latest published statistical report for 2017th year in Serbia approximately 31450 TJ of heat energy had been consumed, with 81% energy classified as industry and household consumption, and around 19% of that energy classified as "other consumers", which are educational, healthcare, administration, and other public institutions, which induces the need for heating energy savings where it is possible [4].

According to [5], consumption of kindergartens in Kragujevac is from approximately 106 kWh/m^2 to 325 kWh/m^2 (when connected to the district heating system), which is around 22% higher annual heating consumption than in the neighbouring countries, whereas, in the paper, multiple reconstruction measures for heating energy savings were suggested. In [6] heating energy audit for a kindergarten in Kragujevac had been conducted, with the conclusion that with an appropriate reconstruction of the thermal envelope (without roof) 32.87% annual heating energy savings and a payback period of 2.5 years can be achieved. To further increase their research, authors have evaluated PV panel instal-

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lation for the same kindergarten in [7], with an estimated 11.8 years of payback period and annual energy savings of approximately 50%. In [8] for the city of Niš, by evaluating different measures of thermal insulation of building envelope and its reconstruction, as well as heating and cooling investments and improvements, up to 86.6% of annual heating energy reduction was achieved, but the payback period of the initial investment was higher than 15 years.

In [9], one of the conclusions for preschool buildings was that, among other factors (thermal insulation of building envelope, more efficient cooling and heating systems, etc.), changes in human behaviour can have a positive effect on the environment and reduce costs significantly. Also, in [10] multiple suggestions for energy savings in commercial buildings based on occupant behaviour were presented, with estimated energy conservation improvement by 24.7% for U.S medium-sized office. A lot of research was conducted in attempts to predict human behaviour in buildings and their influence on energy consumption. For example, in [11] the effects of occupant behaviour on indoor climate and energy consumption were evaluated. Simulations conducted for a single occupant in one room resulted in a 330% decrease when the efficient behavioural model was implemented. On the other hand, according to [12], even if it is possible to have fully automated indoor environment control, occupants should have some degree of indoor environment control, or at least to have the perception of control.

This paper aims to evaluate heating energy savings potential based on control of a heating system during the presence of the preparatory preschool groups of children (half-day groups) in a case study of a kindergarten in the city of Kragujevac. For this purpose the dynamic simulation software "EnergyPlus" was used. Considering that preparatory preschool groups are present in only one part (section) of the building and during a limited time of four hours, it will have higher energy implications if heating is applied for the whole kindergarten as if there were full-day groups (presence of seven hours in the kindergarten). In other words, this paper points out the problem of irrational use of energy during the stay of a small number of people in a building with a large number of heated rooms. In relation to this, the possibility of energy savings by heating only zones in which people are present for a certain period instead of heating the entire building was investigated.

2 Description of the analysed building

Analysed kindergarten can be separated into two segments. The first segment has only ground floor, while the second segment has two floors and basement (unheated zone). The Figure 1 represents the isometric view of the analysed kindergarten with marked sections and orientation. The 3D model of the kindergarten created via "SketchUp" software is used as geometry input for the "EnergyPlus" software, which takes into account all building losses required for analysis [13]. Also, the building built in 1978 was classified as a medium-heavy type of building. It was assumed that the whole building is insulated according to the national Regulations on energy efficiency of building construction [14].

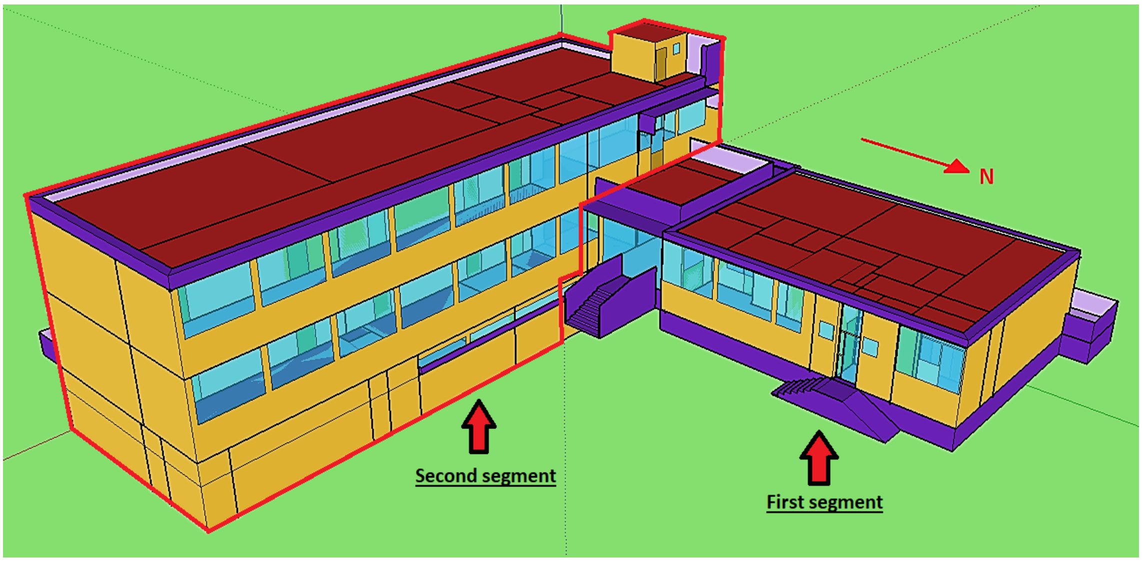


Figure 1. Isometric view of analysed kindergarten with marked segments

Information about the heated floor area, as well as volume areas and the number of heated zones in first and second segment, is shown in Table 1.

Table 1. Heated floor and volume areas and number of heated zones

	Heated floor area [m^2]	*Heated volume [m^3]*	*No. of heated zones*
First segment	188.48	597.63	18
Second segment	612.13	2052.38	15
Total	800.61	2650.01	33

Although there is a similar number of heated zones in both segments, it can be seen (Table 1) that the first segment has quite lower heated surface and volume areas compared to the second segment, mainly because it has only one floor.

In Table 2 the thermal characteristics of the kindergarten building constructions are given.

Table 2. Thermal characteristics of the building constructions

Construction	*Layer*	*U-value [W/m²K]*
Roof	Gravel (4 cm), bitumen waterproofing membrane (1.5 cm), bitumen (8 cm), bitumen waterproofing membrane (5 cm), polyurethane foam (4 cm), cement mortar (1.5 cm), reinforced concrete (5 cm), polystyrene foam (14 cm), brick (20 cm) and lime mortar (2 cm).	0.143
Exterior wall	Lime mortar (2 cm), mineral wool (12 cm), brick (30 cm) and lime mortar (2 cm).	0.277
Ground floor	Gravel (10 cm), concrete (10 cm), bitumen waterproofing membrane (1.5 cm), concrete (10 cm), cement mortar (1.5 cm), expanded cork (4 cm), polystyrene (6 cm), cellulose fibres (0.1 cm), cement mortar (1.5 cm) and parquetry (2.5 cm).	0.298
Floor above unheated space	Lime mortar (2 cm), brick (20 cm), reinforced concrete (5 cm), cement mortar (1.5 cm), expanded cork (4 cm), polystyrene (6 cm), cellulose fibres (0.1 cm), cement mortar (1.5 cm) and parquetry (2.5 cm).	0.286
Basement exterior wall	Cement mortar (2 cm), polystyrene foam (10 cm), reinforced concrete (30 cm) and cement mortar (2 cm).	0.3
Window	Double-glazed PVC window, filled with Argon.	1.512
Exterior door	PVC	1.598

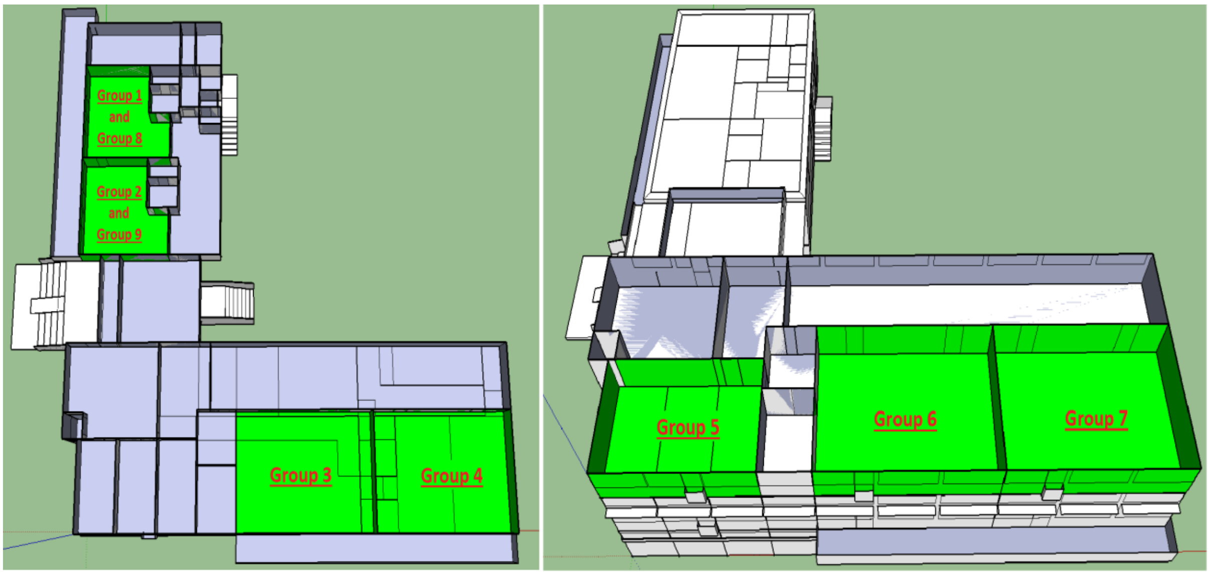
Table 3 presents the conditioned zones' window opening areas as well as the window to wall ratio [%] based on the cardinal direction of the analysed building.

Table 3. Conditioned zones' window opening area and window to wall ratio with their cardinal direction

	Total	*North*	*East*	*South*	*West*
Window opening area [m²]	289.1	90.7	35.55	119.47	43.38
Gross window to wall ratio [%]	42.56	41.35	27.91	56.65	35.66

3 Different groups of children and their location in analysed kindergarten

In Figure 2, the rooms where different groups of children are located are shown. All information was obtained from employees in kindergarten.



a) b)

Figure 2. Different groups of children and their location in the analysed kindergarten, a) first floor and b) second floor

There are nine groups of children in total. Children's group locations are based on data from the 2016/2017 year. It can be seen that groups 1, 2, 8 and 9 are located in the first analysed section, while groups 3, 4, 5, 6, and 7 are located in the second section. The groups are formed according to the age of children (Table 4).

The children of full-day groups are usually present in kindergarten from 8^h to 15^h, and the children of half-day groups from 16^h to 20^h, during weekdays. During weekends and holidays there is no presence of people in the kindergarten.

Table 4. Groups of children within the analysed kindergarten

	Age (years)	*No. of children*	*Full-day/half-day*
Group 1	1-1.5	22	Full-day
Group 2	1.5-2	25	Full-day
Group 3	6-7	35	Full-day
Group 4	6-7	35	Full-day
Group 5	3-4	31	Full-day
Group 6	4-5	35	Full-day
Group 7	5-6	38	Full-day
Group 8	6-7	16	Half-day
Group 9	6-7	17	Half-day

As it can be seen from Table 4, seven groups of children are classified as full-day groups and two groups are classified as half-day groups. Also, there are 254 children in total in kindergarten of which 221 are within full-day groups and 33 within half-day groups.

4 Location, weather conditions, and heating of the analysed kindergarten

4.1 Location and weather conditions

The location of the kindergarten is in the city of Kragujevac (44.02° latitude and 20.93° longitude). In Figure 3, the average daily outdoor dry bulb temperature is shown, which is obtained from the WeatherFile that is used as input for dynamic simulations in "EnergyPlus" software.

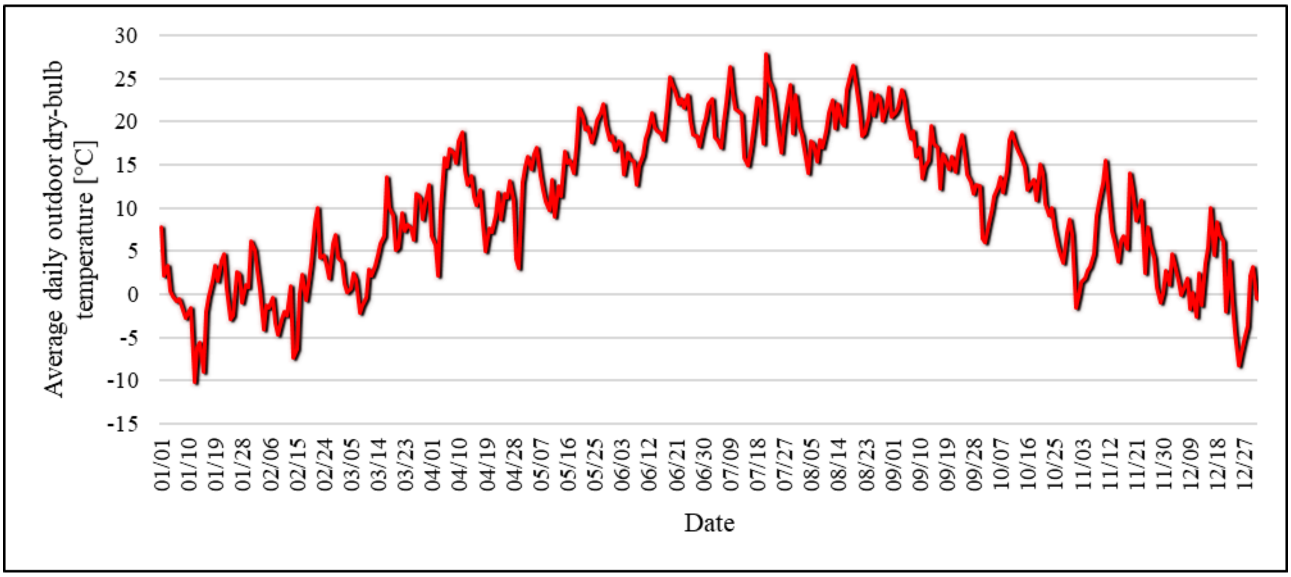


Figure 3. Average daily outdoor dry bulb temperature for the city of Kragujevac

The average outdoor dry-bulb temperature during the heating season amounts to 4.18°C. On the other side, the maximum and minimum outdoor dry bulb temperature during the heating season has a value of 18.77°C (11th of April) and -10.14°C (12th of January), respectively.

4.2 Heating of the analysed building

The analysed kindergarten is connected to the district heating network by a heat exchanger placed in the basement. End-use heating devices are baseboards (radiators), which are placed in the heated zones. Three cases of the heating system operation were analysed (Table 5). They are characterized by the heating set temperature which is determined by the people occupancy. In other words, if there are people (children) in one of the kindergarten segments the heating set temperature is 20°C. Otherwise, it has value of 12°C. For the Case 1 the heating system operation is the same for the weekdays and weekends when there is no presence of children. In Serbia, tenants often do not know how to use thermostatic radiator valves. Also, the valves are not often used because the tenants have low level of knowledge about heating costs and savings. In the Case 2 the weekend heating set temperature amounts 12°C, which means that the heating system will be turned on if the indoor mean air temperature decreases below 12°C. For the Case 3 the weekday heating set temperature of 20°C applies only to kindergarten segments where children are present (06:30 – 20:00 h (first segment) and 06:30 – 16:00 h (second segment)).

Table 5. Three analyzed cases of the heating system operation

Case 1	*Daily heating intervals*	*Weekday heating set temperature [°C]*	*Weekend heating set temperature [°C]*
Both segments	00:00 – 06:30h	12	12
	06:30 – 21:30h	20	20
	21:30 – 00:00h	12	12
Case 2	*Daily heating intervals*	*Weekday heating set temperature [°C]*	*Weekend heating set temperature [°C]*
Both segments	00:00 – 06:30h	12	
	06:30 – 21:30h	20	12
	21:30 – 00:00h	12	
Case 3	*Daily heating intervals*	*Weekday heating set temperature [°C]*	*Weekend heating set temperature [°C]*
First segment	00:00 – 06:30h	12	
	06:30 – 20:00h	20	12
	20:00 – 00:00h	12	
Second segment	00:00 – 06:30h	12	
	06:30 – 16:00h	20	12
	16:00 – 00:00h	12	

The heating season lasts from 15th of October to 15th of April. The simulated ventilation of the kindergarten is natural and amounts to 0.5 1/h. It should be noted that it was assumed that there is no infiltration in the analysed kindergarten. The building is completely sealed in terms of air leakage. Also, it was assumed that the kindergarten has fully opened position, which means that it is not surrounded by any other object.

5 Results and discussion

The obtained simulation results of monthly heating consumption of the analysed kindergarten are shown in Figure 4.

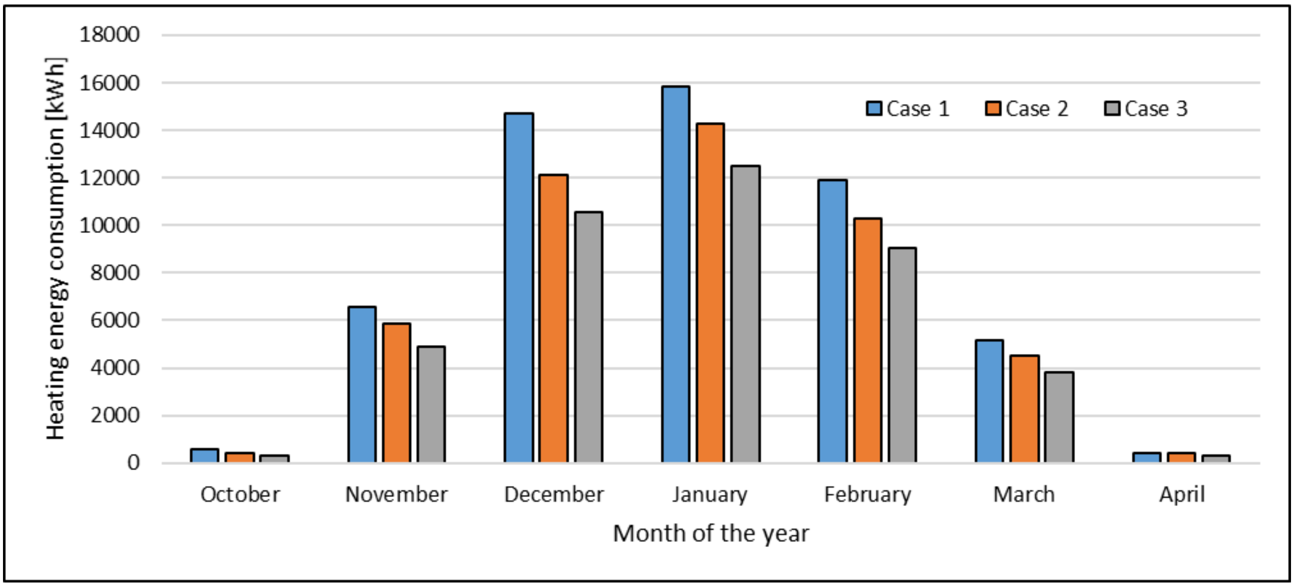


Figure 4. Monthly heating consumption of kindergarten for all analysed cases

By analysing Figure 4, it can be concluded that the highest monthly heating energy consumption of the kindergarten is in January for all three cases, with approximately 15848 kWh of energy used in the Case 1, 14287 kWh in the Case 2 and 12505 kWh in the Case 3. On the other side, October and April are the months with the lowest heating energy consumption, with less than 570 kWh in each of the analysed cases for each of the respective months.

It can be also concluded that for each month heating energy consumption is the lowest for the Case 3 (see Table 7), compared to the Case 1 and Case 2. Further analysis shows that the annual heating energy consumption of 55148.6 kWh corresponds to the Case 1 and 47871 kWh to the Case 2. The lowest annual heating consumption of 41448.7 kWh is related to the Case 3.

In Figure 5, the monthly average percentage difference of heating energy consumption is shown for the second (Case 2) and third analysed case (Case 3), compared to the first case (Case 1).

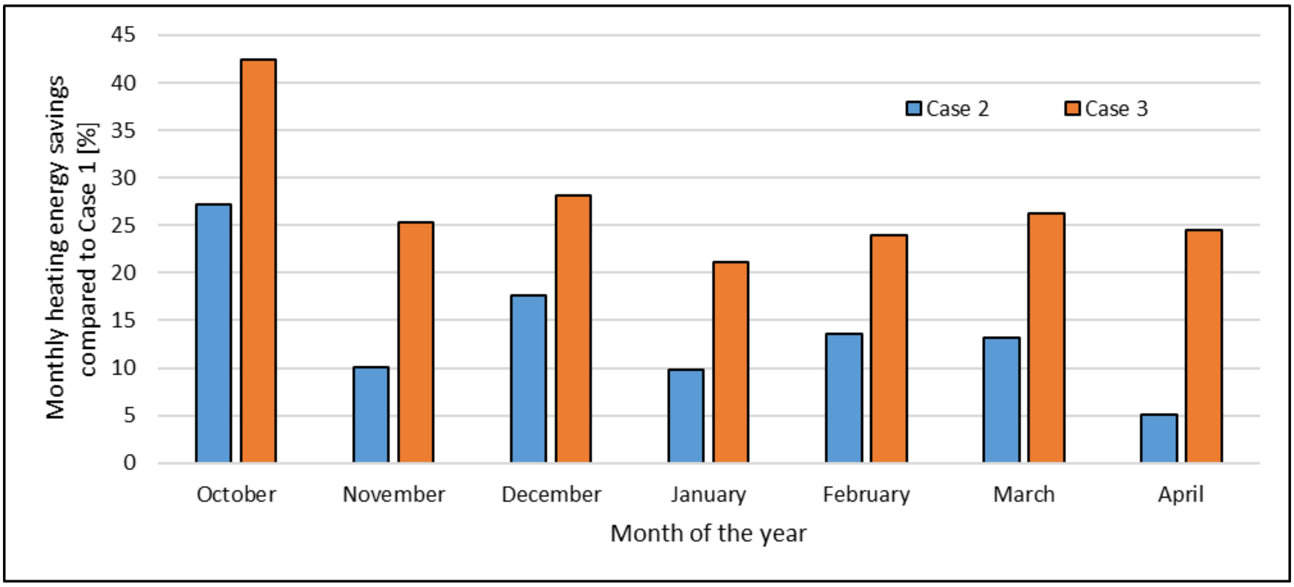


Figure 5. Monthly average percentage difference of energy savings for the Case 2 and 3 compared to the Case 1

According to the results from Figure 5, the highest percentage difference of heating energy consumption is in October (27.22% for the Case 2 and 42.41% for the Case 3 compared to Case 1). The lowest percentage difference is observed in April for Case 2 (5.15%) and January for Case 3 (21.1%). Also, except for January and April, in the Case 2 percentage difference is higher than 10%, while in the Case 3, the heating energy savings are higher than 20% for each month of the heating season.

The overall savings of heating energy in the Case 2 (47871 kWh) compared to the Case 1 (55148.6 kWh) can amount 13.2% or 7277.5 kWh. For the Case 3 (41448.7 kWh) these savings can reach 24.84% or 13700 kWh.

6 Conclusion

In this paper the potential of heating energy savings in the case of one kindergarten in the city of Kragujevac by using "EnergyPlus" simulation software was evaluated. The main objective of the paper is to determine the amount of heating energy that can be saved if kindergarten is separated into two sections and if different schedules for heating system activation defined according to the presence of children in respective heated zones during different intervals are applied. The main reason for separating the kindergarten into two sections are its full-day and half-day groups of children. The full-day groups are present in both sections of the analysed kindergarten from 8^h to 15^h, while the half-day groups (preparatory preschool groups) are present only in one section of the kindergarten for a total time of four hours (16^h-20^h). Three cases of the heating system operation were analysed. According to the simulation results, 13.2% (7277.5 kWh) of heating energy could be saved if the temperature of the heating system activation during weekends (weekend heating set temperature) is decreased for all heated zones from 20°C to 12ºC. On the other side, if with the decrease of the mentioned temperature only the part of the building where children are present (preparatory preschool groups) would be heated during weekdays, the heating energy savings for the kindergarten would amount to 24.84% (13700 kWh). The obtained results lead to the conclusion that special attention must be paid to the control of the heating system operation within this group of non-residential buildings. The influence of occupant behaviour on indoor environment and energy consumption of these buildings will be the subject of future investigations.

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