EFEKAT OSENČENJA OD SUSEDNIH ZGRADA NA ENERGETSKI UČINAK NESTAMBENE ZGRADE ZA KLIMATSKE USLOVE U SRBIJI

ADJACENT BUILDING SHADING EFFECT ON THE ENERGY PERFORMANCE OF A NON-RESIDENTIAL BUILDING FOR CLIMATIC CONDITIONS IN SERBIA

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U ovom radu ispitan je uticaj prisustva okolnih objekata na energetsko ponašanje jedne nestambene zgrade za klimatske uslove u Srbiji. Po prvi put je ovaj uticaj razmatran za različite rasporede prisustva ljudi, stvarno, prosečno godišnje i maksimalno prisustvo, i dve različite metode ventilacije (Metoda 1 i 3), definisane prema trenutno važećem standardu EN 16798. Nalazi ove studije ukazuju na to da predviđene ukupne potrebe za toplotnom energijom zgrade mogu biti pod značajnim uticajem usled osenčenja koje izazivaju susedni objekti. Kroz energetske simulacije zgrade ustanovljeno je da zgrada sa ekeftom osenčenja troši od 6.43% ðo 11% više energije od zgrade kod koje je prisustvo okolnih objekata zanemareno. Zanemarivanje ovog uticaja vodi ka pojavi greške u predviđanju energetske potrošnje zgrade. Posmatrajući istovremeni uticaj prisustva ljudi i okolnih objekata ova greška može dostići vrednost od čak 21.13%. Na osnovu prikazanih rezultata, kako bi se predviđeno energetsko ponašanje zgrade približilo stvarnom ponašanju, preporučuje se upotreba rasporeda stvarnog prisustva ljudi. Raspored maksimalnog prisustva ljudi, u svakom slučaju, treba izbegavati. Iz istog razloga, efekat osenčenja od susednih zgrada treba uzeti u obzir u studijama energetskih simulacija zgrade. Takođe, ovaj efekat treba uzeti u razmatranje prilikom planiranja i razvoja novih urbanih naselja.

***Ključne reči:** grejanje; ventilacija; osenčenje; prisustvo ljudi; nestambena zgrada; simulacija*

In this paper, the impact of the presence of surrounding buildings on the energy behavior of a non-residential building for climatic conditions in Serbia was examined. For the first time, this impact was considered for different people occupancy schedules, real, average yearly and maximum occupancy, and two different ventilation methods (Method 1 and 3), defined according to the currently valid standard EN 16798. The findings of this study indicate that the predicted total heating energy demands of a building may be significantly affected due to the shading caused by adjacent objects. Through building energy simulations, it was found that a building with a shading effect consumes from 6.43% to 11% more energy than a building where the presence of surrounding buildings is neglected. Neglecting this impact leads to an error in predicting the building's energy consumption. Observing the simultaneous impact of the people occupancy and surrounding objects, this error can reach a value of as much as 21.13%. Based on the presented results, in order to bring the predicted energy behavior of the building closer to its actual behavior, it is recommended to use the real occupancy schedule. The maximum occupancy schedule, in any case, should be avoided. For the same

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reason, the adjacent shading effect needs to be accounted for in building energy simulation studies. This effect should be also taken into consideration when planning and developing a new urban settlements.

Key words: *heating; ventilation; shading; people occupancy; non-residential building; simulation*

1 Introduction

Ventilation of spaces can be achieved in various ways by simple manual window opening (natural ventilation) and/or by complex mechanical ventilation systems with or without heat recovery. In this geographical area, the vast majority of kindergartens, including newly built ones, do not have mechanical ventilation systems, but only natural ventilation is used. In such conditions, the quality of the indoor environment is often unacceptable. In the future, educational buildings will have to meet the criteria of very low or net-zero energy consumption in addition to the criteria of the indoor environment quality. Ahmed et al. [1] assessed the indoor environment quality and energy performance of four NZEB daycare centers and three NZEB school buildings from Finland and Estonia. Results showed that all buildings achieved low CO_2 levels. In contrast, the measured energy use in 5 buildings out of 7 was increased by factor 2.1-3.0 compared to calculated annual energy use due to a full-time operation of the ventilation system and presence of hot kitchens. According to the [2] demand controlled ventilation (DCV) system can reduce the energy use significantly compared to a constant air volume (CAV) system. The total energy demand for the fan can be reduced with 24% compared to a CAV, by controlling the air flow rate using the CO_2 concentration which is in correlation with people occupancy. People occupancy and its behaviour plays a key role in the energy demand of either residential or non-residential buildings, and its importance will only increase when moving towards NZEB. To reduce energy use in buildings, the accurate modelling methods for energy demand that take into account both building characteristics and user behaviour are needed [3]. Accurate occupancy data can encourage users to save energy by managing a building automation system based on actual occupancy. The analysis of a Norwegian primary school revealed that the savings in energy use are around 40% [4], if the volume of supply air is controlled by the actual number of people inside the space. Sekki et al. [5] assessed the energy saving potential of heating and electricity consumption in the studied daycare centres and schools in the city of Espoo in Finland. The heating saving potential was 10.4 kWh/m^2 and the electricity saving potential 4.3 kWh/m^2. They found that mechanical ventilation was in operation even when the buildings were unoccupied. Due to the lack of information, people behaviour is often included in the building performance simulation software through a fixed occupancy schedule. To obtain more accurate energy demand simulations, detailed and realistic people occupancy schedules are needed. Sekki et al. [6] introduced a new indicator for building energy efficiency which takes into account both space and occupancy efficiency. Their findings indicate that there is a relationship between the measured energy consumption of daycare centres and occupancy but not strong, due to the deviations related to the different types of occupation hours.

Accurately forecasting urban building energy consumption is critical to accelerating the transformation of sustainable cities [7]. However, individual building energy consumption not only depends on its own characteristics and user behaviour but is also influenced by surrounding buildings, especially in high-density urban areas [8-13]. Faure et al. [8] developed a novel urban building energy modelling (UBEM) simulation tool that was used to analyze the impact of the surrounding shadowing environment on the overall UBEM performance. The analysis was conducted for two urban areas in Stockholm (Sweden). Their results revealed that up to 12% of the overall difference in thermal energy demand intensity could be attributed to the change in the shadowing environment. Farrar-Nagy et al. [9] studied the impacts of shading and glazing combinations on residential energy use in a hot dry climate (Tucson, Arizona). The results showed that the total cost of cooling and heating is reduced by more than 10% by adding the presence of the adjacent houses. The effect of the neighboring buildings shading on the thermal performance of a non-air-conditioned house in a warm sub-humid climate was assessed in [10]. Experimental measurements and simulations using EnergyPlus of the unoccupied house, located in Morelos State, Mexico, were conducted. The main effects of the neighboring buildings shading were the reduction of indoor air and envelope surface temperatures. It was shown that not taking into account the neighboring buildings shading gives a difference in average indoor air temperature up to 2.3 ˚C. Tereci et al. [11] analysed various generic urban forms for residential building quarters, in Stuttgart (Germany), with regard to their overall energy performance. For selected forms, detailed simulations of the heating and cooling energy demand were carried out, including the shading effects of neighbouring buildings. They demonstrated that when shading is considered the building consumption increases by up to 20% at 60% site density. In Hong Kong, the influence of adjacent shading on the energy requirement of a residential building was investigated by Chan [12]. It was found that some layout design can provide reduction in annual cooling of up to 18.3% compared to the layout design without adjacent shading effect. The shading effect of neighboring trees and buildings on the energy requirement of a building in four different climate regions in Canada was investigated by Nikoofard et al. [13]. The study was conducted using a developmental version of the HOT3000 building simulation software in which ESP-r was adopted as its simulation engine. A two-story research house was selected as a base case house for the study. They concluded that annual heating and cooling energy may be affected by as much as 10% and 90%, respectively.

In all previous investigations building occupancy was neglected or calculated by using the maximum number of occupants and yearly operating times of studied buildings. The impact of shading from neighbouring buildings was evaluated separately from the effect of people occupancy. In contrast to residential buildings, the people occupancy can have a strong impact on the energy consumption of a non-residential buildings. The main objective of this study is to assess the combined effect of people occupancy and shading from adjacent buildings on the energy performance of a non-residential building in Serbian climatic conditions. Building energy simulations were carried out considering the adjacent shading, different people occupancy schedules and two ventilation methods in order to evaluate the heating energy requirements of a kindergarten. The study includes for the first time variable weekly occupancy schedule, for kindergarten in Serbia, derived from the realistic occupancy data. This paper is aimed to present the effect of both people occupancy and adjacent shading on the accuracy of building energy performance simulation.

2 Ventilation methods for non-residential buildings (kindergartens)

Ventilation is a process by which, naturally and/or mechanically, the outdoor air is brought into the desired space in order to maintain the appropriate quality of the indoor environment. The quality of the indoor environment is expressed through the required level of ventilation, which is based on the criteria of human health and comfort. According to the standard EN 16798, design parameters for indoor air quality shall be derived using one or more of the following methods: Method 1, Method 2 and Method 3.

The Method 1 takes into account air pollution caused by emissions of harmful substances originating from people (q_p) and the building itself (q_B). The standard gives the recommended values of the total ventilation requirements (q_{tot}) for kindergartens, which differ according to the categories of indoor air quality (C1, C2, C3 and C4) and the levels of building pollution: very low-polluted buildings (VLP), low-polluted buildings (LP) and non-low-polluted buildings (NLP). For children as users of these buildings, it is recommended to provide a high level of air quality (C1). In addition to this category, simulations were conducted for the lowest air quality category (C4), which refers to the minimum ventilation requirements prescribed by the WHO (Table 1).

The basis for the calculation of ventilation requirements according to the Method 2 are the limit values for the concentration of pollutants. To calculate the design ventilation air flow rate, the most critical or relevant pollutant shall be identified and the pollution load in the space shall be estimated.

Table 1. Recommended values of ventilation requirements of kindergartens for the first (C1) and fourth (C4) air quality category of the Method 1 [14]

Type of building	Category of air quality	q_{tot}, l/(s·person)		
		Very low-polluted building (VLP)	Low-polluted building (LP)	Non-low-polluted building (NLP)
Kindergarten	C1	11	12	14
	C4	4	4	4

When this method is used CO_2 representing the pollutant emission from people shall be used as one of the substances. The limit value of this concentration of 950 ppm corresponds to the total ventilation requirement of the air quality category C1, while the limit value of 1750 ppm corresponds to the ventilation requirement of the air quality category C4 (Table 1). For the mentioned reason and the impossibility of determining the emissions of pollutants from the building and HVAC systems, in the selected kindergarten, the Method 2 was not considered.

The Method 3 refers to determination of the certain pre-defined minimum ventilation air flow rate estimated to meet requirements for both perceived air quality and health in the occupied zone. The pre-defined ventilation air flow rates shall be expressed by one or more of the following parameters: total design ventilation for people and building components (q_{tot}); design ventilation per unit floor area (q_m); design ventilation per person (q_p); design air change rates (ach) and design air flow rates by room and building type (q_{room}) [14]. The value of the pre-defined minimum ventilation air flow rate of 0.5 ach was chosen since it is often used in practice and investigations of this type of non-residential buildings.

3 Methodology

3.1 *Building model*

A kindergarten on the territory of the city of Kragujevac was selected for the case study. The building is composed of three levels, basement, ground floor and first floor (Fig. 1). As it can be seen from Fig. 1 the kindergarten is surrounded by two buildings that can affect its heating consumption. The higher object (with a height of 18 m) refers to a residential building, while the lower one (with a height of 9 m) represents the object of an elementary school. Their shortest distance from the kindergarten, which has a height of 10 m, is 9 m (residential building) and 20 m (school building). The total heated floor area of the building is 1269.14 m^2. The 3D models of the kindergarten and neighbouring buildings created via SketchUp software [15] are used as geometry input for the EnergyPlus software [16]. The EnergyPlus software is confirmed and verified [17], and provides the ability to simulate the energy behavior of very complex buildings in very difficult conditions.

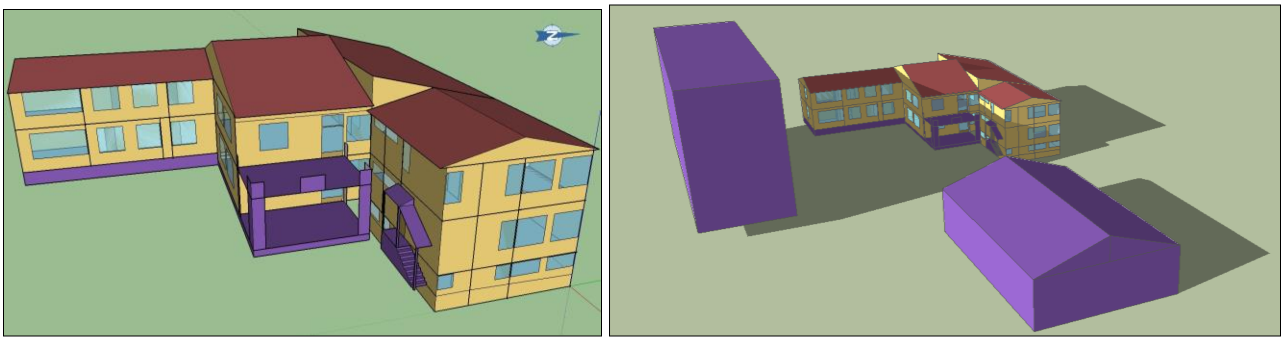

Figure 1. Isometric view of the analysed kindergarten and adjacent buildings

The 3D model of the kindergarten was made under the assumption that the values of the overall heat transfer coefficient of all elements of its thermal envelope are less than or equal to the maximum allowed values, determined by the Rulebook on energy efficiency of buildings [18]. In Table 2 the thermal characteristics of the kindergarten building constructions are given.

Table 2. Thermal characteristics of the building constructions [19]

	Building constructions						
	Roof	Exterior wall	Ground floor	Floor above unheated space	Floor under unheated space	Exterior window	Exterior door
U-value [W/m^2K]	0.288	0.293	0.267	0.281	0.294	1.5	1.6

3.2 *Building operation*

When simulating the energy behavior of a building, it is necessary to understand and know how people use the building. This is one of the conditions that must be met in order to bring the predicted energy consumption of the building closer to the real one. In many studies, the shadowing impact and the impact of people occupancy are neglected. In this regard, this paper includes an analysis of kindergarten energy consumption with different ventilation methods and differently defined people occupancy: real (actual), average yearly and maximum people occupancy. Fig. 2 shows the actual percentage children occupancy by educational groups in the selected kindergarten during 2016/2017 year. According to their age, children are divided into different educational groups: younger nursery group (YN), older nursery group (ON), younger educational group (YE), middle educational group (ME), older educational group (OE) and mixed educational group (MXE). In 2016/2017 year there were two ON, YE and OE groups, three ME groups and one YN and MXE group. Each of these groups of children was in a separate room.

Table 3. Average yearly and maximum people occupancy for each of the analyzed educational group [19]

	Educational group					
	YN	ON	YE	ME	OE	MXE
Average yearly people occupancy (%)	43.50	53.72	56.37	53.78	55.64	53.03
Maximum people occupancy (%)	100	100	100	100	100	100

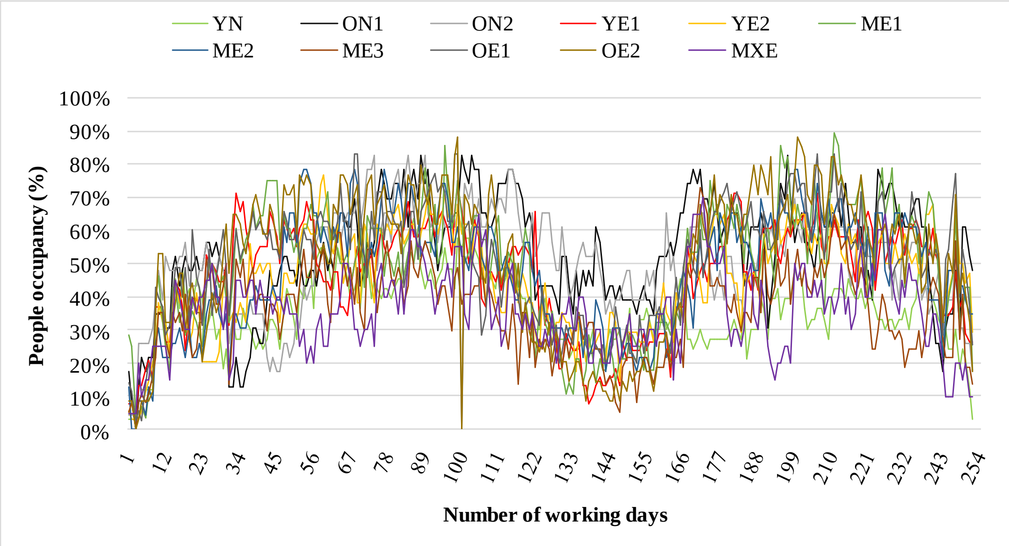

Figure 2. Real percentage people occupancy during 2016/2017 year in the analyzed kindergarten [19]

The average yearly people occupancy schedules for each of the educational groups (Table 3) are determined on the basis of the real children occupancy of the corresponding educational group in six kindergartens, on the territory of the city of Kragujevac, for the period of three years, from 2015/2016 to 2017/2018. The maximum people occupancy, given in Table 3, is based on the highest possible (maximum) presence of children of a certain educational group. The children occupancy in these schedules is, as with the average yearly occupancy schedules, constant throughout the year.

As for the heating system, the kindergarten is connected to the district heating system. Radiators are installed in all heated rooms. It was assumed that the heating system during the entire heating season (October 15 - April 15) maintains the indoor air temperature at 16˚C, in the period when the kindergarten is closed (4 pm - 6 am) and at 20˚C when the kindergarten is open to users (6 am - 4 pm). In this non-residential building the ventilation is performed naturally, by opening windows. Although there are no mechanical ventilation systems, it was assumed that these systems, but without heat recovery, are installed in order to establish and maintain the appropriate quality of indoor environment. Only the rooms where children stay are ventilated. It should be noted that the adopted value of air infiltration for all rooms is 0.2 ach. This value meets the condition of the standard, which refers to the ventilation requirement for the kindergarten spaces in periods when there are no people present. Unlike the heating system, it was adopted that ventilation system operates only during the maximum children occupancy in kindergarten during the day, from 8 am to 2 pm. In addition to affecting the operation of the ventilation system, the occupancy schedules also affect the amount of heat gain from people. In order to bring the heating consumption closer to the real one, the adopted people heat gains are 38.3 W/person, for children under 4 years of age and 62.1 W/person for children aged 4 to 6 years [20].

3.3 *Simulation cases*

Firstly, a kindergarten without adjacent buildings was modeled and simulated. Its energy performance was simulated for two ventilation methods (Method 1 and Method 3) and every occupancy type. In the Method 1, two ventilation requirements were selected, C1 and C4, which are characterized by the highest and lowest level of air quality, respectively. Both of these categories include simulations for all three levels of building pollution (Table 4). According to the Method 1, the operation of the ventilation system is conditioned by the people occupancy schedule. In other words, for the real occupancy, the amount of air that is introduced into the rooms corresponds to the current (daily) presence of children. The air flow rate for the other two occupancy types corresponds to the average yearly and maximum people occupancy, but its value does not change during the heating season. On the other side, the ventilation requirements of the Method 3 are independent of the people occupancy. Their values, calculated on the basis of the volume of the ventilated room (0.5 ach), are also constant during the heating period.

To assess the effect of adjacent shading, the models of the neighbouring buildings were associated with the model of the kindergarten. The energy performance of the kindergarten with and without an adjacent shading effect, for every selected ventilation method and occupancy type, was evaluated (Table 4). To simulate weather conditions of the city of Kragujevac (latitude of 44.02˚N, longitude of 20.92˚E) the EnergyPlus weather file was used. This file contains weather data representing the long-term typical weather condition over a year in the city of Kragujevac [21]. It is formed by concatenating twelve typical meteorological months selected from a database of 30 years of data.

Table 4. Simulation cases of the studied kindergarten

Methods of ventilation	Category of air quality	Ventilation requirements (l/(s·person))	People occupancy	Shading effect
Method 1 (VLP) - M1, VLP	C1	11	Real occupancy (R) Average yearly occupancy (Y) Maximum occupancy (M)	With building shading (BS) Without building shading (WBS)
	C4	4		
Method 1 (LP) - M1, LP	C1	12		
	C4	4		
Method 1 (NLP) - M1, NLP	C1	14		
	C4	4		
Method 3 - M3	/	0.5 (ach)		

4 Results and discussion

The values of the predicted heating consumption of the studied kindergarten are presented in Fig. 3 and 4.

The people occupancy and the presence of surrounding buildings have a significant impact on the heating consumption of the kindergarten. The impact of the people occupancy should be observed from two angles, depending on the applied ventilation method. The number of people in the room determines the total internal heat gains from people as well as the total amount of fresh air that is introduced into the same room by the ventilation system. According to the Method 1, an increase in the people occupancy causes an increase in the flow rate of supplied air and energy for heating the kindergarten, and vice versa (Figure 3 and Figure 4 (left)). The lowest energy consumption is for the air quality category C4, when the air flow rate is the lowest and equal to 4 l/(s·person). On the other side, the highest energy consumption of a building reffers to the air quality category C1 and non-low-polluted building level (NLP), with the air flow rate of 14 l/(s·person). The air flow rate in Method 3 is conditioned by the volume of the room being ventilated, not by the people occupancy. In this case, the increase in the people occupancy leads to a decrease in the demands for heating the kindergarten (Figure 4 (right)), due to higher internal heat gains. With the maximum people occupancy, the heating demands will be the least. The described phenomena are noticed in both models of kindergartens, whether with or without the presence of surrounding objects. The total predicted needs for heating kindergarten with and without shading effect, for different ventilation methods and types of children's occupancy schedule, as well as their mutual monthly and seasonal deviations, are shown in Table 5.

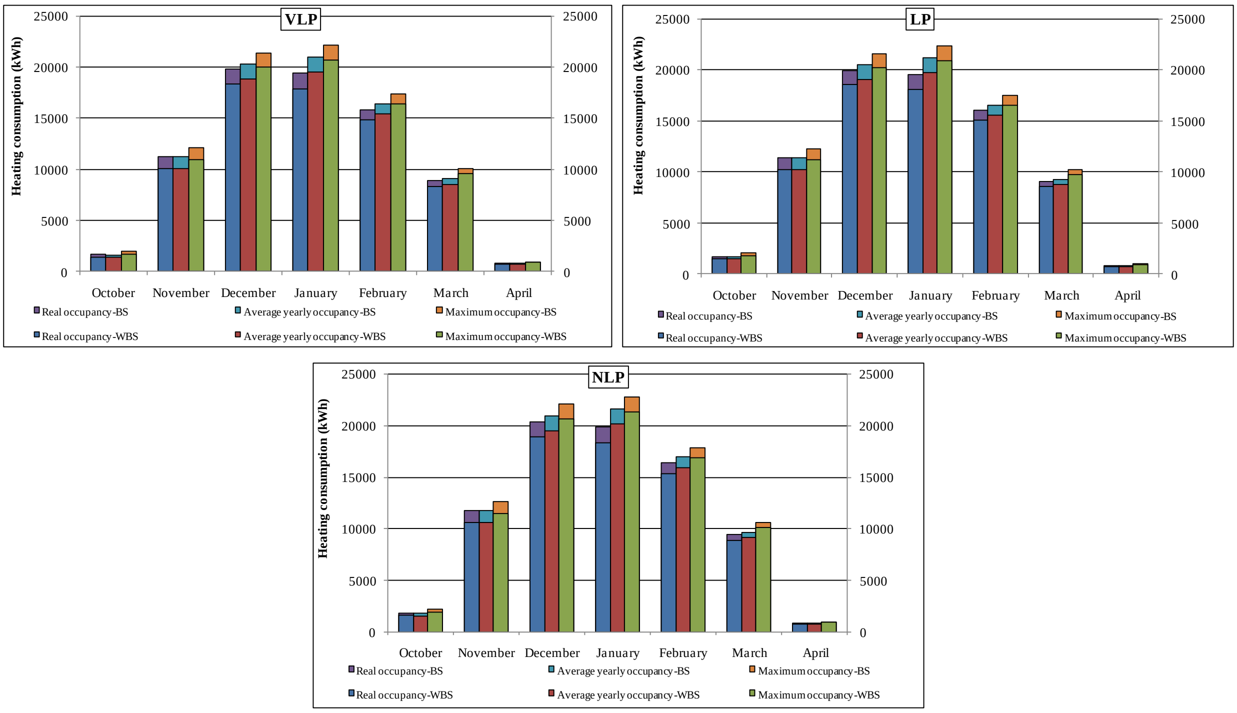

Figure 3. Predicted heating consumption of the analyzed kindergarten with and without building shading effect, for the ventilation Method 1, air quality C1 and different people occupancy schedules

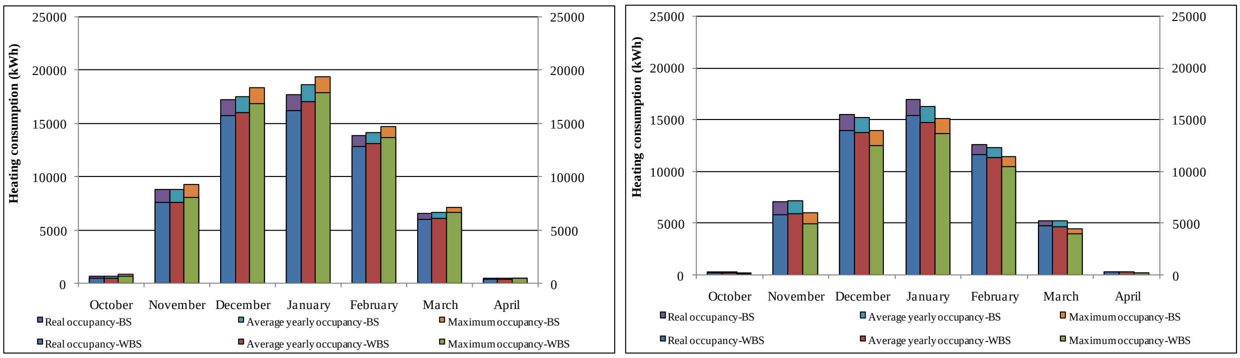

Figure 4. Predicted heating consumption of the analyzed kindergarten with and without building shading effect, for the ventilation Method 1, air quality C4 (left) and ventilation Method 3 (right), for different people occupancy schedules

On the basis of the obtained results, it can be concluded that the heating consumption of the kindergarten, while ignoring the presence of surrounding objects, both on a monthly and seasonal level, is lower than the heating consumption of the kindergarten whose behavior is simulated with the presence of surrounding objects, for all ventilation methods and types of the people occupancy schedules. A kindergarten that has an open position, that is not surrounded by other objects, has higher heat gains from solar radiation through, above all, the glazed surfaces of its thermal envelope (windows).

The greatest impact of the kindergarten shading, observed on a monthly basis, was recorded in the month of October, regardless of the ventilation method, air quality category and level of building pollution. This can be explained by the small share of diffuse solar radiation (less cloudiness) in the total solar radiation, compared to other months. Although the shading of the kindergarten was the greatest in the coldest months, December, January and February, due to the lowest height of the Sun during the year, its influence on the heating consumption is somewhat smaller due to the high intensity of diffuse solar radiation. On average, the lowest impact is in the month of February. Observing the results of consumption for the months of November and March, in November the shading effect is greater, both due to the greater shading of the object and the longer retention of the shadow.

Table 5. Monthly and seasonal percentage deviations of the predicted heating consumption of the kindergarten with and without the presence of surrounding objects, for different ventilation methods and types of people occupancy schedules

Ventilation method	People occupancy	Shading effect	Heating consumption (kWh)		Monthly percentage difference of consumed heat energy (%)							Seasonal percentage difference (%)
					O	N	D	J	F	M	A	
M1, VLP, C1	R	WBS	71497	WBS vs BS	-15.87	-10.58	-7.35	-7.76	-6.31	-6.28	-8.28	-7.76
		BS	77516									
	Y	WBS	74446		-16.09	-10.61	-6.98	-6.96	-6.01	-6.06	-8.01	-7.37
		BS	80373									
	M	WBS	80128		-12.32	-9.30	-6.55	-6.55	-5.56	-5.17	-6.82	-6.71
		BS	85889									
M1, LP, C1	R	WBS	72522	WBS vs BS	-15.23	-10.35	-7.24	-7.67	-6.21	-6.08	-8.02	-7.64
		BS	78518									
	Y	WBS	75543		-15.30	-10.38	-6.90	-6.89	-5.95	-5.92	-7.87	-7.26
		BS	81455									
	M	WBS	81245		-12.04	-9.09	-6.48	-6.48	-5.48	-5.05	-6.57	-6.61
		BS	86994									
M1, NLP, C1	R	WBS	74627	WBS vs BS	-13.85	-9.85	-7.06	-7.50	-6.05	-5.78	-7.53	-7.38
		BS	80576									
	Y	WBS	77788		-13.90	-9.85	-6.75	-6.75	-5.79	-5.62	-7.39	-7.02
		BS	83664									
	M	WBS	83517		-11.22	-8.71	-6.35	-6.36	-5.35	-4.92	-5.94	-6.43
		BS	89258									
M1, C4	R	WBS	59312	WBS vs BS	-31.97	-14.05	-8.64	-8.70	-7.35	-8.47	-12.95	-9.37
		BS	65447									
	Y	WBS	60854		-32.23	-14.09	-8.47	-8.25	-7.18	-8.35	-12.92	-9.14
		BS	66979									
	M	WBS	64285		-25.67	-13.12	-7.89	-7.66	-6.75	-7.64	-11.31	-8.49
		BS	70247									
M3	R	WBS	52095	WBS vs BS	-48.26	-17.36	-9.60	-9.04	-7.97	-9.84	-17.97	-10.28
		BS	58066									
	Y	WBS	50844		-47.71	-17.24	-9.72	-9.39	-8.12	-9.90	-17.49	-10.48
		BS	56795									
	M	WBS	45797		-53.01	-18.96	-10.33	-9.87	-8.57	-10.51	-18.31	-11.00
		BS	51459									

According to the values of the total heating consumption during the heating season, the predicted consumption of the kindergarten without the presence of adjacent buildings is lower from 6.43% to 11%, compared to the consumption of the same building, but with the adjacent shading effect. Including all ventilation methods and types of people occupancy schedules, the value of this consumption is on average 8.2% lower than the consumption of a building with a shading effect. The calculated percentage values represent an error in predicting the heating consumption of the studied building. Comparing the results according to the fresh air flow rate, it can be concluded that the error in the prediction of energy consumption decreases with the increase of the fresh air flow rate. With its increase, the heating demands are higher, while the effect of solar gains is smaller. In other words, with Method 3, the average seasonal error has a value of 10.59%, and with Method 1, the category of air quality C1 and the level of building pollution NLP is 6.94%. For the same reason, for Method 1, and with regard to the different used people occupancy schedules, the smallest error occurs for the maximum people occupancy for which the fresh air flow rate per person is the highest. However, for Method 3 and this people occupancy schedule, the highest error was obtained. The reason for this lies in the fact that the ventilation of the room according to this method does not depend on the number of people present, but on the volume of the room. The fresh air flow rate in the rooms is the same for all people occupancy schedules. Since the maximum people occupancy requires less heating needs, due to greater heat gains from people, the effect of solar gains is also greater.

The effect of using a different people occupancy schedules, real, average yearly and maximum occupancy schedules, on the prediction of the energy behavior of the same building model with the adjacent buildings, was evaluated in [19]. It has been demonstrated that the use of the maximum people occupancy gives the sagnificant error in predicting the heating consumption, from 7.33 to 11.38%. More precisely, the heating consumption for the Method 1 is 7.33 to 10.8% higher, while for the Method 3 it is 11.38% lower then the building consumption with real people occupancy. The mentioned values are also obtained by comparing the results of total heating consumption for kindergarten, shown in Table 5. Data from this Table can also be used to examine the combined effect of the people occupancy and the presence of adjacent buildings on the heating consumption of the selected building. For this purpose, the consumption of the building at the real people occupancy and with models of neighboring buildings will be compared with the consumption at the maximum people occupancy and without models of neighboring buildings. Due to the different impact of the people occupancy, the results of the comparison with Method 1 must be observed separately from the results obtained for Method 3. Namely, with Method 1 the people occupancy effect is opposite to the adjacent building shading effect. A larger number of people leads to greater heating needs, while neglecting the presence of surrounding objects leads to its reduction. In this regard, if both of these impacts were ignored during the simulations, the heating needs would differ from -1.78% to 3.65% from the needs of the building with the real people occupancy and models of surrounding buildings. Although it seems that this difference is negligible, in this way it gives the wrong impression that the obtained simulation results are correct. On the other hand, with Method 3, both of these effects act in the same direction. Therefore, if these effects were not taken into account, the predicted energy consumption would be as much as 21.13% lower than the predicted consumption, which would approximately correspond to the actual energy behavior of the building.

5 Conclusion

In this paper, the impact of the presence of surrounding buildings on the energy behavior of a non-residential building for climatic conditions in Serbia was examined. For the first time, this impact was considered for different people occupancy schedules, real, average yearly and maximum occupancy, and two different ventilation methods (Method 1 and 3), defined according to the currently valid standard EN 16798. The findings of this study indicate that the predicted total heating energy demands of a building may be significantly affected due to the shading caused by adjacent objects. Through building energy simulations, it was found that a building with a shading effect consumes from 6.43% to 11% more energy than a building where the presence of surrounding buildings is neglected. Neglecting this impact leads to an error in predicting the building's energy consumption. Observing the simultaneous impact of the people occupancy and surrounding objects, this error can reach a value of as much as 21.13%. Based on the presented results, in order to bring the predicted energy behavior of the building closer to its actual behavior, it is recommended to use the real occupancy schedule. The maximum occupancy schedule, in any case, should be avoided. For the same reason, the adjacent shading effect needs to be accounted for in building energy simulation studies. This effect should be also taken into consideration when planning and developing a new urban settlements.

6 References

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