User's Perception on Thermal Comfort in Educational Building Before Energy Renovation of the Building Envelope

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***Abstract*— The research analyzes the subjective thermal comfort perception of the Faculty of Physical Education and Sport users at the University of Banja Luka. The survey was designed in accordance with the review and requirements of the EN ISO 7730 and BAS EN 16798-1 standards to provide insight into the structure and behavior of the users (length of stay at the institution, work habits, position, and nature of workplace use, clothing level, etc.) and to determine the thermal comfort levels in the workplace during winter and summer. The survey included a total of 64 respondents (42 employees and 22 students) to identify key issues related to indoor thermal comfort before the energy renovation, which would later serve as a basis for reassessment after the renovation. In addition to the survey, the existence of mechanical air conditioning appliances was assessed, along with their usage frequency and temperature variations during the workday. The research results indicated greater user satisfaction during the winter season compared to the summer, where it was evident that the majority of users perceived workplace conditions as fairly warm to excessively warm during the summer months.**

***Key words*—thermal comfort, Indoor environmental quality, users perception, workplace conditions**

I. Introduction

Understanding how spatial characteristics and environmental conditions affect the comfort and energy-related behavior of building occupants is important for improving the performance of educational building. This study focuses on identifying differences in thermal comfort between university staff and students, with the aim of gathering the data before energy renovation measures in the building of the Faculty of Physical Education and Sport at the University of Banja Luka and compare it after the renovation is done. According to the EN 16798-1 standard, indoor air quality is determined by air temperature, relative humidity, ventilation rate, and CO_2 concentration, which are influenced by the quality and sealing of the building envelope, the number of occupants in the room (occupancy), user behavior, air exchange rate, and, of course, the quality of outdoor air [1-2]. Compared to residential and office buildings, educational buildings have 3-4 times higher user density [3]. Indoor environmental quality is primarily determined by thermal comfort and indoor air quality [4].

The analysis of parameters affecting building energy efficiency is conducted within a broader study in Case Study 1 – Energy-Efficient Renovation of Public Buildings at University of Banja Luka (UNIBL), as part of the ENPOWER project – Strengthening Scientific Capacity for Energy Poverty, coordinated by the University of Banja Luka. These Analyses are carried out on representative examples of public educational university buildings constructed and renovated in different periods, aligning with previous European projects that emphasize building renovation as key to addressing energy poverty [5-7]. Thermal comfort is based on six key parameters: environmental factors (air temperature, air velocity, mean radiant temperature, and relative humidity) and personal factors (metabolic activity and thermal resistance of clothing). Beyond measurable thermal comfort parameters, conducting surveys is essential to gain insights into user satisfaction with the indoor environment, as well as to consider physiological and subjective parameters such as the sense of thermal comfort at ankle height, head height, clothing level, etc.

Previous research by Wang and Norbäck on subjective indoor air quality (SIAQ) and thermal comfort indicates that complaints related to room temperature may reflect a suboptimal thermal environment, while factors such as excessive indoor humidity, insufficient thermal insulation, window condensation, and the presence of dampness or mold can significantly impair SIAQ. [8] Complementing these findings, another study suggests that student thermal comfort during periods of natural ventilation is primarily influenced by operative temperature and perceived air movement, with relatively low sensitivity to humidity levels or objective indicators of indoor air quality. [9]

The methodology used to create the survey was based on the EN ISO 7730 standard. This standard defines two parameters for quantifying thermal comfort – PMV and PPD.

PMV (Predicted Mean Vote) predicts the average response of a group of people exposed to the same environment; however, since individual responses may vary significantly around the average value, it is also useful to predict the number of people who will adequately assess thermal comfort. PPD (Predicted Percentage of Dissatisfied) is an index that provides a quantitative estimate of thermally dissatisfied individuals, i.e., those who feel either too warm or too cold. According to this standard, the assessment is conducted on a seven-point scale (from -3 to +3) of thermal comfort, encompassing factors of warmth, cold, and neutral perception (0). PMV and PPD express the overall sense of thermal comfort, but thermal discomfort may also arise from unwanted cooling or heating of specific body parts. The most common cause of local discomfort is draught, but it may also be triggered by a large temperature difference between the head and ankles, overly warm or overly cold floors, or excessive temperature gradients within the room's height [10].

II. SURVEYING USERS IN THE BUILDING OF THE FACULTY OF THE PHYSICAL EDUCATION AND SPORT AT THE UNIVERSITY OF BANJA LUKA

The research was conducted in the premises of the Faculty of Physical Education and Sport at the University of Banja Luka, including students (20) and employees (42). The building housing the Faculty of Physical Education and Sport is a freestanding structure with two floors (ground floor + 1) and a storage area in the basement. It was built in 1968, lacks thermal insulation on the envelope, and has original wooden-framed windows with ordinary double glass in single-hung frames.

Fig. 1. Faculty of Physical Education and Sport at UNIBL

It is representative of the construction of such buildings during the period from World War II until the introduction of the first thermal regulations related to building envelopes (1945–1970). Examining the building's functional layout reveals that it is a three-tract structure, horizontally divided into an administrative section and a section designated for classrooms (Figure 2). Administrative offices are predominantly oriented to the north, with fewer rooms on the south side. Additionally, the building contains larger halls used by permanent staff and occasional users. The left part of the building is designated for training halls and lecture rooms. Figure 1 shows the locations of the rooms where user surveys were conducted.

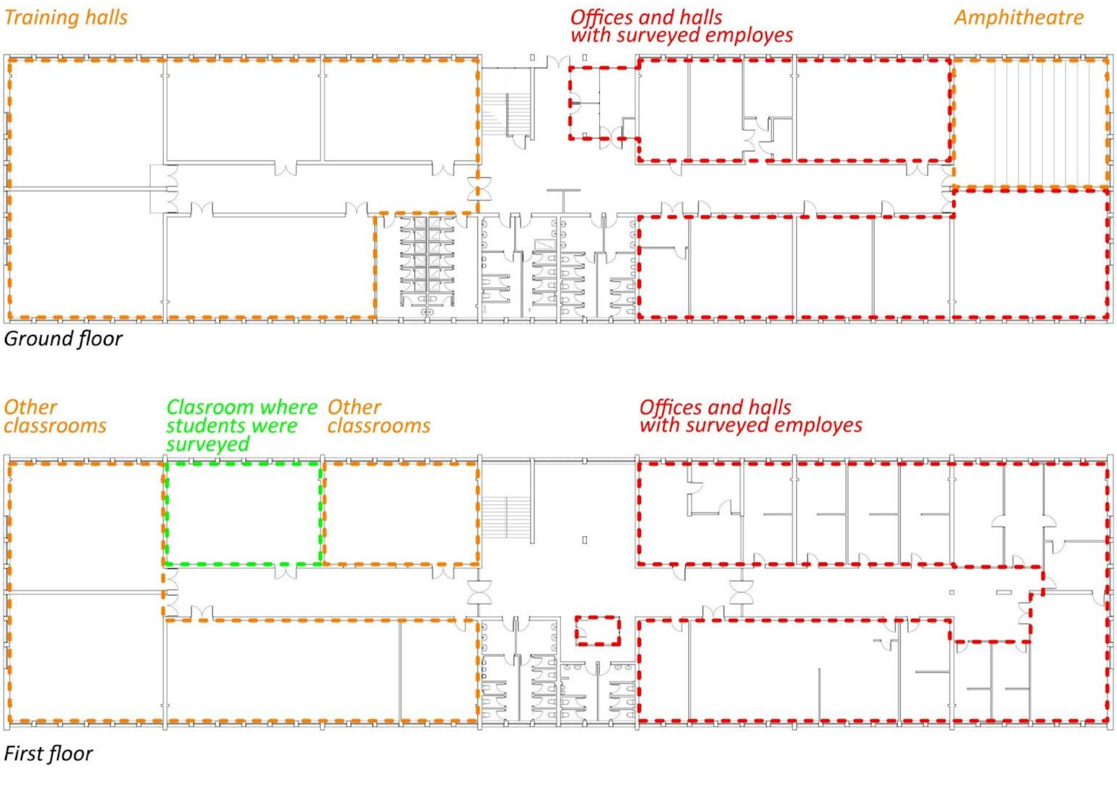

Fig. 2. Faculty of Physical Education and Sport at UNIBL – floor plans

III. RESEARCH METHODOLOGY

Previous research has defined three approaches to assessing thermal comfort: subjective perception, measurement of thermal comfort parameters using devices, and digital simulations of physical parameters. This research is based on a combination of user survey data and analysis of specific physical parameters of the workspace. Surveys were conducted among students and employees, with respondents divided into two groups to enable analysis of differences between permanent and occasional users of the space, as well as between age-differentiated categories of respondents. The research covered various parts of the building to ensure data representativeness. In addition to subjective assessments of thermal comfort, physical characteristics of the workplace were analyzed, including the distance from windows and heating elements, the presence and frequency of use of air conditioning and ventilation systems, and temperature variations during the workday. This data provided a more detailed understanding of the factors influencing users' thermal comfort. Descriptive statistical methods were used for data analysis. The comparison of mean variable values was performed using the Independent Samples t-test. The relationship between categorical variables, presented in contingency tables, was examined using the χ^2 test with Yates' correction. Fisher's Exact Test was used for frequencies less than five (5) in an individual table. A significance level of $p = 0.05$ was applied. Data analysis and statistical processing were carried out using SPSS (Statistical Product and Service Solutions), version 22.

The average age for employees was 47.5 years, while students averaged 23.75 years. In terms of Body Mass Index (BMI), employees had an average BMI of 25.08, while students had an average BMI of 23.76. Employees had spent an average of 14.14 years in the faculty premises, whereas students had spent an average of 1.82 years. Regarding daily presence in the building, 92.86% of employees spend between 4 and 8 hours daily, while students generally stay for 1-4 hours daily (13.64%). During summer, lightweight clothing was predominantly worn by students (81.82%), whereas employees typically wore normal clothing (57.14%). In winter, students often wore winter clothing indoors (71.43%), while employees mostly wore normal work clothing (52.38%). Physical activity levels during work tasks showed that static activities like reading and writing were most common for both employees (47.37%) and students (72.72%). Very light physical activity was recorded in 34.21% of employees and 13.64% of students; light physical activity was recorded in 2.63% of employees, while moderate to heavy physical activity was recorded in 15.79% of employees and 13.64% of students. When it comes to body position during work, 72.73% of students work while sitting relaxed, and 27.27% sit upright. Employees reported working in the following positions: sitting activity (58.33%), sitting relaxed (25%), leaning forward (13.89%), and sitting light activity (2.78%).

A statistically significant difference ($p < 0.001$) was found in the duration of time spent in the building by employees and students during the day, as well as in clothing levels during the summer ($p = 0.004$) (Table 1).

TABLE I. SURVEY ANALYSIS

		employees	students	p
Gender	Male	22 (52,38%)	14 63,64%)	0,551$^{\Delta}$
	Female	20 (47,62%)	8 (36,36%)	
Age	Mean	47,5	22,23	
	St. Deviation	9,136	3,116	
Body Mass Index(kg/m^2)	Mean	25,0761	23,7552	0,135§
	St. Deviation	3,3938	2,96949	
Stay in the premises of the faculty (years)	Mean	14,139	1,818	
	St. Deviation	7,3294	1,1807	
Stay in the faculty premises during the day	1 - 4 hours	3 (7,14%)	19 (86,36%)	< **0,001**$^{\nabla}$
	more than 4 hours	39 (92,86%)	3 (13,64%)	
level of clothing in summer	light summer clothing	18 (42,86%)	18 (81,82%)	**0,004**$^{\nabla}$
	normal clothing	24 (57,14%)	4 (18,18%)	
Level of clothing in winter	winter clothing inside room	20 (47,62%)	15 (71,43%)	0,128$^{\Delta}$
	normal work clothing	22 (52,38%)	6 (28,57%)	
The degree of activity when performing the work task	static activities such as reading and writing	18 (47,37%)	16 (72,72%)	
	very light physical activity	13 (34,21%)	3 (13,64%)	
	light physical activity	1 (2,63%)	0	
	moderate to heavy physical activity	6 (15,79%)	3 (13,64%)	
Body position at the workplace	leaning forward	5 (13,89%)	0	
	sitting relaxed	9 (25%)	16 (72,73%)	
	sitting activity	21 (58,33%)	6 (27,27%)	
	sitting light activity	1 (2,78%)	0	

$^{\Delta}$ χ2 test with correction according to Yates, § Independent Samples t test, $^{\nabla}$ Fisher's Exact Test

In the analysis of thermal comfort, in addition to subjective parameters of thermal comfort, physical characteristics of the workplace were also considered (Table 2). These characteristics include:

- Distance of the workplace from the radiator – being too close can lead to overheating, while being too far can result in a feeling of cold, especially in the winter months. The average distance of the workplace from the radiator is

238.21 cm for employee workplaces, while it is 467.14 cm for places in lecture halls.

- Distance of the workplace from the window – workplaces near windows may be exposed to drafts, and if the window sealing is poor, users may feel slight infiltration of external air. The average distance of the workplace from the window for employee workplaces is 259.23 cm, while it is 486.23 cm for places in lecture halls.
- Distance of the workplace from the door – this can cause more direct exposure to the air temperature in the hallway, while more distant places may have more stable conditions. The average distance of the workplace from the door for employee workplaces is 346.43 cm, while it is 520.82 cm for places in lecture halls. This parameter shows that in most rooms, workplaces are positioned closer to windows than to doors.

Testing the positions of workplaces in employee rooms and student lecture halls resulted in highly statistically significant differences ($p < 0.0001$) both in relation to the radiator, window, and door (Table 2). This can be attributed to the key characteristics of the spaces where students and employees predominantly spend their time. Faculty staff typically spend the majority of their working hours in smaller offices, where their workstations are positioned closer to windows, radiators, and/or air conditioning units. In contrast, students primarily occupy larger lecture halls, with opposite spatial and environmental features than offices.

TABLE II. POSITION OF WORKPLACES IN EMPLOYEE ROOMS AND STUDENT LECTURE HALLS IN RELATION TO THE RADIATOR, WINDOW, AND DOOR

		employees	students	p
The distance of the workplace from the radiator (cm)	Mean	238.21	467.14	< **0,001**§
	St. Deviation	170.336	241.679	
The distance of the workplace from the window (cm)	Mean	259,23	486,23	< **0,001**§
	St. Deviation	145,970	241,662	
Distance from the workplace to the door (cm)	Mean	346,43	520,82	< **0,001**§
	St. Deviation	156,717	179,126	

§ Independent Samples t test

Since the rooms do not have a centrally regulated ventilation and cooling system, it was interesting to analyze the presence of individual devices in offices and lecture halls used to regulate these conditions. Table 3 shows the data from surveys regarding the use of these devices, and it was concluded that the use of cooling devices is more pronounced during the summer months – 18 employees reported using such devices, while 22 do not; it was also found that the temperature in the room changes significantly during the workday in the summer months – 21 employees and 6 students reported temperature changes, while 20 employees and 16 students claimed there were no significant changes (Table 3).

Testing the responses of employees and students regarding the use of heating and cooling devices and temperature changes revealed a highly statistically significant difference in the use of additional heating devices during the winter ($p = 0.002$) and for cooling devices in the summer ($p < 0.0001$), while ventilation with mechanical devices in the summer showed a statistically significant difference ($p = 0.043$) – Table 3. This can be explained by the fact that only a limited number of offices are equipped with air conditioning units, whereas none of the classrooms have such systems. As a result, a statistically significant difference has emerged.

TABLE III. THERMAL COMFORT – USE OF HEATING AND COOLING DEVICES AND TEMPERATURE CHANGES

		employees	students	p
Ventilation of the room with mechanical devices - in winter	yes	3 (7,5%)	0	0,546∇
	no	37 (92,5%)	22 (100%)	
Ventilation of the room with mechanical devices - in summer	yes	8 (19,05%)	0	**0,043**∇
	no	34 (81,04%)	22 (100%)	
Using additional devices to heat the room in winter	yes	13 (31,71%)	0	**0,002**∇
	no	28 (68,29%)	22 (100%)	
Using additional devices to cool the room in summer	yes	18 (42,86%)	0	**0,0001**∇
	no	24 (57,14%)	22 (100%)	
The temperature changes significantly during the working day - in winter	yes	13 (32,5%)	6 (33,33%)	1,000Δ
	no	27 (67,5%)	12 (66,66%)	
The temperature changes significantly during the working day - in the summer	yes	21 (51,22%)	5 (23,81%)	0,072Δ
	no	20 (48,78%)	16 (76,19%)	

∇ Fisher's Exact Test, Δ χ^2 test with correction according to Yates

IV. DISCUSSION

As previously explained, EN ISO 7730 defines the analysis of thermal comfort through PMV and PPD, taking into account factors related to the feeling of thermal comfort at ankle height and at head height, in both summer and winter seasons.

The analysis of the conducted survey led to the following conclusions (the answers with the highest percentage of respondents are explained) – Table 4 and Graph 1.

Most employees rated thermal comfort at ankle height during the winter months as neutral or quite cool, while students gave similar responses, mostly neutral or cool. When analyzing the feeling of thermal comfort at head height in winter, the responses were somewhat more uniform – 21 employees and 14 students rated this parameter as neutral/comfortable. Thermal comfort at ankle height in the summer – employees rated it with 10 votes as neutral/comfortable and 12 votes as warm, while 11 students also rated it as neutral/comfortable and 5 as quite warm. The last parameter that is thermal comfort at the head height in the summer – both employees and students rated it outside the neutral zone. Fifteen employees stated that the thermal comfort feeling was too warm, and 12 said it was warm, while 7 students found it warm and 6 quite warm

TABLE IV. THERMAL COMFORT FEELING IN THE WORKPLACE – RESULTS OF THE SURVEY

		too warm	warm	quite warm	Neutral / pleasant	Quite cool	cool	cold	Total
A feeling of thermal comfort at the height of the ankle - in winter	employees	1	3	3	13	14	5	2	41
	students	0	2	0	11	2	4	2	21
Feeling of thermal comfort at head height - in winter	employees	1	5	3	21	6	4	1	41
	students	1	2	0	14	4	1	0	22
A feeling of thermal comfort at the height of the ankle - in summer	employees	9	12	7	10	0	1	2	41
	students	1	4	5	11	1	0	0	22
Sensation of thermal comfort at head height - in summer	employees	15	12	5	8	0	1	0	41
	students	3	7	6	5	1	0	0	22

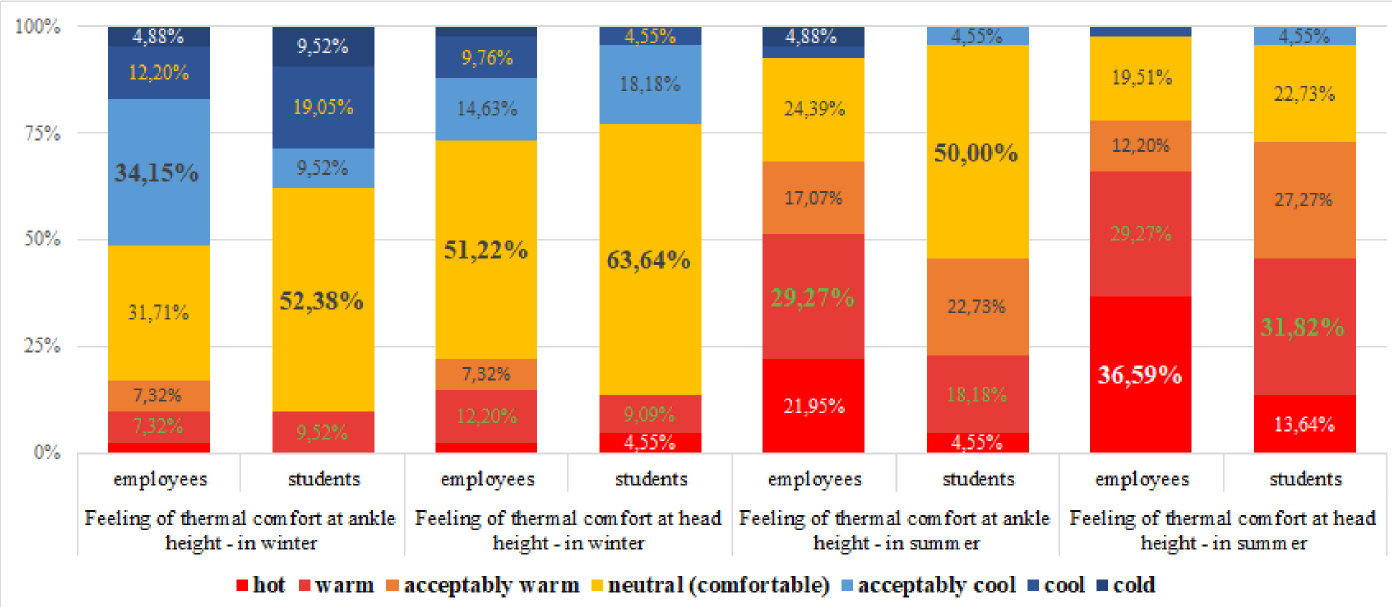

Fig. 3. Thermal comfort feeling in the workplace – results of the survey

Distribution of responds is shown in Table V and Figure 4. It is noticeable how employees showed worse thermal perception in summer period with values ranging from acceptably warm to warm, what does not fit to comfort zone.

TABLE V. FEELING OF THERMAL COMFORT IN THE WORKPLACE

	employees	students
ankle height - winter	**-0,44**	**-0,57**
head height - winter	**-0,02**	**0,05**
ankle height - summer	**1,22**	**0,68**
head height - summer	**1,76**	**1,27**

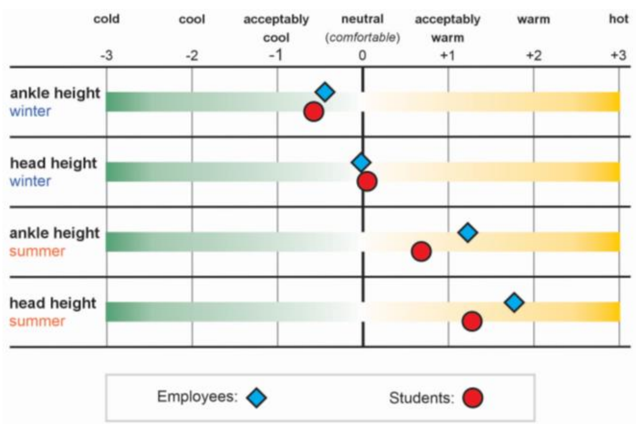

Fig. 4. Feeling of Thermal Cofmort in the workplace

V. CONCLUSION

A survey on users' subjective feeling of thermal comfort in the educational building (FPES) covered 64 respondents (42 employees and 22 students), achieving a sample that includes different age groups and users who spend varying amounts of time in the building. For the purposes of the study, a survey was conducted in accordance with the EN ISO 7730 standard, along with space mapping to determine the position of workspaces in relation to key parameters influencing thermal comfort.

The survey revealed differences in thermal comfort perceptions between employees and students, with seasonal and height-related variations. In winter, both groups rated thermal comfort at ankle height as neutral to cool, while at head height, most found it neutral or comfortable. In summer, employees felt warmer, especially at head height, where many rated it as too warm. Overall, employees reported more discomfort than students, particularly in the summer months. These findings suggest the need for targeted adjustments to improve thermal comfort in the workplace, especially during warmer seasons.

The results showed that users perceive their subjective comfort better during the winter months, while in the summer months, responses tended to indicate feelings of warm and excessively warm indoor conditions. This research will be extended to include the measurement of physical parameters of indoor comfort, allowing for a comparison between these two methods. Additionally, the study will be repeated after the building renovation process to assess the impact of the renovation and improvement of comfort on both the subjective feeling of comfort and the real physical parameters of thermal comfort.

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САЖЕТАК

Истраживање анализира субјективни осјећај топлотног комфора корисника Факултета физичког васпитања и спорта Универзитета у Бањој Луци. Анкета је осмишљена у складу са прегледом и захтјевима стандарда *EN ISO 7730* и *BAS EN 16798-1* на начин да се изврши увид у структуру и понашање корисника (дужину боравка у институцији, радне навике, позицију и карактер кориштења радног мјеста, степен одјевености и др.); те да се утврди осјећај топлотне угодности на радном мјесту зими и љети. Спроведена анкета обухватила је укупно 64 испитаника (42 запослена и 22 студената) како би се идентификовали кључни проблеми везани за унутрашњи осјећај топлотне угодности прије енергетске обнове нетранспарентног И транспарентног омотача зграде, а што би касније служило и као ослонац за поновно испитивање након спроведене обнове зграде. Поред спроведене анкете, извршено је и утврђивање постојања механичких уређаја за климатизацију и вентилацију, учесталост њиховог коришћења и промјене температуре током радног дана. Резултати истраживања показали су веће задовољство корисника у зимској сезони поредећи са љетном, гдје је видљиво да већина корисника сматра услове на радном мјесту прилично топлим до сувише топлим у љетним мјесецима.

ИСПИТИВАЊЕ КОРИСНИКА О ОСЈЕЋАЈУ ТОПЛОТНОГ КОМФОРА У ЗГРАДИ ОБРАЗОВНЕ НАМЈЕНЕ ПРИЈЕ ЕНЕРГЕТСКЕ ОБНОВЕ ОМОТАЧА ЗГРАДЕ

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