EMERGENCY CONVERSION OF SPORTS HALLS INTO TEMPORARY HOSPITALS CAUSED BY COVID-19 PANDEMIC
Case Studies of Thermal Comfort and Energy Consumption Analysis

by

Mirjana J. MILETIĆ [a*], ***Marija G. STAMENKOVIĆ*** [a], ***Milan Lj. DJORDJEVIĆ*** [a], ***and Dragan F. KOMATINA*** [b]

[a] Faculty of Technical Sciences, University of Priština in Kosovska Mitrovica, Kosovska Mitrovica, Serbia
[b] Faculty of Architecture, University of Montenegro, Podgorica, Montenegro

Original scientific paper
https://doi.org/10.2298/TSCI220416148M

An emergency caused by the COVID-19 pandemic affected the rethinking of existing healthcare systems. The increased need for hospital beds appeared short after the outbreak of the pandemic and the solution was to adapt the existing buildings, primarily public ones. Among all, sports buildings, i.e. sports halls were successfully used around the globe for conversion into hospitals. Topic of the paper was to investigate whether sports halls in Serbia, which were also used as temporary hospitals, are suitable for conversion in terms of energy consumption needed for achieving thermal comfort. Two case studies were analysed. The energy simulations were done using the DesingBuilder software. The results of thermal comfort summary and energy consumption led to the conclusion that this building type in Serbia could be successfully used for hospital purposes. Although the multiple increase in energy consumption was noted during the heating period, the results were within the limits required by both national and international standards.

Key words: *thermal comfort, conversion, sports halls, temporary hospitals, energy simulations*

Introduction

Nowadays society faces threats and risks that initially affect social context, beyond structural and physical aspects [1]. Since the social resilience has its significant foothold in the built environment, one of the key concepts used to describe the ability to overcome the growing challenges of the 21st century is adaptability. With the emergence of the COVID-19 pandemic in March 2020, a new perspective on adaptability of existing building stock has emerged. Many recent studies correlated air quality, temperature and population density with the number of SARS-CoV-2 cases [2]. Due to the high infectivity of the COVID-19, the need for a large number of hospital beds, especially for patients with mild and moderate symptoms, appeared in a very short time. Available capacities were quickly exceeded and therefore, many governments resorted to urgent adaptation of large-scale non-hospital buildings [3-7], as well as the construction of new specialized hospital buildings [8-10]. In the past year, three COVID hospitals were built in Serbia [11-13]. But before the capacities were expanded, public buildings were converted into temporary hospitals during the peaks of the pandemic: sports buildings [14-16],

* Corresponding author, e-mail: mirjana.miletic@pr.ac.rs

fair halls [17, 18], school buildings and dorms [19-21]. Non-e of these buildings had previously been planned to accept the function of a hospital building, hence they had to respond to the conflicting demands of different building types. Flexibility and transformation have become the key concepts for the post-pandemic architecture and urbanism [22].

When converting public buildings into temporary hospitals, it is necessary to respond to the challenge of providing comfort conditions-thermal, hygienic, visual, and acoustic [23]. Since patients do not stay for a long time in a temporary hospital, the conditions of visual and acoustic comfort are not so relevant. It is more important to consider the conditions that provide the required amounts of fresh air, especially in cases of conversion of sports halls that are characterized by a large volumes and high ventilation rates. A crucial parameter in terms of emergency conversion of sports halls into temporary hospitals is thermal comfort. The question arose whether and to what extent sports buildings, with their physical characteristics and HVAC systems, could meet health standards and specific requirements in the case of COVID-19 pandemic.

The topic of the paper was a comparative analysis of energy consumption and thermal comfort of two sports halls in the operating conditions for which they are intended and also as hospital buildings. In other words, it was examined whether the emergency converted sports halls into temporary hospitals can meet thermal comfort conditions, during both cooling and heating period, according to national and international regulations.

Sports buildings in response to the challenge of the COVID-19 pandemic

Around the globe, sports buildings have been widely used for conversion into temporary hospitals, especially at the beginning of the pandemic [7, 24-29]. These buildings have proved suitable for conversion, primarily because of the large courts areas that served various hospital purposes [30]. Organizing space to accommodate and treat patients was the biggest of all challenges.

Sports facilities provide a great capacity for accommodating patients due to relatively easy assembly and disassembly of partition elements within the buildings, once they have served the purpose.

Indoor sports facilities have been also converted into temporary hospitals in Serbia, fig. 1. Regarding functional organization and equipment, the sports halls were used for accommodation and the offices were turned into hospital premises (laboratory, X-ray machine*, etc.*), which were also used for dining and social contents. The benefit was the use of existing toilets and showers. Although most of the patients' activities were related to other indoor spaces, they spent most of their time in the hall space. In addition, the hall space has the largest volume, so it is necessary to consider the fulfilment of the comfort conditions, especially thermal comfort.

Figure 1. The conversion of sports halls in Serbia into temporary hospitals;
(a) *Štark Arena*, Belgrade [31], (b) Sports Hall *Čair*, Niš [32], and (c) Sports Hall *Atenica*, Čačak [33]

Comparison of thermal comfort in sports and hospital buildings

Both building types, sports and hospital, are complex systems in terms of thermal comfort conditions. Different premises uses also require different comfort conditions within a building type. These facts indicate the complexity of the whole building analysis for achieving required thermal comfort in sports and a hospital buildings. Bearing in mind that the sports building does not completely take over the purpose of the hospital by conversion and that the hall, as the most important part of a sports building, is mainly intended for accommodation of patients, only the hall space was taken into consideration for achieving thermal comfort.

Comparative analyses of the energy consumption of the sports halls were conducted, separatly for cases when they serve for sports and hospital purposes. The input parameters for the analyses, as well as the maximum allowable specific energy requirements per year for heating and cooling according to National[*] [23, 34-36] and International regulations [37-39] are shown in tab. 1.

Table 1. Comparison of required values/ranges of thermal comfort parameters and the maximum allowable specific energy requirements per year for heating and cooling for sports and hospital buildings according to National (A) and International regulations (B)

Building type	Applied standards	Thermal comfort parameters									Max. energy use
		Winter thermal comfort design			Summer thermal comfort design			Air velocity $[\text{ms}^{-1}]$	Humidity		
		Air temperature [°C]	Activity [met]	Clothing [clo]	Air temperature [°C]	Activity [met]	Clothing [clo]		Winter [%]	Summer [%]	$[\text{kWhm}^{-2}\text{year}^{-1}]$
Dry sport hall	A	18	3.0	0.6	26	3.0	0.2	0.1	~40	~60	<90
	B	13-16	3.0	0.4	24	3.0	0.35				<215 heating <62 cooling
Hospitals	A	22	1.0	1.0	26	1.0	0.5				<120
	B	22-24	0.9	1.4	23-26	0.9	1.2				<163 heating <75 cooling

Materials and methods

Two representative sports halls in Belgrade, Serbia, were selected for investigating thermal comfort levels after they have been converted into temporary hospitals. The analysis of the buildings was conducted on the basis of project documentation and empirical research in the field, in terms of thermal zoning, infrastructure, occupancy, activities, HVAC systems*, etc.* On the other hand, when it comes to equipping temporary hospitals, the capacities, arrangement of beds, internal partitions and communications within the halls were set based on empirical research.

DesignBuilder software (version 5.03.007.) was used to develop geometric models and simulate energy consumption required to meet thermal comfort. The parameters needed for thermal comfort calculations were set in accordance with the regulations.

[*] National regulations define only the maximum allowable specific energy requirements per year for heating

Case studies: sports halls in Belgrade, Serbia

Selected sports halls for case studies are located within the Sports centre *Voždovac*(S1) and Sports centre *Šumice* (S2). Although these specific buildings have not been converted into temporary hospitals, further analysis has shown why they could be considered as representative examples for conversion in the capital and throughout the territory of the Republic of Serbia.

Primarily, on the basis of project documentation and field research, it was confirmed that the existing infrastructure and spatial characteristics of the buildings were capable to meet the requirements needed for the hospital purposes. This means that in addition the halls, where patients are intended to be accommodated and treated, the other premises of the buildings could serve for hospital purposes (laboratory, X-ray machine, oxygen sites*, etc.*), for dinning and social activities (tv room, library*, etc.*). Also, the patients are intended to use existing toilets and showers.

These buildings are located nearby densily populated urban areas so the accommodation and treatment for potential patients can be provided in a short time, while reducing the capacity load of local hospitals.

The buildings were built in the early 1970's, during the period of the most intensive construction in our area [40]. Regarding the characteristics of materialization, the most common materials of the time – bricks and concrete were used for both buildings, and they were covered with steel lattice roofs, which was also a common roof structure for this type of building [41]. These facts confirm the assumption that selected buildings could be considered representative, because most of active sports centres in Serbia were built in the same period and have similar construction characteristics. The main difference between these sports centres is the location of the sports halls. Within one of them, the sports hall is in the middle and the building has a compact basis (S1), fig. 2(a). The hall in the other building is peripherally located, *i.e.* most walls are exterior and the basis is disjointed (S2), fig. 3(a). Although the polyvalent courts are the same sizes, the areas of the halls differ. Larger hall S1 has two-sided oriented stands, while the hall S2 has one-sided oriented stand. These different design solutions are also in line with the selection of representative large-scale sports buildings.

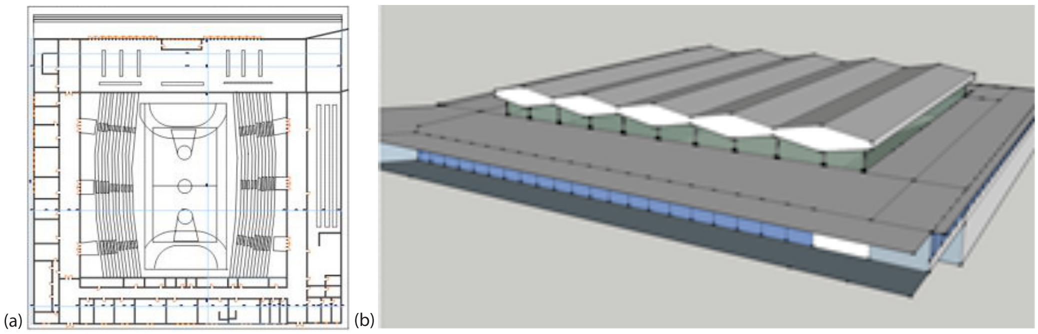

Figure 2. Sports centre *Voždovac* (S1); (a) base [42] and (b) 3-D model

In terms of functionality, a sports building generally consists of a hall with a court zone and a spectators zone – stand(s), locker rooms, showers, toilets and administration zone [41]. All these entities represent particular thermal zones that require different thermal comfort conditions. This indicates the complexity of energy simulations. For the purpose of this paper, only sports halls were treated for energy simulations, since they are the most important spaces in conversion of sports buildings into temporary hospitals.

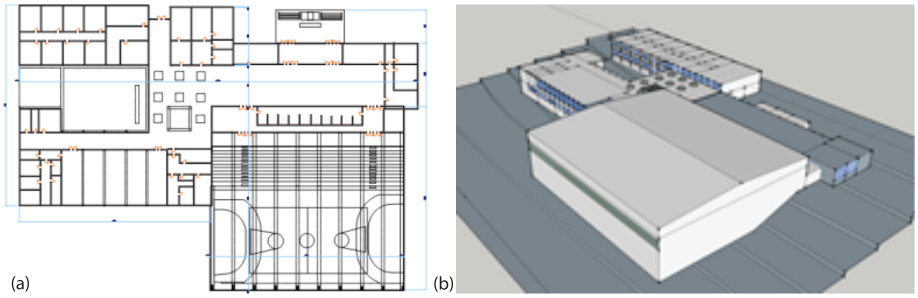

Figure 3. Sports centre *Šumice* (S2); (a) base [43] and (b) 3-D model

Thermal properties of the hall S1 – Sports Centre Voždovac

The sports hall occupies 2004.32 m^2 of the total building area of 4906.91 m^2. The gross wall area of the hall is 1172.40 m^2, and the window opening area is 212.46 m^2. The thermal zone encompasses the volume of 25053.99 m^3.

The elements of the thermal envelope are external walls with window areas, ground floor and the roof. Structure of building elements [41] are shown in tab. 2, as well as their *U*-values and the maximum allowed *U*-values according to National [23] and International regulations [38].

Table 2. Thermal envelope structure, calculated *U*-values and the maximum allowed *U*-values according to National (A) and International (B) regulations

Envelope elements	Layers, thickness, δ [m] (Outermost to innermost)	U-value [$Wm^{-2}K^{-1}$]	U_{max} [$Wm^{-2}K^{-1}$], (A)	U_{max} [$Wm^{-2}K^{-1}$], (B)
External wall (partition)	Brick 0.22 Cement plaster 0.013	1.97	0.9	0.5
Transparent part	Wooden frames; insulation glass	1.96	1.5	0.85
Ground floor	Urea formaldehyde foam 0.13 Cast concrete 0.1 Floor screed 0.07 Timber flooring 0.03	0.25	0.4	0.15
Roof	Bitumen felt 0.015 Polyurethane 0.04 Roofing felt 0.005 Concrete 0.10 Air gap 1.80 Painted oak 0.02	0.395	0.2	0.15

As can be seen, the actual *U*-values for most envelope elements do not comply with National regulation. The reason for this is the differences between the regulation at the time the building was designed and constructed (Regulation on Technical Measures and Provisions for Thermal Protection of Buildings, 1970) and the current regulation (Regulation on Energy Efficiency in Buildings, 2011), as well as the fact that the building envelope has not been improved since it was built.

Thermal properties of the hall S2 - Sports Centre Šumice

Total building area of this sports and youth centre is 5213.40 m^2, of which the hall occupies 1661.63 m^2. Thermal envelope of the hall encompasses internal and façade walls with window areas, ground floor and the roof. The gross wall area of the hall is 1675.52 m^2, the area of internal walls is 350.63 m^2, the window opening area is 100.09 m^2 and the volume of the thermal zone is 19939.56 m^3.

Structure of the thermal envelope elements [42], calculated *U*-values and the maximum allowed *U*-values according to National [23] and International regulations [38] are shown in tab. 3.

Table 3. Thermal envelope structure, calculated *U*-values and the maximum allowed *U*-values according to National (A) and International (B) regulations

Envelope elements	Layers, thickness, δ [m] (Outermost to innermost)	U-value [Wm^{-2}K^{-1}]	U_{max} [Wm^{-2}K^{-1}], (A)	U_{max} [Wm^{-2}K^{-1}], (B)
External wall	Brickwork outer 0.38 Cement plaster 0.013	1.56	0.4	0.35
External wall of the hall Internal partition	Gypsum plasterboard 0.025 Expanded polystyrene 0.10 Gypsum plasterboard 0.025	0.338	0.9	0.5
Transparent part	Wooden frames; insulation glass	1.96	1.5	0.85
Roof	Bitumen felt 0.015 Polyurethane 0.04 Roofing felt 0.005 Syporex 0.15 Air gap 0.026 Painted oak 0.02	0.37	0.2	0.15
Ground floor	Urea formaldehyde foam 0.13 Cast concrete 0.10 Floor screed 0.07 Timber flooring 0.03	0.25	0.4	0.15

By comparing the actual and maximum allowed *U*-values, it can be noticed again that most elements do not meet either National or International regulations. Thus, high energy consumption is needed for achieving thermal comfort, regardless of the purpose of the hall.

Dynamic simulations

Modelling the geometry of buildings was done in the environment of DesignBuilder, version 5.0.3.007. Since the design of temporary hospitals involved beds and partitions, 202 and 191 beds were provided in the halls S1 and S2, respectively. Models of buildings with beds and partitions are shown in fig. 4. After conversion sports halls S1 and S2 became S1H and S2H, respectively. It is important to emphasize that although the rest of the buildings were not considered for energy consumption, each building was divided into thermal zones and modeled as a whole.

Energy simulations were done according to national and international comfort models. It was necessary to set various templates and modules for both building types in DesignBuilder. For the cases when the halls are used for sports activities, *Dry sports hall* template was selected within the Activity module, with *D2_DrySpHall_Occ* occupancy template and *Exercise/Sport* as metabolic activity. For simulating the hospital conditions, *Generic ward hospitals* template

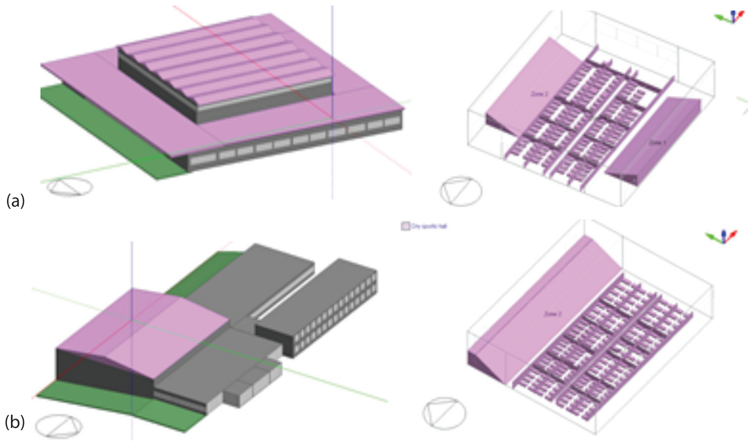

Figure 4. Models of buildings and corresponding temporary hospitals design; (a) S1H and (b) S2H

was selected within the Activity module, with *Hosp_WardPatients_Occ* occupancy template, and *Bedroom/Dwelling* as metabolic activity. HVAC system models were set with *Radiator heating, boiler HW* and *Mechanical ventilation* for all cases. Both buildings use electricity from grid for cooling and oil for space heating.

Environmental and personal factors affecting thermal comfort (air temperature, air velocity, clothing and activity level) were set according to tab. 1, while operative temperature, radiant temperature of surrounding surfaces and humidity were calculated.

Results and discussion

Energy consumptions needed for achieving thermal comfort were obtained based on set modules, templates and input parameters, as previously described. Thermal comfort summaries for sports halls S1 and S2, as well as for the cases after conversion into hospitals S1H and S2H, according to National [23, 34-36] (A) and International regulations [36-38] (B) are shown in tabs. 4 and 5, respectively. The displayed values of radiant and operative temperatures and humidity were calculated for extreme conditions for both heating and cooling period.

Considering categories of indoor environmental quality and corresponding levels of expectation (high, medium, moderate and low), it is optimal to achieve II category (medium level) [36]. The range of operative temperature for sports buildings is 14-23 °C, while for hospital buildings it is 20-24°C during heating and 23-26 °C during cooling periods. Simulations with input parameters in accordance with National regulations, tab. 4, show that the obtained values for an extreme winter day are within the required range for category II for models S1 and S2, but are lower for models S1H and S2H. The values for models S1H and S2H belong to categories III (moderate) and IV (low level), respectively. In addition, these sports halls should not be excluded from conversion into temporary hospitals, because the obtained values are for extreme conditions that do not last long.

The same explanation applies to the results obtained for the hottest day, when the operative temperature values fall into category IV of thermal comfort.

Sub-hourly distributions of temperatures during extreme cooling conditions for cases S1H and S2H are shown in figs. 5 and 6 (cases S1 and S2 are not shown for the purpose of brevity). The figures show that the maximum air temperature is obtained from 14.00-15.00 hours for each case considered.

Table 4. Thermal comfort summary for sports halls S1 and S2 and temporary hospitals S1H and S2H according to National regulations (A)

Thermal comfort	Building			
	S1	S2	S1H	S2H
Heating				
Air temperature [ºC]	18.00	18 .00	22.00	22.00
Radiant temperature [ºC]	12.82	11.94	16.24	15.09
Operative temperature [ºC]	15.41	14.97	19.12	18.55
Outside dry bulb [ºC]	–8.40	–8.40	–8.40	–8.40
Cooling (15th July)				
Air temperature [ºC]	26	26	26	26
Maximum operative temp per day [ºC]	29.0	29,4	28.0	28.2
Outside air temperature at peak load [ºC]	34.0	34.0	34.0	34.0
Humidity [%]	Heating cooling	Heating cooling	Heating cooling	Heating cooling
	44.8 55.5	48.3 58.5	47.3 58.5	47.2 58.5

Table 5. Thermal comfort summary for sports halls S1 and S2 and temporary hospitals S1H and S2H according to International regulations (B)

Thermal comfort	Building			
	S1	S2	S1H	S2H
Heating				
Air temperature [°C]	16.00	16.00	22.00	22.00
Radiant temperature [°C]	11.19	10.36	16.24	15.09
Operative temperature [°C]	13.60	13.18	19.12	18.55
Outside dry bulb [°C]	–8.40	–8.40	–8.40	–8.40
Cooling (15th July)				
Air temperature [°C]	24	24	24	24
Maximum operative temp per day [°C]	28.5	28.5	26.2	26.5
Outside air temperature at peak load [°C]	34.0	34.0	34.0	34.0
Humidity [%]	Heating cooling	Heating cooling	Heating cooling	Heating cooling
	41.0 55.7	41.0 52.7	51.5 59.0	51.5 60.0

Simulations with input parameters in accordance with International regulations, tab. 5, show that the obtained operative temperature values for an extreme winter day fell into Category III (13-25 °C) for models S1 and S2. The same applies during the summer season, because the values during extreme conditions are at the upper limit of the Category III. When it comes to the hospital cases (models S1H and S2H), the obtained operative temperature values for an extreme winter day are at the lower limit of the Category III. Regarding cooling conditions, the maximum values obtained for the hottest day also fell into Category III.

The obtained results for humidity with input parameters in accordance with both National and International regulations and for all models are within the domain of required values,

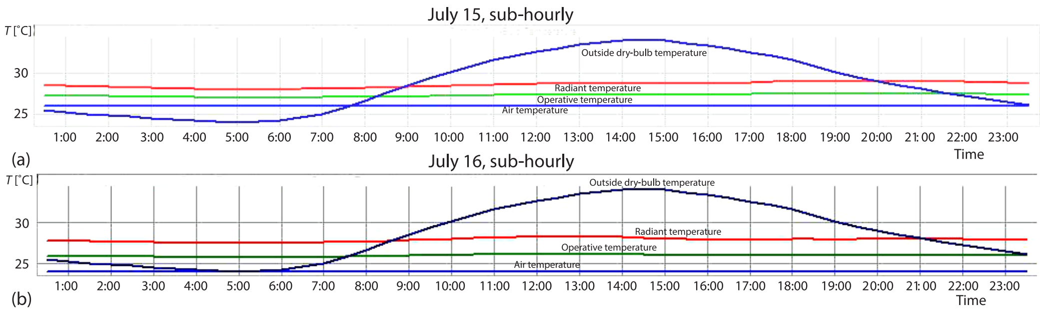

Figure 5. Temperature profiles for extreme cooling conditions S1H (A and B)

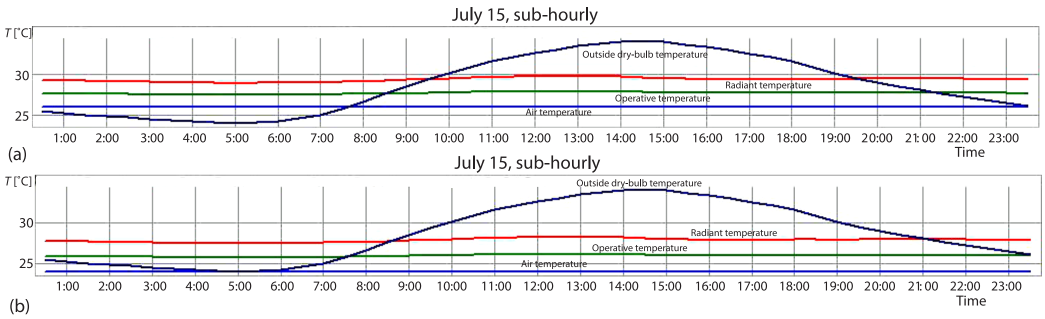

Figure 6. Temperature profiles for extreme cooling conditions S2H (A and B)

even for extreme design conditions. This is especially important for hospital cases, as high humidity could adversely affect the recovery and health of patients.

From the previous analysis, it can be noticed that the operating temperature values were not in the optimal range during extreme heating and cooling conditions, especially for hospital cases. However, these sports halls should not be excluded from conversion into temporary hospitals for the reasons already mentioned, as well as because the patients intended for accommodation and treatment have mild and moderate symptoms.

It is important to emphasize that the fresh air rates are always met, because ventilation systems in sports buildings are designed to deliver abundant volumes of fresh air.

In order to determine whether the conversion of sports halls into temporary hospitals is justified in terms of energy consumption for cooling and heating, simulations of models S1, S2, S1H and S2H were done with input parameters in accordance with National [23, 34-36] (A) and International [37-39] (B) regulations. Obtained values for energy consumption $Q_{\mathrm{H,nd}}$ are shown in tabs. 6 and 7.

Since the heating season in Serbia is from October 15$^{\mathrm{th}}$ to April 15$^{\mathrm{th}}$ and cooling season is from April 15$^{\mathrm{th}}$ to October 15$^{\mathrm{th}}$, energy consumptions during April nad October was calculated for both heating and cooling. In addition, the energy sources are also different.

The results of energy consumption during the cooling season indicate moderate increase for cases after conversion into temporary hospitals compared to the corresponding sports halls: 29-51% with input parameters in accordance with National, tab. 6, and about 68% with input parameters in accordance with International regulations, tab. 7.

On the other hand, major increments in energy consumption after conversion occur during the heating season: 274-292% with input parameters in accordance with National, tab. 6, and about 348% with input parameters in accordance with International regulations, tab. 7.

Table 6. Energy consumption for sports halls S1 and S2 and temporary hospitals S1H and S2H according to National regulations (A)

Simulated period	$Q_{H,nd}$ [kWhm^{-2}]			
	S1	S2	S1H	S2H
January	44.73	46.11	113.37	114.98
February	34.17	35.35	92.44	93.48
March	21.85	21.97	75.39	74.93
April (1st-15th)	6.03	5.85	27.48	26.98
April (15th-30th)	0.10	0.10	0.11	0.12
May	2.23	2.03	2.86	3.05
June	4.89	4.45	6.46	6.90
July	7.09	6.28	8.99	9.92
August	6.88	6.86	8.77	9.83
September	1.40	1.41	1.93	2.16
October (1st-15th)	0.38	0.43	0.57	0.65
October (15th-30th)	5.80	5.60	26.01	26.89
November	23.93	23.84	76.79	76.86
December	40.53	51.83	105.63	107.29

Table 7. Energy consumption for sports halls S1 and S2 and temporary hospitals S1H and S2H according to International regulations (B)

Simulated period	$Q_{H,nd}$ [kWhm^{-2}]			
	S1	S2	S1H	S2H
January	39.89	41.00	113.37	114.98
February	29.95	30.90	92.44	93.48
March	17.56	17.49	75.39	74.93
April (1st-15th)	4.38	4.07	27.48	26.98
April (15th-30th)	0.40	0.32	0.73	0.76
May	4.58	4.36	6.79	7.39
June	8.59	8.12	13.92	14.77
July	11.11	11.51	18.00	19.51
August	11.55	11.93	17.29	18.85
September	3.16	3.25	4.85	5.47
October (1st-15th)	0.81	0.89	6.06	1.51
October (15th-30th)	1.67	1.62	26.01	26.89
November	19.44	19.24	76.79	76.86
December	35.67	35.32	105.63	107.29

Although confusing at first sight, this multiple increase in energy consumption for heating can be easily explained by recalling the basic differences between sports halls and hospitals - occupancy patterns and metabolic activity of the people who reside in them. Sports halls should provide comfort to people who stay in them for several hours during the day and who have high levels of physical activity. In the case of hospitals, it is the opposite.

In addition, the obtained results show that these sports halls belong to Classes E and F according to National classification of energy efficiency of buildings [23].

After the emergency conversion into temporary hospitals, the needs of these facilities for heating energy far exceed the lower limit of energy Class G. National regulations have defined classification parameters for heating energy, while the efficiency classification of cooling needs is to be defined in the future. The considered facilities are obviously energy inefficient according to modern standards, which is a consequence of the implementation of obsolete standards from the time of their construction.

Conclusion

Sports buildings were successfully used for conversion into temporary hospitals worldwide, especially at the beginning of the COVID-19 pandemic. Their most important purposes were accommodation and treatment of patients. In order to investigate whether sports halls in Serbia are suitable for conversion, two representative halls were analysed using the DesignBuilder software for thermal comfort and energy consumption simulations. Based on the obtained results it could be concluded that sports halls with their physical characteristics and systems meet specific requirements for temporary accommodation and treatment of patients in the case of COVID-19 pandemic. One of the most important findings is that existing sports halls in Serbia can provide thermal comfort to patients with mild and moderate symptoms of illness in all winter and summer weather conditions of the domestic climate. Although some of the simulated comfort parameters were not in optimal range during extreme hot weather conditions, they are generally acceptable for the patients for whom these facilities are intended. The increase in energy consumption achieve thermal comfort during the summer is moderate, while the increase during the winter is much higher (up to 350%), which is a consequence of the differences in the occupancy patterns and metabolic activity of occupants and energy inefficiency of the buildings considered. The general conclusion is that despite the large increase in energy consumption, these emergency conversions of sports halls into temporary hospitals are justified regarding the thermal comfort that can provide to patients.

References

[1] Alizadeh,H., Sharifi, A., Analysis of the State of Social Resilience among Different Socio-demographic Groups during the COVID-19 Pandemic, *International Journal of Disaster Risk Reduction, 64* (2021), 102514

[2] Tanis, C., *at al.*, Investigating the Impact of the Air Quality and Weather on the Spread of Sars-CoV-19 in Istanbul, Turkey, *Thermal Science, 25* (2021), 4A, pp. 2755-2765

[3] Chen, S., *et al.*, Fangcang Shelter Hospitals: a Novel Concept for Responding to Public Health Emergencies, *The Lancet*, *395* (2020), 10232, pp. 1305-1314

[4] Sacchetto, D., *et al.*, COVID-19 Surge Capacity Solutions: Our Experience of Converting a Concert Hall into a Temporary Hospital for Mild and Moderate COVID-19 Patients, *Disaster Medicine and Public Health Preparedness*, *16* (2020), 3, pp. 1273-1276

[5] Candel, F. J., *et al.*, Temporary Hospitals in Times of the COVID Pandemic, An Example and a Practical View, *Revista Espanola de Quimioterapia*, *34* (2021), 4, pp. 280-288

[6] Marinelli, M., Emergency Healthcare Facilities: Managing Design in a Post Covid-19 World, *IEEE Engineering Management Review*, *48* (2020), 4, pp. 65-71

[7] Fang, D., *et al.*, Large-Scale Public Venues as Medical Emergency Sites in Disasters: Lessons from COVID-19 and the Use of Fangcang Shelter Hospitals in Wuhan, China, *BMJ Global Health*, *5* (2020), 6, e002815
[8] Luo, H., *et al.*, Ultra-Rapid Delivery of Specialty Field Hospitals to Combat COVID-19: Lessons Learned from the Leishenshan Hospital Project in Wuhan, *Automation in Construction*, *119* (2020), 103345
[9] Nong, V. M., *et al.*, The Second Wave of COVID-19 in a Tourist Hotspot in Vietnam, *Journal of Travel medicine*, *28* (2021), 2, pp. 1-3
[10] Keeley, C., *et al.*, Staffing Up for the Surge: Expanding the New York City Public Hospital Workforce during the COVID-19 Pandemic, *Health Affairs*, *39* (2020), 8, pp. 1426-1430
[11] ***, The Government of the Republic of Serbia, COVID Hospital in Batajnica to Start Working Tomorrow, https://www.srbija.gov.rs/vest/en/164390/covid-hospital-in-batajnica-to-start-working-tomorrow.php
[12] ***, The Government of the Republic of Serbia, COVID Hospital Opened in Krusevac, https://www.srbija.gov.rs/vest/en/165313/covid-hospital-opened-in-krusevac.php
[13] ***, The Government of the Republic of Serbia, New COVID Hospital Opens in Novi Sad, https://www.srbija.gov.rs/vest/en/177736/new-covid-hospital-opens-in-novi-sad.php
[14] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – "Štark Arena" (in Serbian), Official Gazette of the RS, No. 97/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-arena.html, 2020
[15] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – "Čair Hall" (in Serbian), Official Gazette of the RS, No. 50/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-cair.html, 2020
[16] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – Sports hall (Blue hall), Atenica in Čačak (in Serbian), Official Gazette of the RS, No. 102/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-cacak.html, 2020
[17] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – "Belgrade Fair" (in Serbian), Official Gazette of the RS, No. 50/2020 and 54/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-sajam.html, 2020
[18] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – "Novi Sad Fair" (in Serbian), Official Gazette of the RS, No. 50/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-novosadski-sajam.html, 2020
[19] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – High school of Economics "Stana Milanović" in Šabac (in Serbian), Official Gazette of the RS, No. 100/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-sabac.html, 2020
[20] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – Medical high school "Dva heroja" Novi Pazar (in Serbian), Official Gazette of the RS, No. 57/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-novi-pazar.html, 2020
[21] ***, Decision on Opening of a Temporary Facility for Accomodation and Treatment of Persons with COVID-19 Infectious Diseases Caused by SARS-COV-2 Virus – "Dorm of the Faculty of Medicine Niš" (in Serbian), Official Gazette of the RS, No. 57/2020, https://www.paragraf.rs/propisi/odluka-o-otvaranju-privremenog-objekta-za-smestaj-i-lecenje-sajam-dom-studenata-nis.html, 2020
[22] Megahed, N. A., Ghoneim, E. M., Antivirus-Built Environment: Lessons Learned from Covid-19 Pandemic, *Sustainable cities and society*, *61* (2020), 102350
[23] ***, Regulation on Energy Efficiency in Buildings (in Serbian), Official Gazette of the RS, No. 61/2011
[24] ***, Time, The World's Sports Stadiums are Being Converted into Hospitals to Fight the Coronavirus Outbreak, https://time.com/5813442/coronavirus-stadiums-hospitals/
[25] ***, VOA, Brazil Transforms Sports Venues into Field Hospitals for Coronavirus, https://www.voanews.com/a/americas_brazil-transforms-sports-venues-field-hospitals-coronavirus/6186415.html
[26] ***, BBC, Coronavirus: Stadiums and Sports Centres Become Field Hospitals, https://www.bbc.com/news/av/uk-wales-52142809

[27] ***, Institut Guttmann, Institut Guttmann Turns its Sports Hall into Field Hospital to Face COVID-19, https://www.guttmann.com/en/noticias/institut-guttmann-turns-its-sports-hall-field-hospital-face-covid-19-0
[28] ***, Reuters, Vietnam Turns Danang Stadium into Field Hospital Amid Virus Outbreak, https://www.reuters.com/article/us-health-coronavirus-vietnam-fieldhospi-idUSKCN2521B0
[29] ***, AARP, Outbreak Turns Stadiums into Hospitals and Food Pantries, https://www.aarp.org/health/conditions-treatments/info-2020/coronavirus-sports-stadiums.html
[30] ***, National Geographic, See how Sports Stadiums Have Transformed to Help Pandemic Relief Efforts, https://www.nationalgeographic.com/history/article/sports-stadiums-transformed-help-pandemic-relief-efforts
[31] ***, BIZLife, https://www.bizlife.rs/arena-od-sutra-ponovo-kovid-bolnica/
[32] ***, Telegraf, https://www.telegraf.rs/sport/ostali-sportovi/3262873-zeleznicar-nis-rukomet-ehf-kup-odustajanje-kovid-bolnica
[33] ***, Morava Info, https://moravainfo.rs/hala-u-atenici-spremna-da-u-svakom-trenutku-primi-obolele-od-korone/
[34] ***, SRPS EN ISO 7730, Ergonomics of the Thermal Environment Analytical Determination and Interpretation of Thermal Comfort Calculation of PMV and PPD Indices and Local Thermal Criteria, 1994
[35] ***, SRPS EN 16798-1:2019, Energy Performance of Buildings - Ventilation for Buildings – Part 1: Indoor Environment Inputs Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics- Module M1-6, 2019
[36] ***, SRPS CEN-TR 16798-2:2019, Energy Performance of Buildings - Ventilation for Buildings – Part 2: Interpretation of the Requirements in EN 16798-1 – Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics (Module M1-6), 2019
[37] ***, ASHRAE 55, Thermal Environmental Conditions for Human Occupancy, American Society of Heating, Refrigerating and Air-Conditioning Engineers, ISSN 1041-2336, 2010
[38] ***, CIBSE Guide A: Environmental Design, The Chartered Institution of Building Services Engineers London, ISBN-10:1-903297-66-9, 2006
[39] Bawaneh, K., *et al.*, Energy Consumption Analysis and Characterization of Healthcare Facilities in the United States, *Energies*, *12* (2019), 19, 3775
[40] Popović, M. J., *et al.*, *Atlas of Multyfamily Housing in Serbia*, Faculty of Architecture, Belgrade, Serbia, 2013
[41] Ilić, S., *Sportski Objekti* (in Serbian), Slobodan N. Ilić, Beograd, Srbija, 1998
[42] ***, Glavni Projekat Sportskog Centra Voždovac (in Serbian), Sportprojekt, Beograd, Srbija1974
[43] ***, Glavni Projekat Centra za Kulturu i Sport Šumice (in Serbian), Biro Krivaja, Beograd, Srbija, 1972

Paper submitted: April 16, 2022
Paper revised: July 18, 2022
Paper accepted: August 17, 2022