DOI: 10.2507/34th.daaam.proceedings.xxx

ANALYSIS OF EXISTING DESIGN TEMPERATURE FOR HEATING IN SARAJEVO IN LIGHT OF CLIMATE CHANGES

Rejhana Blažević, Armin Teskeredžić & Melisa Zečević

This Publication has to be referred as: Blažević, R[ejhana]; Teskeredžić, A[rmin] & Zečević, M[elisa] (2023). Analysis of existing design temperature for heating in Sarajevo in light of climate changes, Proceedings of the 34th DAAAM International Symposium, pp.xxxx-xxxx, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/34th.daaam.proceedings.xxx

Abstract

Designers of heating systems and planners of the district heating consider large number of variables that influence the final proposal of the system which will meet the heating needs. Size of the system and investment costs depends on different parameters but are mostly influenced by the outside design temperature. Engineers are aware of the climate change influence but during design process they need either legal or scientific proof that they can use new/updated values of the design temperatures at the specific location. In this paper, an analysis of hourly air temperature values for the city of Sarajevo, Bosnia and Herzegovina (B&H) was conducted in the latest available 20 years dataset. Data on the outside air temperature were obtained by the Federal Hydrometeorological Institute of Bosnia and Herzegovina. Five different methods were briefly explained and used for determination of the new design temperature for Sarajevo based on the period 2001–2020. Results of the analysis demonstrate that the currently valid and official outside design temperature was low and needs to be revised. As a small-scale example, calculation of the heating needs of one residential unit was made in order to demonstrate the influence of different design outside temperature on the heating needs. These numbers were then extrapolated on the district heating system and the benefits of the proposed approach were underlined. Performed analysis suggest an urgent change in the design temperature for all cities in Bosnia and Herzegovina as it was demonstrated on the example of Sarajevo in this paper.

Keywords: outside design temperature; heating system; heat load; climate change;

1. Introduction

The negative impact of man on the environment is increasing, and global warming has become an everyday topic. In the past 100 years, and especially the last twenty, the average global temperature of the Earth's surface has increased significantly. The period from 2011 to 2020 is the warmest decade since outside temperature measurements have been made [1]. Global warming, which is defined as the warming of the earth due to human activities is one of the biggest problems today [2], [3]. The increasingly frequent weather disasters are precisely the result of climate change (extremely hot summers with more and more hot days and heat strokes, fires due to dry soil, hurricanes and tornadoes in the Western Hemisphere, floods due to heavy rains) [3], [4]. Considering that the human factor has played a major role in the deterioration of the climate, countries together with world organizations are working to reduce the human impact in the future. An increasing number of countries are turning to renewable energy sources and shutting down fossil fuel power plants with the aim of reducing greenhouse gas emissions into the atmosphere. Recent research has shown that if the global temperature were to rise by 2°C by 2050, it would have a terrible impact on agriculture and people's lives in general, and all the previous deteriorations would become even more pronounced and would make life on Earth more difficult. Therefore, the current trend is towards an increase of 1,5°C in order to reduce the impact of climate change [5], [6]. Data for the European Union (EU) show that around 40% of the total final energy consumption goes to the building sector [7]. In terms of CO_2 emissions, residential and commercial buildings account for 36% of total emissions. Energy is used in households for various purposes (hot water, cooking, household appliances), however 70% of the total energy consumption in buildings is used for heating [8].

The climate varies from place to place and directly affects the investment and exploitation costs of the plant, so it is important for the designer to know the outside design parameters, in order to be able to take the influence of the climate into account in an appropriate way. Many studies have investigated the various possible effects of climate change, from rising outside temperatures to changes in precipitation. Spinoni at al. [2] in their study investigated whether energy demand for cooling and heating buildings can be expected to increase or decrease under climate change. For this purpose, they considered two indicators of weather-related energy consumption for heating and cooling buildings: heating degree-days and cooling degree-days. The results they obtained show a projected general decrease in heating degree-days over Europe and increase in cooling degree-days. Vucijak et al. [9] presented practical usability of the one of the statistical process control methods for the evaluation of the climate change effects to the precipitation patterns. They compared the precipitation patterns from the 1961-1990 reference period with the precipitations from the 2000-2010 period in the Bihać area in Bosnia and Herzegovina. As a conclusion they stated that the monthly precipitation patterns have changed, but the observed changes in the total monthly precipitation are statistically expected. Different studies, for different locations, have shown a constant decrease in the number of degree-days for heating. For example, Cvitan et al. [10] analysed climate change for the area of Croatia from the aspect of changing needs for heating and cooling indoor living spaces. As a result of the research, they found a decrease in the need for heating and an increase in the need for cooling in Croatia in the period 1901-2008. Zaninovic et al. [11] analysed in their work relevant meteorological parameters in the design of thermal protection of buildings for 15 locations in Croatia for the 1961 - 1990 period in order to harmonize Croatian norms with norms in European countries. Popovic et al. [12] investigated climate change in Serbia as a result of global warming and assessed the future climate in accordance with the results of climate modelling according to the most used Intergovernmental Panel on Climate Change (IPCC) scenarios. Their assessments indicate that the territory of Serbia will be exposed to influences that may have consequences for the entire society. Muhamedagic et al. in their earlier work [13] announced the need to revise the outside design temperature. They analysed temperature values for the period from 2001 to 2010 and calculated outside design temperature by using only one method.

In this paper, the influence of climate change on the outside design temperature in Sarajevo, and because of that on the required annual energy for heating the interior space, is analysed. For determining new outside design temperature, data on hourly temperature values in Sarajevo for the period from 2001 to 2020, which were obtained by the Federal Hydrometeorological Institute for the Bjelave measuring station, were used. Different approaches for determining the outside design temperature for the winter period were considered, and it was shown that the values of the outside design temperature are highly dependent on the methodology by which they are calculated. The investment value of the building and the power of the central heating system depend on the outside design temperature, because the amount of heat is directly proportional to the difference between the indoor and outside design temperature. The calculated amount of heat required to heat the building directly affects the selection of heating plant equipment (boilers, pipelines, pumps), and reliable determination of the outside design temperature is of great importance when it comes to properly sizing the heating system.

2. Indicators of climate change in Bosnia and Herzegovina

At the beginning of this millennium, the average increase in the mean annual temperature in the territory of Bosnia and Herzegovina was 0,6°C for the period of the last hundred years, and now that increase is more than 1°C. An example of a hundred-year time series shows that the impact of climate change on the climate of our country is evident. In the Strategy for adaptation to climate change and low-emission development of Bosnia and Herzegovina for the period 2020 - 2030 [4], it is stated that according to the analyses of meteorological data for the period 1961 - 2014, the average annual temperature maintains a continuous increase in the entire territory. A positive linear trend was observed in the average annual temperature, which was particularly pronounced in the last 30 years [14]. The increase in air temperature on an annual basis, ranges from 0,4 to 1°C, and during the growing season from April to September, up to 1,2°C. Annual temperature trends at all analysed stations are statistically significant, and the changes are more pronounced in the continental part. The most significant change in this period is observed in the number of cold days and the number of warm days. At all meteorological stations, the number of cold days has a negative trend [4].

In Figure 1 it is shown increase in average annual temperature in the last decade (1990-2000) compared to the reference period (1961-1990) in B&H expressed in °C.

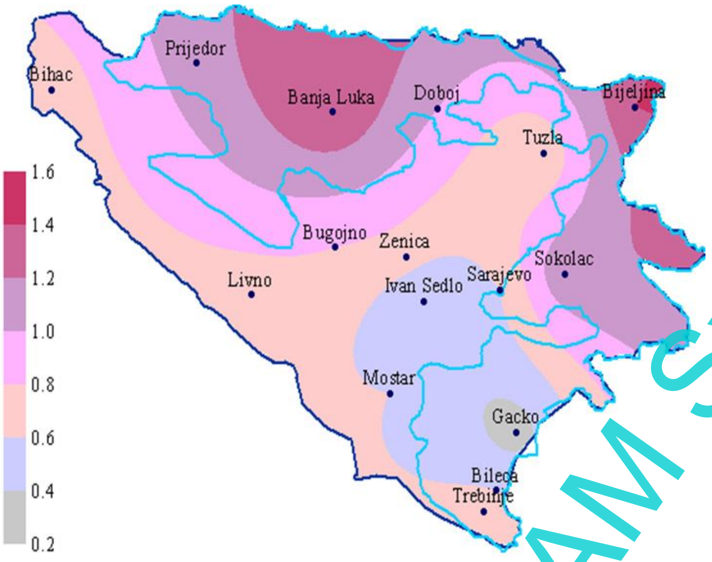

Fig. 1. Increase in average annual temperature in the last decade (1990-2000) compared to the reference period (1961-1990) in B&H expressed in °C [15]

Figure 2 shows the change in average annual outside air temperature for the twenty-year time period 2001-2020 for Sarajevo. An indicator of the severity of the impact of global warming is a linear increase in temperature.

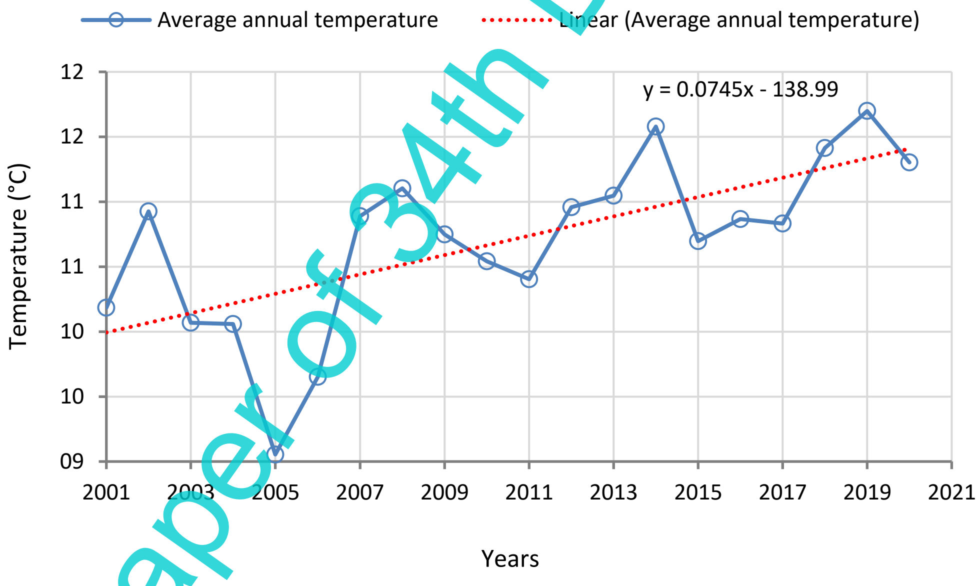

Fig. 2. Average annual temperature trend for Sarajevo in the period 2001-2020.

In addition to the increase in temperature, changes are also noted when it comes to the snow cover. Specifically, for Sarajevo, it is possible to monitor two parameters:

- number of days with snow (sleet, snow) and
- number of days with registered snow cover.

Figure 3 shows the data related to the number of days with snow and the number of days with a registered snow cover in Sarajevo for the period from 1992 to 2020. Also, a linear decrease in the value of the number of days with snow is shown.

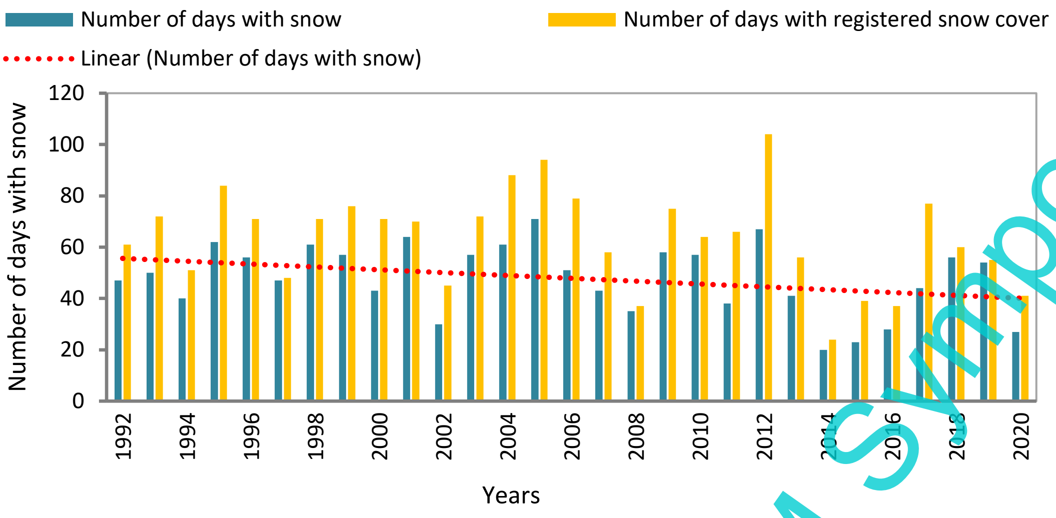

Fig. 3. Number of days with snow and number of days with registered snow cover for Sarajevo (1992-2020)

3. Methodology for determining the outside design temperature

There is no single way to define and determine the outside design temperature for now. It could conditionally be defined as "the lowest temperature of the outside air, at which the HVAC system ensures the pre-required parameters of thermal comfort inside the treated space, regardless of the duration of such condition of the outside air" [16], [17]. However, the lowest temperature that appeared in that place in an observed period is not taken as the outside design temperature of a place, because it occurs very rarely and lasts for a short time. The heating system, which would be designed based on such an absolute minimum, would be over-dimensioned, investment expensive and exploitation uneconomical, because it would very rarely work at full capacity. For the heating system not to be oversized, short-term lowering of the temperature in the building is allowed at extremely low outside temperatures. There are several methods for determining the outside design temperature. They are mainly based on the statistical processing of outside temperatures over a longer period, 10, 20 years or longer.

For the purpose of writing the paper and making calculations, data on hourly values of outside air temperature obtained from the Federal Hydrometeorological Institute for the period 2001-2020 were used. To calculate the outside design temperature, three different periods were analysed, namely two periods lasting 10 years and one period lasting 20 years in order to get a better general picture of the advantages and disadvantages of certain methods. The current value of the outside design temperature used in the design of the heating system for Sarajevo is -18°C and it was obtained according to B. M. Chaplin for a series of 30 years (1956-1985). However, due to global warming and climate change, it is to be expected that this value has changed. The methods used to calculate the new outside design temperature are described below.

3.1. B. M. Chaplin method

The most widespread method for determining the outside design temperature in the areas of the former Yugoslavia is the method named after the Russian scientist B. M. Chaplin. This method was used for determination of the existing and still valid outside design temperatures for all larger places in Bosnia and Herzegovina. According to the Chaplin methodology, the outside design temperature is determined depending on the average temperature of the coldest month in a period of 10 or 20 years (t_m) and the absolute minimum (t_{min}) from the same period, which should be the most current. The ratio of the participation of these two temperatures in the value of the outside design temperature, t_{ODT}, is given by the following expression [16], [17]:

$$t_{ODT} = 0{,}4t_m + 0{,}6t_{min} \quad (1)$$

where $t_m[°C]$ is the mean monthly temperature of the coldest month in the observed period (20 or 10 years) and $t_{min}[°C]$ is the absolute minimum temperature in the observed period (at least 10 years), that is, the lowest temperature that occurred in the observed time period.

Table 1 shows the average monthly air temperatures for the analysed period. From Table 1 it can be seen that for the analysed time period the coldest month is January and that the value of the mean monthly temperature of the coldest month in the observed period is $t_m = 0{,}39$ °C.

	2001-2020											
Month	J	F	M	A	M	J	J	A	S	O	N	D
t$_m$ (°C)	0,39	2,33	6,26	10,75	14,76	19,41	21,47	21,47	15,88	11,17	6,51	1,20

Table 1. Average monthly air temperature (2001-2020)

The second parameter required by the method is the absolute minimum, which specifically in this case means that it is necessary to find the lowest temperature that occurred in the given period (for a series of 20 years, the lowest temperature occurred on January 8, 2017 at 6:00 AM with a value -22.2°C, and it lasted for only an hour). By including in expression 1, the outside design temperature for Sarajevo for the period 2001-2020 is obtained, which is -13,16°C.

3.2. DIN 4701, 1955

This approach to determining the outside design temperature, as well as the ASHRAE approach, starts from the duration of the outside temperature or the frequency of its occurrence. According to DIN 4701, the outside design temperature is the lowest two-day mean value of the outside air temperature that has been reached or failed ten times in a period of twenty years, or in average once every two years [18].

3.3. NOVAK triad

In 1987, the scientist Novak together with his collaborators has developed a method for the calculation of the outside design temperature for the needs of the former Yugoslavia, which is why this method is also called JUS U.J5.600. This method defines the outside design temperature as the mean value of the coldest triad, that is, the coldest three consecutive days of the year for the time series of the considered years [17], [19].

3.4. ASHRAE

The ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) approach for determining the outside design temperature is based on the length or duration of the outside temperature. Therefore, according to American regulations, the outside design temperature is defined as the lowest temperature that occurred for a certain number of hours or days at the observed location. This approach considers the percentage of occurrence of hourly air temperature values above some reference value for a long period of time. The first temperature value that reaches or exceeds the defined threshold (reference value) is considered the outside design temperature. This method is widely accepted in America. According to the American regulations (ASHRAE), there are two different approaches, namely, the old approach that observes the three coldest months of the year (December, January and February, i.e., 2160 h/year) and the new approach that takes into account the whole year during the calculation (8760 h/year) [20], [21].

According to the old ASHRAE approach, there are two different criteria: 99% and 97,5% of hourly temperature values during the 3 coldest months (December, January and February, which is a total of 2160 h/year) when the outside air temperature is equal to or higher from the reference. This practically means that according to the 99% criterion, only in 1% of cases is it allowed for the outside air temperature to be lower than the outside design temperature, i.e., can be overcome in an average of about 22 h/year. The 97,5% criterion is somewhat milder compared to the 99% criterion, and its application results in the outside design temperature being 1 to 2°C higher than the value of the temperature obtained according to the 99% criterion. According to the 97,5% criterion, the outside air temperature will be exceeded on average about 54 h/year, i.e., it is allowed that in 2,5% of cases the outside air temperature is lower than the outside design temperature [20].

A new ASHRAE approach reported in ASHRAE Fundamentals from 2009 [21] looks at the distribution of temperature throughout the year. This approach has two criteria, stricter and milder:

- The stricter criterion requires the representation of the outside temperature in 99,6%, but calculated according to hourly values for the whole year and not for the three coldest months, and this means that the outside temperature must be lower than the outside design temperature 35 h/year. For a period of 20 years, this would mean that the outside air temperature should be the same or lower for 700 hours during the 20 years, while a minimum of 350 hours should occur in a period of 10 years.
- The milder criterion is with hourly representation of outside temperature 99%, and it means that 88 h/year the outside temperature is lower than the outside design temperature [20].

3.5. Method based on minimum annual temperature

This method can be characterized as the simplest that was used in this work and is not related to the duration of the phenomenon. The method based on the minimum annual temperature is based on the determination of the mean values of the absolute minimum annual temperatures for a multi-year series. The expression that defines this method is:

$$t_{ODT} = \frac{\sum_{i=1}^{n} t_{GOD,min,i}}{n} \tag{2}$$

where $t_{GOD,min,i}[°C]$ is absolute minimum annual temperature and n represent number of years.

The calculated outside design temperatures according to different methods were used in the calculation of total heat losses according to standard EN 12831. For the purposes of the calculation, a family house located in Sarajevo, with a total heating area of 62,72m^2, was analysed. Figure 4 shows the geometry of observed residential unit with all internal and external dimensions.

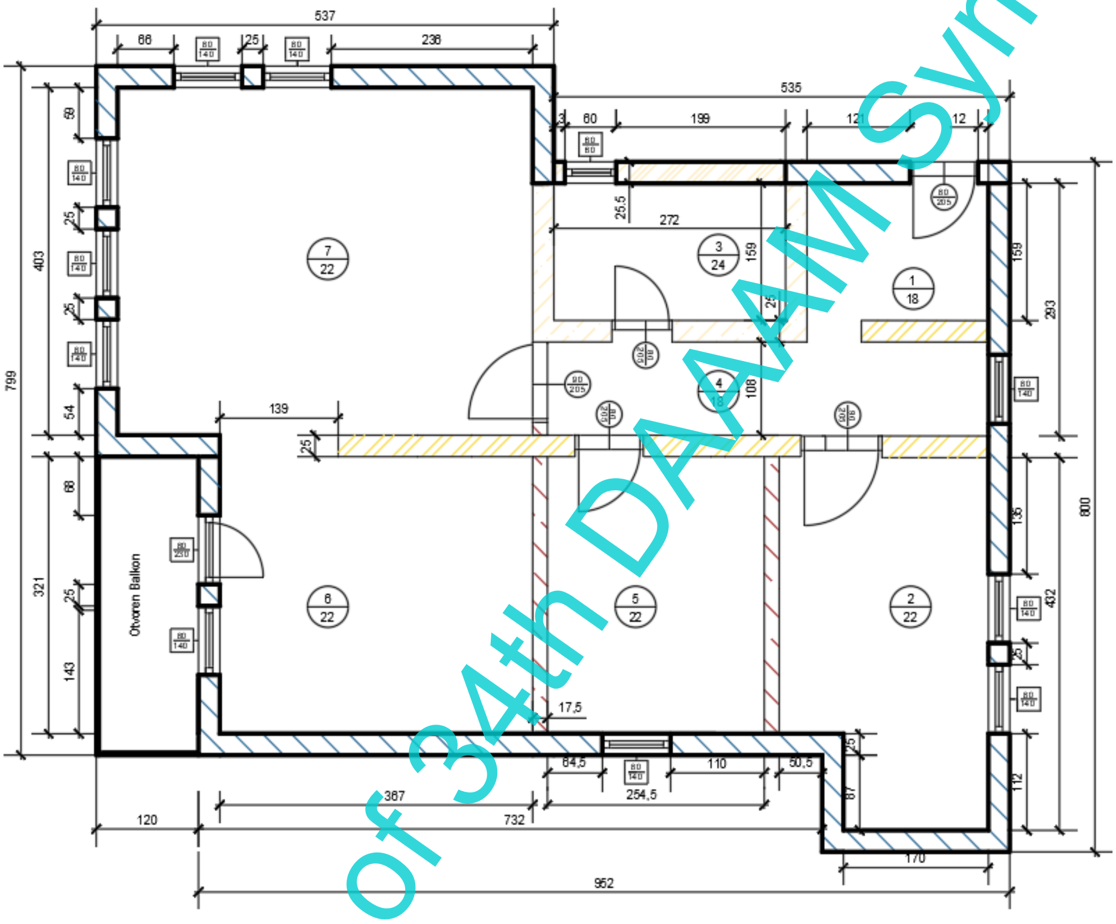

Fig. 4. The geometry of observed residential unit

Heat transfer coefficient for construction elements is given in Table 2.

Heat transfer coefficient [W/m^{2}K]	**Outer wall**	**Inner wall 1**	**Inner wall 2**	**Inner wall 3**	**Floor**	**Ceiling**	**Windows**	**Outer door**	**Inner door**
	0,36	1,71	1,13	2,13	2,09	3,0	1,9	3,5	2,0

Table 2. Heat transfer coefficient for construction elements

4. Results and discussion

The annual temperature change determines the length of the heating period, that is, the number of working days of the heating system. The official value of the average annual temperature for Sarajevo according to measuring data from station Bjelave for the period 1931-1960 is 9,7°C, and that value is still used for calculation [22]. Figure 5 shows the annual temperature trend in Sarajevo for the period from 2001 to 2020, where the value of the mean annual temperature according to the data of the Bjelave measuring station is 10,7°C. Based on the annual temperature variations in Sarajevo, a trend of increasing temperature can be observed, especially in the last 20 years.

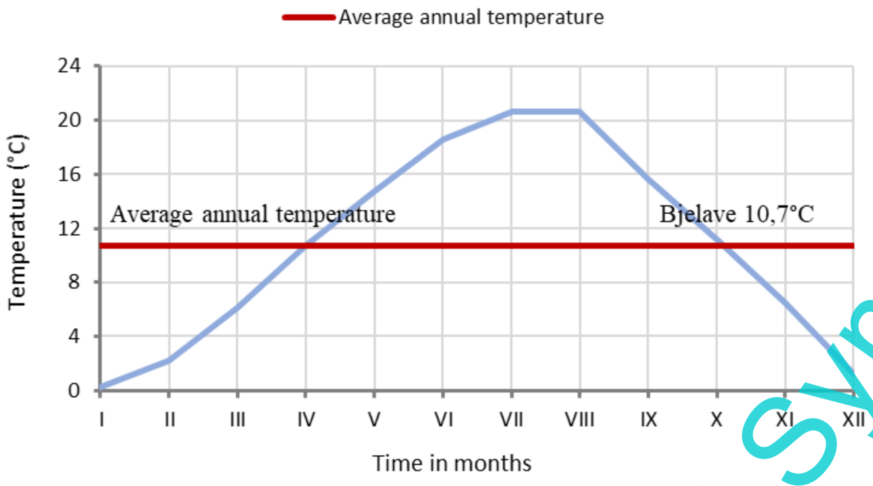

Fig. 5. The annual air temperature trend for Sarajevo for the period 2001-2020.

Since the absolute minimum temperatures in the observed period are used to determine the outside design temperature according to B. M. Chaplin, Figure 6 shows three different temperature values by month for the time period from 2001 to 2020: absolute maximum, mean outside temperature and the absolute minimum.

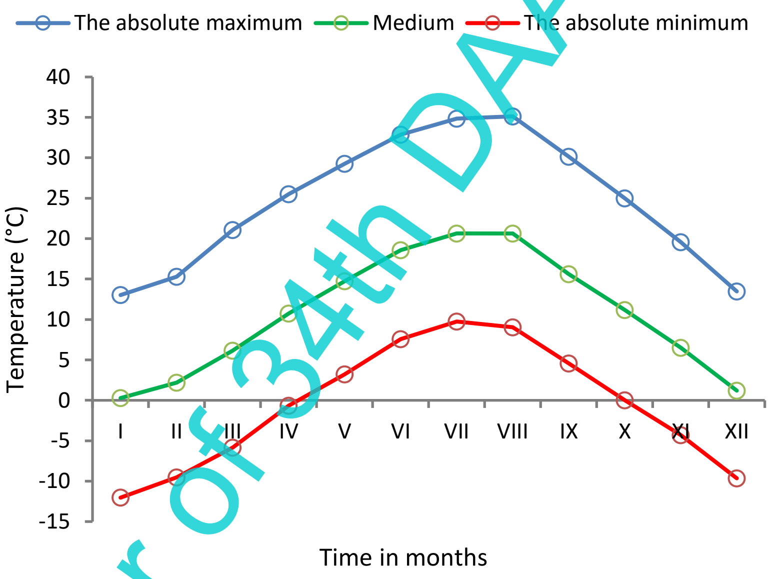

Fig. 6. Absolute maximum, mean outside temperature and absolute minimum for a 20-year time series for Sarajevo

Table 3 provides an overview of the calculated values of the outside design temperature according to several methods. Based on the obtained results, the lowest value of the outside design temperature for a period of twenty years was obtained using the Novak triad and the method based on minimum annual temperatures, while the highest was calculated using a new criterion according to the ASHRAE approach with 99% representation of hourly temperature values during the whole year. Based on the obtained results, it can be seen that the stricter criteria (99,6%) according to the new ASHRAE approach approximately corresponds to the earlier criterion of 99%, while the milder criteria (99%) according to the new ASHRAE approach approximately corresponds to the earlier criterion of 97,5%.

When it comes to the outside design temperature calculated according to B. M. Chaplin, the temperature values are lower if the time period observed is longer. However, an increase in the outside design temperature is evident, from -16°C as calculated for the 20-year time series from 1966 to 1985 according to [17] to -13,16°C for the 20-year time series from 2001 to 2020. It is important to note that when designing the heating system, the official outside design temperature for Sarajevo is still -18°C, which was calculated according to B. M. Chaplin for a series of 30 years (1956-1985) [19]. It can be observed, also, that there is a good agreement between the outside design temperature obtained according to B. M. Chaplin, DIN 4701 and the old ASHRAE 99% approach.

B. M. Chaplin	DIN 4701	Novak-triade	ASHRAE old approach		ASHRAE new approach		Absol. min. temp.
			99%	97,5%	99,6%	99%	
Time period: 2001-2020							
-13,16	-12	-15,13	-12	-9,6	-11	-8,4	-14,04
Time period: 2001-2010							
-10,85	-11,2	-12,14	-11,8	-9,7	-11,2	-8,7	-14,66
Time period: 2011-2020							
-13,07	-12,5	-15,13	-12,1	-9,4	-10,7	-7,7	-13,41

Table 3. Comparison of outside air temperature design parameters for heating determined by different approaches for Sarajevo (2001-2020)

By analysing the data, it was determined that the temperature lower than or equal to -12°C occurs 443 hours during 20 years, and that would be an average of 23 hours a year, which represents only one day a year. The coldest year in the considered period of 20 years was 2017, and in that year the temperature lower than or equal to -12°C occurred 90 hours during the year, which represents an incomplete 4 days. Therefore, a heating system dimensioned according to a temperature lower than the outside design temperature obtained according to the DIN 4701 method (-12°C), ASHRAE 99% (-12°C) or B. M. Chaplin (-13°C), especially in residential buildings, would be oversized.

Figure 7 shows a frequency curve based on which it is possible to see how many days or hours a year the mean two-day outside temperature is below or above a certain value. The two-day mean value of the outside temperature, which was reached or undershot 10 times in a period of 20 years, which means on average once every other year, is -12°C. It can be seen from Figure 7 that the periods of outside temperature duration are longer if the outside temperature values are higher in cold periods.

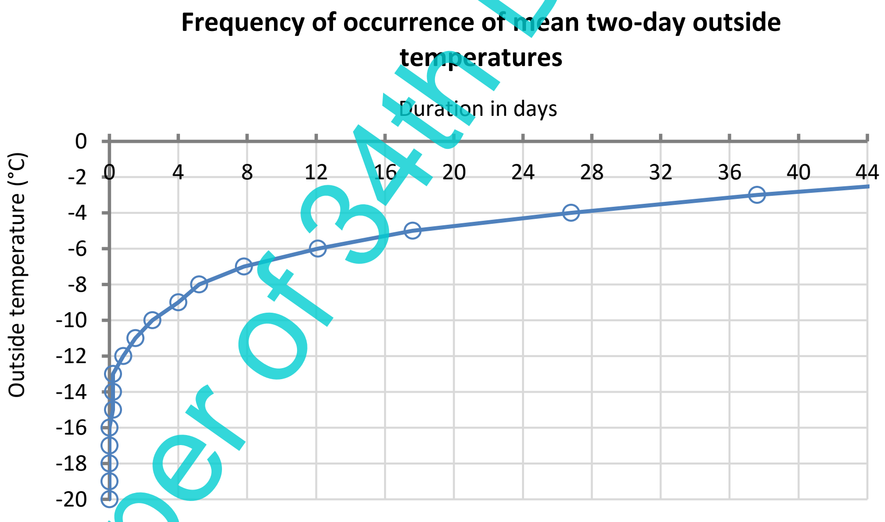

Fig. 7. Outside temperature as a function of duration and frequency

Table 4 shows the heat load for the analysed residential unit when the currently valid outside design temperature for Sarajevo (-18°C) is used in the calculation, as well as the heat load obtained using new outside design temperatures calculated according to different methods. It can be noted that the total heat load at the currently valid outside design temperature of -18°C is 10,95 kW. The total heat load of the building using the new outside design temperature calculated according to the Chaplin methodology is 9,6 KW, which represents a reduction of 12,3% compared to the value of the total heat load at the currently valid outside design temperature.

If the new outside design temperature calculated according to the Novak-triad (-15,13°C) is used for the calculation of the total heat load of the object, it is also obtained that the heat load is less compared to the heat load obtained with the valid outside design temperature about 7,3%. Using the ASHRAE standard, five different values of the outside design temperature were obtained, however, one value of the outside design temperature obtained by the old and one by the new approach was used for the calculation of the heat load.

Heat load	Official for Sarajevo	B. M. Chaplin	DIN 4701	Novak-triade	ASHRAE old (99%)	ASHRAE new (99%)	Absol. min. temp.
	- 18°C	**- 13,16°C**	**- 12°C**	**- 15,13°C**	**- 12°C**	**- 8,4°C**	**- 14,04°C**
Transmission heat load $Q_{T,i}$ W	9766,26	8570,47	8283,87	9057,19	8283,87	7394,43	8787,88
Ventilation heat load $Q_{V,i}$ W	1185,10	1041,19	1006,70	1099,77	1006,70	899,65	1067,35
Total heat load $Q_{i,}$ W	**10951,37**	**9611,65**	**9290,57**	**10156,95**	**9290,57**	**8294,08**	**9855,24**

Table 4. Total heat load at different values of the outside design temperature calculated for a 20-year time period

By comparing the heat losses calculated according to the ASHRAE (old and new approach) and the heat losses obtained with the currently valid outside design temperature (-18°C), it is possible to see that the heat losses are lower by 15,2% with the new outside design temperature according to the old ASHRAE approach, or 24,3% with the outside design temperature according to the new ASHRAE approach. The same percentage reduction of the heat load of 15,2% is obtained with the outside design temperature calculated according to DIN 4701 because the same value of the outside design temperature is obtained as according to the old ASHRAE 99% approach. The last method used to calculate the outside design temperature is the method based on the minimum annual temperature and the value of the outside design temperature was obtained -14,04°C. The total heat load calculated with the outside design temperature obtained according to this method is 10% less than the heat load obtained with the valid outside design temperature. Finally, it can be concluded that the calculated heat load is less in the range of 10% to 24.3% obtained according to the new value of the outside design temperature according to any of the methods compared to the currently valid outside design temperature for Sarajevo.

Chosen example is a small-scale project and differences in the heat demand are not clearly visible and convincing. But if we upscale the level of abstraction and apply the same principle at the district heating of the small municipality we will end up with more convincing numbers. If we assume that instead of originally calculated heat demand of one municipality with 60 MW by using -18°C design temperature, we now apply the value according to DIN 4701 (-12°C, the new heat demand would be 50,5 MW. Now we are talking about large numbers. Consequently, we have less investment in the heat source facility (solar collectors and backup heat pump) but also in the pipeline and substations equipment. The potential savings will be clearly visible and the tightly sized system will operate smooth in all conditions. In our analysis we neglected the thermal accumulation of the buildings where they can play the role of the heat sources and sinks and, we did not mention weather predictor methods in control of the heating systems. These combined approaches can help new and modern systems to maintain the thermal comfort even if the temperature drops below designed value.

5. Conclusion and further work

Different methods for calculating new values of outside design temperature were presented in this paper. It has been shown that different methods result in different values of the outside design temperature. However, according to each of the analysed methods, higher values of the outside design temperature compared to the actual value were obtained for Sarajevo. This can be attributed to the climate change process in Bosnia and Herzegovina. By using the currently valid outside design temperature initially determined according to B. M. Chaplin for a period of 30 years (1956-1985) and new value of the outside design temperature calculated according to B. M. Chaplin for a more recent time period (2001-2020) on example of one residential unit presented in the paper, the heat load was lower by 12,3%. While comparing the heat load calculated with the outside design temperature obtained according to the DIN 4701, a reduction of 15,2% was visible. Therefore, the outside design temperature calculated according to any of the analysed methods, compared to the currently valid, resulted in a reduction of the heating needs. From the obtained results, it can be concluded that there is an urgent need for revision of existing and calculation of new outside design parameters. Since energy consumption in buildings in B&H is more than 50% of the overall final energy consumption, this topic becomes very important.

Based on conducted analysis, it can be concluded that the heating systems designed according to the valid outside design parameters are over-sized and there is a need to correct the outside design parameters. Oversized systems are not only more expensive but are also more energy consuming due to their control difficulties. Further research will be complemented by the analysis of the other outside parameters that were not included in this work, such as heating degree days and heat load duration curves. These values complemented with the concept of thermal inertia of buildings where building can be treated as heat source and/or sink, together with an advanced weather predictor method, should result in optimal size of the heating systems for individual and collective housing or for district heating projects as well.

6. References

[1] Zhang, Y., Zou, M., Yang, S., Lin, Y. & Ye, C. (2017). Colder-winter monthly-temperature forecasting in general trend of global warming via multiple sine functions decomposition. In 36th Chinese Control Conference (CCC) Dalian, China, pp. 4551-4555, DOI: 10.23919/ChiCC.2017.8028073.

[2] Spinoni, J., Vogt, J. V., Barbosa, P., Dosio, A., McCormick, N., Bigano, A., & Füssel, H. M. (2018). Changes of heating and cooling degree-days in Europe from 1981 to 2100. International Journal of Climatology, Vol. 38, No. S1, e191-e208, https://doi.org/10.1002/joc.5362

[3] Reddy, M. P., Aneesh, A., Praneetha, K., & Vijay, S. (2021). Global Warming Analysis and Prediction Using Data Science. In 2021 Fifth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC) (pp. 1055-1059). IEEE. DOI: 10.1109/I-SMAC52330.2021.9640944

[4] Radusin, S., Jevtić, I., Cero, M., Abdurahmanović, I., & Cupać, R. (2020). Strategy for adaptation to climate changes and low-emission development of Bosnia and Herzegovina for the period 2020–2030. UNDP.

[5] Hoegh-Guldberg, O., Jacob, D., Bindi, M., Brown, S., Camilloni, I., Diedhiou, A., ... & Zougmoré, R. B. (2018). Impacts of 1.5 C global warming on natural and human systems. Global warming of 1.5° C.

[6] Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., ... & Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. Proceedings of the National Academy of Sciences, Vol. 115, No. 33, pp. 8252-8259, https://doi.org/10.1073/pnas.1810141115

[7] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (EPBD). Off. J. Eur. Union, (2010**)**. 153, pp. 13–35.

[8] De Rosa, M., Bianco, V., Scarpa, F., & Tagliafico, L. A. (2014). Heating and cooling building energy demand evaluation; a simplified model and a modified degree days approach. Applied energy, Vol. 128, pp. 217-229. https://doi.org/10.1016/j.apenergy.2014.04.067

[9] Vucijak, B., Midzic Kurtagic, S., Ceric, A., Kupusovic, T., & Spago, S. (2012). Assessment of climate change effects to precipitation patterns using statistical process control methods. Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, Volume 23, No.1, ISSN 2304-1382, ISBN 978-3-901509-91-9, Ed. B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, pp. 277-280

[10] Cvitan, L., & Sokol-Jurković, R. (2011). Changes of heating and cooling demands in Croatia during the period 1901-2008. Croatian Meteorological Journal, Vol. 46, No. 46, pp. 27-33.

[11] Zaninović, K., Gajić-Čapka, M., Žibrat, Z., & Šimetin, V. (2001). Meteorological parameters in the design of thermal protection of buildings. Građevinar, Vol. 53, No. 10, pp. 619-629.

[12] Popović T, Đurđević V, Živković M, Jović B & Jovanović M. (2009). Climate change in Serbia and expected impacts. Environment towards Europe, Fifth Regional Conference – Belgrade, pp. 6 – 11.

[13] Muhamedagic, R., Martinovic, S., & Lulic, H. (2013). Global warming and outdoor design temperature, 17th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2013, pp. 289 – 292, Istanbul, Turkey.

[14] Radusin, S., Medić, V., Cero, M., Abdurahmanovic, I., & Avdić, S. (2016). Third National Report and Second Biennial Report on Greenhouse Gas Emissions of Bosnia and Herzegovina under the United Nations Framework Convention, UNDP, Sarajevo.

[15] Vukmir, G., Stanišljević, LJ., Cero, M., Cacan, M., Marković, M., Rudež, M., Laganin, O., Kostić, R., Oprašić, S., Ćatović, S., & Lukić, T. (2009). Initial National Communication of Bosnia and Herzegovina under the United Nations Framework Convention on Climate Change, UNDP, Banja Luka.

[16] Todorović, B. (2009). Designing of central heating plants. Projektovanje postrojenja za centralno grejanje, Univerzitet u Beogradu, Mašinski fakultet, 11. izdanje, ISBN 978-86-7083-678-5, Beograd.

[17] Kulić, E. (2002). Building energy use – situation in B&H and worldwide - part II specific energy consumption characteristics development of domestic standards on heat loss calculations. Mašinstvo Vol. 2, No. 6, pp. 111 – 124.

[18] DIN 4701-1 (1997). Rules for calculating the heating load of buildings, Part 1: Basics of the calculation. Regeln für die Berechnung der Heizlast von Gebäuden, Teil 1: Grundlagen der Berechnung, DIN Taschenbuch 84, Beuth, Berlin.

[19] Kulić, E. (2019). Energy use in building construction. Zbornik Međunarodnog Kongresa o KGH, Vol. 32, No. *1*, pp. 135-147.

[20] American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2001). ASHRAE Handbook of Fundamentals, Chapter 27. Climatic Design Information, ASHRAE, Atlanta.

[21] American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2009). ASHRAE Handbook of Fundamentals, Chapter 14. Climatic Design Information, ASHRAE, Atlanta.

[22] Kulić, E. (1989). Principles of designing heating systems. Principi projektovanja sistema grijanja, Mašinski fakultet Univerziteta u Sarajevu, Sarajevo.