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*Published in:*
SISÄILMASTOSEMINAARI 2023

Julkaistu: 01/01/2023

*Document Version*
Publisher's PDF, also known as Version of record

*Please cite the original version:*
Velashjerdi Farahani, A., Jokisalo, J., Korhonen, N., Jylhä, K., & Kosonen, R. (2023). OVERHEATING RISK OF APARTMENTS IN THE HELSINKI REGION DURING THE HOT SUMMER OF 2021. teoksessa *SISÄILMASTOSEMINAARI 2023* (Sivut 89-94). (Sisäilmayhdistys raportti; Nro 41). SIY Sisäilmatieto Oy.

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# OVERHEATING RISK OF APARTMENTS IN THE HELSINKI REGION DURING THE HOT SUMMER OF 2021

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## ABSTRACT

During heat waves, room air temperatures without cooling can raise health risk levels. Therefore, it is important to study the actual room air temperatures in residential buildings during hot summers. In this study, the hourly indoor temperatures of 6057 apartments during the hot summer of 2021 were measured and analyzed in the Helsinki region. These apartments are different in size and age. The results showed that the indoor temperature in 96% of the apartments exceeded 27 °C, 34% exceeded 30 °C, and around 5% of them exceeded 32 °C. The results showed a significantly high risk of overheating in most of the apartments despite differences in room number and age.

## INTRODUCTION

Human-induced climate change has been the cause of the rise in global mean temperature. More frequent, more serious, and much longer heatwaves are associated with it [1], [2]. This issue is associated with indoor overheating risks during hot summers and can threaten the occupants' well-being and thermal comfort. These risks may be higher in residential buildings in Nordic countries since they are not equipped with cooling systems. Thus, investigating overheating risks in Nordic residential buildings during climate change-associated summers seems to be necessary. This study is a field measurement of indoor temperature in residential buildings in Helsinki, Finland during the hot summer of 2021. The main objective of this study is to investigate the actual temperature in apartments during the hot summer and study the effects of the size and the construction year of the apartments on overheating.

## METHODS

### Data collection

The hourly room air temperature data of apartments was collected from mid-May to the end of August 2021in the Helsinki region. The design year, the area, and the number of rooms in the apartments are reported. Temperatures were measured in 10597 apartments by the IoT sensors installed in each apartment's main corridor to get the average room air temperature of the apartment. The sensors can measure temperatures in the range of -40 to +60 °C with an accuracy of ±0.2 °C.

The data analysis was done using python programming with Jupiter notebook. the measurements were done in more than 10000 apartments, but there is missing data in some of the apartments. The apartments with more than 15% of the time missing data are filtered out. Moreover, the apartments with missing data for more than three hours in a row, and the ones with the highest temperature of more than 40 °C and the lowest temperature of less than 18 °C are removed. This way, the faults in IoT sensors and the potential unoccupied apartments are avoided to influence the analysis. The apartments with an acceptable amount of data are selected and through linear interpolation, the needed data is processed. Overall, there are 6057 apartments with full hourly measurements from the 15th of May to the 31st of August 2021.

**Buildings' description**

The apartments are categorized into 5 groups based on Finnish building codes which were used during the design process of the buildings. This way the effects of building codes' criteria on overheating are considered. The group of before 1977 represents a period when there was no building code [3]. The first building code came into force in 1977 and set regulations for U-values of the building envelope [4]. In 2003 the regulations for window U-values changed along with a new regulation of heat recovery of ventilation [5], [6]. A separate group of 2010-2012 can be defined by tighter U-value requirements, [7] which came into force in 2010. The update in 2012 set a criterion of a maximum of 150 Kh over 27 °C during June-August to address overheating [8] that must be proofed by simulations. The number of apartments in each design year category summer is shown in Table 1.

*Table 1. The number of apartments in each design year group.*

| Design year groups | No. apartments |
|---|---|
| Before 1977 | 1802 |
| 1977-2003 | 2188 |
| 2004-2009 | 949 |
| 2010-2011 | 245 |
| After 2012 | 873 |

On the other hand, the apartments are different in size and the number of rooms. The area of the apartments varies between 20 to 230 $m^2$ and the apartments have from 1 to 5 rooms. The breakdown of each apartment type in the data is shown in Table 2. As can be seen, most of the measured apartments have two or three rooms, and few of them are with 5 rooms.

*Table 2. The number of apartments in each apartment type group.*

| Type groups | No. apartments |
|---|---|
| 1-room | 437 |
| 2-room | 2743 |
| 3-room | 1990 |
| 4-room | 769 |
| 5-room | 79 |
| 6-room | 3 |

**Outdoor air temperature during the hot summer of 2021**

The year 2021 was a hot summer in Finland with 30 hot days. A hot day is defined as a period of days with the daily maximum hourly outdoor temperature above 25 °C [10]. Fig. 1 shows the daily maximum, average, and minimum hourly temperatures at the Helsinki Vantaa weather station during the summer of 2021. In 2021, the longest heatwave lasted for 16 days and took place in July. Moreover, the maximum temperature exceeded 30 °C in 7 days.

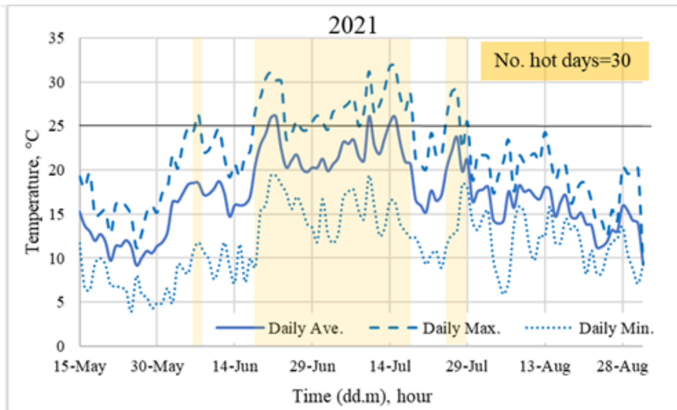


*Figure 1. The daily maximum, average, and minimum temperatures at the Helsinki Vantaa weather station during the summer of 2021.*

**Temperature assessment criteria**

To define overheating in the apartments, the requirements suggested by the Ministry of the Environment and Ministry of Social Affairs and Health of Finland are used. Based on the requirements of the Ministry of the Environment of Finland, only 150 Kh above 27 ◦C is allowed for the simulation results in the design phase of the new residential buildings during the summer months (June-August) [12]. The number of degree hours above 27 ◦C in the studied apartments is compared to the value of 150 Kh even though the results are from field measurements done from mid-May to the end of August [12], The limit for the indoor air temperature of 32°C outside the heating season [13] concerning the health and well-being of occupants in all the living spaces that are used. For elderly people who are cared for in residential living spaces, this maximum value is reduced to 30 °C [13]. The degree hours above 27 °C, 30 °C, and 32 °C are calculated for mid-May to the end of August 2021 for all the studied apartments.

**RESULTS**

**Overheating risk assessment**

To define the overheating risk, each apartment's maximum temperature for the whole summer is analyzed and compared to the three indoor temperature criteria (27, 30, and 32 °C). Fig. 1 shows the percentage of apartments with the maximum temperature of the whole summer above the criteria. The maximum temperature of the whole summer period is higher than 27 °C in 96% of the apartments. It is above 30 °C in 32% of the apartments, while in 4% of the apartments, the maximum temperature of the whole summer exceeds 32 °C. This shows that there is a significant number of apartments where the room air temperature is high from the thermal comfort point of view during the hot summer.

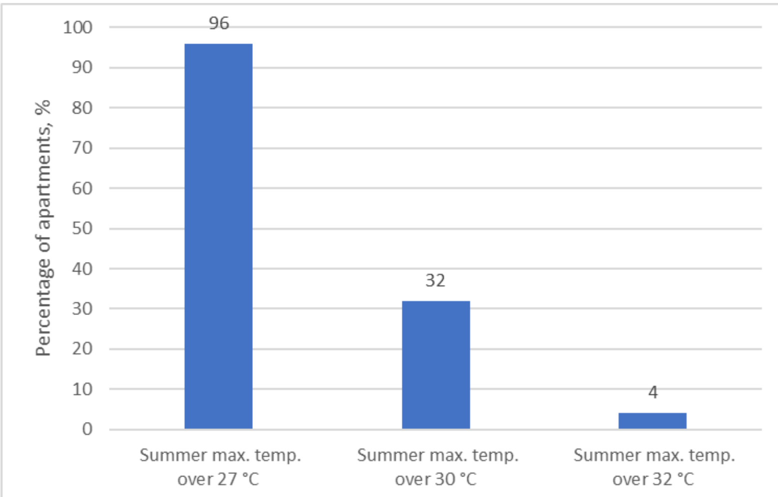


*Figure 2. The percentage of apartments with the whole summer maximum hourly temperature exceed 27 ℃, 30 ℃ and 32 ℃.*

Despite many apartments with the whole summer hourly maximum temperature higher than the indoor temperature criteria, the number of hours with high temperatures is needed to thoroughly understand the overheating issues in apartments. Thus, the degree hours above 27 °C, 30 °C, and 32 °C for each apartment during the whole summertime are analyzed. Fig. 3 displays a summary of the degree hours above the criteria of the 98 percentiles of the apartments. The degree hours above 27 °C are significantly high with an average of 444 Kh which is much higher than the building code required value of 150 Kh for new apartment buildings. The maximum degree hours above 27 °C is around 1200 Kh. These results show the high risk of overheating concerning thermal comfort during the hot summers. The average degree hours above 30 °C and 32 °C are 3 Kh and 0.3 Kh, respectively, which are relatively low. The maximum degree hours above 30 °C are around 300 Kh which shows a high risk of overheating for elderly occupants of residential buildings.

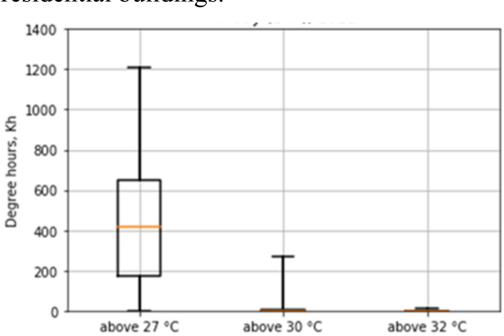


*Figure 3. The degree hours above the criteria in all the apartments.*

**Overheating risk and apartments characteristics**

All the apartments are categorized into 5 design year groups and 6 apartment type categories. Since the number of degree hours above 30 °C and 32 °C is relatively small, the degree hours above 27 °C for each group are shown in Fig. 4. In all the groups, the overheating risk in terms of degree hours above the criteria is high. The degree hours above 27 °C are lower in the newest apartments (after 2012). This category includes the apartments designed based on the latest Finnish building code and the requirement of degree hours above 27 °C to be lower than 150 Kh during the summer. However, the average degree hours above 27 °C in this category is about two times higher than 150 Kh.

On the other hand, the degree hours above 27 °C are higher in the apartments with 1 or 2 rooms than in the apartments with 3 or 4 rooms. However, the number of apartments with 5 and 6 rooms is relatively small in this data and the comparison between these two groups and the small apartments does not seem to be reasonable.

Number of apartments in each category

| before 1977 | 1977-2003 | 2004-2009 | 2010-2011 | after 2012 |
|---|---|---|---|---|
| 1802 | 2188 | 949 | 245 | 873 |

| 1 room | 2 room | 3 room | 4 room | 5 room | 6 room |
|---|---|---|---|---|---|
| 473 | 2743 | 1990 | 769 | 79 | 3 |

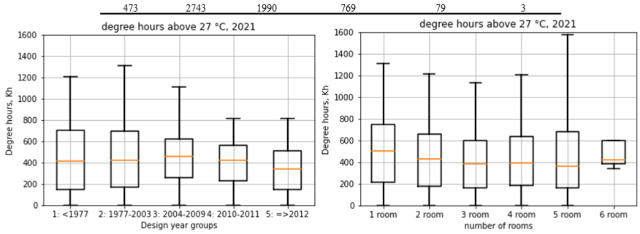


*Figure 4. The degree hours above 27 ℃ in different design year and type categories.*

## CONCLUSION

This paper has presented the results obtained from a thorough field study on indoor temperature conditions in more than 6057 Finnish apartments during the whole summer of 2021 in the Helsinki region. The overheating analyses have been undertaken to show the temporal aspects of overheating, with additional consideration of the apartments' age and the number of rooms. Finnish regulations and guidelines were used to define overheating risk.

In almost all the apartments, the maximum temperature of the whole summer exceeds 27 °C. Moreover, the average degree hours above 27 °C is around three times higher than the building code required value for the new apartment buildings (150 Kh). The maximum temperature of the whole summer exceeds 30 °C in one-third of the apartment. This shows the high well-being risk of overheating for the elderly occupants of residential buildings during hot summers.

The analysis signifies that the new apartments designed based on the latest Finnish building code after 2012 have lower overheating than the older ones. However, the average degree hours above 27 C in these apartments is higher than the required value of the building code. On the other hand, apartments with 1 or 2 rooms are with higher overheating than the ones with 3 or 4 rooms.

**Acknowledgments**

This study is part of the following projects: HEATCLIM (Heat and health in the changing climate, Grant Numbers. 329306, 329307) funded by the Academy of Finland within the CLIHE (Climate change and health) program.

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