Addressing the Overheating Crisis and Its Socio-Economic Implications: A Case Study in London's High-Risk Areas

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Abstract. Purpose- The number of excess deaths in England and Wales during the second heatwave period in 2022 was the greatest it has been since 2018. Greater London is particularly at risk for indoor overheating due to the predicted increase in hot summers from 50–60% by 2050, which can have serious negative effects on the socio-economic state of the city. The purpose of this study is to assess and predict the risk of overheating in a residential apartment building in a high-risk London heatwave location.

Methodology-This study uses computer simulation and on-site measurements to create a virtual model for IES VE dynamic thermal modelling and perform overheating assessment simulations in a London apartment complex using the CIBSE TM59 methodology.

Findings- The percentage hours with exceeding temperature surpassed 50% above the standard threshold in the 2020s scenario, which increased two folds for the 2050s and 2080s. Moreover, the bedrooms' operational temperatures are found to be terribly above the safety standard.

Implications- The findings implicate examining the economic viability and effectiveness of various solutions in the future to prevent residential building overheating in London. Further investigation can be done by conducting in-depth experiments on the susceptibility of various floors to overheating.

Originality/value- The paper offers novel insights into the overheating risk assessment in London, particularly focusing on households in high-risk areas. The study contributes to the conversation on sustainability practices and their socio-economic implications by highlighting the urgent need for retrofitting frameworks to promote sustainable building design and practices.

Keywords: Overheating · Built environment · Socio-economic · CIBSE TM59 · Building retrofitting

1 Introduction

After the dreadful heat wave of 2018, the second heatwave period (10–25 July) in 2022 witnessed the highest number of excess deaths in the England and Wales region, with 2,227 excess deaths (10.4% above average) (UK Health Security Agency & Office

K. Al Marri et al. (Eds.): *BUiD Doctoral Research Conference 2023*, LNCE 473, pp. 172–181, 2024.
https://doi.org/10.1007/978-3-031-56121-4_17

for National Statistics 2022). As global temperatures rise, the risk of experiencing a hot summer is expected to increase, rising to 50–60% by 2050 (Met Office 2022). Additionally, it is predicted by the UK government that by 2070, summer temperatures will increase by 1.3 °C to 5.1 °C and winter temperatures will increase by 0.6 °C to 3.8 °C in a high emission scenario. Since the external environment is a key driver of indoor conditions, extremely hot summers would translate to a higher overheating risk in UK homes, potentially having negative effects on the occupants' health and well-being (Petrou et al. 2019). In addition to the terrible death tolls, persistent overheating can have cumulative negative effects on a variety of socio-economic factors, including the physical and emotional health of inhabitants, discomfort, reduced productivity, and financial concerns (Mourkos et al. 2020; Murage et al. 2020; Mavrogianni et al. 2022). The socioeconomic implications of all these factors are hence unfavourable.

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Statistics conducted by the UK government show that Greater London and the South-East of England are particularly vulnerable to indoor overheating in residential buildings (Botti et al. 2022). Over half of London was shown to be at high risk of overheating in the Approved Documents of the Building Regulations in England, with the remaining half at moderate risk, which is extremely worrisome (HM Government 2010). In addition to the London houses, the risk of overheating is particularly superior in highly urbanized and densely occupied apartment blocks due to compactness, airtight insulation, and limited ventilation (Aliya, Saleh & Al-Khatri 2021). Besides, overheating risks are mostly associated with urban centres, building attributes, and occupant behaviour, notably in homes built after the 1980s with less heat loss and insufficient ventilation (Botti et al. 2022). For example, in an apartment building, the top floor and south/west facing apartments may receive more sunlight than the ground floor apartments. Thus, the harmful effects of home overheating are amplified in a densely populated area like London, where there are 145–210 or more residences per hectare (Centre for London 2016) and call for major refurbishments.

Since 2008, the UK has pledged to mitigate the effects of global warming and overheating risks by lowering CO_2 emissions by 80% below baseline levels of 1990 by 2050 (Petrou et al. 2019). Similarly, the Climate Change Committee's most recent assessment of heat-related risks in UK buildings provides several mitigating measures, such as integrated passive and/or mechanical cooling (Climate Change Committee 2022). However, just 3% of UK houses currently have air conditioning, therefore without proper cooling methods implemented through new construction and retrofitting, non-mechanical cooling in residential dwellings will not be sufficient by 2050 (Hughes & Natarajan 2019). Therefore, it is crucial to raise awareness of the issue and take the necessary steps to ensure that people can comfortably reside in such dwellings even during the warmest parts of the year in the UK.

Thus, the motivation of this study is to assess and predict the risk of overheating in a residential apartment building situated in a high-risk area of London during the heatwave-prone months. The above discussion prompted the development of two significant research questions:

1. Are naturally ventilated London homes considered safe for the occupants during the summer months?
2. What future overheating risks await these homes in the absence of refurbishments or mitigation strategies?

This study, therefore, intends to answer the above-mentioned research questions by conducting overheating risk assessments on a case study building in London following the CIBSE TM59: 2017 Design Methodology for dwellings.

2 Theoretical Underpinning

2.1 Overheating Causes and Drivers

The risks and factors of overheating in UK homes have been studied extensively for the past two decades since the UK government announced its heatwave strategy during the 2003 heatwave (Hughes & Natarajan 2019). The most significant contributors to indoor overheating were found to be the structure and location of the building. The risk for overheating in cold and temperate regions, such as the United Kingdom, is mostly influenced by the ambient air and solar radiation, as well as the relative humidity and wind speed (Taylor et al. 2023). Moreover, the microclimate around the building is considerably responsible for the warming that occurs inside due to the lack of surrounding vegetation and the presence of heat-radiating surface materials like concrete (NHBC Foundation 2012). Additionally, exterior factors such as heat transfer, ventilation losses, and radiative heat gain then interact with the features of the building to affect indoor overheating (Taylor et al. 2023).

Some of the main causes of overheating in the summer addressed in multiple recent studies are larger glazing areas (south/west/east facing), no/poor external shade, limited/restricted window operations for privacy and security reason, and greater insulation and air tightness (Mitchell & Natarajan 2019; Petrou et al. 2019; Aliya, Saleh & Al-Khatri 2021; Botti et al. 2022; Taylor et al. 2023). Besides old builds, a growing body of research suggests that newer buildings, even meeting high energy efficiency criteria, can also become too hot in the summer (Salem, Bahadori-Jahromi & Mylona 2019). This is because homes in the UK are typically designed for cold climates with high thermal mass for storing heat with little thought given to reducing the risk of overheating in the summer (Taylor et al. 2023).

2.2 Overheating Criteria

Overheating in homes, whether naturally or artificially ventilated, may now be assessed with a relatively new design methodology called CIBSE TM59 (Mourkos et al. 2020). This methodology was created in 2017 to evaluate the risk of domestic overheating after the Zero Carbon Hub (Zero Carbon Hub 2015) issued an evidence evaluation highlighting the lack of guidelines for residential overheating (CIBSE 2017). The TM59 is a standardized approach for evaluating and predicting the risk of overheating in residential buildings using Dynamic Thermal Simulations (DTS), suitable for predominantly but not limited to naturally ventilated houses and flats (Table 1).

Table 1. TM59 criteria (a) and (b) for naturally ventilated homes

	Rooms analysed	Criteria	
a	Living room, kitchen, bedrooms	$H_e\ (\Delta T \geq 1\ °C) \leq 3\%$	(1)
		The percentage of occupied hours that are greater than or equal to 1 °C from May to September inclusive should not be more than 3% of the occupied hours of 09:00–22:00 for the living room and kitchen and 24 h for bedrooms	
b	Bedrooms	$(T_{op} > 26\ °C) \leq 1\%$	(2)
		The operative temperature should not be more than the 26 °C threshold for more than 1% of the assumed sleeping hours of 22:00–07:00 annually (33 h/year)	
Source: CIBSE 2013, 2017 where H_e is the hour of exceedance during $\Delta T \geq 1$ °C			
ΔT is mentioned in the TM52 criterion 1 as $\Delta T = T_{op} - T_{max}$ (CIBSE 2013)			(3)
T_{op} is the operative temperature of the room analysed			
T_{max} is the maximum acceptance temperature and can be expressed as $T_{max} = 0.33T_{rm} + 21.8$			(4)
T_{rm} is the subjective operating mean temperature (°C) and can be estimated by $T_{rm} = (1 - \alpha)\ T_{0d-1} + \alpha T_{rm-1}$			(5)
where α is a constant usually taken as 0.8, while T_{0d-1} and T_{rm-1} are the daily and running mean temperatures, respectively, of the day before the day of interest (T_{0d}) (Mitchell & Natarajan 2019; Petrou et al. 2019; Mourkos et al. 2020)			

The TM59 guideline combines the CIBSE TM52 criterion 1 for limiting thermal comfort and avoiding overheating risk in European buildings and CIBSE Guide A for limiting bedroom temperatures as criteria (a) and (b) respectively (CIBSE 2017). The guide further provides a variety of input data for DTS, including internal gain profiles, occupancy, equipment, and lighting profiles which are described in the methodology section. In short, the goal of the TM59 method is to supply a normative framework for analysing overheating that can "assist design decisions" across industries (Mourkos et al. 2020).

3 Methodology

This study examines a London apartment building as a case study using a computer simulation approach with IES VE modelling software (IES 2023a) to analyse the risk of summer overheating in the first-, mid-, and top-floor units and predict future risks. The apartment was simulated using on-site measurements for IES VE dynamic thermal modelling to ensure compliance with TM59 criteria. Additionally, a multitude of inputs such as weather and construction data, thermal gains, occupancy profiles, and window operations were incorporated into the software to run the overheating assessment simulations.

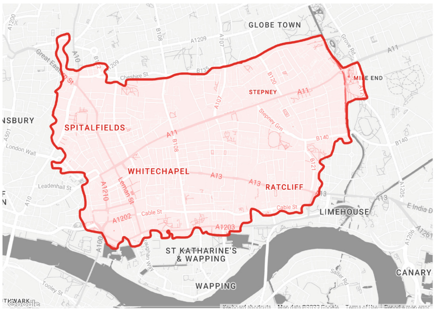
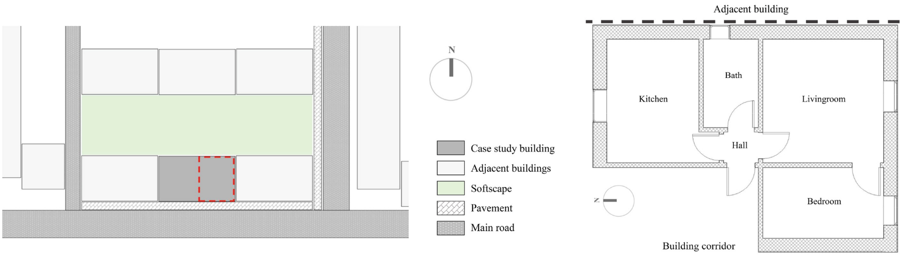


Fig. 1. London E1 postcode zone (Source: Google Maps)



a. b.

Fig. 2. (a) Site boundary condition, and (b) Double bedroom flat floor plan (Source: Author)

3.1 Building, Location, and Weather Data

The case study building is a five-story apartment in Central London's E1 postcode region, which falls under the city's high overheating risk locations according to Building Regulations 2010: Approved Document O (Fig. 1) (HM Government 2010). The building is an old-built with its main façade facing south and shares adjacency with multiple adjacent buildings. Figure 2a illustrates the building's boundary conditions, which should be considered while evaluating TM59 because nearby microclimate factors like pavement and highways have a significant influence on heat-island effects. Also, Fig. 2b shows a typical floor plan of the flats, which features a south-facing living room and bedroom separated by a north-facing kitchen.

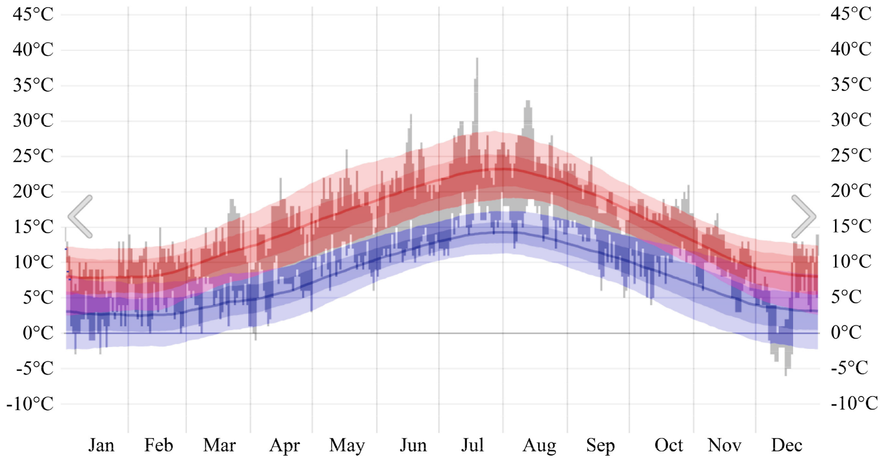


Fig. 3. Annual temperature profile of London 2022 (Source: Met Office 2022)

By TM59 guidance, the latest CIBSE 2016 DSY1 weather file for the 2020s, high emissions, 50% percentile scenario was obtained from CIBSE TM49 (CIBSE 2014) and the London Weather Centre (LWC) (Fig. 3) was chosen as the weather station based on the case study location (Virk & Eames 2016; CIBSE 2017; Met Office 2022). The current study considered the summer months from May 1st through September 30th, 2020, a period of 30 years reflective of probable future climatic conditions. Additionally, using future DSY1 files for the 2050s and 2080s, this study examined the risk of overheating in the absence of refurbishments to the case study building.

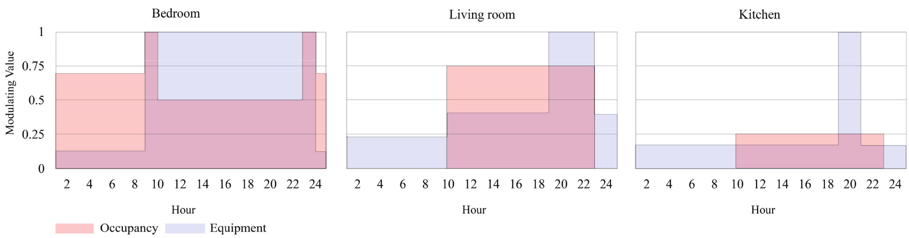


Fig. 4. Occupancy and Equipment profiles for a 1-bedroom (double bed) flat (Source: CIBSE 2017)

3.2 Thermal and Construction Data

The Standard Assessment Procedure (SAP) (BRE 2014) report was used to obtain the construction details while on-site measurements were used for the dynamic model. In addition, the CIBSE Guide A was used to determine the precise thermal parameters of the building materials such as U-values, density, heat capacity, etc. (CIBSE 2015). Figure 4 shows the recommended occupancy and equipment daily profiles for the bedroom, living room, and kitchen, which were used for the Apache simulation in IESVE software. Next, window operation profiles were developed in the IESVE Macroflo application based on the TM59 recommendation, which suggests opening windows only when a room is occupied and when the indoor dry bulb temperature is above 22 °C for naturally ventilated homes. Following that, these profiles were then linked to the corresponding room's occupancy profiles.

3.3 Computer Simulation

The overheating risk assessment was performed by the IESVE simulation engine, which has undergone comprehensive validation using industry-standard methods (EERE 2023; IES 2023b). First, a virtual thermal model of the case study building, and its surrounding environment (adjacent buildings, pavement, motorway) were modelled in the software. Next, a complex custom workflow was used to develop the thermal model for DTS, including setting up the TM59 weather file, categorizing rooms as independent thermal zones, and assigning relevant data. Since CIBSE emphasises precision in simulation setup, assigning data for overheating evaluation is a vital stage. So, there were three major steps in this process:

1. Assigning appropriate thermal templates.
2. Assigning proper construction data obtained from CIBSE Guide A.
3. Creating and assigning window operations by room and criteria.

4 Results

Following the methods described above, the three case study flats were simulated for the overheating assessment using DSY1 2020s, 2050s and 2080s scenarios for the predicted risk assessments. A summary of the TM59 findings is shown in Fig. 5, where it is evident that all of the living rooms on the three floors fail criteria a, and bedrooms fail both (a) and (b). Likewise, the kitchens on all levels pass the overheating assessment due to their north orientation and have been excluded from the discussion.

The results for criterion (a) reveal that the living rooms are most susceptible to overheating, which will only rise exponentially in the 2050 and 2080 scenarios. The percentage of hours in the first-floor living room that surpasses the 3% threshold (formula 1) is 6% in the current 2020s scenario, but rises to 9.3% and 13.6% in the 2050s and 2080s, respectively (Fig. 5). The mid-floor living room shows the highest proportion of hours that are exceeded, which is 7.3% in the present year and nearly doubles in the 2080s scenario. The top-floor living room exceedance, on the other hand, is less than

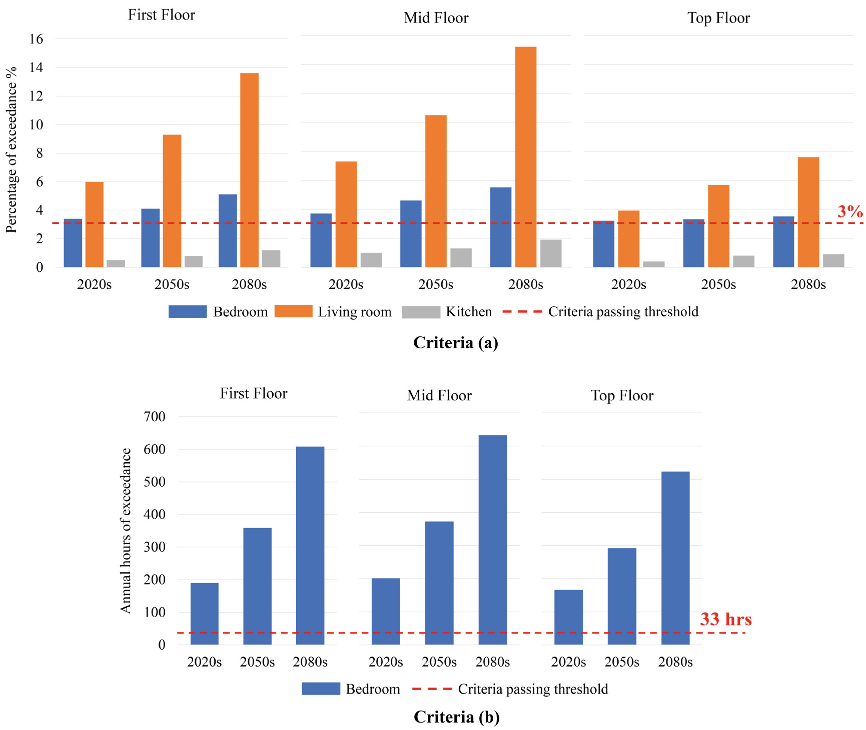


Fig. 5. Summary of results for overheating risk – TM59 criteria (a) and (b) (Source: Author)

the other assessed floors but is nevertheless greater than 3% over the years, hence failing criteria a. Furthermore, the bedrooms exhibit a similar trend of rising overheating risks for first and midfloor levels, where they are slightly above the threshold percentage in the 2020s scenario, at 3.4% and 3.7%, respectively. The bedrooms in the 2080s scenario exhibit the most exceedance for these floors, which are 5.1% and 5.5%, respectively. In comparison, the bedroom on the top floor performed better than those on the lower floors and slightly crossed the cutoff in all scenarios, which varied between 3.2 and 3.5%.

Furthermore, Fig. 5 shows the bedrooms on all three levels fail criterion (b), where the operative temperatures between the hours when a bedroom is inhabited (22:00–07:00) should not exceed 26 °C for more than 33h/year (formula 2). Their performance in the current 2020s scenario shows a minimum of 166 h per year of exceeding, which is higher for the mid floor being 201h/year. Additionally, a significant increase in exceeding hours can be observed in the future 2080s scenario, with 633 h annually in the mid, 608 h in the first, and 523 h in the top floors surpassing 26 °C operative temperature.

The above review of the results of the overheating assessment shows the extreme situations of the London apartments during the summer months, which become increasingly unsafe in the long term and thus answers the second research question of this study. Therefore, this study's findings indicate that the risk of overheating in London homes is a persistent issue that is only likely to get worse over the next sixty years, making it extremely dangerous and unsafe for the occupants. The current paper thus addresses the earlier mentioned research questions through this discussion.

5 Conclusion

This study presents a simulation-based method to assess and predict the overheating risk in a high-risk London apartment complex during the heatwave-prone months. This was accomplished by utilizing the CIBSE TM59 methodology to perform dynamic simulation in the IESVE software. The simulation results reveal that the living rooms and bedrooms on the assessed floors of the building are susceptible to overheating, with an exponential increase in risk in the 2050s- and 2080s-year scenarios. The predicted condition of overheating is quite worrying when considering the greatest 5-year average summer mortality rate in England and the case study assessment results. Hence, emphasis has been given to the significance of addressing overheating risks in buildings, especially in high-risk areas, as constant overheating can have adverse effects on the socio-economic state of the dwellers. Moreover, this study aims to raise awareness and offers useful insights for retrofitting methods to reduce the risk of overheating in residential buildings for building designers, legislators, and other stakeholders. Research in the future can further examine the economic viability and effectiveness of various solutions to prevent residential building overheating in London. Further investigation into the problem can be made through the conduct of more in-depth studies of the susceptibility of various floors to overheating.

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