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Monitoring summer indoor overheating in the London housing stock

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ABSTRACT

In light of current climate change projections in recent years, there has been an increasing interest in the assessment of indoor overheating in domestic environments in previously heating-dominated climates. This paper presents a monitoring study of overheating in 122 London dwellings during the summers of 2009 and 2010. Dry Bulb Temperature and Relative Humidity in the main living and sleeping area were monitored at 10 min intervals. The ASHRAE Standard 55 adaptive thermal comfort method was applied, which uses outdoor temperature to derive the optimum indoor comfort temperature. It was found that 29% of all living rooms and 31% of all bedrooms monitored during 2009 had more than 1% of summertime occupied hours outside the comfort zone recommended by the standard to achieve 90% acceptability. In 2010, 37% of monitored living rooms and 49% of monitored bedrooms had more than 1% of summertime occupied hours outside this comfort zone. The findings of this study indicate that London dwellings face a significant risk of overheating under the current climate. Occupant exposure to excess indoor temperatures is likely to be exacerbated in the future if climate change adaptation strategies are not incorporated in Building Regulations, building design and retrofit.

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1. Introduction

1.1. Background

There is currently overwhelming scientific evidence and consensus that our climate is changing due to anthropogenic greenhouse gas emissions that have recently been the highest in history [1]. The frequency, intensity and duration of heatwaves are projected to increase worldwide [2], and recent research has suggested that the magnitude of increase might be even higher than initially estimated [3]. According to the UK Climate Change Projections 2009 (UKCP09), all UK regions are projected to become warmer, in particular during the summer period. Under the Medium emissions scenario, Southern England will experience the greatest rise in summer mean temperatures of up to 4.2 °C (2.2 °C–6.8 °C) by the end of the century compared to the 1961–1990 baseline period [4]. It is predicted that the Met Office heatwave daytime external temperature threshold (32 °C) may be exceeded for one third of the summer period (June–August) in London by the middle of the century [5].

A well-established relationship exists between high temperatures and heat-related mortality risk at the population level. This was exemplified by the 2003 and 2006 European heatwaves, which led to disruptions and damages to industry, transport and infrastructure, and a significant increase in excess summer mortality, primarily amongst elderly and socially isolated individuals [6–8]. The exceptionally hot conditions in August 2003 are reported to have caused more than 30,000 excess deaths across Western Europe for the 10 days of the heatwave [9], 2091 of which were reported in the UK, and 616 in London alone [10]. As a result, heat-related mortality prevention has become an issue of major public health concern in Europe and the UK [11–13]. Yet studies with detailed empirical data on indoor temperatures during summer as well as information on dwelling and occupant characteristics remain scarce.

Heat effects and consequent heat stress in urban areas are more severe than in rural ones. In addition to a warming climate, the risk of overheating is magnified in cities like London due to the Urban Heat Island (UHI) effect, a well-established phenomenon of inadvertent climate modification linked to urbanisation [14–16]. For example, during periods of hot weather, the highest heat-related mortality rates in the UK are observed in London [17]. It has been estimated that the proportion of excess heat-related deaths attributable to the UHI effect during a warm summer period in 2006

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Nomenclature

BREDEM	Building Research Establishment's Domestic Energy Model
BS EN	British standard European norm
CaRB	Carbon reduction in buildings
DBT	Dry bulb temperature
EPC	Energy performance certificate
micro-CHP	Micro combined heat and power
MKEP	Milton Keynes energy park
PHPP	PassivHaus planning package
RdSAP	Reduced standard assessment procedure
RH	Relative humidity
SAP	Standard assessment procedure
SCAT	Smart controls and thermal comfort
TM	Technical memorandum
UHI	Urban heat island
UKCP09	UK climate change projections 2009
VOC	Volatile organic compounds

was around 38% in outer London, 47% in inner London and 47% in central London [18].

The UK was the first country around the world to introduce a long-term legally binding framework to mitigate climate change. The *Climate Change Act 2008* requires that UK emissions are reduced by at least 80% by 2050, compared to 1990 levels [19]. As this emissions reduction is pursued in the building sector, improved Building Regulations will result in highly insulated and airtight building envelopes. Such building envelopes have the potential to overheat if not designed properly [20,21] and, in particular, if energy efficiency measures are not combined with appropriate passive cooling strategies [22–24]. For instance, studies have indicated that, even under the current climate, indoor overheating is a problem faced by 20% of UK homes [25–27].

As a consequence, frequent occurrences of indoor overheating could potentially result in maladaptation to a warming climate, such as high energy and high carbon cooling strategies that further contribute to climate change. A recent national survey of English housing found that air conditioning is currently very rare in domestic settings. Fixed or portable air conditioning units used in less than 3% of dwellings [28]. However, it has been suggested that air conditioning will become common in many new UK homes in the future [23]. A large expansion of the residential air conditioning market in the UK will inadvertently lead to increased energy consumption for cooling. This is further supported by the historical precedent of aggressive air conditioning penetration in the housing market of other countries, such as the USA [29]. If no other adaptation action is taken and if electricity is provided from the same fossil fuel sources that it currently is (i.e. if energy supply decarbonisation does not take place), the domestic cooling demand in the UK could markedly rise from the current negligible level, thus resulting in a considerable increase of carbon emissions from this source [30–33].

Reducing adverse effects of high indoor temperatures on the building energy consumption, comfort and health of its occupants should ideally be addressed by improved building performance achieved through passive cooling strategies [22–24]. The UK Building Regulations were historically aimed at reducing space heating energy consumption in winter. Whilst they currently include recommendations to limit solar heat gains, they do not adequately address the summer thermal performance of buildings [26]. In 2005, a revised version of the *Standard Assessment Procedure* (SAP), which is adopted by the UK Government as the method for calculating the energy performance of dwellings needed to meet Building Regulations, for the first time included an algorithm for summer overheating calculations in *Appendix P* [34]. However, this is not integral in the SAP calculation as it does not affect the overall SAP rating. In addition, as a simplified, static algorithm, *Appendix P* has significant limitations that have been highlighted by many authors [26,35].

As a response to the issues outlined above, there has been considerable policy and research interest in the assessment of indoor overheating risk in UK housing in recent years [26]. A number of Government and industry reports have highlighted the need to enhance our understanding of building overheating risk and identify optimum solution pathways through long-term planning and improved building design [13,26,36–42]. The majority of academic studies that have attempted to quantify the extent and drivers of overheating risk in UK dwellings under the current and future climate, however, mainly rely on building performance modelling [23,35,43–55].

There is a clear lack of monitored temperature data from large, heterogeneous samples of UK dwellings and the majority of past monitoring campaigns focused on winter rather than summer thermal conditions. However, since the 2003 heatwave, there have been several monitoring studies of UK summer dwelling temperatures of varying sample sizes and heterogeneity in terms of dwelling and occupant characteristics, which are summarised in Table 1.

Existing studies are often characterised by small sample sizes and varying methodological approaches. Producing an accurate picture of the summer temperature profile of UK housing is hence challenging. However, some common patterns emerge from their findings. In agreement with the modelling studies cited earlier, monitoring studies have shown that dwelling type [56–62,65,66] is an important modifying factor of indoor overheating risk. Purpose-built flats and structures that are highly exposed to solar gains appear to be more prone to excess temperatures. Construction age, a proxy for building fabric thermal characteristics, is another key predictor of heat risk [25,27,61,66]. It has been shown that 1960s–70s and post-1990s properties are usually the warmest. There is evidence that newly built or retrofitted highly energy efficient dwellings [27,58] and, in particular, those built to PassivHaus standards [67,68], may be at risk of summer overheating. There is also increasing recognition across the more recently published studies that occupant behaviour can influence overheating risk considerably and needs to be taken into account during building surveys [66–68].

1.2. Study scope

The studies summarised above have improved our knowledge of actual summer performance of UK dwellings. However, few of them have been carried out on large housing samples over long periods of time or have captured adequate information on building fabric characteristics and occupant behaviour. The present study adds to this growing body of literature by evaluating the performance of a large sample of urban dwellings over two summer periods.

This paper investigates indoor temperatures measured in 122 London dwellings that were monitored at 10 min intervals during the summer of 2009 and 2010. The study included an interview questionnaire survey of occupant socioeconomic status, ventilation patterns, appliance use, and other factors. Indoor temperatures were analysed to determine the extent of indoor overheating using existing assessment criteria based on: (a) *deterministic*, fixed thresholds, as exemplified by the 7th edition of *Environmental Design Guide A* by the Chartered Institution of Building Services Engineers (CIBSE) [71] and a recent report by the Zero Carbon Hub (ZCH) [72], and (b) the *adaptive* thermal comfort approach, as defined in the American National Standards Institute – American

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