Renewable and Sustainable Energy Reviews 74 (2017) 201–220

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Chronic overheating in low carbon urban developments in a temperate climate

Robert S. McLeod[a,*], Michael Swainson[b]

[a] School of Civil and Building Engineering, Loughborough University, Leicestershire LE11 3TU, UK
[b] Building Research Establishment, Garston, Watford WD25 9XX, United Kingdom

ARTICLE INFO

Keywords:
Communal heating systems
Passive cooling
Building performance evaluation (BPE)
Post-occupancy evaluation (PoE), thermal comfort
Housing Health and Safety Rating System (HHSRS)

ABSTRACT

Numerous studies have reported on overheating in urban contexts the majority of which have focused on the influences of external factors, such as: heat waves and climatic change. To date very little research has examined the more insidious issue of chronic year-round overheating in temperate climatic zones.

The present study begins by reviewing the potential implications of planning and legislative constraints underlying urban residential design. A case study example is then introduced to examine the potential manifestation of such issues in practice. Detailed field monitoring and survey data from a number of newly built flats in a multi-residential block in London, is presented. Typical of a new generation of urban dwellings the development incorporates a high thermal specification together with low carbon building services, such as communal heating systems and mechanical ventilation with heat recovery. Through detailed zonal measurements of a broad range of environmental and building services parameters it has been possible to isolate the key factors underpinning poor overheating performance for these flats.

The findings of this case study are part of a larger research project investigating the causes of overheating in high density urban dwellings across Greater London. The results suggest that the causes of chronic overheating in these modern low-energy flats are multiple, but typically share common factors stemming from poorly integrated architectural and MEP design decisions. Conflicts between regional planning policies, UK building regulations, and health and safety legislation appear to be compounding the problem.

1. Introduction

There is a growing body of evidence, both from within the UK and across Europe, that modern energy efficient buildings are overheating [1–5]. In tandem complaints of thermal discomfort and reports of adverse health effects from the occupants of such buildings are rising [2,6,7]. The correlation between high energy efficiency ratings and increased risk of overheating is not always linear [8] and there is a need to consider site specific factors, such as: building services, glazing orientation, ventilation restrictions and usage patterns when evaluating the degree of risk [1,4,9,6,10].

Trends towards hotter than average summers and an increased frequency of extreme heat wave events [11] are obvious risk factors in relation to the increasing frequency of overheating in the built environment. Seasonal overheating and extreme events, such as the 2003 heat wave which is reported to have resulted in 2000 heat related deaths in the UK, are well documented [12–15]. Such events must be distinguished from the phenomenon of 'chronic overheating' however which occurs when elevated internal temperatures extend well beyond the summer season and occupants are subjected to prolonged, and in some cases year-round, overheating. Although this phenomenon is growing and is widely known within the UK building services industry [2], such cases are typically resolved out-of-court and rarely enter the public domain.

According to CIBSE TM52, "overheating happens in a building either through bad design, poor management or inadequate services" [10, p. 1]. It is likely in many cases of chronic overheating that several of these key factors may co-exist. Although design issues are often

Abbreviations: **ADL**, Approved Document Part L of the UK Building Regulations; **ADF**, Approved Document Part F of the UK Building Regulations; **AFL**, above floor level; **ANSI**, American National Standards Institute; **ASHRAE**, American Society of Heating, Refrigerating and Air-Conditioning Engineers; **AOV**, automatic opening vent; **CIBSE**, Chartered Institution of Building Services Engineers; **CHP**, Combined Heat and Power; **CSH**, Code for Sustainable Homes; **DCLG**, Department for Communities and Local Government; **EPBD**, Energy Performance in Buildings Directive; **EPC**, Energy Performance Certificate; **HIU**, heat interface unit; **MEP**, mechanical electrical and plumbing; **MRT**, mean radiant temperature; **MVHR**, mechanical ventilation with heat recovery; **NHBC**, National House Building Council; **nZEB**, near Zero Energy Building; **RoSPA**, Royal Society for the Prevention of Accidents; **SAP**, (UK) Standard Assessment Procedure; **SBD**, Secure By Design; **SPG**, Supplementary Planning Guidance; **TER**, Target Emission Rate

* Corresponding author.
E-mail address: R.S.McLeod@lboro.ac.uk (R.S. McLeod).

http://dx.doi.org/10.1016/j.rser.2016.09.106
Received 13 July 2016; Received in revised form 23 September 2016; Accepted 25 September 2016
1364-0321/

highly context dependant; from the perspective of architects, building services engineers and developers it is critically important to understand how poor design integration may result in increased vulnerability to overheating. Similarly from a sustainable building policy perspective it is vital to understand in which areas policies may be interacting perversely as 'design drivers' in relation to exacerbating the risks of overheating.

A number of statutory and policy drivers (enacted at European, national and regional levels) strongly influence the way U.K. architects, engineers and developers currently approach the task of high density urban building design. A significant focus has been placed on the reduction of carbon emissions and this has largely been targeted at reducing heat losses through the thermal envelope [16,17] as well as improving the efficiency of heating systems. The London Plan, which provides a statutory spatial development plan for Greater London, sets out specific policies to encourage the use of decentralised energy in new development proposals; which includes promoting the use of communal heating systems [18].

The potential implications of these design drivers have been documented in a number of comprehensive overheating reviews, including those carried out by the National House Building Council (NHBC) Foundation [2], the Zero Carbon Hub (ZCH) [18] and the Department for Communities and Local Government (DCLG) [3], and highlighted in performance evaluation studies of energy efficient buildings [4,8,19]. It is notable that in a survey comprising house building and public sector stakeholders interviewed in 2012 (as part of a DCLG review of overheating in dwellings) 100% of the respondents reported that, "they were aware, had seen, received complaints about or were concerned about overheating in flats built after 2002, especially those with communal heating systems [3, p96]."

This study illustrates the interaction of these compounding factors by investigating the causes of chronic overheating in a newly completed high density residential complex in Greater London. Through a detailed monitoring programme the research seeks to identify the dominant causes of prolonged overheating (occurring outside of the summer period) in a small number of flats and their adjoining communal areas selected form a larger complex. The research forms part of a wider investigation of the phenomenon of chronic overheating in modern energy efficient buildings across the Greater London region. For legal and ethical reasons the precise location and name of the development has been withheld.

2. Background – review of overheating drivers and definitions

2.1. Policy and legislative drivers

Over the past decade a number of legislative and policy drivers have been enacted at European, national and regional level which are shaping the way U.K. designers and engineers respond to the remit of designing low energy and low carbon residential buildings in urban areas. Many of these factors have been extensively documented in a number of comprehensive overheating reviews including those carried out by NHBC [2] and DCLG [3] in 2012 and ZCH in 2015 [5] as well as in performance evaluations of energy efficient buildings in relation to overheating risks [4,19]. In summary these drivers can be broadly grouped into four main categories: i) those targeting higher fabric performance levels, ii) planning policies promoting low carbon communal and district heating systems, iii) drivers encouraging higher urban densities, along with iv) health and safety guidance and legislation.

Enforcement of energy performance standards for new residential buildings in relation to minimising fabric transmission losses, airtightness and operational carbon emissions falls under the UK Building Regulations Approved Document L (AD L1A) – *Conservation of Fuel and Power* [20]. The 2006 revision of AD L1A saw the imposition of Target Emission Rates (TERs) for all new dwellings as well as the introduction of a design air permeability limit of 10 $m^3/(h.m^2)$ at 50 Pa [21]. This legislative standard became the baseline for the higher levels of energy conservation mandated under the Code for Sustainable Homes (CSH) which was introduced as a voluntary sustainability initiative, in April 2007. From April 2008 all dwellings built with the assistance of public finance in the UK were obliged to meet CSH Level 3, which represented a further 25% reduction in a buildings' Design Emission Rate (DER) beyond the statutory minimum TER value imposed by AD L1A [22]. As a result of this funding policy an increasing number of social housing providers and private developers began to voluntarily build to even higher fabric performance standards [23,24] in order to improve their CSH ratings and progressively upskill their supply chains towards delivering the 2016 Zero Carbon target for new homes in the UK.

Following a review of the legislative burdens imposed on UK housing developers in July 2015, the UK Treasury announced that the CSH and existing Zero Carbon homes methodologies would be abandoned [25]. Despite these overarching policy revisions recent updates to London's Supplementary Planning Guidance (SPG) continues to promote high standards of energy efficiency and the Zero Carbon concept [26]. The London Housing SPG defines 'Zero Carbon' homes as, "homes forming part of major development applications where the residential element of the application must achieve at least a 35 per cent reduction in regulated carbon dioxide emissions (beyond Part L 2013) on-site" [27, p12], with the remaining (AD L) regulated carbon dioxide emissions to be off-set via a fiscal contribution to the relevant borough [27].

The improved retention of thermal energy implicated by improvements to AD L must be considered in the light of changes to Approved Document F (AD F) *Ventilation*. In a review of the evidence of overheating in new homes Dengel and Swainson point out that despite substantial tightening of the background airtightness and fabric requirements in AD L (2006) there were no substantive changes to the means or rate of ventilation specified in AD F [2]. The 2006 edition of AD F refers to fabric air permeability's of around 3–4 $m^3/h.m^2$ (envelope area at a 50 Pa pressure difference) as providing the basis for its prescribed ventilation rates. AD F advises that, "Where special measures are to be taken to achieve greater air tightness, additional ventilation provisions may be required" [28, p7]. However the advice in AD F stops short of defining 'additional provisions' or describing how their efficacy can be evidenced.

In relation to purge ventilation Appendix B of AD F [28] specifies that the area of the opening should be at least 1/20th of the floor area of the room in the case of hinged, pivot or sliding sash windows that are capable of opening 30°or more. For windows that open less than 30°, the area of the opening should be at least 1/10th of the floor area of the room. According to AD F (2006) the required proportion of the floor area is determined by the opening angle of the largest window in the room. The limitations of this approach in relation to over estimating the ventilation purging capacity of windows with heavily restricted opening angles were subsequently addressed in the 2010 edition of AD F, which clarified that, "window which were limited to an opening angle of 15° or less would not be suitable for purge ventilation" [29]. AD F (2010) states that when this purge ventilation design guidance is adhered to a purge ventilation target rate of 4 h^{-1} should be achievable in most cases. This assumption is in turn referenced to guidance found in the British Standard BS 5925 -AMD 8930 [30] which is based upon a number of defined modelling assumptions about the nature of the building and it's boundary conditions.

The evolution of UK safety legislation driven by the Royal Society for the Prevention of Accidents (RoSPA) combined with crime prevention initiatives such as Secured by Design (SBD) has unintentionally created a further impediment to the use of natural purge ventilation strategies in the urban context. As a result of such initiatives window stay restrictors are now installed by default on most new social and