UNIVERSITY OF CAMBRIDGE
Department of Architecture

Heat vulnerability: risk to health and wellbeing in the built environment

Kanchane Gunawardena

The Martin Centre for Architectural and Urban Studies, Department of Architecture,
University of Cambridge, 1-5 Scroope Terrace, Cambridge, CB2 1PX, UK.

krag2@cam.ac.uk

Abstract

Higher temperatures have been established to have an adverse effect on human health and wellbeing. A warming climate and increasing frequency and severity of extreme events are expected to exacerbate heat-related risks, particularly in cities where the influence of the heat island adds to their complexity. Urban heat impacts are as a result regarded as requiring multidisciplinary attention to generate integrated approaches for safeguarding public health and wellbeing. This paper is concerned with identifying how excess heat affects building occupants, which groups may be most vulnerable, and how fundamentally and in what ways should concerns about the potential effects of summer overheating and their mitigation influence built environment design. The method for addressing these questions considered literature from public health, epidemiology, and climate change science. The findings highlighted significant shortfalls in guidance concerned with overheating risk in buildings, while received attention thus far prioritises the typologies of housing, hospitals, and care infrastructure.

To be referenced as:

Gunawardena, K. R. (2015). *Heat vulnerability: risk to health and wellbeing in the built environment.* Cambridge: University of Cambridge.

Master of Philosophy

The following is a paper submitted in partial fulfilment of the requirements for the M.Phil Examination in Architecture and Urban Studies at the Department of Architecture, University of Cambridge, Cambridge, England. Michaelmas Term 2014.

Table of illustrations

Abbreviations

ASC	Adaptation Sub-Committee (of the Committee on Climate Change)
CCC	Committee on Climate Change (independent body established under the Climate Change Act 2008 to advise the United Kingdom Government on reducing greenhouse emissions)
CIBSE	Chartered Institution of Building Services Engineers
DECC	Department for Energy and Climate Change (United Kingdom)
IPCC	Intergovernmental Panel on Climate Change (United Nations)
NPPF	National Planning Policy Framework (England)
SAP	Standard assessment procedure (United Kingdom)

Key definitions

Comfort: Described as a state of physical ease and freedom from pain or constraint (Stevenson, 2010).

Health: The World Health Organisation (WHO) describes it as 'a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity' (Park & Allaby, 2013).

Heatwave: There is no official definition for the United Kingdom. The World Meteorological Organization (WMO) defines it as a condition: *'when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5°C, the normal period being 1961-1990'* (www.metoffice.gov.uk).

RCP 8.5: Representative Concentration Pathway 8.5 assumes high population, relatively slow income growth with modest rates of technological change and energy efficiency, leading in the long-term to high energy demand and greenhouse gas emissions in the absence of climate change mitigation policies. Compared to other Representative Concentration Pathways, this pathway would lead to the highest greenhouse gas emissions and resultant climate impact (Riahi, et al., 2011).

Wellbeing: The Oxford dictionary defines it as a state of mental and physical health, as well as social wellness, satisfaction with their lives, and experiencing a good quality of life (Castree, et al., 2013).

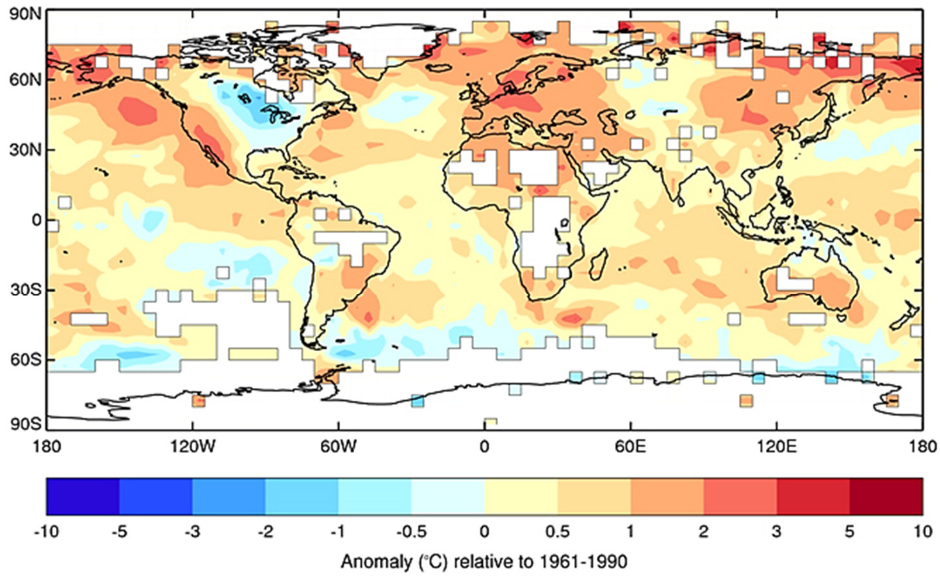


Fig. 1. Global temperature anomalies for 2014 (Jan-to-Oct) from the Met Office, UK.

Introduction

The Fifth Assessment Report by the IPCC (IPCC, 2013) stresses that an average temperature increase >2 K above preindustrial levels can be expected by around the middle of this century if global greenhouse gas emissions continue to increase at their present rate (scenario RCP 8.5). In the United Kingdom, early impacts of climate change are likely to be experienced as increases in the frequency and severity of extreme weather events such as heatwaves, flooding, storms, and drought. As 2014 is on course to be one of, if not the warmest year on record for the United Kingdom and globally (see Fig. 1), heat-related impacts have recently gained significant attention (Slingo, et al., 2014). Epidemiological studies focusing on extreme events such as the 2003 pan-European heatwave have established higher temperatures to have an adverse effect on human morbidity and mortality (Gosling, et al., 2009). Further studies have demonstrated exposure to excess heat as already a considerable health concern, with predicted climate change likely to contribute to higher rates of mortality (Hajat, et al., 2013). Excess heat is therefore a significant health risk that requires strategic planning to mitigate impacts. In recognition of this need and in response to recent heat events (see Table 1), the Heatwave Plan was introduced by the United Kingdom government to guide the National Health Service and social services (PHE, 2014a).

The Heatwave Plan

The annually revised Heatwave Plan was first published in response to the adverse effects of the 2003 pan-European heatwave (PHE, 2014a). For warning thresholds, the Plan refers to temperature definitions provided by the Met Office. These differ regionally with the average at 30°C throughout the day and 15°C overnight. Although excess deaths are apparent at lower temperatures, the warning system is based on triggers of 15-20% increased risk, with different triggers (Table 2) addressing regional relative adaptations to excess heat (PHE, 2014a).

Table 1. Historical extreme heat events (UK).

Events	Excess deaths
1976 June-July: England and Wales	(9.7%)
1976 June-July: Greater London	(15.4%)
1995 July: England and Wales	768 (11.2%)
1995 July: Greater London	184 (23.0%)
2003 August: England and Wales	2,091 (17.0%)
2003 August: London	616 (42.0%)
2006 England and Wales	680*
2009 England and Wales	300*
2013 July: England	650†

Sources: Kovats & Hajat (2008); *PHE (2014a); †Armstrong (2013).

The Plan's responses to heat stress focus on emergency planning (ASC, 2011). The measures suggested aim to alert, prepare, and prevent heat-related adverse health effects. There is no explicit strategy discussed to reduce social vulnerability through cross-agency approaches (Benzie, et al., 2011). Local interests have been delegated this task, with the Plan presented only as a strategic document that requires Local Authorities and their health partners to adapt to local circumstances (PHE, 2014a). Although the Plan gives attention to training local staff and institutional management practices, existing inadequacies in building stock and equipment hindering staff action, have questioned the effectiveness of this attention (Boyson, et al., 2014).

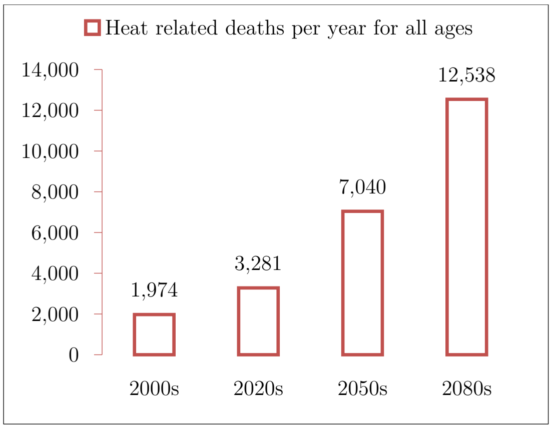
Table 2. Regional threshold temperatures.

National severe weather warning service region	Day °C	Night °C
London	32	18
Southeast	31	16
Southwest	30	15
Eastern	30	15
West Midlands	30	15
East Midlands	30	15
Northwest	30	15
Yorkshire and Humber	29	15
Northeast	28	15

Source: Public Health England (2014a).

Heat risk to health

The first step of a heat vulnerability assessment is to determine how it affects the population. In the very least, excess heat can cause mild discomfort, while at its extreme lead to fatality. Around 2,000 premature deaths are estimated to occur per year in the United Kingdom due to heat-related health risks, with the figure projected to increase by 257% by the 2050s if adaptation measures are not considered (Fig. 2). Although most assume such deaths to happen during extreme events, a significant proportion has been found to occur outside defined heatwaves (Hajat, et al., 2013). The Heatwave Plan acknowledges this, and emphasises the significance of long-term planning in addressing such excess deaths (PHE, 2014a).



Note: based on an ensemble of nine climate model simulations. Data source: Hajat, et al. (2013).

Fig. 2. Estimated heat-related deaths in the UK.

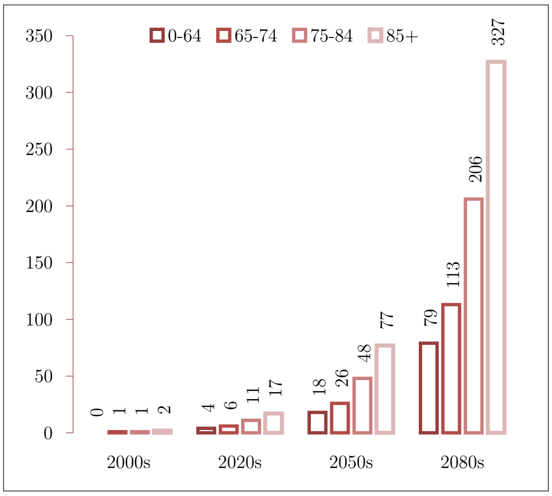
Populations have the ability to adapt to varied climates, which is demonstrated by the variation in heat risk between regions and countries. People acclimatise to their local climates physiologically, behaviourally, and in generational and cultural terms (Hajat, et al., 2013). Although such adaptation is anticipated, the rate at which climate change is expected to increase both the magnitude and variability of future temperatures will be unparalleled since agricultural times. It is therefore unlikely that population adaptation to future warmer climates will be comparable to the past (Hajat, et al., 2013).

Human beings constantly generate heat from metabolic functions. Higher levels of activity produce greater levels of heat (100 W at sedentary to around 1,000 W when strenuously active), which must be dissipated to the surroundings in order to maintain the body's average core temperature of 37°C (ASHRAE, 2013). Healthy adults can efficiently regulate increases in temperature by increasing radiant, convective, and evaporative heat loss by vasodilatation and perspiration. When the air temperature becomes warmer than the skin at 34°C, perspiration becomes the single means of thermoregulation (Gartland, 2008). Humidity is therefore an added exposure factor in thermoregulation, as elevated levels make it difficult to achieve evaporative heat loss through perspiration.

For all peoples, insufficient heat loss leads to overheating (hyperthermia), which results in cardiac stress and potential dehydration from sweating. The additional strain on the cardiovascular system typically results in cardiac complications or Stroke, although both respiratory and renal causes have also been attributed (Hajat, et al., 2007). Exposure to significant heat stress could cause heat cramps, heat exhaustion, heat syncope, or heatstroke. Severe heatstroke occurs when the body's core temperature exceeds 39.4°C resulting in multiple organ dysfunction, which left untreated would rapidly progress to fatality. Even if death is avoided, extreme heat stress may leave permanent damage to organ systems with significant impact to an individual's longevity. Heat stress therefore should not be considered lightly, and certainly not as a threat that only concerns the frail.

Vulnerabilities

The Committee on Climate Change (CCC) asserts that the built environment has a responsibility to safeguard the health and wellbeing of communities (ASC, 2014). The communities that the built environment is designed and realised for, represents a variety of different groups with varying degrees of strengths and weaknesses. The following expands upon the discussed physiological base of how heat affects the population, to include wider socioeconomic and spatial factors that lead to the increased vulnerability of certain community groups.



Deaths per year, per 100,000 population, by age group.
Data source: Hajat, et al. (2013).

Fig. 3. Mean estimates of UK deaths by age group.

Age, ageing, and gender

Age has significant association to heat-related morbidity and mortality, with both the very young and older people at heightened risk. Children, particularly infants are at risk due to their limited ability to thermoregulate and higher potential for dehydration (Hajat, et al., 2007). Older people are at risk due to ageing or senescence resulting in reduced thermoregulatory capacity (Grundy, 2006), which begins to occur from around fifty years of age. Studies of recent heat events have demonstrated older people to account for higher mortality figures than children (Kovats & Hajat, 2008). The 2003 pan-European heatwave for example, presented excess mortality greatest in those aged 75 and over (Johnson, et al., 2005). This increased representation has been documented by further studies in the United Kingdom and elsewhere, and is attributed to the ageing structure of such societies (Hajat, et al., 2007). In the United Kingdom for example, the last two decades has seen the population aged 75 and over (those with the highest vulnerability to heat-related health risks), increase by 24% (ASC, 2014).

The risk to older people is exacerbated by their typical living arrangements. Of those aged over 75, a significant proportion tend to live in cities (~9.5% of the urban population), where heat risks are generally higher due to the urban heat island effect. In addition, nearly a quarter million (those over 70) inhabit urban or suburban flats, approximately half of which are compact arrangements with two rooms or less (ASC, 2014). The risk to such occupants is therefore compounded by their age, and the location and character of the buildings they inhabit.

Gender vulnerability is inconclusive, with both men and women identified to demonstrate greater risk in studies undertaken in different contexts (Brown & Walker, 2008). Studies from Europe for example have shown women to be more at risk in comparison to men (Kovats & Hajat, 2008); particularly those aged 65 and over (explained by their physiology). Beyond physiological reasons, other studies have described social factors as also having a degree of correlation (Hajat, et al., 2007). Men for example have been identified to have greater risk of heatstroke, due to their higher probability of being active in warmer conditions (Kovats & Hajat, 2008).

Specific health conditions

Illness and medical conditions account for greater risks across all groups. Certain conditions that compromise thermoregulation, medications, and alcohol or other substance abuse are significant risk factors. Studies have particularly identified people with cardiovascular conditions, cerebrovascular conditions, and diabetes to have higher vulnerability. For such individuals' higher temperatures can represent added heat stress due to their already compromised state of health (Kovats & Hajat, 2008).

In addition, studies from France and the United States have demonstrated serious physical and psychological disabilities to exacerbate risk (Benzie, et al., 2011). Depression and impaired cognitive states such as dementia or Parkinson's disease, may leave individuals incapable of taking adaptive measures due to their compromised faculties of judgment (Kovats, et al., 2006). Perception of vulnerability is also a significant factor, as studies of older people in London and Norwich concerning heatwave risk found that many did not perceive themselves to be 'at risk', notwithstanding their age or diagnosed chronic ailments (Abrahamson, et al., 2008).

Socioeconomic factors

The Heatwave Plan is based on physiological health-centric evidence that considers the above discussed intrinsic factors to affect heat vulnerability. Although socioeconomic factors have been traditionally discussed for cold-related risks, studies have demonstrated such factors to be also relevant for heat vulnerability (Brown & Walker, 2008). Economic affluence for example has been found to be significant in studies from the United States. This association is related to the increased use of air-conditioning as a mitigation strategy, and the inability of some to afford its use. A study of the 1995 Chicago heatwave for example, highlighted poverty as an explanation for heatstroke in older people in inner city areas, where both elevated energy costs and loss of income-support combined to exacerbate mortality risk (Klinenberg, 2002).

From a biophysical perspective, ethnicity presents no direct association to heat risks (Hajat, et al., 2007). Epidemiological evidence however presents South Asians to have higher prevalence of diabetes and cardiac conditions, which are indirect risk factors (Benzie, et al., 2011). Ethnicity may also present associations from a socioeconomic perspective. A study from the United States for example had found air-conditioning prevalence amongst poor black households to be <50% of white households, with the disparity attributed to reduced access to education and resources (O'Neill, et al., 2005).

Living arrangements have an increasing influence, particularly in relation to vulnerable groups. With older people, changes in household and living patterns may increase risk due to isolation. A study of Chicago's heatwave of 1995 for example, had identified an association between recorded heat-related mortality and isolation (Klinenberg, 2002). As populations continue to age, living independently is likely to become more common in the future (UN, 2013). Heat-related risks to such isolated individuals will as a result be significantly higher. Considering this social dimension to the issue, the Joseph Rowntree Foundation has argued for heat-related risks to be assessed beyond biophysical processes and include contextual sociocultural factors (Lindley, et al., 2011). They advocate the fostering of stronger social networks (Benzie, et al., 2011), and strategic engagement with social capital (Pelling & High, 2005). An example of such action is represented by Philadelphia's community-based 'buddy system', whereby vulnerable individuals are regularly monitored by neighbours (Kovats & Hajat, 2008). The spatial patterns of how poor health, homelessness, low income, or social housing is distributed are also likely to have some influence on the heat vulnerability of a community. The Joseph Rowntree Foundation has therefore argued for the need to include a degree of socioeconomic mapping in any approach that is aimed at addressing heat vulnerability (Benzie, et al., 2011).

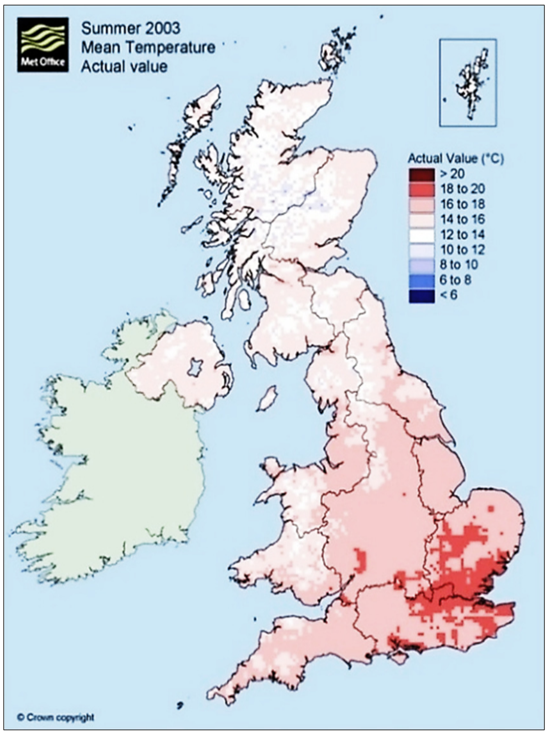


Fig. 4. UK mean temperatures for summer 2003.

Regional variations

Analysis of the 2003 heatwave has presented a model for how regional variations affect heat vulnerability (Fig. 4). The highest temperatures during this event were observed in the southeast region, with emphasis in greater London. The latter had experienced a marked increase of 16%

in emergency hospital admissions, while excess mortality had increased by as much as 42%. The data presented the greatest excess mortality to have occurred where the highest temperatures had the greatest incidence (Johnson, et al., 2005). Longitudinal studies have supported southern England's vulnerability to heat events, with the urban area of London to demonstrate the greatest (Fig. 5) (Hajat, et al., 2007). Such longstanding regional variations have as a result led to degrees of acclimatisation amongst their populations, which in turn manifests as different responses to excess heat. Northern parts of England therefore present lower thresholds for excess mortality than further south, with a study identifying the threshold for the northeast at 16.6°C, while for London it was 19.6°C (Hajat, et al., 2013). Excess mortality with increasing temperature is also observed at higher thresholds in warmer climates than in milder climates (Kovats & Hajat, 2008). Such regional differences challenge the validity of a generalised national threshold. The Heatwave Plan (PHE, 2014a) as a result accounts for this by presenting region-specific thresholds (Table 2).

Urban and rural disparity

Numerous studies have demonstrated heat-related mortality to present greater sensitivity in cities than in rural areas (Kovats & Hajat, 2008). This increased sensitivity is largely attributed to the urban heat island (Hajat, et al., 2007), the significance of which has been identified for specific events (Watkins, et al., 2002). The phenomenon combined with climate change and its likely threat of frequent and severe heatwaves, poses significant risk to wellbeing in urban centres. It is predicted that by the 2050s, rising mean temperatures will triple the heat-related mortality average (ASC, 2014), a large proportion of which is likely to be in cities.

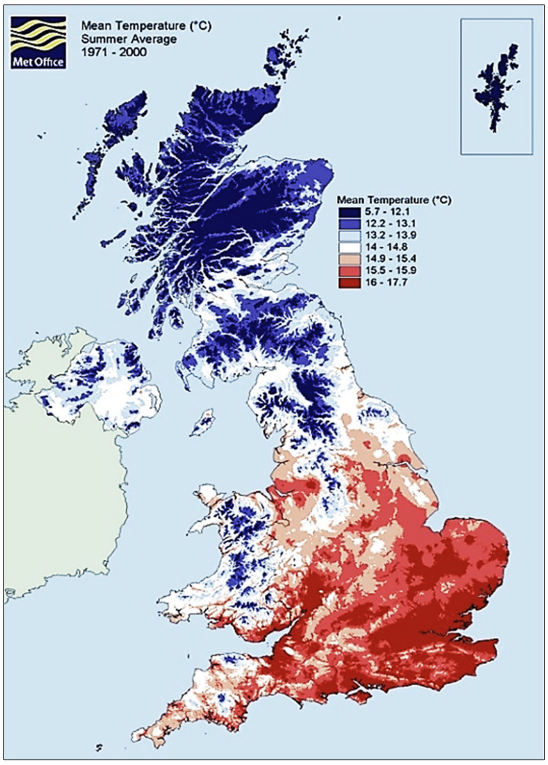


Fig. 5. UK mean temp. summer averages 1971-2000.

Heat islands are dynamic systems, thus are difficult to quantify both spatially and temporally in relation to specific heat events (Kovats & Hajat, 2008). Their relevance also differs, as demonstrated by cities in southern Europe being more adapted to their influence than those in the north. A study from Spain for example found excess mortality during the 2003 heatwave to be no different in rural villages relative to the provincial capital (Kovats & Hajat, 2008).

Built environment concerns

It is impractical for all buildings to comprehensively address the occupant vulnerabilities discussed. Most building commissions anticipate the engagement of defined groups of occupants associated to the function or typology of the building, while allowing for a reasonable degree of adaptation for future changes in use. Occupancy-based risks are thus managed by applying building typology-based mitigations. These prioritise measures for anticipated high-exposure occupants, followed by those for the general population in compliance with regulations.

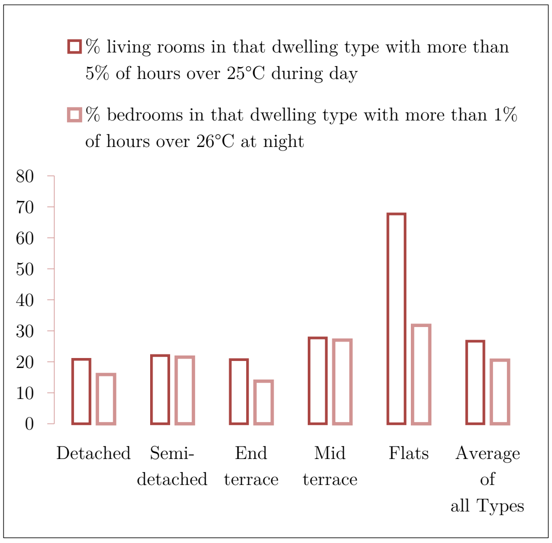
Studies of recent heat events have identified inadequacies in typology-based provisions, with critical typologies stressed as requiring urgent attention and adaptations to tackle future threats. Heatwave mortality data for southern England (from 2003) for example, had highlighted the greatest number of excess deaths to have occurred in hospitals (56%), followed by care homes (24%), and the least in private dwellings (Kovats, et al., 2006). The CCC has warned that in addition to the established higher risk at hospitals and care homes, many private dwellings may already be experiencing summertime overheating (ASC, 2014). Given that the Health and Social Care Act now places strong emphasis on promoting care in the community (GB, 2012), the need for addressing overheating risk across the above three building typologies has never been more urgent.

Hospitals and care homes

Health authorities are aware of the threats posed by a warming climate, with infrastructure adaptation and the development of local management plans prioritised (PHE, 2014). The concern with infrastructure however is that there are significant shortfalls requiring considerable resources to resolve. The CCC has highlighted that around 90% of hospital ward floor areas as being accommodated in a building typology that is susceptible to overheating (ASC, 2014). Notably, wards built in recent times (post-1940s) are at greater risk of exceeding temperatures of 26°C than Nightingale wards (1860-1930s) that predate the National Health Service. As an incentive for expediting the adaptation of these at-risk buildings, the CCC supports the enforcement of a standard for maximum temperatures, and regular reporting of wards that do not have adequate temperature controls (ASC, 2014).

Studies have repeatedly found older people in care homes to be vulnerable to heat-related health issues (Lindley, et al., 2011). This is broadly attributed to the inadequate responsiveness of institutional procedures (Brown & Walker, 2008). Although the Heatwave Plan presents guidance on improving general responsiveness, consequences of extreme events have focused attention on emergency responses. The Plan for example, advocates the provision of ‘cool rooms’ that are maintained below 26°C (PHE, 2014a), although the design parameters for achieving this remain unspecified.

Housing



Note: survey year 2007 was a comparatively cool summer.
Data source: Beizaee et al. (2013).

Fig. 6. UK dwellings found to overheat in summer.

Although southern England mortality data for the 2003 heatwave had demonstrated a lower proportion of excess deaths for persons living at home (Kovats, et al., 2006), a recent study had found 21% of a sample housing stock to be at risk from overheating, even in relatively cooler summer conditions (Beizaee, et al., 2013). The characterisation of housing considerably influences their overheating vulnerability. Main attributes to be concerned with include thermal capacity and insulation of the building envelope, solar gain, and ventilation rates (BRE, 2014). In contrast to larger detached dwellings, apartment flats and mid-terraced housing tend to present increased vulnerability owing to their compact arrangements (Fig. 6). Reviews of the housing stock have revealed those built before 1920 (uninsulated loft conversions in particular), in the 1960s, and post 1990s to be at heightened risk (BRE, 2014). Flats, which have greater susceptibility to overheating, are increasing as a proportion of the total housing stock to constitute 40% of new housing (25% increase since 1996), thereby leading to a corresponding decline in the number of detached housing built (ASC, 2014).

In terms of the general arrangements of housing, top-floor flats and terraced house attic rooms tend to have higher risk of overheating. Having only a single aspect (particularly south-facing) exacerbates the issue by preventing cross-ventilation and being adversely affected by heat flows from adjoining properties. The management of flats also puts such arrangements at risk, as inadequately ventilated communal areas, and reduced capacity to have openable windows due to security concerns, causing such spaces and circulation routes to overheat and transfer gains to adjoining flats (ASC, 2014). Space standards of new flats also contribute to the issue. Rising demand for housing has enabled market forces to condense arrangements to a bare minimum. This is particularly pronounced in the United Kingdom, with spatial standards widely regarded as one of the lowest in western Europe. The most troubling aspect of such high-density arrangements is that 93% of all flats (95% of high-rise flats) are sited in inner cities, where the risk of overheating is heightened by the urban heat island effect (ASC, 2014).

Influenced by energy use concerns, there is considerable opposition to adopting air-conditioning as the principal solution for managing heat stress in the urban built environment. The consideration of passive cooling measures such as building orientation, shading, thermal insulation, and the use of appropriate materials in the design of such built environments is broadly supported as the sustainable pathway to mitigating heat risks (Hajat, et al., 2013). Introducing such measures at the design stage is not only efficient, but also cost effective than subsequent retrofitting. However, as the benefits of these measures pass onto the end-occupier at the developer's capital expense, has generated considerable market hesitancy. This is particularly pronounced with newbuild housing, where the uncertainties in economically valuing occupant health and wellbeing betterment are substantial. The CCC has argued that to overcome such valuation difficulties and general market inertia, the enforcement of regulatory measures such as a 'standard on overheating', as the effective approach for delivering heat-resilience objectives (ASC, 2014).

Existing guidance

The Heatwave Plan defines 'Level 0' as the constant state where long-term planning needs to be considered, reviewed, and implemented. It explicitly refers to long-term spatial planning strategies and adaptations to be significant in reducing future heat-related impacts (PHE, 2014a). As far as city-planning requirements for delivering a built environment that betters community health, social and cultural wellbeing is concerned, England's National Planning Policy Framework (NPPF) only presents a strategic overview (DCLG, 2012). In agreement with its decentralising objective, the framework supports Local Planning Authorities to form collaborative partnerships with public health organisations in order to understand and enhance the health of their local populations (DCLG, 2012). The NPPF as a result makes no explicit reference to addressing overheating or heat vulnerability in the built environment. Lifetime Homes (required by many local planning policies such as the London Plan), and now incorporated into the Code for Sustainable Homes (DCLG, 2010a), also makes no reference to any such requirements.

Table 3. CIBSE (2006) benchmark summer peak temperatures and overheating criteria.

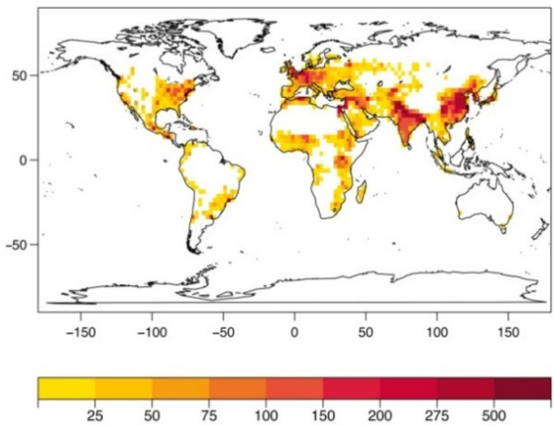
Building use	**Benchmark summer peak temp. °C**	**Overheating criterion** (% annual occupied hours over operative temp.)
Offices	28	1% of 28°C
Schools*	28	1% of 28°C
Dwellings:		
- living areas	28	1% of 28°C
- bedrooms	26	1% of 26°C

* UK, Department for Education and Skills recommends air temperature in a classroom to not exceed 32°C for more than 120 hours above 28°C (DfES, 2006); referred to in Building Regulations Approved Document L2 (DCLG, 2013).

UK, Department of Health (DoH) recommends internal temperatures to not exceed 28°C for more than 50 hours per year in new healthcare buildings (ASC, 2014).

Widely recognised guidance on benchmark summer peak temperatures and overheating criteria for use in the design of non-mechanically ventilated buildings in the United Kingdom is limited (CIBSE, 2006). Statutory guidance on indoor environments is prescribed in Building Regulations, Part F (DCLG, 2010) and Part L (DCLG, 2013). To achieve appropriate standards of internal air quality, Part F (DCLG, 2010) seeks to ensure that adequate ventilation is provided with a high degree of airtightness. To conserve fuel and power, Part L (DCLG, 2013) seeks to ensure that solar gains and gains from servicing works are minimised. The Regulations however do not specify requirements to control overheating on grounds of either protecting health or thermal comfort (ASC, 2014). The only association to addressing overheating is through the 'standard assessment procedure' or SAP (BRE, 2012), which determines non-compliance with Part L if excessive heat gains lead to internal summer temperatures (monthly average) exceeding 23.5°C. The guidance to Part L suggests additional measures such as solar shading to minimise gains (ASC, 2014), which is also advocated by a document (EST, 2005) referred to by the SAP (BRE, 2012). Both however are not material to Building Regulations approval.

The CCC supports overheating risk in new housing to be best addressed by a standard introduced through the Building Regulations. This would ensure the appropriate implementation of actions by developers. Although earliest notable recommendations to address this through the Regulations had been made in 1990, successive governments have been reluctant to give it statutory force (ASC, 2014). The Zero Carbon Hub has instead been commissioned to increase industry awareness on residential overheating risk (DEFRA, 2013), while the National Adaptation Programme (NAP) has called for the SAP to be reviewed (by the DECC) to address overheating concerns (DEFRA, 2013). Designers in the meantime are guided by CIBSE benchmarks and criteria (Table 3), and Departmental guidance for schools and hospitals (CIBSE, 2006).



Estimated change in the mean number of heatwave exposure events for people over 65 per year and per km^2, resulting from climate change under RCP 8.5 emissions scenario, and SSP2 demography scenario that projects a large increase in the global population of older people. Source: The Royal Society (2014).

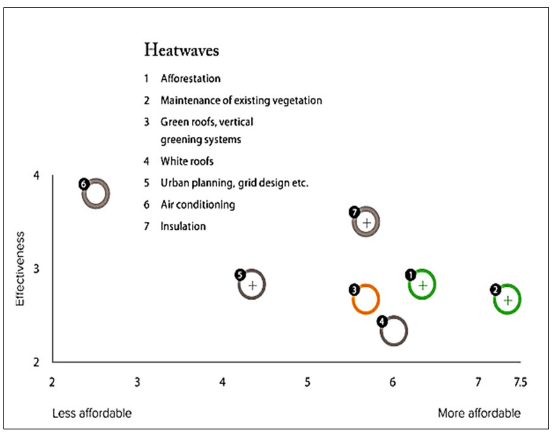
Fig. 7. Heatwave exposure for older people in 2090.

Conclusion

Excess heat adversely affects the health and wellbeing of building occupants. Many discussed groups of occupants may encounter increased vulnerability, with older people identified as requiring greater attention. Given the demographic and climate context of current and future heat-related risks (see Fig. 7), authorities such as the Committee on Climate Change have recognised the necessity for urgent action, and for it to be manifested in the design and implementation of built environments. Given the urgency of the problem, the CCC recommends the introduction of an enforceable building standard as the way in which such concerns could be properly accounted (ASC, 2014). The formulation of such a standard however would need to address the following challenges:

+ The ageing structure of the population means that the workplace demographic will soon include members of an older age group with increased vulnerability to heat, amongst many other risks. Projects such as 'Lifelong Health and Wellbeing' (LLHW) and its 'extending working lives awards', have considered the challenges that people in employment at an older age encounter. The assessment of any overheating standard would need to take account of these findings, and consider whether other building typologies would also need to be included to create environments that support lifelong health and wellbeing in the workplace. The CCC and its consideration of hospitals, care homes, and housing would therefore need to extend to include uses such as offices, retail etc., where older employees will be increasingly likely occupants.

+ The objective to deliver 'zero carbon' homes has encouraged improvements to the energy efficiency of the housing stock. This in turn will result in the mitigation of most climate change impacts and a potential reduction in cold-related mortality. However, all such measures of increasing insulation and airtightness of housing may also be inadvertently increasing the risk of summer overheating. To reconcile these opposing interests, managing overheating risk and improving energy efficiency standards would need to be considered as an integrated exercise.



Source: The Royal Society (2014).

Fig. 8. Options to reduce heatwave impact.

+ Regional variations in climate and the different adaptations of their populations make it difficult to present a nationally applicable threshold for indoor overheating. There is however favourable understanding of outdoor temperature thresholds for mortality, with recent studies beginning to associate them with indoor operative temperatures (e.g., Mavrogianni, et al., 2012). The outcomes of these (and further) studies will be of significance to the development of a regionally responsive overheating standard.

+ Demolition and replacement rates of housing in the United Kingdom are considerably lower than Europe, with the building stock considered to be one of the oldest in the world (DEFRA, 2012). Retrofitting and adaptation are therefore essential for addressing climate change challenges, including overheating. As there is no standard for addressing overheating at present, all current additions to the stock may also require retrofitting in the future. The CCC estimates that at the current replacement rate, 80% of the dwelling stock that will be in use in 2050, as already built (ASC, 2014). This represents a considerable adaptation challenge that is likely to require a long-term strategic approach to funding and implementation.

+ Urban inhabitants are at heightened risk from excess heat due to the heat island effect. Many studies have focused on how built environment design, materiality, morphology (Theeuwes, et al., 2014), and green (Doick, et al., 2014) and blue-space distribution (Volker, et al., 2013) contributes to keeping communities cool. Although the Royal Society assigns lower priority (see Fig. 8) to urban planning considerations (The Royal Society, 2014), the CCC argues for planning policy to be integrated to a framework of measures required for improving resilience to overheating (ASC, 2014). The NPPF in force however is insufficiently detailed to influence such issues directly and has left such matters to be addressed at a local level. While some local interests have means to address such urban scale resilience challenges, most Local Authorities are likely to struggle. It is therefore necessary to assist local interests by providing 'tools' to map risks, develop new strategies, and periodically review implemented actions.

Bibliography

Abrahamson, V. et al., 2008. Perceptions of heatwave risks to health: interview-based study of older people in London and Norwich UK. *Journal of Public Health,* 31(1), pp. 119-26.

Adger, W. N. et al., 2004. *New indicators of vulnerability and adaptive capacity,* Norwich: University of East Anglia.

Armstrong, B., 2013. *Estimated number of premature deaths attributable to heat in England, July 6-14th 2013,* London: London School of Hygiene and Tropical Medicine.

ASC, 2011. *Adapting to climate change in the UK, Measuring progress,* London: UK, Committee on Climate Change.

ASC, 2014. *Managing climate risks to well-being and the economy,* London: UK, Committee on Climate Change.

ASHRAE, 2013. *ASHRAE Handbook 2013 Fundamentals.* Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers.

Barnes, S., 2002. The design of caring environments and the quality of life of older people. *Ageing & Society,* Volume 22, pp. 775-89.

Beizaee, A., Lomas, K. & Firth, S., 2013. National survey of summertime temperatures and overheating risk in English homes. *Building and Environment,* Volume 65, pp. 1-17.

Benzie, M. et al., 2011. *Vulnerability to heatwaves and drought,* York: Joseph Rowntree Foundation.

Boyson, C., Taylor, S. & Page, L., 2014. The national heatwave plan - a brief evaluation of issues for frontline health staff. *PLoS currents,* Volume 6.

BRE, 2012. *The Government's Standard Assessment Procedure for Energy Rating of Dwellings,* Watford: Building Research Establishment, on behalf of the UK, Department of Energy and Climate Change.

BRE, 2014. *The risk to housing from overheating,* Watford: Building Research Establishment.

Brown, S. & Walker, G., 2008. Understanding heatwave vulnerability in nursing and residential homes. *Building Research & Information,* 36(4), pp. 363-72.

Castree, N., Kitchin, R. & Rogers, A., 2013. *A Dictionary of Human Geography.* Oxford: Oxford University Press.

CIBSE, 2006. *CIBSE Guide A: Environmental design.* 7 ed. Norwich: Chartered Institution of Building Services Engineers Publications.

Coley, D. & Kershaw, T. J., 2010. Changes in internal temperatures within the built environment as a response to a changing climate. *Building and Environment,* 45(1), pp. 89-93.

Darby, S. & White, R., 2005. *Thermal Comfort.* Oxford, Environmental Change Institute, University of Oxford.

DCLG, 2010a. *Code for Sustainable Homes,* London: UK, Department for Communities and Local Government.

DCLG, 2010. *Approved Document F - Ventilation,* London: UK, Department for Communities and Local Government / TSO.

DCLG, 2012. *National Planning Policy Framework,* London: UK, Department for Communities and Local Government.

DCLG, 2013. *Approved Document L: Conservation of fuel and power, Volumes 1A and 1B (Dwellings) and 2A and 2B (Buildings other than dwellings),* London: UK, Department for Communities and Local Government / TSO.

DEFRA, 2012a. *UK Climate Change Risk Assessment: Government Report,* London: Department for Environment, Food and Rural Affairs / TSO.

DEFRA, 2012. *Overheating in homes, An introduction for planners, designers and property owners,* Milton Keynes: Zero Carbon Hub on behalf of the UK, Department for Environment, Food and Rural Affairs.

DEFRA, 2013. *The National Adaptation Programme, Making the country resilient to a changing climate,* London: UK, Department for Environment, Food and Rural Affairs / TSO.

DfES, 2006. *Building Bulletin 101: Ventilation for school buildings,* London: UK, Department for Education and Skills.

Doick, K. J., Peace, A. & Hutchings, T. R., 2014. The role of one large greenspace in mitigating London's nocturnal urban heat island. *Science of the Total Environment,* Volume 493, pp. 662-71.

Donald, I. P., 2009. Housing and health care for older people. *Age and Ageing,* May, Volume 38, pp. 364-7.

Environment Agency, 2014. *Under the Weather, Improving health, wellbeing and resilience in a changing climate,* Bristol: UK, Environment Agency.

EST, 2005. *Reducing overheating - a designer's guide, Energy Efficiency Best Practice in Housing,* London: Energy Saving Trust.

Gartland, L., 2008. *Heat Islands: Understanding and Mitigating Heat in Urban Areas.* Oxford: Routledge.

GB, 2012. *Health and Social Care Act 2012,* London: TSO.

Givoni, B., 1994. *Passive and Low Energy Cooling.* New York: Van Rostrand Reinhold.

Gosling, S. N. et al., 2009. Associations between elevated atmospheric temperature and human. *Climatic Change,* Volume 92, pp. 299-341.

Grundy, E., 2006. Ageing and vulnerable elderly people: European perspectives. *Ageing and Society,* Volume 26, pp. 105-34.

Gunawardena, K. R., 2014. *Fundamentals of urban heat islands.* Cambridge: University of Cambridge.

Hacker, J., Holmesl, M., Belcher, S. & Davies, G., 2005. *Climate change and the indoor environment: impacts and adaptation,* London: Chartered Institution of Building Services Engineers.

Hajat, S., Kovats, R. S. & Lachowycz, K., 2007. Heat-related and cold-related deaths in England and Wales: who is at risk?. *Occupational and Environmental Medicine,* 64(2), pp. 93-100.

Hajat, S., Vardoulakis, S., Heaviside, C. & Eggen, B., 2013. Climate change effects on human health: projections on temperature-related mortality for the UK during the 2020s, 2050s and 2080s. *Journel Epidemiol Community Health,* Volume 0, pp. 1-8.

Henderson, G. et al., 2005. *CIBSE Guide B: Heating, ventilating, air conditioning and refrigeration,* London: Chartered Institution of Building Services.

IPCC, 2013. *Climate Change 2013, The Physical Science Basis, Summary for Policymakers (SPM),* Cambridge: Cambridge University Press, on behalf of the UN, Intergovernmental Panel on Climate Change.

IPCC, 2014a. *Climate Change 2014, Impacts, Adaptation, and Vulnerability,* Cambridge: Cambridge University Press, on behalf of the UN, Intergovernmental Panel on Climate Change.

IPCC, 2014. *Climate Change 2014, Impacts, Adaptation, and Vulnerability, Summary for Policymakers,* Cambridge: Cambridge University Press, on behalf of the UN, Intergovernmental Panel on Climate Change.

Johnson, H. et al., 2005. The impact of the 2003 heat wave on mortality and hospital admissions in England. *Health Statistics Quarterly,* Volume 25, pp. 6-11.

Klinenberg, E., 2002. *Heat Wave: A Social Autopsy of Disaster in Chicago.* Chicago IL: University of Chicago Press.

Koppe, C., Kovats, S., Jendritzky, G. & Menne, B., 2004. *Heat-waves: risks and responses,* Copenhagen: World Health Organization.

Kovats, R. S. & Hajat, S., 2008. Heat Stress and Public Health: A Critical Review. *Annual Review of Public Health,* Volume 29, pp. 41-45.

Kovats, R. S., Johnson, H. & Griffiths, C., 2006. Mortality in southern England during the 2003 heat wave by place of death. *Health Statistics Quarterly,* Volume 29, pp. 6-8.

Lindley, S. et al., 2011. *Climate change, justice and vulnerability,* York: Joseph Rowntree Foundation.

Lomas, K. J., Giridharan, R., Short, C. A. & Fair, A., 2012. Resilience of 'Nightingale' hospital wards in a changing climate. *Building Services Engineering Research & Technology,* 33(1), pp. 81-103.

Mavrogianni, A. et al., 2012. Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings. *Building and Environment,* Volume 55, pp. 117-130.

O'Neill, M. S., Zanobetti, A. & Schwartz, J., 2005. Disparities by race in heat-related mortality in four US cities: the role of air conditioning prevalence. *Journal of Urban Health,* 82(2), pp. 191-7.

ONS, 2012. *Population Ageing in the United Kingdom, its Constituent Countries and the European Union,* London: Office for National Statistics.

Oven, K. J. et al., 2012. Climate change and health and social care: Defining future hazard, vulnerability and risk for infrastructure systems supporting older people's health care in England. *Applied Geography,* Volume 33, pp. 16-24.

Park, C. & Allaby, M., 2013. *A Dictionary of Environment and Conservation.* 2nd ed. Oxford: Oxford University Press.

Pelling, M. & High, C., 2005. Understanding adaptation: What can social capital offer assessments of adaptive capacity?. *Global Environmental Change,* 15(4), pp. 308-19.

PHE, 2014. *Adaptation to Climate Change, Planning Guidance for Health and Social Care organisations,* Cambridge: Public Health England, Sustainable Development Unit.

PHE, 2014a. *Heatwave Plan for England 2014 - Protecting health and reducing harm from severe heat and heatwaves,* London: Public Health England / TSO.

Preston, I. et al., 2014. *Climate change and social justice: an evidence review,* York: Joseph Rowntree Foundation.

Race, G. L., 2010. *How to manage overheating in buildings, A practical guide to improving summertime comfort in buildings,* London: Chartered Institution of Building Services Engineers.

Reid, C. E. et al., 2009. Mapping community determinants of heat vulnerability. *Environmental Health Perspectives,* 117(11), pp. 1730-6.

Riahi, K. et al., 2011. RCP 8.5 - A scenario of comparatively high greenhouse gas emissions. *Climatic Change,* Volume 109, pp. 33-57.

Slingo, J. et al., 2014. *2014: A year of recordbreaking temperatures?,* Exeter: Met Office.

Smith, C. L. & Levermore, G. J., 2008. Designing urban spaces and buildings to improve sustainability and quality of life in a warmer world. *Energy Policy,* 36(12), p. 4558–62.

Stevenson, A., 2010. *Oxford Dictionary of English.* 3rd ed. Oxford: Oxford University Press.

Szokolay, S. V., 2008. *Introduction to Architectural Science: The Basis of Sustainable Design.* 2nd ed. Oxford: Architectural Press.

The Royal Society, 2014. *Resilience to extreme weather,* London: The Royal Society.

Theeuwes, N. E. et al., 2014. Seasonal dependence of the urban heat island on the street canyon aspect ratio. *Quarterly Journal of the Royal Meteorological Society,* Volume 140, pp. 2197-210.

UN, 2013. *World Population Ageing 2013,* New York: United Nations publication.

UN, 2014. *World Urbanization Prospects: The 2014 Revision, Highlights,* New York: United Nations.

Vivian, S., Williams, N. & Rogers, W., 2005. *Climate change risks in building - an introduction,* London: Construction Industry Research and Information Association.

Volker, S. et al., 2013. Evidence for the temperature-mitigating capacity. *Erdkunde,* 67(4), pp. 355-71.

Watkins, R., Palmer, J., Kolkotroni, M. & Littlefair, P., 2002. The London Heat Island - surface and air temperature measurements in a park and street gorges. *ASHRAE Transactions,* Volume 108, pp. 419-27.

White-Newsome, J. L. et al., 2012. Climate change and health: Indoor heat exposure in vulnerable populations. *Environmental Research,* Volume 112, pp. 20-7.

Wilby, R. L., 2003. Past and projected trends in London's urban heat island. *Weather,* Volume 58, pp. 251-260.