A Critical Review of Impact of Overheating in Buildings using Matrix Framework Assessment

Martin Adlington, Boris Ceranic

Abstract - In an effort to reduce carbon emissions, changes in UK regulations, such as Part L conservation of heat and power, dictates improved thermal insulation and enhanced air tightness. These changes were a direct response to the UK Government being fully committed to achieving its carbon targets under the Climate Change Act 2008. The goal is to reduce emissions by at least 80% by 2050 compared to the 1990 baseline. Factors such as climate change are likely to exacerbate the problem of overheating, as this phenomenon expects to increase the frequency of extreme heat events exemplified by stagnant air masses and successive high minimum overnight temperatures. However, climate change is not the only concern relevant to overheating, as research signifies, location, design and occupation; construction type and layout can also play a part. Because of this growing problem, research shows the possibility of health effects on occupants of buildings could be an issue. Increases in temperature can perhaps have a direct impact on the human body's ability to retain thermoregulation and therefore the effects of heat related illnesses such as heat stroke, heat exhaustion, heat syncope and even death can be imminent. This review paper presents a comprehensive evaluation of current literature on the causes and health effects of overheating in buildings and has examined the differing applied assessment approaches used to measure the concept. Firstly, an overview of the topic was presented followed by an examination of overheating research work from the last decade. These reviews form the body of the article and are grouped into a framework matrix summarising the source material and identifying the differing methods of analysis of overheating. Cross case evaluation has identified systematic relationships between different variables within the matrix. Key areas focused on include, building types and country, occupants behavior, health effects, simulation tools, computational methods.

Keywords **-** climate change, overheating-thermal comfort, health.

I INTRODUCTION

The definition of overheating in buildings is still unclear [1]. The consensus from research is that it is the amassing of warmth within a dwelling to a level it would cause distress to the inhabitants. Indeed, Zero Carbon Hub [2] suggests, "the term overheating is used to describe when conditions in a building make occupants feel uncomfortable or heat stressed". However, some research has gone further and indicated temperature ranges that may pose a problem. A considered benchmark is the living area of a dwelling exceeding 28˚C and dwelling bedrooms exceeding 26˚C for more than 1% of occupied hours [3] [4]. This criterion has been established from simulations using weather files from a 'design summer year' (DSY), although it is argued this criterion is insensitive and open to abuse [5]. Others have produced their own definition by using the Met Office heatwave classification to compare what influence the external climate has on the indoor comfort temperature [5]. For example, "Sum of all the days with average of night time (11pm-7am) bedroom temperature more than 24˚C for 5 or more days during May-October" [6].

Certainly, in the domestic sector, the problem of overheating is to be a concern for future generations [7]. A substantial amount of evidence points to the European heat wave during the summer of 2003 and even though considered to be unusual, it is expected that these extreme weather events will reoccur frequently by the 2050s [8]. In addition, according to Zero Carbon Hub [2] this phenomenon is alleged to have contributed to the death of approximately 2000 people in the UK and overall more than 35,000 in Europe, even though conflicting research disputes this number. Temperatures during this time repeatedly hit between 26˚ and 37˚ in the daytime and above 19˚ at night [2]. It is thought therefore, the problems of overheating are only set to be exacerbated, as we move into the possibility of extended phases of above average indoor temperatures in buildings.

Different factors contribute to overheating, including highly insulated and air tight buildings, climate change, urban heat island, [9] and an increase in consistently higher temperatures. As well as these issues causing heat stress related illness, there are other concerns, which will have an impact on the comfort level of occupants, such as prolonged exposure to these high temperatures and poor air movement within the dwelling. Moreover, other influences such as occupant behaviour, urbanisation and building characteristics of dwellings will further contribute to the causes of overheating [9].

II MAIN CAUSES OF OVERHEATING

A. Climate Change

Global warming and climate change tend to be discussed interchangeably. However, these two terms have individual meanings. Global warming is deemed to be an accelerated increase in the average temperature over the entire planet. NASA's over one-hundred climate records indicate that all but one of the sixteen hottest years have occurred since the year two-thousand [10]. Further evidence the planet is warming up exponentially. Conversely climate change is a broader term that refers to the issue of polluting the planet, which predominately is created by the burning of fossil fuels creating a gas that is trapping the heat in the earth's atmosphere. As a direct consequence of this heat-trapping gas, not only is the temperature increasing globally, but this carbon pollution is also changing other climatic conditions, such as rain and snow patterns, increasing intense storms and more severe droughts [10]. And as argued by the Climate Change and Health: Director of Public Health Annual Report for Sheffield, climate change is deemed to be as a direct consequence of global warming [11].

The environmental issue of climate change is constantly under discussion in terms of public health. And it is suggested there could be some health benefits from climate change such as a reduction in cold related deaths, this being dependent on locality [12]. However, research shows that 'climate change is an environmental health hazard of unprecedented scale and complexity' and as such the overall impact of climate change is likely to be immensely negative [13].

The 2003 extreme heatwave across Europe is testament to this where the UK Office of National Statistics recorded that more than 2000 excess mortalities occurred in August across England and Wales reasoned to be caused as a direct consequence of the excess heat [14]. Moreover, it was not only the UK which was affected as according to Johnson there was an excess of 11,000 deaths in France during the first two weeks of August. The significant increase in mortality was evident when compared to previous hot summers [15]. In fact, according to the UK Met Office it was estimated that more than 20,000 people died over August within Europe over this record-breaking heatwave, which was thought to be the warmest for up to 500 years [16]. Even though there is an infrequency of severe heat waves, the Met Office predicts that by the 2080's the temperatures in daytime summer are likely to exceed 42ºC in parts of England at least once a decade beneath a greenhouse gas high emissions situation. They further analyse that by 2040 the heatwave of 2003 would be classed as normal summer conditions. And by 2060 it would be ranked as a cooler than a regular summer under a medium high greenhouse gas emissions scenario, Fig 1 [14].

Therefore, it is inherent the issues of climate change will affect the health and wellbeing of most populations [17] over the upcoming decades, as average temperatures are set to increase by at least 2°C above the preindustrial average temperature this century [17]. In addition, in the UK, increases of temperature in Southern England and Northern Britain are expecting an up-surge in mean summertime temperatures of 5.4°C and 2.8°C respectively by 2080 [18]. Indeed, a steady increase in the number of hot days in the central belt of England with a mean temperature above 20°C is evident as shown in Figure 1, indicated by the straight black line from 1772 to 2004 [19]. Also apparent is the increase in the number of hot days as shown in 1995 and 2006, 26 and 19 hot days respectively [19]. To combat the effects of climate change, in terms of the associated overheating health issues it is likely to contribute to; further appropriate mitigation measures will need to be implemented [17]. These should significantly reduce carbon emissions [17], but these mitigation measures should be suitably analysed to ensure they are not exacerbating the increasing problem of heat related illness. Moreover, precedence ought to be given to measures that are deemed to improve indoor air quality and the health and comfort of occupants [20].

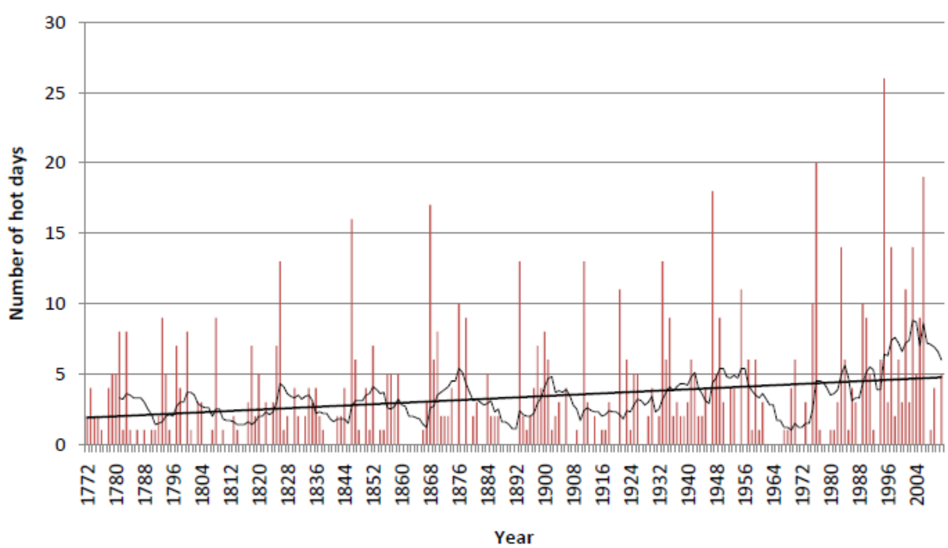

Figure 1 - Number of days with a mean temperature over 20°C in the UK [18]

B. Urban Heat Island Effect

Changes in the global climate are interlinked to what is commonly referred to as the urban heat island effect. Buildings absorb the suns energy and its subsequent heat throughout the day and then reradiate this long wave radiation at night [21]. Consequently, urban areas tend to be warmer than rural areas. These temperature differences between the two are commonly known as the urban heat island intensity effect (UHII) [22]. Moreover, it is estimated that cities occupy over half of the world population and as the rise in temperature in these metropolises intensifies, it will inevitably create an increase in risk of vulnerability to this extra heat to the younger and older generation [23]. Several factors exacerbate the urban heat island issue; the combination of concrete and tarmacadam roads creating high thermal mass and tall buildings reducing ventilation within the canopy, as well as the heat emitted from vehicles can add 1°C to 6°C to the surrounding air temperature [2].

C. Internal and External Heat Gains

Further contributors to overheating internal heat gains are sensible and latent heat emitted within a dwelling from computers, office equipment, lighting, domestic appliances and activities such as bathing and cooking. In addition, occupants produce metabolic heat depending on their activity level [2]. However, variations between dwellings in relation to problems associated with internal heat gain can be substantial depending on their age or type due to more recent homes adhering to increased standards of air tightness and thermal efficiency. Consideration also needs to be given to the problem of external heat gains. Depending on the orientation of the dwelling solar gain though an acceptable source of warmth in some instances can create what is known as the greenhouse effect. Increased thermal standards and the use of double and triple glazed highly energy efficient windows designed to retain heat in cold spells would then prevent unwanted heat in the warmer spells from escaping. This unwanted heat would create a problem at night as the heat is absorbed into the heavy thermal mass materials used today and is then released into the internal spaces at night if there is no ventilation strategy. Therefore, as indicated in Figures 2 and 3, nighttime flushing of the generated daytime heat would need to be implemented to prevent the occurrence of overheating at night. Natural ventilation strategies such as opening a number of windows would be needed. However, concerns over security may prevent occupants from carrying this out so an alternative mechanical system may need to be implemented. However, the impact of heat absorbed into the thermal mass of the materials may prevent the night time temperature reducing below the day time peak. Therefore, reduction of the indoor temperature would be unsuccessful at nighttime.

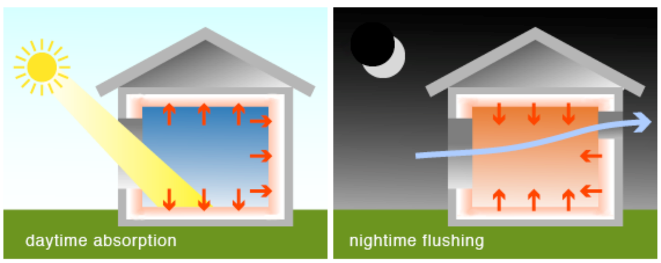

Figure 2 – Nighttime flushing [24].

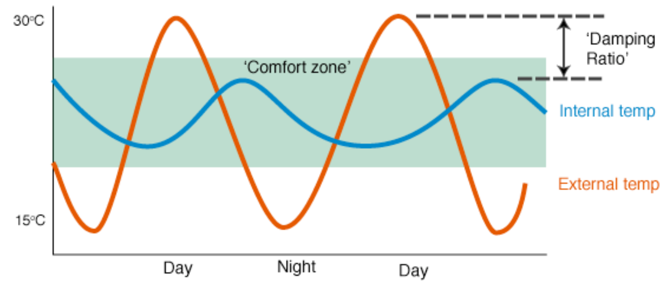

Figure 3 – Nighttime flushing reducing the temperature back to the comfort zone [24].

III HEALTH EFFECTS OF OVERHEATING

There has been an increasing amount of research into the health issues associated with overheating in buildings. In fact, an index developed by Chan et al [25] to directly measure the effects of indoor heat was an important step in assessing the main risk factors of health associated with heatwaves. Called the heat related Health Effects Index (HEI) it focused on the consequences of localised heat. It identified unventilated buildings caused a healthy individual to be affected by heat up to 3.8 times more than if that same person was outdoors [25]. This exposure to heat if prolonged is likely to cause a number of heat related illnesses such as heat stroke, heat cramp and heat exhaustion [26]. Heat stroke is deemed to be the most severe outcome of overheating as it can be potentially life threatening and could possibly require emergency medical treatment.

Certain groups are more vulnerable to the effects created by the problems of overheating-such as the elderly and young children [27]. Evidence suggests that as we grow older we have a decreasing ability to cope with colder climates. As we age our bodies do not retain heat as well as when we are younger due to the issues of less body fat and our blood vessels narrowing (vasoconstriction). Moreover, this will affect the body's ability to retain heat of their own due to a reduced metabolism. However, high temperatures can be just as challenging as older bodies tend to struggle with the increased need to circulate blood to the boundaries of the body to cool down [28]. Individuals with a balanced regulatory system would maintain a core temperature of around 37°C and would normally adjust to the surrounding temperature through conduction, convection, radiation and evaporation [25]. However, not only the vulnerable are at risk as even healthy individuals can suffer the consequences of overheating as the increase in temperature can inhibit the body to maintain thermoregulation. Heat balance and thermoregulation were combined in Fanger's comfort theorem in determining a range of comfort temperatures in which occupants of buildings will feel comfortable. As indicated in this model the body will go through phases of sweating, shivering and regulating blood flow to the outer layers to achieve a neutral thermal sensation [29]. However, as we age our bodies become less efficient at regulating temperature as there is a "a diminished response of the sweat glands to central and/or peripheral stimuli" and "an age-related structural alteration in the eccrine glands or surrounding skin cells" [30].

So, as the temperature rises so does our core body temperature which is why people suffer heat related illnesses.

Within the Governments Housing Health and Safety Rating System guidance it outlines the perceived problems within housing in terms of excess heat within a dwelling. Three figures are implemented to produce a hazard score, the weighting for the class of harm, the likelihood of the occurrence and the spread of possible harms from the occurrence, expressed as a percentage for each of the classes of harm shown in figure 4 [31]. Following the analysis of the data within England shown in Fig 5 the most susceptible age group in terms of heat related illness is age sixty-five years and over [31]. However, following the review of the current data there is very little evidence that the health issues have been researched in detail, especially within care facilities.

Table 1 – Weightings for the Classes of Harm

Class of Harm		Weighting
I	Extreme	10,000
II	Severe	1,000
III	Serious	300
IV	Moderate	10

Figure 4 – Weightings table for classes of harm [32].

Excess heat. Average likelihood and health outcomes for all persons ages 65 years or over, 1997–1999

Dwelling type and age		Average likelihood 1 in:	Spread of health outcomes				Average HHSRS scores
			Class I %	Class II %	Class III %	Class IV %	
Houses	All ages	–	31.0	8.0	25.0	36.0	0 (J)
Flats	Pre 1920	60,000	31.0	8.0	25.0	36.0	5 (J)
	1920-45	90,000	31.0	8.0	25.0	36.0	4 (J)
	1946-79	130,000	31.0	8.0	25.0	36.0	3 (J)
	Post 1979	110,000	31.0	8.0	25.0	36.0	3 (J)
All dwellings		**900,000**	**31.0**	**8.0**	**25.0**	**36.0**	**0 (J)**

Figure 5 – Heat excess health chart [31]

Furthermore, the heatwave plan for England shows that greater temperatures more than 25ºC is likely to result in related morbidity and summer mortality. The body is affected considerably during a heatwave with respiratory and cardiovascular diseases being the main cause of death. Figure 6 as indicated by the heatwave plan summarises the main causes of illness and death during elevated temperatures.

The main causes of illness and death during a heatwave are respiratory and cardiovascular diseases. Additionally, there are specific heat-related illnesses including:

- heat cramps – caused by dehydration and loss of electrolytes, often following exercise
- heat rash – small, red, itchy papules
- heat oedema – mainly in the ankles, due to vasodilation and retention of fluid
- heat syncope – dizziness and fainting, due to dehydration, vasodilation, cardiovascular disease and certain medications
- heat exhaustion (more common) - occurs as a result of water or sodium depletion, with non-specific features of malaise, vomiting and circulatory collapse, and is present
- when the core temperature is between 37°C and 40°C. Left untreated, heat exhaustion may evolve into heatstroke
- heatstroke – can become a point of no return whereby the body's thermoregulation mechanism fails. This leads to a medical emergency, with symptoms of confusion; disorientation; convulsions; unconsciousness; hot dry skin; and core body temperature exceeding 40°C for between 45 minutes and eight hours. It can result in cell death, organ failure, brain damage or death. Heatstroke can be either classical or exertional (eg in athletes)

Figure 6, Heatwave plan for England Making the case: the impact of heat on health – now and in the future. (2018) [37].

IV METHODOLOGY

The focus of this preliminary study was principally developing a framework to establish the differing methods of how the problem of overheating and the associated health issues are analysed and measured. The framework method has been used extensively since the 1980s for the management and analysis of qualitative data [33]. The method is positioned within other analysis methods labelled thematic analysis or qualitative content analysis. This style of research seeks to identify commonalities and dissimilarities in qualitative data [33]. Therefore, ultimately enabling relationships identified between different parts of the data to be extracted before being used in discussing evocative conclusions gathered around topics.

By identifying relevant literature incorporating it into a matrix and analysing it will assist new researchers in organising and critically evaluating the data available enabling them to make informed decisions on what is current in terms of their research topic. As Garrard [34] states, the matrix should be used to produce and thematically catalogue the topics targeted within the sources relative to the research theme [34]. A range of scientific publications were searched through electronic databases; the matrix framework is used as a basis for organising the quality data. It consists of several elements, which are; building types and country, occupant's behaviour, health effects from overheating, simulation and computational tools used. The aim was to understand the differing methods of measuring and analysing overheating in buildings and to identify unexplored research topics suitable for further research. It was decided not to include the findings from each paper reviewed as this was deemed to be outside the scope of this article.

V DISCUSSION AND CONCLUSIONS

The sample review of thirty-five papers is a small snap shot of the current research but it will give an indication of how previous research has been carried out in terms of the methodology and the methods used. As mentioned previously it will assist new researchers in this area going forward in choosing an appropriate methodology.

A range of building architypes is evident within the sample. However, much of the studies are related to urban housing in some form or another with little evidence of research into care and nursing homes, certainly, within the UK.

Simulation software is now used extensively in overheating-in-buildings research. It is the process of modelling a real building with a set of mathematical formulas to identify solutions to a problem. However, errors are common place in modelling with researchers being overly optimistic in their assumptions in some respects. Characteristics of these errors can include the construction quality, exact as-built conditions, unknowable aspects or over simplified assumptions [35]. A further issue with modelling and simulations is the uncertainty of occupant behaviour [35]. Most of the papers reviewed discuss a standard occupancy pattern, but you could argue what is the meaning of a standard occupancy pattern.

In terms of the software used for modelling overheating in buildings Integrated Environmental Solutions (IES) and EnergyPlus are the most widely used as evidenced in the matrix. Both have extensive capabilities and are critically important for providing science centred information to enable decision makers to implement changes for improvements in their field of research [36].

When environmental modelling it is important to obtain the correct weather data. As identified in the matrix there are several methods of achieving this. However, within the UK the UK Climate Projections (UKCP09) is the leading source of climate data used for all regions. UKCP09 provides

V1 POSSIBLE FURTHER RESEARCH

1. How is air quality effected from overheating?
2. A sensitivity analysis on the weather files utilised to determine overheating ought to be carried out.
3. Further field investigations of the relevance of occupant behaviour and energy use impacts on overheating
4. A sensitivity analysis on the weather files utilised to determine overheating ought to be carried out.
5. Further field investigations of the relevance of occupant behaviour and energy use impacts on overheating.
6. More focussed research on thermal comfort for domestic properties needs to be implemented. The preponderance of research on thermal comfort is carried out on office buildings and then presupposed for domestic properties.
7. The function of thermal mass in terms of helping to reduce the problem of overheating.

Ref and Year	Building Type	Country	Occupants	Overheating health risks mentioned	Weather/Climate data	Modelling used	Research Methods
[38] 2013	1919 End Terraced House	UK Manchester	No occupants as this is a simulation pre-constructed building	No mention of the health effects of overheating	UKCIP02 and UKCP09 programmes were used to assess the likely overheating in summer. Design Summer Year (DSY) was used to simulate the expected building performance.	IESEVE (Integrated Environmental Solutions Software System)	Modelling against climate projections used UKCIP02 and UKCP09
[39] 2015	Hospital 1970s design	UK Cambridge	Patients and Staff within the hospital	Sleep will be effected if temperatures reach 24ºC	Test reference Year (TRY), the Design Summer Year and UKCP09 used to predict future weather scenarios.	Dynamic thermal model IES (Integrated Environmental Solutions)	Modelling against current climate data. Twenty-six spaces on three levels were monitored at hourly intervals with Hobo U2 temperature loggers.
[40] 2012	Hospital	UK	Hospital patients, staff and visitors.	15000 excess deaths highlighted in the 2003 heatwave.300 summer deaths in the UK heatwave of June/July 2009	Adaptive refurbishment options are proposed and their relative performance predicted against the existing internal conditions, energy demands and CO2 emissions.	Dynamic thermal model IES (Integrated Environmental Solutions)	Adaptive refurbishment options are proposed and their relative performance predicted against the existing internal conditions, energy demands and CO2 emissions.
[41] 2011	A range of urban dwellings were modelled, terraced houses, flats and housing.	UK	Standard occupancy pattern	Reduced thermal comfort and heat-related morbidity and mortality	CIBSE Design Summer Year (DSY) used to represent the weather conditions for the period of the study. UKCP09 is used to project future climate change.	EnergyPlus 3-1-0 Dynamic Software	Satellite pictures provide profiles of the heat island characteristics around the home.
[42] 2006	Urban Dwellings	France	Vulnerable people over 65 years of age.	This study tended to focus on death and did not generally discuss the associated health issues.	Satellite pictures from LANDSAT 5 provided environmental data. Geographic Information Systems (GIS) was used to calculate the mean surface temperature of land.	No dynamic simulation modelling was carried out on this project.	Next of kin of the deceased persons sampled were contacted and a face to face or telephone interview was conducted. Family Doctors were contacted to obtain info on underlying medical conditions. A logistical regression model was used to investigate the risk factors and mortality i.e. health, social factors, housing conditions, environmental factors and behavioural factors.

[43] 2010	Nursing Homes	Germany	Elderly residents over 65 years old.	Above the threshold of 26ºC increasing ambient temps increased mortality.	Daily ambient maximum temperature.	Time series analysis Poisson regression analysis	Time series analysis between daily ambient temperature and daily ambient temperatures, sex, age and level of care were the parameters used.
[44] 2013	PassiveHaus Dwellings	UK London, Islington	Simulation study only	Cardiovascular strain and trauma. 26ºC mortality increases and an increase in strokes.	UKCP09 Weather Generator (WG). Test reference Year (TRY) was used to assess future climate change.	The IES-VE (2012) v6.4 Apache software	Dynamic Simulation Modelling against Global Sensitivity Analysis and climate data.
[45] 2013	Flats typologies as below... High and Low rise 1965-1974 Low rise post 1990	UK	The modelling included vulnerably people (elderly couple)	No mention of the impact on health in this paper.	Simulations using the CIBSE London design Summer Year (DSY)	EnergyPlus . 3.1.0	Three types of flats modelled and simulations carried out using DSY. The modelling software was also used to measure air quality in terms of particulate matter (PM) entering the buildings if windows were opened.
[46] 2010	Standard domestic house type modelled.	UK London Edinburgh	The occupants were not indicated but it is indicated the study was based around a standard occupancy pattern.	Health issues have not been covered.	Climate data was represented using the UK Climate Impacts Programme UKCIOP2 CIBSE Test Reference Year was also implemented.	ESP-r building software package used.	House type modelled in three scenarios, timber frame, twin leafed masonry dwelling with improved insulation built in 2002, pre-1900 solid wall dwelling.
[47] 2015	Building archetypes of different age/type	UK London	Standard occupant pattern	Health issues have not been covered.	Hourly weather data from 12 weather stations in London from BADC (UK Meteorological Society)	EnergyPlus 8.2	Population data from 2011 census. Office of National Statistics used for mortality rates. House types modelled LUCID. The Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities was used for the weather data
[48] 2015	PassiveHaus Social Housing Flats	UK Coventry	Standard occupancy pattern but with a high number of vulnerable individuals.	Health issues have not been covered.	Outdoor temperature was taken from the local weather station about 3 miles from the site.	No simulation software was used in this study.	4 indoor environmental parameters were monitored. Indoor temperature Humidity CO2 VOCS Occupancy pattern revealed the flats were occupied for most of the day. PassivHaus and Adaptive benchmarks were used to evaluate overheating.

[49] 2014	London dwelling architypes.	UK Various locations.	Standard occupancy, working couple with children.	Heat stroke, as well as aggravating chronic diseases such as cardiovascular and respiratory diseases.	Six different Design Summer Year (DSY) climate files from locations around the UK were used. CCWeatherGen tool used.	EnergyPlus 3.1	15 dwelling architypes were modelled under 3456 dwelling variants. Climate files from six different locations within the UK have been used. A medium emissions scenario was used to model a hot summer in the year 2050.
[50] 2012	19th century solid wall terraced houses	UK, London	A range of occupancy patterns were simulated.	Health issues have not been covered.	2003 (heatwave) weather data for London Heathrow was obtained from the British Atmospheric Data Centre.	EnergyPlus 6.0 under the control of jEPlus parametric tool.	A terraced block of 3 dwellings was modelled to measure both a mid and end terraced property. The English House Condition Survey data was used to ensure models were representative of terraced housing of this type. 12288 simulations were carried out with combinations of interventions. Internal gains were determined using CIBE and ASHRAE guidelines.
[51] 2012	Not specified – just mentions a large number of buildings.	UK, London is assumed but not clearly specified.	Not specified.	Health issues have not been covered.	UKCP09	The IES-VE Apache software (Version not specified)	Thermal modelling of different architectural designs was created and were performed for the four UKCIP emissions scenarios. Historic weather data was morphed using mathematical transformations into future weather years' representative of different climate change scenarios.
[52] 2015	Two types of apartment buildings. 1) Prefabricated concrete beam construction. 2) Modern traditional construction.	Estonian.	Standard occupancy pattern indicated.	Health issues have not been covered.	Outdoor weather temperature was obtained from the nearest weather station. Internal temperatures were assessed based on the target values CR1752, EN15251 and EN ISO 7730.	No simulations were carried out on this study.	Indoor temperatures were recorded for 3 months with the impact of ventilation, orientation and window size were taken into consideration. 24-hour data was used for the analysis as there was little temperature difference between day and night.
[53] 2013	A range of properties have been used for this	England	Standard occupancy pattern indicated.	Health issues have not been covered.	Weather data was obtained for local weather stations (30	No simulations were carried out on this study.	HOBO pendant temperature loggers were used to monitor

	study – detached, semi-detached, end and mid terrace, flats, conversions. Age range pre 1919 to post 1990.				number) from the British Atmospheric Data Centre (BADC 17)		indoor temperature, 252 in the study. 427 interviews were carried out with householders within the study.
[54] 2013	Detached, semi-detached, mid terraced and flats were modelled.	UK Oxford, Bristol, Oxford	Standard occupancy pattern indicated.	Health issues have not been covered.	Design summer year (DSY) files are used to assess overheating in hot summers but not in extreme or heatwave conditions	Integrated Environmental Solutions – Virtual Environments ModelIT and ApacheSim were used to model the dwellings.	Archetypes of English suburban homes simulated. Climate change projections reviewed and selected. Adaption measures reviewed and packages developed.
[55] 2012	Detached, semi-detached and flats - Dutch dwelling stock from 1964 to 2012.	Holland	Occupancy pattern not stipulated.	Mentions heat related illness and death but no detail.	Climate projections from the Dutch metrological institute (KNMI 2006)	IDA-ICE 4.6 assisted by MATLAB-2013b	9,216 studied dwelling cases are assessed for four climate scenarios.

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