A CRITICAL REVIEW OF THE IMPACT OF GLOBAL WARMING ON OVERHEATING IN BUILDINGS

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ABSTRACT

Over the last century global average temperatures have increased up to 1°F. Indeed, since records of comprehensive global temperatures were available as early as 1880, the evidence suggests that 2001-2010 decade has been shown to be the warmest. This change is having a direct impact in terms of an increase in extremely hot days and warm nights and a decrease in cold days. Evidence suggests that different parts of the world are warming at a faster rate than others. However, research predicts that the long-term impact of global warming is only set to increase.

One of the major contributors of global warming is the impact of carbon emissions and in an effort to reduce these emissions the UK Government implemented changes to UK regulations, such as Part L conservation of heat and power that dictates improved thermal insulation and enhanced air tightness. The UK is fully committed to achieving its carbon targets under the climate Change Act 2008. However, there is a caveat that comes with these changes, as coupled with climate change they are likely to exacerbate the problem of overheating in buildings. And because of this growing problem the health effects on occupants of these buildings may well 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 impact of global warming/climate change on overheating in buildings. Firstly, an overview of the topic will be presented followed by an examination of global warming/overheating research work from the last decade. These papers will form the body of the article and will be grouped into a framework matrix summarising the source material identifying the differing methods of analysis of the impact of global warming on overheating. Cross case evaluation will identify systematic relationships between different variables within the matrix.

Keywords: Global Warming, Climate Change, Overheating, Health.

1. INTRODUCTION

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 (Climate.nasa.gov, 2018). 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 earths 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 (Climate.nasa.gov, 2018). 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 (Council and Street, 2014).

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 (Maller and Strengers, 2011). 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 (Confalonieri et al., 2007).

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 (McLeod et al., 2013). Moreover, it was not only the UK which was affected as according to Johnson there was in 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 (Flynn et al., 2005). 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 (Met Office, 2018). 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 (McLeod et al., 2013)

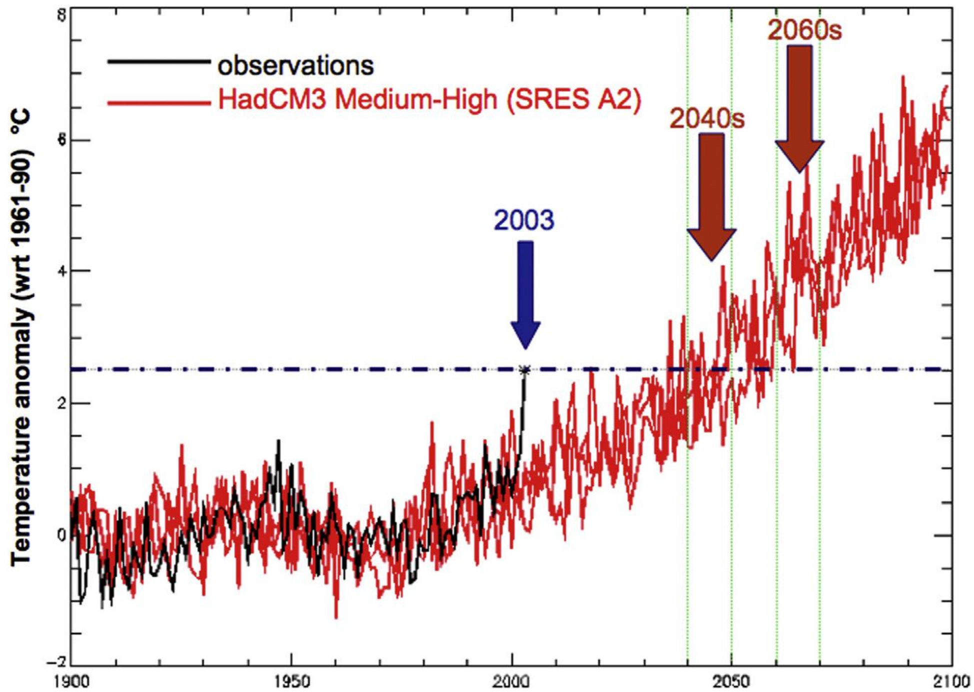

Fig 1, Temperature anomaly of 2003 heatwave in relation to medium high greenhouse gas emissions trend (McLeod et al., 2013)

2. OVERHEATING IN BUILDINGS

When occupants of a building feel uncomfortable or start to suffer a form of heat stress the term overheating is used to describe the concept. Overheating of a building is not just a simple measure of high temperatures but is associated with a complex set of variables (Overheating in new homes, 2012). Incessant periods of high temperatures above what is deemed to be average are argued is the leading factor affecting occupant's health. There are conflicting temperature thresholds in terms of when overheating occurs. The CIBSE Environmental Design Guide A defines the temperature maximums as 28˚C for living rooms and 26˚C for bedrooms and overheating arises when these temperatures are surpassed more than 1% of the time occupied (Environmental Design, Guide A, CIBSE 2006). However, as indicated by the NHBC Foundation in an occurrence like the 2003 heatwave some existing homes could significantly exceed these limits (Overheating in new homes, 2012).

Besides climate change there are other influences within the mix that contribute to overheating. To comply with current legislation in an attempt to reduce carbon emissions the UK is constructing highly insulated and airtight homes and these are tending to overheat in some cases. This is a particular problem for the vulnerable population who may not be in a position to open windows in an attempt to alleviate the inside heat through purge ventilation (Gupta and Gregg, 2013). Other issues of concern that contribute to overheating may be external heat gains for solar gain and internal heat gains from occupant behaviour. However, Mavrogianni et al argues that increased insulation levels and efficient air tightness can be beneficial in some instances. As their research shows, a mid-floor flat of a high rise with the insulations retrofitted decreased the mean summer temperature 1.2 oC (from 29.0 to 27.8 oC) in the living room on the southeast elevation (Mavrogianni et al., 2013).

2. IMPACT ON HEALTH

The impact of heat in terms of increasing mortality rates in the older generation is demonstrated in numerous studies. Moreover, a connotation between morbidity and heat related mortality is well known (Klenk et al., 2010). And as indicated in the heatwave plan for England, the higher temperatures in excess of 25ºC would result in an increase in summer deaths and associated illnesses (Heatwave plan for England 2018). The effects of overheating on the body are numerous, with the main cause of death during a heatwave respiratory and cardiovascular diseases. Figure 2 below 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 37ºC and 40ºC. 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 40ºC 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)

Fig 2, Heatwave plan for England Making the case: the impact of heat on health – now and in the future. (2018).

3. CONCLUSION OF CURRENT PAPERS ON OVERHEATING

This paper presents overheating readings from several researchers. However, due to the limitations on the conference submission of four pages only a small number are shown in this article. This will be extended for the full journal submission.

These papers have been selected from thirty-five reviewed from a range of countries because as indicated by (Lomas and Porritt, 2017) overheating has been observed across Europe and North America. However, the rising level of concern in the UK is now a subject of wider discussion especially with the impact on the vulnerable population such as the elderly and very young. The six papers included in Table 1 are all from research within the UK from 2010 to 2015. This demonstrates the increased level of concern in countries that have a moderate climate such as here in the UK. Research has been conducted on a range of dwellings but with the main focus being domestic house typologies. However, there is some limited research on hospitals and care homes as indicated below, but much more work is needed due to the high vulnerability of the occupants. Typical recordings of temperature data from the domestic typologies focused on the bedroom and living room. It was surprising to see out of the six papers highlighted within this article, that only two used data loggers with the other four focusing only on modelling and simulation studies. And as Symonds et al suggests, there are often discrepancies between simulation results and measurements. Factors such as building characteristics and occupant behaviour can make the validation of such studies challenging for the researcher (Symonds et al., 2017). The weather file chosen is fundamental in assessing the predicted amount and period of raised internal temperatures. And the papers reviewed show there is very little standardisation on the current and future weather files for use in overheating assessment. Some element of regularisation is needed to ensure there is similarity on the assessment criteria for each study (Lomas and Porritt, 2017). Further, modelling software is now a key element of analysing overheating and there are many different types of software available. The review shows that both Integrated Environmental Solutions and EnergyPlus are the main choice of researchers today.

There is a fundamental lack of research on health issues associated with overheating and researchers of overheating doing field work should be collaborating with epidemiology researchers to further understand the physiological issues associated with heat exposure.

Ref and Year	Building Type	Country	Occupants	Temperature Data analysed	Sensors / Recording Equipment	Overheating health risks mentioned	Weather/Climate data	Modelling software used	Research Methods
2015	Hospital 1970s design	UK Cambridge	Patients and Staff within the hospital	26 spaces on 3 levels monitored hourly – July to August	Hobo U2 temperature loggers.	Sleep will be affected 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.
2012	Hospital	UK Cambridge	Hospital patients, staff and visitors.	2 nurses' stations and 3 wards monitored hourly – July to August	Hobo pendant loggers	Secondary data of 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.
2011	A range of urban dwellings were modelled, terraced houses, flats and housing.	UK London (various locations)	Standard occupancy pattern	3456 combinations of dwelling types and characteristics	None used	Reduced thermal comfort and heat-related morbidity and mortality discussed	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.
2013	PassiveHaus Dwellings	UK London, Islington	Simulation study only	Living areas and bedrooms	None used	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.
2013	Flats typologies as below... High and Low rise 1965-1974 Low rise post 1990	UK England with no specific region indicated.	The modelling included vulnerably people (elderly couple)	Living areas and bedrooms	None used	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.
2010	Standard domestic house type modelled.	UK London and Edinburgh	The occupants were not indicated but it is indicated the study was based around a standard occupancy pattern.	Living areas and bedrooms	None used	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.

Table 1

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