Building and Environment 76 (2014) 81–91

Contents lists available at ScienceDirect

Building and Environment

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

The relative importance of input weather data for indoor overheating risk assessment in dwellings

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ARTICLE INFO

Article history:
Received 20 December 2013
Received in revised form
21 February 2014
Accepted 11 March 2014

Keywords:
Overheating
EnergyPlus
Kendalls Tau
Weather files

ABSTRACT

The risk of overheating in UK dwellings is predicted to increase due to anthropogenic climate change and local urban climate modification leading to an increased urban heat island effect. Dwelling geometry characteristics such as orientation, aspect, and glazing, and building fabric characteristics such as thermal mass and resistance can influence the risk of overheating. The majority of simulation-based studies have focused on identifying the importance of building characteristics on overheating risk using a small number of weather files, or focus solely on the impact of external temperatures rather than a full set of climatic variables. This study examines the overheating risk in London dwelling archetypes when simulated under different UK climates, both in the present and under 'hot future' conditions, with the objective of identifying whether the conclusions drawn from location-specific studies can be generically applied to different cities. Simulations were carried out using the dynamic thermal simulation tool EnergyPlus using 3456 dwelling variants and six different Design Summer Year (DSY) climate files from locations within the UK. In addition, a 2050 Medium Emissions scenario weather file was used to model a particularly hot summer in all locations. The results indicate that weather files can influence the ranking of relative overheating risk between dwelling types, with significant variations in the relative ranking between London, Scotland and the North of England, and the rest of England. These results show that studies examining the overheating risk across the UK need to consider the variability of building performance under regional weather conditions.

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1. Introduction

In temperate European countries, the frequency and severity of heatwave events are expected to increase due to climate change [1]. High temperatures may be exacerbated in urban environments, where land surface modification and human activities can cause temperatures to be warmer relative to surrounding rural areas, resulting in the so-called urban heat island phenomenon. The combination of extreme weather and the urban heat island effect is expected to increase the risk of overheating and associated population mortality and morbidity. Overheating has potentially serious consequences; the 2003 heatwave in Europe, for example, caused approximately 35,000 excess deaths, of which 2000 were recorded in the UK [2]. While most epidemiological studies have examined the increase in mortality and morbidity in populations during extreme heat events using external temperatures, temperatures inside buildings are important to consider for a population spending over 95% of their time indoors [3].

The present study examines how the external climate can influence the relative overheating risk inside dwellings by looking at a large range of building types and potential retrofit measures under different UK climate scenarios. The results of the study can be used to determine whether the overheating risks derived for a specific region may be applied throughout the UK, scaled for external temperatures, or whether region-specific simulations need to be run. The outcomes may also be used to assess whether a

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http://dx.doi.org/10.1016/j.buildenv.2014.03.010
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national 'one-size-fits-all' building design and retrofit guidance on overheating risk can be developed for the UK, or whether guidance needs to be specific for climate regions.

1.1. Background

High indoor temperatures can lead to a number of health consequences for individuals, directly causing problems such as heat stroke, as well as aggravating chronic diseases such as cardiovascular and respiratory diseases. The internal temperature in dwellings may be influenced by a number of factors, including:

- building geometry and morphology of surrounding structures;
- building fabric, including levels of insulation in walls, floors, roofs, and the type of windows;
- solar gains
- the level of uncontrolled or controlled ventilation available;
- internal gains from occupants and equipment;
- orientation;
- occupant behaviour;
- pollution, noise and security issues that prevent window opening for natural ventilation;
- the surrounding microclimate, including shadowing from solar radiation and wind.

Understanding the complex relationship between the indoor built environment and exposure to elevated indoor temperatures is of increasing importance due to the consequences of climate change, an ageing population, and rapid change in the domestic building stock due to large-scale programs encouraging energy-efficient refurbishments.

The risks of overheating in UK dwellings has been reviewed for all dwellings [4], and for new dwellings in particular [5]. Research into overheating risk in dwelling can use either a monitoring (e.g. Refs. [6–8]) or modelling (e.g. Refs. [9–12]) approach to understanding the relationship between outdoor temperatures and elevated indoor temperatures. An advantage of modelling studies is the ability to model a large number of dwellings quickly at a lower cost than field studies, and with the possibility of modelling future interventions and climates. Modelling disadvantages include the associated uncertainty in models and the large number of assumptions required to produce such models. Many existing modelling studies have focused on examining the relative risks of overheating inside different dwellings, identifying types of buildings and constructions that are particularly vulnerable. Research by Mavrogianni et al. examined overheating risk in London dwellings using the dynamic thermal simulation tool EnergyPlus, identifying a greater variation in overheating risk within dwelling types according to their orientation, surrounding dwellings, and insulation levels than variation between dwellings types [9].

The modelled relationship between different adaptations, retrofits and overheating risks has also been investigated by Porritt et al. [13], who used building simulation to examine the overheating risk in London inside terraced dwellings, ranking a number of modelled interventions in terms of their effectiveness in preventing overheating. A retrofit toolkit for heatwave adaptations [14] has been proposed as a result of this work. These studies demonstrate how building characteristics can increase the overheating risk inside dwellings under the same climate conditions using building simulation. The influence of occupancy on overheating risk has also been addressed using modelling studies [10].

In addition, investigations have been made for building performance under different climates. Coley and Kershaw proposed the concept of the Climate Change Amplification Coefficient (CT) that represents the potential for any building design to overheat given a known change in the current climate [15]. Research by Jenkins et al. [12] examined the overheating risk in a single nominal dwelling type under a range of probabilistic future climate scenarios for London and Edinburgh, focussing on the effectiveness of three adaptations (no adaptation, window opening, and external shading). Gupta et al. examined adaptations to prevent overheating in UK suburbs in six suburban house archetypes under future climate scenarios in Bristol, Oxford, and Stockport [16]. Oikonomou et al. [17] examined the varying influence of the urban heat island on the risk of overheating risk inside the London building stock.

There has, however, been little research examining the *relative* performance of different building archetypes to overheating under different climate scenarios. Peacock et al. [11] used building simulation to study overheating risk in three domestic building variants for current and future London and Edinburgh climates. The results from this study indicate that the presence of insulation is less likely to trap 'unwanted' gains in Edinburgh – where the external temperatures and solar gain are significantly less – than the equivalent dwelling in London. This suggests that buildings that may be prone to overheating in relatively hot climates in the UK may not be those at greater risk in cooler climates. In addition, simulations of indoor temperatures of commercial buildings has demonstrated considerable differences in overheating risk within London depending on the weather file used [18].

Using building characteristics as markers for overheating risk can allow for faster identification of risk, but the results from Peacock et al. [11] indicate markers may not have the same influence under different climates. The limited research into overheating using different climate scenarios suggests that external climate may influence the relative overheating risks in different dwelling types, and so generalising results from a single location to a national level may not be appropriate. This study quantifies the variation in overheating risk of building archetypes when modelled under different climate conditions.

The objectives of this study include:

1. To review the existing literature on the impacts of climate on overheating risk.
2. Use dynamic thermal simulation to model a set of London building archetypes under different weather files representative of UK climate regions.
3. To analyse the simulation results to determine if the *relative* risk of overheating for different building archetypes changes according to climate region and scenario.
4. To examine the characteristics of the modelled buildings which drive changes in relative risk of overheating between climates.
5. To examine the individual influence of weather file parameters, including temperature, wind speed, direct and indirect radiation, and cloud cover on the internal temperatures inside dwellings of varying geometry.

The simulated buildings included 15 building archetypes developed by Oikonomou et al. [17] with variations in wall, roof, floor, and window retrofit levels, orientation, and overshadowing leading to a total of 3456 dwelling typologies. *Chartered Institution of Building Services Engineers* (CIBSE) Design Summer Year (DSY) [19] weather files for six UK locations were used to represent the range of climates found in the UK under current conditions. In addition, a very hot summer for each location was modelled by morphing the CIBSE files according to 2050 medium emissions scenarios using the CCWeatherGen tool [20]. A total of 41,476 simulation files were produced for the 3456 dwelling typologies under the 12 climates using EPGenerator, a novel in-house tool used for creating EnergyPlus 3.1 batch runs. The files were then simulated over the summer period (May–September), and internal

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