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Ranking of interventions to reduce dwelling overheating during heat waves

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ABSTRACT

Extreme weather events, including heat waves, are predicted to increase in both frequency and severity over the coming decades. Low house building rates and a growing population mean there is a need to adapt existing dwellings. Research presented here uses dynamic thermal simulation to model the effect of passive heat wave mitigating interventions for UK dwellings. Interventions include a range of additions and modifications to solar shading, insulation and ventilation.

Results are presented for typical end and mid terrace houses, with four orientations, two occupancy profiles and using weather data from the 2003 heat wave. Results show the effectiveness of interventions that reduce solar gains through the building fabric, such as external wall insulation and solar reflective coatings. Internal wall insulation is shown to be less effective and can increase the overheating problem in some cases. Control of solar gains through glazing, using shutters and fixed shading, are also effective, particularly for south, east and west-facing rooms.

Results are also presented which demonstrate how it is possible to select combinations of interventions that both eliminate overheating and reduce space heating energy use. The cost of interventions is also considered in the final analysis.

1. Introduction

Much of the focus for UK building refurbishment to date has concentrated on reductions to winter heating energy use. However, climate change projections from the UK Met Office [1] suggest that in addition to increased mean temperatures there are likely to be more frequent and more intense extreme weather events, including heat waves. The European heat wave in August 2003 claimed the lives of over 35,000 people, more than 2000 of which were in the UK, with over 600 in London [2]. The victims were mostly elderly and vulnerable and the situation was exacerbated by the urban heat island effect in major cities. Temperatures recorded in London were up to 10 °C higher than surrounding rural areas [3]. The UK Department of Health currently predict that a 9-day heat wave averaging 27 °C in South East England would lead to over 3000 immediate heat related deaths [4]. Monitored temperature data from a variety of London dwellings during the 2003 heat wave by Wright et al. [5] showed that average indoor temperatures were 2.3 °C higher than the average outdoor temperature of 26.0 °C, with the peak indoor temperature in one apartment room reaching 39.2 °C.

The housing stock in the UK is being replaced at a very low rate and it is estimated that over 70% of the dwellings that will be occupied in 2050 have already been built [6]. There is therefore a need to adapt existing dwellings to provide a safe and comfortable environment in a changing climate. The UK's Institute of Environmental Management and Assessment [7] recently reported that 90% of local government departments were planning for adaptation to climate. Individual UK Government Departments have also recently published their latest climate adaptation plans [8], signalling a shift in emphasis towards policies which combine mitigation with adaptation.

These adaptation plans have generated a need for detailed information and data to aid decision-making. The Chartered Institution of Building Services Engineers (CIBSE) [9,10] has published guidance, addressing specifically the impact of climate change on the indoor environment. They considered occupied hours over the CIBSE comfort threshold temperatures of 26 °C for bedrooms and 28 °C for other living areas [10] for a range of buildings. CIBSE modelled a combination of building interventions over a whole summer for each case, using predicted future climate scenarios. For each dwelling type in the report only one occupancy profile was used – a family, who were at work and school during daytime hours. Consideration of different occupancy types is also absent in other publications, including a technical report by the Energy Saving Trust [11], which suggests useful advice for designers, and a report by Arup for the Three Regions Climate Change Group [6]. They suggested interventions which may be retrofitted or, as in the case of higher thermal mass, are more applicable to new build.

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The results of this research aim to provide detailed quantitative information to inform retrofit decision-making for both individual house owners and organisations responsible for multiple properties, including local authorities and housing associations. It is therefore important to consider the effect of interventions on both overheating reduction and annual space heating energy use. The cost of interventions may also be a barrier to uptake and is included in the final analysis.

Only passive interventions have been considered in this research, as they do not directly contribute to building energy consumption and its associated carbon emissions. The effect on the ranking order due to different resident and occupancy profiles was also investigated.

2. Methodology

The research presented here expands on previous published work by quantifying the effect of a range of single and combined interventions, specifically during real heat wave periods that were known to cause health problems (including increased mortality). The term *interventions* covers a range of physical additions or adaptations to the building fabric as well as behavioural changes, such as modifying ventilation strategies. Table 1 shows the interventions applied in this research split into three categories: insulation, solar control and ventilation.

Computer simulation was used to assess the effectiveness of the interventions listed in Table 1. In order to perform the large number (tens of thousands) of parametric simulations required to model a range of dwelling types, building orientations and occupancy profiles, for single and combined interventions for the research project, it was necessary to choose a simulation tool which could be run in a batch simulation configuration. EnergyPlus v6.0 [12] was used under the control of jEPlus [13], a Java based parametric control interface. EnergyPlus was used to perform dynamic thermal simulations, enabling hourly prediction of the thermal conditions in a multi-zone building model by an iterative calculation process. EnergyPlus, developed by the US Department of Energy, has a comprehensive feature set, is widely used in both academia and industry (through third party interfaces) and has been tested against the IEA BESTest building load and HVAC tests [14]. DesignBuilder (version 2.3.5) [15] was used to construct building geometry and to produce EnergyPlus input data files (IDFs). Initial previously reported results [16], using some different model settings and assumptions, were obtained using Integrated Environmental Solutions Virtual Environment (IES-VE) software [17].

Table 1
Interventions modelled in the assessment (details in Table 3).

Category	Intervention
Insulation	• Increase loft insulation from 100 mm to 250 mm thick • Add external wall insulation to all external walls • Add internal wall insulation to all external walls
Solar control	• Add reflective internal window blinds, closed during the day • Add external window shutters, closed during the day • Close curtains during the day • Add 1.0 m deep overhangs above south, east and west-facing windows (2.0 m deep awnings to rear east and west-facing ground floor windows) • Coat all external walls with high performance solar reflective paint (lower solar absorptivity) • Coat all roof tiles with high performance solar reflective paint (lower solar absorptivity) • Replace existing double glazing with low-e triple glazing to reflect solar radiation
Ventilation	• Night ventilation: allow ground floor ventilation with outside air at night • Window rules: prevent window opening if outside air is warmer than inside air

2.1. Targeted dwellings

South East England is predicted to be the UK region at greatest risk from summertime overheating [1] and within this region, dwellings in Greater London are expected to be at higher risk due to the urban heat island effect. The recent English House Condition Survey (EHCS) [18] shows the most common dwelling types for London and South East England (Fig. 1) and has therefore been used to select appropriate dwelling types for this study.

Terraced housing accounts for 29% of London dwellings, with solid wall being the most common type of construction (approximately one third of terraced houses in London were built before 1919 [18]). Solid wall terraced housing is therefore one of the dwelling types chosen for this research and is the type for which results are presented in this paper.

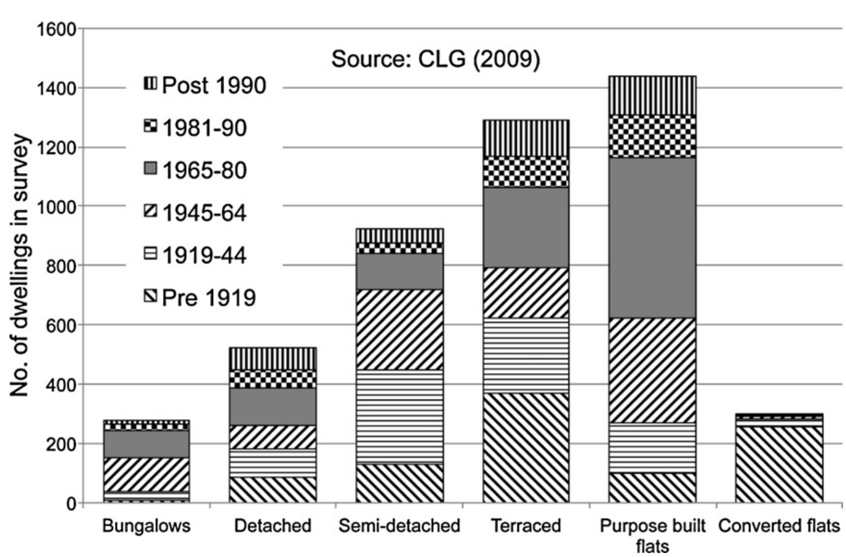

Fig. 1. Dwellings in London and South East England by type and age.