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PP1: Identification and assessment of coping measures for extreme weather events

Adapting UK dwellings to reduce overheating during heat waves

Principal Investigator: Li Shao, Institute of Energy and Sustainable Development (IESD), De Montfort University, Leicester LE1 9BH lshao@dmu.ac.uk
Co-Investigator: Chris Goodier, Department of Civil and Building Engineering, Loughborough University c.i.goodier@lboro.ac.uk
Researcher: Stephen Porritt, IESD, De Montfort University, Leicester LE1 9BH, UK
Tel: +44(0)116 257 7886 sporritt@dmu.ac.uk

Summary and key outcomes

The work builds on previous research to generate systematic, quantitative and holistic guidance to retrofit of UK dwelling to reduce their overheating risk during heatwaves, while at the same time minimise winter heating energy as well as cost of retrofit. An interactive retrofit advice tool has been developed, and made publically available (www.iesd.dmu.ac.uk/crew).

External shutters are the single most effective intervention for most house types considered, typically resulting in 50% reduction of overheating exposure. The exception is the Victorian terraced houses with solid walls, where high-albedo walls or external insulation is often more effective. External insulation consistently outperforms internal insulation, though the latter could be effective as an element of combined adaptations

Of the building types studied,1960s top-floor flats and 2007 detached houses (Tier 2) experience more than twice as much overheating as the other types. Tier 2 buildings are “harder to treat”. Their overheating exposure could not be eliminated using the passive measures tested as one could with Tier 1 building types (ground floor flats, terraced and semi-detached houses). It is possible to substantially reduce overheating and winter heating energy of Tier 1 buildings at moderate cost. The costs for retrofit Tier 2 buildings could be many times higher.

Adaptation should be considered together with mitigation, both in design practice and in regulations. If older houses (e.g. terraced) are retrofitted for reducing carbon emissions without considering summer use, overheating will increase to that of modern houses in Tier 2 and they will be harder to treat.

Overheating exposure can be significantly greater for residents who have to stay at home during the daytime, e.g. elderly or infirm, who should not, where possible, be housed in the most vulnerable dwellings (Tier 2)

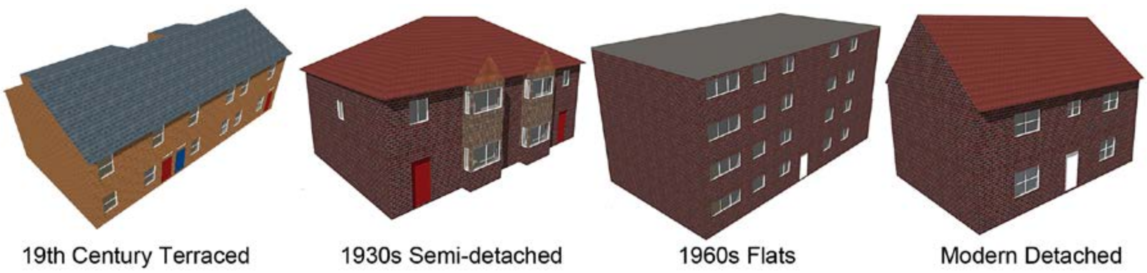

Figure A. Dwelling types assessed in this research

1. Background

The emphasis on UK dwelling refurbishment to date has concentrated on reducing energy use and CO_2 emissions during the heating season. However, there has been increasing evidence pointing to the need for a more holistic approach. Climate change projections show an increase in both the frequency and severity of extreme weather events. These include heat waves, such as the one in August 2003, which resulted in the deaths of more than 35,000 people around Europe, over 2,000 of which were in the UK. Future retrofit planning therefore needs to take account of not only winter thermal performance and associated carbon emissions, but also reducing summer overheating to provide a safe and comfortable environment in a changing climate, for which detailed quantitative advice is required. The research presented here builds on previous published work by quantifying the effect of a range of single and combined interventions during heat wave periods.

2. Methodology

Dynamic thermal simulation computer modelling (EnergyPlus) was used to assess and rank the effectiveness of selected single and combined passive interventions (adaptations) in reducing overheating during a heat wave period for a range of dwelling types, building orientations and occupancy profiles. Three options were considered for providing simulation weather data: morphed weather data used in CIBSE TM36; European weather data to approximate the predicted future UK climate; and real UK heat wave periods from 1976, 1995 and 2003. A parameter tree was constructed using jEPlus to select combinations of interventions for simulation, producing a total of 47,104 simulations for each weather file. Detailed descriptions of the methodology can be found in the academic papers listed in Publications (Section 9).

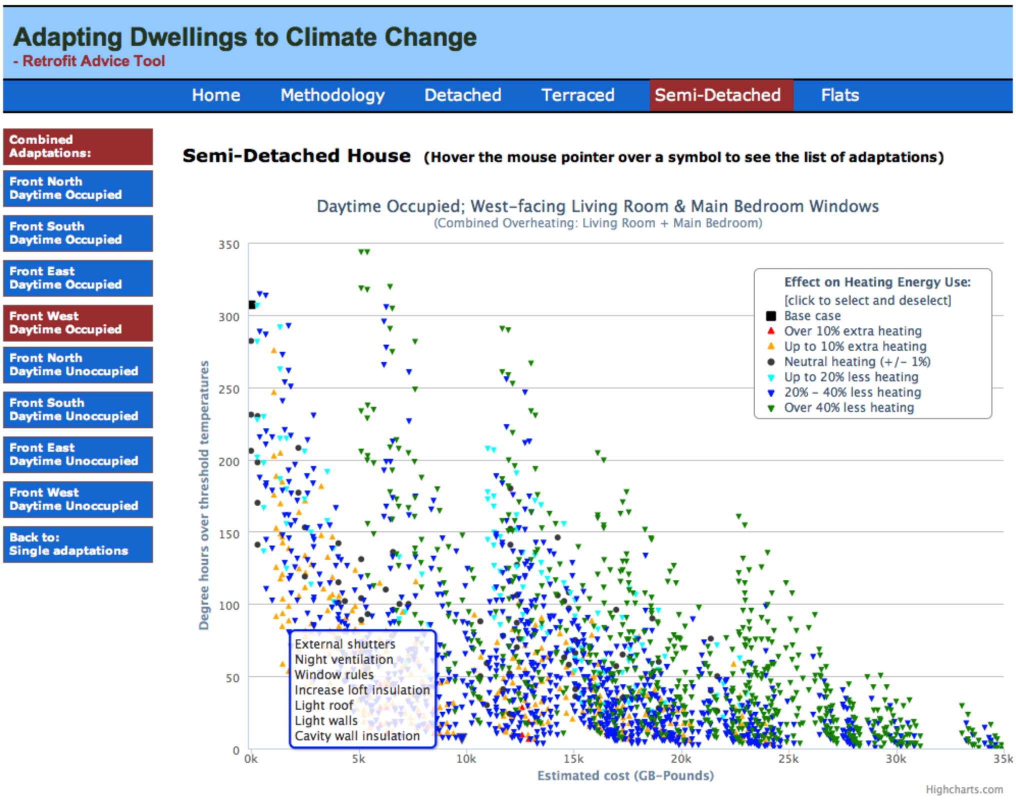

Figure B. Assess summer cooling interventions together with their winter heating implications and costs

3. Overheating exposure of various building types

There are two tiers of building types in terms of overheating exposure. Tier 1 includes the 1930s' semi-detached house, the 1960s' ground floor flat, and the Victorian end- and midterraced houses. Tier 1 buildings typically experience less than half of the overheating exposure of Tier 2 buildings (see Figure C), which include the 1960s' top floor flat and the modern 2007 detached house. It is not surprising for the top floor flat to be in Tier 1 but it is not satisfactory for the modern new build to be in the same category.

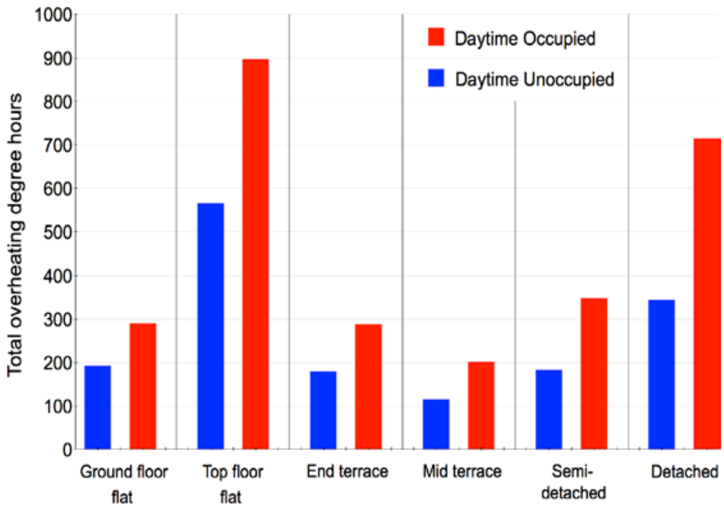

Figure C. Overheating exposure of the targeted house types

4. Ranking of single adaptation measures

External shutters (Figure D) are the single most effective intervention for all house types considered, except the Victorian terraced houses, resulting in typically 50% reduction of overheating exposure. External shutters should be integrated in future window designs and installed systematically at the time of window replacement. For Victorian terraced houses, where solid walls facilitate inward transmission of solar heat, high albedo, light-coloured walls could be more effective, as shown Figure E (compare the blue bars for external shutters and light walls).

Figure D. An example of external shutters used in the Mediterranean region.

The CREW results demonstrate the value of behavioural (zero cost) adaptations. For example, the window rule whereby the building users refrain from opening windows when the outside temperature is higher than that indoors, could result in 30% reduction of overheating exposure, as shown by the red bars in Figure E (compare base case and window rule bars).

External insulation consistently outperforms internal insulation in all building types, occupancies and building orientation considered. Furthermore, internal insulation could lead to worse overheating, in some cases, than if no intervention is implemented, as shown in Figure E (compare red bars for base case and internal wall insulation). However, it should be said that the internal insulation still has a role to play if combined correctly with other interventions by using the retrofit advice tool (see below).

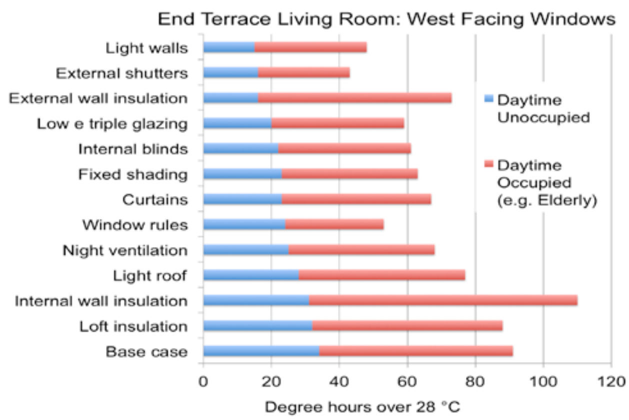

Figure E. Sample graph showing effectiveness of single interventions for terraced house.

5. Effect of occupancy

Figure C shows that across all building types studied, daytime-occupied dwellings (e.g. those used by elder people) experience much higher overheating exposure than those occupied only in the evenings (e.g. family occupancy). This difference in overheating exposure is greater in Tier 1 building types. The overheating exposure associated with daytime-occupancy could be over twice as much as the daytime-unoccupied dwellings (e.g. compare blue and red base line bars in Figure E). This makes the elderly and infirm more vulnerable. The ranking of effectiveness of the single adaptation measures changes too with occupancy as shown in Figure E. Further discussion about the occupancy effect on combined adaptation will be given in the following.

6. Combined adaptation measures

As illustrated in Figure E, no single adaptation measure could eliminate the overheating exposure and combinations of measures are usually needed to maximise overheating exposure reduction. The assessment of compatible combined adaptations (Figure F) involved approximately 100,000 simulations and the process was automated and based on a cluster of parallel processors at IESD. The data analysis was greatly facilitated by the creation of a series of interactive and information rich scatter plots (e.g. Figures B and G), which also forms of parts of the retrofit advice web tool (see below).

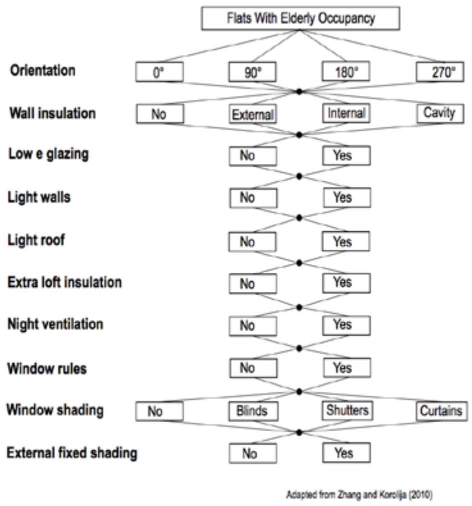

Figure F. Selection of compatible combined adaptations

6.1. Tier 1 building types (Semi-detached, terraced & ground floor flats)

It was found that overheating can be eliminated using the passive adaptations, though low-cost adaptations often lead to greater winter energy use, as indicated by the yellow and red points in Figure G. On the other hand, many adaptations could reduce winter energy use by over 40%, as indicated by the green points. Use the retrofit advice webtool for specific costs of any particular combined adaptations.

<u>Samples of cost/performance</u>: For the semi-detached house, a combined adaptation costing £3k results in 85% reduction of overheating and 20% reduction of winter heating energy use. Better performance is achievable through more expensive interventions. E.g. a combined adaptation costing £10k results in 95% reduction of overheating and 40% reduction of winter heating energy. Cost /performances are broadly similar for other Tier 1 building types.

Figure G. Sample scatter plot of combined interventions for an end terraced house; (each point represent a particular combination of adaptations, with vertical axis indicating the overheating reduction, horizontal axis cost, and the colour of the points winter-heating implications of the adaptations as indicated in graph).

6.2. Tier 2 building types (Top floor flat and 2007 detached house)

The performances of adaptations applied to Tier 2 buildings are dramatically different from those for Tier 1. *Generally, Tier 2 buildings are "harder to treat".* As illustrated in Figure H, overheating exposure could not be eliminated using any of the combined adaptations. For the modern detached house, it is much harder to find interventions which would lead to reduction in winter energy use and most adaptations would result in greater heating energy in winter, as indicated by the contract between the numbers of yellow and blue points in Figure H.

Furthermore, the *costs of interventions are much higher* than those for Tier 1. For example, the highlighted adaptation in Figure H costs £23k with an overheating minimisation performance that was achieved with adaptations costing £3k in the semi-detached house.

It is worth noting that for Tier 2, the cost of adaptation increases significantly for daytime-occupancy, which effectively *penalises the elderly*, who are already more vulnerable as explained in Section 5. For example, for similar levels of overheating and winter energy use reduction, it would cost £13k to retrofit a daytime unoccupied (family) top floor flat, but £17k if the dwelling is daytime occupied (elderly occupancy). There is similar cost increase for the elderly for the 2007 detached house, in contrast to Tier 1 building types where this cost difference is insignificant.

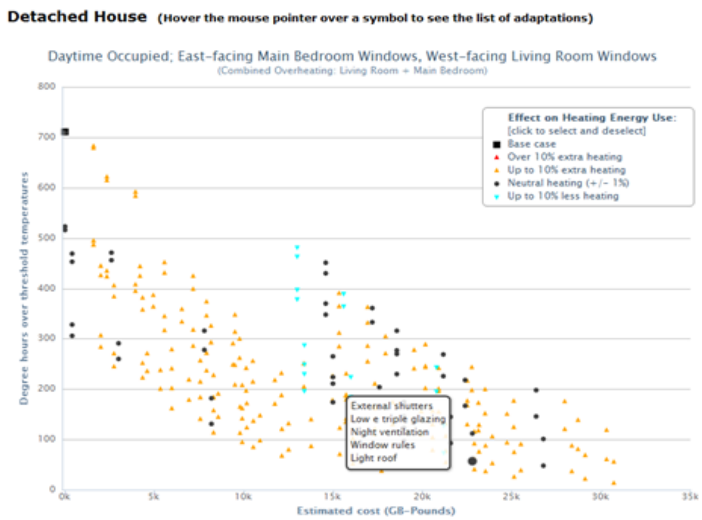

Figure H. Sample scatter plot of combined interventions for a 2007 detached house;

7. The retrofit advice web tool

An interactive retrofit advice tool for designers, decision makers and householders has been developed, and made publically available (www.iesd.dmu.ac.uk/crew), to allow rapid and informed selection of the optimal interventions for their buildings.

The advice tool informs users of both summer overheating reduction and winter heating energy use of interventions, as well as their cost. The integrated consideration of all three aspects is important. For example, many of the best performing interventions with low costs could lead to more heating energy use in winter. On the other hand, with the exception for the modern detached house, many of the cooling interventions would lead to a substantial (>40%) reduction of winter heating energy demand.

Households on top and ground floors of the same block of flats would require different solutions. The advice tool will allow selection of compatible solutions with the least total cost for a target performance

The tool also provides designers, consultants and researchers with an interactive facility to gain insights into the relationships between overheating exposure, intervention performances, costs, construction type, occupancy and orientation.

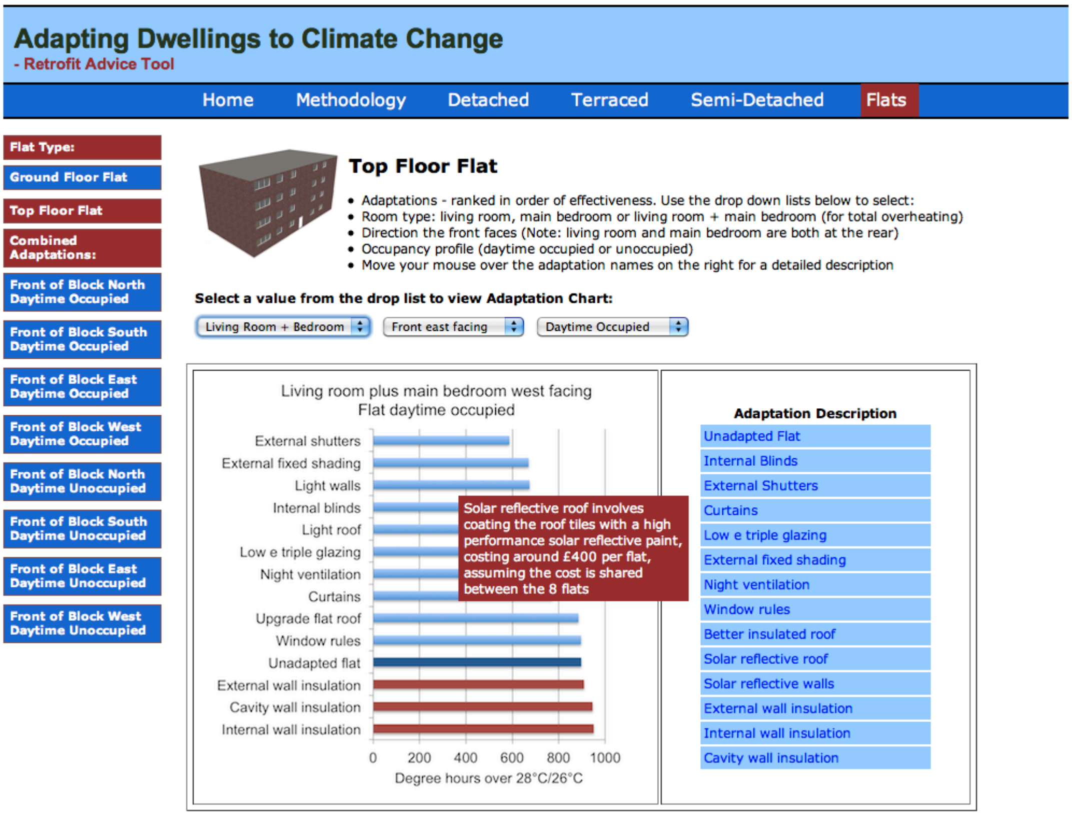

Figure I. A screenshot of the retrofit advice tool for rapid access to guidance information

8. Importance of integrating adaptation with mitigation

The excessive overheating exposure of the 2007 detached house (and many anecdotal evidences of overheating in modern new builds of various types) prompts the question that if older houses are retrofitted to dramatically reduce carbon emissions, e.g. by having comparable standards of thermal insulation as the 2007 detached house, would they overheat as the latter. Our simulation indicates that this is indeed the case. *It follows that unless adaptation is integrated with mitigation in retrofit of existing buildings, one could end up with a building stock that overheats and becomes harder and more expensive to treat*. Worse, if occupants of overheating buildings opt for energy intensive air conditioning as quick (and often cheaper, by first cost) fixes, the mitigation objective would be compromised too.

Secondly, as indicated above, the cost of adaptation is typically £3-10k for Tier 1, and much higher for Tier 2, building types. If £10k is taken as the indicative per house cost, nationally the overall cost would be c.a. £250bn or just over £6bn p.a. till 2050. This is a significant amount and much cost savings could be had by integrating retrofit for adaptation with that for mitigation. The integrated approach to retrofit helps to prevent costly sub-optimal designs when only one of the two aspects is considered for example, in the choice of insulation type.

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