Building and Environment 143 (2018) 740–759

Contents lists available at ScienceDirect

Building and Environment

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

Mitigation versus adaptation: Does insulating dwellings increase overheating risk?

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ARTICLE INFO

Keywords:
Thermal comfort
Overheating
Energy policy
Insulation
Building simulation

ABSTRACT

Given climate change predictions of a warmer world, there is growing concern that insulation-led improvements in building fabric aimed at reducing carbon emissions will exacerbate overheating. If true, this would seriously affect building regulations all over the world which have moved towards increased insulation regimes. Despite extensive research, the literature has failed to resolve the controversy of insulation performance, primarily due to varied scope and limited comparability of results.

We approach this problem through carefully constructed pairwise comparisons designed to isolate the effect of insulation on overheating. We encompass the complete range of relevant variables: latitude, climate, insulation, thermal mass, glazing ratio, shading, occupancy, infiltration, ventilation, orientation, and thermal comfort models — creating 576,000 building variants. Data mining techniques are implemented in a novel framework to analyse this large dataset. To provide confidence, the modelling was validated against data collected from well-insulated dwellings.

Our results demonstrate that all parameters have a significant impact on overheating risk. Although insulation is seen to both decrease and increase overheating, depending on the influence of other parameters, parameter ranking shows that insulation only accounts for up to 5% of overall overheating response. Indeed, in cases that are not already overheating through poor design, there is a strong overall tendency for increased insulation to reduce overheating. These results suggest that, in cases with acceptable overheating levels (below 3.7%), the use of improved insulation levels as part of a national climate change mitigation policy is not only sensible, but also helps deliver better indoor thermal environments.

1. Introduction

The buildings sector accounts for 25% of global fossil fuel related greenhouse gas emissions [1]. These emissions arise primarily from the demand for space heating and cooling [2], hence, improved building insulation lies at the heart of energy reduction policies [3–10]. Taking the UK as an example, buildings represent the sector with the single greatest emissions, accounting for 37% of total CO_2e emissions (210.9 $MtCO_2e{\cdot}y^{-1}$) [11] and, in order to meet the planned national trajectory of emission cuts, considerable reductions are expected from the sector. Increased wall insulation is expected to provide 42% of this reduction, heating-related measures 27%, other measures (such as increased energy efficiency of appliances or lighting) 24%, and building fabric measures other than wall insulation 6% [11]. Consequently, at 48%, improved insulation/fabric will be the largest contributor and therefore critical in meeting the trajectory.

As seen in the European heat wave of 2003, where over 14,000 died inside buildings in Paris alone [12] excessive temperatures (termed *overheating*) in buildings can lead to a severe loss of life. Several studies (see Table 1) have suggested that improved insulation might exacerbate overheating, implying a direct conflict between mitigation and adaptation for this key policy. If correct, these studies suggest alternative routes to mitigation will have to be found, or carbon trajectories rethought with much greater cuts from other sectors such as transport or electricity generation [1,13,14]. However, other studies have found the opposite. For example, the empirical evidence collected during the Paris heat wave shows higher internal temperatures in rooms without insulation [12]. Given that improved insulation in buildings is one of

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https://doi.org/10.1016/j.buildenv.2018.07.033
Received 15 May 2018; Received in revised form 16 July 2018; Accepted 20 July 2018
Available online 26 July 2018

Table 1
Comparative analysis of selected studies regarding overheating and their findings regarding insulation.

Authors	Year	Scope		Method				Assessment			Findings related to overheating and insulation
		Building type	Location	Weather	Field-study	Simulation	Thermal Comfort	Time over threshold	Severity	Energy demand	
Chvatal & Corvacho [15]	2009	Dwellings, offices	Portugal (3), Italy (1), Greece (1)	P	–	✓	A	C	✓	H + C	The performance of improved insulation was twofold. It could increase or decrease overheating depending on the solar gains.
Mavrogianni et al. [18]	2012	Dwellings (various)	UK (1) (London)	P + F	–	✓	*	–	✓	–	Under certain cases, adding or increasing internal solid wall insulation could increase indoor temperatures.
Porrit et al. [17]	2012	Dwellings (terrace)	UK (1) (London)	P*	–	✓	F	W	–	–	Overall, adding insulation helped in reducing internal temperatures. In some circumstances, adding it to the internal layer increased them.
Beizaee et al. [28]	2013	Dwellings (various)	UK (nationwide)	P	✓	–	F + A	C + W	✓	–	Houses built after 1990 or with cavity walls were significantly warmer than the rest despite the mild summer conditions.
Lomas & Kane [27]	2013	Dwellings (various)	UK (1) (Leicester)	P	✓	–	F + A	C + W	✓	–	Houses built before 1919, or those that had solid walls were colder than the rest. Houses built after 1980 were significantly warmer.
McLeod et al. [20]	2013	Dwellings (end-terrace)	UK (1) (London)	P + F	–	✓	F	C	✓	H	The performance of the lower U-values of the Passivhaus was a function of solar heat gains. Overheating would start in 2050.
Mavrogianni et al. [23]	2014	Dwellings (various)	UK (1) (London)	P	–	✓	F	C	✓	–	Occupancy patterns and operation of building features plays a major role in overheating when assessing retrofit strategies.
Taylor et al. [22]	2014	Dwellings (various)	UK (6)	P + F	–	✓	*	–	✓	–	The external climate influences how buildings overheat and the effectiveness of different dwelling retrofit strategies.
van Hoof et al. [21]	2014	Dwellings (various)	Netherlands (1) (De Bilt)	P	–	✓	A	C + W	–	–	Improving insulation exacerbated the duration of overheating when U-values are reduced from $0.2\,W\,m^{-2}K^{-1}$ to $0.15\,W\,m^{-2}K^{-1}$.
Gupta & Kapsali [30]	2015	Dwellings (various)	UK (not specified)	P	✓	–	F + A	C + W	✓	–	Energy efficient dwellings overheated, but the cause pointed to faulty building services, not to the characteristics of the building.
Makantasi & Mavrogianni [24]	2015	Dwellings (flats)	UK (1) (London)	P + F	–	✓	F + A	C	–	H + C	The way wall insulation affected indoor temperatures was a function of the other building characteristics retrofitted.
Sameni et al. [31]	2015	Dwellings (flats)	UK (1) (Coventry)	P	✓	–	A	C + W	✓	–	Passivhaus dwellings overheated, but underlying causes reviewed do not mention issues with improved building fabric.
Mulville & Stravoravdis [36]	2016	Dwellings (semidetached)	UK (2) (London, Edinburgh)	P + F	–	✓	F + A	C + W	✓	–	Improving building fabric (increased insulation and reduced airtightness) increases overheating risk.

Weather: **P**resent, **F**uture. Thermal comfort model: **A**daptive, **F**ixed (absolute values), * (statistical description). –: not performed/assessed. Time over threshold: **C**ounted, **W**eighted. Energy demand: **H**eating, **C**ooling.