OVERHEATING IN SCOTLAND: LESSONS FROM 26 MONITORED LOW ENERGY HOMES

C. Morgan[1]; J.A. Foster[1]; T. Sharpe[1]; A. Poston[1]

1: Mackintosh Environmental Architecture Research Unit (MEARU), Glasgow School of Art, 167 Renfrew Street, Glasgow, G3 6RQ

ABSTRACT

There is growing awareness in the UK that overheating is a significant problem and one that is likely to intensify with climate change, increasing urbanisation, an ageing population and the move towards 'low energy' buildings. Recent research suggested that while overheating may be an issue in the South of England, particularly in urban areas, it was not likely to be an issue for Scotland and the North of the UK in the medium term. This notion is reflected in the lack of awareness of the issue in Scotland. Monitoring of 26 new-build low energy and Passivhaus homes across Scotland over a two year period indicates overheating is prevalent in living areas and in particular in bedrooms where it is acknowledged that respite from high temperatures is important. This paper describes the quantitative and qualitative results, assesses relevant factors, comments on predictive tools used and seeks a robust series of measures to avoid overheating in future low energy homes in Scotland.

Keywords: Overheating, Thermal Comfort, Occupancy, Behaviour, Comfort, Health

INTRODUCTION

There are some concerns related to overheating which are purely energy based, such as excess internal gains from equipment, excess heat from slow response heating systems and the increased use of air conditioning, but the majority of concerns surrounding overheating relate to the health risks it poses. Overheating, or 'excess heat' in dwellings is one of the defined hazards in the UK Government's Housing Health and Safety Rating System (HHSRS) where it is noted high temperatures can increase cardiovascular strain and trauma and when temperatures exceed 25°C there is an increase in strokes and mortality [1].

While overheating may remain no more than an inconvenience for some, the risks become very serious for certain vulnerable groups, including infants, the elderly, the obese, socially isolated, chronic disease sufferers and those living in urban areas [2]. Mild heat-related health effects include dehydration, prickly heat, heat cramps, heat oedema (swelling), fainting and heat rash [2]. Concentration and productivity reduce as a result, while dehydration itself can be serious. More severe health effects include mental health consequences and heat exhaustion which can lead to heat stroke if not managed. Heat stroke can be fatal and is considered to be under-reported due to its similarity with strokes and heart attacks [2, 3]. Health risks are increased by higher night-time temperatures in bedrooms, due to the inability to recover from heat stress during the day [4].

There is growing awareness in the UK that overheating in dwellings is a significant problem [5, 6, 7] and one that is likely to intensify with a warming climate, increasing urbanisation, an ageing population, the move towards 'low energy' buildings [2, 8, 9] and variations in occupant behaviour [9, 10]. Research conducted to date has used computer simulation to assess likelihood of overheating which indicates a low risk of overheating in Scotland, compared with London [11].

EVIDENCE OF OVERHEATING IN SCOTLAND

Post occupancy evaluation (POE) was undertaken for two years in living rooms and bedrooms of 26 dwellings located in six separate developments in Scotland. The POE project was funded by Technology Strategy Board (TSB) now Innovate UK where an element of the study included remote monitoring of indoor air temperature (°C), relative humidity (%RH), carbon dioxide (CO_2) concentrations and window opening occurrences for each dwelling. Data loggers recorded these parameters every five minutes throughout the two year monitoring period. Surveys were undertaken as part of the project and these included a development wide survey on comfort. This paper uses data from occupied Scottish dwellings, constructed since 2009, to highlight overheating in Scotland and draws upon lessons learnt through the data collection period.

Dwelling Ref	**Living Room**			**Bedroom 1**			**Bedroom 2**		
	Orientation	**> 28°C (%)**	**PH > 25°C (%)**	**Orientation**	**> 26°C (%)**	**PH > 25°C (%)**	**Orientation**	**> 26°C (%)**	**PH > 25°C (%)**
BA1	SE	0	-	SE	4	-	-	-	-
BB1	SW	0	-	NE	1	-	-	-	-
BC1	NW	3	-	NE	6	-	-	-	-
DA1	S	1	23	S	50	65	N	46	64
DA2	S	1	18	S	18	27	-	-	-
DB1	S	0	13	S	7	18	-	-	-
DB2	S	2	23	S	15	25	N	24	34
GA1	SW	0	-	SW	7	-	-	-	-
GA2	SW	11	-	SW	69	-	-	-	-
GA3	NW	3	-	SE	22	-	-	-	-
GB1	NE	0	-	SW	0	-	-	-	-
GB2	NE	4	-	SW	8	-	-	-	-
GB3	N	0	-	S	3	-	-	-	-
IA1	W	10	-	W	3	-	E	14	-
IA2	W	0	-	W	9	-	E	3	-
IB1	W	0	-	W	17	-	E	47	-
IB2	W	0	-	W	1	-	E	2	-
IC1	S(W)	1	-	N	1	-	-	-	-
IC2	S(W)	2	-	N	0	-	-	-	-
ID1	W	2	-	S	0	-	-	-	-
ID2	W	1	-	N	4	-	-	-	-
LA5	E	2	-	W	15	-	-	-	-
LA6	E	1	-	W	10	-	-	-	-
TA1	E	0	-	E	0	-	W	0	-
TA2	E	0	-	E	0	-	W	1	-
TB1	E	0	4	E	0	0	W	1	2

Table 1: Percentage of hours exceeding CIBSE and Passivhaus thermal comfort thresholds for one year. > 28°C indicates percentage of year internal temperature exceeds 28°C with 1% considered acceptable. Similar for > 26°C. > 25°C indicates percentage of year internal temperature exceeds 25°C with 10% considered acceptable used for Passivhaus dwellings.

Analysis of the recorded data revealed overheating to be prevalent in the dwellings. Overheating was assessed using former CIBSE thermal comfort criteria where a room is considered to have overheated when temperatures exceed 26°C in bedrooms and 28°C in living rooms for more than 1% of annual occupied hours. This permitted comparison with 'as designed' assessments. The five Passivhaus dwellings were assessed against this criterion as well as the Passivhaus overheating criteria where internal space temperature should not exceed 25°C for more than 10% of the year. Findings from three of the developments are discussed in more detail.

Case Study 1 - Dumfriesshire

The Dormont Estate is situated in South-West Scotland at a latitude of around 55°N, broadly level with Newcastle. Four 3-bed and four 2-bed 2-storey, semi-detached houses were completed in 2011 and certified to the Passivhaus standard using lightweight Structural Insulated Panels panels with MVHR ventilation (complete with posst-heaters), wood stoves and solar thermal panels.

In addition to physical monitoring a range of occupant surveys and feedback exercises were undertaken. The principal and most widespread concern for occupants was that of overheating with comments such as "*Too hot in summer*" and "*Gets too warm upstairs especially difficult at night*".

The risk of overheating was not assessed as part of Building Warrant but the PHPP (Passivhaus Planning Package) assessment established there would be 0.2% overheating, i.e. 0.75% (18 hours) of one day across a year when the temperature in the house overall would rise above 25°C. Examination of the monitored temperatures indicates these temperatures were exceeded for a far greater percentage of the time than this (Table 1).

Figure 1 below shows the recorded data for a two week monitoring period in July 2013 in which the temperatures in all four main (south facing) bedrooms rarely dipped below 25°C and only then in one house and for short periods. For the remainder of the two week period, in all houses, temperatures in the bedrooms rose as high as 33°C but averaged around 27°C.

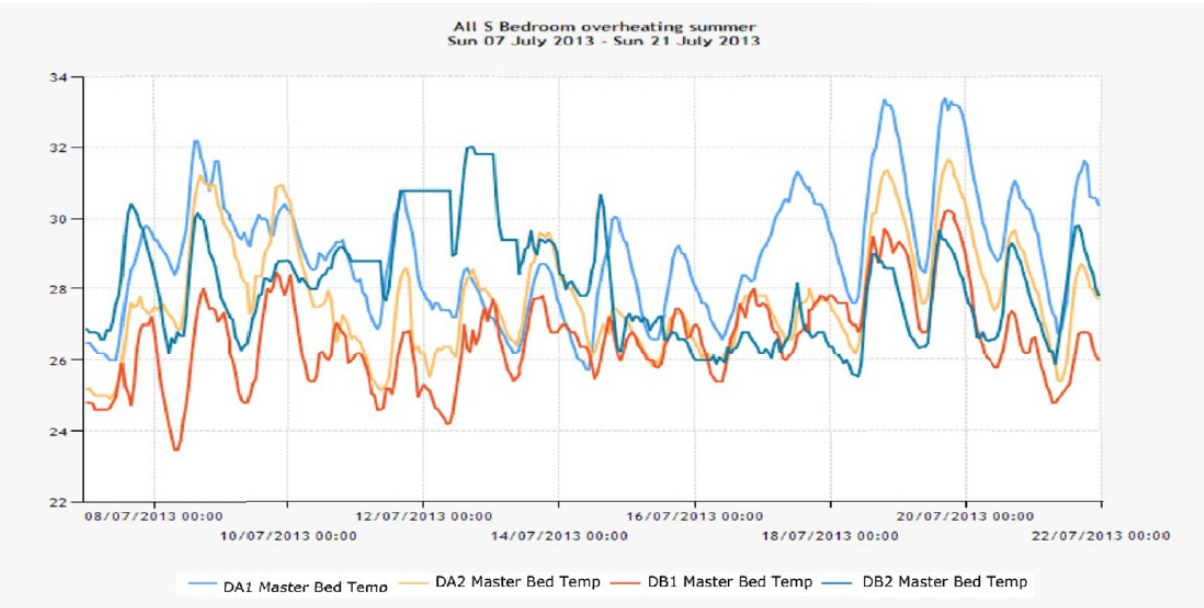

Figure 1: South facing bedroom temperatures in four monitored dwellings 7th – 21st July 2013.

The temperature profiles were similar but less pronounced in living rooms but overheating as defined by CIBSE allows for greater tolerance in living areas. A number of factors identified were attributable to occupants only, such as keeping bedroom doors closed, or being away during the day and unable to take measures necessary to contain the indoor temperatures. A number of the reasons for the overheating can be traced to design and construction decisions but differences between (identical) properties can be traced to occupant behaviour. The highest levels of overheating were found in the dwelling inhabited by a young, single mother with a toddler who of all occupants in the programme was, initially at least, the least interested and engaged in the monitoring process.

Case Study 2 – Central Glasgow

This development provides a total of 117 dwellings located in central Glasgow. Intensive monitoring was undertaken in three one-bedroom flats within a sheltered complex for the elderly and three two-bedroom flats for mainstream occupants. Each dwelling is naturally ventilated with intermittent mechanical extracts located in kitchens and bathrooms, trickle ventilators in the window heads or walls provide make up air. Basements in each block contain an energy centre providing communal central heating and domestic hot water to each dwelling with underfloor heating in the sheltered flats and conventional radiators in the mainstream flats.

The monitoring indicated high percentage of annual hours over the CIBSE comfort threshold temperatures (Table 1) in the bedrooms of the sheltered flats (GA1, GA2 and GA3) and two living rooms (GA2 and GA3). GA1 and GA2 are mostly occupied 24/7 where annual temperatures were found to exceed 26°C for 7% (GA1) and 69% (GA2) of the year. Overheating occurred mostly during the summer in GA1 and occurred extensively during all seasons in GA2, particularly spring and summer. While some of the high temperatures could be associated with solar gain due to the orientation, the research team observed high temperatures in GA2 on their visits to the property. In addition to this the occupant is unable to adapt the internal environment due to mobility issues and reliance is placed on home helpers to alter heating controls, open/close windows and remove clothing.

In the mainstream properties overheating was observed through a mixture of solar gain, internal gains and the preference for warm internal temperatures. However, the occupant of GB3 expressed dissatisfaction with the large south facing bedroom windows and the need to keep curtains closed in bedrooms to provide shade, bedrooms being sited over the communal boiler plant room and security concerns due to the dwellings ground floor position.

Case Study 3 – Inverness, Highland Scotland

In this development 52 dwellings were designed as part of Scotland's 2010 Housing Expo to showcase innovative sustainable housing. The timing of the construction of the development coincided with the recent recession and the contractors undertook a value engineering exercise on the architect designed homes so the dwellings could be constructed. Four pairs of naturally ventilated, timber frame homes (eight in total) were intensively monitored. Four of the dwellings were for social rental (2-storey houses IA1, IA2, IB1 and IB2) and four occupied by owner occupiers (1 and 2-bedroom flats IC1, IC2, ID1 and ID2). Surveys of the 52 dwellings indicated most of the households thought the homes were more comfortable and cheaper to run than former homes, with less heat input in winter due to the passive solar design. However, 62% of the surveyed households found their homes were too hot during the summer, indicating solar gain to be an issue due to west facing glazing and lack of operable windows to promote cross or stack ventilation.

Table 1 indicates 87% of bedrooms and one living room (IA1) in the 2-storey houses to have exhibited overheating. Dwellings IA1 and IA2 are within a terrace orientated east/west, with IA1 at the south end of the terrace. The study found the east facing bedroom to have overheated for 14% of the year, the peak space temperatures in this room were 27°C (winter), 29.6°C (spring), 30.8°C (summer) and 31.8°C (autumn). In the neighbouring dwelling of identical design and layout, IA2, the west facing bedroom was found to have had a higher percentage of time over 26°C with maximum temperatures of 30.4°C. Window opening in this room rarely happened due to an obstruction from a child's cot placed beneath the operable window. The east and west facing bedrooms in IB1 tended to exhibit overheating all year, with a higher proportion of overheating attributed to summer time. The data confirmed temperatures in the east facing bedroom were above 26°C for 47% of the year. This household routinely sets their thermostat to 25°C.

In the flatted dwellings of ID1 and ID2 there were concerns of overheating in the living rooms due to poor construction of the adjoining west facing solar sunspace, ID1 reached temperatures over 28°C for 2%. North facing bedroom in ID2 reached temperatures over 26°C for 4% of the year. Investigations revealed heat gains from the fridge/freezer in the kitchen were warming the separating wall and heating the bedroom, welcome in winter but not during summer.

DISCUSSION

Whilst it is evident low energy buildings in Scotland are overheating it appears that the causes are not clearly appreciated by those procuring, designing and building, even the few measures aimed at reducing overheating are often 'value engineered' out before completion. Nor are causes the same between dwellings. In some instances one dwelling from an identical pair is exhibiting serious overheating which can be linked to occupant behaviour and preference for warmer internal temperatures. In the case of the sheltered homes vulnerability of elderly residents is highlighted due to inability of some immobile occupants to adapt their thermal environment, exposing them to high temperatures both day and night. Internal gains from equipment such as fridge/freezers and televisions are contributing towards overheating in dwellings even when using 'A' rated white goods. Proximity to adjacent plant, uninsulated tanks and pipework and reluctance to open windows due to security fears are all possible contributors. In some cases solar gain can be shown to be an issue, particularly for south-west and west facing rooms but in other homes, North-facing rooms are overheating as much as others. None of the properties monitored had any form of external shading and many had insufficient ventilation arrangements. Four of the five Passivhaus dwellings are overheating considerably more than the design criteria which correlates with Sameni et als [12] findings.

CONCLUSIONS

In all projects discussed, the predictive tools used have failed to identify the overheating risks adequately. Beyond deficiencies in the tools themselves, this can be partly attributed to the varying nature of occupant comfort thresholds and behaviour.

Where models are created in which the same constructions are 'located' in different latitudes, it is to be expected that the risk and extent of overheating will be greater in warmer parts of the UK and in future projections of our warming climate. However, the evidence gathered by MEARU suggests that where low energy buildings have been built in Scotland, a combination of effective heat retention and recovery, occupant behaviour and poor design or installation essentially override the northerly location to create conditions of overheating sufficient to cause concern in the short term.

It could be suggested that after many years of lagging behind some of our European neighbours in designing effective, energy efficient homes for cold weather, the UK has caught up, but in so doing is not yet experienced in the implications of living within energy efficient buildings. Thus high levels of insulation and airtightness as well as insufficient thermal mass have all been blamed for causing overheating although it is often not appreciated that these very measures serve to keep heat out as well as in.

No one measure leads to overheating, it is the failure to understand the full implications of energy efficient designs and occupant behaviour with respect to the potential for overheating which leads to problems. For this reason it is important to address the general lack of awareness about overheating in Scotland and engage with occupants to help them avoid the problem, while ensuring the buildings they live in effectively keep them warm in winter and cool in summer.

REFERENCES

1. Office of the Deputy Prime Minister (ODPM). Housing Heath and Safety Rating System (HHSRS): Operating Guidance. London, ODPM, 2006.
2. NHBC Foundation (2012) Overheating in new homes: A review of the evidence.
3. Department of Health. Heat wave plan for England, 2011. www. dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_127235.pdf.
4. Kovats, S., and Hajat, S. Heat stress and public health: A critical review. Annual Review of Public Health, 2008, 29 (9)1–9.15.
5. DCLG: Investigation into Overheating in Homes. Literature Review. AECOM July 2012.
6. DCLG: Investigation into Overheating in Homes: Analysis of gaps and Recommendations. AECOM March 2013.
7. Building Services Engineering Research and Technology Special Issue: Overheating and Indoor Air Quality Vol 36 (2) (Editorial) 2015.
8. Orme, M., Palmer, J. & Irving, S. (2003) Control of overheating in well-insulated housing. CIBSE/ASHRAE conference in Building Sustainability, Value and Profit. Edinburgh, 13th June 2003, FaberMaunsell Ltd. Available at: http://www.cibse.org/pdfs/7borne.pdf.
9. Porritt, S., Shao, L., Cropper, P.C. & Goodier, C.I. (2011) Assessment of interventions to reduce dwelling overheating during heat waves considering annual energy use and cost. CIBSE Technical Symposium, Leicester, 6th – 7th September 2011. Available at: https://dspace.lboro.ac.uk/
10. Sharpe, T. & Shearer, D. (2013) Learning from our experiments: monitored environmental performance of low energy buildings. Mackintosh Environmental Research Unit, Glasgow School of Art.
11. Arup/Bill Dunster Architects (2005) UK Housing and Climate Change – Heavyweight vs. lightweight construction, ARUP Research + Development, Bill Dunster Architects, UK
12. Sameni, S., Gaterell, M., Montazami, A., Ahmed, A. Overheating investigation in UK social housing flats built to the Passivhaus standard, Building and Environment (2015), doi: 10.1016/j.buildenv.2015.03.030.