Care provision fit for a future climate:

Findings from an extra-care scheme: Case Study C

Rajat Gupta, Laura Barnfield, Matt Gregg, Alan Lewis, Gordon Walker and Louis Neven

This report assesses the current and future risks of summertime overheating in an extra-care case study scheme in England. It also investigates the preparedness of the extra-care facility against the risk of overheating, now and in the future.

Oxford Brookes University · Lancaster University · The University of Manchester

Care provision fit for a future climate

A research study funded by the Joseph Rowntree Foundation

Rajat Gupta, Laura Barnfield, Matt Gregg, Alan Lewis, Gordon Walker and Louis Neven

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Contents

List of figures

List of tables

Executive summary

Anthropogenic climate change is expected to result in hotter and drier summers, with heatwaves of greater frequency, intensity and duration in the UK. This has serious implications for future heat-related mortality, specifically for older people in care facilities, where research has shown they are among those most vulnerable to the negative health effects of overheating. However, there is a limited evidence base on the thermal performance of care schemes, and on how thermal risks are being managed in practice.

This detailed case study report is based on the findings of a study that used four case study care schemes and aimed to examine how far existing care homes and other care provision facilities in the UK are fit for a future climate, and to consider the preparedness of the care sector (both care and extra care settings) in light of the consequences of climate change, with a focus on overheating.

This report focuses on one case study extra care scheme, and should be read in conjunction with the main report (available through the Joseph Rowntree Foundation website) and the three other case study reports.

The project was led by the Low Carbon Building Group of Oxford Brookes University (OBU) in collaboration with the University of Manchester (UM) and Lancaster University (LU). Funding was provided by the Joseph Rowntree Foundation (JRF).

Key findings

- Although analysis using the static overheating method indicated that seven out of the ten rooms monitored (five residential areas, Lounge 2 and the Manager's Office) overheated during the monitoring period, the adaptive method indicated that only three (one bedroom and two private living rooms) overheated.
- Modelling of future climate showed that overheating would not be a problem for Case Study C in rooms except for the main lounge (Lounge 1) using the Adaptive Method and not until the 2050s using the Static Method.
- Modelling indicated that several physical measures could be undertaken to reduce the future overheating risk, including external shutters and reflective roof material. Such measures appear to be best introduced as packages, and in combination with managed ventilation.
- There was a lack of awareness of potential current and future overheating risk within the strategic management and on-site care staff, but which seems to be based on a systemic lack of awareness throughout the care sector.
- In terms of designing for overheating, the issue of confusing advice and standards relating to overheating was raised. Furthermore, there are often conflicts between designing care schemes and appropriate overheating mitigation design measures such as the health, safety and security of residents as well as more qualitative factors such as providing sunlight and good views.
- The dangers of the 'cold' were seen as a higher priority in relation to long-term plans and design strategies as well as the effective working and management of the care home; older people were seen as be susceptible to the cold more than the heat, and also

preferred higher temperatures, and as such both the design and management needed to reflect this. However, the interviews with the residents indicate that they felt that the residential area was generally too hot and there was a lack of adequate ventilation, without electric fans.

Priorities for action

- Install monitoring devices within key areas of the building, with digital feedback displays to show and record internal temperatures as well as install a permanent local external temperature sensor.
- Review the management and maintenance processes both within the case study care scheme as well as across the care organisation as a whole.
- Ensure regular reviews and staff training on the heating and ventilation systems and their operation e.g. trickle vents, and the ceiling fans and air-conditioning unit in the main lounge.
- Encourage cross-organisational communication and partnership to improve on-site staff agency and knowledge of the building services installed and encourage active responsibility from on-site staff for ensuring radiators are turned down and ventilation strategies are in place.
- Review potential future physical adaptation measures and include in long-term development strategies for both the individual care scheme and wider organisation.

1. Introduction

Anthropogenic climate change is expected to result in hotter and drier summers, with heatwaves with greater frequency, intensity and duration in the UK. This has serious implications for future heat-related mortality, specifically for older people in care facilities, where research has shown they are among those most vulnerable to negative health effects of overheating. However, there is a limited evidence base on the thermal performance of care facilities and on how thermal risks are being managed in practice.

This report provides an overview of the key findings for Case Study C, one of four case study care schemes involved in the research study outline below.

Further information on the wider study can be found in the final report available via the **JRF website.**

1.1 Research study and approach

The research project, Care Provision Fit for a Future Climate, aimed to examine how far existing care homes and other care provision in the UK are fit for a future climate, and to consider the preparedness of the care sector in light of the consequences of climate change, with a focus on overheating. The study, which ran from January to December 2015, reviewed existing evidence as well as using four case study care facilities in England to explore experiences and learning further. The project was led by Oxford Brookes University and included research teams from Oxford Brookes University, the University of Manchester and Lancaster University. The research is funded by the Joseph Rowntree Foundation.

The research used a case study based and interdisciplinary approach; drawing from building science and social science methods, which included:

- **A literature review** of existing evidence from both UK and international studies on the climate change risks in the care sector and the impact of design, institutional contexts, management and staff practices on the risk of summertime overheating and the thermal comfort and safety of residents during hot weather.

- **A design review** of the current and future climate change risk and possible physical adaptive measures to reduce overheating risk in four case study care schemes (two residential care homes and two extra care schemes) using dynamic thermal simulation.

- **Interviews** with designers, managers, care staff and residents of the four case study buildings to address how well building design, management and occupant practices address overheating risks and vulnerabilities. Secondary analysis of data from a previous research study was also undertaken to provide supporting evidence.

- **Monitoring** of environmental conditions in the case studies to assess current overheating risks and experience during summer months (June-September 2015).

- **Building and occupancy survey** of the case study buildings to identify building design features that can contribute to or support avoidance of overheating and enable or prevent occupants to control their thermal environment during periods of hot weather.

1.2 Overview of case study

Table 1 outlines the main characteristics of Case Study C. As an extra care facility, it has communal living and dining areas as well as individual private one and two-bed flats containing kitchen and living areas, bathroom and bedroom/s. Extra care facilities accommodate older people who are becoming more frail and less able to do things, but who still require and/or desire some level of independence. Case Study C provides residential and care support as required, with the residents' ranging from individuals who are bed-bound to those who are physically and mentally able.

Table 1. Main characteristics of Case Study C.

Category	Case Study C
Region	South West England
Location	Suburban
Type of facility	Extra care (purpose built)
Ownership	Not-for-profit RSL
Gross internal area (GIA) m^2	4,823
No. of beds/dwellings	50 flats
Number of occupants	52
Average age of residents	86
Per cent of residents over 85 years	83% (approx. 43)
Age of facility (Building regulations year)	2006 (2002)
Construction type	Brick and block insulated cavity/rendered insulation with block; concrete beam and block floors
Ventilation and/ or cooling scheme	Mixed mode: Natural ventilation with some extract ventilation in residential; communal kitchen and sanitary areas and air conditioning in lounge and dining
Single or multi-aspect bedrooms	Single
Exceptional design standards or certification	CSH/EcoHomes Good

2. Overview of building characteristics

The design and local environmental context can either ameliorate or exacerbate the impact of climate change and increase the risk of overheating in a locality. Such characteristics include:

- Site location e.g. proximity to the coast, elevation, urban density and surrounding building types.
- Landscaping e.g. trees and green space coverage.
- Building orientation and internal layout.
- Construction type and materials.
- Physical attributes of the building such as building height, passive design measures to reduce external and internal heat gains, and heating, ventilation and cooling controls.

Occupant management of their thermal environment can be greatly influenced by the controls afforded to them through the design of both the building itself and the actual user controls for heating, ventilation and cooling. In addition, internal heat gains from occupants, lighting and appliances and other electrical goods can further increase the overheating risk within the building.

2.1 Local environmental context

Within Case Study C, a number of local environmental features were identified through the building survey in terms of their impact on the overheating risk as outlined in Table 2. Case Study C is located in a built-up residential suburb area of a major city in the South West of England. There are large areas of hard covering (tarmac, buildings and paving) in the local area which can lead to the 'urban heat island effect', which increases the air temperature locally. Hard urban materials retain heat and transpiration cooling is limited where there is little vegetation. Despite this, the site is set at the back of residential buildings and as such is surrounded by back gardens (Figure 1), which have a large amount of green coverage and vegetation that can help reduce external ambient temperatures.

2.2 Evaluation of design features

Within Case Study C, a number of features were identified through the building survey as either good practice or areas which require further review, as outlined below. Table 2 provides a summary.

Figure 1. GoogleMaps image of Case Study C.

Table 2. Local environmental and building design features.

Positive characteristics (aspects that can help mitigate overheating risk)	Negative characteristics (aspects that can help exacerbate overheating risk)
• Located at back of residential dwellings with large green gardens (>50% green cover). • Large green corridor 300m northwest of building. • Secure green space around building with low shrubbery, and minimal hard paving. • Where large areas of hard paving are present, it is northerly facing. • Relatively heavyweight wall and floor materials used. • Internal blinds and curtains present in most rooms. • Brise-soleil (fixed louvres) and overhanging eaves to provide additional shading in the main south-facing communal area. • Solar control coated glazing in main lounge. • Low energy light fittings. • Openable windows in corridors to enable cross-ventilation. • Trickle vents and openable windows present in all rooms. • Simple heating controls present (zoned thermostats and individual radiator TRVs).	• South West England. • Low-rise semi-detached suburban surroundings. • TRVs at low level (poor accessibility for physically frail). • Communal heating and hot water system with distribution pipework throughout building. • Window restrictors present. • Low-reflective roof (low albedo). • Single aspect flats. • No external shading devices on private residential flats.

The main positive design features include the provision of green cover, external shading of the main lounge area (Figure 2), trickle vents (Figure 3) and openable windows in corridors to enable cross-ventilation (Figure 4). There are several additional features within the main lounge to further reduce the overheating risk including fixed ceiling fans (Figure 5) and an air-conditioning unit. Such features, although present in the main lounge, are not featured in other areas, which mainly rely on internal blinds and mobile electric fans (Figure 6) to provide relief during hot weather.

Figure 2. External brise-soleil and large overhanging eaves on building façade to main communal lounge area.

Figure 3. Trickle vents installed on all windows.

Figure 4. Cross-ventilation in communal areas provided by openable windows at sides and ends of corridors.

Figure 5. Fixed ceiling fans installed in main communal lounge to provide additional air circulation during periods of hot weather.

In the communal areas, both stack and cross-ventilation is possible due to the use of openable windows, walls and roofs (Figure 7). However, there appears to be less consideration of passive ventilation strategies in the private residential flats. The fact that the residential flats are single aspect means that cross-ventilation is unlikely to happen. In addition, although trickle vents were installed, there was evidence that they were not always in use. Despite this, there was evidence of the occupants (staff and residents) adapting their environment to suit their needs through passive means (Figure 8) as well as active means such as mobile electric fans and air conditioning units (Figure 9). There was also evidence that the occupants used internal curtains and blinds to reduce solar heat gain and glare. However, this blocks their views and counteracts the design feature of low windows to allow sedentary residents to sit and retain a view to the outdoors.

Figure 7. Internal entrance door to private flat propped open to provide additional air-circulation within flat (such practices may not be used by all residents due to privacy and security issues).

Figure 6. Openable rooflights in communal areas provide opportunity for stack ventilation.

Figure 8. Ventilation and cooling measures in residential areas include electric fans, internal blinds and curtains as well as openable windows.

In terms of the heating system, it is a communal system which requires pipework throughout the building. This can add to internal heat gains, particularly if run 24/7 all through the year. Whilst it is understandable for it to be left on during the summer months to provide hot water, the heating was also found to be on, leading to additional, unnecessary heat gains. It must be noted that this is partly a management issue, but alternative service design, such as localised electric hot water units in the flats could reduce the impact of the heating system on the overheating risk. The heating controls appear relatively simple, with only thermostatic radiator valves (TRVs) in the individual residential flats. There are zoned thermostats present in communal areas without locks/restrictors which enables all able occupants (including residents) to alter the settings. Feedback from staff indicates that this can result in overuse and subsequently inefficient use of the heating system and as such there were reports that the thermostats had been disconnected from the main system.

3. Climate modelling of current and future overheating risk

Current climate conditions and future climate change projections were simulated to assess the magnitude of the risk of overheating in the care/extra care homes, using Integrated Environmental Solutions' Virtual Environment thermal calculation and dynamic simulation software. Current conditions (baseline) and future climate weather year files were used to simulate climate impact. These weather files represent average weather rather than heatwaves (or cold snaps) and have been obtained from a catalogue of weather files developed by the PROMETHEUS project (Eames et al., 2011).[1] The approach taken resulted in four simulations for each site's climate risk assessment. In summary, these are:

- current conditions – baseline weather years;
- 2030s climate period, high emissions (H), 50% probability – future weather years;
- 2050s climate period, high emissions (H), 50% probability (future weather years); and
- 2080s climate period, high emissions (H), 50% probability (future weather years).[2]

The following section outlines the results for the overheating tests from dynamic thermal simulation. The results are based on analysis of overheating using both the adaptive and static methods as well as the PMV method (See Explanation Boxes 1, 2 and 3).

Explanation Box 1: The Static Methods (SM) Approach

The static method for assessment of overheating used in both the modelling and measuring analysis of the case studies data is based on the static criteria outlined in CIBSE Guide A (2006). The static method enables simple calculations to be undertaken when assessing the performance of a building, however it does not account for the adaptation of the occupants to their environmental context such as external temperatures. The table below outlines the relevant criteria to this study (based on Table 1.7 (Non-air conditioned spaces) of CIBSE Guide A (2006)).

Building / Room type	Summer comfort temperatures (°C)[1]	Benchmark summer peak temperature (°C)	Overheating criteria
Offices	25	28	1% annual occupied hours over operative temperature of 28 °C
Living areas (dwellings)	25	28	1% annual occupied hours over operative temperature of 28 °C
Bedrooms (dwellings)	23	26	1% annual occupied hours over operative temperature of 26 °C

Notes:-

[1] Generally temperatures within ±3K are acceptable in terms of the thermal comfort response of sedentary persons. However, the updated Guide A (2015) states that, 'a variation of ±2K would be noticed and might cause some complaint at the extremes.'

Explanation Box 2: The Adaptive Methods (AM) Approach

The adaptive comfort and overheating methodology used within this study is that outlined in CIBSE TM52, which is based on BS EN 15251:2007 and to which CIBSE Guide A (2015) refers to. It relates the indoor comfort temperature to the outdoor air temperature. According to this method comfortable temperatures are based on adaptation to external temperatures during the preceding few days, i.e. the running mean (T_{rm}):

$$T_{comf} = 0.33\ T_{rm} + 18.8$$

The assessment for spaces is based on the level of thermal expectation recommended for the occupants. For example, areas in which very sensitive occupants such as unwell or elderly persons resided were assessed using Category I – *High level of expectation only used for spaces occupied by very sensitive and fragile persons* - suggested acceptable comfort range ±2K from the main equation (above).

Three criterion of the adaptive comfort method provide a robust and balanced assessment. If two or more of these criteria were met, the room is deemed to have overheated:

- **Criterion 1:** hours of exceedance: The number of hours during which ΔT is greater than or equal to one degree (K) during the recommended period May to September (or available period) inclusive shall not be more than 3 per cent of occupied hours.
- **Criterion 2:** daily weighted exceedance (W_e): the time (hours and part hours) during which the operative temperature exceeds the specified range during the occupied hours, weighted by a factor that is a function depending on by how many degrees the range has been exceeded. W_e shall be ≤6 hours in any one day.
- **Criterion 3:** upper limit temperature: the absolute maximum value for the indoor operative temperature: ΔT shall not exceed 4K.

Explanation Box 3: Predicted mean vote (PMV)

Where a building is mechanically cooled (or where fans are used to provide thermal comfort), predicted mean vote (PMV) is applied to assess acceptability. PMV is calculated by a formula taking into consideration operative temperature, air speed, relative humidity (RH), metabolic rate and clothing level. Operative temperature and RH are taken from the climate model of the building, metabolic rate (1.1) and clothing level (0.5) are taken from building occupant surveys, and air speed is derived from normal fan operation.

An indoor environment should aim to achieve a PMV index near to or equal to zero. Above zero ranges from warm to hot and below zero ranges from cool to cold.

- For Category I (see above), the PMV index is +/-0.2. This means the estimated PMV should fall within plus or minus two tenths of a point above or below zero (neutral).

The rooms chosen for modelling are shown in Figure 9. All were also monitored (see section 4).

Figure 9. Location of rooms modelled.

Table 3 shows the overheating results from the climate modelling. Overheating appears to not be a risk for most spaces until the 2050s climate period; however, the lounge overheats in the current climate for the Adaptive Method (AM). The lounge also presents overheating complications for staff by 2080s and temperatures above recommended thresholds by in all climate periods. More overheating details, including heatwave graphs are presented below in the section on building resilience against current and future overheating risk.

Table 3. Modelled overheating risk, current and future.

	Adaptive Method (TM52 Criteria Failed)				Static Method (% of occupied hours over temperature threshold)			
	Current climate	2030	2050	2080	Current climate	2030	2050	2080
Lounge 1 (GF, S-facing)	2 & 3	1 & 2	1,2,3	1,2,3	0.5	0.9	1.8	6.6
Manager's office (GF, SE-facing)	-	-	-	2	-	-	0.8	4.7
Flat 1 bedroom (GF, Sw-facing)	-	-	2	2	0.1	0.2	1.0	4.5
Flat 2 bedroom (FF, NE-facing)	-	-	-	-	-	-	0.4	2.0
Flat 2 living room (FF, NE-facing)	-	-	2	1,2,3	-	0.2	1.0	3.8
Notes:- *Boxes shaded green did not show signs of overheating, boxes shaded red showed signs of overheating.*								

4. Measuring overheating risk

The following shows the results from the analysis of the measured environmental conditions and uses both the adaptive and static methods (See Explanation Boxes 1 and 2).

4.1 Rooms and environmental conditions monitored

In Case Study C, ten rooms were identified across the residential, communal and office areas and indoor data loggers were installed (Table 4; Figure 10). They were chosen to provide a variety of room type (e.g. residential, communal and office space) and orientation. The choice of room was also dependent on the agreement of the care manager and residents' themselves.

Data was recorded every 15 minutes from midnight on 18th June to midnight 1st October 2015 (105 days in total). In terms of data limitations, some of the data loggers stopped working (through faults with the sensors or the data loggers being switched off by occupants). In addition, an external data logger was installed within the internal courtyard but issues with data extraction has meant the data are unusable.

Whilst overheating analysis is mainly based on temperature, the thermal comfort of occupants is also affected by other environmental conditions such as relative humidity and air flow. As such, in some areas, the relative humidity and CO_2 levels (proxy for ventilation/indoor air quality) were also monitored to provide a more comprehensive understanding of the indoor environmental conditions in the building.

Table 4. Location of data loggers installed.

Location			Orientation	Variables monitored	Comments
Residential areas	Flat 1 (living room)	GF	SW	T	Data loggers concentrated in bedroom due to occupant being bed-bound
	Flat 1 (bedroom)	GF	SW	T / RH / CO_2	
	Flat 2 (living room)	FF	E	T / RH / CO_2	8.5 days data missing (Bedroom data logger only)
	Flat 2 (bedroom)	FF	E	T	
	Flat 3 (living room)	FF	W	T / RH	
	Flat 3 (bedroom)	FF	W	T	
Communal areas	Main Lounge / Dining	GF	S	T / RH / CO_2	6.5 days data missing (CO_2 only)
	Secondary Lounge	GF	SE	T	6 days data missing
Office areas	Staff office	GF	NE	T / RH	
	Manager's office	GF	SE	T / RH	

Notes:-
GF=Ground floor; FF=First floor; NE=Northeast-facing; SW=Southwest-facing; SE=Southeast-facing; S=South-facing; W=West-facing; E=East-facing T=temperature; RH=relative humidity levels; CO_2=Carbon dioxide levels (proxy for ventilation/indoor air quality).

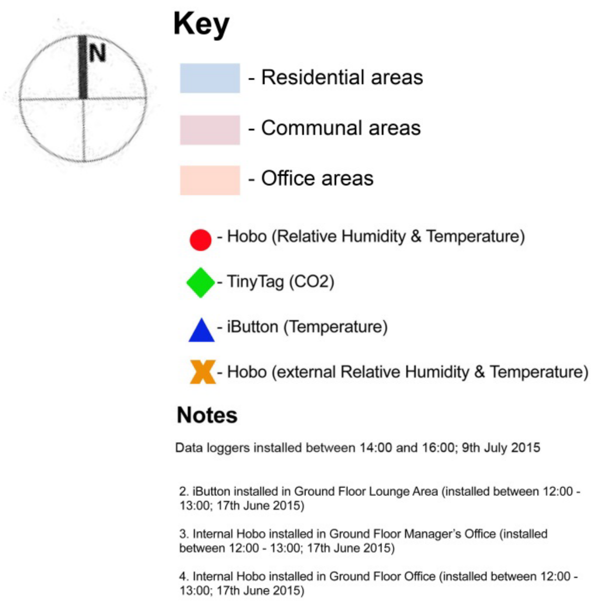

Figure 10. Location and type of data loggers installed.

4.2 Residential areas

Indoor and outdoor temperatures during the monitoring period

Table 5 outlines the overall minimum, mean and maximum temperatures in the three flats (bedrooms and living rooms) across the monitoring period. As it demonstrates, all bedrooms reach temperatures higher than 26°C (point at which overheating/occupant discomfort may occur according to CIBSE Guide A, 2015) during the monitoring period and the mean temperature of all three bedrooms was 24.5°C. In this context, it is worth noting that CIBSE Guide A (2015) states:

"Available field study data for the UK (Humphreys, 1979) show that thermal discomfort and quality of sleep begin to decrease if the bedroom temperature rises much above 24°C."

In addition, the recommended summer indoor comfort temperature for bedrooms (CIBSE Guide A, 2006) is 23°C; as the average mean bedroom temperatures are all higher than this, it indicates that either these areas are generally uncomfortable for the occupants, or that the occupants are satisfied with higher indoor temperatures.

In terms of the living rooms, the average mean temperature across the three living rooms was 24.6°C. This is very close to the CIBSE Guide A (2006) recommended indoor temperature for non-air-conditioned living rooms (25°C). In terms of differences in temperature across the period, in both the living room and bedroom of Flat 1, the range was 6K. In contrast, the temperature ranges in Flat 2 and Flat 3 were greater; around 8-9K. It is worth noting that the indoor environment of Flat 1 is controlled by the carers, whilst the residents in Flat 2 and Flat 3 control their own environment.

Table 5. Minimum, mean and maximum temperatures in monitored residential areas.

	Flat 1		Flat 2		Flat 3	
	Living room	**Bedroom**	**Living room**	**Bedroom**	**Living room**	**Bedroom**
Orientation	Ground floor		First floor		First floor	
Location	Southwest-facing		East-facing		West-facing	
Occupancy patterns	Rarely occupied	1 occupant 00:00-23:59 (Mon-Sun)	1 occupant 08:00-21:00 with approx. 4 hours out per day (Mon-Sun)	1 occupant 21:00-07:00 (Mon-Sun)	1 occupant 08:00-21:00 with approx. 4 hours out per day (Mon-Sun)	1 occupant 21:00-07:00 (Mon-Sun)
Min temperature	23.1°C	22.9°C	20.8°C	21.5°C	20.3°C	21.2°C
Mean temperature	25.0°C	24.7°C	24.4°C	24.9°C	24.4°C	24.0°C
Max temperature	29.1°C	28.3°C	30.0°C	29.6°C	29.4°C	30.1°C

To understand specifically when periods of high indoor temperatures were, the indoor temperatures were analysed in relation to the local outdoor temperature (Figures 11 and 12). Due to the lack of reliable data from the external data logger, this data were from a nearby weather station (data downloaded from wunderground.com). Both figures indicate that, generally, temperatures were higher than the CIBSE Guide A summer comfort temperature (bedrooms, 23°C; living rooms, 25°C), particularly in the bedrooms and there were significant periods where the temperature was above 24°C (increased likelihood of discomfort). Furthermore, there were significant peaks in all rooms that correlate with peaks in outdoor temperature (red vertical band on graphs).

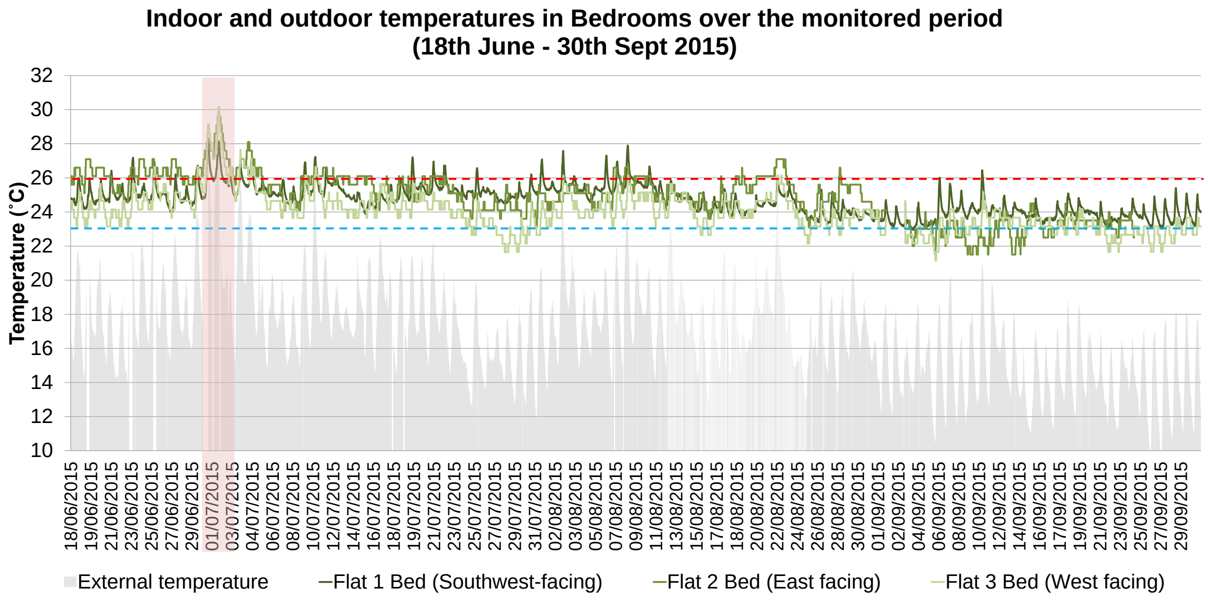

Figure 11. Indoor and outdoor temperatures in bedrooms over monitored period. *Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (26°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (23°C); red vertical band indicates peak indoor and outdoor temperatures.*

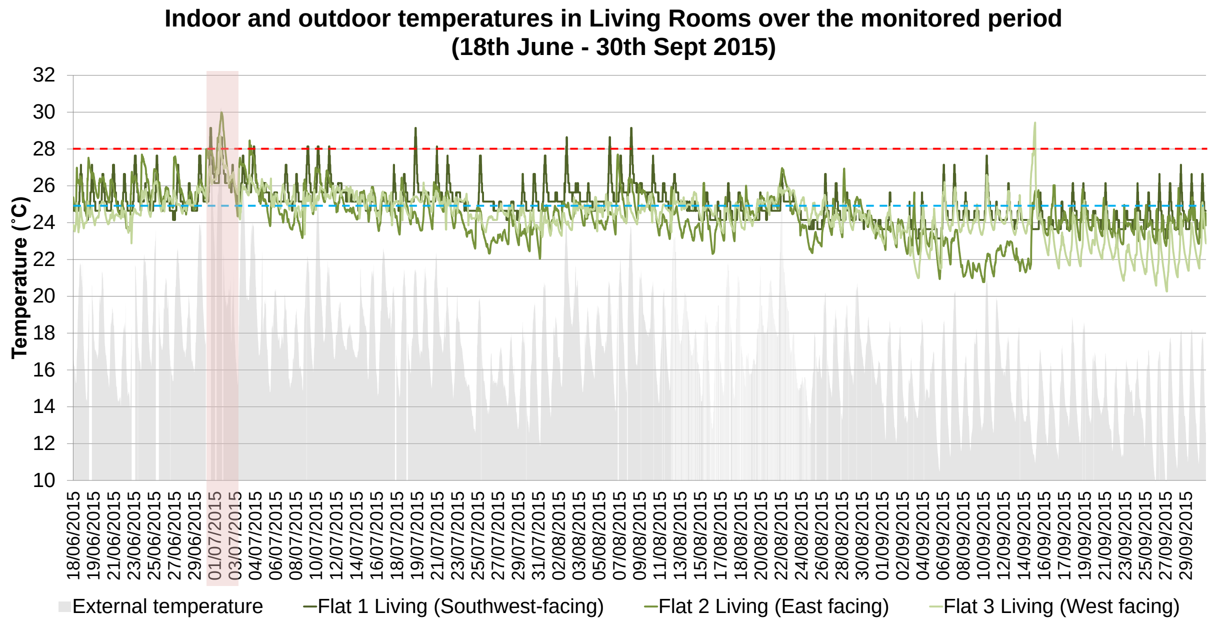

Figure 12. Indoor and outdoor temperatures in private living rooms over monitored period. *Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (28°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (25°C); red vertical band indicates peak indoor and outdoor temperatures.*

Indoor temperatures during hot outdoor periods

The Heatwave Plan for England (2015) recommends that Heatwave Action is undertaken if threshold temperatures are reached on at least two consecutive days. For Case Study C, these threshold temperatures are 30°C during the day and 15°C overnight. These were not reached during the monitoring period. Despite this, there were periods of high outdoor temperatures. Figure 13 provides an overview of the monitored bedrooms during such a period and indicates that the indoor temperatures rise significantly during such periods; particularly on the second day in the bedrooms in Flats 2 and 3. The overnight drop in temperature in Flat 1 bedroom suggests that night-time purging of hot air is happening (through ventilation enabling heat out of the room, and the cooler outdoor air in). However, the fact that the temperatures rise again during the day indicates inadequate ventilation management and cooling strategies in the bedrooms.

Such findings also suggest that if outdoor threshold temperatures for heatwaves (as used in the Heatwave Plan) were reached, it is likely there would be significant overheating in the bedrooms. Figure 14 demonstrates similar findings in relation to the living rooms of the flats.

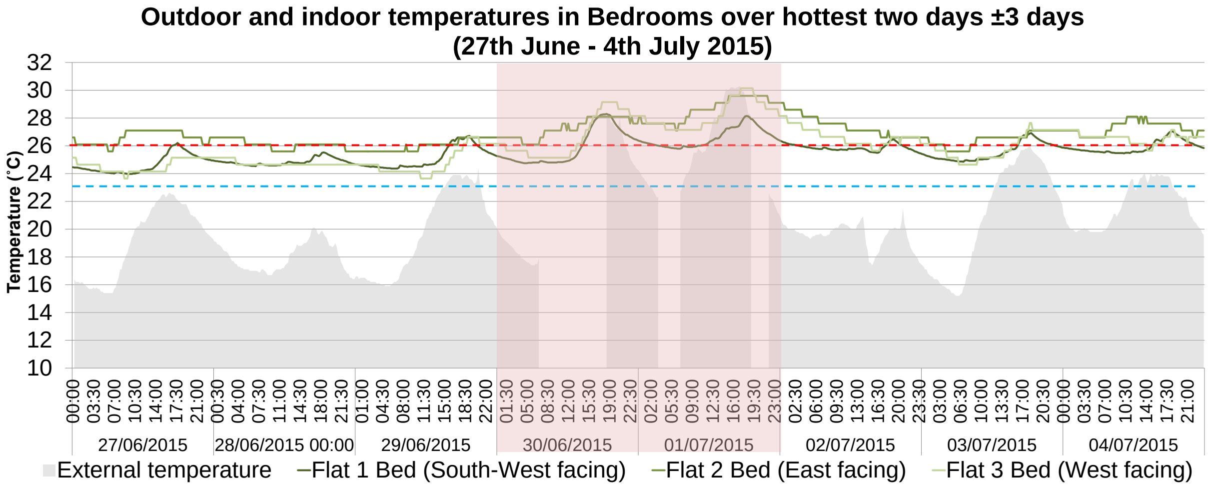

Figure 13. Indoor and outdoor temperatures in bedrooms over hottest period. ***Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (26°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (23°C); red vertical band indicates peak indoor and outdoor temperatures.***

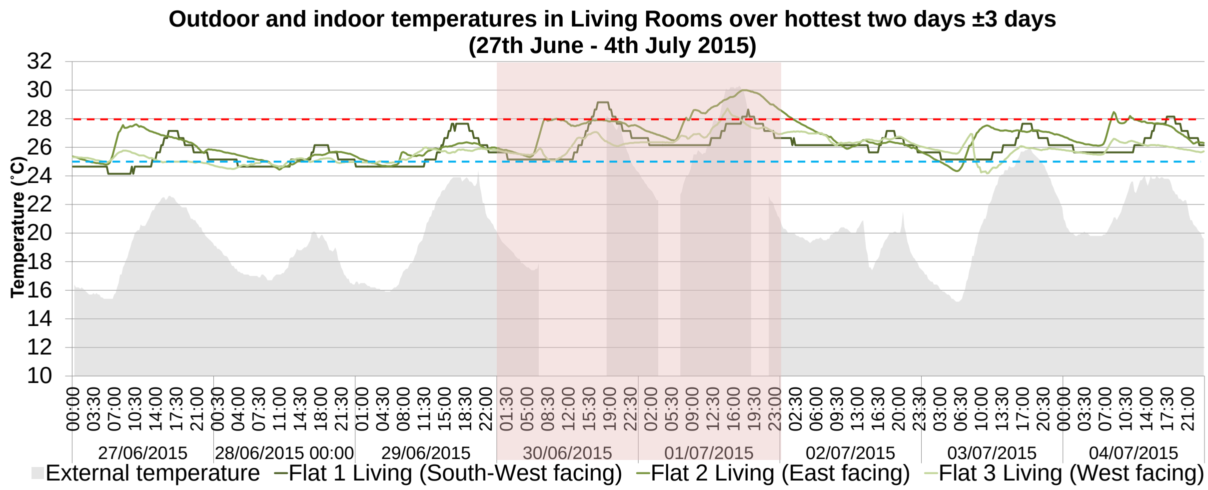

Figure 14. Indoor and outdoor temperatures in living rooms over hottest period. ***Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (28°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (25°C); red vertical band indicates peak indoor and outdoor temperatures.***

Current overheating risk

The monitoring data was analysed using both the static and adaptive method (Table 6):

- Adaptive method: Two living rooms (Flat 1 and Flat 2) and one bedroom (Flat 2) failed two or more criteria and as such overheated.
- Static method: Overheating in all three bedrooms and two living rooms (Flat 1 and Flat 2) (Figures 15 and 16).

It is worth noting here that, in general the thermal environment in Flat 1 is controlled and managed by care staff, whilst Flats 2 and 3 have able residents who manage their own environment. However, the resident of Flat 1 is confined to the bedroom, and the living room is rarely occupied.

Table 6. Overheating results for bedrooms using adaptive and static methods.

	Adaptive Method (TM52 Criteria Failed)	Static Method (% of occupied hours over temperature threshold)
Flat 1 (Bed) (GF, SW- facing)	-	6.0
Flat 1 (Living) (GF, SW- facing)	1,2,3	1.4
Flat 2 (Bed) (FF, E-facing)	1,2,3	24.1
Flat 2 (Living) (FF, E-facing)	1,2	1.0
Flat 3 (Bed) (FF, W-facing)	-	5.0
Flat 3 (Living) (FF, W-facing)	-	0.2
Notes:- Green indicates no overheating; red indicates overheating has occurred.		

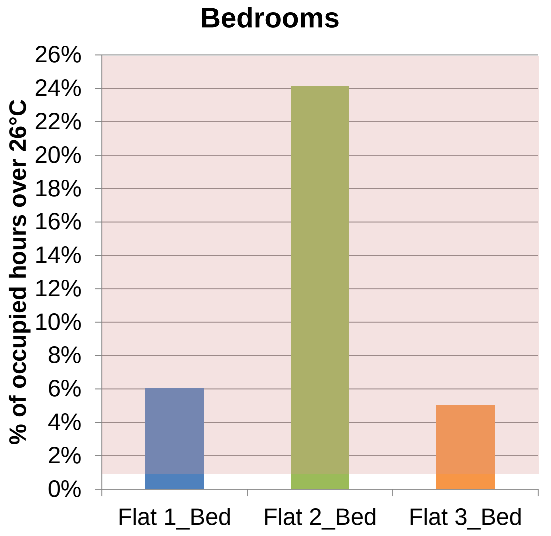

Figure 15. Overheating in bedrooms as defined by Static Method. *Note: Overheating occurs if temperature is above 26°C for over 1% of occupied hours.*

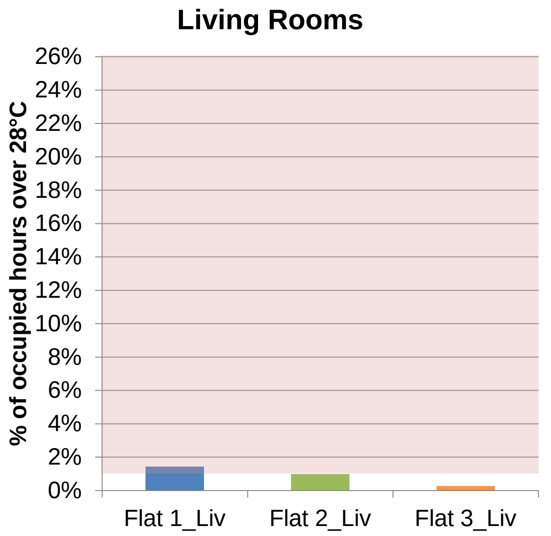

Figure 16. Overheating in living rooms as defined by Static Method. *Note: Overheating occurs if temperature is above 28°C for over 1% of occupied hours.*

CO_2 and relative humidity levels

Relative humidity levels were monitored in Flat 1 (Bedroom), Flat 2 (Living Room) and Flat 3 (Living Room). CO_2 levels were monitored in Flat 1 (Bedroom) and Flat 2 (Living Room). As Figure 17 demonstrates, throughout the monitoring period, relative humidity levels in all rooms were generally between 40-60%RH; 40-70%RH are generally considered acceptable. Figure 18 indicates that for the majority of (total) time the CO_2 levels were below 1,000ppm in Flat 1 (Bedroom) and Flat 2 (Living Room); prolonged periods in which CO2 levels are above 1,000ppm can result in lower occupant concentration, energy and tiredness and are indicative of poor ventilation.

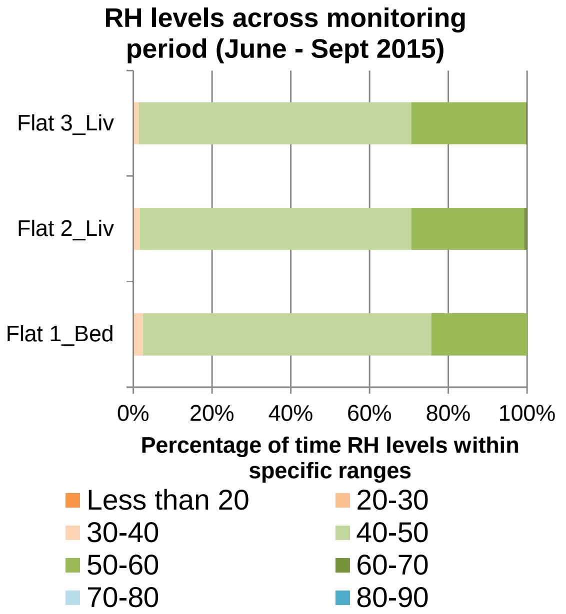

Figure 17. Relative Humidity in monitored residential areas.

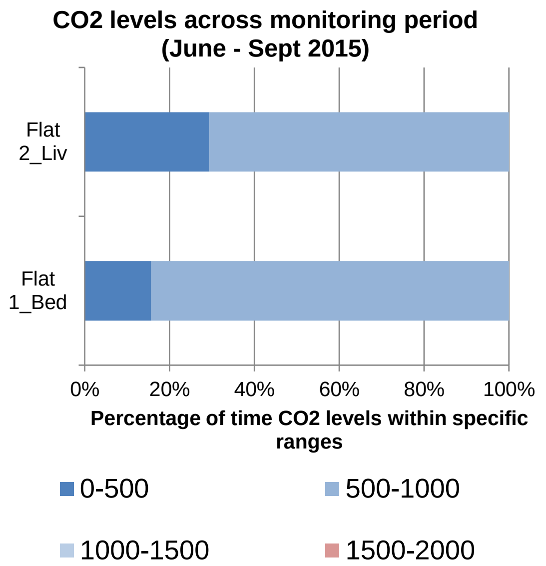

Figure 18. CO_2 levels in monitored residential areas.

4.3 Communal areas

Indoor and outdoor temperatures during the monitoring period

Table 7 outlines the overall minimum, mean and maximum temperatures in the two communal areas, across the monitoring period. As it demonstrates, the indoor temperatures ranged significantly in Lounge 2 (approximately by 10 degrees) and it also had an average mean temperature higher than the recommended CIBSE Guide A (2006) summer indoor comfort temperature for non-air-conditioned living areas (25°C).

Lounge 1 has an air-conditioning unit and fixed electric fans and as such, more stable temperatures would be expected; the temperature range over the monitoring period was approximately 5K, with an average mean temperature of 25.2°C. The CIBSE Guide A (2006) recommended levels for such an area are 23-25°C.

To understand specifically when there were periods of high indoor temperatures, the indoor temperatures were analysed in relation to the local outdoor temperature (Figure 19). As the red shaded vertical band in Figure 19 indicates, there were peaks of high indoor temperatures that correspond with high external temperatures. In addition, the temperature in Lounge 2 appears to be above CIBSE Guide A's summer comfort temperature for living areas (25°C), as well as being above 26°C (maximum temperature for 'cool areas', according to PHE Heatwave Plan for England, 2015).

The dark blue horizontal band indicates the comfortable range (CIBSE Guide A, 2006) for air-conditioned living areas; it indicates that Lounge 1 was often on the high side of this band, and also often went above 26°C (maximum temperature for 'cool areas', according to PHE Heatwave Plan for England, 2015). This is despite additional physical design features installed to reduce the overheating risk, and suggests that these are either inadequate and/or not being managed effectively. The building survey suggests that the management of both the air-conditioning unit and fixed ceiling fans could be improved; during visits, the control for the air-conditioning unit was lost.

Table 7. Minimum, mean and maximum temperatures in monitored communal lounge areas.

	Lounge 1	Lounge 2
Occupancy patterns	Approx. 20 occupants 07:00-18:00 (Mon-Sun)	Occupants unknown (5 max at one time) 07:00-18:00 (Mon-Sun)
Location	Ground floor	Ground floor
Orientation	South-facing	Southeast-facing
Min temperature	22.9°C	20.2°C
Mean temperature	25.2°C	25.8°C
Max temperature	28.4°C	30.2°C

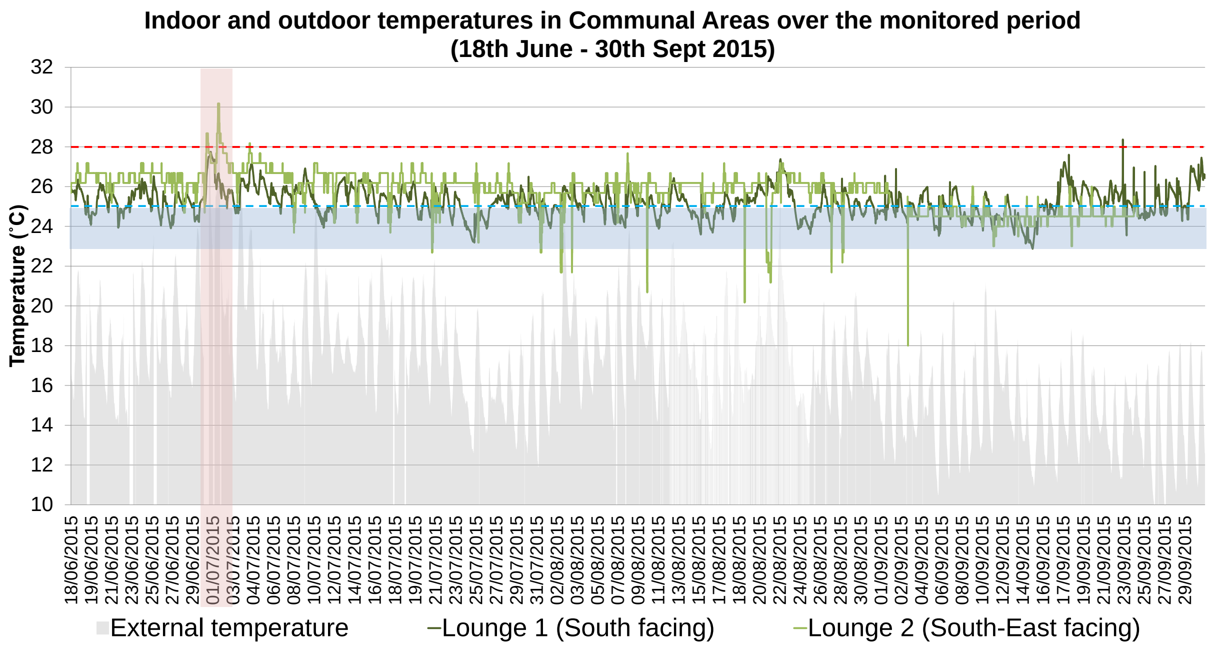

Figure 19. Indoor and outdoor temperatures in communal lounge areas over monitored period.

Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (28°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (25°C); red vertical band indicates peak indoor and outdoor temperatures; blue horizontal band indicates comfort range for air-conditioned living areas (23-25°C).

Indoor temperatures during hot outdoor periods

The Heatwave Plan for England (2015) recommends that Heatwave Action is undertaken if threshold temperatures are reached on at least two consecutive days. For Case Study C, these threshold temperatures are 30°C during the day and 15°C overnight. These were not reached during the monitoring period. Despite this, as Figure 20 suggests, there were peaks in indoor temperatures in the two lounges when there were peaks in outdoor temperatures; although this is more obvious in Lounge 2 (non-air-conditioned area). However, even in Lounge 1 during hot periods of weather the indoor temperature rises above 26°C; the maximum threshold temperature for 'cool rooms' as per the Heatwave Plan for England guidance. This indicates that additional ventilation and cooling methods and management would be required in order to keep either room as a 'cool area' during heatwave periods.

Current overheating risk

The monitoring data was analysed using both the static and adaptive method:

- Adaptive method: No overheating risk, although Lounge 2 fails Criterion 1.
- Static method: Overheating in Lounge 2 (1.1% of occupied hours over 28°C).

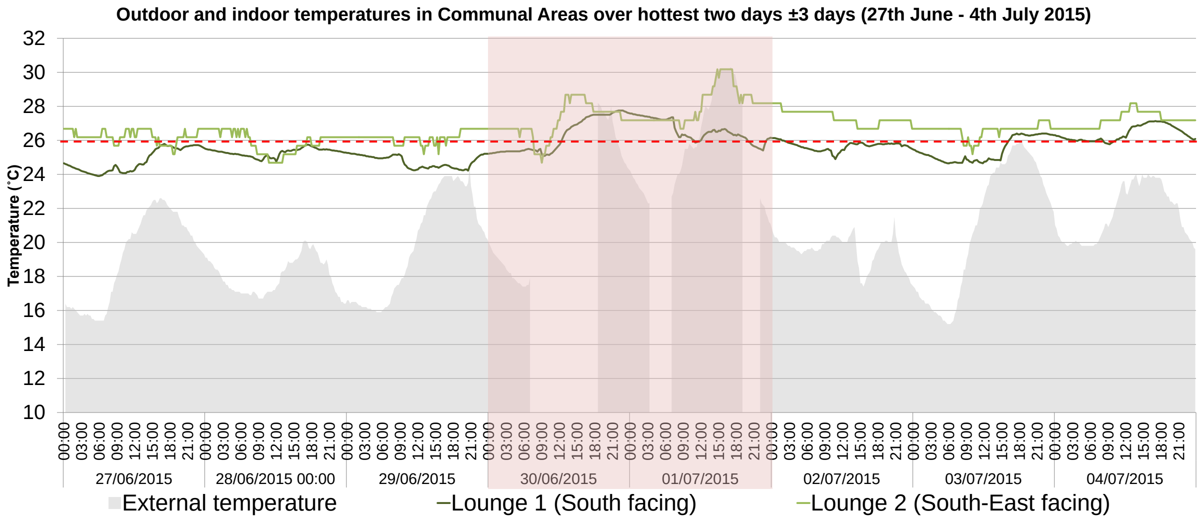

Figure 20. Indoor and outdoor temperatures in office areas over hottest period.

Notes:- Horizontal red dashed line indicates PHE Heatwave Plan maximum indoor temperature threshold of 26°C for 'cool areas' (to be provided during periods of hot outdoor temperatures)

CO_2 and relative humidity levels

CO_2 and relative humidity levels were monitored in Lounge 1. As Figure 21 demonstrates, throughout the monitoring period, relative humidity levels in both rooms were generally between 40-60%RH; 40-70%RH are generally considered acceptable. Figure 22 indicates that for the majority of time the CO_2 levels were below 1,000ppm; prolonged periods in which CO_2 levels are above 1,000ppm can result in lower occupant concentration, energy and tiredness and are indicative of poor ventilation.

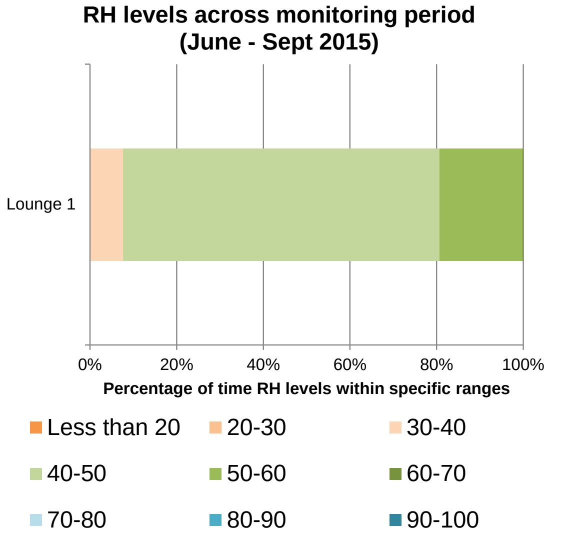

Figure 21. Relative Humidity in monitored communal Lounge 1.

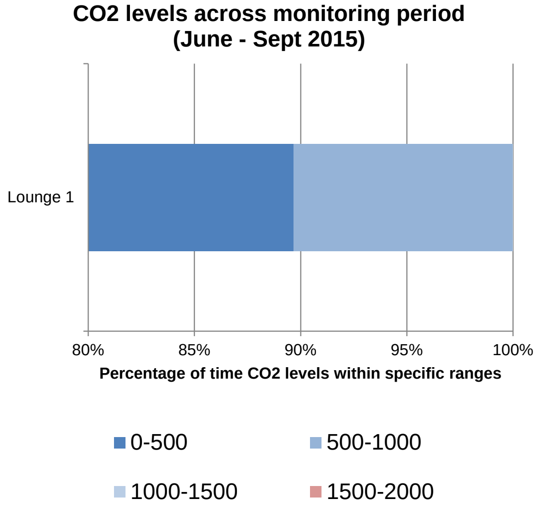

Figure 22. CO_2 levels in monitored communal Lounge 1.

4.4 Office areas

Indoor and outdoor temperatures during the monitoring period

Table 8 outlines the overall minimum, mean and maximum temperatures in the manager's and staff offices across the monitoring period. As it demonstrates, there was a significant difference in the mean indoor temperatures of both rooms during the monitoring period, and the average mean temperature of the Manager's Office is above CIBSE Guide A's recommended summer comfort temperature for offices (25°C according to CIBSE Guide A (2006)). The range of temperatures in the two offices across the period were similar (6-7k difference).

To understand specifically when such periods of high indoor temperatures were, the indoor temperatures were analysed in relation to the local outdoor temperature (Figure 23). There appears to be some correlation between indoor and outdoor temperatures, particularly in the manager's office and there were 'spikes' in the indoor temperatures during the period of highest outdoor temperatures (highlighted by red vertical band in Figure 23). Whilst the indoor temperatures of the staff office were nearly always around the summer comfort temperature for offices (25°C, CIBSE Guide A (2006)), the temperatures within the manager's office were nearly always above it, and even went above the maximum recommended threshold limit (28°C) on a number of occasions.

Indoor temperatures during hot outdoor periods

The Heatwave Plan for England (2015) recommends that Heatwave Action is undertaken if threshold temperatures are reached on at least two consecutive days. For Case Study C, these threshold temperatures are 30°C during the day and 15°C overnight. These were not reached during the monitoring period. In relation to the 'peak' outdoor temperatures during the monitoring period, at which indoor temperatures in the residential and communal areas also peak, Figure 23 shows that the offices display a correlation with outdoor temperatures but not to the same extent as the residential and communal areas. Figure 24, which shows the temperatures during this period of hot weather, indicates that whilst the temperature within the staff office appears to return to 'normal' levels relatively soon after the warm period, the manager's office does not; it appears to be more responsive to outdoor temperatures. This is likely to be due to its orientation and lack of adequate shading devices (it faces southeast and has only internal blinds).

Table 8. Minimum, mean and maximum temperatures in monitored office areas.

	Staff Office	Manager's Office
Occupancy patterns	Approx. 3 occupants; 08:00-17:00 (Mon-Fri)	1 occupant; 08:00-17:00 (Mon-Fri)
Location	Ground floor	Ground floor
Orientation	Northeast/North-facing	Southeast-facing
Min temperature	21.5°C	24.3°C
Mean temperature	24.4°C	26.6°C
Max temperature	28.7°C	30.3°C

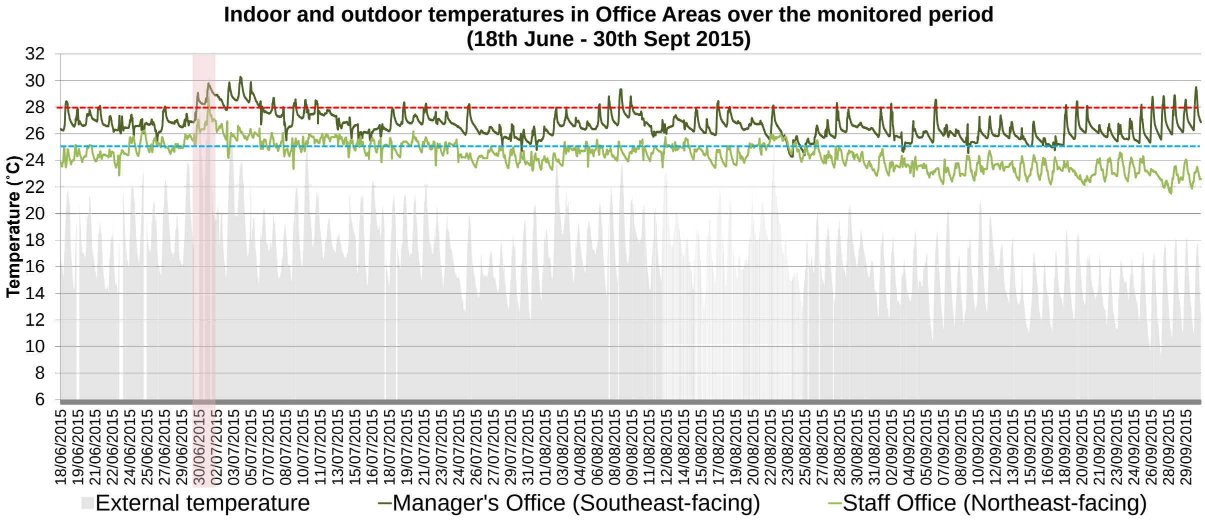

Figure 23. Indoor and outdoor temperatures in office areas over monitored period.

Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (28°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (25°C); red vertical band indicates peak indoor and outdoor temperatures.

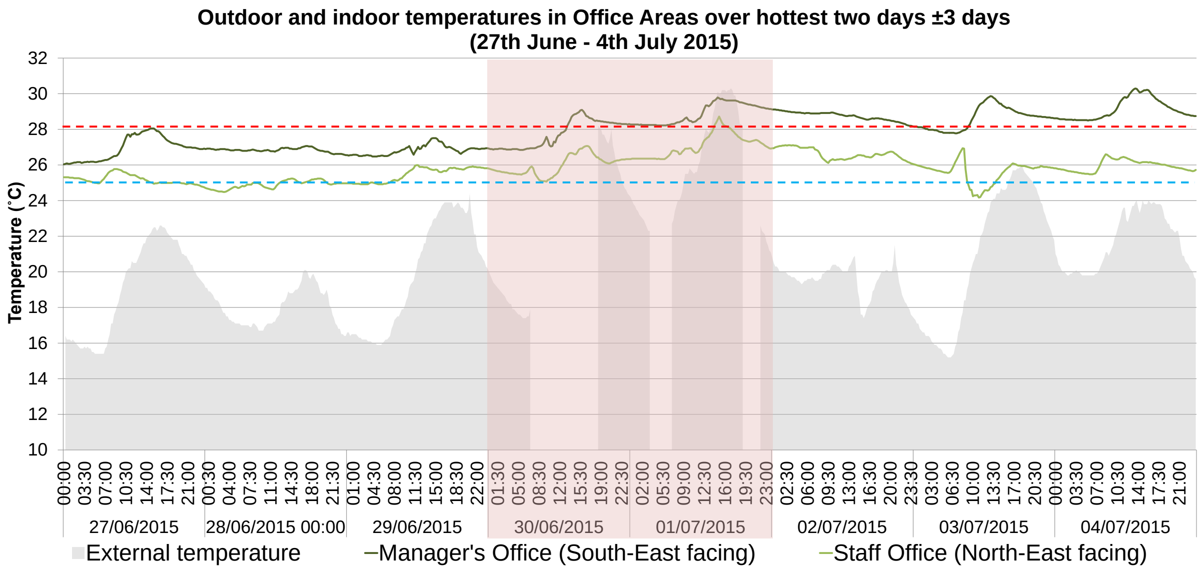

Figure 24. Indoor and outdoor temperatures in office areas over hottest period.

Notes:- Horizontal red dashed line indicates CIBSE Guide A maximum indoor summer temperature (28°C); horizontal blue dashed line indicates CIBSE Guide A indoor summer comfort temperature (25°C); red vertical band indicates peak indoor and outdoor temperatures.

Current overheating risk

The monitoring data was analysed using both the static and adaptive method (Table 9):

- Adaptive method: No overheating risk; although the Manager's Office fails criterion 1.
- Static method: Overheating risk present in Manager's Office.

Table 9. Overheating results for office areas using adaptive and static methods.

	Adaptive Method (TM52 Criteria Failed)	**Static Method** (% of occupied hours over temperature threshold)
Staff Office (GF, NE- facing)	-	0.4
Manager's Office (GF, SE- facing)	1	10.6

Notes:-
Green indicates no overheating; red indicates overheating has occurred.

Relative humidity levels

Relative humidity levels were monitored in both offices (Figure 25). For over 80% of the monitoring period the relative humidity levels in both offices were between 40-60%RH. This is within the acceptable limits (40-70%RH) and is indicative of a comfortable indoor environment; despite the Manager's Office experiencing high temperatures.

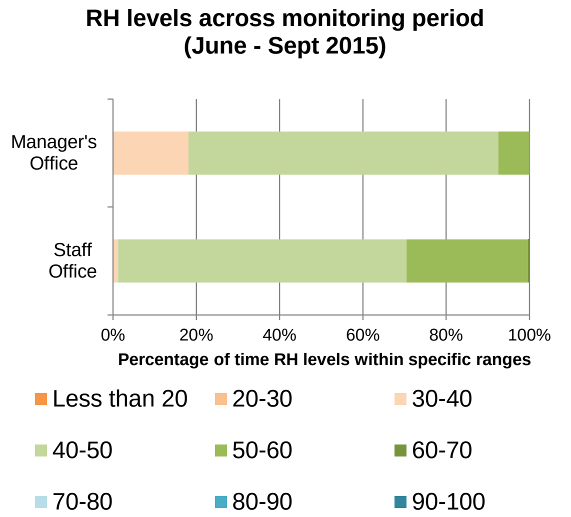

Figure 25. Relative Humidity levels in monitored office areas.

5. Design, management, care practices and resident experiences

5.1 Design and asset/strategy management

One member of the design practice responsible for the design of Case Study C was interviewed along with a development director for the organisation responsible for Case Study C. The interviews lasted approximately one hour and involved questions on the design, briefing, procurement and management of the building, along with wider questions on design and strategizing for future climate change and overheating in the care sector. The key themes raised in the interviews are described in following sections.

Attitudes and awareness towards overheating and future climate change

Both interviewees were aware of overheating and future climate change adaptation, however, both stated that it is not considered in terms of strategic planning due to length of care sector long term planning (thirty years) but also due to the pervading attitude that overheating is not considered a major issue in both the construction and care sectors, as well as across the wider society;

"…the whole issue of overheating is not yet a really meaningful discussion in this country." (Designer).

Both were also aware of the Heatwave Plan for England, but felt it did not necessarily relate directly to their roles and responsibilities.

Low prioritisation of overheating and future climate change

Financial, spatial and care requirements and standards are prioritised above aspects such as overheating and future climate change adaptation;

"…a building like this…typically hasn't got more than a fifty year lifespan not because it's designed to fall to pieces after fifty years…but quite frankly standards change, we're replacing care homes and housing schemes that were built in the sixties…they're perfectly good buildings but they're the wrong shape and size for current standards." (Designer).

The perception of older people's needs in terms of thermal comfort also appeared to influence the prioritisation of overheating with the focus on providing warmth not cooling;

"They tend to feel the cold and tend to be happier in warmer spaces…because they're feeling the cold…temperatures will be higher and …there is the whole issue of perceived temperature and…relational temperature design." (Designer)

And;

"If I can heat buildings for nothing I'm prepared to put up with one or two days where it gets twenty-four/twenty-five degrees inside especially as my residents like it at twenty-four/twenty-five in the winter so you know." (Management).

Conflicting advice, calculations and standards

There is confusion around advice and standards relating to energy and environmental performance of new buildings;

"Now in theory Building Regulations are now dealing with this. However, if you and actually as soon as Building Regulations absorb into them energy performance standards and BREEAM and obviously Codes for Sustainable Homes it will help. At the moment though we're seeing three or four different parallel systems and there's plenty of scope for confusion there so I actually think that although you know in theory standards are rising the actual achievement of those and the technical means by which they are achieved

are actually is very much in the hands of the gods." (Designer).

Conflicts in designing care and extra care schemes

Potential conflicts in designing for the needs and requirements for older people and designing to reduce overheating were identified, for example;

"…older people spend a lot of their time sitting down so there's no point in having windows starting at you know one point two metres because all they can see is the sky and so you want to be able to have full length windows wherever possible." (Management).

And;

"…you've got to put double doors on to stop heat loss. Absolute bloody nightmare for older people they can't understand it, why do I, I don't go through two doors to get into a shop, I don't go through two doors to get into my house…" (Management)

And;

"…draughts are much more unpleasant for older people so ventilation is an issue you have to be careful with, they'll just shut the window." (Designer)

And;

"Returning to overheating I think that's about management as well of blinds, curtains, opening windows and so on…In projects like this no mainly [architects do not provide such fittings] because residents are encouraged to bring their own in. We will have provided curtain tracks…but not very much and…that's in the hands of the residents and the staff and obviously the organisation to steer that." (Designer).

There can also be conflicts between the provision of natural light and solar gain and reducing the risk of overheating;

"…there is always a balance to strike between daylight and over-much sunlight particularly for older people…strongly contrasting light in rooms can be a problem for people…one of the things we have to design for is avoiding confusion through contrasting colours and light. So a degree of solar shading is a good idea, how far you take that of course is a different question." (Designer).

Responsibility, management and maintenance of services

The need for simple or invisible controls was emphasised by both interviewees as well as the issues with more sophisticated systems in terms of lack of understanding from daily users;

"…it comes back to the technical design with simple controls. Obviously the other approach is to have invisible controls …our intention is to try and design things as simply as possible but clearly the kind of menu of things in passive house design work very well and if it's done well then you can live in a passive house and do nothing to the controls whatsoever and it will keep you at the right temperature." (Designer).

Responsibility for and control over the services is complex, particularly in schemes with residents suffering from dementia;

"…disconnecting the thermostat …it gets them very confused and then that …creates frustration, creates angst, stress …and so if they think they're controlling the heating that's fine …I suppose in some ways we are violating that because we're fooling people into thinking they are controlling things when they're not but for their own benefit. Is that morally right? I don't know. Sometimes it's quite a difficult thing to think about." (Management).

And;

"We're working increasingly for people with either dementia or some degree of confusion and their ability to control is frankly pretty

minimal, that means somebody else has got to control it for them and that some somebody else may or may not know how to do that and so the default is just to leave it on hot because that's safe…and they can always open a window…" (Designer).

Disconnect between design intent and actual management of systems

Procurement methods such as Design and Build were seen as an issue in terms of enabling design intent to be followed throughout such building and development schemes, and often design intent can be meted out through changes in specification of materials and services;

"The biggest issue here is procurement. …because most housing work is procured through a design and build process and most design and build processes put a great deal of trust in the contractor because levels of specification are not clear. That may be fine, there are excellent contractors around but…there is also a completely straightforward and completely understandable tendency for people to do only what they are asked to, the result is that we don't have much control in much of the residential work we're doing now over detailed environmental or building standards." (Designer).

The disconnect can also be due to complex management structures, as well as a lack of communication at handover on how to use and maintain unfamiliar technologies;

"…we have normally a week or two where we take the building over…because we (building/development team) at that stage in my past experience don't understand the heating system ourselves we can't possibly teach carers. Our management teams do not understanding heating systems basically, it's as simple as that. In buildings today with MVHR, with BMS' controlled by external temperatures, internal temperatures, carbon dioxide readings et cetera, et cetera, et cetera there's no way that anybody other than a mechanical engineer, well electrical engineer or somebody with a bit of technical nous can understand what the hell's going on so no they rely on us and that's why we were bringing in BMS bit by bit." (Management).

5.2 Management and care practices

Semi-structured interviews were conducted in September 2015 with three members of staff in Case Study C. Interviews lasted approximately 50-65 minutes. Interviewees were asked about their perceptions of the potential threats posed by excessive heat, their awareness of the PHE Heatwave Plan, current heat management practices, and their approach to coping with heatwaves. The key themes that emerged from the interviews are described in the following sections.

Scepticism about heatwave risk

Interviewees expressed scepticism about the potential health risks to occupants of heatwaves in the UK. Two interviewees observed that summertime temperatures are often higher in other countries than in the UK. All interviewees reported that there had been no heat-related emergencies in the housing scheme. Although one interviewee noted that some occupants find the building too warm in summertime and that even in winter the building is "hot everywhere," another suggested that overheating was never a problem in the building and that occupants were more likely to complain of being too cold than too hot.

Operation of heating

The extra-care housing scheme had a gas-fired communal heating system, with heat distributed via radiators and, in the restaurant, via under-floor and trench heating. The heating system was controlled centrally by a Building Management System (BMS), and locally by room thermostats (in communal areas only) and thermostatic valves on radiators. At the central level, the heating was in operation throughout the year to allow occupants to turn on radiators even in summer if they wished to do so. All interviewees felt that some occupants would require heating at times during the summer. One interviewee observed that a problem with this approach is that some occupants, particularly those with dementia, do not understand how to control the heating and will "fiddle" with thermostats. This can lead to care-staff being called to help occupants adjust heating, increasing the pressure on staff workload. The interviewee believed that it was therefore easier to leave the thermostatic valves in occupants' apartments on the highest setting; occupants can then open a window if they are too warm. The interviewee admitted that this was "a terrible waste." Interviewees also noted that thermostats in communal areas, which are accessible to staff and occupants, are often set inappropriately.

One interviewee explained that all occupants pay an equal amount for heating regardless of how much they use. The total heating bill for the housing scheme is divided by the number of apartments, with those in 2-bed apartments being expected to pay marginally more than those in 1-bed apartments. The interviewee argued that the benefit of this approach is that it encouraged occupants to put the heating on if they felt cold, and to not worry about the cost of energy bills, adding that: "the biggest killer in the elderly is the cold, so I'd rather they were hot."

Coping with heatwaves

The housing scheme's manager was aware of the PHE Heatwave Plan and used PHE guidance to prepare information sheets for staff and occupants. Other staff were unaware of the PHE Heatwave Plan, but carers were aware of some best-practice principles featured in the plan. During hot weather occupants were encouraged to increase their fluid intake, although one interviewee observed that some occupants do not like to drink too much water as it will cause them to require the toilet more frequently; incontinence and mobility impairments can then lead to "accidents." It was observed that some occupants used electric fans in summer. Carers also encouraged occupants to wear appropriate levels of clothing in hot weather, although one interviewee noted that some occupants like to wear the same types of clothing throughout the year.

One interviewee commented that those occupants who receive care generally do not shower more frequently in hot weather, even when this was offered, explaining that, "I don't think they change their habits." Similarly, an interviewee observed that occupants have "plenty of choice" in the restaurant, but that most are of the generation that expect to have a cooked meal at lunchtime, even during hot weather. Consequently, "it's mainly the staff and the relatives who are younger than the tenants who have salads."

Interviewees questioned some aspects of PHE guidance. One interviewee felt that it was unnecessary to create "cool rooms" as outdoor temperatures in the UK will never be as high as those in some other countries. Occupants' GPs had not been consulted regarding their potential vulnerability to heatwaves, with one interviewee commenting that all older occupants are equally vulnerable to excessive heat. No business continuity plans had been drawn up in preparation for possible heatwaves.

Lack of structural investment

Internal blinds were added to some communal areas to reduce heat-gain from sunlight. The installation of blinds or curtains in apartments was regarded as the responsibility of occupants or their family. One interviewee observed, however, that occupants cannot be expected to sit indoors during the daytime with the curtains closed, and consequently occupants closed blinds rarely, even on sunny days. One interviewee suggested that keeping the building cool was about using common sense, saying: "If it's hot you open a window." Another interviewee, however, remarked on the difficulty of obtaining through-ventilation in the apartments, most of which were single-aspect with windows on one side only. The problem was compounded by some occupants' reluctance to leave open the front door to their apartment owing to concerns about security or intrusion by people with dementia. One interviewee noted that there were sometimes tensions between occupants about whether corridor windows should be open.

5.3 Resident experiences

Semi-structured interviews were conducted with five occupants in Case Study C. Interviews lasted approximately 15-30 minutes. Occupants were asked how they maintained thermal comfort in warm weather, and how easy or difficult is was to do this. Additionally, a researcher discussed thermal comfort issues with occupants at a tenants' meeting. The key themes that emerged from the interviews and the tenants' meeting are described in the following sections.

Perceived thermal comfort

In one-to-one interviews, three occupants reported that the building is generally comfortable during the summer. One said that even in summer he felt cold if there was a draught, such as when the front door to his apartment was open. One said that "the building is hot," adding that,

"It's like sitting in a greenhouse." (resident).

This occupant identified heat from sunlight as a particular problem, saying that,

"…If we didn't have the blinds I think we'd roast." (resident).

However, the interviewee also described how the (windowless) kitchen always seemed to be warm, but that it was difficult to identify the source of the heat.

At a tenants' meeting, chaired by the scheme manager and attended by approximately 15-20 occupants, summertime indoor temperatures were discussed. Asked if the housing scheme was a comfortable temperature in summer, three occupants instantly responded by saying it was hot. Other occupants did not dispute this viewpoint. It was suggested that occupants on the upper floor find it hotter. A further two occupants implied that they find the building warm in summer, with one describing extensive use of electric fans and the other stating that it is difficult to "get a through-breeze" (i.e. there is no through-ventilation). A sixth occupant described the building as "hot enough" in summer. In total three occupants mentioned that they use electric fans in summer, with one saying that she had fans on "practically all day" in her "bedroom, hallway and lounge." Two occupants reported propping open the front door to their apartment in order to get through-ventilation, although another occupant stated that she kept her door locked to prevent intrusion by people with dementia.

Views on summertime temperatures in the communal spaces, particularly the restaurant, were more mixed. One occupant suggested that the restaurant is hot, while another said, "It's hot and if they put the air conditioning on, it's cold." Regarding the restaurant, one occupant said, "Usually it's quite comfortable," but that it was necessary to sit away from the air conditioning units if these were on. Another observed that, *"Sometimes it chills of a night-time."* (resident).

Barriers to thermal comfort in hot weather

In interviews, one occupant observed that restricted window opening made it difficult to ventilate the apartment, while another said that her apartment was much easier to ventilate and cool since she removed the window restrictors. In the tenants' meeting, several occupants noted that it was difficult to achieve through ventilation. In interviews, while one occupant said he often left open the front door to his apartment to improve ventilation, two other occupants did not leave their front doors open for fear of intrusion by people with dementia. One occupant did not leave open windows unattended for fear that burglars or cats would get into her apartment. The occupant had additional concerns about squirrels and rats that prevented her from leaving open patio doors unattended. One occupant reported that his patio door was open only when a carer was present, which occurred for approximately fifteen minutes four times a day, as mobility impairments prevented him from getting to and from the door. Two occupants reported that they did not use the trickle vents, with one saying that he left these for the carers to operate. Two occupants in interviews, and three who attended the tenants' meeting, reported using electric fans.

An occupant who described her apartment as like "a greenhouse," with sunlight causing significant heat gain also said that she liked having some sunlight and was reluctant to shut it out with the blinds. Another occupant, whose apartment received little direct sunlight, thought the large window in his living room made the room feel cold. One occupant said they often sat outside in the summer, while another said he did not do this because it was often too hot even with the use of a gazebo.

Two occupants reported that the food provided by the restaurant was similar throughout the year, with little seasonal variation. One occupant reported that he wore short-sleeved shirts throughout the year as the building was generally warm.

6. Building resilience against current and future overheating risk

A number of applicable physical measures were modelled and simulated in the case study building. The measures tested are listed in Table 10. Also modelled was **managed ventilation** (Table 11). As the heatwave of the 2080s climate period is somewhat comparable to that which was monitored during the summer of 2015, the data from the modelling of the 2080s climate period can be used as a proxy to visualise effective adaptation measures for like conditions.

Table 10. Physical adaptation measures tested.

Measure		Notes	Rank*
1	**Reduce external temperature by managing the microclimate**		
1.1	Increased greenery: trees	Negligible impact	-
1.2	Green Roof		3
2	**Exclude or minimize the effect of direct or indirect solar radiation into the home (fabric changes)**		
2.1	External shading (louvered shutters)	Selected for adaptation package	4
2.2	Interior shading (blinds)		5
2.3	Glazing upgrade (low-e triple glazing)		7
2.4	Solar control film		8
2.5.a	Increase external wall reflectivity		9
2.5.b	Increase roof reflectivity	Selected for adaptation package	2
3	**Limit or control heat within the building**		
3.1	Expose or introduce thermal mass	Walls only	6
3.2	Natural ventilation through windows	Selected for adaptation package	1
3.3	Ceiling fans	Assessed against adaptation package	N/A**
3.4	Mechanical ventilation	Already in place / no change	N/A

Notes:
** Rank is based on measure effectiveness considering both overall overheating risk mitigation and impact on internal temperatures for most spaces during heatwave periods (particularly in the 2080s climate period). 1 is the best and 7 is the lowest.*
***Ceiling fans are highly effective but not ranked as their effectiveness is measured differently.*

Table 11. Ventilation practices.

	Current practice (as modelled)	Managed ventilation
Living room windows **Living room exterior door** **Bedroom window**	Always open during summer (May-Sept)	Windows are closed if internal temperature is >27°C, otherwise open

6.1 Residential areas

Flat 1 Bedroom

The most effective adaptations are **managed ventilation and external shutters**. Increasing the thermal mass is also effective as modelled in the Flat 1 bedroom; however, the method of application would be practically disruptive. Though reflective roof is inconsequential for this room it is combined with the package due to its effectiveness throughout the rest of the extra-care home.

For all climate periods (less so in the 2080s) the type and package of measures applied without managed ventilation is relative inconsequential, i.e., managed ventilation is essential for the success of the adaptation package and is quite effective as a singular adaptation. One key point to notice is that managed ventilation should not stand alone by the 2080s as an adaptation measure. As is seen in Figure 26 during the heatwave it is effective at first instance of a peak temperature but on Aug 8-9 where the temperature is not able to drop enough in the room overnight, there is too little ventilation and the internal temperature remains too high.

For this reason **by the 2080s managed ventilation must be combined with the full adaptation package (external shutters and increased roof reflectivity)**.

All variations on the bedroom model overheat in the 2080s climate period using the SM (Table 12). The full adaptation package does however reduce the overheating risk by one-half. This will have a positive impact on reducing required energy use to cool the space through electric ceiling fans and/or air-conditioning units. (There is no overheating in the 2030s climate period). It is unlikely that passive physical measures alone will keep the bedroom from overheating in the 2080s climate period.

In summary at 2030s the most effective response **managed natural ventilation** and or **Ceiling fans** to achieve internal temperature below 26°C or satisfactory PMV (thermal comfort). By the 2080s a **full adaptation package** is required, as well as ceiling fans as the adaptation package will only reduce peak interior temperature by about 4°C.

Table 12. Overheating risk (2080s) in Flat 1 Bedroom using adaptive and static methods, and relative impact of physical adaptation measures.

Adaptive Method (TM52 Criteria Failed)				Static Method (% of occupied hours over temperature threshold)			
Base model	Ref. roof+ shutters	Man. Vent.	Full package	Base model	Ref. roof+ shutters	Man. Vent.	Full package
2	-	-	-	4.5	3.5	3.8	2.1

Notes:-
Green indicates no overheating; red indicates overheating has occurred.

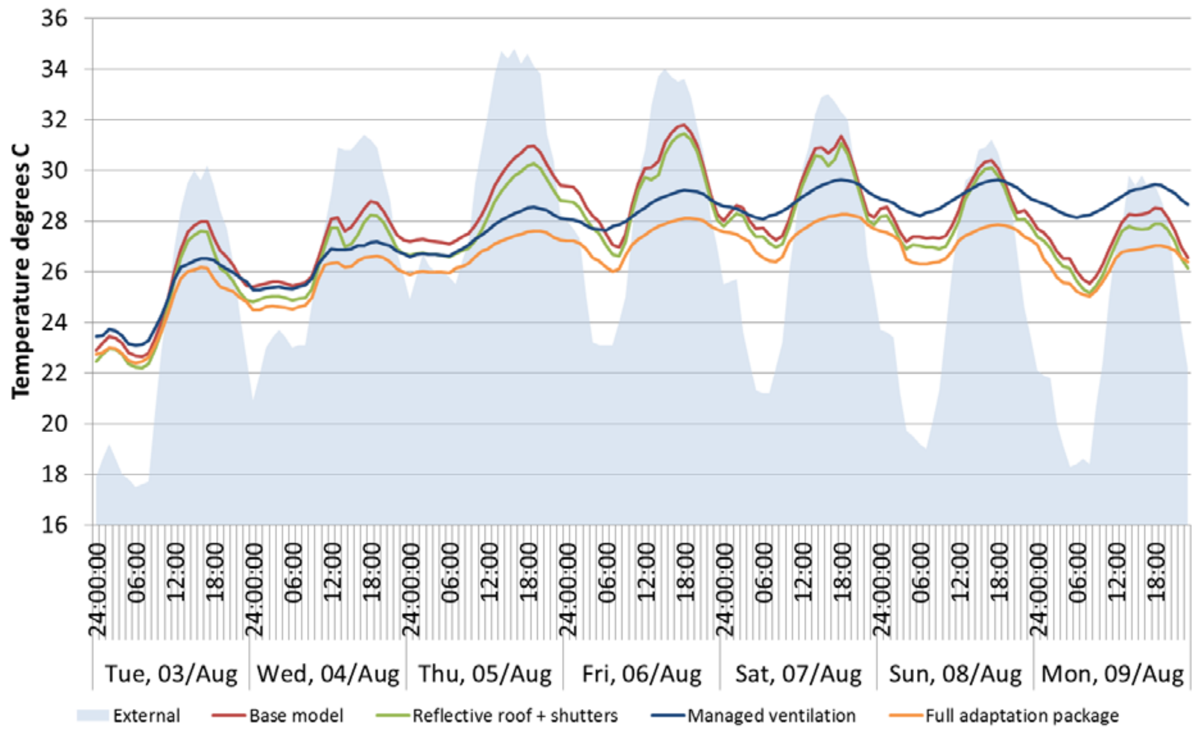

Figure 26. Modelled temperatures in Flat 1 Bedroom, and relative impact of physical measures (2080 heatwave).

Flat 2 Bedroom

The most effective adaptations are managed ventilation, reflective roof material and shutters. Again, for all climate periods managed ventilation is essential for the success of the adaptation package and is quite effective as a singular adaptation (more so before the 2080s).

Similar to Flat 1 bedroom, managed ventilation should not stand alone by the 2080s as an adaptation measure. A similar response can be seen in Figure 27; notably here, night-time temperatures are not able to drop as low as potentially possible (Aug 7-8). For this reason **by the 2080s managed ventilation must be combined with the full physical measures package**.

In summary, although there is no overheating risk in the 2030s, the most effective measures to reduce temperatures are **managed natural ventilation** and or **Ceiling fans** to achieve internal temperature below 26^{o}C or satisfactory PMV (thermal comfort).

By the 2080s a **full adaptation package** is required (Table 13). Though the adaptation package will reduce peak interior temperature by about 4-5^{o}C and eliminate overheating risk, **ceiling fans** will be required in addition to provide satisfactory PMV.

Where a building is mechanically cooled (or where electric fans are used to provide thermal comfort), predicted mean vote (PMV) is applied to assess acceptability. This is because increased air movement used to create a cooling effect (example used in this study: ceiling fans) does not actually change the operative temperature in a space. PMV is calculated by a formula taking into consideration operative temperature, air speed, relative humidity (RH), metabolic rate and clothing level. An indoor environment should aim to achieve a PMV index near to or equal to zero. Above zero ranges from warm to hot and below zero ranges from cool to cold (see Explanation Box 3).

Table 13. Overheating risk (2080s) in Flat 2 Bedroom using adaptive and static methods, and relative impact of physical adaptation measures.

Adaptive Method (TM52 Criteria Failed)				Static Method (% of occupied hours over temperature threshold)			
Base model	Ref. roof+ shutters	Man. Vent.	Full package	Base model	Ref. roof+ shutters	Man. Vent.	Full package
-	-	-	-	2.0	1.4	2.1	0.8

Notes:-
Green indicates no overheating; red indicates overheating has occurred.

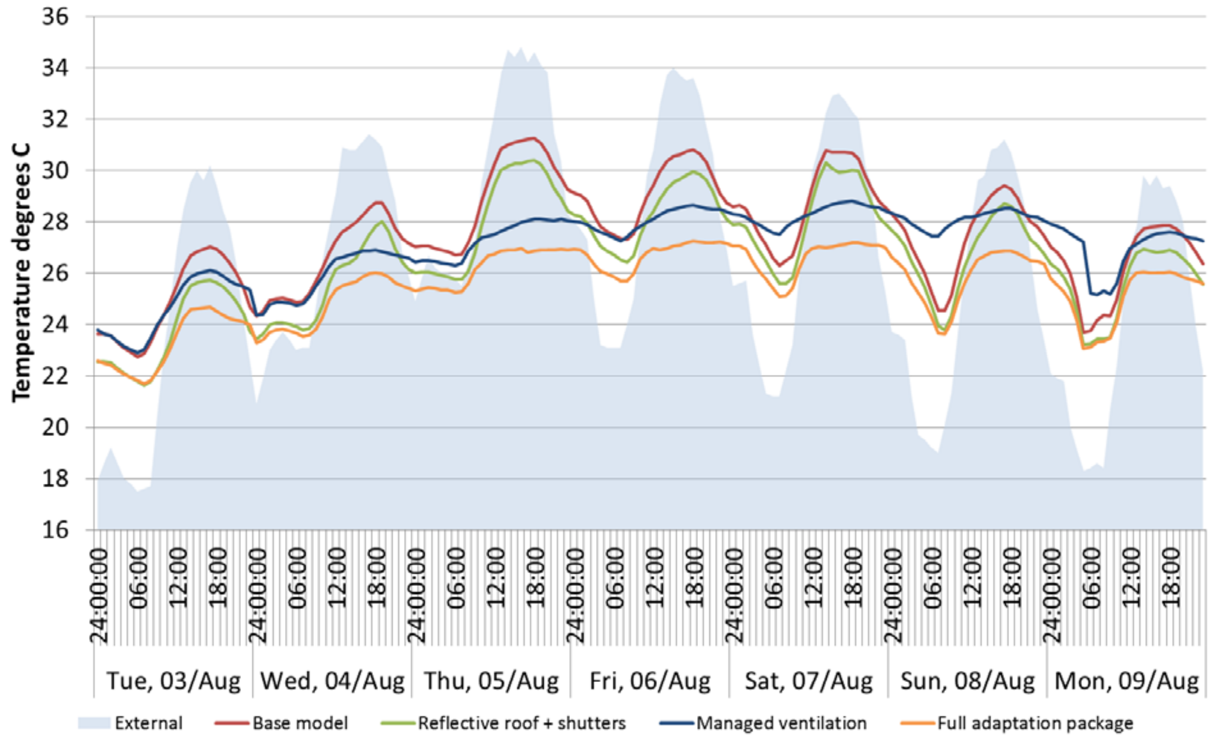

Figure 27. Modelled temperatures in Flat 2 Bedroom, and relative impact of physical measures (2080 heatwave).

Flat 2 Living Room

The most effective adaptations are **managed ventilation, shutters and reflective roof material.** Again, for all climate periods managed ventilation is essential for the success of the adaptation package and is quite effective as a singular adaptation (more so before the 2080s).

The overheating results for the 2030s show an interesting problem. Applying managed ventilation (alone or even with the full package) in the 2030s (and the 2050s) is actually problematic. In the most extreme case, doing so actually creates an overheating risk where it does not occur in the base model. The problem is likely due to the impact of internal gain being greater than external temperature gain on the internal temperatures, most likely through a lack of adequate air circulation in the room following the closing of windows and hence an increase in internal gains. However, as Figure 28 shows, managed ventilation could be appropriate in extreme heatwave periods.

The adaptation package **(external shutters, reflective roof material and managed ventilation) + ceiling fans** are able to satisfy the PMV during the heat wave period of all climate periods in the living room (Figure 29). Though the adaptation package will reduce peak interior temperature by about 4-5^{o}C and eliminate overheating risk, **ceiling fans** will be required in addition to provide satisfactory PMV.

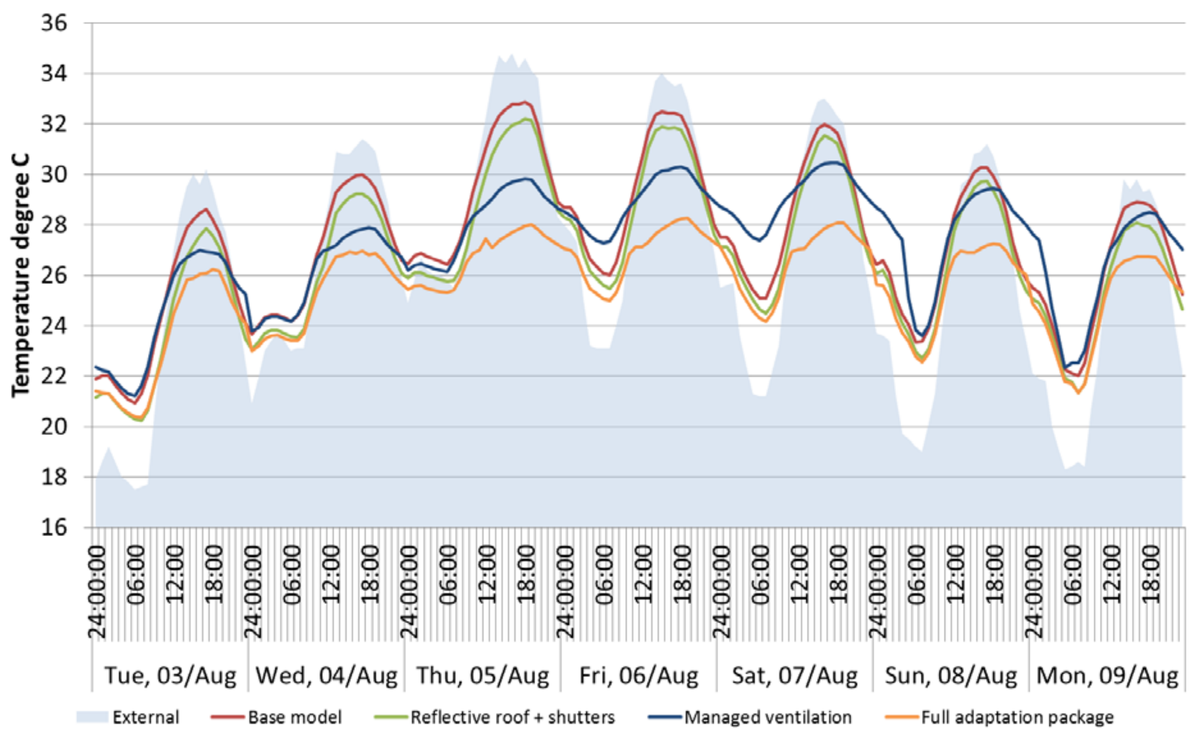

Figure 28. Modelled temperatures in Flat 2 Living Room, and relative impact of physical measures (2080 heatwave).

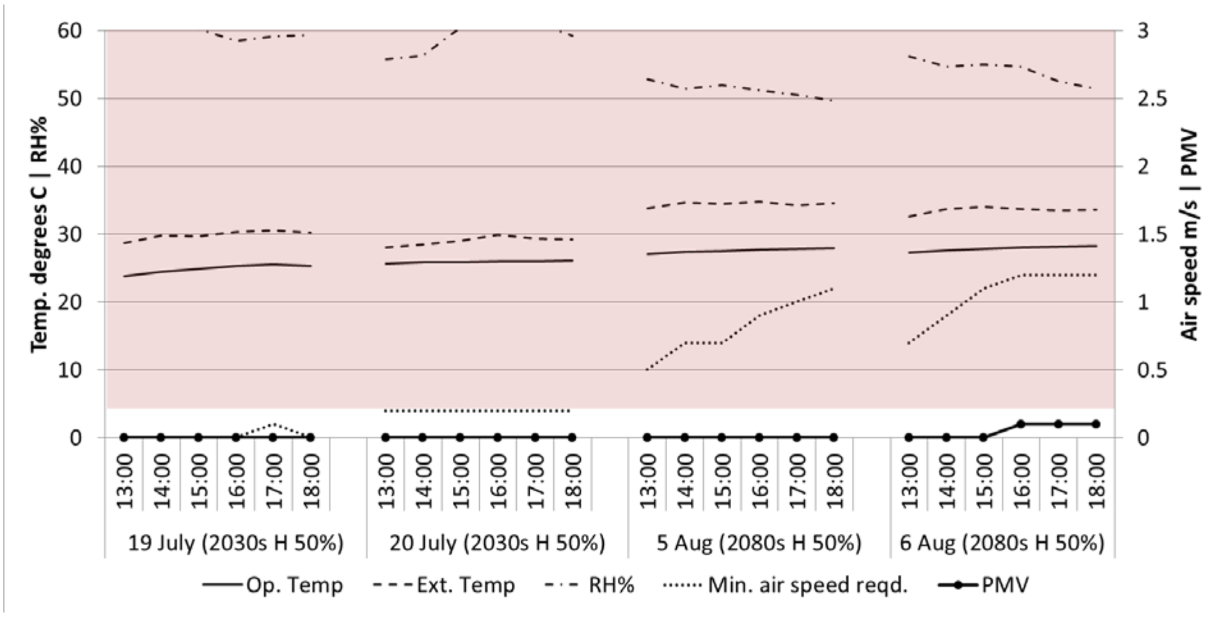

Figure 29. PMV of adaptation package - Heatwave in Flat 2 Living Room, 2030s and 2080s. *Note: any PMV points within the red area are overheated for most vulnerable occupants.*

6.2 Communal area

The communal area modelled was Lounge 1. The two most effective adaptations are **reflective roof material and internal blinds**.

Shutters cannot be easily retrofitted to the lounge due to the elaborate form of the lounge, the quantity of glazing, the elaborate forms of each section of glazing and the existing shading fins. Coincidentally, shutters are also comparably not an effective adaptation by the 2080s climate period. Interestingly managed ventilation (alone) is the worst adaptation for the lounge, creating greater interior temperatures; however, when managed ventilation is combined with the other two most effective adaptation options the results are more effective than without it. The negative impact of managed ventilation without solar control is likely due to the unrelieved (un-ventilated) solar gain in the lounge when temperatures are not high enough to open windows.

In the 2030s climate period, the full adaptation package (i.e. **reflective roof material, internal blinds and managed ventilation**) resulted in a decrease of 3^{o}C from the peak interior temperature of the baseline model of the lounge (i.e. from 31^{o}C to just above 28^{o}C). The base model lounge is on the edge of overheating in the 2030s climate period; the AM shows overheating but the SM does not (however, 1/10 of a percentage away). Both versions of the adaptation package (with and without managed ventilation) are significantly effective in reducing overheating risk for the lounge. By the 2050s though there is 3/10 of a percent difference, the full package alleviates overheating using the SM, whereas the package without managed ventilation overheats.

Figure 30 shows Lounge 1 during the peak heatwave in the 2080s climate period. All variations on the lounge model overheat in the 2080s climate period. The full adaptation package does however reduce the overheating risk by almost two-thirds (Table 14). This will have a positive impact on reducing required energy use to cool the space (through air-conditioning and/or use of electric fans). It is unlikely that passive measures alone will keep the lounge from overheating in the 2080s climate period. It is suggested that the lounge be retrofitted with a reflective roof and automated blinds (or blinds controlled by staff) immediately. Within the next 10 years managed ventilation can be integrated to further reduce overheating risk and to reduce peak temperatures during heatwaves.

Table 14. Overheating risk (2080s) in Lounge 1 using adaptive and static methods, and relative impact of physical adaptation measures.

Adaptive Method (TM52 Criteria Failed)				Static Method (% of occupied hours over temperature threshold)			
Base model	Ref. roof+ blinds	Man. Vent.	Full package	Base model	Ref. roof+ blinds	Man. Vent.	Full package
1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	6.6	4.3	12.3	2.6

Notes:-
Green indicates no overheating; red indicates overheating has occurred.

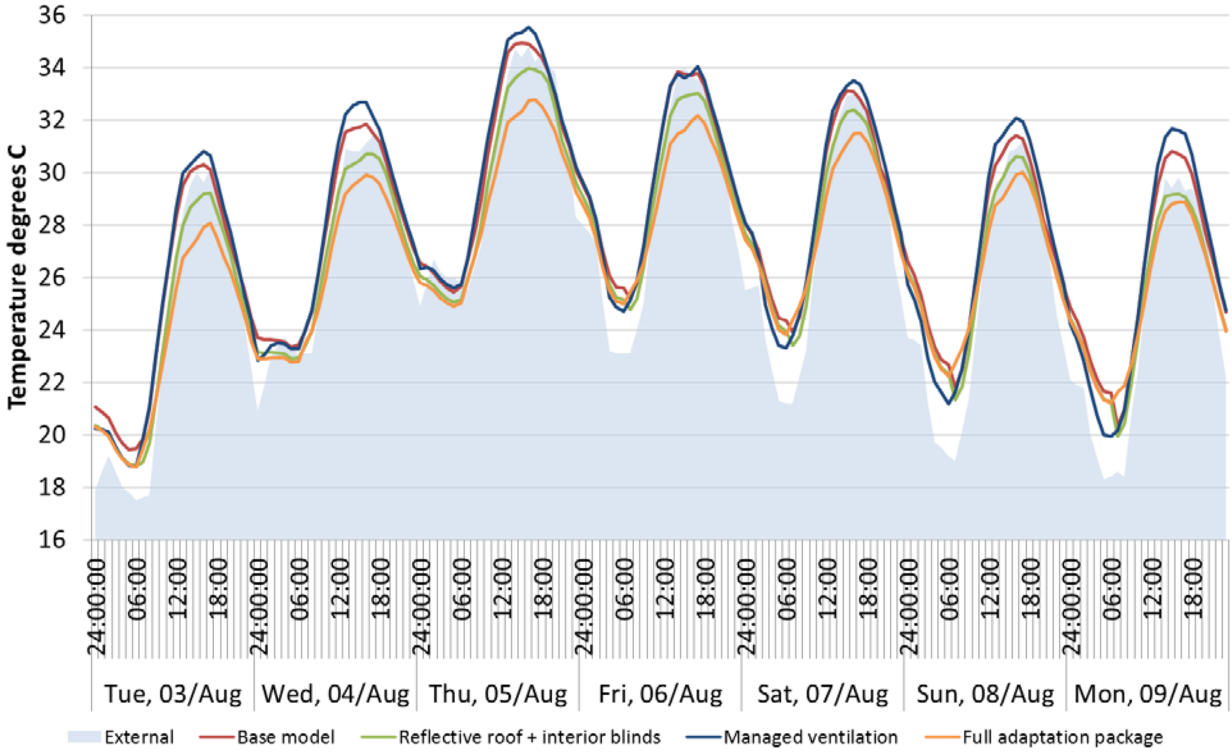

Figure 30. Temperatures in Lounge 1, and relative impact of physical measures (2080 heatwave).

In terms of ceiling fans, which Lounge 1 has installed already, they alone are unable to satisfy the PMV (+/-0.2) during the selected peak periods of the 2080s climate period in the base model of the lounge. However, after the lounge is retrofitted with the full adaptation package, ceiling fans are mostly able to satisfy the PMV for the 2030s peak periods, but not for the 2080s (Figure 31).

The lounge is significantly different in response to overheating from the other spaces. In summary, at 2030s the most effective response is the **full adaptation package (i.e. reflective roof material, internal blinds and managed ventilation)**. **Ceiling fans** (already installed) are required to provide satisfactory PMV in the space in addition to the recommended package.

By the 2080s all of the above recommended adaptations are insufficient to ensure a thermally comfortable space during the heatwave period. This appears to have been expected as the designers installed air conditioning in the space. Obviously, air conditioning, if sufficiently sized and managed appropriately, would alleviate all overheating concern from the current situation. However, its use can be avoided up to the 2030s by passively retrofitting aforementioned measures. To have these measures installed will also reduce the cooling demand required by the air-conditioning unit by the 2080s.

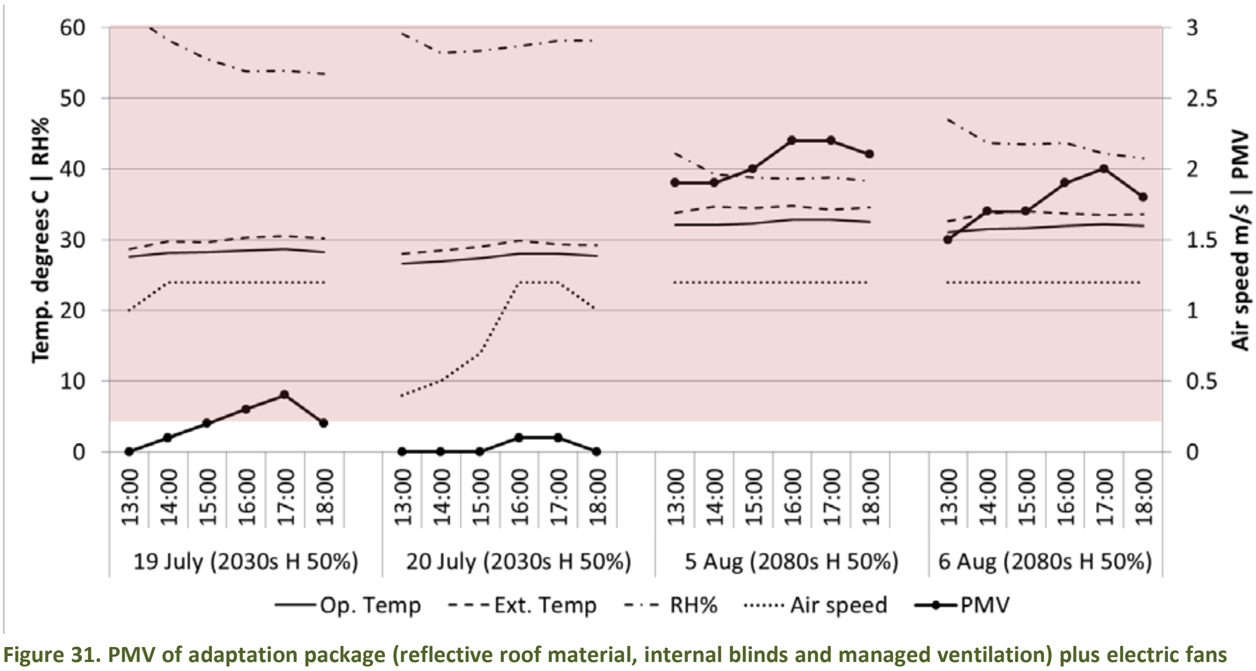

Figure 31. PMV of adaptation package (reflective roof material, internal blinds and managed ventilation) plus electric fans for Lounge 1 during heatwave periods, 2030s and 2080s. *Notes:- any PMV points within the red area are overheated for most vulnerable occupants (the staff threshold is higher at 0.7).*

6.3 Office Area

The Manager's Office was modelled for adaptation measures. The most effective adaptations for the Manager's Office are **reflective roof material, external shutters and managed ventilation. External shutters, solar control film, and green or reflective roof finishes** are all effective in reducing the peak internal temperature during the 2030s. Like Lounge 1 however, managed ventilation is not effective when applied alone at the 2030s climate period. In the 2080s climate period managed ventilation is, however, more effective than the combination of reflective roof and shutters.

Shutters, solar control film, and green or reflective roof are all effective in reducing the peak internal temperature during the 2030s. By the 2050s (or before) it is suggested that the extra care home begin installing the full adaptation package, keeping in mind that managed ventilation by the 2080s is essential and highly effective as a stand-alone option. Any single adaptation option (or combination of the three) applied before this will reduce the risk of overheating.

It is unlikely that passive measures alone will keep the office from overheating in the 2080s climate period (Figure 32 and Table 15). All variations on the office model overheat in the 2080s climate period using the SM. The full adaptation package does however reduce the overheating risk by one-half. This will have a positive impact on reducing required energy use to cool the space.

Table 15. Overheating risk (2080s) in Manager's Office using adaptive and static methods, and relative impact of physical adaptation measures.

Adaptive Method (TM52 Criteria Failed)				Static Method (% of occupied hours over temperature threshold)			
Base model	Ref. roof+ shutters	Man. Vent.	Full package	Base model	Ref. roof+ shutters	Man. Vent.	Full package
2	2	2	2	4.7	2.4	2.3	2.0

Notes:-
Green indicates no overheating; red indicates overheating has occurred.

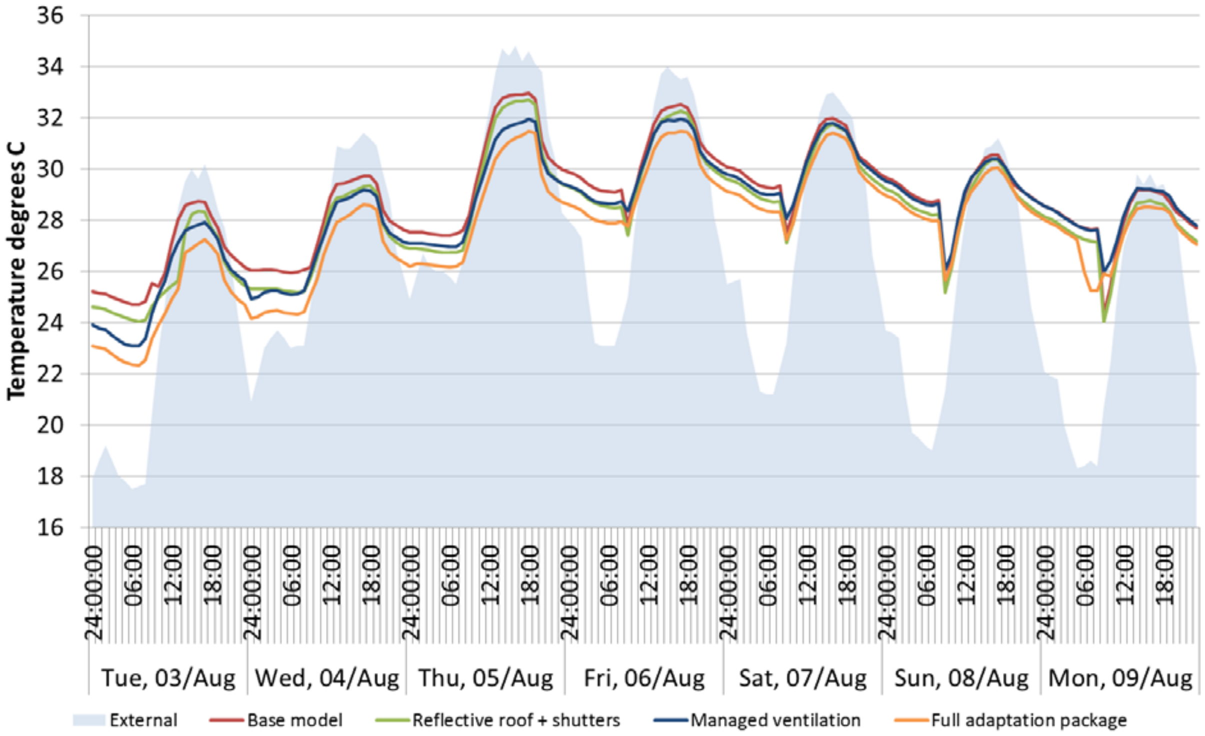

Figure 32. Temperatures in Manager's Office, and relative impact of physical measures (2080 heatwave).

7. Summary of findings

- Although analysis using the static overheating method indicated that seven out of the ten rooms monitored (five residential areas, Lounge 2 and the Manager's Office) overheated during the monitoring period, the adaptive method indicated that only three (one bedroom and two private living rooms) overheated.

- Modelling of future climate showed that overheating would not be a problem for Case Study C in rooms except for the main lounge (Lounge 1) using the Adaptive Method and not until the 2050s using the Static Method.

- The design of the building had both the potential to reduce and exacerbate the overheating risk such as external shading (reduce risk) and single aspect residential rooms (exacerbate risk).

- Modelling indicated that several physical measures could be undertaken to reduce the future overheating risk, including external shutters and reflective roof material. Such measures appear to be best, introduced as packages, and in combination with managed ventilation.

- There was a lack of awareness of potential current and future overheating risk within the strategic management and on-site care staff, but which seems to be based on a systemic lack of awareness throughout the care sector. This is possibly due to the fact that no heat-related problems had been reported within the care scheme, and wider care organisation. This has led to a lack of prioritisation of future long-term retrofit measures of strategies to mitigate overheating risk and the use of only short-term management measures such as providing liquids and ensuring residents' spend time outdoors and wear lightweight clothing in periods of hot weather.

- In terms of designing for overheating, the issue of confusing advice and standards relating to overheating was raised. Furthermore, there are often conflicts between designing care schemes and appropriate overheating mitigation design measures such as the health, safety and security of residents as well as more qualitative factors such as providing sunlight and good views.

- In terms of management practices during periods of hot weather, generally staff were aware of the Heatwave Plan and instigated recommended short-term adaptation measures such as keeping residents hydrated and wearing lighter clothing. However, these were sometime compromised by residents' habits and concerns, such as requiring 'cooked' meals and additional showers.

- The dangers of the 'cold' were seen as a higher priority in relation to long-term plans and design strategies as well as the effective working and management of the care home; older people were seen as be susceptible to the cold more than the heat, and also preferred higher temperatures, and as such both the design and management needed to reflect this. However, the interviews with the residents indicate that they felt that the residential area was generally too hot and there was a lack of adequate ventilation, without electric fans.

- In terms of on-site management of heat, there was confusion surrounding the responsibilities over the heating system particularly between the care staff, the on-site management team and off-site maintenance and building management teams which can lead to ineffective use.

8. Recommendations

The following Table 16 summarises the recommended adaptations per room from the modelling findings, phased over time. As noted earlier, because the modelling appears to be conservative in findings as compared to the evaluation of the summer of 2015's actual performance (albeit representing only a single summer), it is recommended that the case study closely monitor the following years and potential for overheating. If in fact the monitored results continue year after year or become more problematic it is suggested that the entire package as a whole be installed at the next possible opportunity, e.g. retrofit/renovation.

Other recommendations include:

- Install monitoring devices within key areas of the building, with digital feedback displays to show and record internal temperatures as well as install a permanent local external temperature sensor.
- Review the management and maintenance processes both within the case study care scheme as well as across the care organisation as a whole.
- Ensure regular reviews of heating and ventilation systems and their operation and condition e.g. trickle vents, and the ceiling fans and air-conditioning unit in the main lounge.
- Provide regular guidance and training on the management of heating and ventilation systems to on-site staff, particularly in relation to the ceiling fans and air-conditioning unit in the main lounge.
- Encourage cross-organisational communication and partnership to improve on-site staff agency and knowledge of the building services installed and encourage active responsibility from on-site staff for ensuring radiators are turned down and ventilation strategies are in place.
- Review potential future physical adaptation measures and include in long-term development strategies for both the individual care scheme and wider organisation.

Table 16. Phased physical measures package recommendations.

Time period	Room	Passive measures					Semi-active measures		Active measures	
		Draught proofing	Upgrade low-E double/triple glazing	Reflective ext. wall insulation	Reflective roof	Exposed thermal mass (ceiling)	Blinds (int.)	Shutters (ext.)	Managed nat. ventilation	Ceiling fan
Now	Lounge 1 (GF)				✓		✓			
	Manager's office (GF)				✓+			✓+		✓
	Flat 1 bedroom (GF)								✓+	✓
	Flat 2 bedroom (FF)								✓+	✓
	Flat 2 living room (FF)								✓**	✓
2020 – 2049 (2030s)	Lounge 1 (GF)								✓	
	Manager's office (GF)				✓+			✓+		✓
	Flat 1 bedroom (GF)							✓+	✓	
	Flat 2 bedroom (FF)							✓+	✓	
	Flat 2 living room (FF)							✓+		✓
2040 – 2069 (2050s)	Lounge 1 (GF)									
	Manager's office (GF)				✓+			✓	✓	
	Flat 1 bedroom (GF)				✓+			✓		
	Flat 2 bedroom (FF)				✓+			✓		
	Flat 2 living room (FF)				✓+			✓		
2070 – 2099 (2080s)	Lounge 1 (GF)									
	Manager's office (GF)				✓					
	Flat 1 bedroom (GF)				✓					
	Flat 2 bedroom (FF)				✓					
	Flat 2 living room (FF)				✓					

Key:
✓ - Recommended adaptation; ✓+ - Advanced option; ✓** - Only required during heatwaves.

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End notes

1. PROMETHEUS was a 30-month project led by the University of Exeter that aimed to develop a new set of probabilistic reference years (up to 2080) that can be understood and used by building designers. The PROMETHEUS weather files cover over 40 locations across the UK and have been used by leading engineering and architectural firms to test the resilience of their building designs to climate change. Further details can be found: http://www.arcc-network.org.uk/project-summaries/prometheus/#.VuaGQPmLSWh

2. Refer to the main report and Boxes 1-3 for overheating and climate change modelling definitions. Future climate change modelling is probabilistic and will likely be updated as time progresses. An effective approach to climate change modelling for the coming century in previous projects, including those under the Design for Future Climate (D4FC) programme, simulates three climate periods, generally 2030s, 2050s and 2080s. Central estimate, i.e. 50% probability, was also a commonly used probability in D4FC projects. High emissions scenario (IPCC SRES A1FI) is an emissions scenario path roughly being currently followed given the current CO_2 emissions and global economic, technical and social trajectory (Innovate UK, 2015; Gupta et al., 2015).

About the authors

Rajat Gupta is Director of the Oxford Institute for Sustainable Development (OISD) and Low Carbon Building Research Group at Oxford Brookes University (OBU), where he also holds a professorial chair in Sustainable Architecture and Climate Change. His research expertise is in climate change adaptation of buildings, evaluating building performance evaluation and low carbon communities. Rajat has won nearly £8 million in research grants from ESRC, EPSRC, Innovate UK, World Bank, UNEP, RICS and British Council. Until recently he was PI on a £1.4m ESRC/EPSRC funded EVALOC project, evaluating impacts of low carbon communities on energy behaviours. He has been instrumental in developing and pilot-testing the world's first global Common Carbon Metric (CCM) for the United Nations Environment Programme's Sustainable Buildings and Climate Initiative (UNEP-SBCI).

Laura Barnfield is a Research Fellow in Building Performance Evaluation and Low Carbon Communities at Oxford Brookes University (OBU). Laura has been a key researcher on the ESRC-funded project EVALOC, evaluating the impacts of low carbon communities on localised energy behaviours. Prior to joining Oxford Brookes in 2012, Laura worked in an architecture practice in Oxford on a range of projects in the transport, commercial, public and residential sectors. She ran a £3 million young people's centre in Oxfordshire, which included both low carbon technologies and high specification building fabric. Prior to this, she gained experience in urban design and planning when working on several urban residential developments in the north-west of England.

Matt Gregg is a Research Fellow in Architecture and Climate Change at Oxford Brookes University (OBU). Matt is currently involved with the ESRC-funded EVALOC project evaluating the impacts of low carbon communities on localised energy behaviours. In 2012 Matt completed an EPSRC-funded three-year project, SNACC – Suburban Neighbourhood Adaptation for a Changing Climate – where he worked with a multidisciplinary team focusing on suburban neighbourhood-level adaptation to climate change. Developing from this work, Matt is currently involved in further research involving adaptation package development and simulation regarding climate change-induced domestic overheating.

Alan Lewis is a Lecturer in Architecture at the University of Manchester. His research centres on the implications of an ageing society for housing design, and on the production of design standards and their effects on the built environment. Alan's projects have explored the production and consumption of architecture, particularly in relation to the practices of design professionals and building users. He has explored the ways in which architects construct user representations of older occupants and script these representations into housing design, and how building standards have shaped the built environment, particularly in relation to daylighting and urban design. In investigating the consumption of architecture, he has explored how older occupants interact with buildings in maintaining thermal comfort, and worked on a study (EVOLVE) of the relation between housing design and older occupants' quality of life.

Gordon Walker is Co-Director of the DEMAND Centre (Dynamics of Energy, Mobility and Demand) and Professor at the Lancaster Environment Centre at Lancaster University. He has wide-ranging expertise in the social and spatial dimensions of sustainable energy technologies, transitions and social practices, and has written key works on cross-cutting issues of energy and environmental justice. He has led a series of multi-partner projects funded by UK research councils and government departments focused on the dynamics of energy demand, community energy, energy poverty, zero carbon housing, renewable energy and public engagement, and flooding and resilience. His books include Environmental justice: concepts, evidence and politics (Routledge, 2012) and Energy justice in a changing climate: social equity and low carbon energy (Zed, 2013).

Louis Neven obtained his PhD in 2011 at the University of Twente on how designers and engineers represent older technology users, and how older users respond to their designs. He subsequently worked for Lancaster University on a project on ageing and sustainable heating technologies, and for Utrecht University on a project on micro/nanotechnology and ageing. Louis is currently a Lector (research professor) and leads the Active Ageing research group at Avans University of Applied Sciences in Breda, the Netherlands.

A pdf version of this publication is available from the Low Carbon Building Research Group, Oxford Brookes University website (http://architecture.brookes.ac.uk/research/lowcarbonbuilding/).

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Low Carbon Building Group
Oxford Institute for Sustainable Development
Oxford Brookes University
Gipsy Lane Campus
Oxford OX3 0BP
Email: rgupta@brookes.ac.uk
Website: http://architecture.brookes.ac.uk/research/lowcarbonbuilding/

Care provision fit for a future climate

Findings from an extra-care scheme: Case Study C

A Joseph Rowntree Foundation funded study

May 2016

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