Care provision fit for a future climate:

Findings from an extra-care scheme: Case Study D

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.

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

May 2016

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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

- Nine out of the ten rooms monitored overheated, with high indoor temperatures even outside periods of hot external weather, particularly in the communal areas.
- Modelling of future climate showed that overheating would not be a problem for Case Study D until the 2080s.
- Whilst there were design features such as wide balconies and vertical panels that reduced the overheating risk, modelling indicated that several further physical measures could be undertaken to reduce the future overheating risk, including external shutters and exposing thermal mass.
- 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 wider care organisation and sector itself.
- There was a lack of long-term structural investment in adaptation and mitigation measures, with on-site staff generally relying on short-term adaptation measures such as mobile electric fans, increasing fluid intake. 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.

- In terms of on-site management of heat, the heating controls were overly complex, and the staff managed the localised controls, even in individual flats. There also appeared to be a lack of knowledge across all the on-site staff and management in terms of how the heating system is maintained and managed overall; an issue with the underfloor heating in the residential areas had not been resolved since its completion. There was also a lack of responsibility for managing the heating and ventilation systems on site; the majority of the care staff are not employed directly by the organisation who runs the scheme, and as such are not there to manage the building.

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 and repair of the heating system and controls within the building alongside guidance and training (preferably workshop / practical-based) on how to use and manage the heating and ventilation strategies and controls given to residents and on-site management and care staff would help enhance ownership and understanding of how to manage the thermal environment.
- A review of the air-conditioning unit in the Manager’s Office is recommended, as temperatures, although stable, were particularly high in this room and occupants had commented on this.
- Review the management and maintenance processes both within the case study care scheme as well as across the care organisation as a whole.
- 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 D, 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 D. 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 D 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 D.

Category	Case Study D
Region	South East England
Location	Suburban
Type of facility	Extra care (purpose built)
Ownership	Not-for-profit RSL
Gross internal area (GIA) m^2	5,500 (estimated)
No. of beds/dwellings	60 flats
Number of occupants	63
Average age of residents	85
Per cent of residents over 85 years	80%
Age of facility (Building regulations year)	2012 (2006)
Construction type	Steel frame with insulated brick/render wall finish; reinforced concrete slab floors
Ventilation and/ or cooling scheme	Mixed mode: Natural ventilation with MVHR in residential, communal kitchen and sanitary areas and air conditioning in office
Single or multi-aspect bedrooms	Single
Exceptional design standards or certification	BREAAM Excellent

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 D, 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 D is located in a built-up residential suburb area (Figure 1) of a major city in the South East of England, which is an area that is likely to suffer from higher temperatures in the future. 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.

2.2 Evaluation of design features

Within Case Study D, 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.

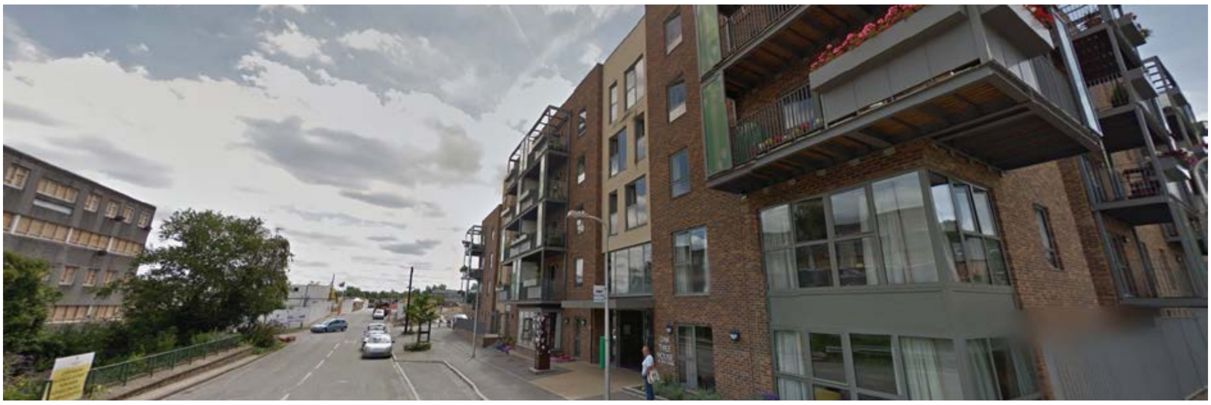


Figure 1. GoogleMaps StreetView of Case Study D location.

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)
• Large green corridor 100m southwest of building. • Band of mature trees approx. 60m away (southerly aspect). • Mature tree retained on site (south west). • Balconies with vertical panels for shading. • In-built planters on balconies for additional green cover. • Internal courtyard with raised planting beds (open to south west). • White roof (high albedo). • Heavyweight wall and floor materials used. • Internal blinds and curtains present in most rooms. • Low energy light fittings. • Openable windows in all areas (incl. corridors to enable cross-ventilation). • Trickle vents and openable windows present in all rooms except one office.	• South East England. • Semi-built up suburban area with low level terrace and medium-rise flats adjacent. • Paved roads to all four sides of site including exposed carpark on west of site. • TRVs at low level (poor accessibility for physically frail). • Communal heating and hot water system with distribution pipework throughout building. • Complex heating controls in residential flats. • Lever handles on windows not suitable for some residents with physical frailties (adaptations required). • Window restrictors present. • Single aspect flats.

The main positive design features include the use of wide balconies with vertical panels (Figure 2) to enable shading to both the flat with the balcony but also the flat below (note however, that there is no shading to the top floor flats); trickle vents (Figure 3), light-coloured roof finish that increases the albedo (reflectivity) of the roof (Figure 4) and as such should reduce heat gain.

Figure 2. Wide balconies and fixed vertical panels provide additional shading to residential flats.

There was evidence of changes in the design, which could result in increasing the overheating risk; one was the fixed vertical panels. These were originally designed to be moveable, and as such could be adapted to enhance their shading. However, due to concerns from the clients that this posed a finger-trapping risk to the residents, this feature was removed and they became fixed panels.

A further change in the use of one room (from reception area with open, glazed frontage to the main manager's office with no requirement for an openable glazed screen) has led to an air conditioning unit being placed in this room in order to provide the occupant's some degree of thermal comfort. The design was not adapted as the change in use was undertaken towards the end of the construction programme and alternative options were not discussed with the original architects.

Figure 3. Trickle vents are present in all windows, and appeared to generally be in use.

Figure 4. Flat roof with white finish increases reflectivity and thus reduces heat gain. Image also shows large windows at ends of corridors to provide additional air circulation and ventilation (note restrictors).

Aside from the vertical panels and balconies there are no other forms of external shading, instead internal blinds and/or curtains are relied upon to provide shading. It was noted that the effectiveness of these would vary from flat to flat as the residents' were encouraged to install their own internal blinds/curtains. In addition, such measures restrict views for occupants (Figure 5), who often spend most of their day in the rooms, which can reduce overall quality of life for the residents. There were also further design aspects within the flats particularly that are likely to increase the overheating risk such as the fact that most were single aspect, which reduces the potential for cross-ventilation, and the windows all had restrictors on; albeit ones that could be unlocked and removed (Figure 6). Whilst the windows in the adjacent corridors were openable, and as such, if the entrance doors to the flats were left open, cross-ventilation could be obtained, this poses numerous security, privacy and fire risks. In addition, it was reported that adaptations to the window lever handles had to be made for one resident with severe arthritis so that they could operate the window independently; it was not possible for them to open the window otherwise.

Figure 5. Curtains in living room of flat closed to reduce solar heat gain, and glare in south-east facing flat.

Figure 6. Window restrictors in flats have locks and can be removed if the residents want to.

The heating controls within the flats also appeared to be overly complex; room thermostats for each room as well as a programmer control. Qualitative feedback from both residents' and staff indicate that residents' are generally told not to (and do not) use the programmer. Furthermore, an issue with the underfloor heating in some of the bathroom had been reported, and in order to combat this problem, the flats left the room thermostat for the bathroom on 'max' (35°C) (Figure 7).

This is likely to contribute significantly to the internal heat gains during the summer, particularly as the main heating system is left on all year round. The reasons for the heating system being left on included the need to provide hot water for all flats throughout the year and the belief that some residents' desired heating during the summer months as well as a lack of complete knowledge about how the heating system worked within the on-site care staff and management. This appears to be due to the fact that the heating and hot water system is managed off-site by a separate building management and maintenance team.

Within the communal areas (lounges, corridors and dining areas) the on-site management had put locks over the thermostats to prevent unwanted access by residents' and enabled the management staff to control the thermal environment within these areas, without interference from others. However, this relies on the staff having adequate understanding of the heating system in order to ensure it is used efficiently.

Within office areas, the main design feature that is likely to contribute to the overheating risk was the installation of window restrictors that could not be removed (Figure 8). In office areas where there are large amounts of ICT equipment, this is likely to increase the internal heat gains significantly and also results in a lack of control within the staff over their thermal environment.

Figure 7. Room thermostat for bathroom set to 'max' due to issues with the underfloor heating. The overall heating system is left on during the summer months in case residents' require heating, and the staff have set the flat programmers to be on all day.

Figure 8. Restrictor in office.

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)

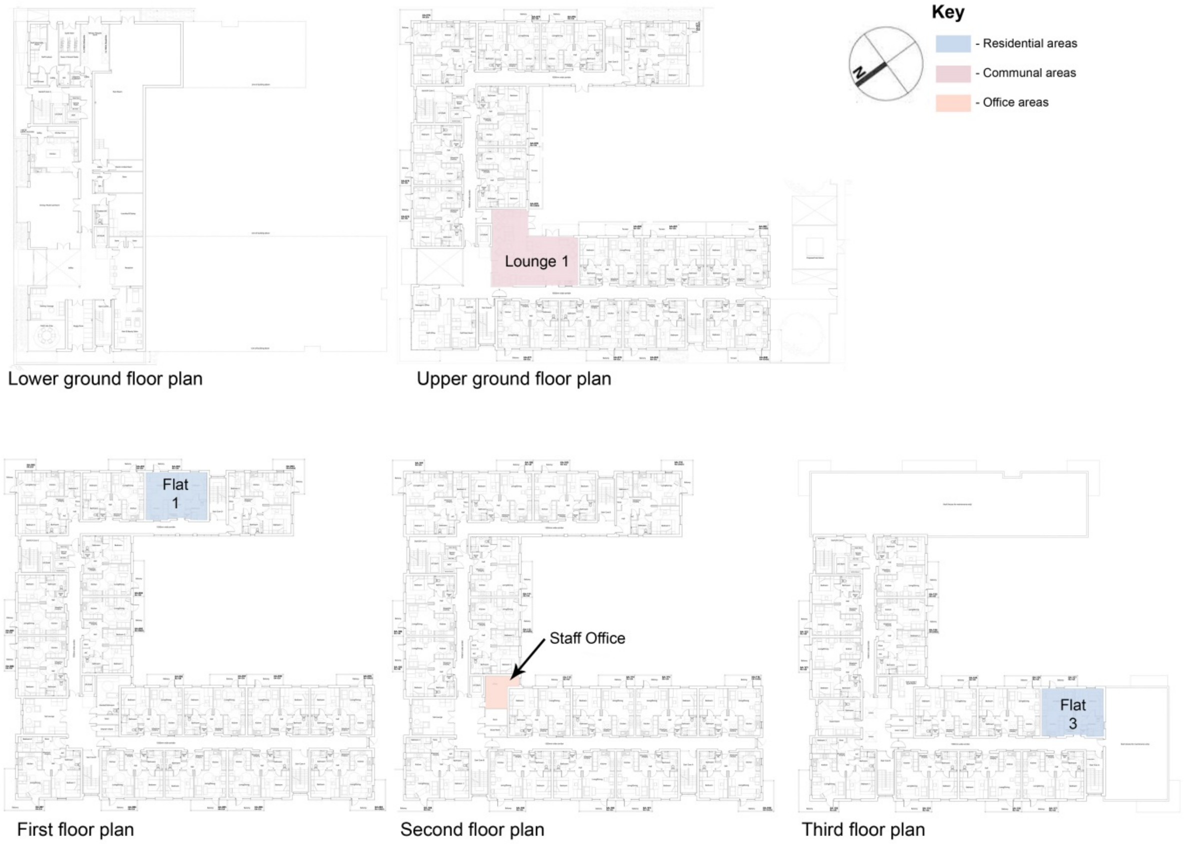
Where a building is mechanically cooled (or where fans are used to provide thermal comfort), predicted mean vote (PMV) is applied to assess acceptability. PMV is calculated by a formula taking into consideration operative temperature, air speed, relative humidity (RH), metabolic rate and clothing level. 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).

Table 3 shows the overheating results from the climate modelling. Overheating appears to not be a risk for most spaces until the 2080s climate period. The Adaptive Method (AM) indicated no overheating risk for staff.



Lower ground floor plan

Upper ground floor plan

First floor plan

Second floor plan

Third floor plan

Figure 9. Location of rooms modelled.

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 (UGF, SE/SW-facing)	-	-	-	1 & 2	-	-	0.3	5.6
Staff office (SF, SW-facing)	-	-	-	-	-	-	-	-
Flat 1 bedroom (FF, SE-facing)	-	-	-	-	-	-	0.1	1.2
Flat 1 living room (FF, SE-facing)	-	-	-	2	-	-	0.2	2.0
Flat 3 bedroom (TF, SE-facing)	-	-	-	-	-	-	-	3.3
Flat 3 living room (TF, SE-facing)	-	-	-	-	-	-	-	2.7

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 D, 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 19th June to midnight 1st October 2015 (104 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/lost by occupants). In addition, an external data logger was installed within the internal garden area to provide local outdoor temperature and relative humidity data.

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)**	FF	SE	T / RH / CO_2	20 days data missing (Bedroom data logger only)
	Flat 1 (bedroom)	FF	SE	T	
	Flat 2 (living room)	SF	SE	T	20 days data missing
	Flat 3 (living room)	TF	SE	T / RH / CO_2	20 days data missing (Bedroom data logger only)
	Flat 3 (bedroom)	TF	SE	T	
Communal areas	**Dining area**	LGF	NE	T	20 days data missing
	Lounge 1	UGF	SE/SW	T / RH / CO_2	
	Lounge 2	SF	NE	T	
Office areas	**Staff office**	SF	SW	T / RH	
	Manager's office	LGF	-	T / RH	

Notes:-
LGF=Lower ground floor; UGF=Upper ground floor; FF=First floor; SF=Second floor; TF=Third floor; NE=Northeast-facing; SW=Southwest-facing; SE=Southeast-facing; T=temperature; RH=relative humidity levels; CO_2*=Carbon dioxide levels (proxy for ventilation/indoor air quality).*

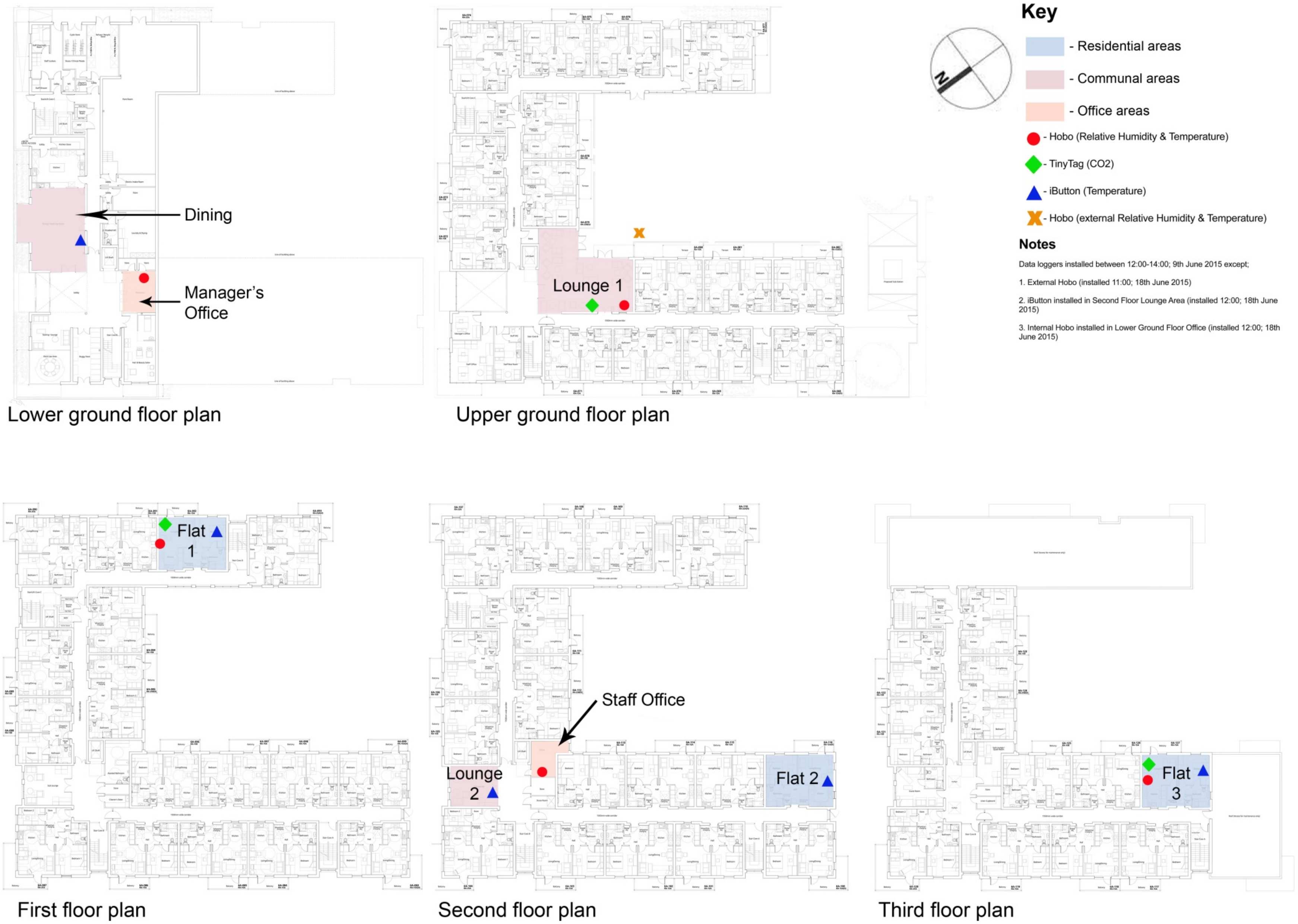


Figure 10. Location and type of data loggers installed.

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, both bedrooms reached 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 across the two bedrooms was 26.4°C. The minimum temperature in Flat 3 Bed over the monitored period was 24°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."*

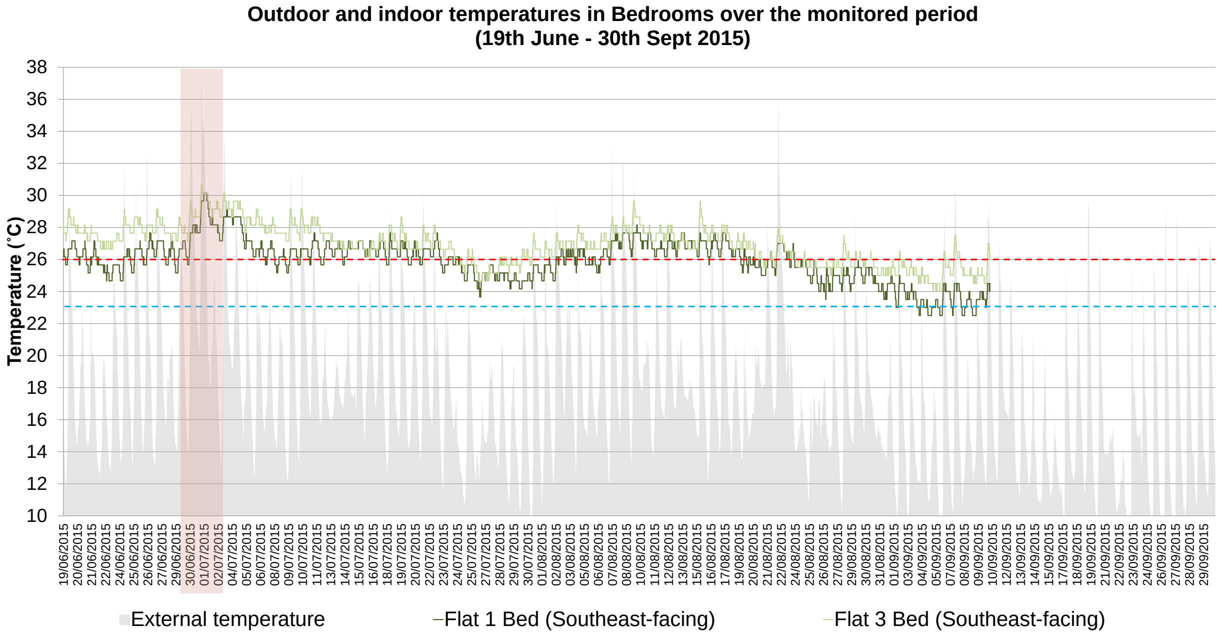
In terms of the living rooms, the average mean temperature across the three living rooms was also 26.4°C. This is above the CIBSE Guide A (2006) recommended summer indoor temperature for non-air-conditioned living rooms (25°C). In terms of differences in temperatures across the period, the range is around 6-8K. The maximum temperatures were high across the rooms; from 30.2-30.9°C.

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	First floor		Second floor		Third floor (no balcony above)	
Location	Southeast-facing		Southeast-facing		Southeast-facing	
Occupancy patterns	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 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)
Min temperature	23.3°C	22.5°C	22.0°C	23.3°C	22.5°C	22.0°C
Mean temperature	26.7°C	25.9°C	25.4°C	26.7°C	25.9°C	25.4°C
Max temperature	30.9°C	30.2°C	30.6°C	30.9°C	30.2°C	30.6°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). They correlate with Table 6 in that bedroom temperatures appear relatively high compared to the summer indoor comfort temperature of 23°C (CIBSE Guide A) and there were significant periods in all bedrooms where the temperature is above 24°C (increased likelihood of discomfort). In terms of the living rooms, generally temperatures appear to be on the high side, with the temperatures being above the summer indoor comfort temperature of 25°C for living areas.

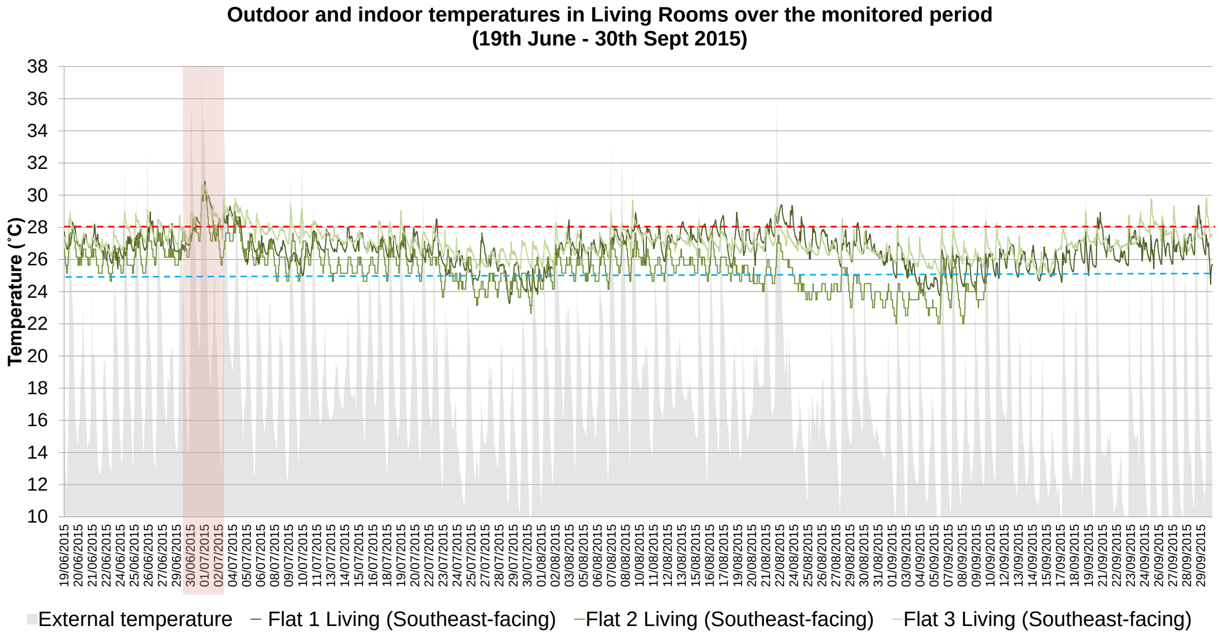
Furthermore, temperatures in the majority of the rooms (bedroom and living rooms) reach above 26°C on several occasions. Public Health England's (PHE) Heatwave Plan for England guidance suggests that care settings provide at least one 'cool room' that remains below 26°C, particularly during extended periods of hot weather, in order to provide vulnerable residents' with relief and reduce the health risks of hot weather. Such a finding indicates that none of the residential areas would be suitable rooms in heatwaves. Figures 11 and 12 also demonstrate the correlation between indoor and outdoor temperatures; the red vertical band on the graphs highlights a period in which there were peak temperatures, both in terms of local outdoor and indoor temperatures.



Outdoor and indoor temperatures in Bedrooms over the monitored period
(19th June - 30th Sept 2015)

Figure 11. Indoor and outdoor temperatures in residential areas in Case Study D 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.



Outdoor and indoor temperatures in Living Rooms over the monitored period
(19th June - 30th Sept 2015)

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 D, these threshold temperatures are 31°C during the day and 16°C overnight. These were reached during a period from 30th June to 1st July 2015 (based on the on-site external monitoring data). Figure 13 indicates that before, during and after this period, temperatures in the bedrooms are always above 24°C (increased likelihood of discomfort; dotted light red line); most likely due to the heating being on during the summer months. In addition, Figure 13 as well as Figure 14 indicate that during this period, living room and bedroom temperatures increase significantly, in relation to the outdoor temperature 'peaks' and all, except Flat 2 living room, do not return to the same temperatures prior to the heatwave, at least for the next three days. This indicates there are issues with the heating, ventilation and cooling management and strategies throughout the residential areas.

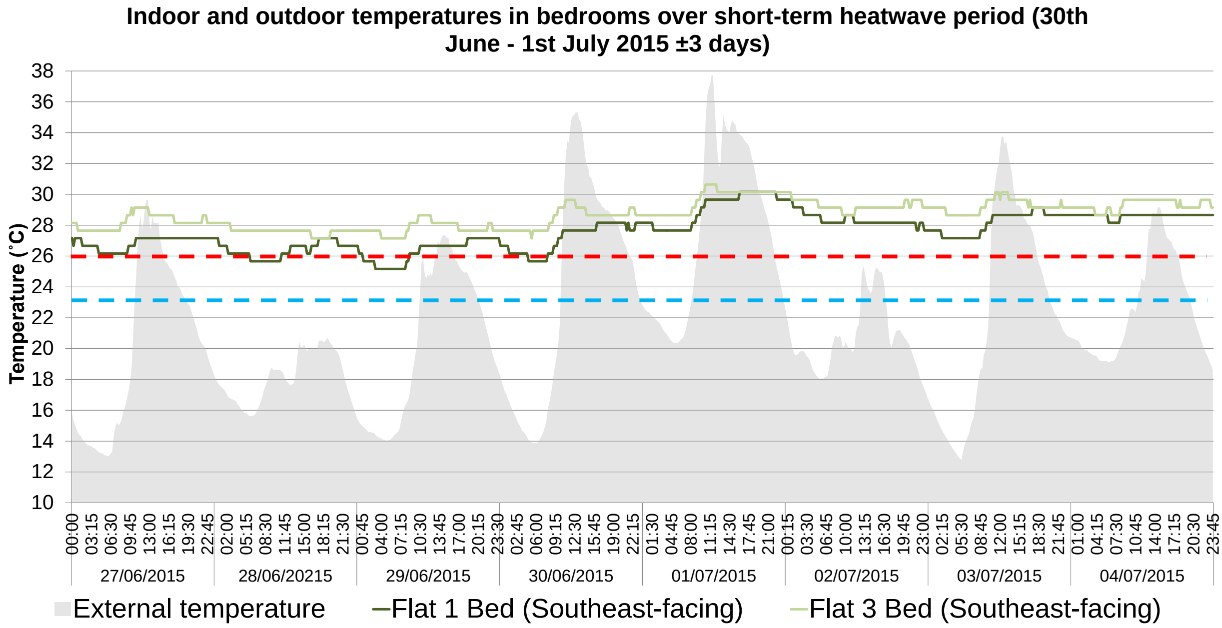


Figure 13. Indoor and outdoor temperatures in bedrooms over hottest period.

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.

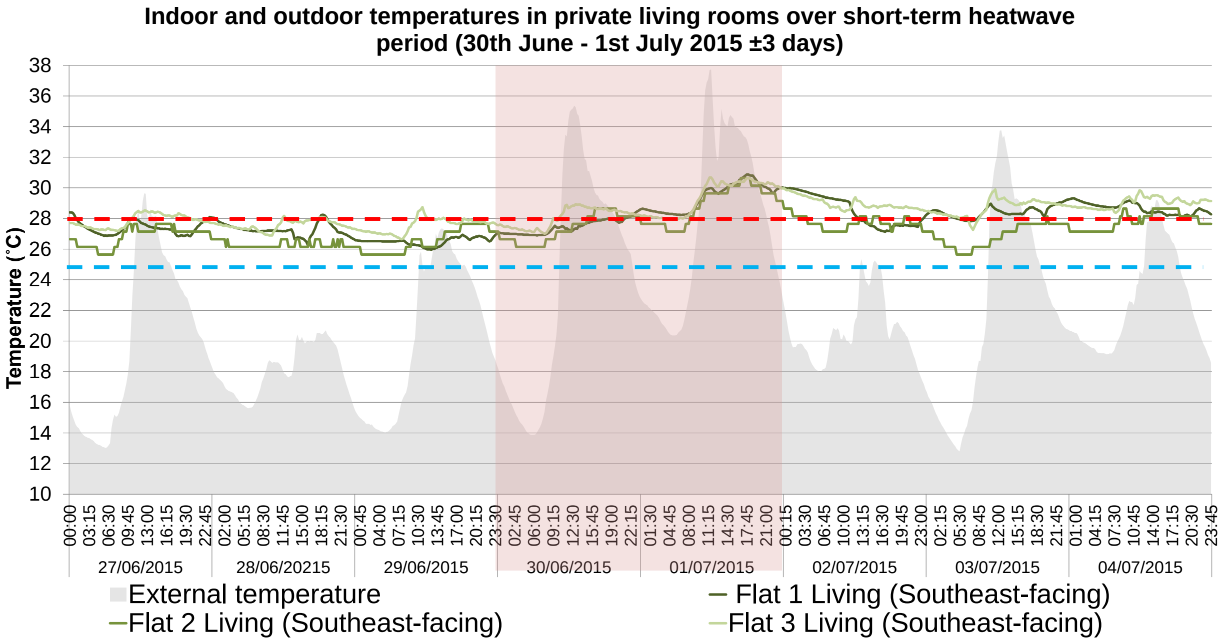


Figure 14. Indoor and outdoor temperatures in living rooms over hottest period.

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: No flats overheating, but all rooms fail on Criterion 1.
- Static method: Overheating in all rooms (two bedrooms and three living rooms, Figures 15 and 16).

It is worth noting here that, in general the thermal environment in all flats is controlled and managed by the residents, but who do sometimes rely on staff to open windows and trickle vents and turn down TRVs.

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) (FF, SE- facing)	1	49.9
Flat 1 (Living) (FF, SE- facing)	1	9.3
Flat 2 (Living) (SF, SE-facing)	1	3.2
Flat 3 (Bed) (TF, SE-facing)	1	76.0
Flat 3 (Living) (TF, SE-facing)	1	17.6

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

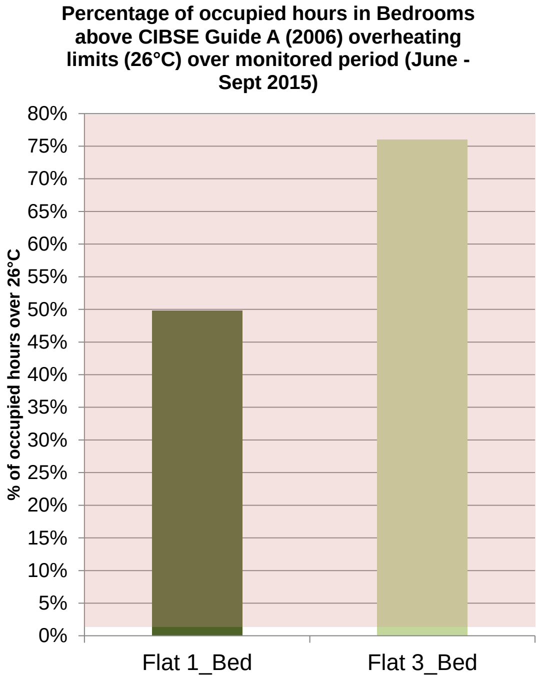


Figure 15. Overheating in bedrooms as defined by Static Method. *Note: Overheating occurs if temperature is above 26°C for over 1% of occupied hours.*

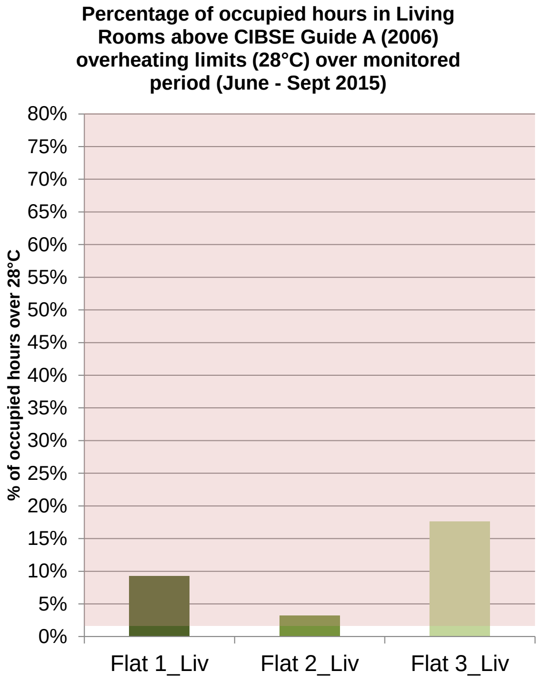


Figure 16. Overheating in living rooms as defined by Static Method. *Note: Overheating occurs if temperature is above 28°C for over 1% of occupied hours.*

CO_2 and relative humidity levels

Relative humidity and CO_2 levels were monitored in Flat 1 (Living Room) and Flat 3 (Living Room). As Figure 17 demonstrates, throughout the monitoring period, relative humidity levels in all rooms were generally between 40-50%RH; although levels were between 30-40%RH for 33% of the time in Flat 1 (Living Room). Levels between 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; 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.

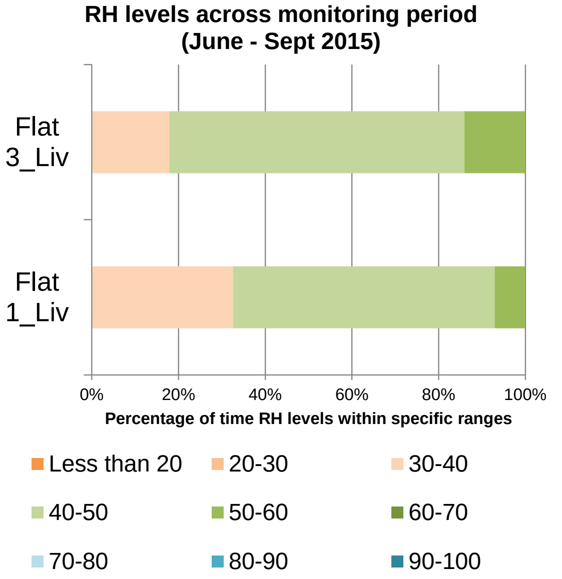


Figure 17. Relative Humidity in monitored residential areas.

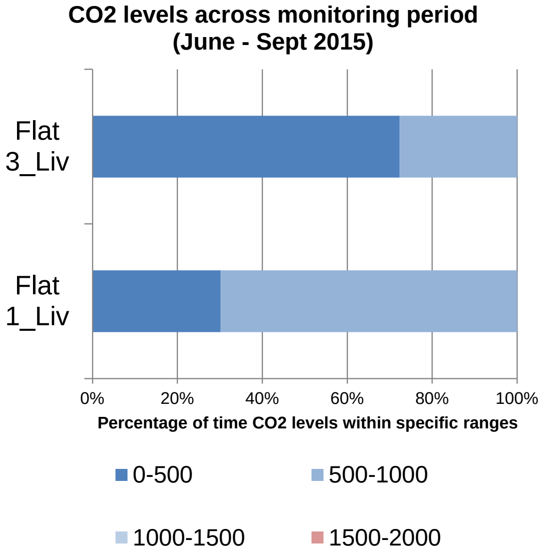


Figure 18. CO_2 levels in monitored residential areas.

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 by approximately 8-9K in Lounge 1 and Dining but in Lounge 2 the temperatures ranged even more; there was a difference of 11K across the monitoring period. Despite this, it has the lowest average mean temperature across the three rooms; lower than the recommended CIBSE Guide A (2006) indoor summer temperature for non-air-conditioned living areas (25°C). Both Lounge 1 and the Dining area have average mean temperatures above the recommended indoor summer temperature.

To understand specifically when there are 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 (above maximum comfort threshold of 28°C, CIBSE Guide A) in all three rooms that correspond with high external temperatures.

Outside this period, the indoor temperatures, particularly in Lounge 1 and the Dining area are high; generally above the recommended summer indoor comfort temperature for non-air conditioned living areas (25°C; CIBSE Guide A). In addition, Lounge 1, which is one of the largest communal areas within the building, appears to be generally above 26°C, which is the maximum temperature for 'cool areas', according to PHE Heatwave Plan for England, 2015), particularly during periods of higher external temperatures during the earlier summer months. Interestingly, the northerly-facing Lounge 2 generally has lower temperatures. This may be in part due to the orientation but also the fact that it is not occupied as much as Lounge 1, and also is not adjacent to a kitchen area (as the Dining area is), which is likely to contribute significantly to internal heat gains.

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

	Lounge 1	Lounge 2	Dining
Occupancy patterns	Approx. 15-20 occupants 16:00-21:00 (Mon-Sun)	Approx. 2 occupants 10:00-16:00 (Mon-Sun)	Approx. 15-20 occupants 08:00-19:00 (Mon-Sun)
Location	Upper Ground floor	Second floor	Low Ground floor
Orientation	Southeast/South-facing	Northeast-facing	Northeast-facing
Min temperature	22.8°C	18.6°C	21.5°C
Mean temperature	26.1°C	24.4°C	25.6°C
Max temperature	31.3°C	29.6°C	30.2°C

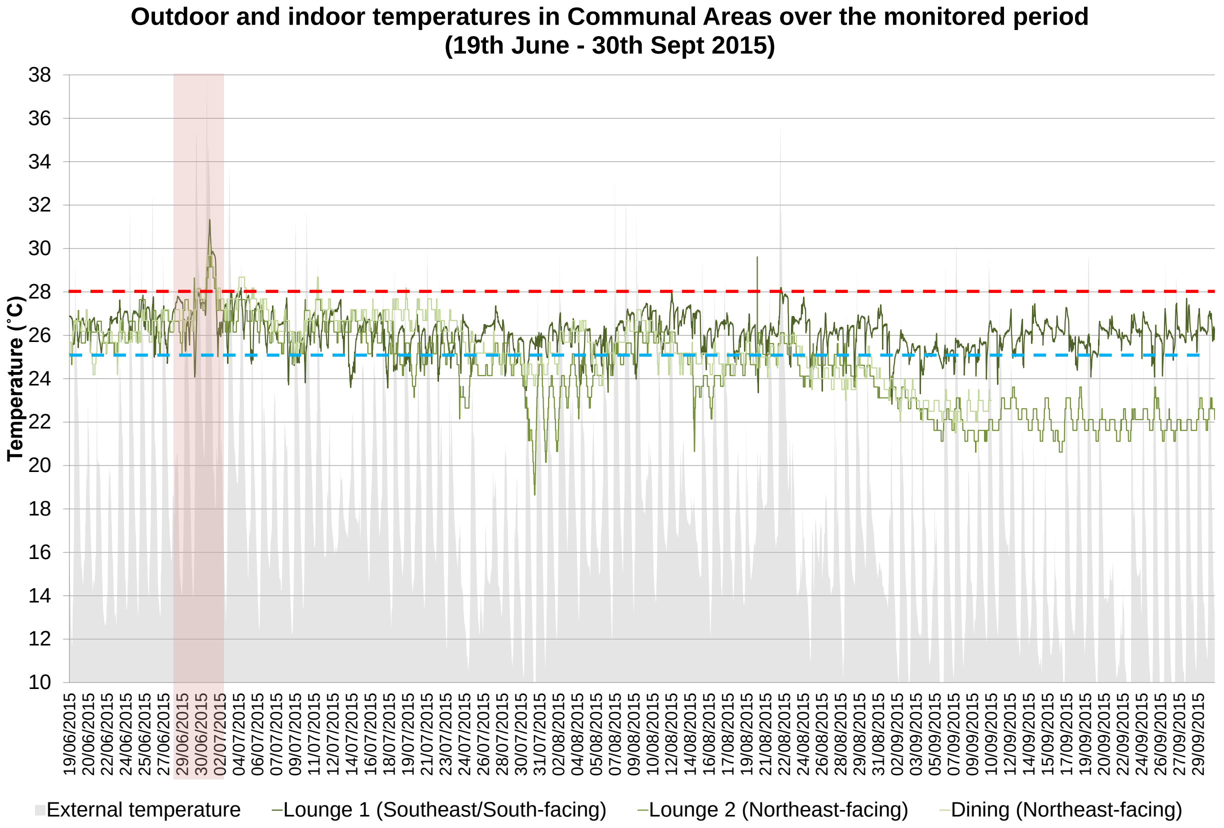


Figure 19. Indoor and outdoor temperatures in communal areas over monitored period.

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.

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 D, these threshold temperatures are 31°C during the day and 16°C overnight. These were reached during a period from 30th June to 1st July 2015 (based on the on-site external monitoring data).

Figure 20 shows the indoor temperatures in the communal areas across this period (±3 days). As it demonstrates, the indoor temperatures during this period spiked significantly, particularly on the second day of the heatwave; this suggests that the ventilation and cooling strategies do not provide adequate overnight cooling in order to reduce indoor temperatures. Furthermore, before, during and after the heatwave period, temperatures in all rooms are generally above 26°C; which means these rooms could not be used as 'cool areas' as recommended by the Heatwave Plan for England without additional heating management as well as further ventilation and cooling methods.

Current overheating risk

The monitoring data was analysed using both the static and adaptive method (Table 8):

- Adaptive method: Overheating identified in all three communal areas.
- Static method: Overheating in all communal areas.

Table 8. Overheating results for communal areas using adaptive and static methods.

	Adaptive Method (TM52 Criteria Failed)	**Static Method** (% of occupied hours over temperature threshold)
Lounge 1 (UGF, SE/SW-facing)	1, 3	1.1
Lounge 2 (SF, NE-facing)	1, 3	1.4
Dining (LGF, NE-facing)	1, 3	4.4

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

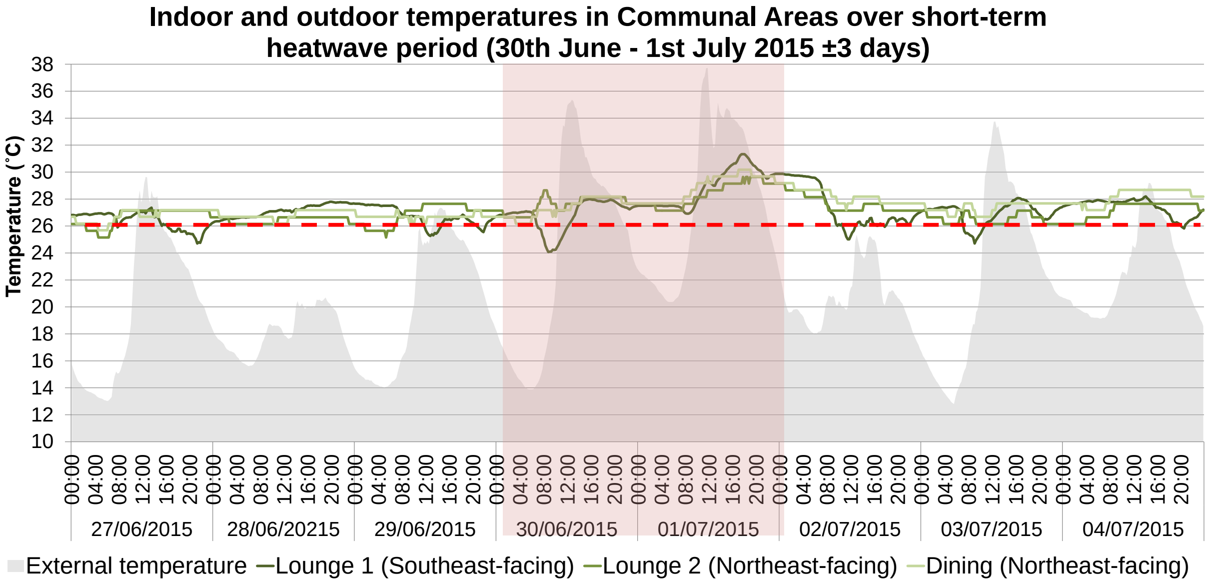


Figure 20. Indoor and outdoor temperatures in office areas over hottest period. *Notes:- Horizontal red dashed line indicates PHE Heatwave Plan maximum indoor temperature threshold of 26°C for 'cool areas' (to be provided during periods of hot outdoor temperatures)*

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.

This is likely to be due to the staff management of ventilation in the room; the external doors and most windows are opened first thing in the morning, along with two sets of internal double doors (into corridors) to ensure air flow throughout the space.

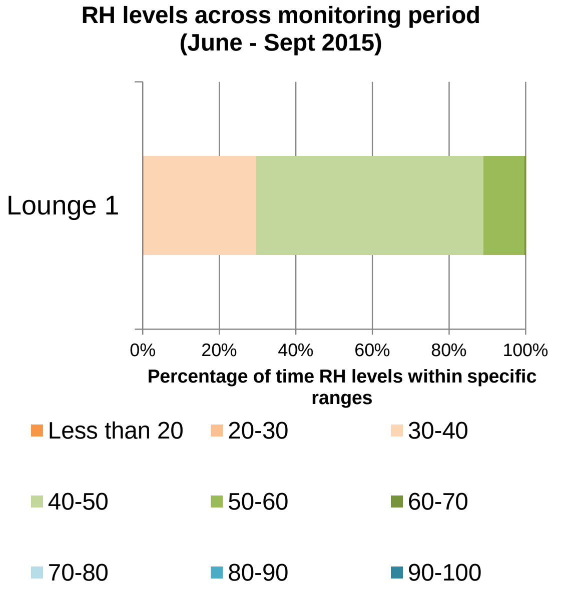


Figure 21. Relative Humidity in monitored communal Lounge 1.

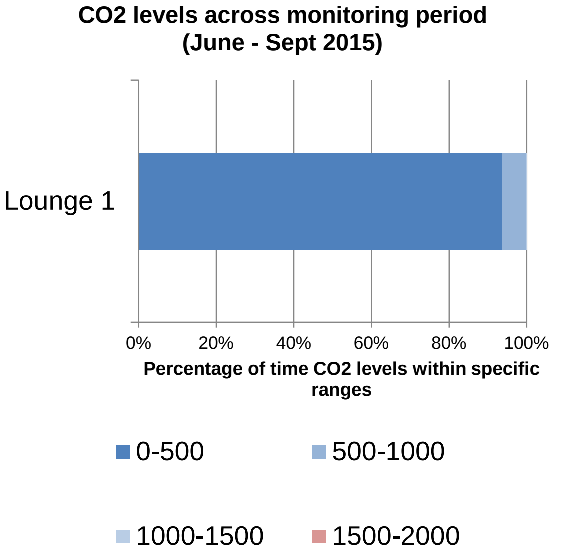


Figure 22. CO_2 levels in monitored communal Lounge 1.

4.4 Office areas

Indoor and outdoor temperatures during the monitoring period

Table 9 outlines the overall minimum, mean and maximum temperatures in the manager's and staff offices across the monitoring period. . As it demonstrates, the average mean temperature of the Manager's Office is lower than that of the Staff Office; this is to be expected as the Manager's Office is air-conditioned. However, CIBSE Guide A (2006) recommended range for an air-conditioned area is 23-25°C; the monitored temperature in the Manager's Office range from 25-28°C. The Staff Office has natural ventilation only (trickle vents and openable windows, restricted by 10cm (max) restrictors). The average mean room temperature across the monitoring period in the Staff Office was over 2°C higher than the recommended summer comfort indoor temperature for offices (25°C; CIBSE Guide A (2006)).

To understand specifically when such periods of high indoor temperatures are, the indoor temperatures were analysed in relation to the local outdoor temperature (Figure 23). There appears to be little correlation between indoor and outdoor temperatures, particularly in comparison to the period in which there were 'spikes' in the indoor temperatures of residential and communal areas during the period of highest outdoor temperatures (highlighted by red vertical band in Figure 23). Despite this, temperatures within both offices are particularly high during June and July. Figure 24 also shows that the temperatures within the Manager's Office were generally always above the acceptable indoor summer temperature range for air-conditioned rooms (CIBSE Guide A, 2006) throughout the monitoring period (23-25°C; dark blue horizontal band); and the temperatures within the Staff Office were significantly above 25°C (summer comfort indoor temperature, CIBSE Guide A).

Despite this, the temperatures within the Manager's Office appear much more stable than those in the Staff Office. This is to be expected due to the air-conditioning unit present in the Manager's Office.

Table 9. Minimum, mean and maximum temperatures in monitored office areas.

	Staff Office	Manager's Office
Occupancy patterns	Approx. 2 occupants; no set daily usage	2 occupants; 08:00-17:00 (Mon-Fri)
Location	Second floor	Lower Ground floor
Orientation	Southwest-facing	Northeast (but no external windows)
Min temperature	24.8°C	24.6°C
Mean temperature	27.1°C	25.9°C
Max temperature	29.8°C	27.8°C

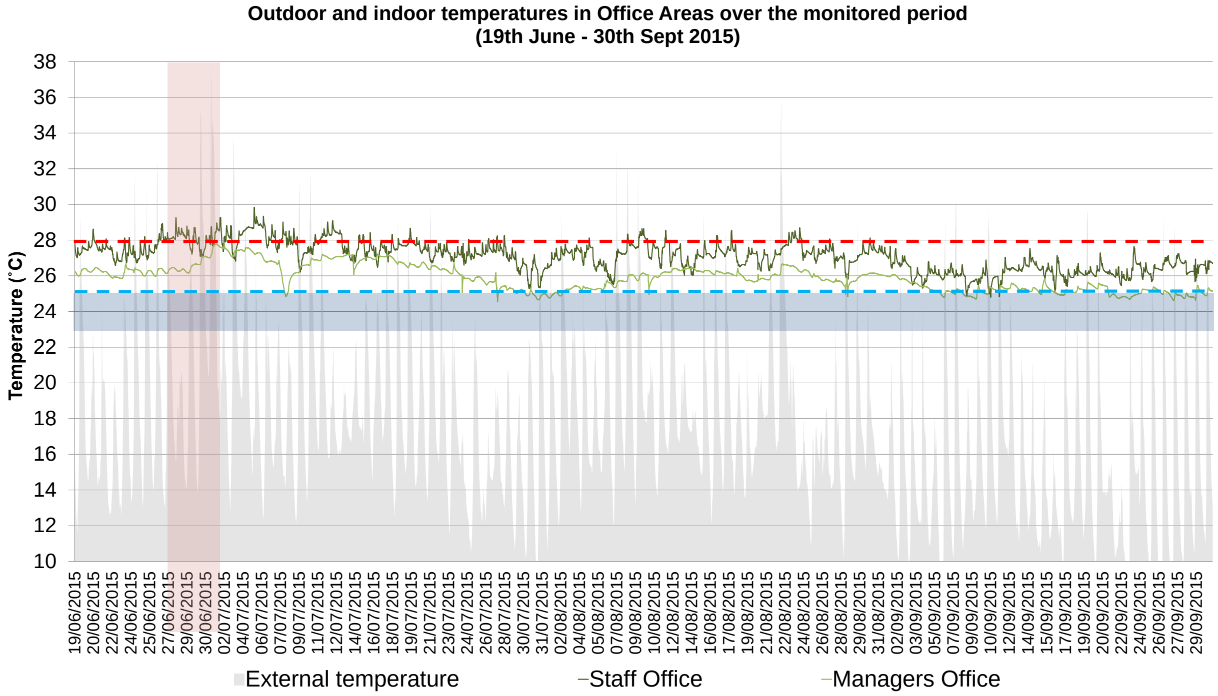


Figure 23. Indoor and outdoor temperatures in office areas over monitored period.

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); horizontal blue band indicates CIBSE Guide A indoor summer comfort temperature for air-conditioned offices (23-25˚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 D, these threshold temperatures are 31°C during the day and 16°C overnight. These were reached during a period from 30th June to 1st July 2015 (based on the on-site external monitoring data). Figure 24 shows the indoor temperatures in the office areas across this period (±3 days). As this demonstrates, there appears to be little correlation between indoor and outdoor temperatures; although the indoor temperature of the Manager's Office does increase over this period by almost 2°C. This suggests that the air-conditioning unit is not performing as efficiently as it should in terms of temperature control, particularly in short periods of high external temperatures.

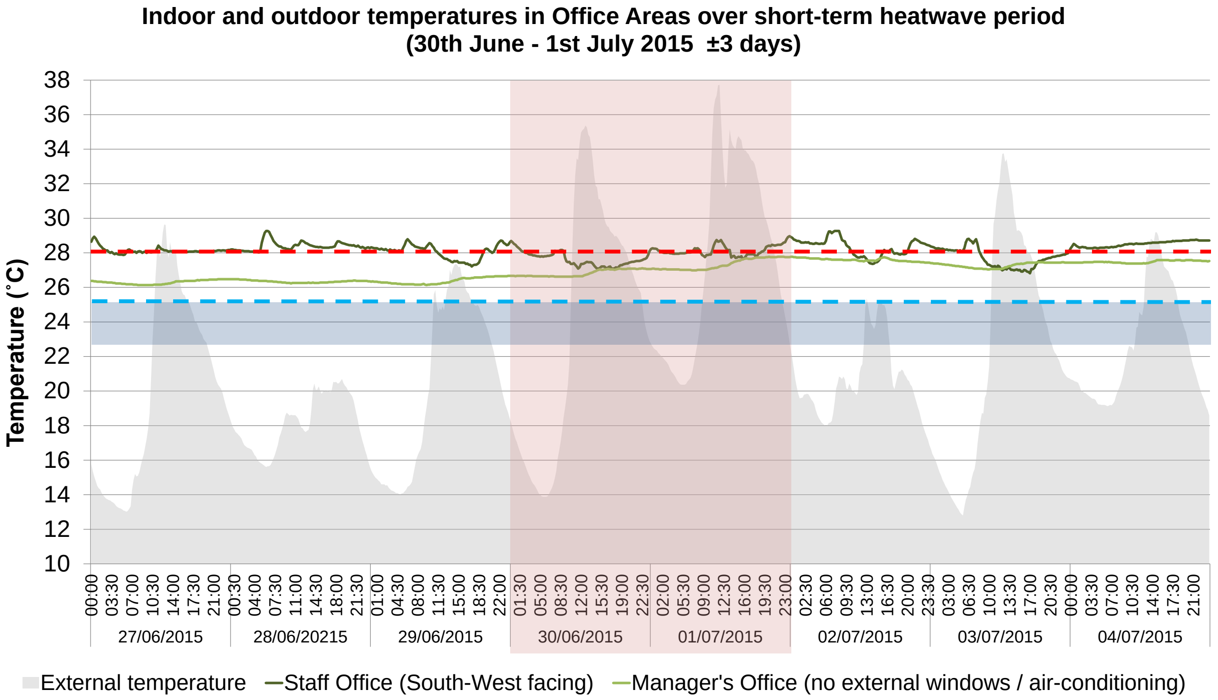


Figure 24. Indoor and outdoor temperatures in office areas over hottest period.

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); horizontal blue band indicates CIBSE Guide A indoor summer comfort temperature for air-conditioned offices (23-25°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 10):

- Adaptive method: No overheating risk.
- Static method: Overheating risk present in Staff Office.

Table 10. Overheating results for office areas using adaptive and static methods.

	Adaptive Method (TM52 Criteria Failed)	**Static Method** (% of occupied hours over temperature threshold)
Manager's Office (LGF, no ext. windows)	-	0.0
Staff Office (SF, SW- facing)	-	4.1
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 70% 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 Staff Office experiencing high temperatures.

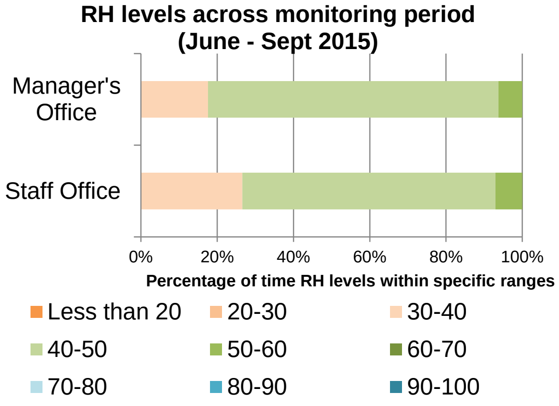


Figure 25. Relative Humidity levels in monitored office areas.

5. Design, management, care practices and resident experiences

5.1 Design and asset/strategy management

Members of the design practice responsible for the design of Case Study D were interviewed along with a housing manager for the organisation responsible for Case Study D. 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 below.

Awareness and attitudes towards future climate and overheating

Whilst the management respondent was aware of the Heatwave Plan, the designers were not. Despite this, the designers were aware of overheating and future climate change adaptation and guidance such as the London Plan. In terms of attitudes towards future climate change and overheating, the designers stated (in relation to the wider design context);

"We don't design to shut the sun out, we design to let it in." (Designer).

The management respondent did not think that overheating and future climate change was a current priority in terms of the organisations overall strategy.

Low prioritisation of overheating and future climate change

Health and safety issues are prioritised over the need for ventilation and shading, for example the need for restrictors but also the designers wanted to include movable screens to provide additional shading to the balconies. However, due to health and safety reasoning specific to older people these were removed from the design;

"…risk of fingers being caught you know and the screens might be too heavy for the older people to move." (Designer).

Conflicting advice, calculations and standards

The designers commented on the fact that there were no explicit national performance standards for overheating; it is combined with annual thermal comfort and due to the focus on energy performance, the priority is winter thermal comfort. However, the designers used the example of the London Plan and its requirement to "carry out an overheating analysis."

The designers also commented on the wide variety of performance standards and requirements, from BREEAM requirements, local council and planning conditions as well as the care organisations own requirements.

Disconnect between design intent and actual management of systems

The specification of controls and ventilation strategy was undertaken by the Design & Build contractor, and as such the designers did not participate in the handover, meaning that the intent of passive design measures (such as openable windows on either end of the corridors) may not have been communicated to the end-users;

"Again this is the problem with design build is that we're not really there all the way through and so what actually happens as part of the handover is not in our control as much as I think we would probably recommend." (Designer).

Responsibility, management and maintenance of services

The designers stated that it is likely that the heating systems are controlled centrally by the organisations, with localised controls for the residents, and this was confirmed by the management interviewee. Furthermore, the management interviewee commented on the fact that due to Case Study D being an extra care scheme, the majority of the staff who work in the building are not employed by the organisation (they are independent care staff who are contracted standard hours) and as such they are ‘not there to manage the building’.

Specifically in terms of the window controls, the designers and management stated that issues had been raised in terms of the windows being too heavy and difficult to operate by older residents.

5.2 Management and care practices

Semi-structured interviews were conducted in early October 2015 with two members of staff in Case Study D. Interviews lasted approximately 44-73 minutes. Interviewees were asked about their perceptions of the potential threats posed by excessive heat, their awareness of the Public Health England Heatwave Plan, current heat management practices, and their approach to coping with heatwaves. The key themes that emerged from the interviews are described below.

Operation of heating

The extra-care housing scheme had a gas-fired communal heating system, with heat distributed via under-floor heating. The heating system was controlled locally by digital heating controls and room thermostats. The heating was in operation throughout the year to allow occupants to turn on the heating in their apartments, even in summer, if they wished to do so. One interviewee observed that occupants with sight loss or dementia struggled to use the digital heating controls and that often occupants or members of their family “messed” with the digital controls, causing the heating to work incorrectly. To prevent occupants from being too cold, the scheme manager had set most of the individual digital heating controls in occupants’ apartments to run constantly at full temperature. Occupants were then encouraged to turn their heating on and off using the room thermostats. One interviewee, however, observed that carers often found that the “heating’s way up” in occupants’ apartments, and consequently carers frequently had to turn thermostats to a lower setting.

Coping with heatwaves

The scheme manager reported that he was aware of the Public Health England (PHE) Heatwave Plan, having received a copy via e-mail from his line manager prior to the hot weather that affected the UK in late June/early July 2015. The manager used PHE guidance to write information sheets, which were circulated to occupants at tenants’ meetings and displayed on posters around the housing scheme. The manager felt the PHE recommendations helped to reinforce the advice already offered to occupants, particularly as they came from an “official” source, and that they prompted scheme managers to think about the implications of heatwaves. It was observed that the PHE material could not be issued to the occupants unedited, as there was too much text, the typeface was small, and some recommendations were irrelevant.

Other staff, including carers, were unaware of the PHE Heatwave Plan, although they were aware of some of the best-practice principles featured in the plan, and one interviewee suggested the information sheets written by the scheme manager were helpful for occupants. Interviewees, however, observed that there had never been a heat-related emergency in the housing scheme, and were unsure about how occupants' health might be adversely affected by heat.

Support and advice offered to occupants during hot weather included advising occupants to increase their fluid intake, and checking that occupants were wearing clothing appropriate to the weather. One interviewee believed that the occupants generally chose suitable clothing. If an occupant said they were too warm, one interviewee suggested that they would check the thermostat was turned down in the occupant's apartment and suggest closing the blinds or curtains. Other measures included switching on electric fans, if occupants had access to these. In extreme circumstances, occupants might be advised to consider purchasing a standalone air conditioning unit. It was reported that occupants who received care were offered more showers during warm weather. One interviewee noted that many of the occupants prepared their own food, and so the interviewee did not know whether they varied their diet throughout the year to reflect the seasons.

Regarding some of the recommendations in the PHE Heatwave Plan, an interviewee explained that as the housing scheme provided "independent living," it was up to individual occupants to follow their GP's advice on the potential health risks posed by heatwaves; occupant's GPs had not been contacted by the care providers nor by the housing scheme's managers. The interviewee liked the idea of creating "cool rooms," suggesting that this could be achieved by installing air conditioning in the restaurant and foyer area. The interviewee felt that one benefit was that this would encourage occupants to socialise.

Lack of structural investment

One interviewee observed that the building is "really good at keeping the heat in," but that it could be too hot, particularly during the summer. The primary means of cooling the building was to open windows. Windows did not open very far as they were fitted with safety devices to restrict window opening. Occupants were allowed to disengage the window restrictors in their apartments, although one interviewee suggested that this was difficult to do as the window restrictors were "fiddly," and that some occupants probably did not know that this was possible. Windows in communal areas were closed at night for security reasons, making it difficult to practice night-time purging, where windows are opened only when the external air temperature has dropped below that of the internal temperature. One interviewee suggested that occupants could leave open the front doors to their apartments in order to increase ventilation rates, although it was also noted that there had been a problem with theft in the building, and that some occupants would be wary of people with dementia wandering around the building. It was also possible for occupants to open smoke vents at the ends of corridors, in order to provide ventilation, although these would be shut at night. Occupants were expected to provide their own electric fans.

Heat-gain from sunlight was regarded as a problem in the building, and interviewees observed that there was extensive glazing. The primary means of reducing solar gain was through the use of internal blinds. Occupants or their family were expected to provide their own blinds or curtains. One interviewee reported that some occupants had not installed blinds or curtains, despite being advised to do so. It was also suggested that it was difficult to keep blinds closed in communal areas after around 10am, as these rooms were in use by this time, and the occupants would not want the blinds to be closed.

5.3 Resident experiences

Semi-structured interviews were conducted with three occupants in Case Study D. Interviews lasted approximately 30-45 minutes. Occupants were asked how they maintained thermal comfort in warm weather, and how easy or difficult is was to do this. The key themes that emerged from the interviews are described below.

Perceived thermal comfort

All three interviewees found their apartments too warm in summer and reported that they struggled to keep their homes comfortably cool. Solar heat gain was a problem in all three cases, although one interviewee observed that other apartments in the housing scheme did not receive direct sunlight and consequently felt cooler. One interviewee felt she had acclimatised to the heat to some extent, and felt cold when she entered other (north-facing) apartments in the scheme. However, her apartment could still be uncomfortably warm, commenting that the hot weather in late June/early July 2015 nearly “killed me.” In summer all three interviewees used electric fans, and kept windows and balcony doors open throughout the day.

Barriers to thermal comfort in hot weather

Two occupants reported that they put the heating on in the bathroom during the summer, one because it was sometimes cold when taking a shower, while the other kept the thermostat set to 35°C in order to prevent noise from an airlock in the under-floor heating. The latter situation seems likely to undermine effective heat management.

One occupant appreciated the restricted window-opening as she believed it would help to keep her grandchildren safe when they visit, although another said she did not know how to disengage the restrictor if she required more ventilation. One interviewee rarely opened the window in her living room, as it would be entangled in her net curtains (installed by the occupant). Two occupants kept their bedroom windows open “twenty-four seven,” in winter and summer, one because it helped her with breathing, and one because she liked “fresh air” and felt “closed in” unless it was open. Both of these occupants kept their balcony doors open during the day; one occupant opened the door to the full extent in summer form 9am until 9pm, unless it was raining hard; the other occupant had the balcony door open, during the day, throughout the year. The third interviewee kept the living room window open and the balcony door ajar sometimes during summer, but was afraid to open these fully for fear that insects would get in. This occupant used improvised fastenings made from elastic bands to hold the balcony door ajar. None of the three occupants interviewed ever left the front door to their apartments open for ventilation purposes, two for security reasons. One added that she believed that the scheme manager would not allow her leave the front door open because of the risk of intrusion by thieves or people with dementia (although this was not the manager’s perspective). All three interviewees reported that they used electric fans in summer, but two said that these were noisy, which made it difficult to use these at night.

Two of the occupants kept their curtains closed during sunny days in order to reduce solar-heat gain. One said this caused her to feel “shut in” and that she missed the view, while another commented that, “It’s a shame but it’s something you’ve got to do.” A third occupant occasionally closed the curtains in her apartment to minimise solar gain, but said that she did not “like to shut out the sunlight completely.” Asked if she would prefer to have an awning to reduce solar gain, one occupant raised concerns that this might become a nesting place for pigeons.

Two interviewees reported that they used their ovens every day, even during hot weather, as they liked to have a hot meal daily throughout the year. One occupant generally ate in the restaurant or ate microwaved meals, and consequently used her oven rarely. One occupant said that her fluid intake had increased since moving into the housing scheme, and suggested that the “dry air” affected her COPD.

One occupant said that she wore similar clothes winter and summer while indoor, suggesting that the internal temperature varied little throughout the year. Two occupants reported that they sometimes slept on top of the duvet during hot weather. Both of these occupants reported that they showered more frequently in summer than in winter, but suggested that this was more to remove sweat than to cool down.

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 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.

From the assessment of adaptation option effectiveness, the following adaptations are analysed in the following sections:

- **Exterior shutters and exposed thermal mass** (top two most effective individual options for most spaces).
- **Managed ventilation**: Windows are closed if internal temperature is greater than 27°C, otherwise open.
- **Full adaptation package**: Exterior shutters, exposed thermal mass and managed ventilation.

Table 11. Physical adaptation measures tested.

Measure		Notes	Rank*
1	**Reduce external temperature by managing the microclimate**		
1.1	Increased greenery: planters with seasonal green cover, e.g. vines		5
1.2	Green Roof	Lowers the effectiveness of existing roof	10
2	**Exclude or minimize the effect of direct or indirect solar radiation into the home (fabric changes)**		
2.1.a	External shading (retractable canopy – tensile roof over courtyard)	N/A for First floor flat	6
2.1.b	External shading (louvered shutters)	Most eff. in lounge & TF flat	1
2.2	Interior shading (blinds)		9
2.3	Glazing upgrade (low-e triple glazing)		7
2.4	Solar control film		8
2.5.a	Increase external wall reflectivity		4
2.5.b	Increase roof reflectivity	Already in place	N/A
3	**Limit or control heat within the building**		
3.1	Expose or introduce thermal mass	Ceiling only	3
3.2	Natural ventilation through windows	Most eff. in FF flat (not recommended for lounge)	2
3.3	Ceiling fans	Assessed against adaptation package	N/A**
3.4	Mechanical ventilation	Already in place	N/A
3.5	Reduce internal gains	Internal gains sufficiently low	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.*

6.1 Residential areas

Flat 1 Bedroom

Overheating is only a problem in 2080s and the most effective adaptations are managed ventilation, exposed thermal mass and external shutters (Table 12). The package applied without managed ventilation is relatively inconsequential, i.e., managed ventilation is essential for the success of the adaptation package and is quite effective as a singular adaptation (Figure 26).

To summarise:

- 2030s – no adaptation needed
- 2050s – install ceiling fans or begin ventilation management practices.
- 2080s – Ventilation management would be entirely sufficient however thermal mass and/or shutters could also be added.

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	Shutters + Thermal mass	Man. Vent.	Full package	Base model	Shutters + Thermal mass	Man. Vent.	Full package
-	-	-	-	1.2	0.7	0.1	-

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

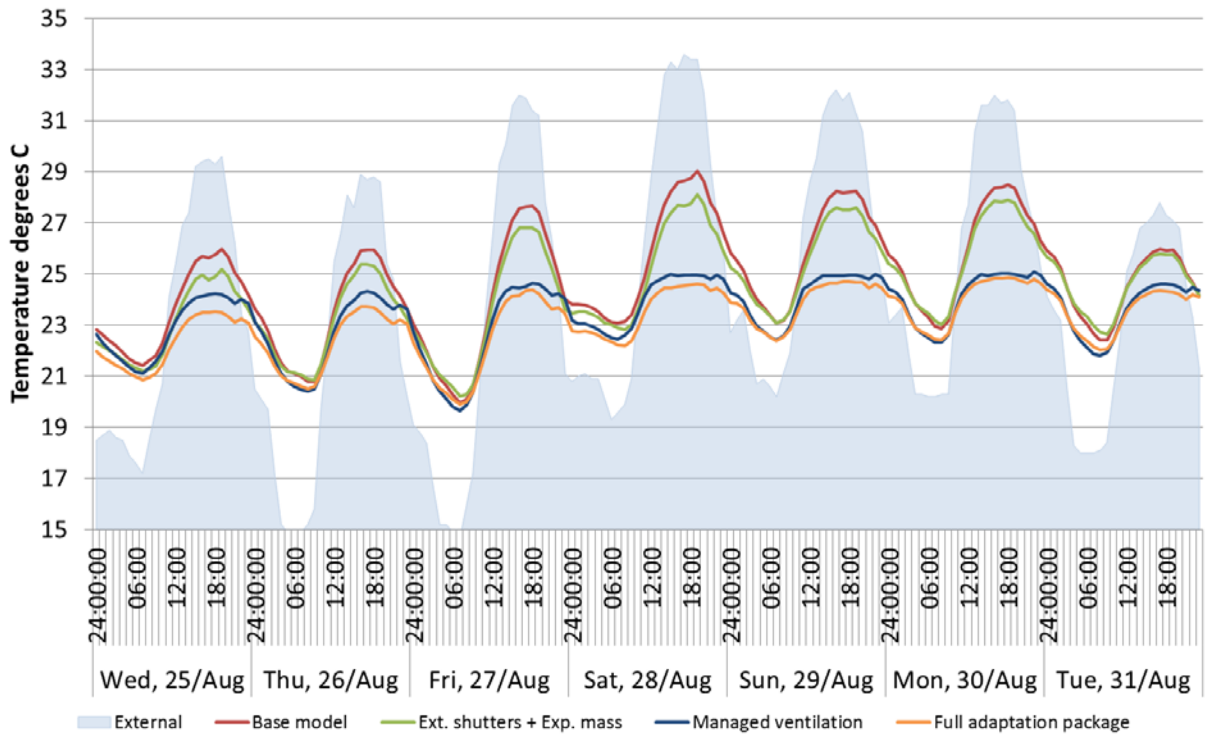


Figure 26. Modelled temperatures in Flat 1 Bedroom, and relative impact of physical measures (2080 heatwave).

Flat 1 Living Room

Overheating is only a problem in 2080s, and the most effective adaptations are managed ventilation, exposed thermal mass and external shutters (Table 13). The package 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 (Figure 27).

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).

Following the adaptation, fans are not necessary to satisfy the PMV during the 2030s - 2080s climate periods (Figure 28). Ceiling fans would however be effective before full adaptation package is implemented or as the adaptation package is phased in.

To summarise:

- 2030s – no adaptation needed.
- 2050s – install ceiling fans or begin ventilation management practices.
- 2080s – ventilation management would be entirely sufficient to mitigate the impact of heat waves and overheating. No other adaptations are needed.

Table 13. Overheating risk (2080s) in Flat 1 Living Room 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	-	-	-	2.0	1.1	-	-

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

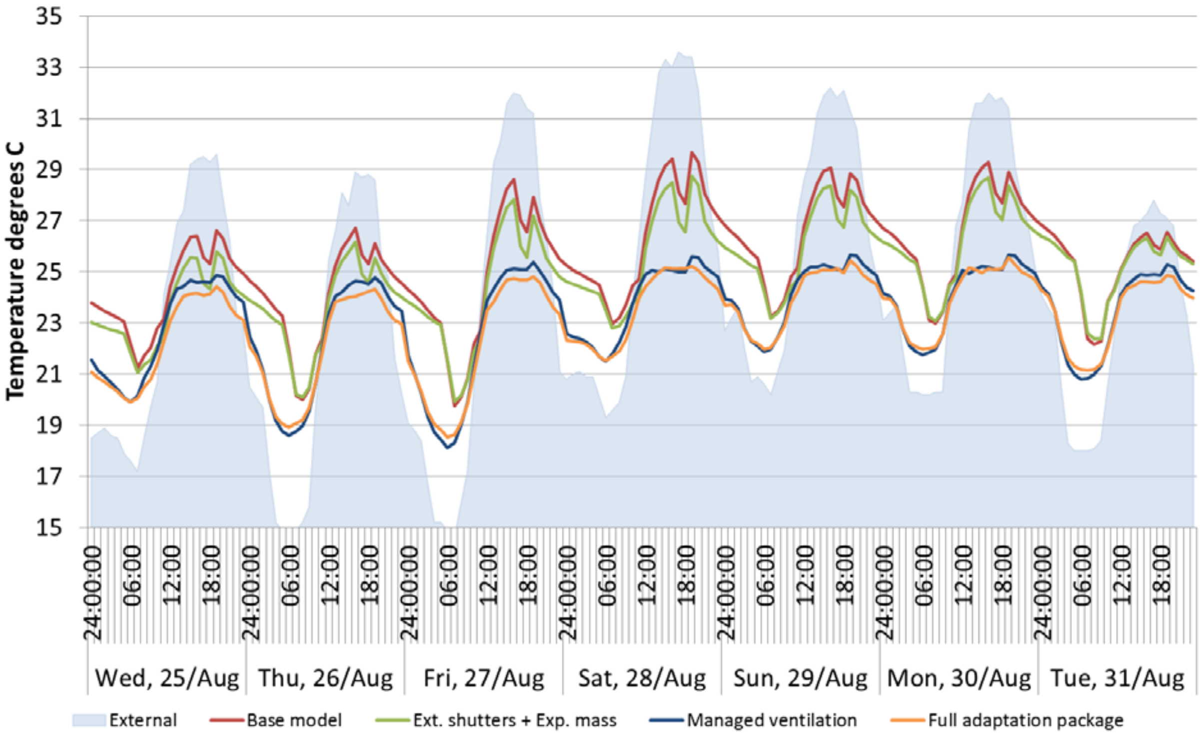


Figure 27. Modelled temperatures in Flat 1 Living Room and relative impact of physical measures (2080 heatwave).

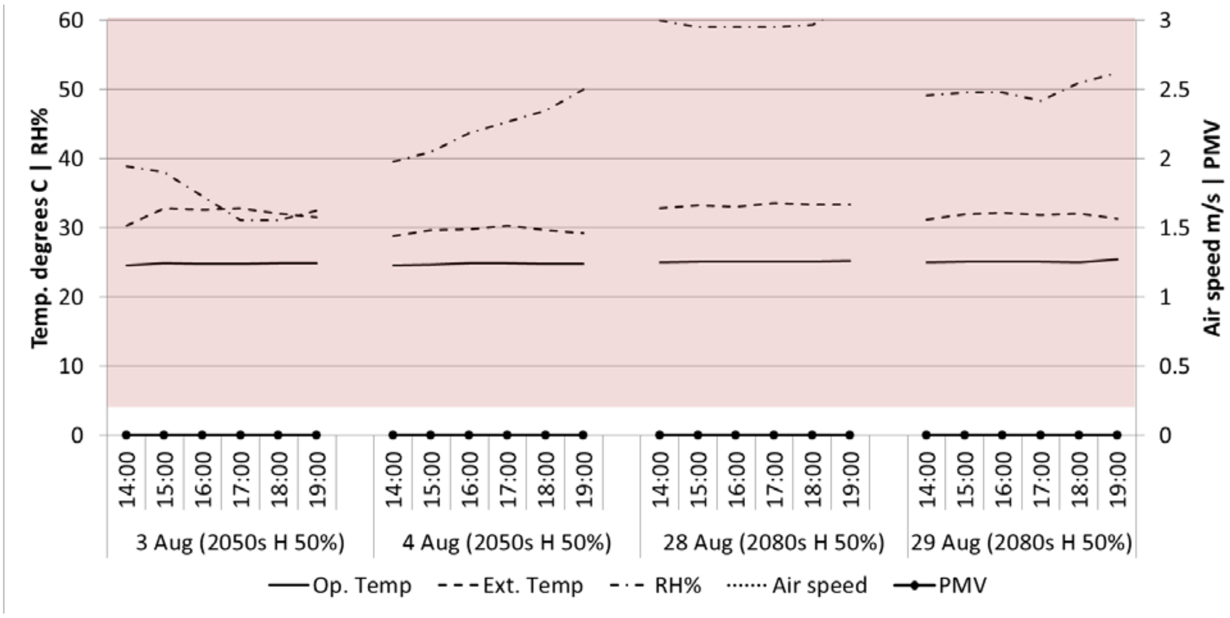


Figure 28. PMV of adaptation package with electric fans - Heatwave in Flat 1 Living Room, 2030s and 2080s. *Note: any PMV points within the red area are overheated for most vulnerable occupants.*

Flat 3 Bedroom

The most effective adaptations for Flat 3 Bedroom are **external shutters, canopy cover, and green cover**. From this list it is obvious that the Flat 3 is overheating as a result of too much incident solar gain.

As can be seen in Figure 29 and Table 14 managed ventilation alone would be a serious hindrance to Flat 3, locking in gain, and not allowing the temperature to drop internally to be ventilated. If managed ventilation were done at 27°C instead of 25°C the results would likely be more beneficial.

Though the package with or without managed ventilation mitigates overheating risk, external shutters alone are also sufficient in completely mitigating overheating risk.

To summarise:

- 2030s – no adaptation needed.
- 2050s – install ceiling fans/ no adaptation needed.
- 2080s – external shutters would be entirely sufficient to mitigate the impact of heat waves and overheating. No other adaptations are needed.

Table 14. Overheating risk (2080s) in Flat 3 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
-	-	-	-	3.3	-*	13.8	-

Notes:-
Green indicates no overheating; red indicates overheating has occurred.
* Package not necessary; external shutters sufficient as single measure to mitigate overheating risk.

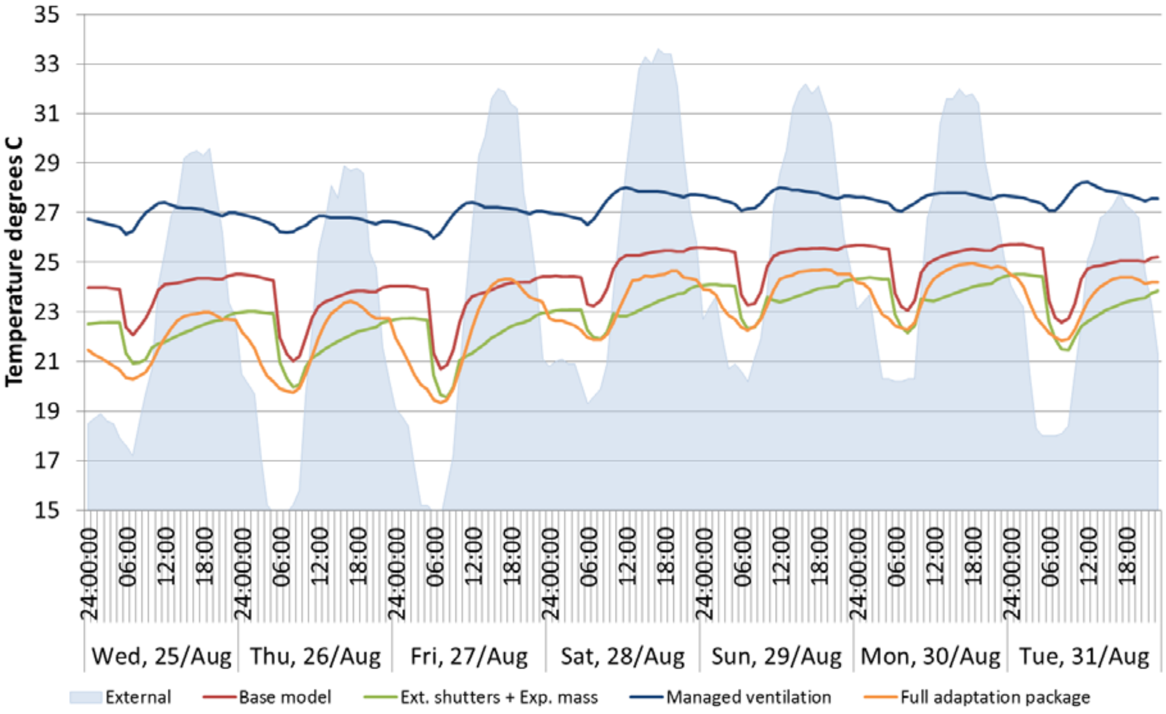


Figure 29. Modelled temperatures in Flat 3 Bedroom, and relative impact of physical measures (2080 heatwave).

Flat 3 Living Room

The most effective adaptations for Flat 3 Living Room are **external shutters, canopy cover, and green cover**. From this list it is obvious that the Flat 3 Living Room is overheating as a result of too much incident solar gain.

As can be seen in Figure 30 and Table 15 managed ventilation alone would be a hindrance to the Flat 3 living room, locking in gain, and not allowing the temperature to drop internally to be ventilated.

Though the package with or without managed ventilation mitigates overheating risk, external shutters alone are also sufficient in completely mitigating overheating risk. Though this is the case, from Figure 30 it is obvious the full adaptation package is more effective than the package without managed ventilation (by 2.5°C) during heatwaves (2080s).

To summarise:

- 2030s – no adaptation needed.
- 2050s – install ceiling fans/ no adaptation needed.
- 2080s – external shutters would be entirely sufficient to mitigate the impact of heat waves and overheating. Full adaptation package is recommended however for heatwave conditions.

Table 15. Overheating risk (2080s) in Flat 3 Living Room 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
-	-	-	-	2.7	-*	5.4	-

Notes:-
Green indicates no overheating; red indicates overheating has occurred.
* Package not necessary; external shutters sufficient as single measure to mitigate overheating risk.

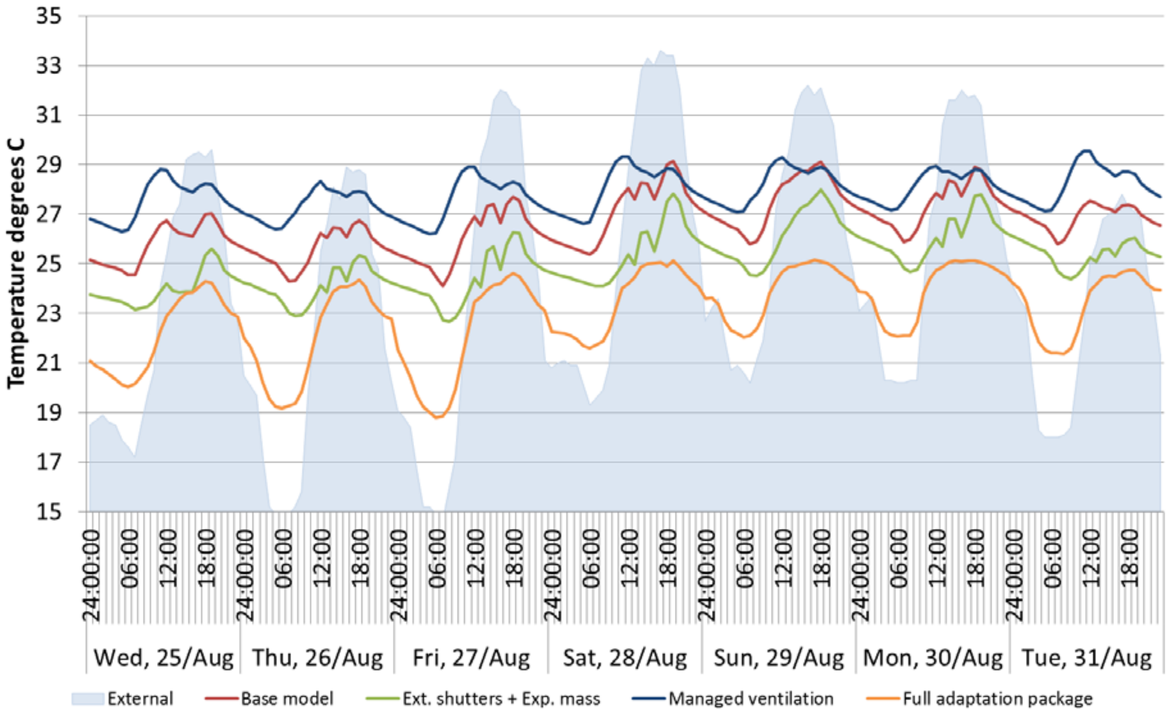


Figure 30. Modelled temperatures in Flat 3 Living Room, and relative impact of physical measures (2080 heatwave).

6.2 Communal area

The two most effective adaptations for Lounge 1 are **external shutters and exposed thermal mass**. Managed ventilation (alone and in the package) results in greater overheating for Lounge 1. This is worse in the 2030s climate period where it also tends to increase the peak daily temperature on some days.

In the 2030s only the shutters and thermal mass combination is recommended; however by the 2080s it is recommended that managed ventilation be integrated and to implement the full adaptation package only during heat wave periods. As can be seen in Table 16, the full package with managed ventilation results in almost 9% more annual occupied hours of overheating than the package without managed ventilation; however, as can be seen in Figure 31, the full adaptation package with managed ventilation results in an almost 4°C drop during daytime peak periods.

A likely reason managed ventilation causes more overheating in the lounge is because the lounge faces south/southwest. There is a problematic situation that occurs when high levels of incident radiation from the sun and internal gains combine with external temperatures that are only moderate (windows close when the internal temperature is >25°C). The managed ventilation is designed to block external heat gain due to high external temperatures (as demonstrated by the effectiveness in Figure 31).

Though internal peak temperatures reach 29°C, ceiling fans are able to satisfy the PMV (see Explanation Box 3) during the selected peak periods in the base model of the lounge for all climate periods. According to the figures, fans are not needed (nor are other adaptations) during the 2030s climate period. **It should be noted that where fans can manage internal peak temperatures they are also able to manage overheating on the whole.**

To summarise:

- 2030s – no adaptation needed.
- 2050s – install ceiling fans.
- 2080s – fans are sufficient; however, to reduce the level of energy use by fans (though minimal) shutters could be installed or thermal mass exposed in ceiling (or both), in addition, for best results employ managed ventilation only during heat waves.

Table 16. 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	-	-	-	5.3	1.3	10.6	10.0

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

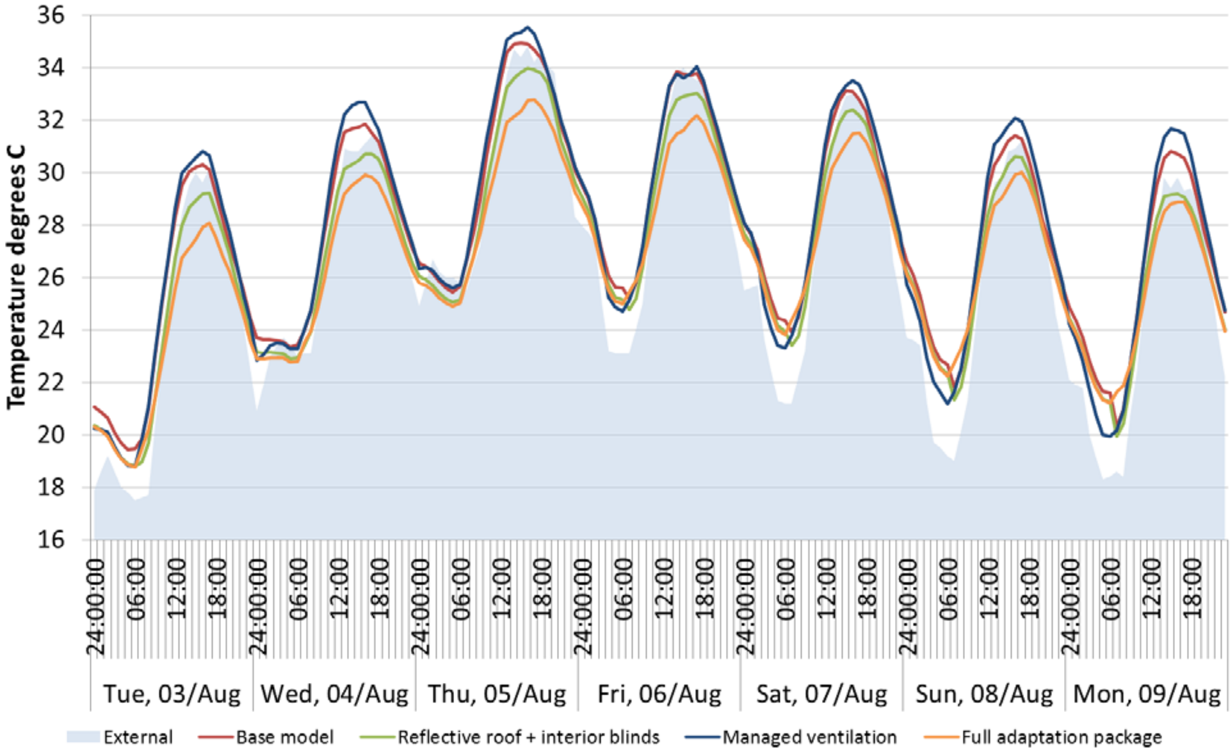


Figure 31. Temperatures in Lounge 1, and relative impact of physical measures (2080 heatwave).

6.3 Office Area

The most effective adaptations for the staff office are **exposed thermal mass and external shutters.** There is no overheating in the office for any climate period; however, the suggested adaptation package (exposed thermal mass, external shutters and managed ventilation) is effective in reducing the peak temperature to recommended operative temperature during the 2080s climate period (Figure 32). Prior to this, no adaptations are necessarily needed; ceiling fans (if managed correctly) would be sufficient for providing adequate thermal comfort during the summer months.

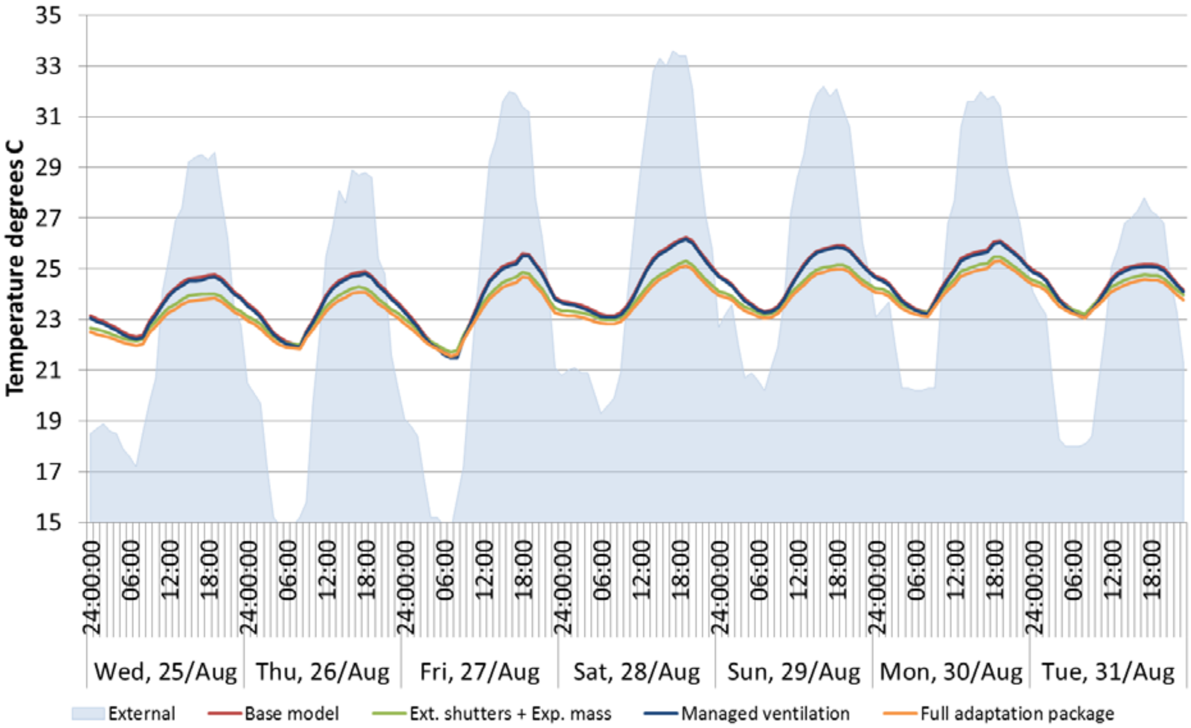


Figure 32. Temperatures in Staff Office, and relative impact of physical measures (2080 heatwave).

7. Summary of findings

- Analysis using the static overheating method indicated that nine out of the ten rooms monitored overheated during the monitoring period, although the adaptive method indicated that only three (all communal areas) overheated. This indicates that none of the communal areas could be used as ‘cool rooms’ during heatwave periods, as recommended by the PHE’s Heatwave Plan. It also highlights the need for appropriate overheating analysis methods to be used and a standardisation of the definition and analysis methods for overheating in care schemes.

- The monitored data indicated that the temperatures throughout the scheme were high, even outside periods of hot external weather.

- Modelling of future climate showed that overheating would not be a problem for Case Study D in rooms except for the main lounge (Lounge 1) until the 2080s using the Adaptive Method. The static method indicates that overheating will happen in all rooms, except the Staff Office, but not until the 2080s. The modelling did not include the heating being on all year round and the issue with the heating system itself, which appears to be a major contributing factor to the building’s internal heat gains.

- 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). Changes in design features, in part due to the lack of designer input towards the end of the construction process, appear to have also exacerbated some overheating risk.

- Modelling indicated that several physical measures could be undertaken to reduce the future overheating risk, including external shutters and additional exposed thermal mass. 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 structural investment and prioritisation of future long-term retrofit measures and 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 unaware of the Heatwave Plan yet still instigated 'best practice' short-term adaptation measures such as increasing residents' fluid intake and wearing lighter clothing. However, these were sometime compromised by the fact that the scheme provided independent living and as such it was up to individual residents to follow GP's advice and look after themselves accordingly during periods of hot weather.

- 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, although the design of the heating controls was to enable individual resident control, it was generally found to be overly complex, and the staff managed the localised controls even in individual flats. There also appeared to be a lack of knowledge across all the on-site staff and management in terms of how the heating system is maintained and managed overall; an issue with the underfloor heating in the residential areas had not been resolved since its completion. There was also a lack of responsibility for managing the heating and ventilation systems on site; the majority of the care staff are not employed directly by the organisation who runs the scheme, and as such are not there to manage the building.

8. Recommendations

The following Table 17 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 and repair of the heating system and controls within the building alongside guidance and training (preferably workshop / practical-based) on how to use and manage the heating and ventilation strategies and controls given to residents and on-site management and care staff would help enhance ownership and understanding of how to manage the thermal environment.
- A review of the air-conditioning unit in the Manager's Office is recommended, as temperatures, although stable, were particularly high in this room and occupants had commented on this.
- Review the management and maintenance processes both within the case study care scheme as well as across the care organisation as a whole.
- 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 17. 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 (uGF)									✓+
	Staff office (SF)									✓+
	Flat 1 bedroom (FF)									✓+
	Flat 1 living room (FF)									✓+
	Flat 3 bedroom (TF)									✓+
	Flat 3 living room (TF)									✓+
2020 – 2049 (2030s)	Lounge 1 (uGF)									✓+
	Staff office (SF)									✓+
	Flat 1 bedroom (FF)									✓+
	Flat 1 living room (FF)									✓+
	Flat 3 bedroom (TF)									✓+
	Flat 3 living room (TF)									✓+
2040 – 2069 (2050s)	Lounge 1 (uGF)									✓
	Staff office (SF)					✓**+		✓**+		✓
	Flat 1 bedroom (FF)								✓+	✓
	Flat 1 living room (FF)								✓+	✓
	Flat 3 bedroom (TF)							✓+		✓
	Flat 3 living room (TF)							✓+		✓
2070 – 2099 (2080s)	Lounge 1 (uGF)					✓**		✓**	✓*+	
	Staff office (SF)					✓**		✓**		
	Flat 1 bedroom (FF)								✓	
	Flat 1 living room (FF)					✓**+		✓**+	✓	
	Flat 3 bedroom (TF)					✓+		✓		
	Flat 3 living room (TF)					✓+		✓		

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

Acknowledgements

The authors would like to thank the Joseph Rowntree Foundation for supporting this work. We would also like to thank the architects, asset managers, care home managers, staff and residents of the four case study sites, who helped with the data collection process. We are grateful to the policy-makers, practitioners and researchers who attended our workshop in December 2015 to discuss emerging findings and recommendations from this study.

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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 CO2 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/).

The Joseph Rowntree Foundation has supported this project as part of its programme of research and innovative development projects, which it hopes will be of value to policy-makers, practitioners and service users. The facts presented and views expressed in this report are, however, those of the authors and not necessarily those of JRF.

First published May 2016 by Oxford Brookes University

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 D

A Joseph Rowntree Foundation funded study

May 2016