MAYOR OF LONDON

Care Home Overheating Audit Pilot Project

Methodology

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Greater London Authority
July 2020

Published by
Greater London Authority
City Hall
The Queen's Walk
More London
London SE1 2AA

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Copies of this report are available
from www.london.gov.uk

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Referencing this report
Eleni Oikonomou, Rokia Raslan, Rajat Gupta, Alastair Howard and Anna Mavrogianni (2020). Care Home Overheating Audit Pilot Project - Methodology Report. Mayor of London, GLA, London, UK

CONTENTS

1. Introduction and background

This audit pilot case study was commissioned by the Greater London Authority (GLA) in early 2019 and is an audit undertaken by University College London (UCL), in collaboration with Oxford Brookes University. The team assembled for this pilot was drawn from UCL Institute for Environmental Design and Engineering (UCL-IEDE) and UCL Energy Institute (UCL-Energy) and, draws on complementary experience from Oxford Brookes University, who act as sub-contractors on defined tasks. The project was governed by a Project Advisory Group made up of four members: The Greater London Authority, University of Oxford Brookes, University College London.
This study builds on the work undertaken previously as part of the Joseph Rowntree Foundation (JRF) funded study on ‘Care provision fit for a future climate’ [1].This study monitored overheating risk in four care settings outside London. The study also provides a baseline for the Natural Environment Research Council (NERC) funded ‘Climate Resilience of Care Settings (ClimaCare)’ project. This project has undertaken detailed monitoring, modelling and social data collection on a broadly representative sample of the UK care sector.

This audit pilot case study involves a care home overheating audit, the findings of which will support the aspirations in the Mayor’s London Environment Strategy (LES) [2], specifically in relation to the resilience of critical infrastructure and occupants, in the context of London’s changing climate.

LES aspirations on the resilience of critical infrastructure and occupants

Objective 8.4
The Mayor wants to ensure that London’s people, infrastructure and public services are better prepared for and more resilient to extreme heat events.
Policy 8.4.2
Ensure critical infrastructure providers and occupants of homes, schools, hospitals and care homes are aware of the impacts of increased temperature and the UHI (Urban Heat Island) effect, to protect health and reduce health inequalities.

This ‘Audit Methodology Report’ is the first stage of the outputs of the audit pilot case study and precedes a separate report on the audit findings, including recommendations (second output) and a best practice overheating checklist (third output).

This report details the methodology used to undertake the audit process for Victoria Care Centre, a care home situated in West London, through testing a ‘real’ facility, with a view to developing a generic methodology for the mitigation of overheating risks in London's care homes.

1.1 Background

Climate change, the Urban Heat Island (UHI) effect, the construction of high-rise buildings and tighter energy efficiency standards [3] have all been contributing towards the occurrence of elevated summertime indoor temperatures. These, alongside the projected increase in the frequency and magnitude of extreme weather events, are expected to significantly impact public health and the economy [4,5].

According to the newly produced UK Climate Impacts Programme (UKCIP18), the UK is expected to experience hotter, drier summers and heatwaves are projected to occur with greater frequency, intensity and duration [6]. Heat mortality in London has been found to start increasing at fairly low temperatures, that is, between average temperatures of 19 °C and 21.5 °C and early season heatwaves seem to have greater impact, as well as heatwaves with longer durations and highest temperatures [7].

In 2003, the unprecedented heatwave resulted in over 30,000 excess deaths across Western Europe [8] (70,000 excess deaths in Europe as a whole [9]) of which approximately 2,000 were reported in the UK [10,11] and more than 600 in London alone, with the older population being particularly hard hit. Allowing for the size of its population, more people died in London in comparison to any other region in the UK [12]. The older population group in England presented a 23% increase in excess mortality, with this figure almost tripling in London, where 59% more older people died [10]. The summer of 2018, the hottest England has ever experienced, also resulted to a significant excess mortality impact on those aged over 65 years old in England and London [13]. Such extreme heat episodes are expected to be common by the 2050s, thus increasing significantly heat exposure with adverse consequences for human comfort, task performance and heat-related morbidity and mortality [14,15]. This highlights the need for greater health protection during the summer months.

Those most vulnerable to the heat are older people above 65 years old, the very young, the physically or mentally infirm [16]. The UK's population is rapidly ageing, with 24% of the total population expected to be over 65 by 2037, in comparison to 18.2% in 2017 [17]. London's population aged 65 and over is projected to age the fastest, with an increase of just under 25% between 2016 and 2026 [18], making climate proofing of dwellings occupied by vulnerable people and, in particular, care homes, an urgent need [19]. Epidemiological studies on the 2003 heatwave, among other European heat events, showed that older people residing in care settings are at the highest risk of heat-related mortality [16,20], with nursing homes experiencing a stronger effect than care homes (see Section 1.2 for care home and nursing home definitions) and these relationships remaining largely unchanged for all regions in England, including London [16,21]. In addition, the 2018 Environmental Audit Committee's (EAC) report on heatwaves [22] indicated that one out of four heat related deaths in England occur in care homes and that excess deaths attributed to hot weather in nursing homes increased by 42% in some parts of the UK during the 2003 heatwave [21]. The need to include heatwave climate resilience in inspections of care settings has been acknowledged by the Committee on Climate Change and its Adaptation Subcommittee (CCC ASC) and so has the current lack of evidence based guidance for the mitigation of overheating [22,23].

There is a projected increase in the demand for all care provision types in the UK, that is, nursing, care homes and extra-care settings [24], which is expected to be higher in London due to its older population growing the fastest in comparison to other UK regions [18]. In the UK, there are currently 11,300 care establishments with approximately 421,000 residents over 65 years [25]. Unfortunately, data on indoor thermal conditions of care settings in the UK is scarce due to the limited number of studies focusing on care environments. However, there is some evidence that both older and newbuild care settings are already overheating under non-extreme summers [26–28]. These studies examined a number of care and/or extra-care settings in the UK as case studies.

The JRF 'Care provision fit for a future climate' report [26,28], in particular, drew attention to the 'culture of warmth', that is, the prioritisation of warm environments due to the well-known adverse effects of cold weather on older people that often lead to summertime heat-related risks being overlooked. The JRF report authors highlighted the need for more effective responses to overheating in the care home sector and further research in this area.

Areas such as London are of particular concern, as it is an area that is located in the southeast of the UK, where the effects of climate warming are expected to be more noticeable. Its UHI effect further exacerbates indoor overheating risk and so does its poor air quality, which can further exacerbate health conditions associated with the respiratory system[3,22,29,30]. Even though there is currently no universally accepted indoor overheating criterion linked to health and comfort deprivation, there is a well-established association between high outdoor temperatures and mortality [11,31]. More information on overheating temperature thresholds can be found in Section 2.3.2. Recent research evidence indicates that building characteristics and occupant behaviour can modify heat exposure appreciably [32–36] and thus may play a key role in the prevention of indoor overheating. In particular, building designs and operations allowing excessive solar gains and/or incorporating inadequate methods for heat dissipation are linked to increased indoor heat exposure with detrimental health impacts disproportionally affecting the most vulnerable residents. Maladaptation to a warming environment could also lead an increase in carbon emissions associated with comfort cooling, as well as higher operational costs and an intensification of the UHI effect. Thus, further research is needed to assess the potential of passive cooling strategies in the mitigation of indoor overheating risks in care home environments.

1.2 What is a care home & why focus on this domestic setting?

The term ‘care home’ refers to specialised accommodation with 24-hour care provision by qualified care assistants. According to the Care Standards Act [37], “an establishment is considered a care home if it provides accommodation, together with nursing or personal care, for any of the following: (a) persons who are or have been ill, (b) persons who have or have had a mental disorder, (c) persons who are disabled or infirm, (d) persons who are or have been dependent on alcohol or drugs”. The term covers both residential and nursing homes, (the latter of which involves 24/7 onsite nursing staff) [38]. Contrary to care homes, residents of extra care housing live in self-contained dwellings, usually in the form of grouped houses or flats that often present some common facilities (e.g. lounge, dining) [39].

The audit pilot case study targets primarily older residents of care home settings, that is, those aged over 65 years old, who are more likely to spend their time indoors. Spending more time at home, particularly during the hottest time of the day, makes this group more likely to experience higher levels of overheating in comparison to the general population [35]. Since the indoor environment is an important moderator of heat exposure in older populations, poor building design and the lack of effective heat management in care settings may contribute to increased indoor heat exposure with vulnerable residents being the most severely affected. Care facilities function as both a home for residents and a workplace for staff, meaning that the people sharing those spaces can have diverging needs and preferences making overheating prevention measures difficult to enforce.

Interactions between staff and residents play an important role in preventing overheating in care settings and it has previously been noted that staff are often made to prioritise warmth due to wide recognition of the detrimental effect cold weather can have on old-age health, leading to overheating risks being overlooked. Understanding the factors that contribute to indoor summertime overheating in care homes is crucial in developing methods to prevent overheating and the subsequent negative health impacts.

1.3 Requirements of the commission

The GLA's audit pilot case study has involved the undertaking of pilot work in a care home setting in London, including the investigation of the physical and thermal environments, and by conducting surveys with residents, frontline care staff and care home managers to understand their comfort levels and how they relate to the thermal environment. Through detailed modelling work, it then tests methods to assess future overheating risks and to evaluate the effectiveness of overheating mitigation strategies.

The audit pilot case study will inform the development of a standardised method for the assessment of overheating in care home environments and will test the pathways for raising awareness on the impact of overheating on health and well-being and the associated mitigation measures. The pilot findings are considered in the context of existing literature to generalise findings and provide mitigation guidance for consideration by the wider care home stock.

The outputs from this work are in the form of three reports:

The **'Audit Methodology Report'**. This focuses on the development of an audit process for care homes through testing a 'real' facility, with a view to developing a methodology for the mitigation of overheating risks in London care homes. This report follows the completion of an audit in one London care home as a pilot, taking into consideration both its internal and outdoor environment.

The **'Audit Findings and Recommendations Report'.** This is a separate report, based on the identified emergent themes and key recommendations from the analysis of the data gathered for the selected care home. This includes recommendations on the physical mitigation measures that will assist in the reduction of indoor overheating and residents' exposure to excess heat and interventions, activities, behaviour change initiatives and policies that could be implemented to further reduce overheating and/or exposure to heat, as well as an understanding of other schemes in the local area.

A '**Best Practice Overheating Checklist**'. This has been produced, in consultation with Public Health England, on the pilot care home. This could also be disseminated more widely to other care homes. This checklist complements Public Health England's (PHE) *Beat the heat: keep cool at home checklist* [40], highlighting the housing characteristics that are likely to lead to overheating and associated mitigation measures, as well as PHE's *Beat the heat: keep residents safe and well* [41], raising awareness on plans and actions safeguarding residential and nursing home residents in hot weather. The Checklist is attached as an appendix to the Executive Summary.

The views and experiences of staff, residents and carers have been included.

1.4 Aims and objectives

The aim of this audit pilot case study is to develop a standardised audit process that will assist the overheating risk mitigation for older people residing in care home settings, using the selected care facility as a testing basis. Undertaking a single audit was deemed sufficient for the purposes of this feasibility study. The objectives are to:

- Identify possible indoor and outdoor sources that contribute to overheating in care settings;
- identify workable solutions, both hard- and soft- engineered, and explore whether they could mitigate the heat exposure of the ‘at risk’ care home residents;
- examine the feasibility of the solutions identified, both in terms of cost and practicality in the specific care home setting;
- raise awareness of both the short- and long- term overheating consequences on the health and well-being of older residents in care home settings through the formulation of an audit process and the identification of behaviour change solutions and mitigation measures that could be taken up by care home managers; and,
- utilise project findings to support mitigation guidance, that is, by producing a best practice overheating checklist (in consultation with Public Health England) suitable for dissemination in the London’s care home stock.

The following sections describe the project planning, the methodology for developing the audit (Section 2), the selected care home and the process for the pilot testing (Section 3) and the results and relevant conclusions of the pilot testing (Sections 4 and 5).

2. Project planning and methodology

2.1 Project implementation stages

The pilot is set out in three main stages, i.e. planning, fieldwork and reporting.

The first stage involved the planning of the method that facilitated the audit assessment and the assessment of the associated risks. The **second stage** involved the undertaking of the audit by liaising with the selected care home's management team, staff, carers and residents. The reporting and presentations, as described in Section 1.3 – *Requirements of the commission*, are part of the **third stage**. There was a significant overlap between stages one and two due the number of tasks that concern both these two stages that were undertaken concurrently. Based on the GLA's specification requirement, the work programme and method are broken down into four main tasks: (1) the monitoring study, (2) the physical survey, (3) the survey and interviews, (4) the building modelling and analysis, followed by (5) the final report and dissemination presentations. In terms of resources, tasks 1 and 3 were undertaken by Oxford Brookes University (OBU), tasks 2 and 4 by University College London (UCL) and task 5 with the contribution of both UCL and OBU.

2.2 Quality assurance

Quality assurance (QA) for the audit pilot case study was provided by members of the Project Advisory Board (PAB) for the Natural Environment Research Council (NERC) funded 'Climate Resilience of Care Settings'. The study has been peer reviewed by: Professor Mike Davies (UCL), Dr. Anastasia Mylona (Chartered Institution of Building Services Engineers, CIBSE), Dr. Emer O'Connell (Public Health England, PHE) and Ross Thomson (Public Health England, PHE). The PAB for this project has vast experience in the subject matter and complementary world-leading expertise in low carbon architecture, climate change adaptation of buildings and cities, thermal comfort, indoor environmental quality, health and wellbeing in the built environment, health impact assessment and overheating policy work. The GLA is a member of the PAB as is UCL and OBU.

As part of the quality assurance process for the audit pilot case study, a methodology planning exercise was undertaken. This was reviewed as the audit pilot case study progressed. Potential methods were assessed and mapped against the tasks and areas for investigation they would inform. To inform this, examples of how they had been applied and evidence supporting the suitability of each method for the intended outcome was considered. The resulting methodology is based on a mixed-method approach that combines several innovative approaches under each task. The data was collected and analysed using different but complementary strategies in such a way that the resulting combination builds on the strengths and minimises the weaknesses of single approaches. To ensure that information collected from participants and stakeholders is kept secure from accidental or deliberate loss, destruction or disclosure, in addition to GLA's Data Protection Policy, UCL has put in place appropriate information security policies, processes (https://www.ucl.ac.uk/legal-services/privacy) and measures to ensure GDPR compliance, if applicable.

2.3 Development of the audit methodology

The following sections discuss in detail the components facilitating the development of the audit methodology:

2.3.1 Understanding the nature of the initiative

The GLA is particularly concerned about the impacts of heat on older people as they are less able to cope with higher temperatures and more likely to have chronic medical conditions and a limited ability to adapt their behaviours and/or environments to stay cool. In addition, those residing in care homes, are often more at risk because of health conditions and frailty issues and may not be provided with sufficient adaptive facilities, such as cool rooms, or they may be too frail to safely move. This indicates a pressing need for the creation of a safe environment in relation to summer overheating for the older population residing in care home environments.

2.3.2 The audit criteria

This section details the criteria utilised for two different purposes in this pilot: (a) the overheating criterion and operational assumptions against which the thermal performance of the pilot care home is evaluated and (b) the criteria against which the overheating reduction solutions identified in the methodology report are assessed. It also discusses the risks associated with the criteria and the data collection methods employed.

Overheating criterion

Definition - There is currently no universally accepted overheating criterion as to what level of indoor temperature constitutes a risk to human health or causes significant discomfort [42–44]. The CIBSE Guide A (2015) indicates that sleep quality may be compromised at temperatures higher than 24 °C and suggests an absolute bedroom temperature threshold of 26 °C. The temperature thresholds of 24 °C and 26 °C are also the suggested temperature thresholds for residential spaces of sedentary use, above which the space is assumed to be overheated, for winter and summer respectively. In addition, TM59 states that comfort in naturally ventilated bedrooms during night time is guaranteed only if operative temperatures do not exceed 26 °C for more than 1% of annual hours [46]. In this study, the care home’s modelled indoor summertime environment is tested against the 26 °C overheating threshold, during a 'heatwave' period, a period with an at least three-day moving average external temperatures above 21.5 °C [7].

Risk considerations – The selection of the 26 °C overheating measure is based on a simplified approach that suits the limited scope and time duration of this pilot testing process. However, the selection of an appropriate overheating threshold is a complex issue that is yet to be defined with clarity. Emerging practice suggests it should be based on a threshold value alongside a maximum time of exceedance, a maximum temperature difference between the internal and external environment and a measure of extremity [29,46]. For these reasons, future studies may employ different and/or more complex overheating criteria.

Data collection – Data on indoor temperatures is gathered via indoor temperature sensors, dynamic thermal modelling and occupants and staff interview and questionnaires.

Overheating mitigation acceptability criteria
Definition – To propose measures that will be effective, achievable and acceptable by the care home stakeholders, a range of criteria is employed to assist the decision-making process. The range of criteria employed for the all-round efficiency assessment of overheating mitigation measures include overheating mitigation effectiveness, implementation cost, feasibility, disruption, usability, impact on energy demand and carbon emissions, health and safety and visual amenity.

Risk considerations – The overheating mitigation acceptability criteria was selected with the aim of providing an all-round efficiency assessment of the proposed measures through an informed and transparent decision-making process. However, this is not necessarily an exhaustive list of criteria and should be reconsidered and expanded/adapted to the priorities set by the care home stakeholders each time.

Data collection – Data on the measures performance against each acceptability criterion is based on evidence from literature and widely available databases, for example, in terms of relative cost, taking into consideration the specific requirements and unique characteristics of the pilot care home.

3. Case study sampling, profiling and the pilot testing process

3.1 The selection process

As a first step, the Care Quality Commission (CQC) database involving the entire care home population registered in the UK, that is, just over 4000 premises, was pre-analysed to identify the London properties. Of the 337 care homes identified in London, an email or online contact form was available for approximately 85. All care homes with valid contact details were approached electronically, however only two of them provided an initial response. Of those two, only Victoria Care Centre followed it through and expressed an interest in participating to the study.

The first meeting between UCL, the GLA and the care home manager took place on-site on the 31st October 2018. A subsequent technical meeting and presentation was also arranged on-site between UCL and one of the directors of the Care Home on the 6th of December 2018, however the latter was unable to attend due to an unforeseen clash of meetings. The technical details of the project, including the duration, equipment involved, sample size, data protection and research ethics approval processes, were discussed with the care home manager instead, who forwarded the information to the director for final approval. The study was granted approval by the Victoria Care directors on the 10th January 2019.

3.2 Case study profile: Victoria Care Centre

Victoria Care Centre, shown in Figures 1 and 2, is in Park Royal, in the west London Borough of Ealing. It is situated in the grounds of Central Middlesex Hospital, and is surrounded by industrial buildings and a large, currently unoccupied, apartment block (Figure 3). It was purpose built as a nursing home and was opened in 2013. The home offers a wide range of personalised care plans for adults both over and under 65 years old, including those with dementia, mild behaviour disorders, sensory impairments and injuries. Most of the residents are old but there are some who are younger, living with dementia and other learning disabilities. There are currently 115 rooms, but planned extension work (due to begin in late spring 2019) will increase this to 153.

Following the Care Quality Commission (CQC) inspection, the care home was found to be fully occupied and operational. The Centre provides both short- and long- term nursing options, as well as respite care needs. At the time of the last CQC inspection (May 2018), most residents were older people, some of whom were living with dementia. The overall rating in relation to the five main CQC service areas taken into consideration. These being:

safe, effective, caring, responsive and well-led service. The Care Home was rated as being ‘good’ at the time of the inspection. The CQC assign health and care services with four possible ratings: outstanding, good, required improvement and inadequate.

Figure 1. Location of Victoria Care Centre in west London and areas photograph of the building from south (Map: Map data ©2019 Google. Image: Image ©2019 Maxar Technologies)

Figure 1 and Figure 2. Victoria Care Centre viewed from east (left) and west (right)

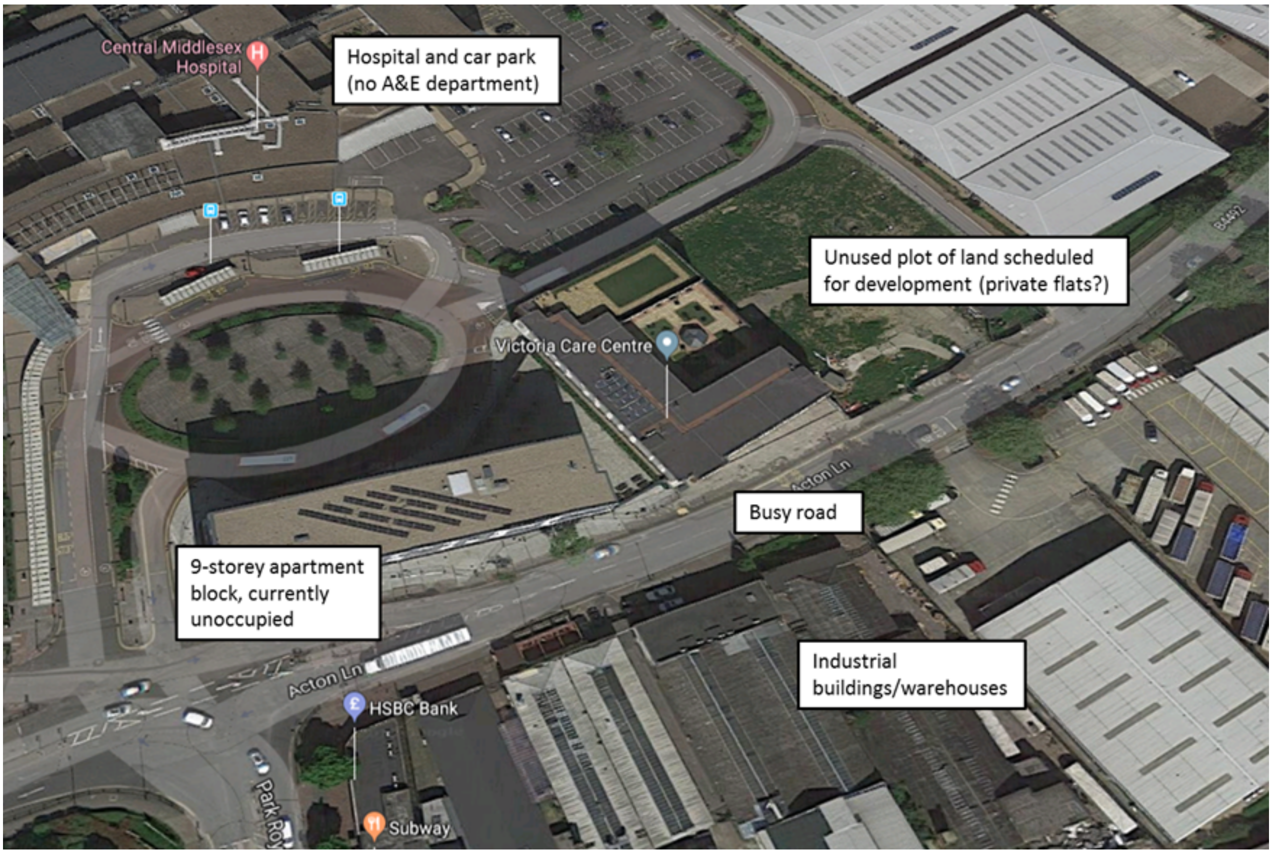

Figure 3. Victoria Care Centre and surrounding buildings (Image ©2019 Maxar Technologies)

Building configuration and occupancy profile

The care home is sited in a purpose-built, modern U-shaped building with a flat roof and is arranged around a central courtyard with a main entrance façade facing south east. The building currently comprises of 5 floors with plans for an additional 6th floor to be added in the near future. All levels incorporate suspended ceilings embedding the lighting, heating and hot water distribution systems, resulting to a low effective floor to ceiling height (2.3 – 2.4 m) in all except for the ground level (3.75 m). The communal spaces are clustered on the ground floor. These include the main reception, a bistro, offices, a doctor/nurse consultation room, a manager's office, hair salon, cinema/meeting room, the plant room, kitchen, laundry and a small staff room. The ground floor also has an outdoor covered area for a small car park and deliveries. The remaining floors are home to the residents (all in single ensuite rooms, such the one pictured in Figure 4) and include dining rooms, dayrooms (TV lounges), nurse stations/treatment rooms, staff rooms and offices (Figure 5).

The residents on the first floor are generally more able-bodied and independent than the residents on the other floors, although only a few are independently mobile. The residents on the second and third floors require more intense nursing and care and are not independently mobile. Rooms on the fourth floor are slightly larger, and the residents are not necessarily elderly but have dementia and similar cognitive disabilities. Common rooms appear to be scarcely/minimally occupied, except for the ground, first and third floor's lounges, where approximately 20 people may be found, mostly during the morning and afternoon. There is a secure open space on the first floor accessible from some of the residents' rooms, dayrooms and the library and a smaller secure open space on the 4th floor on the north-west wing.

Figure 4. Typical resident room (1st floor, room 11): Whole room (left), window showing wooden beam and security window restrictors added post-occupancy as original window restrictors (centre) and ensuite shower and toilet (right)

Figure 5. Cinema room (left), 1st floor dining room (centre), 1st floor west corridor (right)

Building services and equipment
The plant room (on the ground floor) contains a large cold-water storage tank and four boilers which run in tandem to provide domestic hot water and space heating. Equipment gains are particularly high in the plant room, kitchen and laundry (including three gas-fired tumble driers). Other heat generating equipment dispersed throughout the residents' living zone include 140 TVs, 8 kettles, 70 pressure mattress pumps working continuously and battery chargers for electric equipment used for lifting and moving hard-to-move residents. All light fixtures utilise energy efficient LED light bulbs. All corridor lights remain on 24/7 for safety reason but are dimmed down automatically when the occupancy sensors do not detect any motion. Bathroom lights are also occupancy sensitive and so is the bathroom extract ventilation.

Mechanical cooling in the building is available only in the plant room (a unit was installed post-occupation to help keep the cold-water storage tank cool), kitchen storage (to help keep food fresh) and one unit which regulates temperatures in the treatment rooms where stored medication needs to be kept below certain temperatures. The treatment rooms are stacked vertically on the 1st, 2nd, 3rd and 4th floors in the south corner of the building adjacent to the main lift. Resident rooms do not have air conditioning (AC). However, during the physical survey, the manager noted that due to summer overheating issues currently experienced on the 5th floor, an air conditioning system is planned to be installed on the 6th floor as soon as it is completed.

Cooling down measures
Except for AC in the plant, kitchen storage and treatment rooms, the cooling measures that are currently utilised are window opening, the provision of fans to all residents and moving residents to the ground floor common areas that are cooler during heatwaves. According to the management, all windows remain open in the summer, throughout day and night, but only up to 100 mm due to the safety restrictors present. If too hot, then the ground floor doors and the first-floor patio doors may be kept fully open throughout the day only and the same applies to the ground floor windows, for which a higher openable area is allowed. Of all ensuite floors, the manager reported that the first floor is generally able to maintain lower temperatures due to the presence of patio doors that can be kept fully open. Doors to residents' rooms are generally kept open for safety and to allow cross ventilation. A small number of residents (fewer than 10) have requested their own keys for their rooms and residents can choose to close their doors when they want more privacy. The manager also reported that fans are normally provided to all residents during the summer, however, the fan provision is going to be restricted for the first time this year due to the new guidance that prohibits the use of fans where residents with highly infectious diseases are treated to avoid infection spreading.

Internal overheating sources
The gas-fired domestic hot water and space heating circulation system seems to be a significant source of overheating, since it is utilised all year round (Figure 6). Normally there is a bypass so that hot water does not go through the space heating pipework in the summer, however the pipework is long and when space heating is off the managers found that the joints were leaking. Instead of fixing the problem, given the extensive number of the leaks throughout the building, it was decided that both the space heating and domestic hot water circulation network, (including space heating flow and return, domestic hot water flow and return and domestic hot water secondary return), will be active all year round. The pipes circulating hot water include flow and return pipes for both space heating and domestic hot water. They run vertically from the ground floor's plant room until they reach the first floor's suspended ceiling, where they branch out horizontally through the corridors and then travel vertically again to the top floor. As shown in Figure 6, the pipework seems to be well insulated. However, the comparison between the second and third floor corridor thermal images presented in Figure 7, reveal a distinct difference in floor temperatures, implying a significant heat release to the former from the pipework travelling through the first-floor suspended ceiling. During summertime, between approximately mid-May to mid-September, the radiators are switched off manually via thermostatic radiator valves (TRVs).

Figure 6. Corridor ceiling showing insulated piping (left) and corridor radiator (right). All radiators have heating element at the base, with a large casing above to reduce the risk of residents burning themselves.

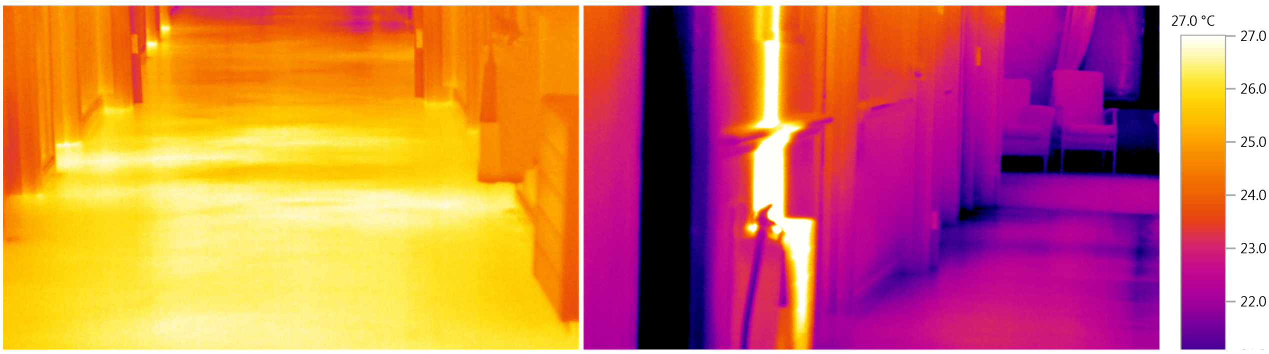

Figure 7. Thermal imaging showing a distinct floor temperature difference between the first floor corridor (left) and the second floor corridor (right)

3.3 The pilot testing process

The research approach for the pilot testing was socio-technical and interdisciplinary, drawing from building science and social science methods, which involved conducting primary research as follows:

3.3.1 Physical survey

A physical survey was undertaken in Victoria Care Centre on the 7th March 2019 to establish the building's physical, technical and occupancy profile to be used as input in the dynamic thermal simulation model. One researcher visited the property and conducted a survey 'walk-through', accompanied by a staff member of the care establishment to ensure safe guarding provisions were met. Information, including building configuration, structure type, internal conditions, equipment installed and their operation, were collected via observation, photographic evidence and informed via discussion with the accompanying care home member of staff. The Standard Assessment Procedure (SAP) and Carbon Trust survey frameworks were consulted in the development of an audit checklist for this task (see Appendix 1).

3.3.2 Environmental Data Monitoring

Due to project timeline, indoor temperatures, relative humidity and CO_2 concentrations were continuously monitored at 5-minute intervals from 7th – 31st March 2019, to empirically measure the indoor environment. Two residents' rooms, two communal areas and one office were monitored (Figure 8). In addition, outdoor temperature and humidity data was gathered from Weather Underground, an online resource using meteorological data gathered from weather stations around the world, in this case from the nearby Heathrow weather station. Indoor temperature and relative humidity (RH) were monitored using Hobo UX100 devices (with an accuracy of ±0.21 °C and ±3.5% within the ranges experienced). CO_2 concentration was monitored at 5-minute intervals using Tinytag TGE-0011 devices (with an accuracy of ±50 ppm + 3% of reading). So a CO_2 reading of 1000 ppm is accurate to within + or – 80 ppm (50 ppm + 3% of 1000, i.e. 30 ppm).

Figure 8. Victoria Care Centre floor plans, showing locations of monitoring devices

3.3.3 Social survey and interviews

Resident and staff surveys and interviews were undertaken to establish thermal comfort and preferences (with concurrent temperatures measured), and to evaluate likely causes of over- or under- heating in the building. These were based on the interviews conducted for the 2016 Joseph Rowntree Foundation project, ‘Care provision fit for a future climate’. As the study was conducted during the heating season, (March 2019), the focus was on under-heating and experiences of feeling cold and efforts to get warmer. The surveys consisted of 5 questions relating to the respondents’ current conditions (thermal comfort, thermal preference, clothing, activity and controls). Thermal comfort and preference provided an indication of the respondents’ sensation/comfort levels. The clothing they were wearing, activity, (what they had been doing in the previous 15 minutes), and controls, (relating to whether windows and doors were opened or closed, or whether heating, fans, lights or air conditioning were on), provided contextual information alongside their comfort and preference data. The interviews focussed on a broader understanding of the respondents’ experiences in the care home and were tailored to the respondents: Residents were asked about what they do to remain thermally comfortable and how easy or difficult this is to achieve; frontline staff/carers were asked how they respond to residents’ needs and risks to residents if comfort levels are not maintained; management were asked about broader protocols and procedures within the home.

3.3.4 Data modelling and analysis of the modelled output

The modelling phase of the study used the widely tested and validated dynamic building performance software EnergyPlus v8.9.0.001 [47] to simulate the baseline summer thermal performance of the care home to assess its current and future state of overheating. The model shown in Figure 9 provided individual output for each room of the case study care home and was tested against the actual measurements from the environmental data sampling to provide confidence in the model. The modelling and monitoring data comparison is presented and discussed in Section 4.3.1 and Section 5 below.

Since future climate weather files are not currently available for UK Climate Projections 2018 (UKCP18), the dynamic thermal modelling quantified overheating risks under the current and two future climate change projections (2050s and 2080s) consistent with the UK Climate Projections 2009 (UKCP09), in conjunction with a range of building structure and operation variations. The UKCP09 based weather files were sourced from CIBSE, i.e. for Design Summer Year 1 (DSY1) and under the high emissions, 50% percentile scenario.

The testing of various modelling scenarios quantified overheating risks and temperature exposure of the care home residents and informed the feasibility assessment for the promotion of passive cooling systems and overheating mitigation behaviour change measures. The overarching aim was to assist the formulation of recommendations about the activities, initiatives and policies that the care home could implement/adopt to reduce indoor overheating and heat exposure in care home environments. The following subsections: details the assumptions underlying the base case scenario, describe the range of base case and alternative scenarios tested and explain the focus of the analysis.

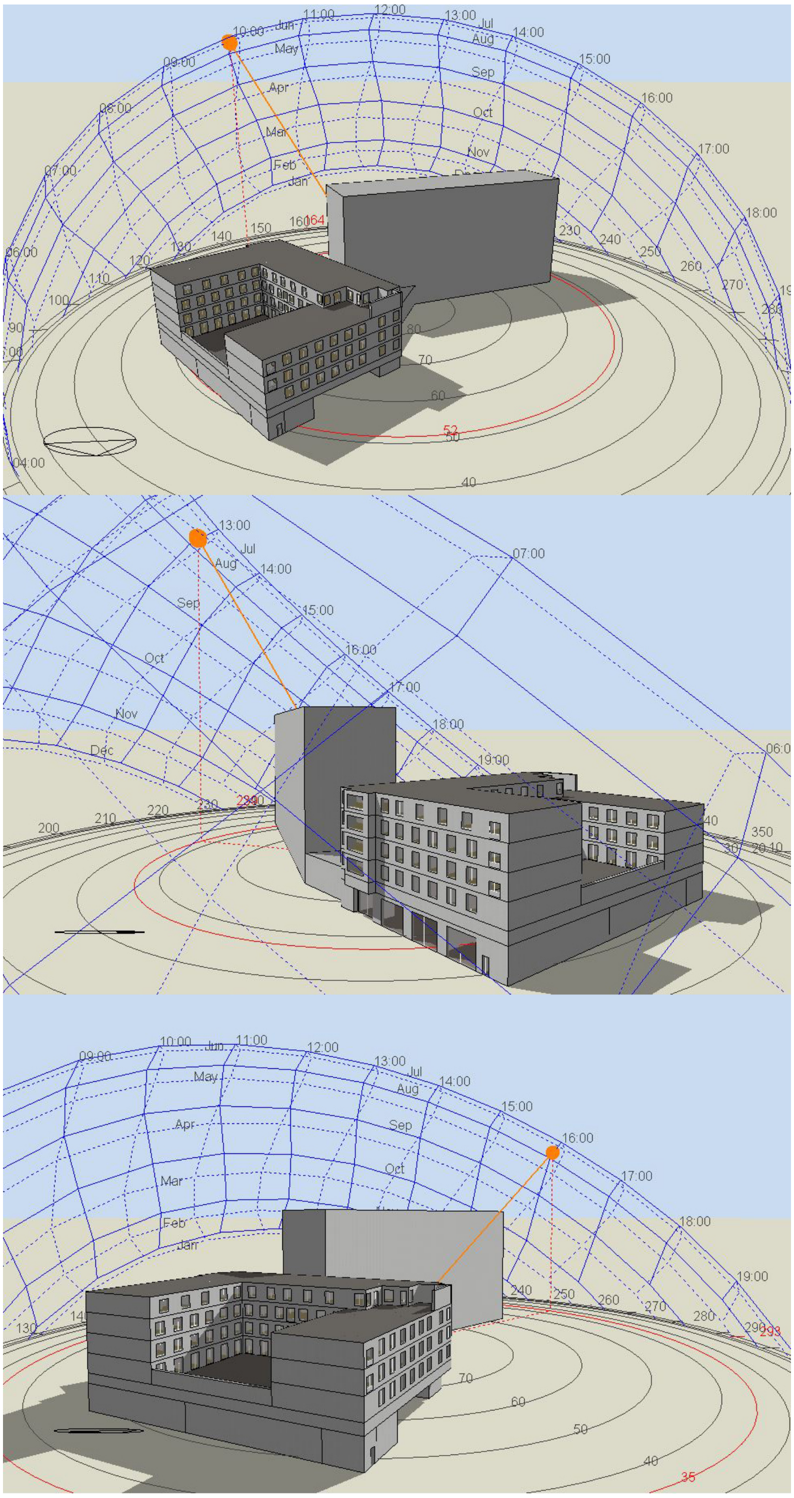

Figure 9. Rendered view of the modelled building at 10am (top), 1pm (middle) and 4pm (bottom)

Base case data input to the thermal model
The thermal modelling input is primarily based on the data collected during the site visit investigation, the information shared by the manager and the technical paperwork obtained to ensure the model represents the building's individual characteristics as much as possible. Where information was not available, for example, for aspects such as temperature thresholds for window opening, information was sourced from CIBSE's '*Design Methodology for the assessment of overheating risk in homes'* (TM59) [46]. CIBSE's TM59 is a standardised overheating risk assessment methodology suitable for the investigation of overheating in all domestic properties, using dynamic thermal modelling, and is based on CIBSE Guide A (2015) and CIBSE TM52 [48] environmental design and thermal comfort criteria. This study has utilised the TM59 methodology to some extent, however without strictly adhering to TM59's generic modelling input and requirements (such as standardised operational schedules and annual calculation of hourly temperatures) and is not meant to provide typical TM59 analysis/output. Doing so would have required strict adherence to TM59's occupancy and operational profiles, which would not necessarily be representative of the circumstances experienced in the case study, as well as significantly longer thermal modelling run times for the calculation of annual temperatures, which would not suit the limited time frame of this study. Future work could include a sensitivity analysis to facilitate a more robust investigation for the identification of key variables contributing to summertime overheating and their influence on the year-round building's performance. The study's main thermal modelling assumptions underlying the base case scenario are presented below:

Building structural and thermal characteristics - Victoria Care Centre is a block and beam structure, built under the 2010 Building Regulations. The building constructional and thermal characteristics were obtained from the architectural drawings and technical documentation provided by the care home manager. The presence of consistently applied thermal insulation on walls and roofs was also supported through the thermal imaging obtained during the site visit. Table 1 details the construction type and U-values inputted for the building fabric elements.

Occupancy schedules and internal gains - Ensuite bedrooms are assumed to be constantly occupied by a single person. As described earlier in Section 3.2, the lounge occupancy was reported to vary significantly per floor, however for comparison purposes, all lounges were assumed to be occupied by five people throughout the day and be unoccupied during the night. Equipment internal gains per zone were set according to the TM59 guidelines for bedrooms and living rooms. Pipework distribution gains were calculated based on the simplified method provided by the Domestic Building Services Compliance Guide [49].

Ventilation and internal door schedules - Window opening is based on the TM59 threshold, that is, natural ventilation operates in every zone whose temperature exceeds 22 °C, unless the external temperature is higher than the internal. The window openable area per room is assumed to be 15%. Providing that the temperature criteria described above are met, windows can remain open day and night. External doors on the ground and first floor operate on the same 22 °C exceedance basis, can remain fully open during daytime (9 am-9 pm) and are fully closed during the night. Ensuite and lounge internal doors are assumed to be open 80% of the time. All other doors, e to offices and staff rooms, are assumed to be closed.

Table 1 Constructional and thermal data input

Element	Construction characteristics	U-value (W/m^{2}K)
External roof	Block and beam, insulation at the outmost layer	0.12
Ground floor	Concrete, topside insulation	0.22
External floor	Concrete, insulation at innermost layer	0.21
External wall	Cavity wall, concrete block	0.23
Glazing	Double glazed PVCU	1.4

Weather data – As per the TM59 overheating analysis guide, the latest CIBSE Design Summer Year 1 (DSY1) weather files, based on UKCP09 and under the high emissions, 50% percentile scenario, for the closest location available to the site under examination Heathrow, was utilised in this study. Three DSY1 weather files were selected to represent external temperature measurements for the summer period (May to September) under current (2020s) and future (2050s and 2080s) weather climates. The 2020s, 2050s and 2080s weather files gave 25, 57 and 85 days per year with three-day moving average temperature above 21.5 °C respectively. For the simulations, the 11-day period (19-29 July) with the highest average temperatures was selected.
Figure 10 shows the hourly temperature distribution per weather projection for the selected period.

Subsequent summertime monitored data – Following the summertime monitoring as part of the ClimaCare project (Appendix 2),
Figure *10* was updated to include the temperatures monitored between 19th and 29th July 2019. Overall, external temperatures were monitored from 1st June until the 19th September at 5-minute intervals, excluding the period of 7th June and 11th July due to a monitoring device error. Based on the monitoring data available, there were only two periods identified during the 2019 summer with a three-day moving average above 21.5 °C, i.e. 22nd-26th July and 24th-27th August. Between the two, the longest 5-day heatwave period in July was selected for the validation of the dynamic thermal modelling output. This overlaps with the 11-day heatwave period selected for the analysis of the dynamic thermal modelling output.

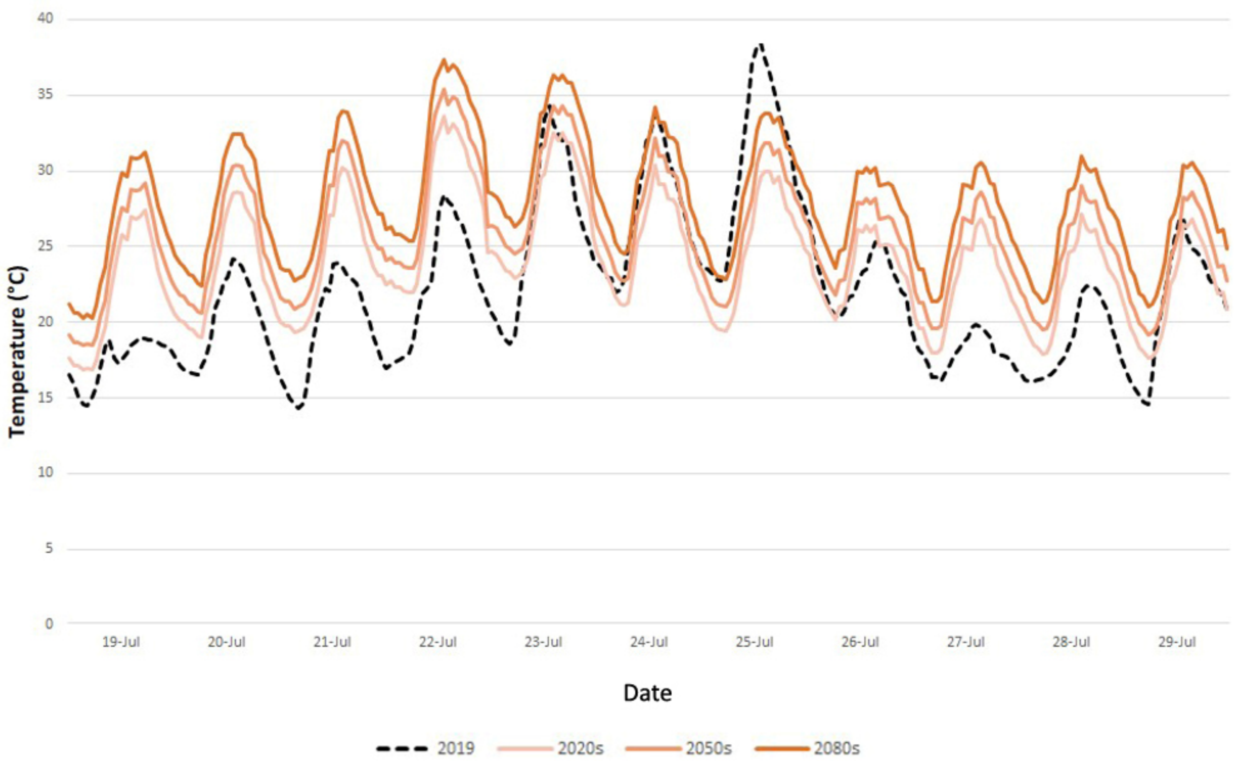

Figure 10. Hourly external dry bulb temperature distribution as measured on site (2019) and under the high emissions, 50% percentile scenario DSY1 weather files for 2020s, 2050s and 2080s

The range of base case and alternative scenarios tested – Table 2, summarises the thermal modelling scenarios tested to quantify overheating risks and identify effective mitigation interventions in Victoria Care Centre. It includes three temporal variations of the base case scenario, under the 2020s, 2050s and 2080s climate projections (Test 1), and several alternative mitigation scenarios, including a range of ventilation, shading and active cooling scenarios, tested under the 2020s and the 2080s climate projections (Tests 2-10).

Table 2. The range of thermal modelling scenarios tested

Test ID	Scenario	2020s	2050s	2080s
1	Base case	X	X	X
2	Increased window opening capacity by doubling the openable window area	X		X
3	Reducing pipework heat gains, assuming the space heating distribution network is switched off during summer	X		X
4	Implementation of internal shading on sunny days	X		X
5	Implementation of (a) movable external shutters with low and (b) high reflectivity and (c) fixed external louvres and side fins on every window	X		X
6	Cooled supply air, provided at 25 °C, tested in both a (a) naturally ventilated and (b) sealed building	X		X
7	Cooled supply air, provided at 20 °C, tested in both a (a) naturally ventilated and (b) sealed building	X		X
8	Combined passive measures – increased window opening capacity and external window shading	X		X
9	Combined passive and active measures – external window shading and cooled supply air at 25 °C in (a) a naturally ventilated or (b) sealed building	X		X
10	Combined passive and active measures – external window shading and cooled supply air at 20 °C in (a) a naturally ventilated or (b) sealed building	X		X

Data output and analysis – The analysis focuses on the care home's ensuites and lounges, as these are the zones where the vulnerable occupants are most likely to spend their time. The 11-day average temperature estimates are reported as day- and night- time averages for areas of the same activity, which are named *interzone average temperatures* for the purposes of this study. They are obtained by averaging the 9 am - 9 pm or 9 pm - 9 am hourly temperature estimates per zone type.

4. Results of pilot testing

As explained in Section 3, the pilot testing process involved a physical survey, environmental data monitoring, social surveying and interviews and the dynamic thermal modelling investigation. The data collected during the physical survey have been presented in detail in Section 3.2 – *Case study profile: Victoria Care Centre* and has fed into the analysis of the data collected through the remaining data collection methods. This section presents the results from the analysis of this data, collected through the environmental monitoring (Section 4.1), the social surveys and interviews (Section 4.2) and the dynamic thermal modelling process (Section 4.3).

4.1 Environmental Data Monitoring Results

4.1.1 Indoor and outdoor temperature

Indoor temperature was monitored using Hobo UX100 data loggers in one office, two lounges and two residents' rooms to cover the hybrid nature of care settings that have residential, communal and workspaces.

Figure 11 shows indoor temperatures over the full monitored period from 7th March – 1st April 2019. The ground floor office contains two desks. It is an internal room, with doors into the front desk/reception and into the bistro area. The office is not always occupied during office hours, with a finance manager working part-time. Temperatures in this office remained between 20-25 °C. The remaining monitored lounges and residents' rooms had significantly warmer temperatures, predominantly in the 25-30 °C range.

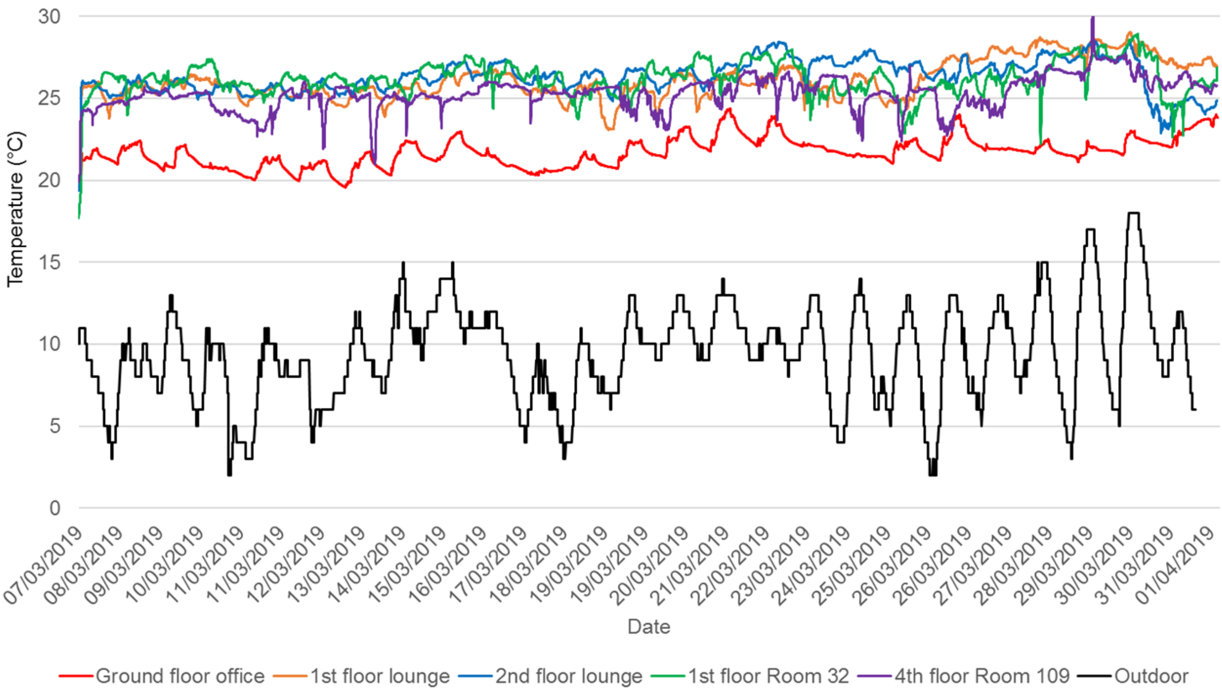

Figure 11. Indoor and outdoor temperatures monitored from 7th March – 1st April 2019

The boxplot (Figure 12) shows more clearly the distribution of temperatures over the monitored periods. It is worth noting that this includes overnight readings, and although the ground floor office and 1st and 2nd floor lounges are unlikely to have been occupied overnight, the residents' rooms will have been occupied for the majority of monitored hours. It is also worth noting that on the 1st floor, both the lounge and room 32 have doors which open out onto the 1st floor outdoor area, giving them more flexibility in ventilation and cooling strategies than most other rooms in the building. The boxplot indicates that the temperatures in the ground floor office remained within the recommended range of 21-23 °C for the majority of working hours. Areas occupied by residents were significantly warmer, being over 25 °C for 85% (1st floor lounge), 94% (2nd floor lounge), 93% (1st floor room 32) and 70% 4th floor room 109) of the time (Figure 13).

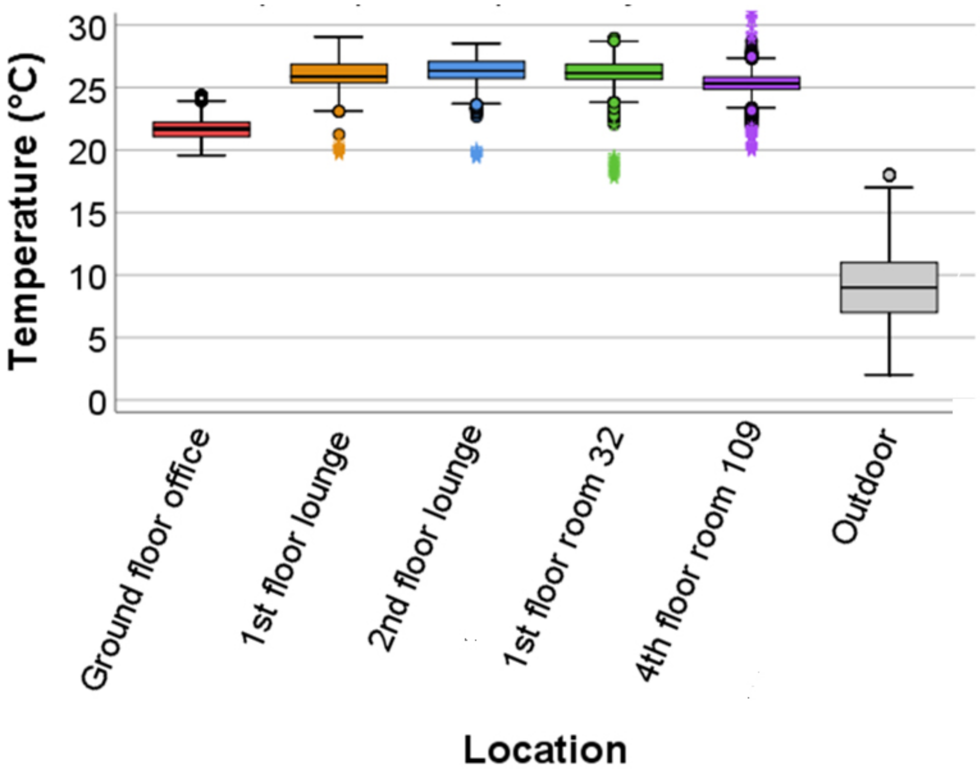

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Figure 12. Boxplot of temperature distributions over the monitored period (7th March – 1st April 2019)

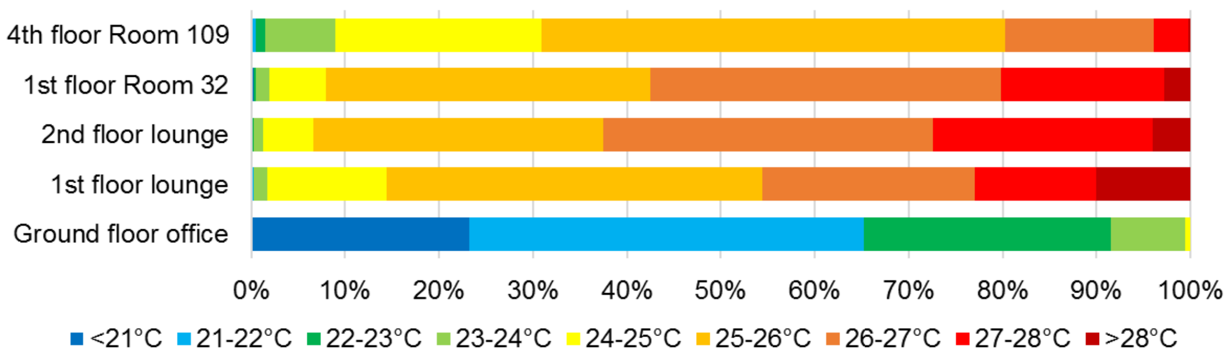

Figure 13. Distribution of temperatures in each monitored room (7th March – 1st April 2019)

Plotting trend lines for indoor temperature vs. outdoor temperature for each of the zones showed that there was a consistent trend of indoor temperatures increasing with outdoor temperatures, with all correlations significant at the <0.01 level. The strongest correlation was in the ground floor office, which although an internal room, had a door to the bistro area which had a large south-east facing glazed façade and doors opening onto the street to the south-east and the delivery area to the north-west. Both lounges had moderate correlations between indoor and outdoor temperatures, both much stronger than those in the residents' rooms. Interestingly, although 1st floor room 32 had a north-east facing door onto the 1st floor open area, its correlation was the same as that of the 4th floor room which only had a single south-west facing window.

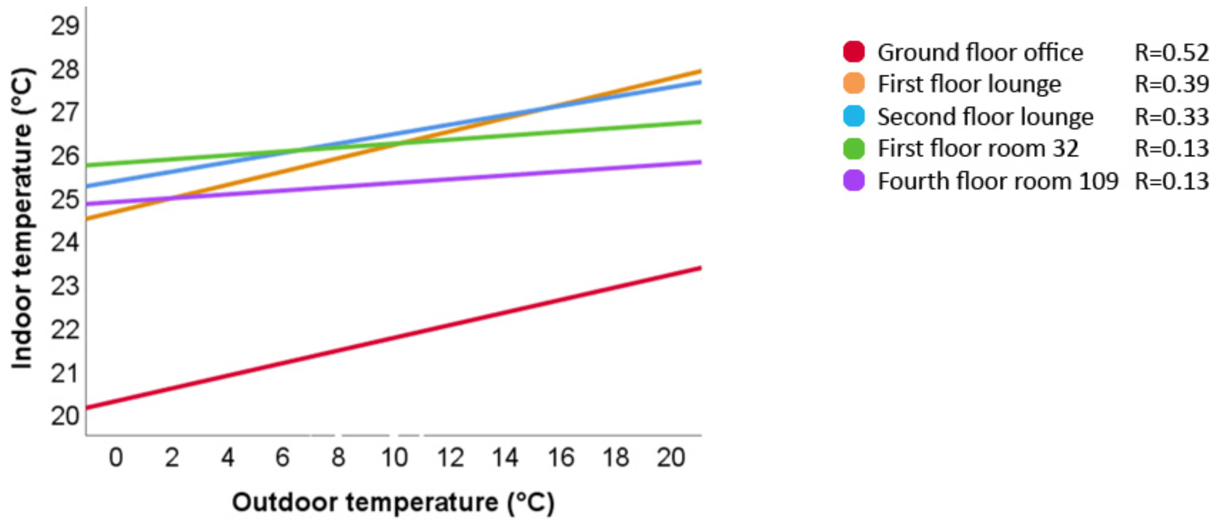

Figure 14. Correlation between outdoor and indoor temperature in each monitored room, with text colour indicating linear trend line colour (7th March – 1st April 2019)

These results make it clear that during the monitored period, in the monitored rooms, there was no concern that the residents were experiencing low temperatures that may have been detrimental to their health. On the contrary, temperatures were often in excess of 27 °C (as much as 27% of the time in the 2nd floor lounge and 20% of the time in the 1st floor room 32).

4.1.2 Indoor Relative Humidity

Relative humidity was monitored in the same areas as temperature and over the same period. Whilst outdoor RH averaged 81%, indoor RH rarely exceeded 40% (Figure 15). Again, there was a clear distinction between the RH profiles for the ground floor office and the other monitored areas.

There are pros and cons of having lower RH levels. Lower levels help prevent the spread of dust mites (below 50% RH is best), viruses (between 40-60% RH is best) and mould growth [50]. Lower levels also reduce condensation. However, lower RH levels can influence perceptions of temperature, making it feel colder, and if too low can increase the spread of viruses [51]. Low RH has also been linked to dry throats, sore eyes and headache [52].

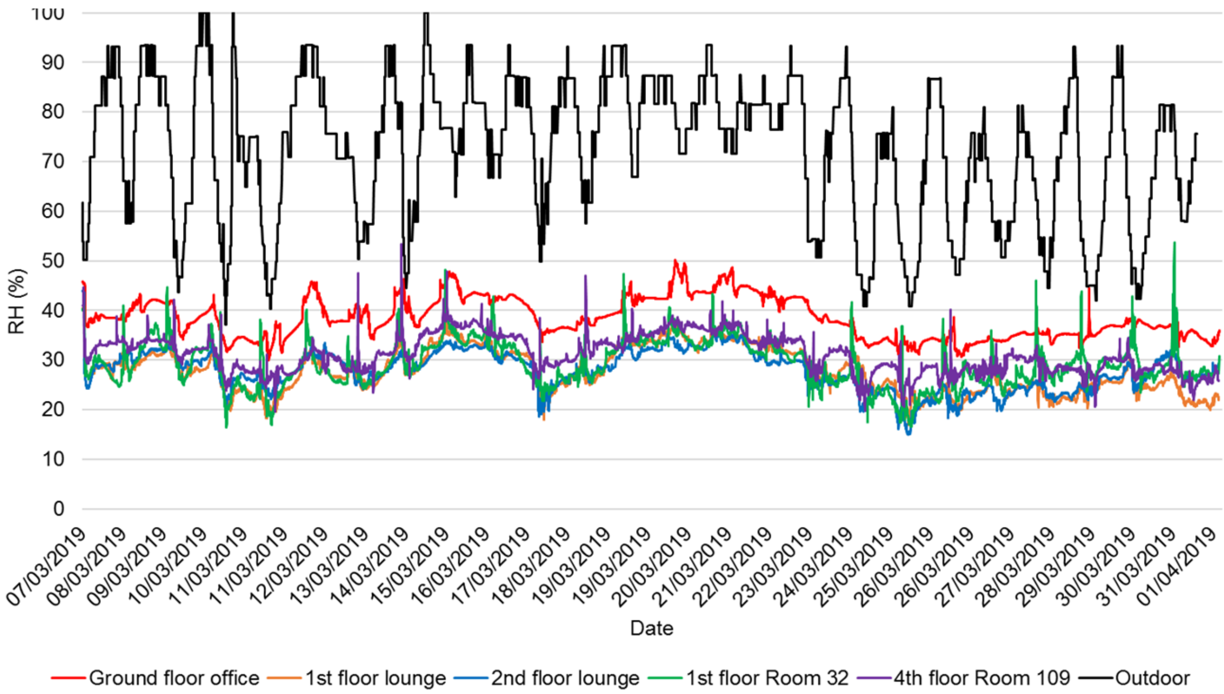

Figure 15. Indoor and outdoor RH monitored from 7th March – 1st April 2019

The boxplot (Figure 16) and bar chart (Figure 17) show the distribution of RH levels throughout the monitored period. The majority of RH levels in resident areas were in the 25-35% range, which is in the range that would encourage the spread of viruses.

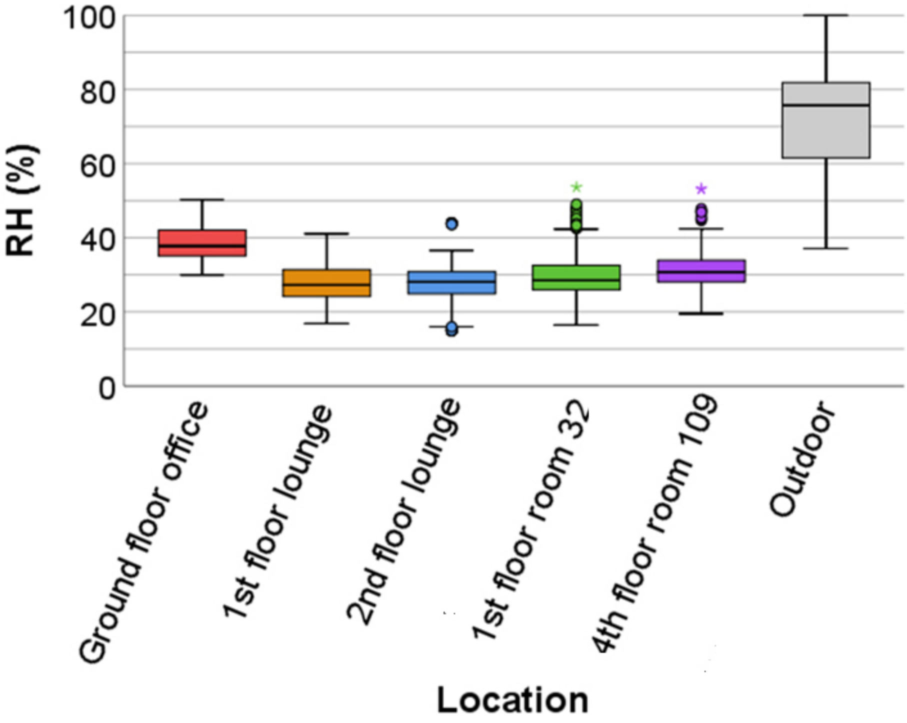

Figure 16. Boxplot of RH distributions over the monitored period (7th March – 1st April 2019)

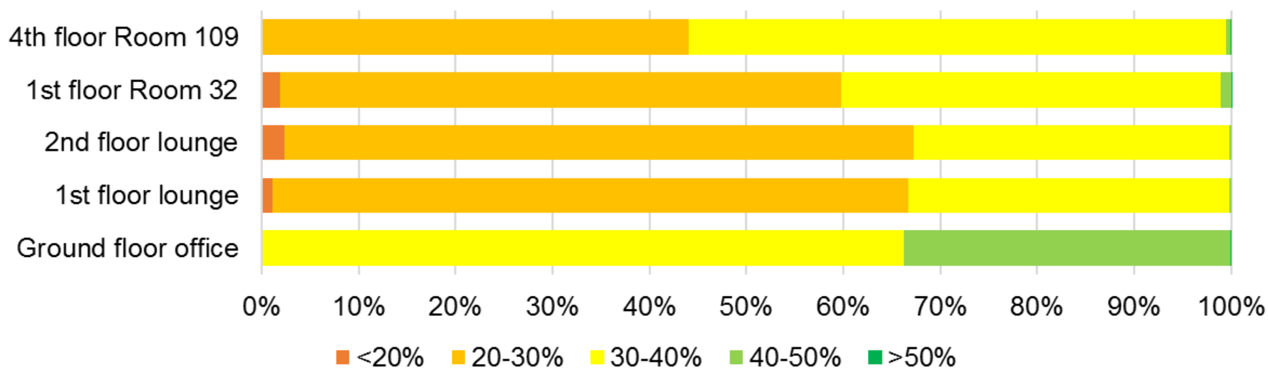

Figure 17. Distribution of RH in each monitored room (7th March – 1st April 2019)

The correlation between indoor and outdoor RH levels was stronger than the equivalent for temperature. In all monitored rooms, the correlation was significant at the <0.01 level.

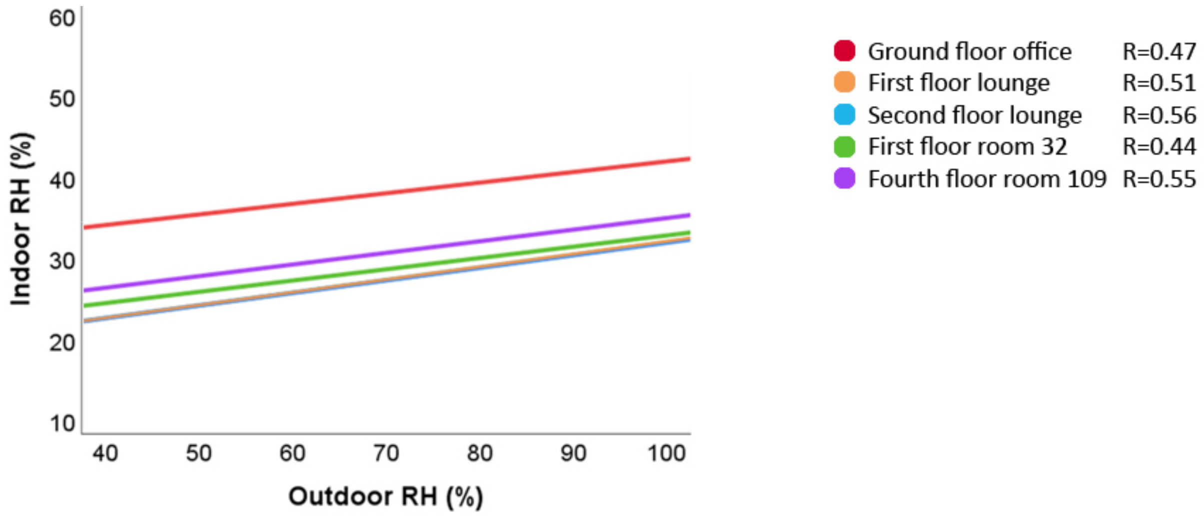

Figure 18. Correlation between outdoor and indoor RH in each monitored room, with text colour indicating linear trend line colour (7th March – 1st April 2019)

It is worth noting that the monitoring period covered the heating season, and radiators were on in the majority of rooms in the building. Heating has the effect of drying the air, lowering relative humidity levels, so it would be interesting to compare these to the monitored levels during the non-heating season.

4.1.3 Indoor CO2 concentration

CO_2 concentration was monitored in the same areas as temperature and RH and over the same period. Concentrations fluctuated much more rapidly than temperatures or RH levels, as can be seen in Figure 19. Occasional spikes of concentrations above 1000 ppm, but for the majority of the time they were in the 500-700 ppm range.

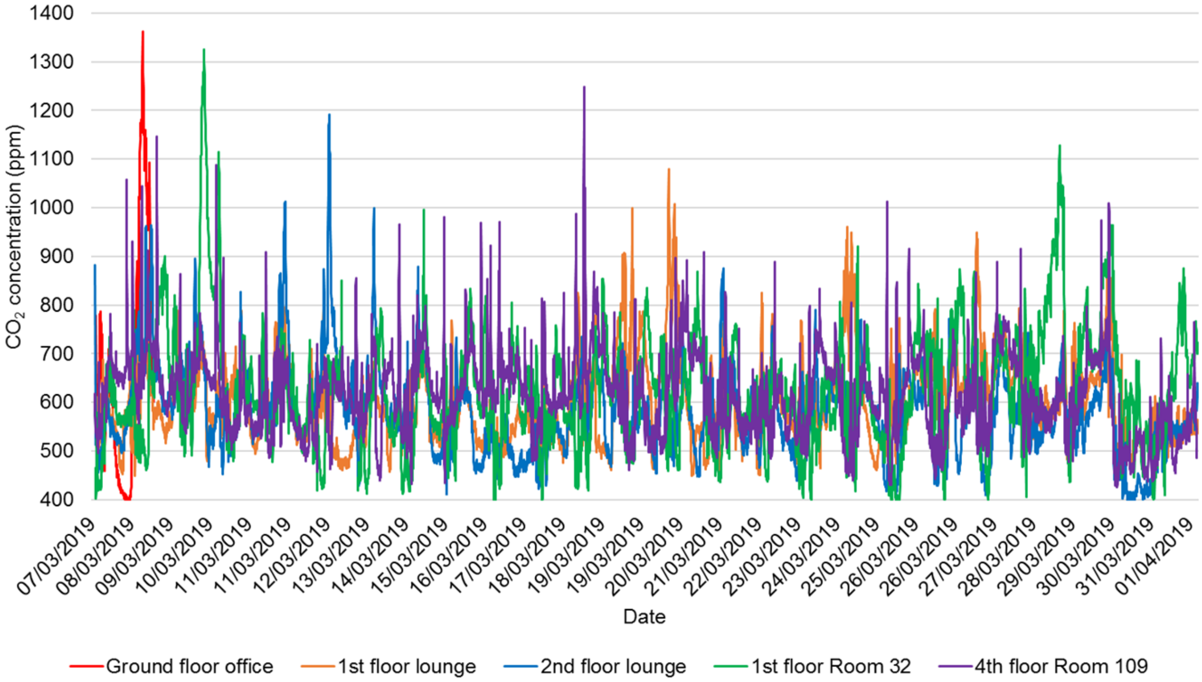

Figure 19. CO_2 concentrations monitored from 7th March – 1st April 2019

Figure 20 and Figure 21 give a clearer indication of how CO_2 concentrations were distributed over the monitored period, with levels exceeding 800 ppm for much less than 10% of the time in all monitored residents' areas. Research has suggested that these levels are well within safe limits for occupants and would have no detrimental effects on health or cognitive abilities [53].

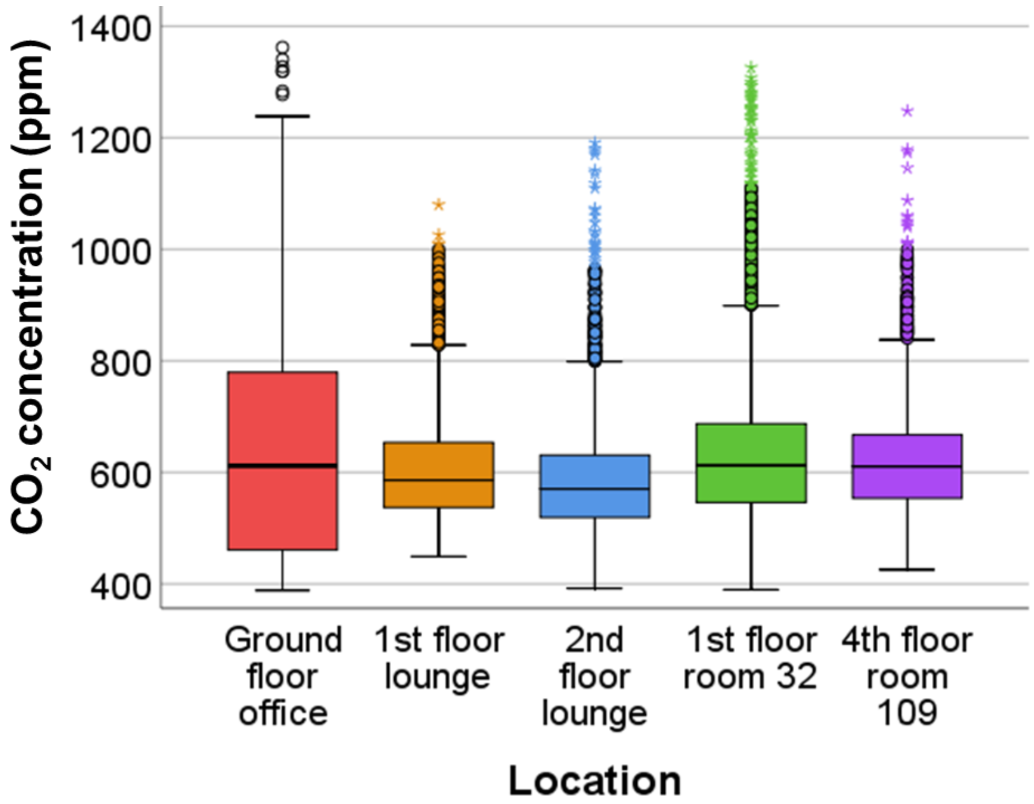

Figure 20. Boxplot of CO_2 concentration distributions over the monitored period (7th March – 1st April 2019).

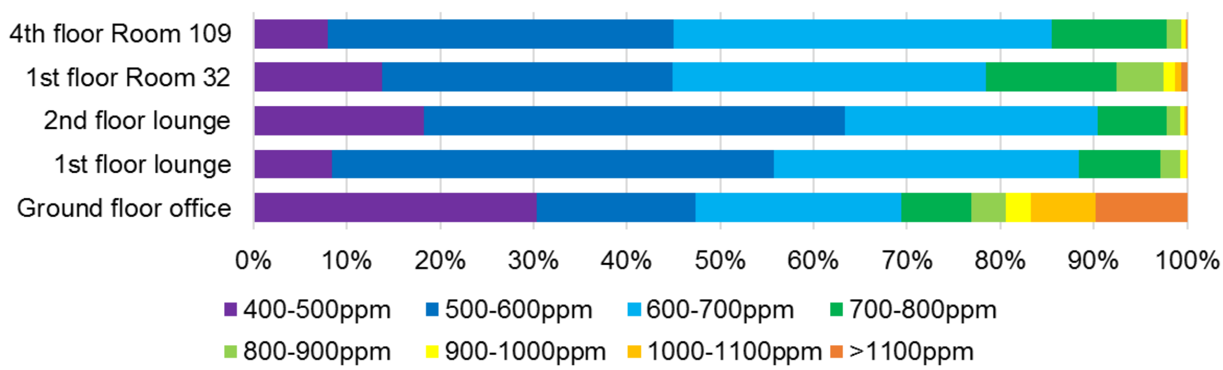

Figure 21. Distribution of CO_2 concentrations in each monitored room (7th March – 1st April 2019).

These results indicate that CO_2 concentrations were at ‘healthy’ levels throughout the care home. Since this monitoring period was during the heating season when windows were less likely to be opened due to colder outdoor temperatures, it is likely that during the non-heating season CO_2 concentrations may be even lower on average.

4.2 Survey and interview results

4.2.1 Residents

Due to the nature of the care home, (catering mainly for residents with dementia or who are frail and in need of palliative care), the number of residents who were physically able, cognitive and able to communicate effectively when being interviewed was limited. Two residents were interviewed: one a bedbound female on the 4th floor who was the first resident in the home over three years previously (R52); the other an independently mobile male with less cognition and communication (R32). The average temperatures measured in their rooms during the interviews were 26.7 °C and 26.5 °C respectively.
The questions that formed the first part of the interview can be found in Appendix 3.

Both respondents felt neutral (Q1) and preferred ‘no change’ (Q2). R52 was in bed wearing a nightgown and had a thin sheet and blanket covering her. Being bedbound, her activity was passively laying down watching television, with her bedroom door opened, the radiator off and curtains half-closed. R32 was sat on his bed in his underwear with a towel wrapped around him. He had a large fan on, the radiator off and windows and doors closed.

R52 described how, having asthma, she was “not allowed” to get cold, but said that the radiators were effective in controlling the temperature (and comfort levels) of her room: when she feels too cold she asks her carers to turn the radiator up, when she’s too warm she asks them to turn the radiator down (but never off). She occasionally asks to have her window opened but said that she’s discouraged from doing this because of her asthma. Her bedroom door was usually kept open during the day to allow air to circulate, to allow her to call for assistance if required, and to allow staff to monitor her more easily. This is the case for the vast majority of residents in the care home.

R32 has the benefit of being on the first floor in a room with a door that opens onto the first-floor open area. Although he said he never touches the radiator himself (leaving that to the staff), he does have some autonomy over his conditions as he is able to open and close his external door depending on whether he feels too hot or too cold. This was his primary source of climate control for his room, although he indicated that his radiator will be turned up or down by staff. He indicated that feeling cold rarely happened and that he was more likely to feel too hot in his room.

Neither resident said they had ever had need of an additional electric heater in their room to help maintain warm enough temperatures, and neither said they had (or ever had had) a thermometer in their room to help monitor temperatures.

4.2.2 Staff

One manager (M1) and two carers/nurses (S2 and S4) were interviewed. They were asked the same five personal comfort questions as the residents, and the concurrent temperatures were noted during the interviews (23.3 °C for M1, 26.4 °C for S2 and 26.5 °C for S4). All three members of staff were female and wearing similar clothing: the standard uniform of short sleeved top, trousers, socks and shoes. All three had been on their feet walking indoors prior to the interviews. All three indicated they were felling ‘neutral’ (Q1) and preferred ‘no change’ (Q2). Although the >26 °C temperatures combined with the active work they had been carrying out may have suggested they would be feeling warm, the temperature analysis above has shown that these temperatures would have been quite normal for the residents’ areas of the building, and staff may well have adapted their expectations accordingly. All three members of staff had been working in the building for over one year, thus experiencing all seasons of climate.

Staff were asked how they would respond to residents indicating they were too cold. Their responses overlapped, with all three saying they would first check the residents (by feeling their hands, feet or forehead), to confirm that they were cold. Because many of the residents have dementia and other conditions that may make it difficult for them to judge for themselves how warm or cool they are, and also communicate this, staff did not necessarily take residents at their word without double checking. In response to a resident being genuinely cold, the radiator may be turned up or additional clothing or a blanket over the legs provided. For bedbound residents, sheets and blankets may be adjusted regularly. Other measures such as opening/closing windows and trickle vents were less likely to be used for warming residents up, but the interviewees indicated these measures may well be used in the summer to mitigate overheating. The vast majority of residents are unable to take these measures themselves so rely on their carers to act accordingly.
All three interviewees referred to the building’s highly regarded maintenance team who were on-site or on-call 24-7 to help with any problems with heating etc. in the building. Being a relatively new building, survey respondents had not perceived any major problems with the heating system that would require any emergency action to keep the residents within safe comfort levels (despite the leaky pipes forcing the heating to remain on throughout the non-heating season).

The staff members were also asked if they could identify the potential health risks to the residents of being too cold. Between them, they identified increased risk of hypothermia, pneumonia, chest infections, coughs and colds, exacerbated asthma conditions and patients with thyroid problems who are unable to control their core body temperature. However, the recurring theme in all the staff interviews was that they rarely had concerns about the building (and patients) being too cold, but rather had experienced the building being too warm, particularly (but not exclusively) in the summer. All three interviewees perceived overheating to be more of a concern for themselves than for the residents – the residents' needs coming first. Their uniform does not vary throughout the year, so adapting what they wear was not an option. Instead they said that they would drink more when they were feeling too hot, and one interviewee (M4) said that during periods of overheating she would make sure that she was working with another member of staff at all times in case either of them fainted.

Full transcripts of the interviews are available on request.

4.3 Dynamic thermal modelling results

4.3.1 Baseline scenario results

The baseline simulation tested how the base model performed under the current (2020s) and future (2050s and 2080s) weather data during the selected 11-day heatwave period (19th July – 29th July). During this period, the 2050s and 2080s weather data predict an average outdoor temperature increase of 1.8 °C and 3.9 °C, respectively, in comparison to the 2020s climate data. **Figure 22** shows the relationship between the average external and internal temperature distribution in a fourth floor ensuite room in 2020s, 2050s and 2080s. The location of the selected ensuite (R109) is depicted in

Figure A 1 of Appendix 4. Just like external temperatures, internal temperatures increase by approximately two and four degrees in the 2050s and 2080s respectively, in comparison to the 2020s. Under all-weather files, the internal temperatures follow the external but remain consistently higher than the external and significantly more so during the night than day. Even though the windows remain open whenever the internal temperature exceeds 22 °C and the external temperature is lower than the internal, the limited window openable area (15% of the total window are per zone) alone cannot significantly reduce night-time temperatures, which remain above the 26 °C threshold for all weather files, except for a few night-time hours in 2020s.

Following the collection of summertime monitored data as part of the ClimaCare project Appendix 2, Figure 22 was updated to include monitored data for ensuite R109. The monitored data followed similar trends in that internal temperatures tend to fluctuate less than external temperatures and be lower during the night and higher during the day. As shown in Figure A 3 of Appendix 5 throughout the five-day heatwave period of 22nd to 26th July. However, internal temperature fluctuation was much lower, i.e. between 31.5 °C and 32.5 °C, in comparison to that observed in the modelled data, reaching a maximum temperature difference of 4.5 °C. The small diurnal internal temperature variation means that temperatures remained at significantly lower levels than peak external daytime temperatures but well above the 26 °C overheating threshold throughout day and night. Figure A 4 of Appendix 5 shows a first floor ensuite both as monitored and modelled, where the temperature difference between day and night temperatures also remains at a much narrower range than predicted by dynamic thermal modelling.

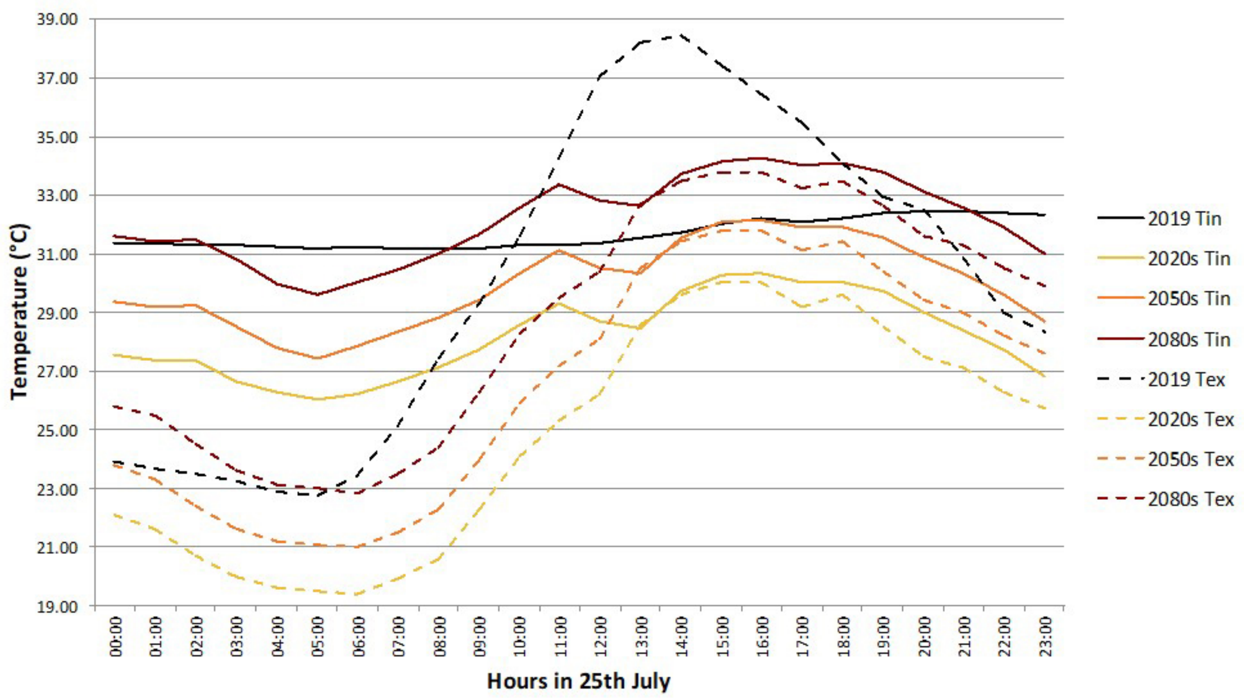

Figure 22. Internal temperature distribution, compared with external temperatures, in a fourth floor ensuite (R109) as measured on site in 2019 and under different weather files

Figure 23 shows that the ensuite internal temperatures tend to be higher, the higher the floor level. The location of e suites on the floor plan is depicted on

Figure A 1 of Appendix 4. There is generally a small difference in the temperature distribution between the floors accommodating ensuites (1st – 4th floor), with the exception of the first floor that presents significantly lower temperatures during night-time and it is up to 0.5 degrees lower daytime temperatures in comparison to the floor above. These lower temperatures may relate in part to the 1.5m high void space underneath the first floor (and above the ground floor and open garage) acting as a thermal buffer and in part to the increased daytime ventilation available to the first floor due to the ability to fully open doors in the rooms overlooking the courtyard.

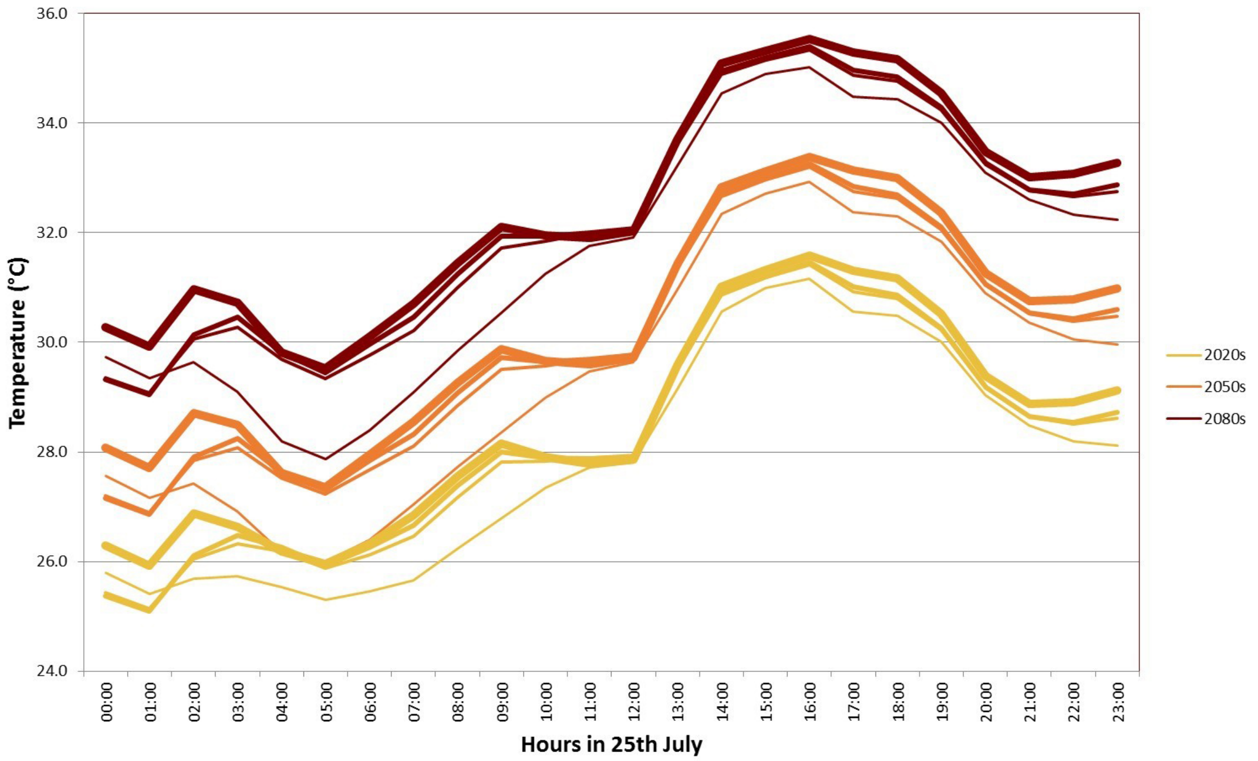

Figure 23. Hourly internal dry bulb temperature distribution in the vertically stacked SE facing ensuites of the first (R11), second (R44), third (R77) and fourth floor (R107) under different climate scenarios – higher floor levels are represented by thicker line widths

The 2019 summertime monitoring data also revealed the presence of temperature stratification in relation to floor level. The monitoring data is not available for vertically stacked rooms, however Figure A 3 of Appendix 5 shows that for the rooms monitored during the five-day heatwave period, internal temperatures are overall higher the higher their floor level.

Figure 24 shows the average day- and night- time temperatures during the 11-day heatwave period in three zone types, i.e., ensuites, lounges and corridors. Lounges were the zone with the highest daytime internal temperatures (29 °C, 30.7 °C and 33 °C in 2020s, 2050s and 2080s respectively), perhaps due to the increased internal heat gains during daytime (attributed to use of TVs, kettles and higher occupancy levels). Corridors presented the lowest daytime temperatures, probably due to the lack of direct solar gains as none of their walls are external. Overall, internal temperatures were found to be significantly higher during daytime in all zone types and all three zones presented similar night-time temperatures. All average temperatures were found to increase with higher external temperatures under the 2050s and 2080s climate scenarios. Average day- and night- time temperatures of the ensuites and lounges monitored presented a similar but much weaker trend in terms of temperature difference, with night-time temperatures remaining at much higher levels than those predicted by the dynamic thermal modelling simulations. In addition, the ensuites and lounges monitored maintained temperatures that were much closer in comparison to those predicted by the thermal model, with lounges often maintaining cooler temperatures than ensuites (also see Figure A 3 of Appendix 5). However, since monitored data are only available for a limited number rooms located on different floors and orientations, i.e. a 1st and 4th floor ensuite and a 1st and 2nd floor lounge, a just comparison cannot be made.

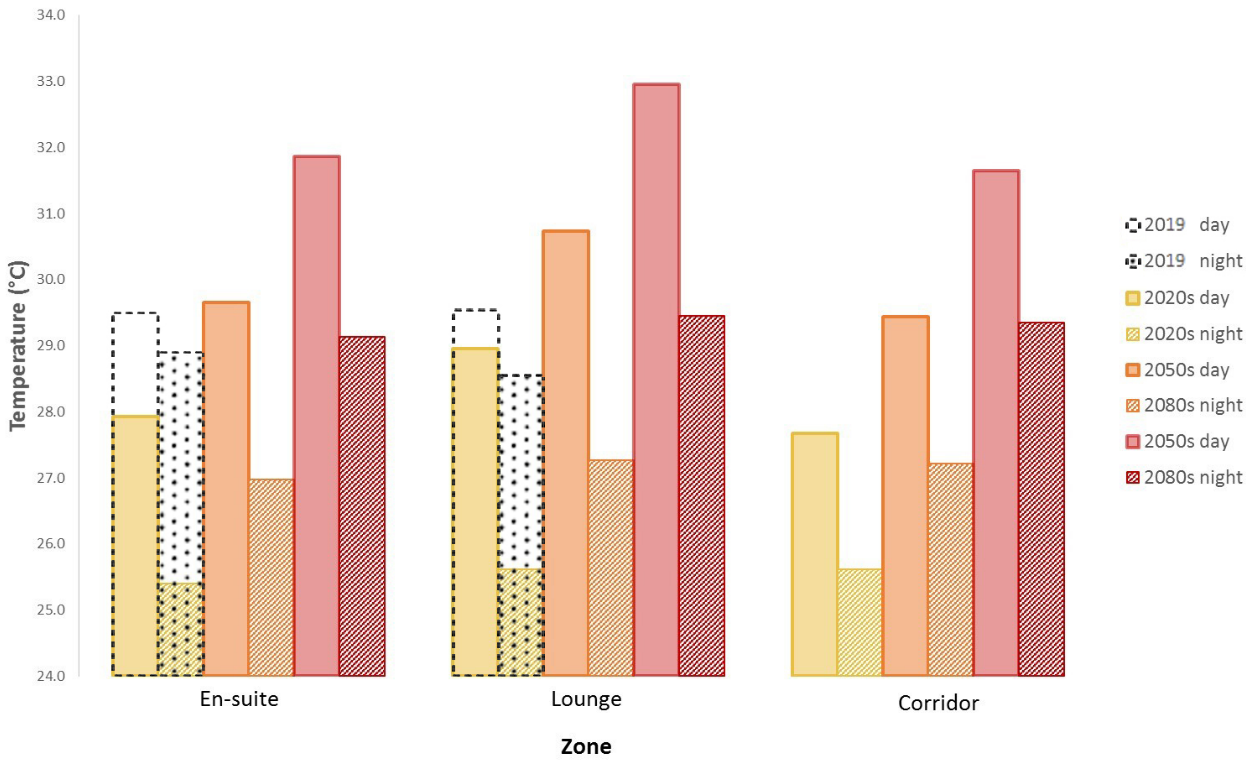

Figure 24. Average day and night building interzone temperatures between the 19th and 29th of July per activity area in 2020s, 2050s and 2080s and as measured between the 22nd and 26th July 2019 in specific rooms

Figure 25 illustrates the 11-day average daytime temperatures in individual lounges on different building floors under two different climate scenarios (2020s and 2080s). The location of lounges on the floor plan is depicted in Figure A 1 of Appendix 4.

Figure A 1 of Appendix 4. There is considerable variation in temperatures between lounges, ranging between 27.8 °C and 29.7 °C in 2020s and between 31.8 °C and 33.8 °C in 2080s. Of all lounges, those on the ground and first floors present the lowest temperatures and especially those located around the inner courtyard of the building, such as, lounges 2 and 3. This is likely to be linked to the increased overshading of their facades, as well, as the increased ventilation available since the courtyard doors can fully open during daytime hours. The latter also applies on the ground floor lounge (GF_Bistro). Figure 25 also includes the data available for the two lounges monitored during the 5-day heatwave period that took place in July 2019.

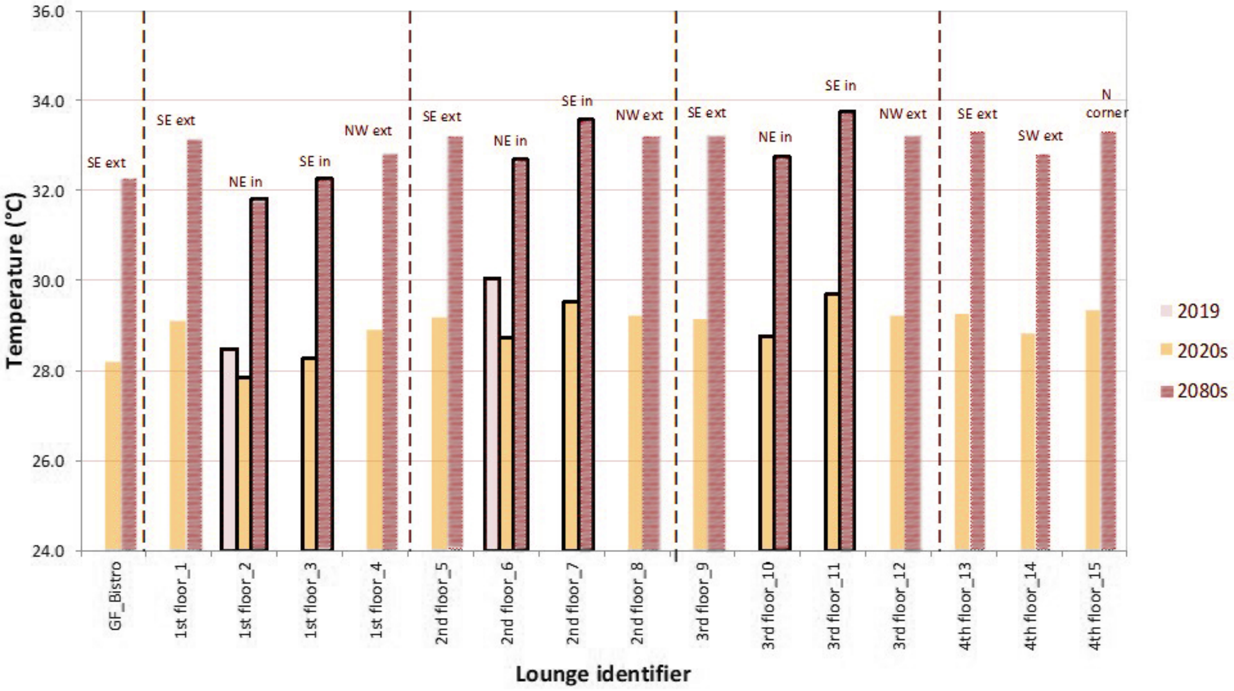

Figure 25. Average daytime lounge temperatures during the 5-day heatwave period in 2019, as measured, and during the 11-day heatwave under different weather scenarios – black border bars represent lounges facing the internal courtyard

4.3.2 Overheating mitigation scenarios

This section presents the results of the alternative scenarios described in Section 3.3.4. These were developed to investigate the capacity of mitigating high internal temperatures during a heatwave period using passive, active measures or a combination of both. The simulation results of mean day- and night- time indoor temperatures of ensuites and daytime only temperatures of lounges, during the 11-day heatwave period selected, are presented in Figure 26 and Figure 27 for 2020s and 2080s respectively.

The graphs show that of all passive measures, the implementation of external window shading and increased ventilation are the most effective measures in lowering internal temperatures in comparison to the base case (Test 1). The implementation of increased ventilation was achieved by doubling the window openable area per zone from 15% (Test 1) to 30% (Test 2) and was able to reduce internal temperatures by approximately one degree during daytime. External window shading had a similar effect. In particular, three external window shading methods were tested:- window shutters of low (Test 5a) and high reflectivity (Test 5b), closed on sunny days, and permanent louvres (50mm deep) and combined with side fins (Test 5c), as shown in Figure A 2 of Appendix 4, to ensure that lower sun angles are blocked. While there was no measurable difference between the first two, the effect of shutters resulted in marginally lower internal temperatures by approximately 0.2 °C in comparison to the implementation of permanent louvres and side fins.

While the daytime temperature lowering effects were similar for both external window shading and the increase in window openable area, the night-time temperature averages were lower with the latter by up to 0.5 °C. Internal shading (Test 4) proved to be significantly less efficient in comparison to external shading, since it only managed to lower base case temperatures by up to 0.2 °C. Similarly, the effect of reducing heat losses from the pipework running through the building, by ensuring the heating circulation system is switched off in the summer, revealed a surprisingly marginal effect in internal temperatures, although the assumptions associated with pipework heat losses need to be investigated further to ensure they are accurately represented in the simulations.

The combination of the two best performing passive measures was also tested. The joint implementation of external shading and increased ventilation (Test 8) led to approximately 1.5 and 2 °C lower temperatures in 2020s and 2080s respectively. The louvres and side fins were the preferred external shading type in this scenario. Although they present a slightly lower performance when compared to the shutters ‘as simulated’, they were considered to be the best option for two reasons: (a) they minimally obstruct views and (b) shutter operation for the simulation purposes was modeled optimally such that shutters were assumed to be closed whenever the window was receiving direct sunlight. However, in reality manually operated shutters are not likely to be operated in the same way.

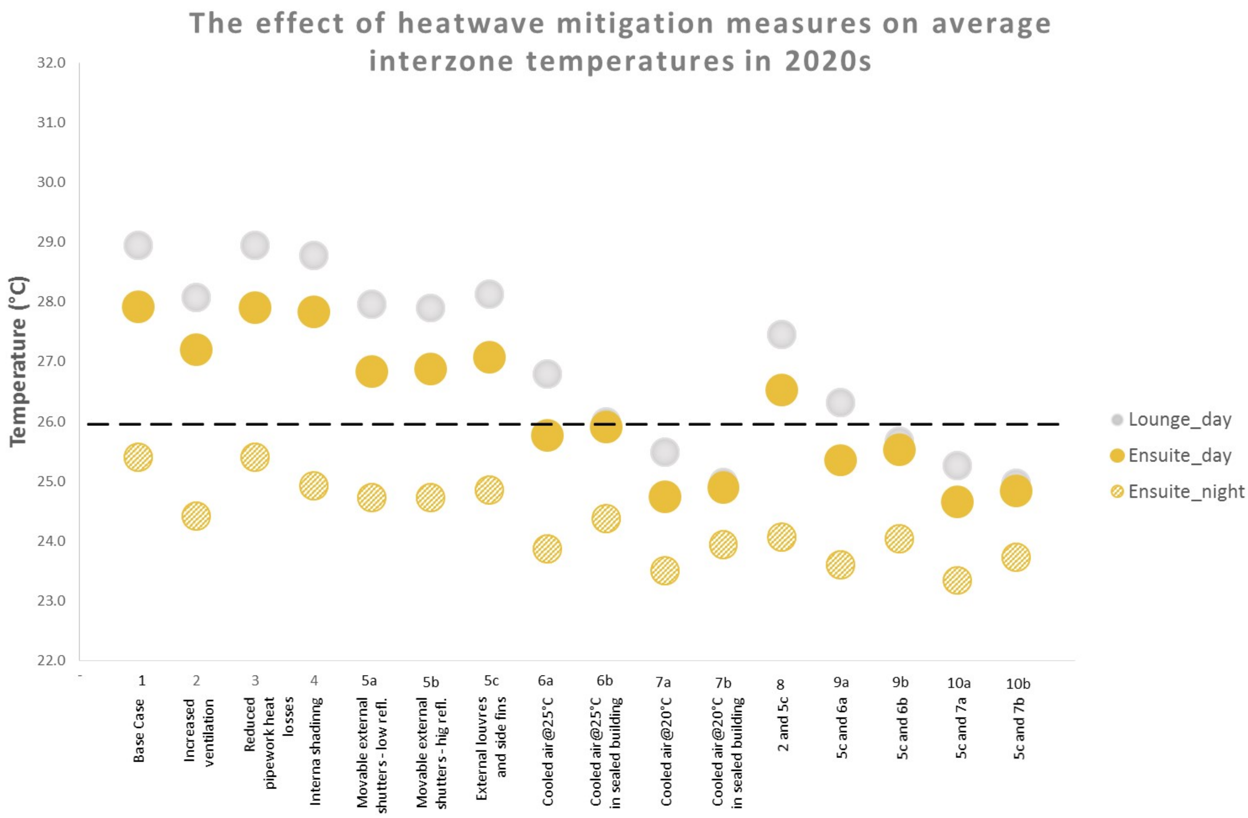

Figure 26. Average daytime and/or night-time building interzone temperatures during the 11-day heatwave period under base case and alternative scenarios in the 2020s – the 26 °C overheating threshold is marked with a dashed line

Unfortunately, not even the best performing passive measure scenario (Test 8) is able to keep average internal temperatures under the 26 °C threshold for daytime temperatures in the 2020s and for both day- and night- time temperatures in the 2080s. For this reason, a number of active measures were tested both with and without the contribution of passive measures. This involves the implementation of cooled supply air through a centralised mechanical ventilation system. Tests 6a and 7a allow natural ventilation but ensure that the supplied air does not exceed 25 °C and 20 °C respectively while test 6b and 7b represent a 25 °C and 20 °C cooled air supplied in an air-tight building, where natural ventilation is not allowed. Then, the same mechanical and/or natural ventilation settings were coupled with external window louvres and side fins to investigate their combined effect (Tests 9a, 9b, 10a and 10b). The results show that a cooled air supply at 25 °C can effectively lower internal temperatures under the 2020s-climate projection scenario, which remain under the 26 °C threshold for all zone types and day times only when combined with external shading and a sealed building (Test 9b). Moving into the 2080s however, (Figure 27), all average internal temperatures investigated remain under the 26 °C threshold only if the air supply is cooled at the significantly lower temperature of 20 °C (Test 10b).

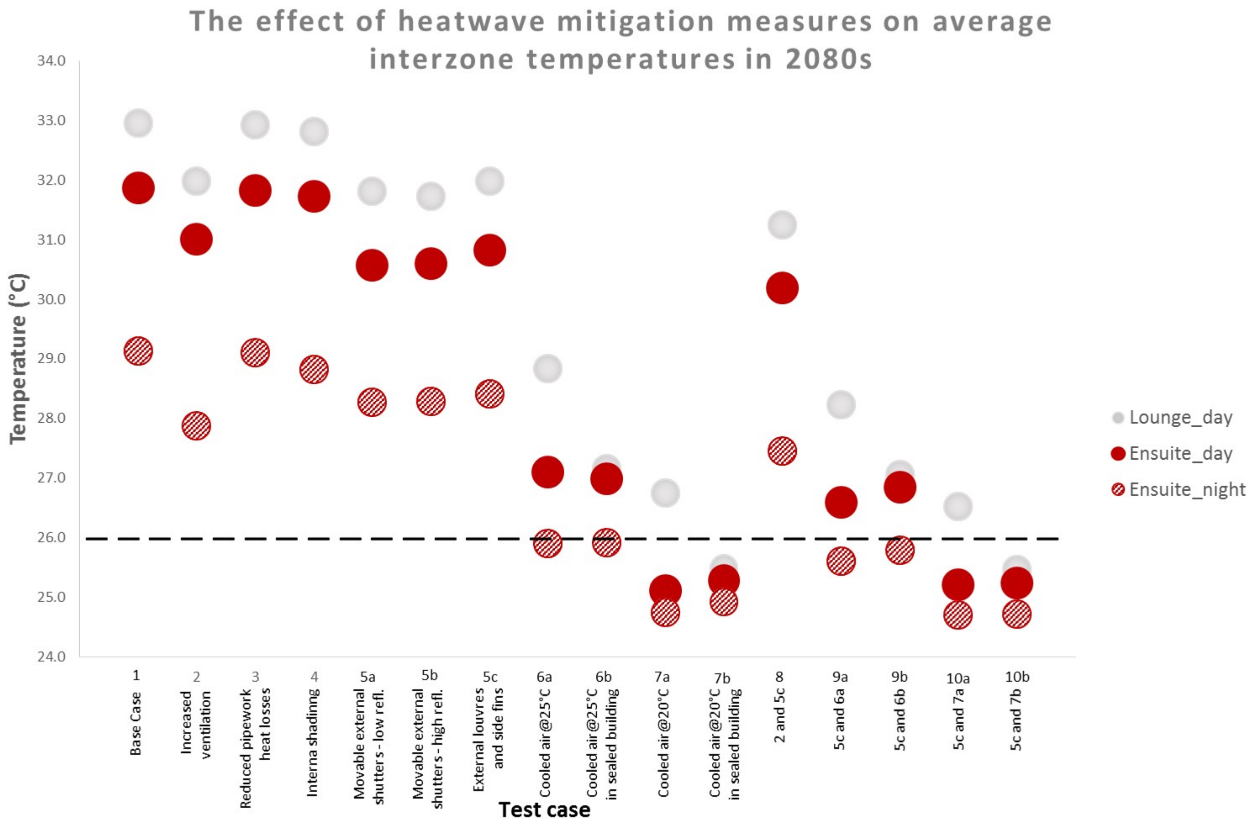

Figure 27. Average daytime and/or night-time building interzone temperatures during the 11-day heatwave period under base case and alternative scenarios in the 2080s – the 26 °C overheating threshold is marked with a dashed line

Figure 28 represents the hourly temperature distribution in a typical ensuite (R77, third floor) under the base case and selected interventions tested in the 2080s climate. The graph shows that the joint implementation of external shading and an increased openable window area (Test 8) is more effective in reducing internal temperatures rather than shading alone (test 5a). However, there is a high internal temperature fluctuation that is significantly higher during daytime and can only be lowered using mechanical cooling. When cooled at 25 °C, the air supply can lower both day- and night- time temperature appreciably, even in a naturally ventilated building (Test 6a). When combined with external window shading (Test 9a) or a sealed building (Test 6b) the temperatures can be lowered further but can only remain at around or below 26 °C when the cooled air supply is combined with both a sealed building and external window shading.

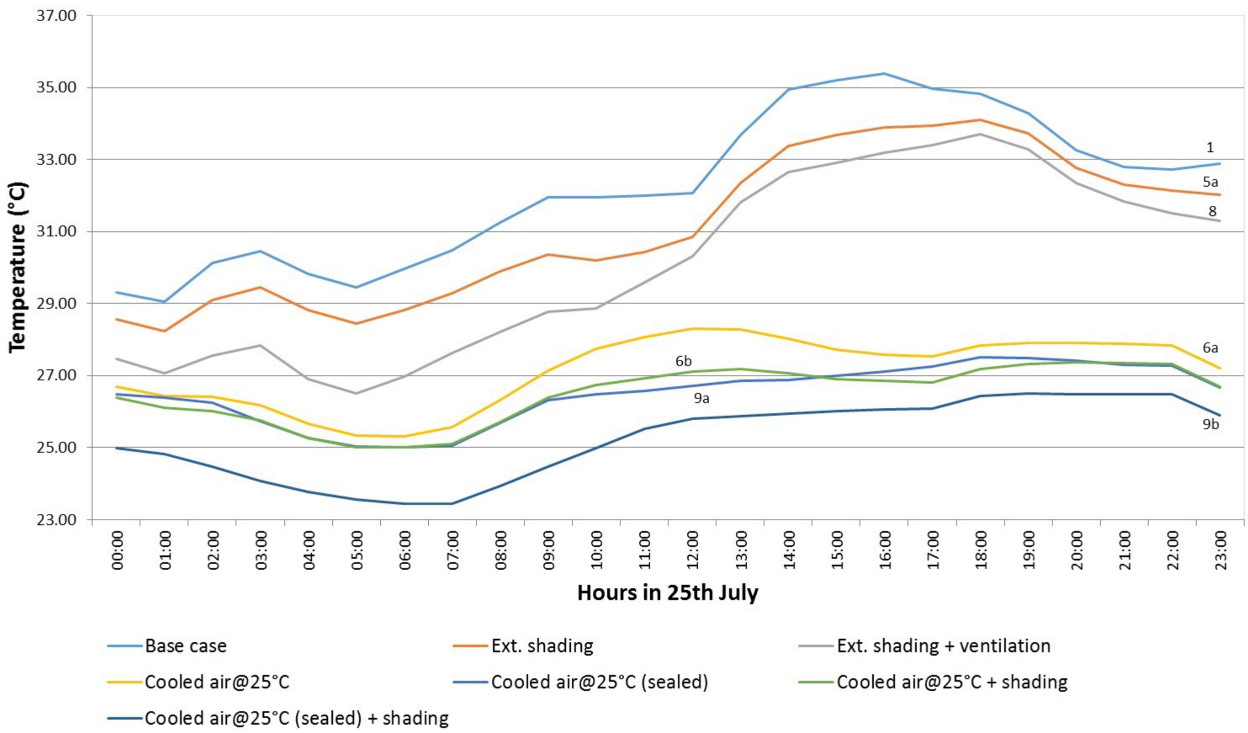

Figure 28. Hourly temperature distribution in a third floor SE facing ensuite (R77) under the base case and selected alternative scenarios in the 2080s

5. Discussion and key findings

This report provides the findings into the care home's indoor and outdoor environment over a period in the late winter/early spring of 2019 through monitoring and social surveying and over a warm summer weather period, under the current and future climates, through the implementation of thermal modelling analysis. This section discusses: - how the modelled data relates to the 2019 summertime monitored data that was subsequently obtained through the ClimaCare project (Appendix 2), presents the key findings from each investigation method, discusses their limitations and contributions and introduces the accompanying recommendations report.

Validation against actual measurements from the ClimaCare project

Following the 2019 summertime monitoring, the hourly modelled internal temperatures were compared with the real collected data to test confidence in the model's predictive ability. The comparison depicted the presence of a significant temperature difference between day and night in both lounges and ensuites, However, the monitored internal temperatures fluctuated significantly less and remained at much higher levels during night-time than those predicted by the model. Contrary to the modelled output for 2020s, where night-time internal temperatures for both lounges and ensuites appear to stay close or below the 26 ˚C overheating threshold most of the time, the night-time monitored data remains well above this threshold. Both the modelled and monitored data agree that internal temperatures tend to increase with higher floor level. Even though the modeled output showed that higher temperatures throughout the day was more likely to be experienced in lounges, the real data measured in two ensuites indicated that they generally maintained higher temperatures than lounges. However, this comparison is caveated by the fact that (a) only a limited number of rooms was monitored and thus was available for validation purposes and (b) internal temperatures were compared under heatwave periods of substantially different lengths and of similar but not identical weather conditions.

Overall, these findings indicate that the model is well specified in part but should be calibrated to provide a better fit with experimental data. The discrepancy is likely to be attributed to an overestimation both in terms of the building's ventilation capacity and the lounges' internal heat gains and an underestimation of its thermal mass capacity. This will be explored further as part of the ClimaCare project, as the brief extends beyond the scope and duration of the current audit pilot project.

Key findings from the monitoring survey

The monitoring period from the 7th March to the 1st April 2019 has given insight into the indoor environmental conditions of the case study building. Key findings from the environmental monitoring were:

- Temperatures in resident areas (both lounges and bedrooms) were in 26-28 °C range for the majority of time. Outdoor temperatures were in the 7-11 °C range for the majority of time during the same period.
- Temperatures in the monitored office on the ground floor were significantly lower than in the other monitored areas (in the 22-23 °C range for the majority of the time).
- However, as several other offices and staff rooms are located on the same floor as residents' rooms, these (according to staff members interviewed) experience similar high temperatures to the rest of the floors.
- The relative humidity levels were generally in the 25-35% range, good for keeping mould and condensation levels down, but increasing the risk of viruses being able to spread.
- CO_2 concentrations were well within acceptable limits even during this cooler part of the year when windows were more likely to remain closed.
- Residents on the 1st floor with rooms that open out onto the outdoor space can open their doors for additional ventilation and cooling.

Key findings from the interviews with residents, carers and staff

The main findings from the two residents, two carers/nurses and one manager that was interviewed are summarised below:

- The small sample of residents interviewed were comfortable with temperatures in the 26-27 °C range.
- Residents knew that being too cold could pose a risk to their health (for example, by exacerbating asthma symptoms) but trusted that the radiators can maintain comfortable temperatures.

- Due to diminished independence, residents relied on asking staff to control radiators, provide extra clothing, blankets or bedding, or to open/close windows and doors to maintain a comfortable indoor environment.

- Staff members appeared to be more aware of the negative effects of overheating in the summer but would put the needs of the residents before their own needs.

- Staff members' main method of keeping cool during hot weather was to drink more water.

- Staff members were aware of the increased health risks of residents getting too cold but said that these were rare occurrences in the building. Several also mentioned the health risks associated with residents getting too hot.

Key findings from the analysis of the thermal modelling data

The modelling and analysis provided further insights in the following areas:

- Current modelled internal building temperatures during a simulated 11-day heatwave period, are likely to increase by approximately two degrees in the 2050s and four degrees in the 2080s.

- Of all the lounges, those on the ground and first floor presented the lowest temperatures, and especially those facing the building's inner courtyard. Top floor ensuites presented the highest temperatures.

- The most efficient passive measure in the reduction of internal overheating was found to be the combination of external window shading and increased ventilation through a larger openable window area. However, passive measures alone did not succeed in maintaining average internal temperatures below the 26 °C overheating threshold in the 2020s (daytime) and 2080s (both day and night).

- The most effective method to reduce overheating was found to be the provision of cooled supply air in a sealed building with external window shading.

In conclusion

It was not possible to obtain summertime monitoring temperatures during the course of the audit pilot study and thus calibrate the dynamic thermal model accordingly, due to the limited and fixed timescale. However, the monitoring data collected at a later stage as part of the ClimaCare project was compared against the thermal modelling output and provided some confidence in the model. If time permitted, some useful information could have been also provided on the quality of the model by modeling the care home during the winter monitoring period as well.

However, the heating season monitored data is still important/useful as overheating and heat related mortality can occur all year round, even when external temperatures are low, depending on the heating system settings and controls. In addition, the output from this audit pilot study will be further utilised and validated through the detailed environmental monitoring deployed as part of NERC's ClimaCare project. The insights from the heating season monitoring can further enhance/complement the ClimaCare project, which look into the summertime overheating risks and possible adaptation measures in more detail.

This audit pilot case study was not meant to test the effectiveness of an exhaustive list of overheating solutions but rather provide some preliminary proof of concept results to demonstrate the efficacy of the proposed approach.

Overall, the audit pilot case study results during the monitoring period indicate little risk to the residents in terms of underheating, a potentially increased risk of the spread of viruses due to the low RH levels and a significant potential for the observed overheating to increase both in terms of intensity and duration during the non-heating season. Staff members made it clear that underheating had never been an issue in the care home but overheating, particularly in the summer, had been a concern.

The residents appeared content with their indoor environment, and confident that controlling the radiators was enough to maintain comfortable conditions both in the winter and the summer. The thermal modelling analysis revealed that summertime internal temperatures are currently likely to be well above 26 °C during daytime in ensuites and lounges but seem to cool down significantly during the night. Internal temperatures are likely to increase by approximately 4 °C by 2080s, setting night-time temperatures also well above 26 °C and daytime temperatures at dangerously high levels.

The results and findings highlighted earlier in this report are further interpreted and compared with evidence from literature in the accompanying recommendations report to provide:

- Consideration by the CQC to include overheating risk due to climate change in their inspection assessments of care homes.
- Insights into the factors contributing to heat exposure in the pilot care home.
- An understanding of other schemes in the local area.
- Recommendations for outdoor and indoor measures that the specific care home could adopt to reduce indoor overheating and its residents’ temperature exposure.
- Recommendations on activities, initiatives, behaviour change interventions.
- Policies that the care home could adopt to further reduce overheating and/or exposure to heat.

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Appendix 1

Audit checklist

The following checklist was based on the SAP and Carbon Trust surveying frameworks.

Technical paperwork	Data collected	Comment
Architectural drawings, including floor plans, sections and facades		
Energy Performance Certificate (EPC) / detailed SAP calculation documentation		
Display Energy Certificate (DEC)		
Advisory Reports		
Maintenance Records		
Equipment documentation		
Energy bills		

Space Heating (SH) and cooling	Data collected	Comment
Identify heated/unheated areas		To be noted on floor plan
Main SH system type		
Main SH emitter type		
Main SH controls (Room thermostat, programmer, TRV, bypass, flow switch) – check setpoints		
2nd main SH type (if applicable)		
2nd main SH emitter type (if applicable)		
2nd main SH controls (if applicable)		
Secondary SH system (if applicable)		
Cylinder/pipework insulation level		
Space cooling present?		
Are there any areas of over- or under- heating?		

Ventilation and occupancy	Data collected	Comment
Identify occupancy patterns per zone		To be noted on floor plan
Ventilation types utilised (natural, extract only, MVHR etc.)		
Mechanical ventilation controls		
Location of mechanical ventilation inlet/outlets		To be noted on floor plan
Window/door opening patterns		
Draught lobby present?		
Do exterior doors close automatically/quickly?		
Trickle vents present/utilised?		
Are there any draughts present?		

Lighting and other equipment	Data collected	Comment
Percentage of energy saving light bulbs		
Are there sensors for lighting control present, e.g. occupancy/daylight sensitive?		
Any unused areas lit?		
Other heat generating equipment present?		
Is equipment switched off when not in use or have energy saving features enabled, e.g. IT?		
Any RES systems present?		

Appendix 2

ClimaCare overview and preliminary outputs

The Climate Resilience of Care Settings (ClimaCare) is an interdisciplinary pilot project funded by the Natural Environment Research Council (NERC, NE/S016767/1) addressing the challenge of adapting UK care settings to climate change. ClimaCare work initiated in October 2019 and is due to be completed by July 2020. The project brings together research teams from University College London (UCL), Oxford Brookes University (OBU) and the London School of Hygiene and Tropical Medicine (LSHTM), who are working closely with a very active team of non-academic project partners, i.e. the MetOffice, Care Quality Commission (CQC), Public Health England (PHE), Chartered Institution of Building Services Engineers (CIBSE), Greater London Authority (GLA) and PRP Architects. The project partners form the Project's Advisory Board (PAB) that regularly review the direction of the research, advises on how the research is conducted and on how its impact can be maximised both in the UK and internationally.

Aims and objectives

The project's aim is to undertake feasibility work by developing novel methods, knowledge and insights that will enable care provision in the UK to become resilient to rising heat stress under climate change. The specific objectives are to:

- undertake pilot work in five care homes in London to monitor their thermal environments and conduct surveys with frontline care staff and managers regarding the challenges of heat;
- test novel approaches for understanding the comfort levels of care home residents and relating this to the thermal environment;
- test novel measurement techniques for assessing the impact of heat exposure on the health of residents;
- test methods to assess future overheating risks in care settings and evaluate the effectiveness of overheating mitigation strategies on thermal comfort and health outcomes;
- bring together multidisciplinary research perspectives with those of care home practitioners and other stakeholders and use them to plan a large-scale, interdisciplinary study.

Methods

The ClimaCare project has developed a research approach to understand the summertime conditions experience by residents and staff across a range of care homes. The case study recruitment process involved approaching all London-based care homes identified either directly through CQC's database or indirectly through the assistance of CQC. The five care homes recruited, including Victoria Care Centre, which was recruited and utilised as a case study for the GLA's Care Home Overheating Audit Pilot Project, are in various parts of central, west and north-east London and incorporate a range of characteristics in terms of occupant capacity, building typology and age and type of construction. Their heat vulnerability is investigated through environmental monitoring and surveys, measurement of core body temperature, dynamic thermal modelling of future overheating risks and investigating the effectiveness of different strategies for reducing the risk of overheating under a range of current and future climate scenarios. Unlike the GLA's Care Home Overheating Audit Pilot Project monitoring that took place in one case study for just over three weeks (7^{th} to 31^{st} March 2019), the ClimaCare monitored five case studies over a period of approximately three and a half months (1^{st} June – 19^{th} September 2019).

Indoor and outdoor environmental monitoring

Hydrothermal loggers were utilised to record dry bulb temperature and relative humidity at repeated time points in resident rooms, communal spaces, offices, as well as outdoor temperatures in close proximity to the monitored buildings during the summer of 2019.

Social surveying

The environmental monitoring was accompanied by occupant surveys to relate the residents' thermal sensation with the indoor environment, activity and clothing levels. Semi-structured interviews were also conducted with frontline staff carers, managers and building professionals to enhance end-to-end understanding of how overheating is currently managed in practice and assess existing environmental, behavioural and organisational barriers to the implementation of heat risk mitigation strategies in such settings.

Core temperature and heart rate monitoring

The psychological responses to high ambient temperatures are assessed in a subset of 20 randomly-chosen care home residents. On selected hot weather days, participants are asked to (a) provide information on their activities and thermal comfort sensation at regular intervals, (b) ingest a telemetric temperature monitor to measure their core body temperature and (c) wear a heart rate monitor that measures changes in resting heart rate. This aspect of the ClimaCare study was not an element of GLA's Care Home Overheating Audit Pilot Project. ClimaCare aims for it to be deployed in all five case studies.

Dynamic thermal modelling

The physical, technical and user characteristics of each building to be used as input in the EnergyPlus V8.9 dynamic thermal simulations were established via physical surveys. The performance of the thermal models was compared against the monitored temperatures. Following the testing and calibration, current and future overheating risks were quantified using the CIBSE weather files for the 2020s high emissions (50th percentile) and 2080s low- and high- emissions scenarios (50th percentile). The 2020s weather file represents current climate and the 2080s low- and high- emissions scenarios are representative of the projected 2°C and 4°C Global Mean Surface Temperature (GMST) increase above pre-industrial levels [1]. The effectiveness of a wide range of climate change adaptation and overheating mitigation strategies were tested, such as behaviour change, management practices, building design, retrofit and operation.

Community building

The multidisciplinary research perspectives in the areas of climate science, building thermal simulation, building monitoring and health are drawn together through the ongoing engagement with non-academic stakeholders and focus-group based workshops to explore (a) ways of working and developing plans of interventions that could be tested in subsequent larger-scale work and (b) explore implications for guidelines and regulations relating to the design and operation of care settings from the perspective of thermal comfort.

Emerging findings

The preliminary project findings show that the care home age may play a critical role in overheating. Staff and residents in older, heavyweight buildings were less likely to feel hot in the summer. Monitored summertime temperatures were generally higher in bedrooms than lounges and average daily temperatures were between 23 and 29 ºC, with the exception of heatwave periods, when they soar well above 29 ºC. The daily maximum temperatures recorded ranged between 31.2 ºC and 34.3 ºC. Residents appeared to be content with their conditions, even at temperatures in excess of 30 ºC while members of staff consistently described their conditions as warmer than reported by the residents. However, staff members were willing to tolerate uncomfortably hot temperatures if they felt it was in the residents' best interest.

Initial analysis from the dynamic thermal modelling of the five case study care homes during a five-day heatwave period (22 – 26 July) indicated that the average internal temperatures experienced by active and bedbound occupants are expected to increase by approximately the same degree as average external temperatures, i.e. 1.5 ºC and 3.9 ºC under the 2080s low- and high- emissions scenarios, respectively. The modelled 2020s average internal temperatures remained predominantly above 26 ºC in all case study care

[1] DEFRA. The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting: Making the country resilient to a changing climate (2018)

homes and were projected to remain at significantly higher levels under the future climate scenarios. A combination of selected soft- and hard- engineered passive strategies reduced temperatures between approximately 1.3 ºC and 4.4 ºC, depending on the building type. However, they were not able to reduce average temperatures below the 26 ºC threshold, under any of the climate scenarios tested. The findings indicated that older buildings with higher heat loss and thermal mass capacities are likely to benefit more from the application of high albedo materials rather than external shading methods, whereas newer and highly insulated seem to benefit more from higher ventilation rates and appropriate external shading systems. Overall, modern buildings were found to benefit more from passive interventions rather than older buildings, with the latter maintaining slightly lower temperatures at all times. Night ventilation emerged as the single most impactful passive technique for all building types.

A national scale follow-up project

Building on the foundations of the ClimaCare pilot project and taking into account the findings from the GLA's audited care home, Victoria Care Centre, the follow-up *Governing the Climate Adaptation of Care Settings* project proposed by the ClimaCare team has been funded by the UK Research and Innovation (UKRI). This is a 28 month larger-scale interdisciplinary study, with a start date from 1 May 2020. This novel interdisciplinary project aims to quantify climate related heat risks in care provision at a national level, and enhance our understanding of individual behaviours, organisational capacity and governance to enable the UK's care provision to develop equitable adaptation pathways to rising heat stress under climate change. It will collect, for the first time in the UK, longitudinal temperature and humidity data in a panel of 50 care settings in order to quantify the recurring risk of summertime overheating. The project will also identify and assess social, institutional and cultural barriers and opportuniyies underpinning the governance of adaptation to a warmer climate in care and extra-care homes. The team will work closely with stakeholders from a range of disciplines to participate in the development of health and climate resilient care setting case examples. The project aims to generate impact scenarios along three main pathways:

Pathway 1

By providing building construction practitioners responsible for the design and delivery of healthy care homes with improved climate change adaptation design and decision making tools. This will facilitate the development of best practice guidance provided by professional organisations and associations.

Pathway 2

By providing policymakers and regulators, such as the CQC, with evidence based recommendations to help revise regulation and policies pertaining to thermal comfort and energy efficiency in care settings.

Pathway 3

By providing care home managers, frontline staff and residents with best practice guidelines for the optimum operation of care environments in a warming climate.

Quality control process

The project methods, findings to date and future work proposal presented here have been discussed in detail by all project partners during the regular PAB meetings. They have also been reported extensively in project workshops and presented to the CQC, as part of the Adult Social Care (ASC) Extended Leadership Team meeting.

Appendix 3

Interview guide

1. FEELINGS

At present I feel:

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

2. PREFERENCE

I would prefer to be:

Warmer	A bit warmer	No change	A bit cooler	Cooler

3. CLOTHING

Tick as appropriate:

Short sleeve shirt/blouse	Long sleeve shirt/blouse	Trousers/ long skirt	Shorts/ short skirt
Vest	Dress	Pullover	Jacket
Short socks	Long socks	Tights	Tie
Shoes	Sandals	Boots	
Other (specify)			

4. ACTIVITY

In the last 15 minutes:

Sitting (passive work)	Standing relaxed	Walking indoors
Sitting (active work)	Standing working	Walking outdoors
Other (specify)		

5. CONTROLS

Tick as appropriate:

Internal door open	Blinds/curtains down	Air conditioning on	Fan on
Window open	Lights on	Heating on	Extra heater on
Other (specify)			

Appendix 4

Building layout/structure

Figure A 1. Victoria Care Centre floor plans showing the location of the bistro, lounge and the ensuites selected for the temperature analysis

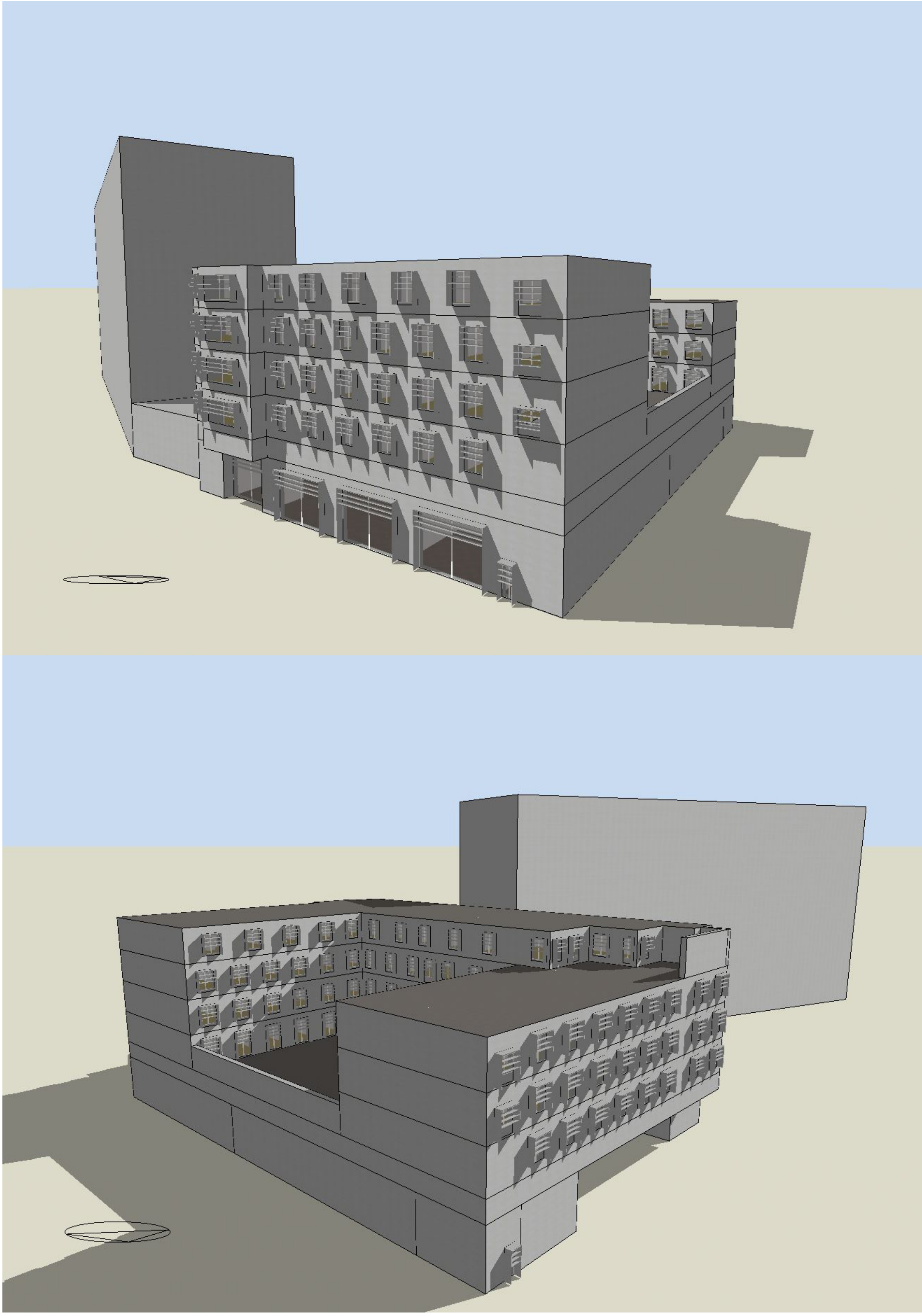

Figure A 2. Rendered views of the DesignBuilder model incorporating external window louvres and side fins

Appendix 5

Supplementary graphs

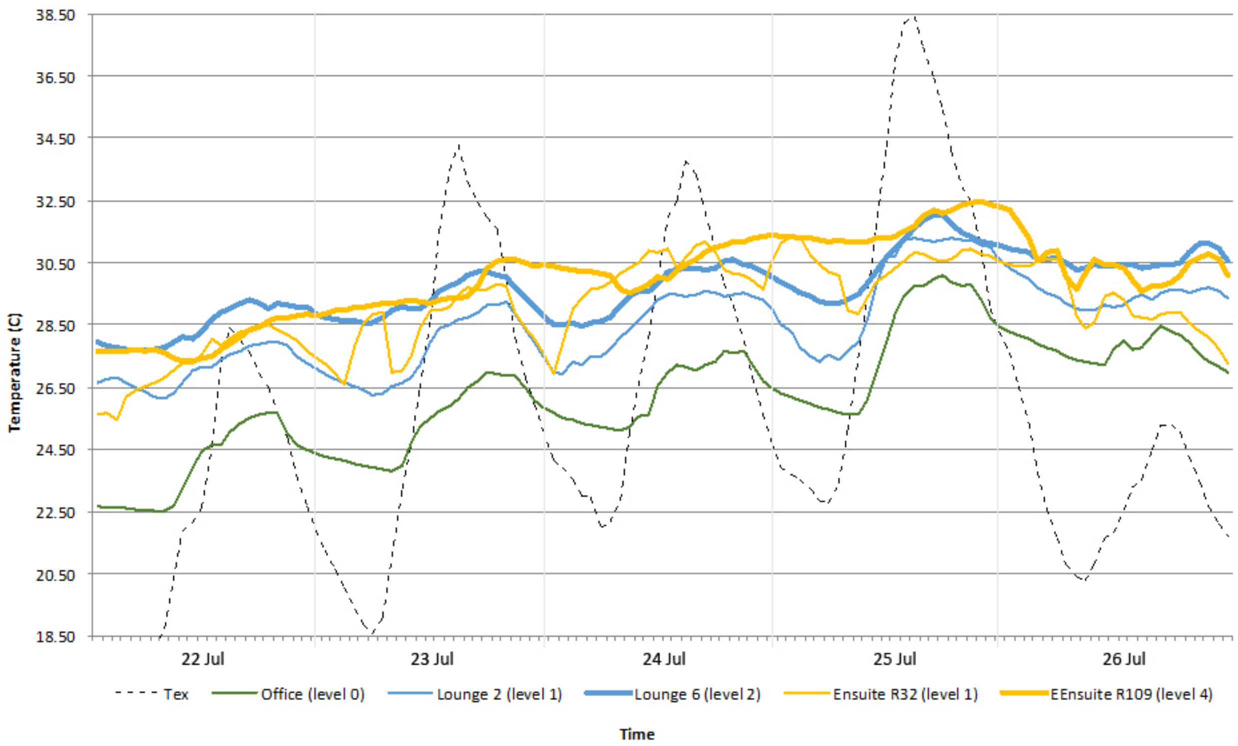

Figure A 3. Average hourly external temperature (Tex) and internal temperature distribution in different rooms and floors (levels 0-4) of Victoria Care Centre, as measured on site

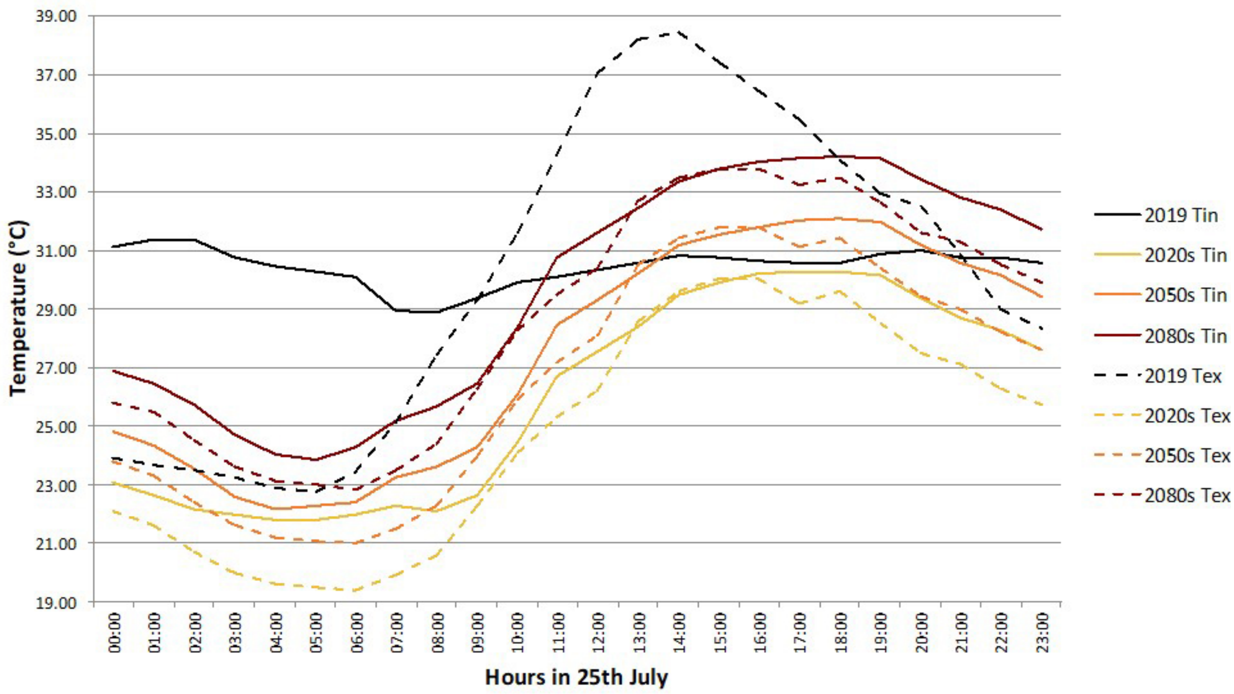

Figure A 4. Internal temperature distribution, compared with external temperatures, in a first floor ensuite (R32) as measured on site in 2019 and under different weather files

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