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BRE Client Report

Assessment of Overheating Risk in Buildings Housing Vulnerable People in Scotland

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Executive Summary

Increased overheating of buildings is a potential impact of a changing climate, and vulnerable people are often at greater risk from the direct and indirect impacts of overheating in buildings. Furthermore, thermal comfort is a complex issue as it depends on a number of environmental factors (including air temperature, radiant temperature, air speed and humidity) and personal factors (including age, gender, state of health, clothing level and activity level). To date there is only anecdotal evidence of overheating being a problem in healthcare buildings housing vulnerable people in Scotland. This scoping study, completed by BRE on behalf of ClimateXChange aims to:

- Identify what information and data is currently available to inform future research into the potential impacts of overheating in buildings housing vulnerable people in Scotland.
- Assess how extensive, accessible and robust this data is, assess whether the data could be usefully applied within future research, and consider whether additional data will be required (including making practical recommendations to assist the collection of relevant data to inform future work).
- Obtain insight to any overheating mitigation measures that may have been undertaken in a sample of facilities, highlight relevant best practice and make recommendations to help inform and shape future research in this area.

The study, which considered 5 x sample hospitals with in-patient facilities (each of which have been operational for significantly different lengths of time, vary in size and generally employ different design principles in terms of their form, layout and original energy design), is based upon questionnaire responses from facility teams, site visits / walk-around surveys, and investigation and analysis of any suitable data at the sites.

It should also be noted that, due to the small sample size contained within the project the findings, conclusions and recommendations summarised below may not be representative of other facilities of similar age, size, design, use, etc., as a number of local, site-specific, personal, operational, and/or other issues may have influenced the responses and other findings obtained during the study.

<u>Conclusions and Recommendations</u>

Given the complex, and in many cases, site specific nature of thermal comfort and overheating issues in hospital buildings, it may not be appropriate to link / group common overheating ‘issues’ to common hospital archetypes.

Whilst all sites generally aim to operate with a target operational temperature in the region of 21 to 22°C, there is anecdotal evidence of overheating issues being present in four out of the five sites examined within the study, at least at certain times of year, under specific external conditions or in specific areas of the facility (e.g. south facing facades). The zoning and control of the heating systems, solar gain, and lack of effective natural ventilation were identified as the most significant, and common, contributors to overheating in the five sites that were studied. Encouragingly, all five sites advised that, in addition to direct risks to patients, they were also aware of the potential for indirect risks from overheating (e.g. potential impacts on raising cold water temperatures to temperatures that could increase risk from legionella) and all suggested that they were mitigating this risk. Additional overheating related issues such as the risk of fatigue to medical staff from overheating was also raised at one site.

Whilst anecdotal evidence of overheating was identified, the study found a significant lack of data that would enable a robust assessment of overheating in in-patient areas. All properties have a Building Energy Management System (BEMS) however, such systems are designed primarily for the purposes of controlling heating and/or ventilation plant. As such, owing to the fact that they operate with a small number of sensors, distributed in locations for the purpose of system control and not in relation to the in-patient areas of interest, the existing systems are generally unsuitable for recording data (e.g. air temperatures or similar) that would enable a robust assessment of comfort.

In terms of mitigation measures, the study found that all sites generally used openable windows, local fans and curtains/blinds to mitigate overheating, although sites reported different levels of success with these measures. Additional measures used by some sites included the use of window films as well as calls to the Estates helpdesk to investigate overheating / turn heating down/off. None of the sample sites measured (objectively or subjectively) the effectiveness of the mitigation measures despite anecdotal evidence of continued requests for supplementary fans from wards and offices.

As no robust or easily interrogate-able data is logged or otherwise available, the study recommends that consideration be given to undertaking a programme of cost effective monitoring (of selected in-patient facilities) to capture data that will enable a robust assessment of the nature and severity of overheating at selected sites. Further consideration will however, need to be given as to which sites should form the basis of such a future study, so that any future works can maximise learning. For example, this study has highlighted that ventilation strategies, heating plant zoning and control (or the lack thereof) are likely to be contributing factors to overheating however, system zoning and control (and ventilation system design and use) is likely to vary significantly from site to site and will therefore typically require site specific solutions. Further work may therefore wish to be considered in terms of developing appropriate general guidance, overheating mitigation principles and/or system design / amendment / refurbishment scenarios (including case studies) to help inform NHS Boards of how best to tackle overheating.

Consideration should also be given to engaging with building users, as well as knowledgeable personnel within Estates teams, during this process as some individuals will have considerable knowledge in the issues affecting their facilities and the suitability (or otherwise) of retrofit solutions.

Table of Contents

1 Introduction and Project Aim

To date there has been no significant research that has assessed the current, or projected, thermal comfort performance of Scottish healthcare buildings or buildings housing vulnerable people despite anecdotal evidence that overheating is an issue in some NHS facilities and care homes. Vulnerable people are often at greater risk of the direct and indirect impacts of overheating as they can be aware of discomfort but may be less able to assess the reason for, or nature of this, and overheating risk can be further exacerbated due to a changing climate as well as energy efficiency refurbishment works as we aim to reduce carbon emissions. Research is therefore needed address this gap in knowledge, and to help identify current, and future, risks and identify appropriate mitigation measures.

A project steering group consisting of ClimateXChange, Scottish Government, Health Protection Scotland, Health Facilities Scotland and Adaptation Scotland, was set up to consider this issue and ClimateXChange has commissioned the Building Research Establishment Ltd (BRE) to deliver an initial scoping study in order to assess the feasibility of undertaking future research to identify the current and future risk of overheating in buildings housing vulnerable people in Scotland, as well as potential measures to mitigate risks.

The aims of the scoping study were as follows:

- To identify what information and data is currently available to inform future research into the potential impacts of overheating in buildings housing vulnerable people in Scotland.
- To assess how extensive, accessible and robust this data is.
- To assess whether the data could be usefully applied within the future research.
- To consider whether additional data will be required and to make practical recommendations to assist the collection of relevant data to inform the future study.
- To obtain insight to any overheating mitigation measures that may have been undertaken in facilities.
- To highlight relevant best practice and make recommendations to help inform and shape the future research project.

This report presents the findings of the study.

2 Project Methodology and Description of Works

An inception meeting was held with the project steering group on the 9th February 2017 and a proposed methodology was developed and agreed. This included the following key stages:

- Stage 1: Assess the NHSScotland building stock asset data with a view to categorising assets (suited to the purposes of the study) and identifying suitable sample properties
- Stage 2: Collect and assess the extent, and suitability, of existing data via engagement with 4 x representative, sample, properties across different regional NHSScotland Boards
- Stage 3: Make recommendation to enable suitably robust data capture

The methodology and findings related to each stage is explained in more detail below.

2.1 Stage 1: Building stock analysis / Sample property selection

NHSScotland comprises 14 regional Health Boards and 8 national Special Boards and a significant number of building assets with in-patient facilities. In addition, the NHSScotland estate consists of a wide variety of ages of building, building types and building design. As well as needing to identify and select sample properties, the study also initially sought to consider if there was a relatively quick, and appropriate way, in which to categorise assets in the hope that the sample properties chosen represented various ‘common’ Scottish hospital design types so that maximum learning could be obtained.

2.1.1 Hospital ‘type’ classification

The steering group identified 6 broad classifications of Scottish hospital ‘types’ as being most common in Scotland. These are presented in Table 1 below which also includes details relating to ‘typical’ building features, construction and procurement methods typically adopted. Table 1 has been reproduced in Appendix A where a number of specific hospital examples of each classification (using data provided by the steering group) has also been listed.

Ref	Build date (approx)	'Typical' ward type design	Typical features	Typical construction	Procurement
A	pre mid-1950s	Nightingale	Open plan 8-30 multi-bedded room ward model, with shared ablution block.	Solid masonry wall, >3m high plaster ceilings, single glazed timber sash windows, natural vent, cast iron radiators, steam distribution, coal boiler.	Traditional
B	late 50s - early 60s	Racetrack	Mix of >10% 1 bed and 4 (or 6) bedded rooms, central support rooms incl. shared WCs, Showers etc.	Concrete frame, cavity infill panel, flat roof, 2.4 - 2.7m suspended ceilings; timber/steel single glazed windows, mix natural vent with extract from ensuites, bath & dirty utilities etc.; radiators, steam distribution, gas boiler.	Traditional
C	late 60s - early 80s	Falkirk	Mix of >20% 1bed and 4 (or 6) bed rooms, each with ensuite WC/ shower, around central support rooms.	Concrete frame, cavity infill panel, flat roof, suspended ceilings; aluminium single glazed windows, mix natural vent with extract from ensuites, bath & dirty utilities etc.; LST radiators, steam/ MTHW distribution, gas boiler.	Traditional

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D	late 80s - 2000	Courtyard	Mix of 30-50% 1 bed and 4 bed rooms, each with ensuite WC/ shower, typically in L, T or Y shape corridors, with support rooms alongside.	Steel frame, metal insulated panel cladding / pitched roof, some brick or rendered block, 2.4 – 2.7m suspended tile ceilings, aluminium double glazed windows (max 100mm opening); mix natural vent with lots of mechanical vent in specialist and support rooms etc.; radiant ceiling panel, gas boiler.	Design & Build / Design, Build, Finance and Manage
E	late 80s - 2000	CSA template	'Common Services Agency' (CSA) 30 bed; Typically comprising 6 x 1 bed and 4 x 6 bed (each with ensuite WC / shower).	Typically a one storey ward template. Usually built on existing hospitals sites, commonly for elderly or mental health patient services.	
F	2000 onwards	Finger	Mix of 50-100% 1 bed, and occasionally 4 bed rooms, each with ensuite WC/ shower, typically in long thin wings around open (occasionally closed) courtyards, with support rooms centrally and/or alongside.	Frame, highly insulated cladding panel / pitched roof, some brick or rendered block, suspended tile ceilings, aluminium double glazed windows (max 100mm opening); mechanical vent in majority of rooms, with some natural vent, where practical for patients; heat/chill ceiling beam, gas boiler with CHP or renewables. BREEAM 'excellent' target set.	Design & Build / Design, Build, Finance and Manage

Table 1: Built asset classifications applied during the study

It should be noted that the above are very broad 'typical' bandings and that classifications may overlap and/or certain assets may not fit strictly within the classifications due to time lag in the design/construction process given that time periods from 'inception' to 'opening to patients' can be between 5 - 10 years, or sometimes longer, for larger, more complex facilities. Occasionally there are also anomalies e.g. Golden Jubilee Hospital, Clydebank, which was constructed in era C but looks like era D due to a US concept design featuring 100% 1 bed rooms. Typically, NHS sites will also have multiple blocks from multiple eras, carrying out multiple functions.

Whilst other hospital design types exist elsewhere in the UK (e.g. Nuffield, nucleus, cluster, radial), BRE were advised that these types do not commonly occur in NHSScotland.

2.1.2 Asset data

BRE were provided with a spreadsheet (from Health Facilities Scotland (HFS)) that contained high level asset information for each of the regional Health Boards. The data included the following information (at both (i) site, and (ii) sub-block, levels): site name, block name/reference, tenure, Estates Asset Management System (EAMS) 'site type' classification, Gross Internal Area, build date and average staffed beds (although it should be noted that there were some gaps in information). The data was analysed in order to evaluate the usefulness of categorising assets by their classification types. Commentary on this analysis is presented in Section 4.

2.2 Sample property identification and engagement

Health Facilities Scotland provided BRE with relevant contacts and a suggested sample property at 4 x different NHS Boards. The properties were selected to provide a mix of eras for the study.

BRE made contact with the facility teams as the respective Boards through a combination of telephone calls, emails and/or follow-up meetings in order introduce the project, its aims, as well as to seek relevant buy-in. During this time the suitability of the proposed sites were discussed in order to confirm that they were suitable for including in the study.

The following issues were identified, and addressed, as follows:

- The originally proposed 'nightingale' site was found to no longer have any in-patient accommodation with patients being cared for within an adjacent 'Common Services Agency' (CSA) template ward type unit.. An alternative 'nightingale' unit was therefore identified and progressed.
- In light of the above, BRE chose to expand the study to include the CSA circa 30 bed unit as this type of unit is repeated fairly widely across Scotland, particularly for elderly and mental health services..

The following sites were therefore selected to form the basis of the project's data collection phase.

Site Ref.	Build Date	Classification	Classification Ref.
1	1886	Nightingale	A
2	~1990	CSA 30 bed template ward type	D
3	1977	Falkirk type	C
4	1988	Falkirk type	C
5	2011	Finger type	F

Table 2: The study sites

2.3 Stage 2: Collect and assess existing data

The data collection was facilitated via a combination of two methods: (i) development of a bespoke questionnaire which was then used to capture site specific information, and (ii) meetings and site visits with key personnel.

In order to ensure a suitable questionnaire was developed and any subsequent data is adequately assessed, it is essential to have an understanding of overheating and the issues affecting occupant thermal comfort. A short introduction to the issues are provided in section 3.0.

2.3.1 Questionnaire development

BRE produced 2 x short questionnaires (to be completed by the Boards) in an attempt to collect background information concerning:

1. The target facility, its energy systems and whether any existing monitoring exists, and
2. The Board's thoughts on overheating related issues and their experiences with mitigation measures.

The questionnaires are provided in Appendix B. The findings are presented and discussed in section 5.

2.3.2 Site visits

BRE also conducted a site visit to each of the target properties, the primary aim of which was to:

- Identify what information and data is currently available to inform the future research into the potential impacts of overheating.
- Assess how extensive, accessible and robust any available data is i.e. investigate whether facilities managers or Building Energy Management Systems (BEMS) record information on temperature, where this data is located and what form any existing data is in.
- To obtain insight to any overheating mitigation measures that may have been undertaken in facilities.

The findings are presented and discussed in section 5.

2.4 Stage 3: Recommendations to enable suitable data capture

The completion of stage 3 makes it possible to then consider whether any additional data will be required and what practical recommendations can be suggested in order to assist the collection of relevant data to inform the future study. These recommendations, which take account of the project findings, are presented in section 6.

3 Overheating and Thermal Comfort

Overheating can be assessed with respect to thermal comfort; health or productivity. Of the three forms of definition, the most commonly applied in the design of buildings is thermal comfort.

3.1 Thermal comfort

Thermal comfort itself has been defined in a number of ways. The International Organization for Standardization (ISO) Standard 7730:2005 defines thermal comfort as ‘that condition of mind that expresses satisfaction with the thermal environment’ (ISO 2005).

While this qualitative definition of comfort reflects more than ('dry bulb air') temperature alone, design criteria for avoiding overheating tend to focus on the assessment of temperature profiles under typical outdoor temperature conditions, and specifically the frequency, duration and magnitude of temperatures above specified thresholds.

Thermal comfort is however a complex issue as it depends on a number of personal and environmental factors. Environmental factors include air temperature, radiant temperature, air speed and humidity. Personal factors include age, gender, state of health, clothing (measured in ‘clo’), and metabolic levels (measured in ‘met’) as defined by Danish physiologist P.Ole Fanger (Fanger 1970). Due to these multiple influences, any definition of overheating in terms of thermal comfort needs to make reference to the circumstances and target groups to which that definition is applied. For example, an environment which is comfortable for someone who is physically inactive may be too hot for someone engaged in sustained physical activity.

3.2 Impaired Sleeping & Health Effects

Due to the 24-hour use of in-patient facilities, hospitals (unlike schools or traditional offices) can experience more frequent and/or prolonged excess heat conditions which can impact negatively on the general comfort of, and reduce sleep quality for, patients. According to Table 1.7 of the Chartered Institution of Building Services Engineers (CIBSE) Knowledge Series publication “KS16: How to manage overheating in buildings - A practical guide to improving summertime comfort in buildings” (July 2010, CIBSE), sleep can be impaired if temperatures in non-air-conditioned buildings exceed about 24°C. However Table 1.5 of the same publication gives a higher range of 23-25°C, suggesting that overheating does not really become an issue until the temperature exceeds 25°C. As noted elsewhere, overheating is however, not only a function of temperature but also other factors including age, gender, exposure to temperature over time, level of clothing, activity level, personal environmental control, etc.

In more extreme situations, 'excess' heat exposure can further impact on health and even lead to fatalities. Excess heat-related mortality includes a continuum of illnesses resulting from the body's inability to cope with excess heat exposure. Heat vulnerable groups include the elderly (above 65 years old), the very young, the chronically ill (e.g. people suffering from cardiovascular or respiratory diseases, or mental illness) and socially deprived population groups (Kovats & Hajat 2008a). Presently however, the incidence of cold-related deaths is markedly higher than that of heat-related deaths.

3.3 Optimal and reasonable conditions

Vulnerable persons (such as some of those in hospital or living in care homes) tend not be as adaptable to changing conditions particularly when we consider sensitivity to changing conditions and their reduced ability to cope with such changes. Discomfort arising from overheating can lead to tiredness, irritability and reduced concentration, and in the case of vulnerable persons, risk to health arising from extremes of temperature becomes a priority.

Owing to variations between individuals, their activity levels, clothing levels, medical conditions and medical procedures (e.g. dialysis, connection to monitoring equipment, etc.), the determination of optimum conditions for every person is not possible. For example, within a particular space one person might desire a higher temperature while another person might desire a lower temperature. In addition, sedentary persons are more sensitive than active persons to changes in temperature. This makes the task of setting reasonable limits for temperature and other environmental parameters a complex matter.

However, extremes of temperature, noise, light levels and airborne pollutants (including dust) will reduce the performance of mental tasks (ref: §1.1.3 of CIBSE Guide A3) potentially affecting staff, and certain conditions will confer a risk to vulnerable patients who may be affected by their infirmities or by underlying medical conditions.

3.3.1 Adaptability

Gupta (2017) points out that "the more vulnerable the occupant, the less likely they are to adapt to changes in temperature". Persons being cared for in hospitals and care homes are likely to be less adaptable to overheating than able-bodied persons for several reasons, including the following:

- they are less able to judge when they are too hot or too cold;
- they are less likely to adjust their clothing levels;
- they are, in some cases, less able to open and close the window of their room;
- sedentary people tend to be more affected by extremes in temperature than people who are physically more active;
- they cannot so easily adjust their daily routine to avoid hot places within the building.

3.3.2 Maintaining suitable conditions

Gupta et al. (2017) point out that due to the frailty of vulnerable persons (e.g. in care homes) that staff are more likely than vulnerable residents to exert temperature control. For this reason, it is important that staff are careful to regulate conditions in a way that caters for the needs of vulnerable patients / residents. Staff will have different metabolic levels (met) and clothing levels (clo) from patients and can 'escape' from hot spots in a building, perhaps being scarcely aware of them. As a result, staff might not take immediate steps to optimise temperatures for patients in the warmest parts of the building. Indeed, the personal perceptions of staff could mislead them. A possible compounding factor is that staff also tend to be more adaptable to external hot weather (e.g. adjusting their clothing levels in response to changing external temperatures) and as a result become more tolerant of higher indoor temperatures. This can perhaps make staff complacent about the need to keep indoor temperatures suitable for those who are less able to adapt to hot conditions.

Condition (at bed height or mid-room height)	**Examples of vulnerability and risk if condition is <u>too high</u>**	**Examples of vulnerability and risk if condition is <u>too low</u>**
Indoor environmental temperature (i.e. air and radiant temperature combined)	Can resulkt in reduced concentration of care or medical staff, leading to risk of mistakes. Medical risks to patients. Impaired sleep.	Physical danger to patients (20°C is minimum recommended temp for very old and very young, even at night (ref: §8.2.3 of CIBSE A3)

Condition (at bed height or mid-room height)	**Examples of vulnerability and risk if condition is too high**	**Examples of vulnerability and risk if condition is too low**
	Overheating typically expressed as number of hours above a threshold. Gupta et al (2017) suggest that ideally temperatures should not go above 25°C (for sleep) (WHO1987) and a cool room <= 26°C during heatwaves.	
Indoor relative humidity (RH)	Risk of microbiological growth if RH above 60%. Oppressive conditions. Thermal discomfort if RH too high however below 26°C the effect of RH on perceived temperature is small (ref: section 8.3.1 of CIBSE A3)	Dry skin, static electricity and other problems if RH falls below 35%. CIBSE recommends that under normal weather conditions RH should not fall below 40%.
Air movement	Cold draughts, risk to patients	Stuffiness, oppressive atmosphere, increased infection risk
Airborne pollution	Distraction of staff, particularly if relative humidity is too low	-

Table 3: Patient vulnerability to key thermal comfort related factors

3.3.3 Relative humidity, comfort and perceived heat

Normally, within a building, the space heating leads to a reduction in relative humidity so that even if the outdoor relative humidity is high the indoor relative humidity can be much lower. If however, when space heating is not applied (e.g. in summer), the indoor relative humidity is likely to be similar to the outdoor relative humidity, (unless an air conditioning system is extracting moisture from the air). Since summertime outdoor humidities in the UK tend to be in the range 70% - 90%, it might be reasonable to suppose that indoor relative humidities during a heatwave could typically be around 70%. According to CIBSE, for temperatures below 26°C, the effect of humidity on warmth can largely be ignored (CIBSE A3 1.3.1.3).

However, humidity is important when considering microbiological growth, static electricity, dust and airborne irritants. CIBSE A3 recommends keeping the indoor RH between 40% and 60%, although it notes that it is acceptable for the relative humidity to fall below 40% during periods of unusually cold weather. Importantly, when the relative humidity is above 65% certain microbiological organisms tend to thrive, whereas if RH falls below 35% then it has been reported that some organisms (e.g. polio) die off quickly.

3.4 Overheating Thresholds

The table below provides a (non–exhaustive) summary of various health-related overheating thresholds.

Description	Threshold	Source
Health effects minimised if indoor air temperatures are not above 24°C	24°C (indoor)	World Health Organisation (WHO) 1987. Reported in CIBSE A3 8.3.1
Adverse health effects increase when external temperature exceeds 25°C	25°C (outdoor)	Housing Health and Safety Rating Systems (HHSRS) 2004. Reported in Gupta 2017
Morgan used 25°C as the threshold for considering the number of hours of overheating within Scottish housing	25°C	Morgan, 2017
Bedheads, wards and corridors not to exceed 25°C in summer	25°C	CIBSE A3 Table 1.5
PassivHaus Standard 2007, not to exceed 25°C for more than 10% of occupied hours	25°C	Reported by Gupta, 2017, Table 2 and by Vellei 2017
Cool room (or cool area) air temperature not exceeding 26°C, to be implemented during heatwave period as defined by HHWS trigger thresholds. Excess deaths may first become apparent at 24.5°C	26°C	PHE Heatwave Plan for England, guidance 2015. Reported in Gupta 2017.
During the summertime, internal temperatures in patient areas should not exceed 28°C dry bulb for more than 50 hours per year. Calculations and thermal modelling should be undertaken to determine performance and inform new design.	28°C for no greater than 50 hours per year	Scottish Health Technical Memorandum 03-01: Specialised ventilation for healthcare premises - Part A: Design and validation.

Table 4: Various overheating thresholds

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3.5 Remedial measures

Scottish Health Technical Memorandum 03-01 (SHTM 03-01) - 'Specialised ventilation for healthcare premises - Part A: Design and validation' [1] suggests a number of methods of reducing temperature rise should be considered, should the SHTM 03-01 summertime peak temperature threshold not be achieved during property design. Recommended options include examining the potential to:

- reduce solar and casual gains;
- use chilled beams or ceilings;
- increase ventilation rates;
- provide mechanical cooling; or
- alter the thermal mass of the structure to "move" the peak temperature event time so that it occurs outside of the occupancy period.

Additional remedial measure for existing facilities could include: closing blinds / curtains or adding solar shading to reduce solar gain, opening windows to increase natural ventilation, night-time cooling, using electric fans to create air movement, use of local air conditioning, taking patients outside and/or moving patients to a cooler room, etc. In addition to these, reducing the amount of heat gains from internal equipment could also help to reduce overheating e.g. via the use of low-energy lighting and low-energy appliances that emit less heat. Providing night-time ventilation (e.g. by opening windows if noise, security and insects permit) can also help to cool down the fabric of the building prior to heat build-up the following day. Similarly, high thermal mass, or innovative phase change material, may also assist. In terms of reducing solar gain, deep balconies, external shading above windows and solar control glass can also help.

The questionnaires and site visits have endeavoured to record the main remedial measures (if required) that are being used at the sample sites.

[1] SHTM 03-01: Specialised ventilation for healthcare premises - Part A: Design and validation http://www.hfs.scot.nhs.uk/publications/1475762746-SHTM%2003-01%20V2%20Part%20A.pdf

4 Findings: Stage 1 – Asset Analysis

NHSScotland publish annual data and statistics on estate performance with their 'Annual State of NHSScotland Assets and Facilities Report (SAFR)[2]'. SAFR is the national strategic report on asset and facilities management for the Scottish Government and NHS Boards' and Special NHS Boards' use. SAFR is widely recognised as a key reference document used to inform decisions on the continuing investment in assets and facilities services to deliver the Scottish Government's '2020 Vision' for sustainable high quality in health.

In addition to this published data, BRE were provided with a spreadsheet which detailed NHSScotland in-patient assets along complete with information on building zones, use and original build date. BRE completed an initial review of this data however it was apparent that classifying assets on the basis of their original 'build date' alone was not a robust way to correctly identify assets of a particular design type classification. As well as such an approach introducing errors (e.g. many older properties will have gone through a process of refurbishment, some designs may have not necessarily reflected the 'common' design of the period, etc.), through the course of the study it also became apparent that attempting to broadly link / group common overheating 'issues' to common hospital archetypes was not appropriate. As reported above, overheating and thermal comfort is a complex issue and there are many site specific factors that can influence overheating. Further considerations on the issues influencing overheating are presented in the following sections.

[2] Annual State of Assets and Facilities Report 2016. NHSScotland. http://www.gov.scot/Publications/2017/07/9798

5 Findings: Stage 2 - Collecting and Assessing Existing Data

The questionnaire results and site visit findings are presented and discussed in section 5.1 and 5.2 respectively. Conclusions are presented in section 6.1.

5.1 Questionnaire results

As reported previously, BRE produced 2 x short questionnaires (see Appendix B) in order to collect background information from the sample Boards concerning:

1. The target facility, its energy systems and the extent of any existing monitoring, and
2. The Board's thoughts on overheating related issues and their experiences with mitigation measures.

A summary of the findings is presented in the following sections. It should be noted that some Boards did not return the questionnaires and where Boards did provide responses, they did not always provide answers to all questions. Where no responses were received BRE have provided a summary response from information gathered via a combination of discussions with site personnel or from gathering necessary information during site visits. The results below clearly indicate where information has been summarised by BRE.

5.1.1 Environmental Data

A number of tables are presented over the following pages as follows:

- Table 6: Questionnaire results – asset, natural ventilation and mitigation measures
- Table 7: Questionnaire results – list of mitigation measures and their success
- Table 8: Questionnaire results – data measurement - general
- Table 9: Questionnaire results – data measurement – internal air temperature

Note: table entries in blue text are based on the BRE findings following discussion with site representatives and/or site visits.

	Asset Information	Site 1	Site 2	Site 3	Site 4	Site 5
1a	Confirm this Asset list is accurate for your NHS Board? Please comment on any changes, eg to "type" classification	This response relates to the above asset only	This response relates to the above asset only	This response relates to the above asset only	Revised asset list returned	This response relates to the above asset only
1b	provide the current bed numbers for each asset listed	12	25	535	271	178
1c	provide the set operational temperature (range) for each asset listed	21C	21C	22C	21C	21C summer, 23C winter
2	Has there been any major energy efficiency upgrades to above property(s) that has/is likely to have an impact on temperature & its control	Biomass pellet boiler ~8 years ago; BEMS upgrade ~ 3 years ago.	BEMS upgrade ~ 3 years ago.	voltage optimisation equipment, LED lighting to public areas, variablse speed drives to pumps, LED external lighting.	At Borders General; PV panels, LED lighting, inverters for motors, plate heat exchangers for DHW, pf correction. At other sites, biomass boilers installed, all external lighting LED.	Constructed in 2012.
3a	Do you measure / assess overheating (yes/some/no)	No	No	No official records kept although Helpdesk calls could be checked and analysed for complaints around overheating in most NHS Lanarkshire sites.	No	All (single) patient rooms have dedicated thermostat, linked to BEMS enabling temperature monitoring (24hrs) and control.
3b	if some/yes, how is this done (please list any methods used)	N/A - staff will call Estates with complaints of under / over heating and BEMS may be adjusted accordingly on site by Estates, following assessment.	N/A - staff will call Estates with complaints of under / over heating and BEMS may be adjusted accordingly on site by Estates, following assessment.	N/A - staff will call Estates / Helpdesk with complaints of under/over heating and BEMS may be adjusted accordingly. BEMS is used to monitor temperature although manual reads may also be taken. Each request is assessed as this is very subjective.	N/A	via BEMS. All room operate within defined temperature control set-points (of 21 or 23C).

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		Site 1	Site 2	Site 3	Site 4	Site 5
	Natural ventilation					
4a	Do you measure / assess use of natural ventilation / windows (yes/some/no)	Not measured, but there are openable windows (double glazed) in all patient rooms / wards.	Not measured, but there are openable windows (double glazed) in all patient rooms / wards.	Not measured currently, but there are openable windows in the hospital that are secondary glazed, have low u-values and are poorly insulated and inefficient	No, only drawings indicating windows fitted with restrictors limiting the opening	No, but there are secure, (slide) openable windows in all patient room.
4b	if yes, how is this done (please list any methods used)	n/a	n/a	n/a	n/a	n/a
	Mitigation measures					
5a	Has there been any mitigation measures implemented to help reduce overheating	Roller blinds fitted. Local fans sometimes used.	New curtains fitted. Fans sometimes used.	very small number of windows have solar film	Yes;	No. No significant issues in patient rooms. Chiller added to cold water supply to control temperature for legionella protection.
5b	if some/ yes, provide an approximate percentage of in-patient assets (as listed above) where mitigation measures have been deployed	no data	no data	less than 5%	?	chillers deployed on all "main" cold water distribution pipes.

Table 6: Questionnaire results – asset, natural ventilation and mitigation measures (continued)

bre

	openable windows		table top fans		Blinds		window film		call to helpdesk to reduce temperature		Temporary A/C units	
	used	success	used	success	used	success	used	success	used	success	used	success
Site 1	y*		y*		y*				y*			
order of most widely used	no data											
Site 2	y*		y*		curtains				y*			
order of most widely used	no data											
Site 3	y	4	y **	4			y		y	2		
order of most widely used	2		1						3			
Site 4	y *		y	3	y	1	y	1			y	3
order of most widely used			2		1		4				3	
Site 5	y*				curtains*							
order of most widely used	no data											

Table 7: Questionnaire results – list of mitigation measures and their success

Notes:

* Entries in blue are based on the BRE findings following discussion with site representatives and/or site visits.

** No formal measurement although the site reports that there continues to be requests for fans from wards and offices.

'success': How successful do you feel these mitigations have been? (score 1 - 5; where 1=not very successful, 3=neutral, 5 = very successful).

'order of most widely used': 1 = most widely used.

		Site 1	Site 2	Site 3	Site 4	Site 5
All spaces will ordinarily have connectivity with a building management system (enabled to record/date-time stamp measured values)						
Is it enabled?		no logging function	no logging function	logging possible	logging possible	approx 48hr logging possible
If yes, is any use made of this data?						
Is the following measured? (y/n)						
Internal environment	Air temperature	y - see separate table	y - see separate table	y - see separate table	y - see separate table	y - see separate table
	Relative humidity					
	Carbon dioxide levels					
External environment	Ambient temperature	y	y	y	y	y
	Ambient relative humidity					
	Solar irradiance					
Energy Systems	Ventilation supply / extract flow rates	n/a				
	Ventilation supply air temperature	n/a		y	y	y
	Ventilation extract air temperature	n/a				y
	Heating supply temperature	y	y	y	y	y
	Heating return temperature	y	y	y	y	y

Table 8: Questionnaire results – Data measurement - general

Note: the entries in blue are based on the BRE findings following discussion with site representatives and/or site visits.

Note: Whilst the above table highlights that a number of values are sensed at the respective sites, the reader should note that all of the above data is sensed for the purposes of heating and/or ventialtion plant control processes (i.e. the automatic control of HVAC plant) and as a result the data may not necessarily be of suitable use for informing an overheating risk analysis. More detailed information is provided in the site surveys findings as presented later in this report.

More detailed information is provided below in relation to internal air temperature data.

		Site 1	Site 2	Site 3	Site 4	Site 5
Internal environment - Air Temperature						
7a	Do you monitor / record the following? ("y" for yes, leave blank for no)	y - for heating zone temp control via an average temperature	y - for heating zone temp control via an average temperature	y	Y	y - used to monitor room temperatures and adequacy of heating control.
7b	At what scale /resolution do you monitor (e.g. single sensor per room, selected room, every room, etc.)	2 x sensors per heating zone, but BEMS only shows average temperature	3 x sensors per heating zone, but BEMS only shows average temperature	selected areas	1/WARD	1 x sensor per patient room. No sensors in corridors.
7c	Where are sensors typically located (e.g. state wall types, heights, etc.)	corridor walls	corridor walls	internal plasterboard walls (1.5m)	WALL	internal walls @ approx 1.4m high
7d	At what frequency / time interval is data recorded?	5-15 mins?	5-15 mins?	constantly	VARIABLE AS REQUIRED	5-15 mins?
7e	Where is the data stored?	not stored	not stored	on Honeywell BMS	BMS	Last 24 hours visible but not stored. Storage likely to be possible but with limited duration without upgrade.
7f	Is data able to be downloaded (define if only possible for internal or internal/external parties)	no download function	no download function	internal	Internal	only on an every 24 hour basis
7g	When were sensors installed (approx date)	with BEMS upgrade ~ 3 years ago.	with BEMS upgrade ~ 3 years ago.	upgrade programme as sensors were installed when the building was opened and many have been replaced	1986	2012 (when constructed)
7h	Have sensors been re-calibrated (approx date)	?	?	yes on maintenance contract	YES	yes on maintenance contract
7i	Can this data be made available to help inform the study, if required?	no data available	no data available	yes	YES	yes - with permisson of PFI owner
7j	Please add any other relevant comments regarding data sensing, storage etc.				N/A	
7k	Is any other relevant data sensed/recorded? - please provide details				Report from Capita Symonds (2011) upon request into ward overheating.	
7l	List the main reasons for monitoring this			To ensure the building is operating effectively & staff comfort levels are maintained	BMS	

Note: the entries in blue are based on the BRE findings following discussion with site representatives and/or site visits.

Table 9: Questionnaire results – Data measurement – internal air temperature

5.1.2 Perception of Overheating Risk and Severity

The second questionnaire (see Appendix B) attempted to record the perceived perceptions of the sample Board's representative regarding (i) the risk and severity of overheating, as well as (ii) their thoughts on the most critical factors contributing to overheating at the respective facilities.

It should be noted that the representative from sites 3 and 5 did not provide a response to this questionnaire.

Interestingly, during the visit to site 2, an 'operational' member of staff (i.e. a charge nurse) was surveyed separately to the estates representative in order to assess if their perceptions were significantly different. Responses from the site 2 estates staff representative and operational staff members are denoted '(estates)' and '(operational)' respectively.

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5.1.2.1 General questions

Q8a: Generally, do you think there is an overheating risk for in-patients in the assets listed?

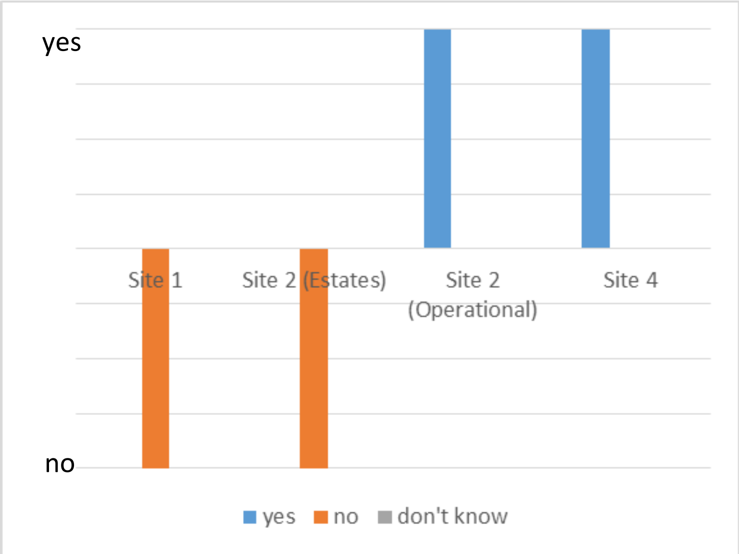

Figure 1: Perception of whether or not there is a general overheating risk for in-patients

Q8b: How serious / severe do you think this risk is (where 1= none/ no/ very low; 3=neutral; 5 = lots/ yes/ very high)?

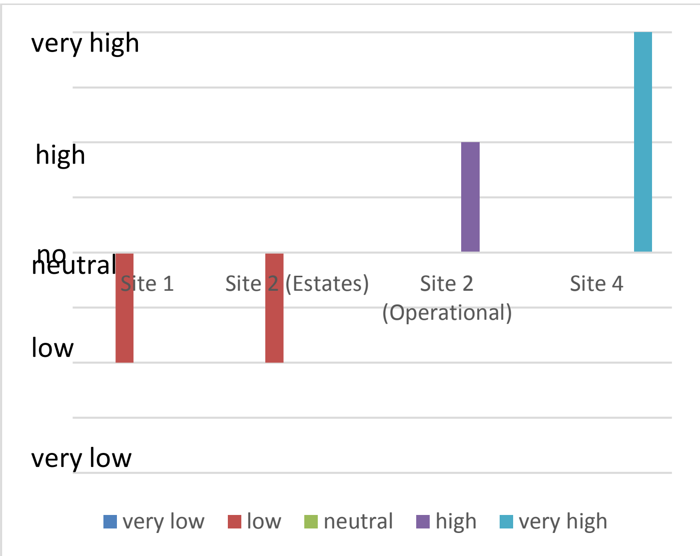

Figure 2: Perception as to how serious / severe this risk is

Q8c: Generally, do you think there is an overheating risk for staff?

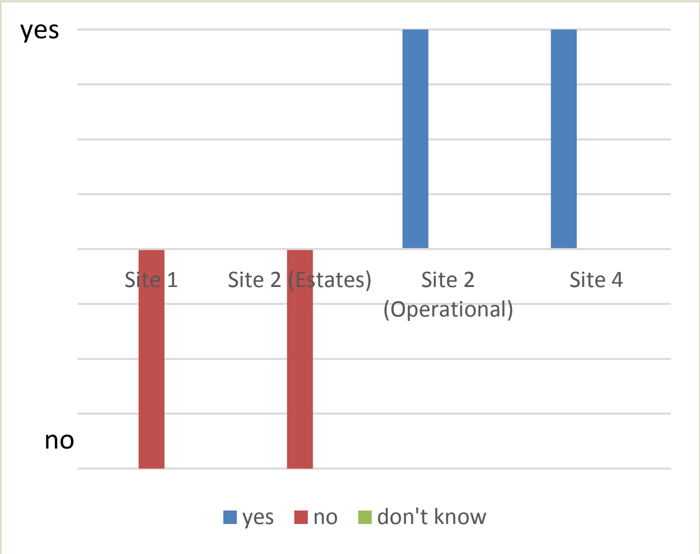

Figure 3: Perception of whether or not there is a general overheating risk for staff

Q8d: How serious / severe do you think this risk is (where 1= none/ no/ very low; 3=neutral; 5 = lots/ yes/ very high)?

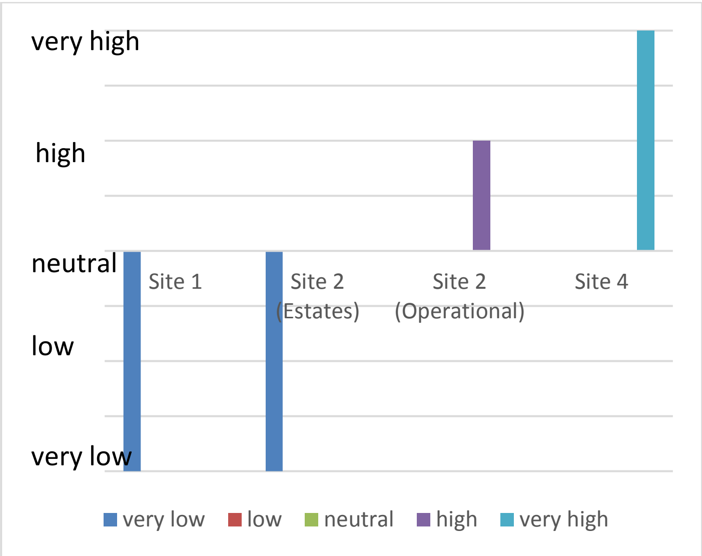

Figure 4: Perception as to how serious / severe this risk is

Q8e: To what extent do you think seasonal weather impact on this overheating risk (where 1= none/ no/ very low; 3=neutral; 5 = lots/ yes/ very high)?

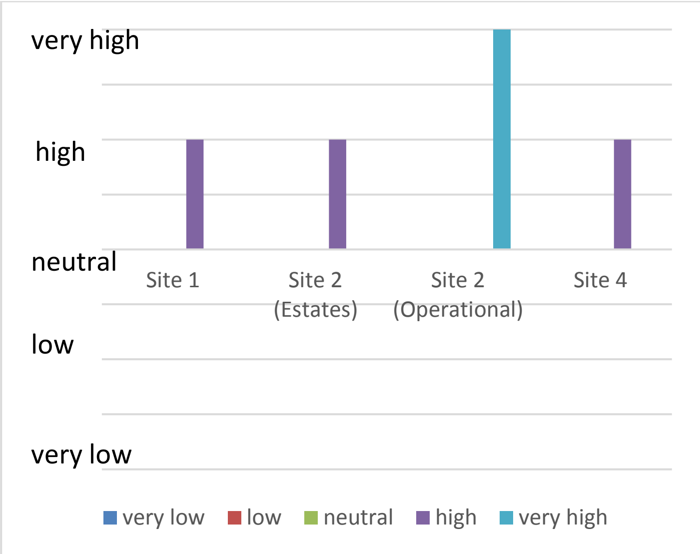

Figure 5: Perception as to what extent the overheating risk is impacted upon by seasonal weather

5.1.2.2 Critical Contributors to Overheating

Respondents were also asked to list and rank the most significant factors they believe contribute to overheating at the respective facilities. The results are presented below in table 10.

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	Site 1	Site 2 (Estates)	Site 2 (Operational)	Site 3	Site 4	Site 5
1	solar gain	solar gain	where there is a high ambient temperature the supply ventilation system can only supply air of this temperature and so it can contribute to overheating	lack of zoning leads to overheating / underheating - large areas zoned and temperature can vary across the zone	window design and H&S restrictions on opening has made overheating a lot worse. A redesign of windows is required	No significant overheating in patient areas / rooms
2		where there is a high ambient temperature the supply ventilation system can only supply air of this temperature and so it can contribute to overheating	No local control over heating e.g. rooms can be warm, windows can be open but the heating can still be on. (BRE note: most likely also a zoning issue)	building design leads to heat gain and retention of heat	Maximisation of space utilisation has led to increased patient numbers in areas	An issue in 1 x treatment room where no openable windows
3			not always possible to ventilate to combat overheating due to nuisance from midges (especially in evening / night)	poor ventilation to core - lack of ventilation in patient rooms	increased equipment and resulting heat gains	
4				window design and H&S (restriction on opening) leads to overheating on occasion	building services design and lack of zoning/control	
5				building design and lack of zoning mean building is slow to respond to changes in temperature and takes a long time to get up to temperature / cool down		

Note: the entries in blue are made by BRE following discussion with site representatives

Table 10: Responses regarding critical contributors to overheating

5.2 Site Visits

BRE conducted a site visit to each of the target properties. The aim of the visit was primarily to assess the nature and/or availability of data that may be of use in assessing overheating risks and also to gain a general appreciation of the building design and overheating related issues. A summary of each site visit is presented below complete with supporting photographs of key site features.

5.2.1 Site 1 (Nightingale type, built circa 1886)

Key findings:

- The in-patient area (12 beds total) are contained within the old / traditional part of the main building and comprises 2 x 4 bed wards to the east wing and 2 x single rooms and 1 x double room to the west. The property has traditional stone solid walls, relatively high levels of glazing and the 2 x 4 bed wards consist high ceilings.
- Windows are top pivot despite appearing to look like sash and case and blinds are fitted to all windows. The windows within the in-patient areas have a traditional restrictor with over-ride facility and are not fitted with mechanical restrictors presumably due to them being on the ground floor. A number of the windows were found to be poorly fitting / poorly sealed which is expected to cause heat loss and/or cold draughts. Additionally, some units had faulty catches meaning they couldn't be shut properly.
- The ground floor of the main building operates as a single heating zone which is served by 2 x temperature sensors installed in the corridor (one to the east and one to the west). The building energy management system is believed to calculate and use the average temperature of the two sensors, for the control of the heating to the zone. One of the temperature sensors had a wall hung cabinet installed directly in front it (see images below). The system also includes an external temperature sensor. It should also be noted that the building energy management system has no logging function and can only display the last 24 hours' worth of the (averaged) temperature data.
- Estates representatives suggested that whilst the facility experiences some overheating issues (mainly in the summer and/or as a result of high levels of solar gain), there wasn't a significant issue or risk due to overheating. The high thermal mass of the building and the fact that windows can be opened wider than other facilities with restrictors are likely to assist incidence of overheating at this facility.

A selection of photos is presented below.


South East corner 4 bed ward area. Window to east elevation (LHS image). South/front elevation (RHS)


Windows openable at bottom section and/or top (LHS). Poor seal evident when in closed position (RHS)

Wall mounted heating zone control temperate sensor (1 of 2) in east corridor

North East corner 4 bed ward area.

View down east corridor from main entrance

Example of a single room (LHS) and an example of the bottom section opening (RHS)

2 bed room in the west corridor

Examples of poor fitting windows (LHS) and faulty catch (RHS)

The heating control temperature sensor (2 of 2) in the west corridor with the carbinet installed directly inadjacent.

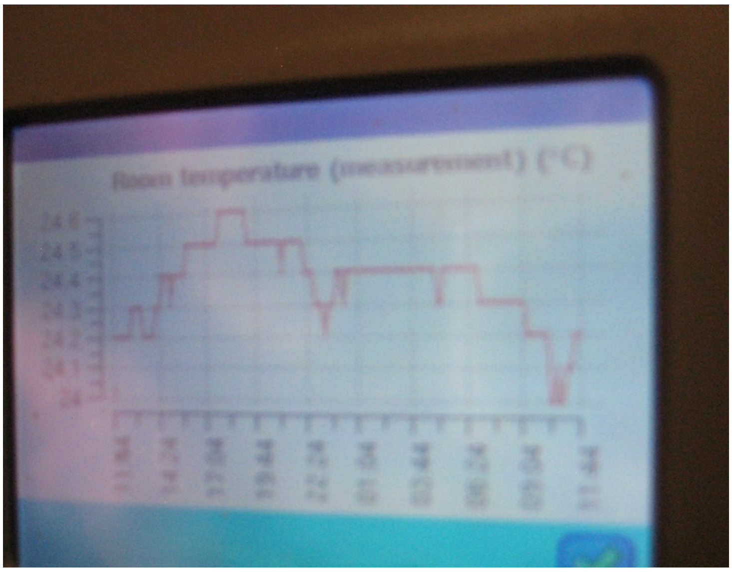
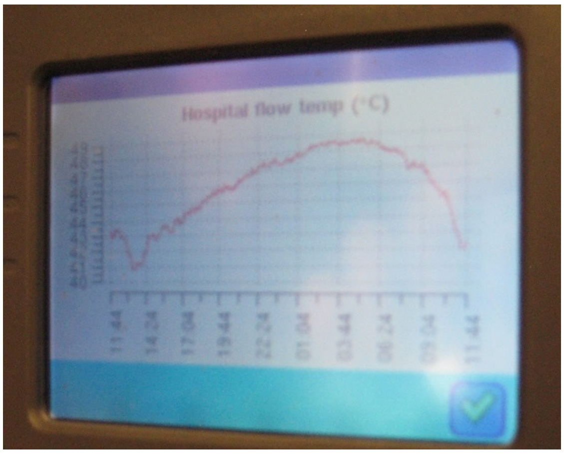


Image of the 'Priva' BEMS display showing the (calculated average) room temperature for the zone containing the in-patient areas. The x axis scale covers 24 hours and the y-axis scale is variable depending upon conditions (but in this example extends from 24 to 24.6°C)



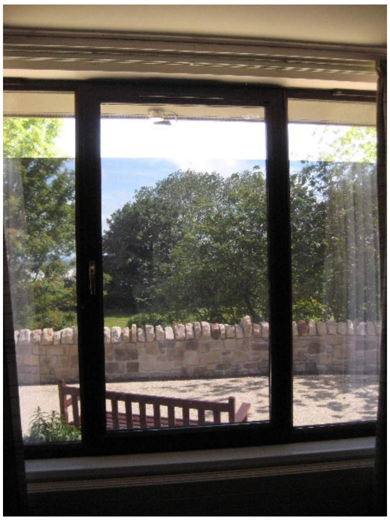
Further images from the BEMS showing heating flow temperature profile and heating compensation setting

5.2.2 Site 2 (variant of a ‘Common Services Agency’ (CSA) 30 bed template ward type, built circa 1990)

Key findings:

- The unit is a local variation of the CSA standalone template; two storey, circa 25 bed unit comprising a number of 4 bed and single rooms. The property appears to be of timber frame construction with harled exterior, pitched concrete tile roof, average levels of glazing and a 2.4m (h) internal ceiling in in-patient room areas.
- Openable windows are tilt and turn type and curtains have recently been fitted to all windows. The windows are not fitted with mechanical restrictors presumably due to them being on the ground floor.
- Estates were unable to be present during the survey, however BRE staff were advised that the facility had the same control system as site 1 and that it operated in a similar way by means of calculating an average temperature from 2 x sensors located in the corridors. The system also includes an external temperatures sensor. As per site 1, it should be noted that the building energy management system has no logging function and can only display the last 24 hours’ worth of the (averaged) temperature data.
- The Estates representative reported that whilst the facility experiences some overheating issues (mainly in the summer and/or as a result of high levels of solar gain coupled with high ambient temperatures, whereby the supply ventilation system will draw in this high temperature air) that there wasn’t a significant issue or risk due to overheating. Interestingly however, an operational staff member working in the facility (a charge nurse) suggested that there are issues, in particular that night time temperatures are commonly either excessively too cold or too hot. They reported generally not being able to open windows in the evening or at night due to nuisance from pests and midges. They also reported incidences of the facility being too cold overnight particularly on occasions when it had been overly hot through the day, and they had requested that Estates turn the heating off. As no control is extended to operational staff, turning off heating during the day typically results in the heating being left off overnight leading to a significant drop in temperature overnight.

A selection of photos is presented below.




Tilt and turn window within a south elevation single room (LHS). Ceiling and bank of 4 x windows within a north elevation 4 bed room (RHS) – this also shows the supply air ventilation grille and light fittings.


Images of the south elevation (west end)

South elevation (east end)

5.2.3 Site 3 (Falkirk type, built circa 1977)

Key findings:

- Site 3 is a Falkirk design type facility built in circa 1977. The in-patient area is largely contained within 2 x 4 or 5 storey 'tower' blocks. The design includes 2 x central courtyards in each tower to enable natural light and ventilation. The building is single glazed but has been retrofitted with secondary glazing. It also incorporates concrete external shading.
- There are a mixture of top hung, side hung and centre pivot openable windows fitted with restrictors. As a result, the potential for natural ventilation is reduced. Natural ventilation provision is further restricted by the secondary glazing and both of these issues means that the openable windows are unable to operate / provide natural ventilation as originally designed.
- The heat distribution system includes a mixture of radiant ceiling panels, low surface temperature radiators and traditional radiators. Heating control is via a Honeywell BEMS however at the time of the site visit was down and therefore could not be interrogated. Discussions with estates staff highlighted that each corner of the tower was separately zoned (i.e. incorporating multiple floors per zone) which presented general difficulties in ensuring appropriate temperature control for all spaces in the zone. In addition, only a limited number of sensors, typically one per floor per zone, were installed and these were typically in corridors. Whilst the BEMS could be set up to log it is felt that this data would not be of significant use in assessing overheating.

A selection of photos is presented below.

Radiator Type 1 - Low surface temperature (LST) in a corridor (not typical in the hospital)

Openable (100 mm) window in a corridor fitted with restrictor

Example corridor


Radiator type 1 – low surface type (LHS). Radiator type 2 – traditional (as commonly installed across the hospital) (RHS)

Ground level

Ground level corridor and courtyard

West Tower



Faulty restrictors (upper RHS and lower images).

Typical 4 bed room

Secondary glazing

Secondary glazing and curtains

Openable lower section – although sometime ‘stuck’ either fully opened or closed.

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Concrete external shading

Single room (without ensuite (sink only) – showing secondary glazing and curtains


Corridor glazing

4th floor, East Tower


New double glazing in corridors (only non-openable units replaced)


Radiant heating panel in suspended ceiling

Radiant panel thermostatic control in ceiling

5.2.4 Site 4 (Falkirk type, built circa 1988)

Key findings:

- Site 4 is a 3 storey Falkirk design type facility built in circa 1988. The facility consists of a main hospital (circa 30,000m^2) (1988) and a dialysis unit (circa 470m^2) (1999). The facility includes approximately 271 beds across 9 x wards.
- The Facilities representative reported that both the acute and geriatric sides of the main hospital comprise low surface temperatures radiators, supply and extract ventilation of tempered air and openable windows (double glazed). He also reported however that the wards have only limited natural ventilation since the introduction of window restrictors and overheating has therefore been, and continues to be, an issue particularly for south facing areas. It was reported that south facing areas can experience internal temperatures of circa 5 – 7°C above ambient and temperatures up to circa 30°C as an approximate maximum. The representative advised that they felt that other key contributing factors was a general increase in patient numbers within rooms due to efforts to increase space utilisation, coupled with significant increases in electrical equipment and resulting heat gains. It was reported that west facing wards (mostly geriatric wards) did not present significant issues as patients tended to be accepting of slightly higher temperatures in that ward. No issues were reported with regard to cold water temperatures throughout.
- The heating, ventilation, air conditioning and water systems are controlled via a Visonik BEMS, although the site is in the process of migrating to a newer Desigo BEMS system (which is currently operational for some control aspects). Heating zone temperature sensing is still currently carried out within the older Visonik system and estates personnel report that the system typically applies a control set-point based calculated from the average of 3 x sensors (1 per floor) with sensors typically being in a 6 bed room. When asked if this temperature data could be made available BRE were advised that estates did not think that the sensor locations were particularly representative of areas where overheating was most significant and furthermore it would be (i) troublesome to set the old BEMS system to log this data, and (ii) very difficult to export the data from the desktop computer running the Visonik BEMS owing to it being a very old machine with no USB, CD or floppy disk drive.
- As a result of the overheating issues experienced at the site Facilities had previously commissioned a study to model the south façade and to assess a number of potential remedial solutions. A copy of this report was provided to BRE and will be passed to the steering group for background information. The study modelled various solutions based on increasing natural ventilation via automatic control of windows and/or use of retrofitting solar shading. It is also worth noting that the representative has also considered the potential for PV integrated, brise soleil, shading however integrating this within the south façade would present cost prohibitive structural related issues.
- It is also worth noting that the laboratory areas within the facility are currently air conditioned and furthermore the chillers servicing these spaces were designed to include some additional capacity. Whilst active cooling may not be overly sustainable this may present a solution should chilling be needed elsewhere in the facility.

A selection of photos is presented below, however, it should be noted that the site requested that no photos be taken within in-patient areas.

South elevation (to west (LHS) and east (RHS) showing the windows to the rooms where overheating can be significant

Roof mounted chiller units (which include some spare capacity) (RHS)

5.2.5 Site 5 (Finger type, built circa 2011)

Key findings:

- Site 5 was opened in 2012. It consists of a mix of psychiatric units and comprising approximately 112 secure single bed rooms and a separate secure care facility inpatient unit comprising approximately 66 secure single bed rooms.

- Site 5 was a Private Finance Initiative development and a facility management company maintain the property on behalf of the asset owner.

- The property, which is largely single storey, is of timber frame construction with concrete floors and a mixture of pitched profiled aluminium, insulated sheet roofing (e.g. over in-patient areas) and composite flat roofs. Double glazing is installed throughout. The property is a mix of single (in-patient) rooms (with an operational temperature of 21°C in summer and 23°C in winter), treatment rooms (with a minimum operational temperature of 21°C), and staff / other ancillary support spaces. Corridors have a design temperature of 16°C and it is reported that staff sometimes complain that it is too cold in corridors. The property is heated by a gas fired wet central heating system and the heat emitters are ceiling mounted radiant panels throughout. There are no solar control window films and no (internal or external) shading installed on the building.

- The single patient rooms include an ensuite and are of a secure design. Each single room includes a ceiling mounted radiant panel and a wall mounted temperature sensor which is linked to the Building Energy Management System and which controls the operation of the radiant panel. The temperature sensor is installed behind a metal face plate. Outside each room is a service cupboard (accessed from the corridor) which includes a manual emergency 'shut-off' switch that can be activated by staff. When this switch is activated all services to the room (i.e. mains cold water, domestic hot water, space heating and power) are isolated. Each single room has trickle vents and the original windows (of an independent top and bottom, side pivot restricted opening sections) have been retrofitted by slide opening windows (independent top and bottom opening sections) complete with a metal mesh barrier (as part of the secure design). The original units were upgraded due to them presenting a potential ligature risk as well as it also being possible for them to be forced (e.g. with sustained kicking) to enable escape. Whilst it was not a factor that influenced the upgrade, the replacement units can provide significant amounts of ventilation to the space. Photographs comparing the two window types are presented below. Each ensuite is ventilated by a mechanical extract ventilation system.

- The retrofitted window design outlined above enables a significant supply of outside air in a secure manner. In addition, being slide openable means that the windows can be opened to any level (i.e. fully closed, fully open or any instance in between. It is however worth noting that when windows are open this can lead to the room temperature reducing to a level below the room heating control set-point (i.e. 21°C in summer and 23°C in winter). When this occurs the control system will automatically supply heat to the radiant panel in an attempt to raise the room temperature back to the set-point despite the fact that the windows are open. This can lead to additional energy being consumed. One possible solution to such an issue would be to have a control link so that if the window is opened the heating supply to the room is automatically held off or, alternatively, the heat supply is held off until a lower limit set-point temperature is reached (e.g. 16°C or 18°C) to help ensure that a suitable background heat level is maintained.

- The property includes a Cylon Controls Building Energy Management System with Unitron Command Centre (v6.7) front-end software. A number of example screenshots are presented below. The system provides an overview of the heating and ventilation and water services plant, its operating status and any system alarms or faults. The system also presents the individual room temperatures (as measured via the temperature sensors as outlined above) and the (open / shut) status of the motorised valve that controls the heat supply to the individual room radiant ceiling panel.
- The BEMS system presents graphs of the room temperatures for the last 36 hour period, however it is reported that the system currently has no logging function beyond this period.
- The site representative suggested that overheating in in-patient areas is, in general, not a significant issue and whilst some south and west facing rooms can experience some localised overheating this can be mitigated by opening windows. It was reported that the maximum for these rooms was circa 23°C or 24°C. The representative could recall only one instance where temperatures were recorded at 25°C and that was due to a faulty valve holding the heating on constantly in one of the single rooms.
- Overheating was reported as being a general issue within a specific treatment room (treatment room 1). The room in question has no openable windows but rather is served with supply and extract ventilation. It is reported that the room gets hot in summer particularly when subject to solar gain. It is believed that the contractual requirement for this space is for a temperature of 21°C however no maximum temperature requirement is defined. As a result, there is no cooling or boost ventilation function to assist cooling the space when it overheats. This was raised as a potential issue by the Facility Management representative as they report that the room is used for storing medical supplies which apparently have a requirement to be stored below 25°C. The radiant ceiling panel in the room is controlled by a wall mounted thermostat however the temperature sensor is not connected to the BEMS system.
- Whilst there does not appear to be significant overheating issues directly affecting in-patient areas, it should be noted that the site has previously experienced issues with the indirect effects of (general) overheating; in the form of elevated cold water temperatures. A number of in-line chillers have since been installed to reduce the temperature of cold water distribution lines and the water temperature at the chiller locations are monitored via the BEMS. It is understood that these chillers have been installed at a number of locations at significant distance downstream from the cold water store meaning that there could be potential for the cold water to be raised to unsuitable temperatures prior to the chiller should the pipework be subject to significant heat gain. Further consideration may wish to be given to investigating this further.
- In conclusion, the presence of single rooms, served by individual heating controls, coupled with the fact that windows that can be opened significantly widely, means that overheating is not significant, and is largely controllable, within in-patient areas in this facility.

A selection of photos is presented below.

An example of the external elevation of one of the ward in patient wings showing the exterior of the single room windows

The South West facing elevation of the 'one of the wards

A typical corridor with high level, ceiling mounted radiant panels, with access to the single rooms

A typical single room layout complete with 'old' style window (LHS)

Close-up of the 'old' style 3-section window with fixed, full height, side section and 2 x independently openable, restricted, side pivot section (RHS lower image). NB: this image was taken prior to the window being retrofitted with the new type as shown on the next page.

Image showing the window head and presence of trickle ventilators at the top of the frame (RHS upper image)

Examplse of the 'new' style (post-retrofit) window with independent and variable opening, top and bottom, side-sliding sections complete with security mesh

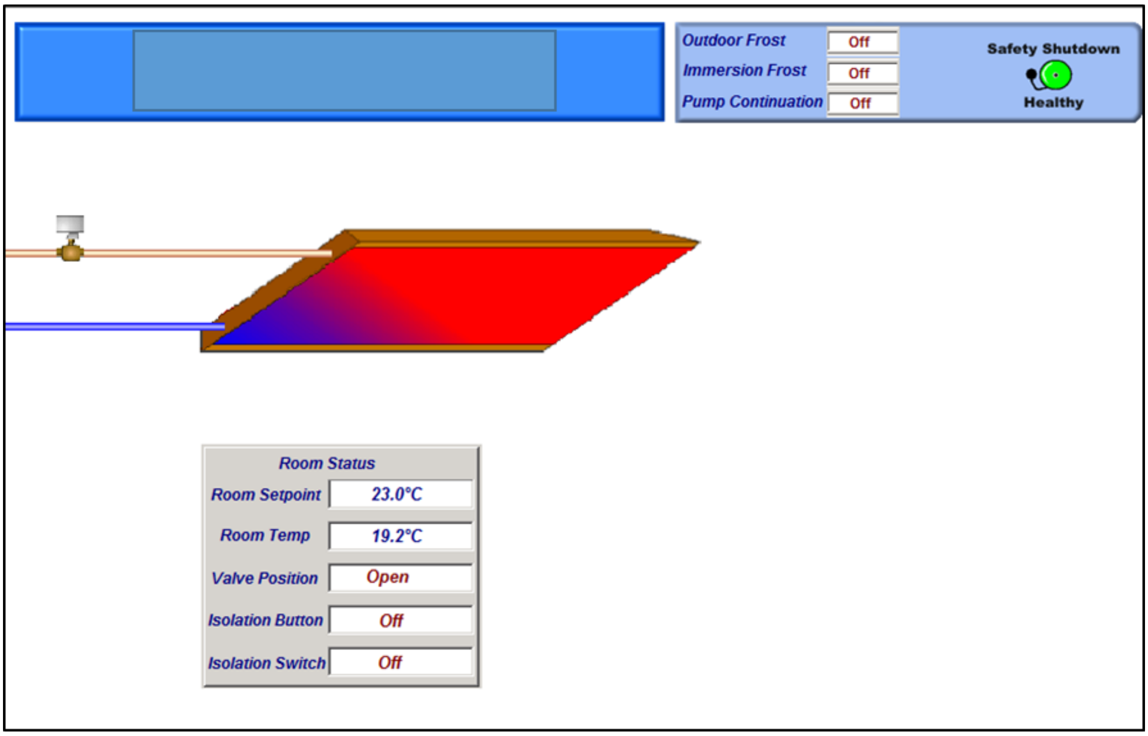
Thumb-turn control of the side-slide opening sections and associated lock

Image showing the metal fascia plate behind which sits a thermistor which acts as the room heating control thermostat

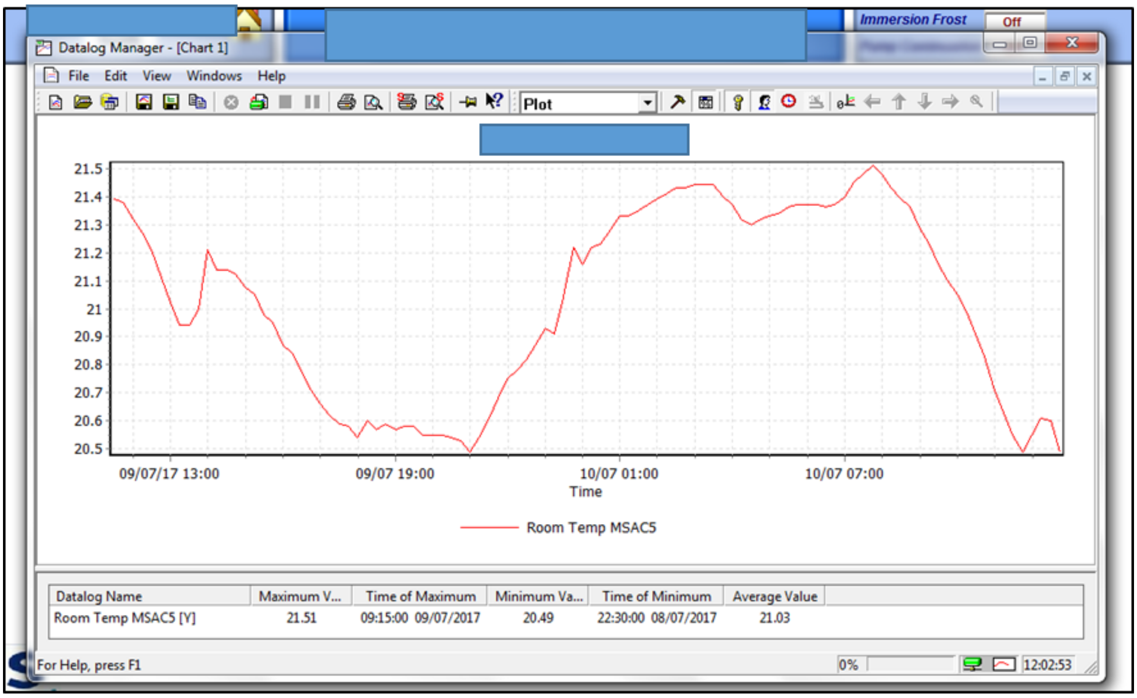
Image showing the emergency 'isolation' push-button and associated controls and services supplying an individual single room. Each room has this function and the control are located within a services cupboard (accessed from the corridor) adjacent to each single room

Example of an 'in-line' chiller (the black unit on the LHS of the image) installed on the mains cold water supply to a ward unit.

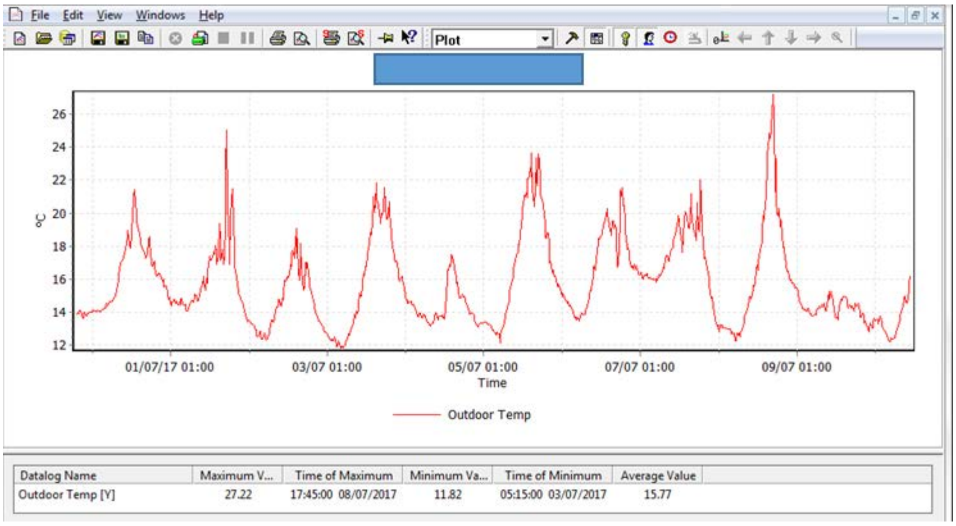
Example screenshots of the site's BEMS system



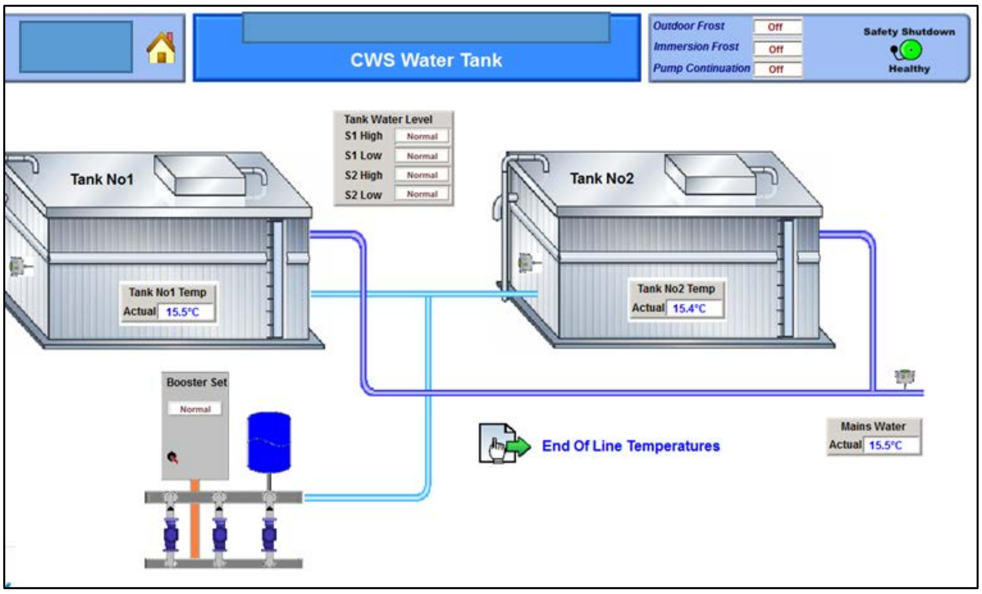
BEMS system overview of the heating control within a single patient room (showing current temperature, the control set-point temperature, position (open/shut) of control valve serving the radiant panel and isolation button status (on/off)). Each single room has the same level of overview.



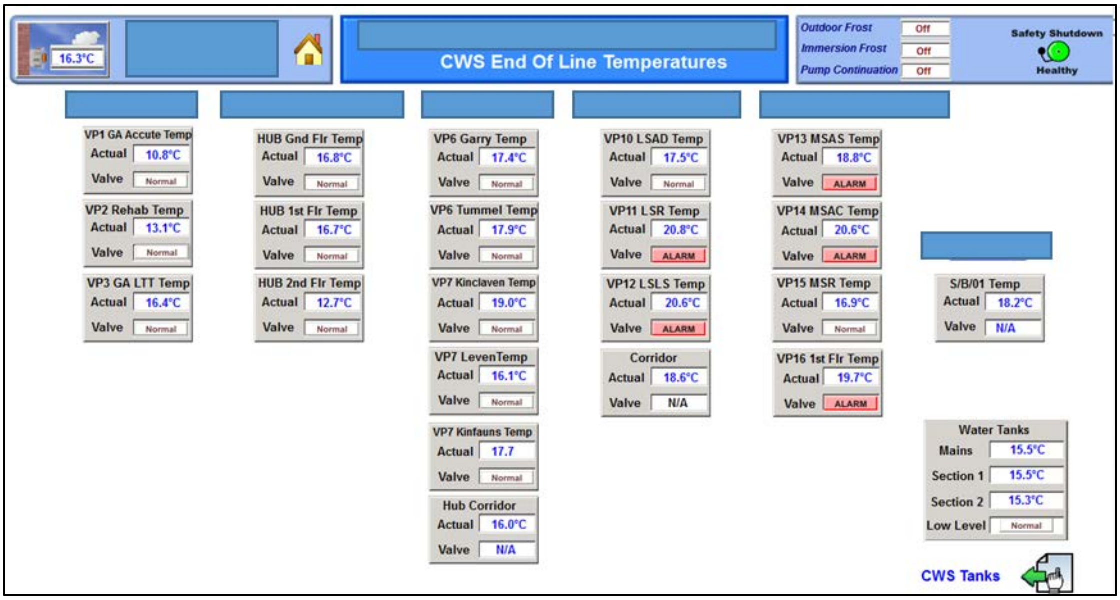
Typical patient room temperature profile (showing a profile between 20.5C and 21.5C over a 36 hour period



External temperature profile (approximately over a 10 day period)



Cold water tank storage and supply pipework temperature monitoring



'End-of-line' cold water supply temperatures (i.e. post chiller) showing that end-of-line temperatures in the one of the unit are above 20°C

6 Conclusions and Recommendations

6.1 Conclusions

The following conclusions are drawn:

General findings

- Given the complex, and in many cases, site specific nature of thermal comfort and overheating issues in hospital buildings, it may not be appropriate to link / group common overheating 'issues' to common hospital archetypes.
- Each of the sample facilities reported a target operational temperature in the region of 21 to 22°C. One facility representative (site 5) reported a target operational temperature of 21°C in the summer and 23°C in the winter.
- All of the Estates team representatives engaged via the project, (with the general exception of site 5), suggested anecdotally, that overheating issues are present in the facilities investigated during this study, at least at certain times of year, under specific external conditions or in specific areas of the facility (e.g. south facing facades). Estates personnel responsible for the facilities suggest that the zoning and control of the heating systems, solar gain, and lack of effective natural ventilation are the most significant contributors to overheating.
- The representatives engaged via the project appeared to be aware of the potential for indirect risks from overheating|: e.g. potential impacts on raising cold water temperatures to temperatures that could increase risk from legionella; however all facilities advised that they had suitably mitigated this risk: e.g. via appropriate use of insulation on cold water pipework or similar.
- It should be noted that one facility (site 5) uses chillers on cold water pipework in order to reduce cold water temperature. The site visit to this facility identified that these chillers were installed at a number of locations at significant distance downstream from the cold water store meaning that there could be potential for the cold water to be raised to unsuitable temperatures prior to the chiller should the pipework be subject to significant heat gain. Further consideration should be given to investigating the reasons for this risk arising.
- Additional overheating related issues such as the risk to medical staff of fatigue from overheating was also raised at one facility.
- Estates personnel at one facility (site 4) had previously commissioned a study in 2011 to model the facility to assess the likelihood of overheating and to examine mitigation options. The report examined a number of approaches including use of automated control on openable windows and solar shading devices.

Existing environmental data and its suitability (or otherwise) for assessing overheating risk

- None of the sample Boards engaged in the project currently record data (e.g. air temperatures in in–patient areas) that would enable a robust assessment of overheating risk. In addition, none of the sample Boards measured or assessed the use of natural ventilation.
- Four out of the five facilities (sites 1, 2, 3 and 4) had a limited number of sensors measuring air temperature. These sensors form an integral part of the heating control system and were generally located in corridors or other common spaces.

Whilst there were some instances of sensors being located in in-patient areas such instances were not significantly widespread, nor did they tend to provide a suitable representation of 'typical' in-patient areas in the facility in question. Furthermore, installations typically consisted of one or two sensors per 'wing' / 'zone' / 'floor' of the facility (owing to their control system function) with temperatures typically being averaged for use by the control system.

- In summary, it is concluded that the control systems with these facilities are not suited to collecting data to enable a robust assessment of overheating risk in in-patient areas (owing largely to the small number of sensors and their relative locations/distribution in relation to the in-patient areas of interest).
- Only one facility out of the five studied (site 5) presented an opportunity for capturing good quality air temperature data however the site operator advised that the system did not currently permit logging beyond approximately 48 hours.

<u>Mitigation Measures</u>

- All of the sample Boards engaged via the project generally used openable windows, local fans and curtains/blinds to mitigate overheating, although Boards reported different levels of success with these measures. Additional measures used by some Boards included the use of window films as well as calls to the Estates helpdesk to investigate overheating / turn heating down/off. One Board reported that they had previously used temporary air conditioning units.
- None of the sample Boards measured (objectively or subjectively) the effectiveness of the mitigation measures. One site (site 3) did however note that there continue to be requests for supplementary fans from wards and offices at the site.

<u>Perceptions of overheating and key contributing factors</u>

Estates representatives at three out of the five of the sites (sites 1, 2 and 4) provided a response in this area. Additional responses were also obtained from an operational staff member at site 2. Key findings were as follows:

- There was a mixed response as to whether respondents thought there was an overheating risk, or not, for in-patients. Site 1 suggests not, whereas site 4 suggests yes. Interestingly whilst the estates representative at site 2 suggests not, an operational representative at the same facility suggests yes.
- In terms of how serious / severe respondents felt the overheating risk was; those who suggested there was a risk identified the risk as either high or very high, whereas those who suggested there was no risk suggested the risk level was low.
- When asked if they thought that there was an overheating risk for staff, respondents answered exactly the same way as they had done regarding in-patients. However, when asked to comment on the severity of the risk the estates representative at sites 1 and 2 reported very low (i.e. lower than the 'low' risk they identified for in-patients). Operational staff at site 2 reported high and site 4 reported 'very high' (both as per the risk previously identified for in-patients).
- When asked to comments as to what extent they thought seasonal weather impact on this overheating risk; all respondents suggested highly or very highly.
- More than one respondent identified the following key factors as contributing to overheating at their respective facilities: solar gain, poor design (including zoning of heating and poor window design, lack of ventilation), window restrictors. Interestingly the single operational representative raised the lack of local control over heating as a contributing factor.

It should be noted that due to the small sample size that the above results are not necessarily representative of facilities of the same building type 'classification' and that a number of personal, local and/or site specific issues may have influenced the responses obtained.

6.2 Recommendations

The following recommendations are made:

- As no robust or easily interrogate-able data is logged or otherwise available, it is recommended that consideration be given to undertaking a programme of cost effective monitoring (of selected in-patient facilities) in order to capture data to enable a robust assessment of the nature and severity of overheating at selected sites.
    - Further considerations and recommendations for suitable data capture to enable assessment of overheating are provided in section 7.
- Further consideration will however, need to be given as to which sites should form the basis of such a future study, so that any future works can maximise learning. For example, this study has highlighted that ventilation strategies, heating plant zoning and control (or the lack thereof) are likely main contributing factor to overheating however, system zoning and control (and ventilation system design and use) is likely to vary significantly from site to site and will therefore typically require site specific solutions. Further work may therefore wish to be considered in terms of developing general appropriate guidance, overheating mitigation principles and/or system design / amendment / refurbishment scenarios (including case studies) to help inform NHS Boards of how best to tackle overheating.
- Consideration should also be given as to whether the steering group wishes to commission a future study that will focus on simply assessing overheating, or one that goes beyond assessing overheating to also investigate practical solutions for mitigating overheating. The latter will undoubtedly require thermal modelling of selected spaces. In addition, it is likely that any solution developed are likely to be site specific so the future study may wish to consider examining facilities that present opportunities for widely applicable solutions and greatest learning. Consideration may also wish to be given to developing case studies to aid knowledge dissemination.
- Consideration should also be given to engaging with building users, as well as knowledgeable Estates teams, in order to help shape the future project (or form part of the project or steering group) as many individuals have considerable knowledge in the issues affecting their facility and the suitability of retrofit solutions.

7 Recommendations to Enable Suitable Data Capture

7.1 Data Requirements

Temperature and relative humidity are strong determinants of thermal comfort, and so monitoring equipment that monitor these variables are of prime importance and should therefore be installed in the locations of interest where patients spend the bulk of their time. There is also some benefit in monitoring other parameters such as window-open/close contact sensors (so that the temperature and RH data can be analysed in conjunction with data relating to window use in order to assess the effectiveness of opening windows), brightness/lux (which can provide a crude indication of sunlight) and occupancy (e.g. a passive infra-red (PIR) detector) to determine whether the environmental conditions at a particular time are relevant to patient comfort.

To ensure robustness of data, it is advised that readings be taken at regular intervals in order to spot 'rogue data' and in order to ensure that datasets are normalised. Similarly, weather data should be collected over the same period that indoor conditions are monitored, in order to permit proper interpretation of the data. Also, as occupier behaviour can also vary, this thereby necessitates the collection of data over a sufficiently long period of time to ensure that a variety of occupancy patters / building use is encompassed.

While carbon-dioxide sensing provides a good indication of the adequacy of ventilation, such sensors tend to be costly. The sensing of relative humidity is much less costly, and excessive humidity levels are a good indicator of inadequacy of fresh air supply. For these reasons, the use of carbon dioxide sensors is not recommended for this application.

Sensors should be positioned to record data that is representative. Temperature and relative humidity loggers (both indoors and outdoors) should be sited out of direct sunlight and away from sources of heat or draughts (i.e. away from lamps, TV sets, ventilation ducts, windows etc.). Furthermore, sensors must be installed at appropriate heights. For outdoor sensing, data loggers will typically need to be waterproof to withstand adverse weather and manufacturers guidance should be consulted, considered and adhered to in order to reduce risk of data loss or equipment failures.

7.2 Types of sensors

In order to assess overheating over a summertime period, electronic sensors for monitoring the conditions in each room are recommended. As a minimum, temperature and relative humidity should be sensed, since these two metrics are crucial for assessing thermal comfort, however window-open/close sensors (to provide a crude indication of ventilation), lux sensors (to determine whether sunlight might be strong) and occupancy sensors (to determine the relevance of the temperature data at a particular instant in time) are also worth considering.

As regards electronic configuration, two options are available:

(1) Standalone data loggers which record conditions at regular intervals (e.g. 15 minute intervals if memory permits) and which store the data in the device's memory. If this option is adopted, data could then be sent for analysis either by sending sensors in padded envelopes or by offloading data locally and sending data files to the persons that are analysing the data. Offloading the data by local staff, from time to time, could enable data to be checked at an early stage to ensure that meaningful readings are being recorded and it is a good safeguard against the loss of data resulting from battery failure or similar. Offloading data could involve the use of laptops, with suitable connectors, or it could involve changing memory cards (e.g. SD cards) and sending the filled memory cards to the persons who analyse the data.

(2) Wireless building monitoring sensors which send wireless signals externally over the mobile phone network or alternatively to a central receiver hub installed locally (with signal boosters if needed) where the central hub can then relay the encrypted data via the internet, over GSM or via manual removal of collected data (e.g. via USB stick of SD card removal) to be analysed. The persons analysing the data can then download data and check, at regular intervals, that the data is sound.

The accuracy of sensors should be sufficient to distinguish between comfortable conditions and uncomfortable conditions. For this reason, a temperature accuracy of 0.5°C or better is recommended both for indoor temperature and outdoor temperature monitoring, and an accuracy of approximately 5% or better for relative humidity loggers.

For the purposes of budget costing, the steering group should allow approximately £100 for the purchase of each combined temperature and RH sensor together with their associated batteries, data-transfer cables and SD cards. Allow £200 per light/lux data logger, £200 per PIR data logger, and £100 per window-open contact sensor. BRE are happy to discuss the data capturing requirements in more detail with the steering group.

7.3 Locations of sensors

The use of sensors to assess conditions is important because healthcare staff cannot easily assess how comfortable a room is for patients. This is because the clothing levels and activity levels of staff differ from those of patients. The appropriate siting of sensors is crucial for ensuring that readings are representative of the conditions experienced by patients. It is therefore recommended that sensors are located at an appropriate height so that they represent conditions experienced by persons in beds, chairs or wheelchairs. A patient in a bed might be 0.8m above the floor whereas a person sitting in a chair or wheelchair might have a head height of 1.2m. Sensors should not be located in places that are subject to direct sunlight, even although direct sunlight could have a significant impact on patient comfort.

In order to ensure that sensors are located appropriately, two options are suggested:

(1) Sensors are installed by BRE staff (or another appointed party) or by NHS staff who have extensive experience in sensing. This approach would involve a high degree of travel and could be costly as a consequence, and in any case would need to accompany by local staff who have authorisation and who are familiar with the geography of the buildings.

(2) Local staff, who have undergone stakeholder training, and who already have authorisation to work in the areas used by the patients, are provided with a pro-forma and sensors which they subsequently install in suitable locations. The pro-forma, once filled in, would then be forwarded to BRE along with photographs of the installed sensors. If BRE staff are concerned about the locations of the sensors at this stage they can then contact the relevant staff and advise them of the necessary adjustments.

Where possible, rooms which are known to be warmer in the summer months should be selected. Where it is not clear which rooms are most prone to overheating, it is recommended that a mixture of south-facing and east/west-facing wards be included in the study, particularly rooms which have a sunny outlook (e.g. rooms on upper floors which are not shaded by nearby buildings). Rooms which face east or west will often receive more summer sunlight than rooms that face south and therefore might actually be more prone to overheating. Any pro-forma given to the local staff who are installing the sensors/loggers would need to include questions relating to the likely impact of direct sunlight (e.g. they may be asked the compass direction of the windows in the ward or day room). The pro-forma is also likely to contain questions about whether curtains are used to reduce the direct sunlight entering wards. The number of sensors needed will depend upon the size of the wards. For example, a small number of sensors might suffice for small wards with a larger number of sensors for larger wards. As a rough guide, the number of temperature sensors should be at least one fifth of the number of beds. In addition, a minimum of two temperature and relative humidity sensors per day room is recommended.

It is also recommended to use a window open sensor on at least one window per ward or day room. Should budget allow then one PIR sensor per ward or day room, and one lux sensor per ward or day room could also be included. At least one outdoor temperature and RH sensor should be used per site, sited in a shaded location (ideally north facing).

bre

Appendix A Broad Classification of Scottish Hospital Type by Build Age / Ward Type

Ref	Build date (approx)	'Typical' ward type design	Typical features	Typical construction	Procure-ment	Examples
A	pre mid-1950s	Nightingale	Open plan 8-30 multi-bedded room ward model, with shared ablution block.	Solid masonry wall, >3m high plaster ceilings, timber sash windows, natural vent, cast iron radiators, steam distribution, coal boiler.	Trad.	Glasgow Royal Infirmary; Aberdeen Royal Infirmary; Lawson Memorial Hospital, Golspie; Insch Hospital; Chalmers Hospital, Banff, Stephen Hospital, Dufftown, Inverurie Hospital; Ayr Central Hospital; Stratheden Hospital, Fife.
B	late 50s - early 60s	Racetrack	mix of >10% 1 bed and 4 (or 6) bedded rooms, central support rooms incl shared WCs, Showers etc.	Concrete frame, cavity infill panel, flat roof, 2.4 - 2.7m suspended ceilings; timber/steel single glazed windows, mix natural vent with extract from ensuites, bath & dirty utilities etc; radiators, steam distribution, gas boiler.	Trad.	Vale of Leven Hospital; Gilbert Bain Hospital, Shetland; Belford Hospital, Fort William; Ninewells Hospital, Dundee?
C	late 60s - early 80s	Falkirk	Mix of >20% 1bed and 4 (or 6) bed rooms, each with ensuite WC/ shower, around central support rooms.	Concrete frame, cavity infill panel, flat roof, suspended ceilings; aluminium single glazed windows, mix natural vent with extract from ensuites, bath & dirty utilities etc., LST radiators, steam / MTHW distribution, gas boiler.	Trad.; (Borders = early D&B)	Monklands Hospital; Aberdeen Royal Infirmary (Phase2 blocks); Western General Edinburgh; Glasgow Royal Infirmary (QE2 block); Gartnavel General Glasgow; Crosshouse Hospital, Kilmarnock; Raigmore Hospital, Inverness; Royal Alexandra, Paisley; Inverclyde Royal, Greenock; Borders General, Melrose
D	late 80s - 2000	Courtyard	Mix of 30-50% 1 bed and 4 bed rooms, each with ensuite WC/ shower, typically in L, T or Y shape corridors, with support rooms alongside.	Steel frame, metal insulated panel cladding / pitched roof, some brick or rendered block, 2.4 – 2.7m suspended tile ceilings, aluminium double glazed windows (100mm opening), mix of natural and mechanical ventilation, radiant ceiling panel, gas boiler.	D&B / DBFM	Lorne & Islands hospital, Oban, Queen Margaret, Fife; Ayr Hospital; Western Isles Hospital, Stornaway; Hairmyers Hospital, East Kilbride; Wishaw General Hospital; Edinburgh Royal Infirmary; Victoria Hospital, Kirkcaldy; Stobhill Hospital; Victoria Hospital, Glasgow; Forth Valley Royal Hospital, Larbert; St Andrews Community Hospital

Ref	Build date (approx)	'Typical' ward type design	Typical features	Typical construction	Procure-ment	Examples
E	late 80s - 2000	CSA template	Common Services Agency' (CSA) 30 bed, typically comprising 6 x 1 bed and 4 x 6 bed (each with ensuite WC / shower).	Typically one storey ward template. Usually built on existing hospitals for elderly or mental health patients.		
F	2000 onwards	Finger	Mix of 50-100% 1 bed, and occasionally 4 bed rooms, each with ensuite WC/ shower, typically in long thin wings around open (occasionally closed) courtyards, with support rooms centrally and/or alongside.	As per '4' above plus... Mechanical ventilation in majority of rooms with some natural ventilation where practical for patients, heated / chilled ceiling beams, gas boiler with CHP or renewables, BREEAM 'excellent' target set.	DBFM / D&B	Aberdeen Emergency Care Centre; Aberdeen Children's Hospital; Murray Royal, Perth; Queen Elizabeth University Hospital & Royal Hospital for Children, Glasgow; Woodlands View, Irvine. St Andrews Community Hospital. Plus, under-construction: Royal Hospital for Children, Edinburgh, Dumfries & Galloway Infirmary; Balfour Hospital, Orkney.

Appendix B Project Questionnaires

Questionnaire 1: Asset and environmental data information

		<insert name of NHS Board>
	Asset Information	
1a	Confirm this Asset list is accurate for your NHS Board? Please comment on any changes, e.g. to "hospital type" classification.	<insert comments here or adjacent to the specific assets on the "assets" tab>
		<insert new lines for comments as appropriate>
1b	provide the current bed numbers for each asset listed	<insert approx number>
1c	provide the set operational temperature (range) for each asset listed	<insert approx number(s)>
2	Has there been any major energy efficiency upgrades to above property(s) that has/is likely to have an impact on temperature & its control	<insert comments adjacent to the specific assets on the "assets" tab giving brief details of the refurbishment>
3a	Do you measure / assess overheating (yes/some/no)	<yes - every property; yes- some properties / mostly; yes - selected properties; no-none>
3b	if some/yes, how is this done (please list any methods used)	<quantitative i.e. by sensed data; qualititative e.g. by patient / staff surveys; >
		<insert new lines for comments as appropriate>
	Natural ventilation	
4a	Do you measure / assess use of natural ventilation / windows (yes/some/no)	<yes - every room/ property; yes- some rooms/ properties / mostly; yes - selected rooms /properties; no-none>
4b	if yes, how is this done (please list any methods used)	<quantitative i.e. by sensed data; qualititative e.g. by patient /staff surveys; >
		<insert new lines for comments as appropriate>
	Mitigation measures	
5a	Has there been any mitigation measures implemented to help reduce overheating	<yes - every room/ property; yes- some rooms/ properties / mostly; yes - selected rooms /properties; no-none>
5b	if some/ yes, provide an approximate percentage of in-patient assets (as listed above) where mitigation measures have been deployed	<insert approx %>

		measure 1	measure 2	measure 3	measure 4	measure 5	measure 6	measure 7	measure 8	m
5c	if some/ yes, how is this done (please list any methods used e.g. fans, moving patients, shading, comfort cooling). Please list the most widely used measures first.	<name>	<name>	<name>	<name>	<name>	<name>	<name>	<name>	<n
5d	How successful do you feel these mitigations have been (score 1 - 5; where 1=not very successful, 3=neutral, 5 = very successful)	1,2,3,4, or 5	1,2,3,4, or 5	1,2,3,4, or 5	1,2,3,4, or 5	1,2,3,4, or 5	1,2,3,4, or 5	1,2,3,4, or	1,2,3,4, or	1,
5e	Has the undertaking been objectively measured in any way (please describe)	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<d
5f	Has the undertaking been subjectively measured in any way (please describe)	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<describe>	<d

	Environment Data											
Note	All spaces will ordinarily have connectivity with a building management system. This should be enabled to record/date-time stamp measured values											
6	Is it so enabled?	< yes / no / reasoning?>										
6a	If yes, is any use made of this data?	<describe>										
		Environment						**Energy Systems**				
		Internal environment			External environment			mechanical ventilation systems			Heating system	
		air temp	Relative Humidity levels	carbon dioxide (CO2) levels	ambient air temp	Ambient Relative Humidity level	global solar irradiance	supply / extract flow rates	supply air temp	extract air temp	supply temp	return temp
7a	Do you monitor / record the following? ("y" for yes, leave blank for no)	...										
7b	At what scale /resolution do you monitor (e.g. single sensor per room, selected room, every room, etc.)	...										
7c	Where are sensors typically located (e.g. state wall types, heights, etc.)	...										
7d	At what frequency / time interval is data recorded?	...										
7e	Where is the data stored?	...										
7f	Is data able to be downloaded (define if only possible for internal or internal/external parties)	...										
7g	When were sensors installed (approx date)	...										
7h	Have sensors been re-calibrated (approx date)	...										
7i	Can this data be made available to help inform the study, if required?	...										
7j	Please add any other relevant comments regarding data sensing, storage etc. in elation to any of the above data types	...										
7k	Is any other relevant data sensed/recorded? - please provide details	...										
7l	List the main reasons for monitoring this	...										

Questionnaire

	Please score the following questions 1 - 5 (where 1= none/ no/ very low; 3=neutral; 5 = lots/ yes/ very high)	*none / no/ very low*		*neutral*		*lots/ yes / very high*	*don't know / not applicable*
8a	Generally, do you think there is an overheating risk for in-patients in the assets listed? (Please note the asset list excludes out-patient areas)	no				yes	don't know
8b	How serious / severe do you think this risk is?	1	2	3	4	5	don't know
8c	Generally, do you think there is an overheating risk for staff?	no				yes	don't know
8d	How serious / severe do you think this risk is?	1	2	3	4	5	don't know
8e	To what extent do you think seasonal weather impact on this overheating risk?	1	2	3	4	5	don't know
8f	Please rank (highest importance first) the factors that you feel are most critical contributors to overheating within in-patient premises. Please consider operational factors (e.g. window opening restrictions; not used due to noise or other factors, etc.) and asset related factors (e.g. poor heating / temperature controls, etc.)						
1	...						
2	...						
3	...						
4	...						
5	...						
6	...						
7	...						
8	...						
9	...						
10	...						

