



Thermal comfort standards, measured internal temperatures and thermal resilience to climate change of free-running buildings: A case-study of hospital wards

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ABSTRACT

In view of the warming climate, there is increasing concern about the likelihood of overheating inside UK buildings that are not mechanically cooled. A number of studies are examining this matter, of which the DeDeRHECC project is one. The recent availability of the UKCP09 future climate data projections has acted as a stimulus to such work. This paper illustrates how field measurement, thermal modelling and the generation of current and future typical and extreme weather years, can be used to provide a picture of the resilience of buildings to climate change. The unified framework for assessing both measurements and current and future predictions that is offered by the BSEN15251 thermal comfort standard is a crucial component. The paper focuses on internal temperatures during the day and at night in wards within the tower building at Addenbrooke's hospital, which has a hybrid ventilation strategy. The maintenance of thermal comfort in such spaces is critically important and installing air-conditioning in response to climate change is expensive and potentially energy intensive. Fans appear to be a simple retrofit measure that may substantially improve the wards' resilience to climate change even in extreme years. Whilst healthcare provides the back cloth, the methodology developed has a much wider utility for assessing thermal comfort in buildings in the current and future climate of the UK.

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1. Introduction

There is increasing debate about the impact that climate change may have on the internal summertime temperatures in UK buildings because future summers are likely to be both warmer and drier and there is likely to be an increase in the occurrence of extreme temperatures. Elevated temperatures in homes are of particular concern and this may be exacerbated as insulation levels increase. Future conditions in non-domestic buildings are also a concern, the owners and operators of buildings are becoming increasingly interested in the resilience of their existing stock and the clients for new buildings wish to know how resilient the proposed designs are likely to be.

In common with other countries within temperate climate zones, the great majority of UK buildings are passively cooled, especially through the use of operable windows and, in non-domestic buildings, mechanical ventilation. For such a building stock, knee-jerk reactions, especially those that leads to, or even

encourage, the installation of mechanical cooling or air-conditioning, must be avoided: this is expensive and could simply exacerbate the climate change problem by increasing energy demand. What is needed is a systematic and rational approach to identifying buildings that are thermally susceptible to the changing climate.

Thermal susceptibility will differ with geographical location, the building type and its function, and the vulnerability of the occupants to elevated temperatures. The need, or not, for adaptation needs to be reliably predicted, a pallet of refurbishment measures for different building types developed, and the sequence of appropriate interventions determined.

These matters are at the heart of much current research in the UK, notably within the Research Councils UK, Living with Environmental Change programme [1] and work funded through the Engineering and Physical Sciences Research Council's (EPSRC), Adaptation and Resilience to Climate Change (ARCC) programme [2]. This programme, gains much momentum from the recently produced climate change scenarios which, together with a weather generator and algorithms developed by others, enables the generation of hourly weather data at a 5 km by 5 km grid resolution [3]. Typical and extreme future weather data suitable for used in

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dynamic thermal models of buildings and in models used in other areas of research, such as flood risk assessment, crop growth studies, etc can be generated.

The ARCC-funded project reported here concerns the Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC). The project is supported by four Healthcare Trusts that have provided access for the monitoring and surveying of 111 spaces in 9 buildings, some 180 data points logged continuously over a two year period. All but 7% or so of the spaces were free-running in summer, i.e. they were not air-conditioned or otherwise mechanically cooled. Free-running spaces are the norm in UK hospitals.

Hospital buildings in the UK are particularly interesting and demanding from both the climate change adaptation and climate change mitigation perspectives. Concerning mitigation, the UK NHS is very large, occupying some 14,040 premises, about 1% of the UK's non-domestic buildings, and it is responsible for nearly 3% of all UK emissions and 30% of public sector emissions [4]. Thus the National Health Service (NHS), the Department of Health (DoH) and the Trusts that run healthcare services have a major role to play in helping to achieve the UK GHG reduction targets. Building refurbishment strategies that will reduce energy demand are of central interest in the DeDeRHECC project (see e.g. [5]).

Concerning adaptation, during periods of high ambient temperature, hospitals are expected to provide a safe haven for those at large who are suffering, especially during heatwaves [6]. Thus, it is precisely at times when temperatures are high that hospitals harbour the greatest concentration of vulnerable individuals. The thermal comfort of sick and vulnerable individuals as well as normal healthy occupants, during both typical and extreme weather conditions, must therefore be considered.

Refurbishment of the NHS stock is challenging. UK healthcare buildings are numerous and diverse in their constructional form, age and servicing strategy, although very little of this stock is air-conditioned: indeed, air-conditioning is avoided specifically because it is expensive to install and operate [7]. In hospitals, control of infection is a major consideration and this also places a major, but actually rather ill-defined, constraint on modifications that can be made to buildings, their services or their operating regimen. Also, the logistics of refurbishment are complex because UK hospitals strive for a high bed utilization, e.g. in the three months to October 2010 the utilization in the Leicester NHS Trust was, depending on the Department, 79–100% [8], and these patients are very susceptible to noise, dust, etc due to refurbishment work. Thus the need for, and method of, refurbishment to increase climate resilience is likely to be very different across the stock and the opportunities for such work, and the time available in which to do it, is likely to be constrained.

Refurbishment must also avoid increased energy use, which argues against air-conditioning. Indeed, the introduction of full mechanical systems into a building that is free-running can be particularly expensive and disruptive. Quick, light touch and non-intrusive strategies are highly desirable. A companion paper [5] examines the practicality of a number of active and passive low-energy refurbishment measures for improving the resilience of hospital wards. Here the simple expedient of introducing personal or ceiling fans to provide comfort with little increase in energy demand, is briefly considered.

The biggest challenge with low-energy refurbishment is the provision of thermal comfort for all hospital occupants during hot weather and such weather will be more frequent as the climate warms. The diverse occupants of hospital have differing thermal comfort requirements, most important are the patients but others include clinicians and nursing staff, support staff (administrators, cleaners, etc) and visitors. At times, any or all of these may occupy

the same space, for example a hospital ward. Whilst patients may be very sensitive to abnormally high or low temperatures (being old, or sick or having impaired thermoregulatory systems) other occupants will have more 'normal' thermal requirements and expectations, but they will inhabit the hospital for many more days (or years) than most of the patients. An examination of prevailing thermal comfort standards and their usefulness for evaluating summertime temperatures in hospital wards, especially those that are not mechanical cooled, is a key aspect of this paper.

The tower at Addenbrooke's hospital in Cambridge, UK provides the vehicle for examining the applicability of thermal comfort standards and the performance of fans. The origin of the building and its geometry and construction is fully described elsewhere [5]. Internal temperatures were measured in the wards and nurses stations during a 46 day period in the summer of 2010. At the start of the period, July, a Level 2 heatwave was declared, although a full heatwave did not materialise [9]. Likely future temperatures and the consequential thermal comfort of occupants, with and without fans operating, are predicted using a calibrated dynamic thermal model.

The tower building has a simultaneous hybrid ventilation system, that is, the mechanical system run permanently and in tandem with the manual system – operable windows. This paper is thus complementary to [10] that examined the future performance of refurbishment measures in passively ventilated ward spaces using the same comfort criteria.

Whilst hospitals are the spring board for the work, it should be of much wider interest, as it leads to a methodology that can be used in many free-running building types to assess internal thermal comfort, overheating risk and resilience to climate change.

2. Methodology

One aim of the DeDeRHECC project, which is the nub of this paper, is to develop a methodology for assessing the resilience to climate change of UK healthcare buildings. The methodology must enable credible models to be built that can predict the internal conditions in current and future, typical and extreme, climatic conditions and enable the widest possible range of innovative refurbishment and low-energy cooling strategies to be evaluated.¹

A five stage methodology is envisaged. Firstly the geometry, construction, servicing strategy and environmental control of the spaces is determined. This requires the study of archive drawings, field measurements and observations, and interviews with facilities management and other staff. Secondly, temperatures are recorded in target spaces to determine the internal temperatures and, when and where possible, air flow rates, CO₂ levels, window opening strategies etc. Although this work focuses on summer conditions, temperatures are recorded throughout the year.² These data are archived cleaned and key parameters produced. Thirdly, the temperatures are compared with the appropriate thermal comfort standard to assess the extent to which the spaces are, or are not, delivering thermal comfort for the weather conditions that prevailed during the monitoring period. Fourthly, a model of the space(s) to be assessed is built within a dynamic thermal model. This model is then 'calibrated' using the weather data recorded during the monitoring period with the monitored internal

¹ Comfort conditions might be controlled by adjusting air temperature of course, but also by controlling air speed, using fans or directional diffusers, or changing the radiant temperatures using heated or cooled ceiling panels – a fairly common strategy in modern hospitals. In the context of fabric refurbishment, the impact of shading on incident short wave radiation is also important.

² A parallel study is investigating energy demands in hospital spaces.

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