Energy and Buildings 130 (2016) 651–666

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Bridging the gap between energy and comfort: Post-occupancy evaluation of two higher-education buildings in Sheffield

Ranald Lawrence*, Charlotte Keime

Sheffield School of Architecture, The University of Sheffield, The Arts Tower, Western Bank, Sheffield, S10 2TN, UK

ARTICLE INFO

Article history:
Received 31 January 2016
Received in revised form 25 July 2016
Accepted 1 September 2016

Keywords:
Energy performance
Thermal comfort
Occupancy patterns
Post-occupancy evaluation
Environmental control
Active versus passive design
University buildings

ABSTRACT

Recent technical guidance has suggested that comfort and energy efficiency should not be seen as mutually exclusive [CIBSE, "TM54: Evaluating operational energy performance of buildings at the design stage", 2013]. Currently, however, there is a lack of comprehensive understanding of energy use during building operation and how it influences user comfort. Through comparison of the complex relationships between energy, thermal comfort, and environmental strategy in two flexible higher-education buildings in Sheffield, this paper demonstrates how designers can utilise aspects of active and passive design to deliver more comfortable, lower-energy workspaces. Analysis of the authors' post-occupancy evaluation of each case study examines what lessons might be learnt and applied to other institutional buildings in order to save energy without compromising occupant comfort.

The findings illustrate how perceptions of comfort can be improved by increasing the degree of environmental control occupants have without necessarily increasing energy consumption. The paper highlights the significance of occupancy patterns to a complete understanding of energy efficiency and comfort, and speculates that the prediction and assessment of energy per occupant may have an important future role to play in bridging the gap between energy performance and comfort.

1. Introduction

In order to limit global temperature rise to as little as possible above 2 °C, the 2008 Climate Change Act established a target for the UK to reduce its CO2 emissions by at least 80% from 1990 levels by 2050. The Act established five-yearly carbon budgets to serve as stepping stones to ensure that regular progress is made towards this long term target [1].

It is estimated that the construction industry has a direct or indirect impact on 47% of all carbon emissions in the UK [2], and non-domestic buildings account for approximately 18% of the UK's carbon emissions [3]. Architects and other industry professionals therefore have a responsibility to reduce emissions from institutional facilities such as university buildings. Building regulations such as Part L are becoming stricter, and standards such as BREEAM, CIBSE, and Passivhaus have been introduced in order to facilitate low energy design. However, most of these standards only measure regulated energy loads. They do not consider the 'whole life cost', resulting in buildings regularly falling short of design ambitions; commonly referred to as the performance gap.

Therefore, researchers and policy-makers are now focussing on occupant behaviour. One ambition is to encourage occupants of institutional buildings to consume energy in a more responsible way and to transfer this behaviour into their everyday lives, creating an 'environmentally friendly' society.

However, developments in the fields of building physics and environmental psychology have often occurred independently from each other, and there has been little comparative analysis of large-scale surveys into energy consumption and environmental performance in recent years [4]. As such, there is still a lack of comprehensive understanding of energy use during operation [5] and how it influences user comfort. As social expectations and the consumption patterns of occupants can defeat the most careful of designs, designers need to focus on how buildings will be used in order to reduce energy consumption in real terms.

Contrary to domestic buildings, where energy consumption has reduced over the past few decades [6], medium to large-scale public and commercial buildings have seen an increase in energy use. This is partly due to the utilisation of 'active' environmental control strategies, often associated with improved environmental quality and comfort. However, these strategies can lead to higher electricity consumption [7], and can also result in increased discomfort by creating unrealistic expectations that they can satisfy all occupants all of the time. Recent research has indicated that from a comfort and

* Corresponding author.
E-mail address: ranald.lawrence@sheffield.ac.uk (R. Lawrence).

http://dx.doi.org/10.1016/j.enbuild.2016.09.001
0378-7788/

Fig. 1. The Arts Tower exterior and internal study space.

Table 1
Statistics of survey participants in the Arts Tower.

Age range		Gender		Role		Regularity		Workstation	
20–35	86%	M	52%	Student	76%	Full Time	62%	Open Plan	80%
>35	14%	F	48%	Admin	24%	Part Time	38%	Shared Office	20%

satisfaction standpoint passive strategies are often the best solution to building in the UK climate, as they give individuals more control of their thermal environment [8].

1.1. Background: the performance gap

According to research conducted by Armitage et al. recent changes in building regulations have had a noticeable impact on thermal energy consumption in public offices, with reductions of almost 40% in buildings built after 2000. However this has been counteracted by higher electrical consumption, with an almost 75% increase between buildings constructed pre-1959 and those built since 2000, resulting in higher overall CO_2 emissions [9].

Much emphasis is placed on achieving energy savings in early design stages. However, with advances in computing power and building simulation software, the accuracy of predictions is increasingly reliant on initial assumptions about occupant behaviour. Therefore, to improve our ability to accurately predict energy consumption, the focus needs to be on understanding the complex relationship between a building and its occupants [10]. Two major steps to reducing energy consumption are understanding where energy is used and the consideration of people and their expectations [11].

1.2. Thermal comfort

Thermal comfort has been defined as ‘that condition of mind which expresses satisfaction with the thermal environment' [12]. It results from a dynamic equilibrium; the interaction between people and buildings in a particular social and climatic context [13]. As individuals have different comfort thresholds, they will react in different ways at different times, making unanimous perceptions of comfort satisfaction in spaces of multiple occupancy very difficult to achieve.

Research has shown that occupants have a certain level of ‘forgiveness’ for buildings where indoor conditions are naturally variable and under their control [14], as well as where the environmental design intent is legible [15]. It is clear that the provision of adaptive opportunities in a building are crucial, as they allow occupants to adapt both themselves to the environment and the environment to their own requirements [16]. However, providing personal control in open plan spaces is usually costly and impractical; temperature and lighting are therefore usually based on average standards and are automatically controlled [17].

1.3. Post occupancy evaluation (POE)

For a particular strategy to be successful, both designers and occupiers of a low energy building must accept responsibility for how a building will be used. Designers need to understand adaptive mechanisms and engage with the occupants in the design stage in order to acknowledge the richness of human/environment interactions [18]. In order to improve low energy design, feedback measures such as POE are becoming more popular as they encourage a dialogue between designers and occupants, building an evidence-base for future design assumptions.

POE evaluates the functional performance of a building by providing an analysis of energy use, as well as how user needs are supported through satisfaction surveys [19]. POE can reduce the longer-term financial impact and energy consumption of mismanaged and poorly understood buildings, and offers an opportunity