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A concept review of power line communication in building energy management systems for the small to medium sized non-domestic built environment

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ABSTRACT

To date, building energy management systems (BEMS) have been well established in the large scale non-domestic field as an energy saving technology, contributing towards sustainable future cities. They utilise complex control interfaces, with control signals passed through purpose built communication wiring. Estimated end-use energy savings, due to BEMS addition, can reach up to 50%, with associated financial savings for building users. The intelligent control, featured in BEMS, enables buildings to adapt; optimising operation based on up to date weather forecasts. Despite the positive savings for future sustainable cities, the additional wiring required and complex control interfaces have inhibited wide scale up take for small and medium sized commercial buildings. Retrofit installation is often time consuming, whilst efficient operation requires additional training for users. BEMS, based on wireless communication technology, are limited by radio-wave reception and therefore suffer in heavyweight constructions and larger premises (greater than 1000 sqm). Following review of available technologies, this paper investigates a novel strategy utilising power-line communication (PLC) for BEMS communication, for versatile applications in the small to medium sized non-domestic (SMSND) premises that make up future sustainable cities. The PLC strategy intends to send BEMS control signals via the established electrical wiring network. Before implementation of this concept, further work is required to overcome the more challenging aspects of PLC technology.

Contents

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1. Introduction

Worldwide, in 2011, the built environment accounted for 118EJ,[1] 34% of global energy consumption. 30EJ were consumed within service sector buildings, 26% of total built environment consumption [1]. Assessing the end-use energy demand in such buildings (Fig. 1), 33% of end-use energy was consumed through space heating and cooling, with a further 14% used on lighting. The demand for energy is projected to rise [2], putting extra stress on energy markets and the environment, yet the energy intensity (energy consumption divided by contribution to GDP) has not improved since the late 1980s, suggesting a lack of improvement in energy-efficiency [3]. To meet the UK government climate change targets (80% CO_2 reduction by 2050), energy-efficient measures, throughout the service sector built environment, are an essential feature in future cities [4].

In 2013, the UK commercial property market was worth approximately £717 billion, with 51% of organisations renting office space [5]. Industry wide, 74% of businesses had commissioned some level of energy-efficiency technology retrofit prior to 2014. Amongst large corporations nine out of ten had commissioned work; whilst only six out of ten SMEs had commissioned projects [6]. Fig. 2 charts the wide range of energy-efficient technologies commissioned during 2012/13.

1.1. Impact of user behaviour on building energy efficiency

Excessive end-use energy demand is commonly exacerbated due to improper occupancy operation. Of the top five technologies commissioned in 2012 and 2013 (Fig. 2), four of them relate to behavioural change or automating control away from the occupant. One 2013 study, assessing the difference between design and actual energy consumption, noted a 94% increase in actual consumption over designed consumption [7]. Assuming lights typically remain on throughout the working day, Garg [8] discovered occupancy sensors reduced lighting energy consumption by 20 to 25%. Intelligent control of the major energy consuming office elements provides excellent potential for energy savings.

The significant discrepancy between predicted and real building performance, shown in Fig. 3, is in part caused by both an underestimation of predicted values for building use and wasteful use of resources by occupants. Both of these “can mainly be attributed to misunderstanding and underestimating the important role that the occupants' energy use characteristics play in determining energy consumption levels” [10]. Occupant behaviour is one of the major factors contributing to excessive energy use during building operation [9,11], alongside effectiveness of services control and deviations from designed build quality. Linking energy optimization systems to forecasts of occupant energy demands and behaviours is identified as an area for future development in sustainable cities.

Given that the impact of users' behaviour on the operation and energy performance of buildings has been established, routes to reduce this impact must be explored. This includes attempts to effect conscious behavioural change in occupants (which can have limited or counter-productive results [12]) or to automate building services, transferring the responsibility of control away from occupants.

The field of building automation is not new; however as sensing, computing and actuating technologies have developed the scope of control has expanded. The use of more extensive sensor/actuator networks have made it more feasible to allow for automation taking precedence over occupant control, allowing for comfortable conditions to be maintained without wasteful behaviours from occupants. The ideal way to respond to occupants' needs is the subject of much research, but most studies confirm that greater automation in control can lead to significant energy saving. For example, studies have shown that the automation of lighting and appliance use – processes often left purely to occupant control - can reduce energy consumed by up to 21% [13], 22% [14], 25% [8], 34% [15] and 50% [16] respectively. The exact savings made depend heavily on the building of application and the level of responsiveness to occupant needs.

It is worth noting, that although building automation can significantly reduce energy use, research has also identified that occupant control can improve occupant perception of comfort [17]. For a building automation system to be accepted by occupants the comfort conditions maintained should be optimal.

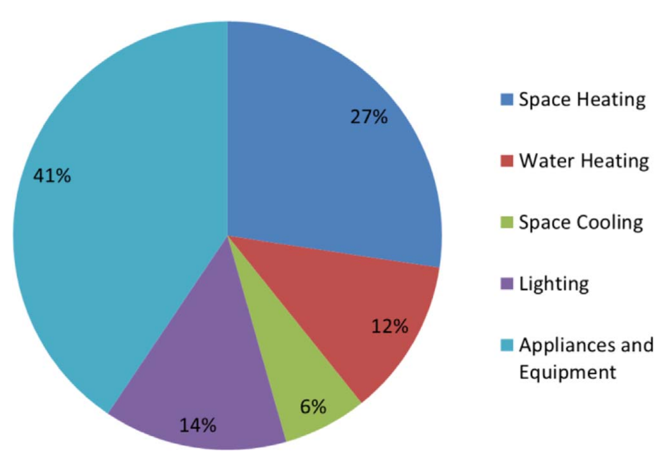

Fig. 1. Service-sector built environment end-use energy breakdown for 2011 [1].

[1] EJ is an exa joule, 10^{18} Joules. 1 EJ is equivalent to 23.9 Mtoe or 278 TW h.