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Review

A persuasive feedback support system for energy conservation and carbon emission reduction in campus residential buildings

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ABSTRACT

There is a need for energy conservation mechanisms, especially in university campuses, as students do not have any direct feedback on their energy consumptions, which leads to excess usages. There are few existing approaches aiming to reduce electricity usages in higher education institutions through real-time feedback applications. These approaches mainly apply student experimental studies with incentives (gift reward). Their feedback systems present data only in near real time using data loggers and Modbus data collector, which are characterised with a slow and unstable data transfer rate. Furthermore, they are not designed for long-term deployment in a wider campus energy management environment. Thus, the challenges for reducing energy consumption and carbon emissions in the higher education sector still remain.

To address these challenges, we have designed, configured and implemented a robust persuasive feedback support system (PFSS) to facilitate energy conservation and carbon emission reduction. This paper presents the complete architecture of the proposed PFSS, its system interface and the real time measurement output strategies. To demonstrate the applicability of the proposed system and to assess its performance in comparison with the previous systems, we used the student halls of residence at the University of Kent as a use case scenario.

Contents

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1. Introduction

According to the Department of Environment, Food and Rural Affairs (DFRA 2009), 152 million tonnes of carbon was produced in the UK in 2009 [1]. The domestic sector accounts for 41.7 million tonnes, which is about 27% of carbon emissions in the UK resulting from energy consumption [1]. It was approximated that the environmental impact and consequences of the carbon emissions could result in issues such as global warming, rise in sea level, and drought [1]. The rising global energy demands, environmental issues, increasing costs and limited natural resources call for efficient and economic management of resources and energy conservation practices. This is especially important in large residential areas such as big urban cities, where energy consumption remains largely invisible to consumers. The consumption of electricity in residential buildings is highly dependent on the behaviours of the residents [2]. Therefore, we need to approach this issue not just with technological solutions but behavioural change as well.

A major challenge for people who are willing to save energy and reduce carbon emissions in their homes is the lack of information and feedback with respect to their energy consumption. They are not able to easily identify the amount of electricity their household consumes, nor are they able to compare their consumption with a typical household of a similar type, size and location. As earlier studies have shown, a monthly feedback provided on the energy bill is not sufficient to reduce consumption [2,3]. EDF Energy, one of the biggest energy vendors in the UK, believes that the challenges of climate change, energy affordability and energy security require the complete transformation of the energy industry, by encouraging conservation at all levels of consumption [4]. EDF Energy made it clear that to close UK's potential energy gap requires measures, such as greater household and business energy efficiency and improved distribution and transmission infrastructures [5].

The current climate change crisis demands an immediate and pragmatic approach to creating systemic shifts in our culture and actions. In the past, education played a role in bringing awareness regarding energy conservation and environmental issues. However, this did not necessarily result in the expected persuasive behavioural change – for example, among students in university campuses [6,7]. Thus, a solution utilising a combination of smart sensors and persuasive technologies is necessary.

In this paper, we present an architecture of a persuasive system platform, its system interface and real-time measurement configurations; aiming to address the energy issues in residential areas in general and university student accommodation in particular. The system provides the ability to identify the biggest energy users, thereby enabling households to decrease their energy consumption. The main contributions of this paper are (i) the introduction of the persuasive feedback support system (PFSS) architecture, (ii) Comparing the PFSS with previous related systems identified, and (iii) presenting the wider applications of the PFSS and its evaluations using a case study. The rest of the paper is laid out as follows: Section 2 reviews the background literature while Section 3 presents the System Architecture of PFSS. Section 4 details the proposed system evaluations and results. Section 5 presents related work and comparison. Finally, Section 6, we present our conclusions and future studies.

2. Background

In this section, we present some definitions of terminologies as it relates to the PFSS design concept. According to Fogg [7], persuasive technology is broadly defined as a technology that is designed to change attitudes or behaviours of the users through persuasion and social influence. A feedback is defined as information regarding the result of a process or action that can be used to modify or control another process or system, especially by noting the difference between the desired and the actual results [7–10]. There have been various studies on feedback in energy conservation and general behaviours in different fields, such as psychology, human computer interactions and engineering technology [8]. Therefore, feedback has a significant part to play in bringing about energy awareness, conservation and motivations needed across various residential settings, especially in student halls [11]. In our initial survey, we found that 80% of the students were not motivated to conserve energy. This was due to lack of real time feedback on student's energy consumption.

An energy delegate is a person appointed to help motivate and encourage others to conserve energy. For example, in a university hall of residence, the energy delegate could encourage other hall members to involve themselves in energy conservation. The energy delegate uses PFSS as a platform and analytic tool together to teach, mentor, motivate, send alerts and perpetuate continuous awareness to flat mates to reduce energy consumption and carbon emissions. Therefore, the persuasive technology is the concept, real time feedback interface and energy delegate are used in the implementation of this concept to form a system.

Since the PFSS has a direct link to the energy delegate who intensifies student's energy use behaviour change and awareness, it forms a physiological factor. Therefore, from a psychological perspective, it has been identified by previous researchers that providing feedback has positive effects on performance of energy efficiency mechanism [12–19]. The feedback of raw energy data on its own is not always sufficient to bring about behavioural changes, without displaying immediate cost and effect [6,12,20–23]. This was shown in our recently published comprehensive literature review on various feedback applications and an initial survey of student's energy related behaviour [12]. Furthermore, a comprehensive literature review of 38 studies of household energy use and feedback systems was conducted in Europe and in the US by Darby in 2000 [8–11]. The review indicates that feedback information regarding rates of electricity usage provided to building occupants can increase awareness. It can also motivate conservation of electricity and carbon emission reduction [8–13].

2.1. Problem statements

In reviewing previous literatures, we have identified several unanswered questions in this field. Therefore, in the present study, we focused on these questions, namely:

(a) Is there a point at which specificity and frequency of energy real-time feedback ceases to lead to increased energy consumption awareness and behavioural change?