



Integrating persuasive technology with energy delegates for energy conservation and carbon emission reduction in a university campus



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ABSTRACT

This paper presents the results of energy conservation strategies implemented in the University residential halls to address energy consumption issues, using IPTED (Integration of Persuasive Technology and Energy Delegate) in the student residential halls. The results show that real time energy feedback from a visual interface, when combined with energy delegate can provide significant energy savings. Therefore, applying IPTED reveals a significant conservation and carbon emission reduction as a result from the intervention conducted in student hall of residents comprising of 16 halls with 112 students. Overall, the intervention revealed that, the use of real time feedback system reduced energy consumption significantly when compared to baseline readings. Interestingly, we found that the combination of real time feedback system with a human energy delegate in 8 halls resulted in higher reduction of 37% in energy consumptions when compared to the baseline amounting to savings of 1360.49 kWh, and 713.71 kg of CO₂ in the experimental halls. On the contrary, the 8 non-experimental halls, which were exposed to the real time feedback and weekly email alert, resulted in only 3.5% reduction in energy consumption when compared to the baseline, amounting to savings of only 165.00 kWh, and 86.56 kg of CO₂.

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1. Introduction

The current scientific consensus, as a result of a plethora of systematic studies, shows that climate change is largely caused by human activities, very likely due to daily increase in the GHG (greenhouse gas) emissions [1]. Researchers describe climate change unambiguously as reality. In the US for instance, the dominant factor affecting emissions trends is CO₂ emissions, which have increased by 21.8 percent over the last 17-year period [2]. Similarly in the UK, between 2009 and 2012 the largest increases in CO₂ emission were experienced in the residential sector, which has increased up to 15.1 per cent [2]. The residential sectors are composed of occupied or unoccupied flats or apartments, owned or rented, single-family or multifamily, housing units and mobile homes [3,4]. However, according to the government statistics, it excludes institutional housing such as hostels or school dormitories, hospitals, night shelters and military barracks [5]. The energy consumption of each residential sector differs considerably

depending on the residential type (i.e.; number and age of members), building type, the number and efficiency of devices, the occupant's energy use behaviours, and other factors [6].

In Australia, it was found that, a significant contributor to the CO₂ emissions is the residential sector, which constitutes 12% of the total Australian energy consumption and has seen a 100% increase since the beginning of the 1990s [7]. Due to the large energy consumption corresponding to residential sectors, any energy efficiency program that implemented to this sector will have a high impact on reaching the objectives of energy consumption and CO₂ emissions [8]. Recently, some applications have been deployed to calculate the magnitude and significance effects of residential energy consumption in the environment, e.g. multilevel regressions, regression analysis and models for daily maximum (peak) and minimum (idle) consumption [9,10,11]. However linking the aforementioned applications to real time feedback on daily consumptions is a great challenge.

In particular, residential energy consumption such as campus resident halls has experience steady increase in energy consumption. This is due to the complexity in student's energy use behaviour, as they do not get any real time feedback on their daily consumptions, any human motivation or mandated to pay for their

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energy usages. This has resulted in continuous increase in the CO₂ emission [12]. The consumption of electricity in student's residential buildings is highly dependent on the behaviour of the students. A major challenge for students who are willing to save energy and reduce carbon emissions at the hall of residents is the lack of intuitive and persuasive information feedback about their energy consumption. Neither can they easily identify how much electricity their appliances consume nor are they able to compare how their consumption to a typical peer neighbour of similar room type, size, and location relates. Background studies have shown a monthly feedback provided on the energy bill is not sufficient to impact change in usages [13,14]. EDF Energy, one of the largest 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 sustainable energy conservations [15]. Researchers, from the “information ecology perspective”, found information technology devices and feedback systems to be useful tools, which enable interface designers to see electricity conservation in households as an informational engaging interplay between people, places, lifestyles, and needs [16].

Designing applications using ICT (information and communication technology) benefits greatly from the development of energy monitors. However, many of them that motivate energy saving do not take the motivation of the particular user into consideration especially combining real time feedback with delegated social peer enforcement to promote behaviour change, which is required to address the complexity in students energy use behaviour [17].

A promising approach to mitigate the student's impact on the environment is to motivate change in their attitudes and behaviours via the IPTED (Integration of a Persuasive Technology and Energy Delegate). IPTED is a real time feedback visual system developed to motivate student's energy usage awareness using a secured login interface. An appointed energy delegate facilitates this behaviour change using induced peer social influence in combination with a dedicated feedback interface. An initial survey carried out in the student's residential halls indicates that student's has the ability to conserve energy but lacks motivations [18,19].

Consequently, if residing students can be made aware of the magnitude of their energy use within each hall and how this directly contributes to problems such as cost of consumption, global climate change, carbon emissions, habitat degradation, and depletion of renewable and non-renewable resources, they may feel motivated due to moral or ethical reasons and empowered to conserve energy. The aforementioned can be sustainable solutions in campus if energy delegate is integrated to sustain the effect in each hall. Therefore, even in the absence of financial incentives, the desire to “do the right thing” for the campus environment, potentially combined with real time feedback and energy delegate among students living in different halls may provide considerable motivation for a sustainable conservation.

This paper, thus, addresses this research gap in student's settings by implementing-specific design in combining real time feedbacks using a delegated energy conservation enforcer. More specifically it elaborates on finding relevant comparison based on psychological-structured survey and experimental results obtained from IPTED implementation. Also, we discuss the implications our research can have on combining the energy feedback sensors with an induced effect of an appointed energy delegate as well as the limitations. The rest of the paper is laid out as follows: the [Second Section](#) presents the literature review, while the [Third Section](#) presents the methodology. The [Fourth Section](#) detailed the achieved results. The [Fifth Section](#) presents discussions of the archived results. Finally, in [Section Six](#), conclusions are drawn from the findings.

2. Context and literature review

In this [Section 2](#), we present the context and literature review, which detail definition of terms, comparison of behavioural change, literature review and students real time feedback as a way to sustainable energy usage behaviours. We focus on real time feedback related study, since they are employed in the majority of the student residential energy interventions in recent years [20,21]. Also in terms of our target group, we narrow our comparisons to suite all the students energy related studies.

2.1. Definition of terms

Feedback in terms of energy or resource consumptions is defined as information that provides a basic mechanism with which to monitor and compare behaviour, and allows individuals to better evaluate their performance. It is one of the most recent strategies in reducing energy consumption. With the integration of ICT, it can be applied also in private homes and can lead to up to 15% in energy savings [20–22]. Energy delegates are students appointed to support, motivate and encourage others to conserve energy using simple instructions via a dedicated real time feedback web interface. 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 the dedicated real time feedback interface 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, dedicated real time feedback interface and energy delegate are used in the implementation and sustainability of this concept to form a persuasive system.

2.2. Social comparison of behavioural change

Comparison can be defined as a relation based on similarities and differences, it can further be expressed as temporal – contrasting one's achievements to past performance or evaluating them to those of others [23]. Social comparative feedback (i.e., the feedback that contains social comparison) is a significant factor for promoting behaviour change in the area of energy conservation, especially in student's environment. It is adopted by the rise of online social networking sites which are a rich source for relevant comparison subjects and provide new opportunities for communicating energy-related feedback [23,24].

Furthermore, social comparison or peer comparison is constituted in the internal human drive to evaluate one's opinions and abilities. In the student's hall of resident, group of similar students living in a similar block of resident can be compared against their peers in their other similar blocks. This type of peer comparison will be effective and motivational if an appointed energy delegate moderates such activities in combination with real time energy feedback from a dedicated monitoring web interface.

In the absence of an objective means to evaluate student's abilities, the energy delegate can then evaluate them through comparison with the abilities of other students, whereby the tendency to compare oneself with another person decreases as the difference between their abilities increases [24]. In the context of energy conservation, peer comparison may be especially effective when relevant others are chosen as comparison subjects [25]. This paper focuses on the effect of peer comparative by appointing an energy delegate to induce motivation and better interpret the real time electricity feedback to other students who care less about energy conservation and carbon emission. The next section detailed the literature review covered in this paper.

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