

Impact of User Behavior in Office Building on Energy Reduction Strategies

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Abstract

There has been a lot of emphasis placed on the assessment of energy use in buildings as a means to the reduction in CO₂ emissions. Smart meter technology that captures and displays not only the energy usage but also the quality of indoor environment are currently used widely within the UK, however, there exists a disconnection between the energy management systems (EMS) technology and the user behavior that could potentially affect the consumption profile. This study was carried out in Northern Ireland and revealed that energy data was hardly shared with the users, which affected their energy conservation strategies.

Keywords: Energy management system; Sustainability; Carbon dioxide emissions; Energy usage; User profile; Northern Ireland

Introduction

Over the last couple years there has been interest in the creation of a Low carbon Society (LCS). The concept of Low Carbon Society, (LCS) first appeared in use in Japan in 2007 to mean one that aspires to make an equitable contribution to the global effort of reducing greenhouse gases to a safe level combining both a high level of energy efficiency and security [1]. Prior to the use of the LCS concept the UK government had published an Energy White Paper “Our Future Energy: Creating a Low-Carbon Economy” (DTI, 2003) [2] that argued for a strategy of achieving more economic outputs and better quality living standards, that results in less environmental pollution and minimizes the use of natural resources. Strachan, Foxon & Fujina, [1] point out LCS could be achieved through the choice of use of low carbon technologies and changes to social models and lifestyles that target energy efficiency and requires consumer responses, very much similar to those in the DTI white paper of 2003.

In practical terms, the emphasis on the assessment of energy use in buildings as a means to the reduction in CO₂ emissions is one of the outcomes of LCS strategy. Smart meter technology that captures and displays not only the energy usage but also the quality of indoor environment are currently used widely within the UK, however, there exists a disconnect between the energy management systems (EMS) technology and the user behavior that could potentially affect the consumption profile, which is another important strategy of the LCS concept.

The United Kingdom, UK is a signatory to the Kyoto Protocol and has made great efforts towards the targets set under the Protocol post 2012. The Climate Change Act (2008) [3] proposes to lower net Green House Gas, GHG emissions by 80% or less by the year 2050 based on 1990 baseline levels. Figure 1, illustrates the respective GHG emission reduction targets for the UK as a whole and the sub targets for Scotland, Wales and Northern Ireland respectively (DECC, 2011b) [4].

The initial estimates of GHG emissions for 2009 and 2010 as indicate notable reduction of 28.3% from the baseline and are indicative of possible targets being met, in the meanwhile, over the same period there was a reduction in CO₂ emissions of 19.4% as indicated in Figure 2 above.

Energy efficiency in non-domestic buildings

Literature review reveals that there are 1.8 million non-domestic

buildings in the UK contributing an estimated 17% of the total emissions (UKGB, 2011) [5] and the Carbon Trust (2009) [6], argue that it is possible to achieved 70-75% reduction in CO₂ emissions of by 2050 at minimal or zero net costs if systems that employ intelligent metering were in place. They however, ignore the impact of occupier behavior and control related issues, a view supported by Bordass et al. [7], Steemers and Manchanda [8] who found out that actual energy demands in office buildings are typically significantly higher than modeled and the annual CO₂ emissions are often two to three times the expected values [9] (Figures 1 and 2).

The UK government set in place a roll out schemes for smart meters from 2014 to 2019 for both domestic and non-domestic buildings, despite the fact that there is dearth of research on feedback on their impact on building performance in use as aptly pointed out by Stevenson & Leaman:

“...it makes it difficult to ascertain whether targets are being achieved in reality, whether the design, procurement, and management strategies are actually working and whether occupants are actually reducing their demands and expectations (particularly in relation to so-called ‘efficiency gains’)...” (2010, 437)

Darby [10] agrees and pointed out that primary cause of much of energy wastage was the invisibility of its consumption and that consumer behavior could be affected by effective feedback that included support in both interpreting the information as well as advice on the what to do with it. It is estimated that this is likely to result in reductions in the range of 5-15% however; other studies have shown that there is a distinct decrease in level of energy savings that was originally made after a few months if habits are not formed [11].

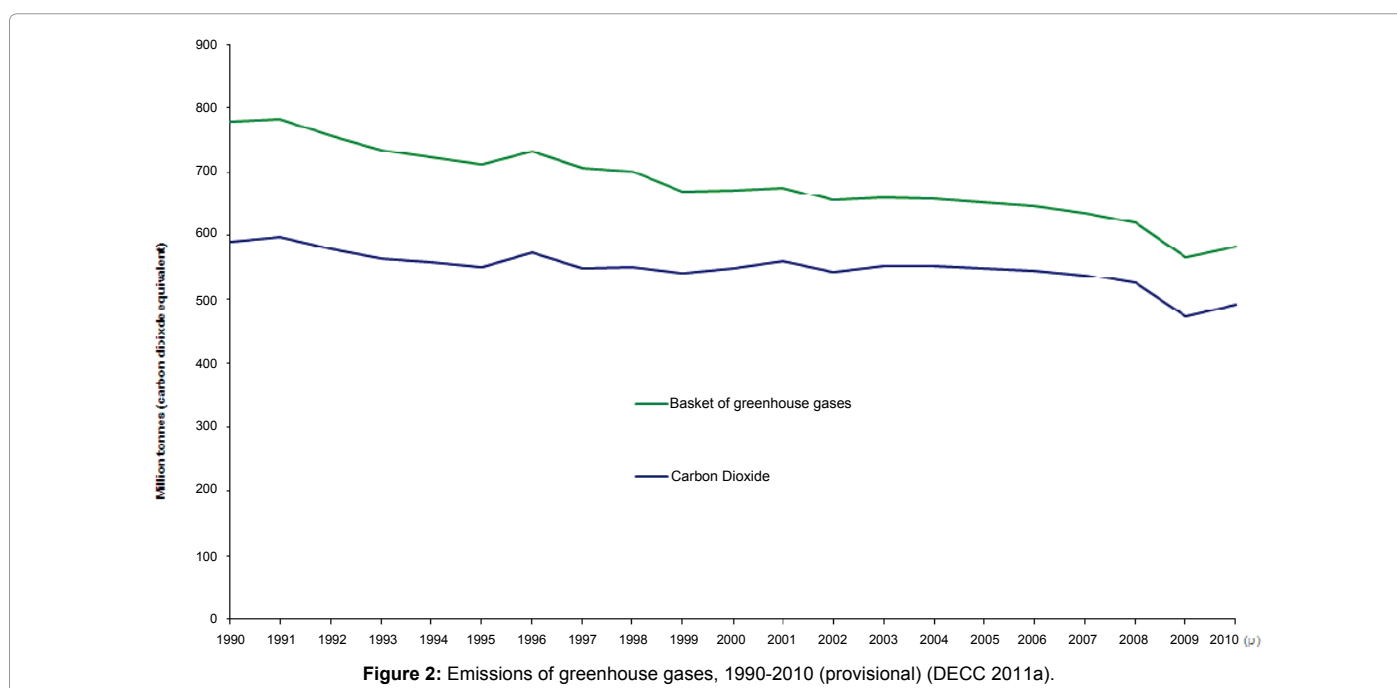
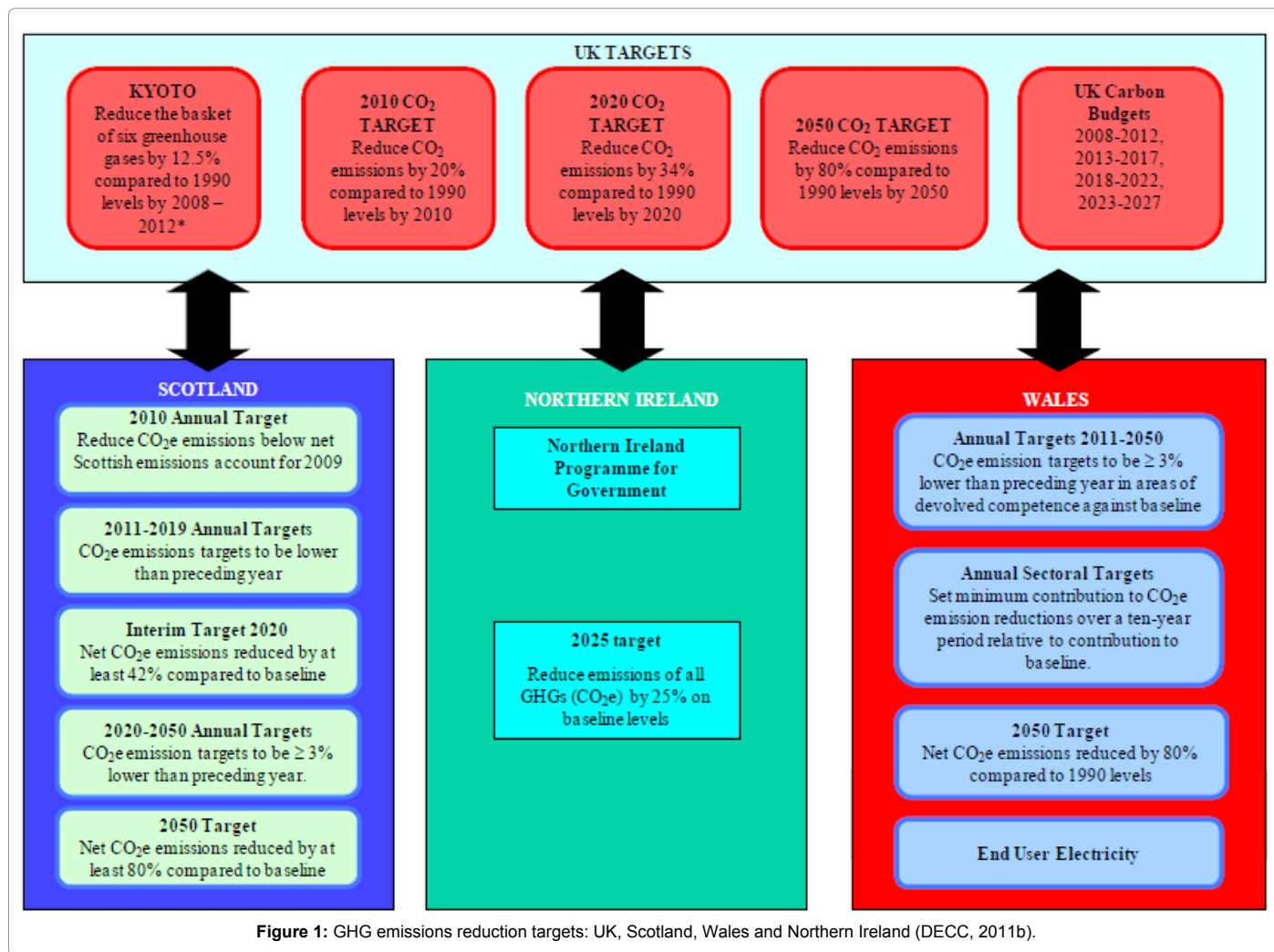
Consumer behavior is affected by culture; for example, a study by Isaacs, Saville-Smith, Camilleri and Burrough [12] in New Zealand

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indicated that people there are comfortable living in rooms with lower temperatures in comparison to other parts of the world. Another study of the high performances residential development by Ajzen [13] revealed that behavior had a significant impact on resource consumption within same housing type; suggesting that more attention needs to be given to behavior in comparison to intelligent physical systems than is currently done. Gram-Hanssen [14] concur pointing out that energy consumption in two different housing of same type and size can vary by up to three times or more, thus pointing to user behavior as ultimate game changer beyond efficient fabric.

Metering technology and EMS

The importance of the quality of feedback cannot be understated and it forms part of good management practices and structure within any organization and are critical in influencing positive energy usage behavior (TSB, 2009; MBEKTN, 2010) [15,16]. There are several metering technologies that have been adapted to measure energy usage in buildings, including a sub meter, an advanced meter and a smart meter. The first is normally location based and is used to obtain part of total energy load of the building; the second are placed in building but read remotely and at frequent intervals and can be placed within the main meter or sub meters with the capability to store and transmit readings every half hourly. The last type, the smart meters, allow for two way communication between the utility company and the consumer building, unlike the first two that are one way communication tools hence, is an intelligent metering technology. Sub-metering technology is cheaper, easy to use and allow for good energy management to take place and could potentially contribute to positive behavioral change of the users of the zone where energy is read if feedback is shared appropriately.

Research Methodology

This paper examines the use of existing sub metering technology in attempt to increase energy efficiency in a non-domestic building environment and whether the data gathered was used to effectively impact positively on the behavior of the energy user. Mixed methodology was used to evaluate data gathered from semi-structured interviews with three professionals involved with the design and control

of the energy management system and another questionnaire that was distributed to the users at the case study building. The questionnaire was based on Likert scale, giving the respondents five options to pick from in relation to the issues of feedback from sub-metering energy technologies in the building. The questions were arranged under three themes; working environment, working practices and Energy Management system as indicated in (Tables 1a-1c).

Case Study: McClay Library at Queens University Belfast

The £50 million McClay Library at Queens University Belfast was opened in 2009 and is located on the environs of the scenic Botanic Park on the University's main campus, it is a four-story structure with a floor plan of 17,400 m². It was the winner of the Most Sustainable Building in the 2010 Royal Institute of Chartered Surveyor's (RICS) Awards Scheme. In addition, significant capital investment was spent with the intention of producing energy efficient building that included Building Management System controlled window openings to provide natural ventilation, and window blinds that work in tandem with the lighting controls adapted according to available daylight (Figure 3).

Monitoring energy usage in the building is a key component in maintaining an efficient operational building environment with energy use target set within 140 kWh/m²/annum and emission of less than 1007 tons of CO₂/per year. The building has sub metering technology to monitors gas and electricity consumption at quarter-hour intervals allowing the building manager to assess whether the building was on course to meeting the targets. In addition, the data center within the McClay is sub metered separately due to the large number of high-energy demand computer processes and other plant and hardware equipment (RICS, 2010) [17].

The metering data combined with the "footfall" i.e. number of people within the building at any one time, allows the identification of direct links between user behavior and energy usage allowing for opportunities to reduce energy load. A strategic response to this is the limiting of the opening hours on certain floors of the library or reducing the number of computers in operation at any one.

S1	The building(s) in which you work has/have been designed in a manner which promotes an energy efficient outlook among its users.
S2	The appliances that are used by employees (e.g. computers, printers etc.) on a daily basis are energy efficient/can be set by users to be energy efficient without affecting their level of performance.
S3	There are a sufficient number of notices/ guides/reminders regards energy efficient practices within the working environment (including appliances) to influence the user so that they are conscious of their energy use.
S4	Your employer places great value on energy efficiency within the workplace and has invested sufficient resources to implement energy efficiency policy.
S5	Your employer has provided sufficient additional training and education regards how to interact with any energy management system technology that exists within this building (or others owned by your employer in which you work).
S6	Your supervisor/manager sets a positive example in terms of being „energy conscious“ and actively promotes the benefits of being energy efficient.
S7	You view your working environment as contributing positively to global efforts to mitigate the effects of climate change and/or your working environment is a positive example of how non-domestic buildings can be energy efficient environments.
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Table 1a: Statements of Working Environment.

S1	You find it difficult to relate to your working practices having a significant impact on the energy demand of the building(s) in which you work.
S2	You are given updates at sufficient intervals from your supervisor/ manager regards how any changes in your work practices are impacting on the energy demand of the building(s) in which you work. .
S3	These updates influence you regards being more energy efficient in terms of your future work practices.
S4	Being „energy conscious“ is a key requirement for your employer regarding your day-to- day working practices and is a criterion for judging your working performance.
S5	Most of your work involves the use of some sort of electronic appliance such as a computer, printer etc. and therefore you believe you are limited in terms of how energy efficient you can be without affecting your productivity.
S6	There is a difference in understanding between general employees and management/owners regards how work practices can be conducted in an energy efficient manner.
S7	You lack motivation to be energy efficient within your working environment as there are no benefits to you as an individual.
S8	There is not enough cooperation between employees in terms of trying to save energy within the working environment

Table 1b: Statements of Working Practices.

S1	You are familiar with how the energy management system within your working environment operates and affects your energy use in terms of your working practices.
S2	You can easily interact with any technology that forms part of the buildings energy management system in your working environment, without interfering negatively with your working practices.
S3	You are aware of working practices that will interfere with and negatively affect the operation of the energy management system.
S4	You are too reliant on the energy management system in place within your working environment to manage the building's energy use and/or could take more responsibility for the impact your work practices has on the energy demand of the building.
S5	You are aware if there is a fault/error with the energy management system based on unusual changes in the behavior of appliances and/or temperature regards your working environment.
S6	You are aware of who to direct queries to within the workplace regards the operation of the energy management system.
S7	Management presents the data from the energy management system to all employees within the working environment to highlight the environmental, economic and social benefits of energy efficient work practices.
S8	The data produced from the energy management system is easily communicated to you in the form of visual displays and/or other methods.
S9	The greater fault with energy management systems is not technical issues but rather ineffective human interaction with the technology.

Table 1c: Statements of energy management systems.

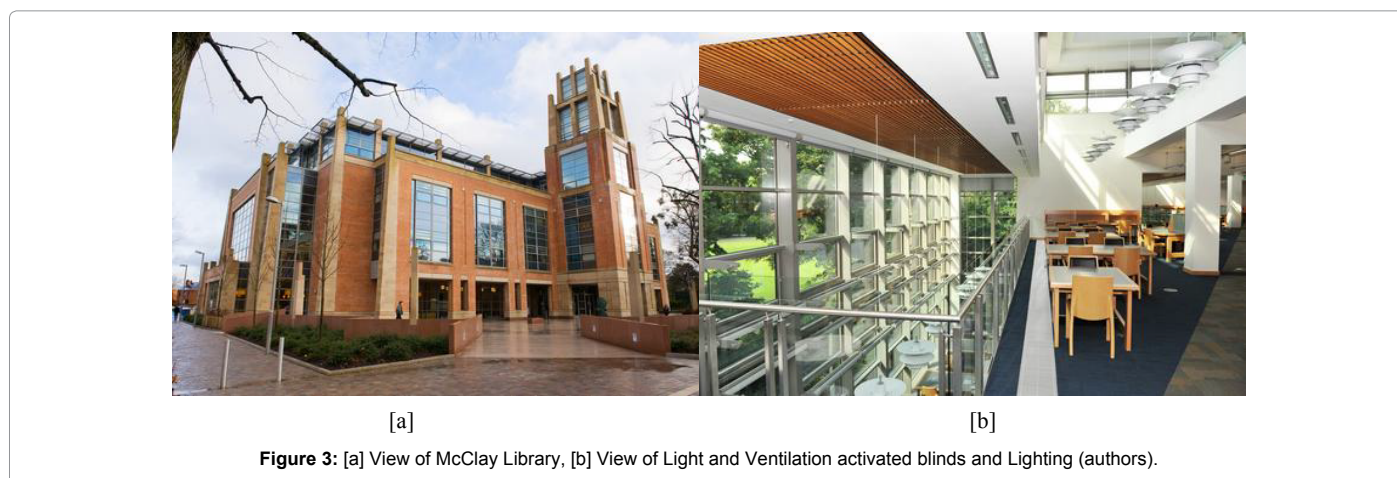


Figure 3: [a] View of McClay Library, [b] View of Light and Ventilation activated blinds and Lighting (authors).

Results

Detailed results of the questionnaire, issued to employees in the case study building, are available on request and displayed here are the breakdown of responses with respect to each statement contained within the questionnaire. The following pages display figures detailing the breakdown of data gathered from respondents in the McClay library, with respect to the structure of the questionnaire. The first selection of graphs, seen in Figure 4 details the breakdown of characteristics of employees in the McClay library, including status of employee, years experience in current position and time spent in front of a computer screen each day.

The sample consisted of 237 questionnaires were sent via email and followed up with hard copies to workers in the Administration Building and 70 responses were received. The questionnaires targeted women and men over 18 years of age, but did not collect data on income of

respondents, as most people are typically not willing to disclose this or would lie. The breakdown of respondents is as given in Figure 4 above. The data was gathered over a 4-week period .The interviews focused on a set of 26 questions. The data collected through questionnaire surveys had numerical value. The data was entered and analysed using *Statistical Package for Social Sciences: SPSS*. This application helped to conduct a classic analysis by using descriptive analysis and associated selection techniques. The goal was to use a descriptive and correlation analysis to study relationship between variables.

Figure 4 above, revealed that the most employees (79.4%) employees spend in excess of 5 hours on their computers each day, in addition, the vast majority of the respondents used the computers between the times of 9 am-1 pm and 2-5 pm. Figure 3a and 3b revealed that most employees regarded the library as designed and built to promote energy efficiency to users as well as were felt that the electrical

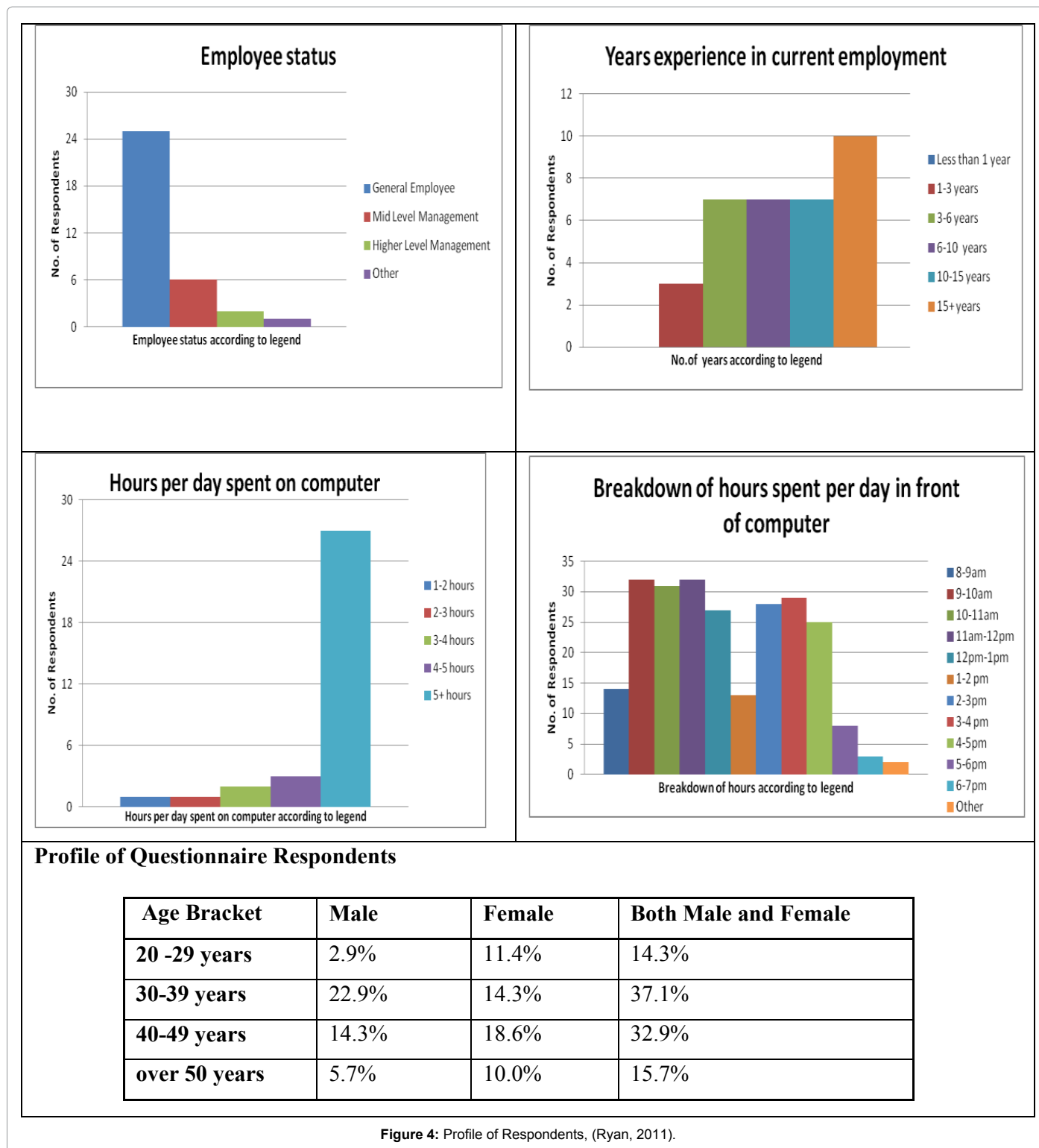


Figure 4: Profile of Respondents, (Ryan, 2011).

appliances they used daily were energy efficient. However, when asked if there was sufficient notices/ guides or reminder on best energy efficient practices that would influence their behavior almost two-thirds (70.58%) were not convinced a stack reminder of importance of appropriate feedback system (S3). Further examinations of the attitude to energy efficient practice (S6) revealed that there was mixed attitude

towards feedback from employer. Equally when asked if the working environment contributed positively towards global efforts in militating against climate change, (S7), almost half (52.94%) were not convinced with the effort by the employer. It suggests that the investments in use of high technology and costs may not have had the desired effect (Figure 5).

Figure 6 below are results from data on Working Practices and they reveal interesting characteristics. When respondents were asked if they were given sufficient updated by their supervisor/ manager regarding how any changes in their working practices impacted the energy demand on the building (S2), 52.94% strongly disagreed or disagreed and when this was added to those unsure, the it revealed that almost four-fifths (79.41%) thought the feedback was insufficient to impact their behavioral practices. In addition, it revealed that half (50%) thought that energy consciousness was not instilled or required of them in comparison to only 17.64%. Most employees also felt that there was a big difference between them and the managers with regard to energy efficient practices (S6), and that most employees (79.41%) individually lacked the motivation to be energy efficient (Figure 7).

The focus of the UK government with regard to reduction in

energy use and climate change emissions has been on physical and intelligent systems with less emphasis on human behavior. Table 1 shows interesting attitudes and beliefs of the users of a building that has won awards as most energy efficient building yet so far reveals otherwise. It revealed that only a third (34.29%) was familiar with energy management system and how it affected their energy use within the building. Literature review consistently pointed to importance of feedback on energy use in buildings, (Figure 7-S7 and 7-S8) revealed that when respondents were asked if the management presented them with energy use data; almost two thirds, 61.76%, disagreed or strongly disagreed. In addition only one tenth, 11.76% have ever received the data communicated to them in visual or other easily understood methods. Most respondents 58.88%, regarded failures in energy management systems as caused by ineffective interaction between humans and the technology [18].

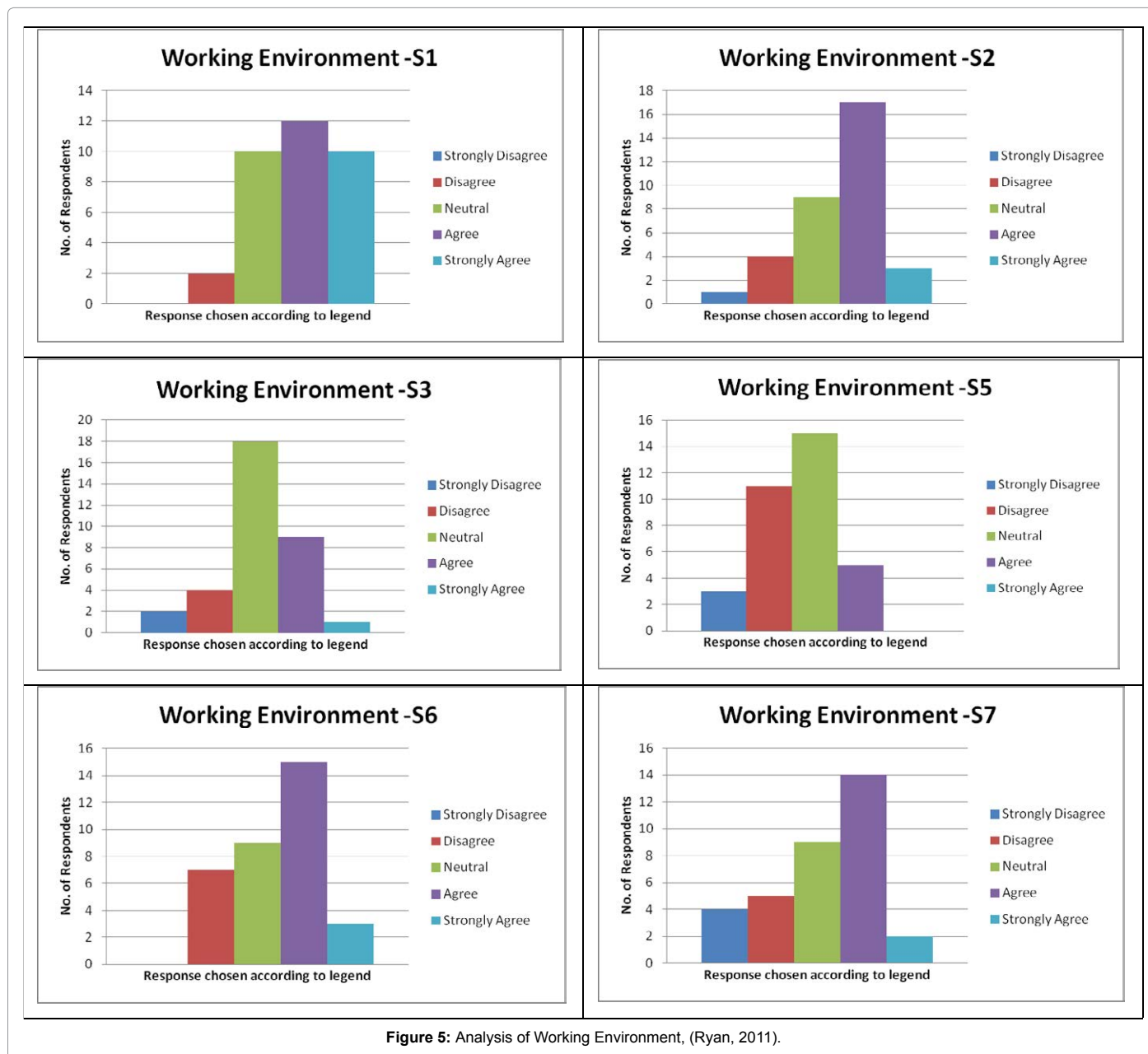
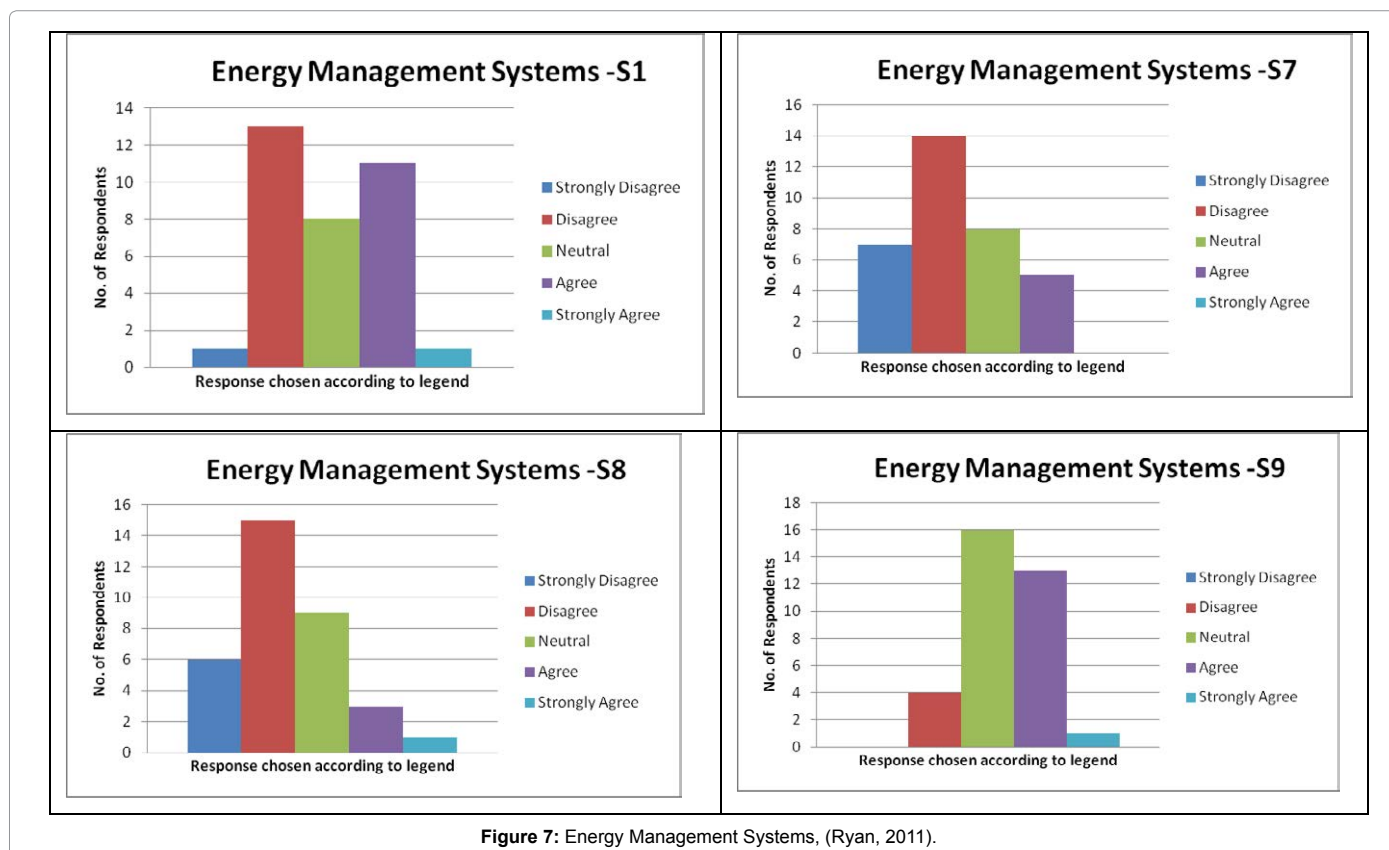
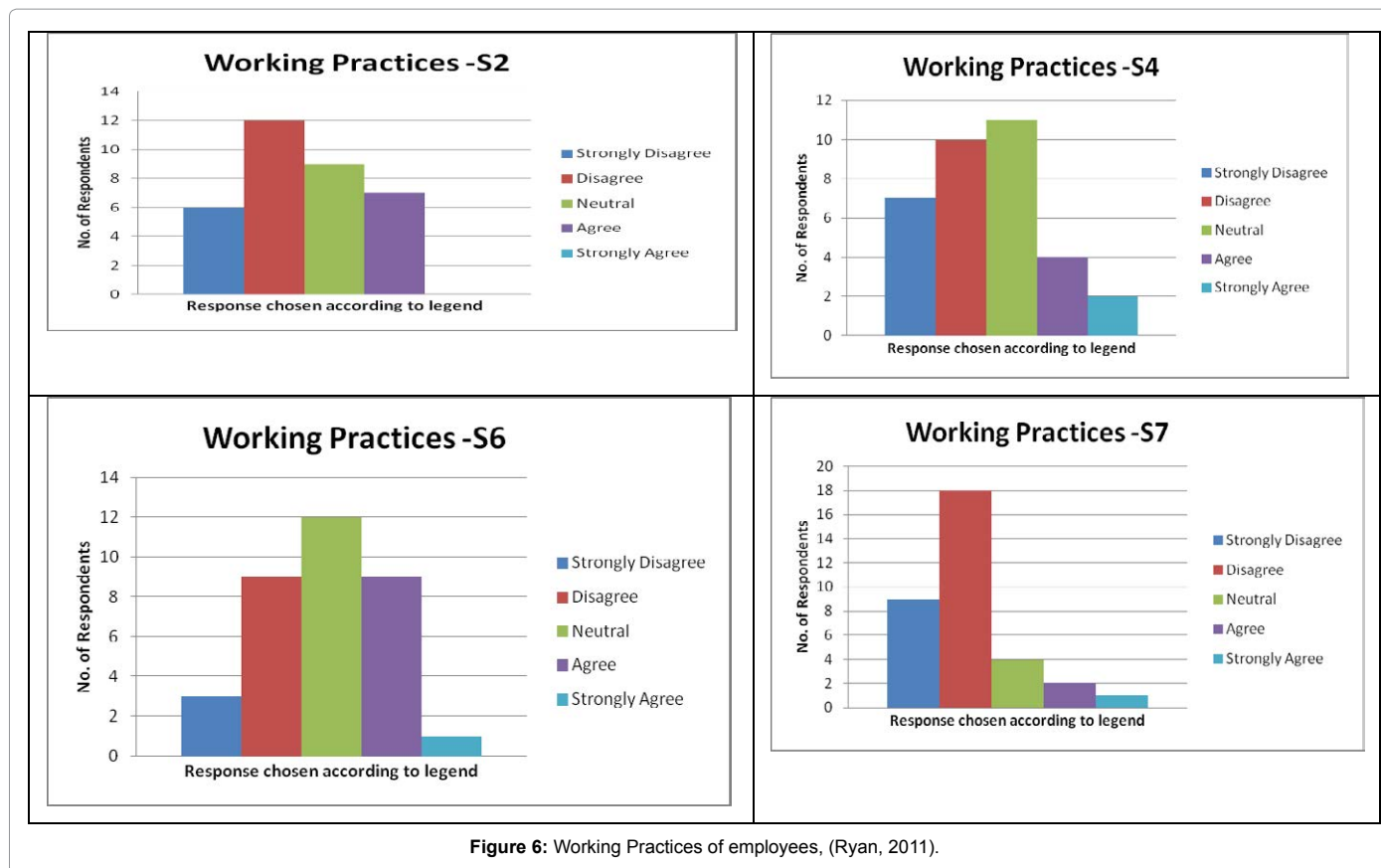


Figure 5: Analysis of Working Environment, (Ryan, 2011).



Conclusion

The work examined the use of sub metering technology with aims of reducing energy use in the building and whether its use affected user behavior. It revealed firstly, that most users who spent most of their working day in the building were not familiar with the workings and benefits of the EMS technology. However, most revealing was the fact that the users of the energy in the building were not provided with feedback and when provided it was not in a user friendly and understandable manner that would affect their working practices or behavior. There was no attempt by the management to communicate and support or reinforce what would have emerged as best practices working behavior that reduced energy consumption, in addition, the employees lacked the motivation to change their behavior to be more energy efficient. The analysis further revealed that there was underlying lack of involvement of the employees in the decisions about the investment in energy efficient technologies, and the importance of changes to their working practices. The decision by the institution to invest in an “energy efficient” building seems to have stemmed from responses to future changes that were coming to the building regulations and also in attempt to shore “corporate responsibility.” If there were any reduction in energy consumptions and CO₂ emissions, it is difficult to attribute them to occupants actually reducing their demands and expectations (particularly in relation to so-called ‘efficiency gains’) as pointed out by Stevenson and Leaman [11].

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