The effectiveness of feedback in relation construction essay

Introduction

This section of the paper is focused on a literature review of relevant engineering research that has been carried out in this area. This review examines various publications and resource guides. The review also provides frameworks to analyse the research. The review will focus on the issues surrounding the use of electrical energy used within buildings, with great attention focusing on how to reduce the amount electrical energy consumed. Various methods can be used to reduce energy consumption, while carrying out research for the literature review it was found that feedback in relation to energy consumption could benefit end users in relation to their energy consumption. The use of energy audits was also investigated and the research conducted found that energy audits reduce energy consumption and increase energy awareness amongst staff and people, however the research identified a problem called the Fallback effect where people drift away from energy savings measures to counter act this problem an engineering tool is used called continuous monitoring. Research in the area of energy monitoring was also investigated previous research found that simply energy monitoring devices can be used to reduce to reduce energy consumption through visualising what energy is being used at any given time. Research into occupant and user behaviour was also investigated, user behaviour is a significant contribution to a product's environmental impact. Simply user behaviour techniques can be made to significantly reduce the amount of energy used to complete the same activity. However while conducting the research numerous obstacles/constraints were found an example of this is economically or financially constraint. The last topic that was researched was the Building Energy Management System (BEMS), (BEMS) is a computer based system which automatically monitors and controls a wide range of building services using information communication technology (ICT). Using a (BEMS) can greatly reduce the amount of electrical energy consumed within a building/facility.

The Effectiveness of Feedback in Relation to Energy Consumption

Domestic energy usage to the end user is virtually invisible. Most consumers only have a vague idea or understanding of what they are using for their different needs. Consumers could make day to day changes in their behaviour to try and reduce energy consumption; this is why relevant feedback in relation to energy consumption is so important.

Early Studies

Early studies carried out on energy feedback in the 1970's and 1980's were conducted by Psychologists. The feedback that was given was seen more as an intervention. An early example of this typically feedback would involve a note being left on a consumer's window each morning, informing the consumer of what their previous day's energy consumption was compared to a reference level. These studies have shown that energy feedback can have some sort of a measureable effect on consumers, at least for a short period of time (Darby, 2006). In later years feedback has been in the form of utility bills issued by the utility company every few months. The bills have tended to show the amount of energy units consumed but there has been a move towards more graphical images to illustrate the description of energy use Roberts et al (2004) conducted qualitative focus groups to explore what was the consumers preferences for energy feedback and found that the participants of the focus group considered bar charts the best way of displaying energy use on bills. Feedback ‘ information about reactions to a product, a person’s performance of a task, etc. which is used as a basis for improvement’ (oxforddictionaries, 2013)Ellis & Gaskell (1978) begun to emphasise that feedback is part of the learning process and that people are the information processors that make sense of the world. A study by Hutton et al (1986) which was carried out in America found that any type of feedback under any condition, directed at any population, will produce positive results. (Darby, 2006) List’s two types of feedback: direct and indirect feedback. Direct feedback: available on demand and learning by looking or payingSelf-meter readingsDirect displaysInteractive feedback via a P. CPay as you goMeter reading with an adviserCost plugs, energy monitors or similar devices on appliancesIndirect feedback: raw data processed by the utility company and sent to the customers which is said to be learning by reading and reflecting. More frequent billsFrequent bills based on readings plus historical dataComparative and normative feedbackDetailed annually or quarterly energy reports

Contribution of Feedback

Feedback covers a whole range of sources/practices. The idea of feedback is to look at in terms of its contribution to the energy usage. Within this people can take information concerning their own energy use. They can act ie: change their behaviour in some way and they can gain a more understanding of energy consumption.

Direct Metering

Direct metering can be used to give a very basic form of energy consumption feedback. Consumers can compare and graph consumption from one meter reading to the next. However over 25% of homeowners appear to regularly check their meters (Attan, 1985). Using this type of feedback has an advantage but requires a greater level of commitment but it is effective as Sluce & Tong (1987) note that with motivated participant's savings as much as 10-20% can be achieved.

Energy reduction through energy auditing

The word energy audit is used widely and may have a different meaning depending on the energy service company. Energy auditing of buildings can vary from a short walk through of the facility to a long detailed analysis of the building (Tuan, 2006). Auditing is applied mostly to buildings but can also be applied to transportation fleets and industrial processes. It is an important first step in energy management services (Randolph & Masters, 2008). Sustainable Energy Authority of Ireland (SEAI) describe an energy audit as a review of how, why and when energy is used. Thumann & Younger (2008) define an energy audit as a process to evaluate where a building or plant uses energy and then identify the areas to reduce the energy consumption. Gomes et al (2010) Also agrees with this as they describe an energy audit as a procedure undertaken to identify what, when and how energy is used within a building they also mention that it is the first step in trying to improve the energy efficiency by identifying the areas of in efficiency and possible recommendations to improve the efficiency. The audit should identify the energy use patterns, the potential gaps for energy and cost savings, the audit may include recommendations to improve the energy efficiency which will reduce energy costs. The energy audit may examine the following electricity, gas, oil and water (SEAI, 2013). While Mohamad (2008) describes an energy audit as a systematic survey or study to identify how the energy is being used within a building or facility. Mohamad (2008) also mentions that an energy audit provides analysis on the amount of energy consumed during a given time in the form of the following electricity, gas, oil and steam also. Using the information gathered it is then possible to list how the energy was used within the building. (SEAI, 2013) Says that an energy audit can be carried out internally if sufficient expertise is available, otherwise an independent expert energy consultant can be sourced externally to provide additional assistance. A typical energy audit may cost in the region of 1% of the total energy costs and should identify areas where significant energy savings can be achieved.

Continuous Improvement Cycle

According to Ryan (2008) a sucesssful energy audit should follow the 5 stage continiuos improvement cycle. Energy Map Principle(Ryan, 2008)CommitIdentifyPlanTake actionReview

Commit

Managers and senior managers must be committed for a successful energy audit. Identify to the manager that energy costs are a concern both financially and environmentally. Team members must also be committed for a successfully energy audit as it requires time and effort.

Identify

This part of the cycle will identify energy consumption through energy bills analysis, Significant Energy Users (SEU's), Energy Performance Indicators (EPI's) and a list of opportunities reduce energy consumption.

Plan

Implementing a plan or strategy in which it outlines objectives and targets that best suit the facility in order to maximise energy reductions. Prioritise methodologies are the plans feasible either technically or financially. Can training be implemented for employees, energy awareness campaign and energy workshops. Implement a project plan with a list of the objectives this should include roles and responsibilities eg: who, how and when.

Take Action

Implementation of the project plan/recommendations, training in relation to energy awareness. Operate Maintain Procure Design (OMPD) Operate at minimum energy require and keep it that way. Maintain good housekeeping. Procurement of resources ie: energy supplier, purchasing equipment and life cycle analysis of equipment. Design energy is core to the design process.

Review

Management review has the programme been managed effectively, program review has the programme been successfully in reducing energy consumption. Continuous monitoring is very important as to determine how successful the campaign has been and also not to let the Fallback effect re-introduce itself. Corrective Action and Preventative Action (CAPA). Regular reporting, quarterly and annual reviews with senior management." By transferring the Energy Manager to the upper-most management level of the company, you are setting the best example for a successful implementation. For example, the Plant Manager can simultaneously lead the energy management team in the company" (Kahlenborn et al., 2012)

Types of energy audits

In a recent study Gomes et al (2010) carried out an energy audit on a school in Portugal and found four types of energy audits. A walk through auditA utility cost analysisA standard energy auditA detailed energy auditWhile carrying out the energy audit on the school a number of opportunities were identified using the information that was collected during the audit. Optimisation with the energy supplierReplace existing electromagnetic ballasts with electronic ballastsReplace indoor fluorescents with more efficient lampsReplacement of existing high pressure sodium with new more efficient lampsInstall motion or P. I. R’s sensors in corridors toilet and other internal areas. Install controls for projectors and interactive whiteboardsPower Factor correction (improves true power to apparent power)Gomes et al (2010) were then able to identify the amount of savings that maybe achieved if all of the above recommendations were implemented. Firstly the investment costs, maintenance costs, cost per kWh were taken into consideration and payback period. After taking all of the above into consideration the initial investment amounted to €17, 572, which resulted in a reduction in electricity of 31, 000 kWh per year, which resulted in an annual cost of around €4, 000. The energy reduction is estimated to reduce CO2 emissions by an estimated 14. 6 tonnes annually.

Energy Monitoring

Domestic Energy Home Monitoring System (DEHMS), simple energy savings measures have the potential to reduce 10% of the UK's carbon emissions. Domestic energy accounts for 30% of the UK's CO2 emission output. Darby (2006) Notes that smart metering technology, which provides real time feedback on domestic energy, can help reduce 5 to 10% of energy usage. Cooper et al (2010) Carried out a study on DEHMS its objective was to integrate and test the effectiveness of strategies delivered through an electronic infrastructure which is able to infer and reason the energy behaviour in households.

DEHMS

The DEHMS system has been installed in 77 household in the UK for a period of 6 months to understand the user behaviours. The primary purpose of the DEHMS is to gather and communicate energy consumption data from gathered from sensors for comparative analysis. The electrical mains power analyser is connected to the main energy cable. A reading is taken every 6 seconds which is relayed back to the DEHEMS gateway which is then forwarded onto the P. C/HMI. The DEHEMS gateway also forwards all the information back to the main DEHMS server. User interface should be simplistic, easy to understand and use.' Express just enough meaning but not too much. Designers need to respect the value of perceived simplicity as well as the need for enough information and for expressiveness on the part of users' (Hindus et al., n. d.)

System Architecture

The DEHMS consists of the followingElectrical mains power analyserIndividual appliance monitorOil appliance monitorAmbient temperature sensorBroadband routerDEHMS gatewayDEHMS dashboard (HMI)P. C Interface/HMIElectrical mains power analyser is a device that is fitted to the main incoming cable to read, display and transit the total energy consumed. Individual appliance monitor is a hand held device that is plugged into a standard 13amp socket to display the energy consumption of the appliance. Oil appliance monitor is a device which read the level of oil within a tank. Ambient temperature sensor is a thermostat which reads the temperature of a room in which it is positioned in. Broadband router is a device which is used as a gateway to connect devices to the internetDEHMS gateway is similar to the broadband router but only accesses the DEHMS server. DEHMS dashboard is a small human machine interface (HMI) in which the user can read the energy consumption. P. C personnel computer interface similar to the DEHMS dashboard only the information is displayed through a P. C.

Constraints that impede energy savings

Financial constraintsLimitation of appliances and building infrastructureLack of information regarding energy efficiency of their applianceGomes et al (2010) while conducting an energy audit found that investing in more energy efficiency lighting can reduce energy cost dramatically over a short period of time with a relatively good payback period. In a survey conducted by Cooper et al (2010) participants wanted to reduce energy consumption but found that the participants were split unequally as 66. 7% are driven by keeping the bills down while 25. 6% were more focused on reducing their carbon footprint. It was noted that saving energy is perceived as a financial problem.

Benefits of DEHMS

DEHMS encourages occupants to reduce energy consumption through real time data acquisition, participants of the study are unanimous that the DEHMS provides interesting informative information regarding their energy consumption. One participant of the study said that the whole family has become more conscious of their energy consumption. Some families have gone further and have started their own research online to try and reduce their energy consumption even further. Accessing data, the data may be accessed through the P. C and can be accessed remotely over the internet. However one participant said that those that access the data over the internet are computer literate and that the DEHMS dashboard is more suitable for people with limited computer skills. Benchmarking, can also be done using the DEHMS as the participants energy data is all sent back to a central server. This is a useful tool as participants can compare energy consumption with similar households with the same amount of occupants. Through the process of benchmarking it is possible to identify any abnormalities and is possible to identify the cause of these abnormalities.

Occupant and user behaviour

User behaviour is a significant contribution to a product’s environmental impact, the end users decision or habits ultimately have a major effect on the energy consumed thus there is a need to investigate and change occupants and user behaviour. Irish buildings consume 40% of the total energy delivered in Ireland (SEAI, n. d.). This figure is predicted to rise in the coming years as we now live in a society that depends on electronic devices (Culley et al., 2007). Culley et al (2007) argue that achieving improvement measures in the area of energy efficiency requires research into energy efficient products and studies carried out on consumer attitude and behaviour.

Consumer attitudes

Wood & Newborough (2002) found two types of areas that effect energy efficiency. Point of SalePoint of UsePoint of Sale is influenced by how energy efficient a product is. Point of Use is influenced by the end user informing the user to turn off when finished. Point of Sale energy savings are influenced by the consumer and are also influenced by government policies such as the European Commission’s eco label (International Energy Agency, IEA, 2003). Truffer et al (2001) Found that consumers do not purchase energy efficient products despite their best intentions, 20% of consumers said they would spend between 10% and 20% extra for energy efficient products however in reality this figure is 1%. Point of Use is an area where little work has been done. Some way of reducing energy is by putting signs near light switches, energy posters, energy stickers, promotional merchandise, incentives, recognition and competitions.

Behavioural change

Kaiser et al (1999) found three different situations where a person had a positive attitude on their behaviour but were prevented from carrying out their behaviour. An example of this is economically or financially constraint, one person may be in a position to replace an appliance with a new energy efficient version when it comes to its end of life, while another may not and will have to commandeer with a less efficient second hand model. People may intend to carry out energy changes but are pressurised by family or friends not to. Lastly people may want to make changes but may not necessarily have the opportunity/infrastructure to do so.

Antecedent information

By providing antecedent information savings can be achieved according to Dennis et al (1990) as much as 60% can be saved in unnecessary lighting by putting signs near light switches. Winnett et al (1984) Also reports that significant energy savings as much as 10% can be made by simply showing energy consumer a 20 minute TV programme on energy savings techniques. However Hayes & Cone (1977) found that a simple poster which describes ways on how to reduce energy consumption and the energy consumptions of individual domestic appliances only had a temporary effect in reducing the energy consumption. Posters had been distributed in one unit of a student complex and found a 30% reduction in energy usage, however in latter weeks the figure had fallen to 9%. It is important to keep practicing these techniques as the Fallback effect can slowly come into effect, Wilthe & Ling (1995) define the Fallback effect as‘ the phenomenon in which newness of a change causes people to react, but then that reaction diminishes as the newness wears off’

Observation

A common problem with observing or studying people is that subjects may behave different because they know that they are being observed or studied, this is what is known as the Hawthorne effect. The hawthorn effect was first introduced by Henry A. Landsberger in Chicago 1950. Landsberger while working at Hawthorn Works (electric factory) examined older experiments from 1924-1932 by Elton Mayo to see if workers could achieve higher levels of production in higher or lower levels of light. Productivity increased when the changes were made however production levels deteriorated again when the study was carried. Suggestion were made that the productivity increased due to the extra motivation from the workers as a result of being observed (Shuttleworth, 2009). Stern (1992) suggests that the responsiveness of consumers to energy savings is seriously affected by the hawthorn effect. Studies carried out by both Winnett et al (1984) and Dennis et al (1990) found that participants in the study were fully aware that they were being examined or observed in relation to their energy consumption. Therefore when any human study is being carried out where useful information is provided, care needs to be taken to account for the Fallback and Hawthorn effect. Over the past number of years new modern technologies have enabled appliances to gain ‘ A’ energy rating status, according to SEAI an ‘ A’ rated appliance will use approximately 55% of the energy of a similar ‘ D’ rated appliance. However customers who invest in these new products may have the best intentions in trying to reduce the amount of energy consumed, often this can have the opposite effect in trying to reduce energy consumption. In 1865, English economist William Stanley Jevons observed that technological improvements that increased efficiency tends to increase the rate of energy consumption. In addition to reducing the amount of energy required, enhanced efficiency lowers the cost of energy required, which often leads to more energy being consumed theoretically offsetting any savings that can be made from the increased efficiency this is often referred to as the Rebound or Jevons effect (Alcott, 2008).

Building energy management system (BEMS)

Building Energy Management System (BEMS) is a computer based system which automatically monitors and controls a wide range of building services using information communication technology (ICT) based on hardware and software systems that are implemented in a holistic approach. These services may include lighting, heating, cooling, ventilation and boilers. Other controls may also be included into the BEMS such as security, fire alarm, maintenance and energy monitoring targeting.

System architecture

According to Bocheng (2012) a BEMS has a three tier architecture consisting of the following. The field space tierNetwork communication tierThe station level managementThe field space tier consists of various measurement devices/sensors which collect all kinds of energy consumption data. The network communication tier switches data between the energy measurement devices and the computers at the various stations where applicable. The station level management provides dynamic real time data monitoring and statistical analysis for the buildings energy data.

Benefits of (BEMS)

A BEMS can provide a whole range of benefits in relation to the buildings overall energy consumption. Automatic switchingOptimization of plant operation and servicesMonitoring plant status and environmental conditionsProvide energy data analysisAutomatic switching this can be done according to time, type of day or environmental conditions. An example of this automatic switching would be controlling lighting to circumvent unnecessary use of energy outside normal working hours or when ambient levels of light are sufficient or adequate to continue with daily operations. Optimising plant operation, an example of this is the optimum start/stop routine. A BEMS can automatically adjust the start/stop times to compensate for external temperature. This is the same principle as using a weather compensator which compares the delta t (ΔT) temperature difference. Monitoring plant status and environmental conditions, the building manager can be alerted to abnormal conditions through alarm functions so that remedial actions can be taken to prevent a catastrophic failure occurring. Therefore a BEMS can not only improve standards but can also improve operation and maintenance. Providing energy data analysis is easily available through a BEMS, data on energy flows, energy consumption, trends and the overall building energy performance are easily accessible through the station or HMI (SEAI, n. d.).

Energy savings through weather compensation

Heating systems are regarded as one of the main energy consumers within a building and as an area where significant energy savings can be achieved with small improvements within their controls. Many years ago heating systems would be left operating at full power without any type of controls. Occupants of the building were the main temperature controllers or thermostats so to speak, who took action by opening windows and running fans etc. Controls of heating systems soon improved due to the price of fossil fuels and heating systems were soon run under the outside compensator principle or weather compensator (Mrez & Barney, 1986).

Weather compensators

A weather compensator consists of an external temperature sensor and an internal electronic controller. The thermostat should ideally be fitted to the shaded side of the building. The external temperature sensor registers the actual temperature and the electronic controller adjusts the heat supply flow temperature if necessary to reflect external temperature conditions. The controller adjusts the heat supply to the radiators and ensures that the room temperatures remain constant. Occupants of the building will not even notice that the weather has changed outside and will therefore experience the same thermal comfort as before (Danfoss, n. d.). According to SEAI's (Building Energy Managers Resource Guide) the energy use from heating and hot water in a naturally ventilated open plan office accounts for 65% of the total energy consumed. While in an air conditioned office heating and hot water accounts for 46% of the total energy consumed.

Conclusion

In conclusion to the research carried out to complete the literature review, it was identified that there are many opportunities that can contribute towards successfully reducing electrical energy consumption. However in addition to this there are also constraints that can affect the success of energy reduction that have been mentioned. Sluce et al (1987) found that direct metering can be used to give a very basic form of energy consumption feedback and noted that with motivated participant's savings as much as 10-20% can be achieved. In addition to this while conducting an energy audit

Gomes et al (2010) found that €4, 000 annually could be saved on electrical energy with an initial investment of €17, 572 by simply retro fitting the existing building with more modern energy efficient lamps and controls.