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Cian O'Driscoll
Department of Architecture, Cork Institute of Technology, Bishopstown, Cork, Ireland

Garrett O'Sullivan
Department of Architecture, Cork Institute of Technology, Cork, Ireland., garrett.osullivan@mtu.ie

Jim Harrison
Department of Architecture, University College Cork, Cork, Ireland

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Recommended Citation
O'Driscoll, C., O'Sullivan, G., Harrison, J., 'The Reduction of plug loads: the next obstacle in Achieving Net Zero Energy Buildings', National Maritime College of Ireland, CERC Conference, October 2013.

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The Reduction of Unregulated Plug Loads: The Next Obstacle in Achieving True Net Zero Energy Buildings

Cian O'Driscoll[1], Dr Garrett O'Sullivan[1] and Dr Jim Harrison[2]

[1] Department of Architecture, Cork Institute of Technology, Bishopstown, Cork, Ireland
[2] Department of Architecture, University College Cork, Cork, Ireland
e-mail: cian.odriscoll@cit.ie

Abstract

As industry pushes for further reductions in the energy consumption of buildings the era of net zero energy, zero carbon buildings has been realised. However, this frontier of highly efficient architecture has unveiled the considerably large problem of plug loads. In a typical office building plug load alone can account for 15% of total energy consumption. In a Net Zero Energy building that percentage can increase to 50+%. This paper discusses the reasons for this increasingly significant building energy load and the importance of reducing it. A methodological approach and results of monitoring the kWh consumption at plug level and room level within the main building of Cork Institute of Technology are presented. This achieved a benchmark of typical office energy usage that is then compared with the monitoring of kWh consumption at plug and room levels within the CIT Net Zero Energy Test-Bed. Calculations of true energy usage are made and potential savings identified. Finally methods of evaluation and emerging technologies are discussed, offering potential solutions to reduce plug load energy use.

Keywords

Plug loads, Net zero energy, Building performance, Operational energy loads, Unregulated energy loads, Post occupancy evaluation.

1. Introduction

The growing concern by building owners and operators of the unregulated energy loads, particularly in low energy buildings, is pushing research globally to address this issue. Given that net zero energy buildings are quickly becoming the benchmark in many countries, achieving a true net zero energy building should not even be considered without reducing unregulated operational loads. Subsequently, there is a global reassertion of focused research in this area.

The term "unregulated" energy loads refers to a building's energy demands outside of the "regulated" heating, ventilation and air conditioning (HVAC) and lighting loads (Whyte and Gann, 2001). These unregulated energy loads are primarily produced by the equipment and activities of those who work in the building, as opposed to the energy that maintains basic building comfort. This paper refers to the key constituent of broader research that aims to deeper investigate the area of unregulated energy loads to inform existing design theories and practices of low energy building design – plug loads. By gaining a concise understanding of how users interact with low energy buildings affords the opportunity to highlight possible ways the relationship can become more harmonious and subsequently result in improved operational energy efficiency.

Typically, an architect severs all ties with a building upon completion. The lack of a developed and maintained feedback loop between the building occupiers and management and the designer is resulting in poor operational building performance. According to many studies lighting, HVAC, and office equipment consume the most energy in a typical commercial building. Plug loads consume roughly 10-15% of commercial electricity use (Sheppy et al., 2011). In a net zero energy building the proportion of energy consumption represented by unregulated plug load can increase to over 50% (Sheppy et al., 2011) of total end-use load. Simulation design forecasting has been shown to underestimate real energy use (Carbonbuzz, 2012).

The European Union (EU) has targeted 20% reduction in primary energy by 2020 (based on 1990 levels). However both by its own and external analysis it is more than 55% off target (EU Parliament, 2012) and (ECOFYS and Fraunhofer, 2012). The key directive is the Energy Performance in Buildings Directive (EPBD). The EPBD guides national legislation for buildings' energy, and in Ireland this is framed by Part L of the Technical Guidance Documents. The directive and national guidance is framed primarily around fabric driven solutions: heating, cooling and lighting services (regulated loads). Therefore these are the areas design teams typically target for reduction. However, due to the decentralised nature of plug loads it is often cheaper to make incremental modifications rather than large-scale upgrades to HVAC and lighting systems. As the percentage of energy loads attributed to plug loads balloons and becomes the predominant energy draw in low energy buildings, it can no longer be ignored.

2. Summary of Energy Use Analysis within CIT

An analysis of existing readings taken from electrical meters in 2010 and 2011 to establish a benchmark in terms of Cork Institute of Technologies total electrical consumption was the first step in undertaking this study. An analysis of CIT's electrical use was then coupled with plug load metering within certain office spaces in CIT. The unoccupied or 'phantom' electrical load quickly became evident. 29% of all electricity consumed within the main building of the CIT campus was consumed when the building was unoccupied. This percentage was cross referenced against existing research that was conducted in this area and it was found that typically the phantom load percentage within commercial buildings tends to be between 30% - 35% (Way and Brodass, 2005). This reaffirmed that these results were on par with international results of similar research. According to Berkeley Labs in the University of California, of this, it is estimated that 75% can be saved using inexpensive incremental improvements.

3. Case Studies of Plug Loads

3.1. Case Study: Analysis of Energy Use within CIT in 2011

At the time of undertaking these case studies the only campus-wide energy use data available to the researcher was 2011 data. Fortunately, daily readings were taking from electrical meters throughout 2011. This data was painstakingly analysed to establish the usage that was attributed to the unoccupied period of 10pm – 8am. This is actually a lenient unoccupied period as it is estimated that three quarters of the total staff and student body have vacated the campus by 7pm. 10pm is the official closing time. The aim was to establish the total amount of energy consumption attributed to phantom loads over a period of a year and calculate the percentage that could potentially be saved.

To put CIT's electrical energy use in perspective, the CIBSE (Chartered Institute of Building Service Engineers) benchmark for electrical usage for a college campus is 80 kWh per square meter. CIT is using 127 kWh per square meter. The financial cost was calculated using the rate per kWh that CIT paid during the year of 2011. The financial implications of these loads are the best asset in driving reform. Applying the Berkeley Labs of the University of California estimate, a minimum of 75% saving can be made on all phantom loads using incremental, non-infrastructural improvements. This would result in a saving of €106,918 per annum for CIT.

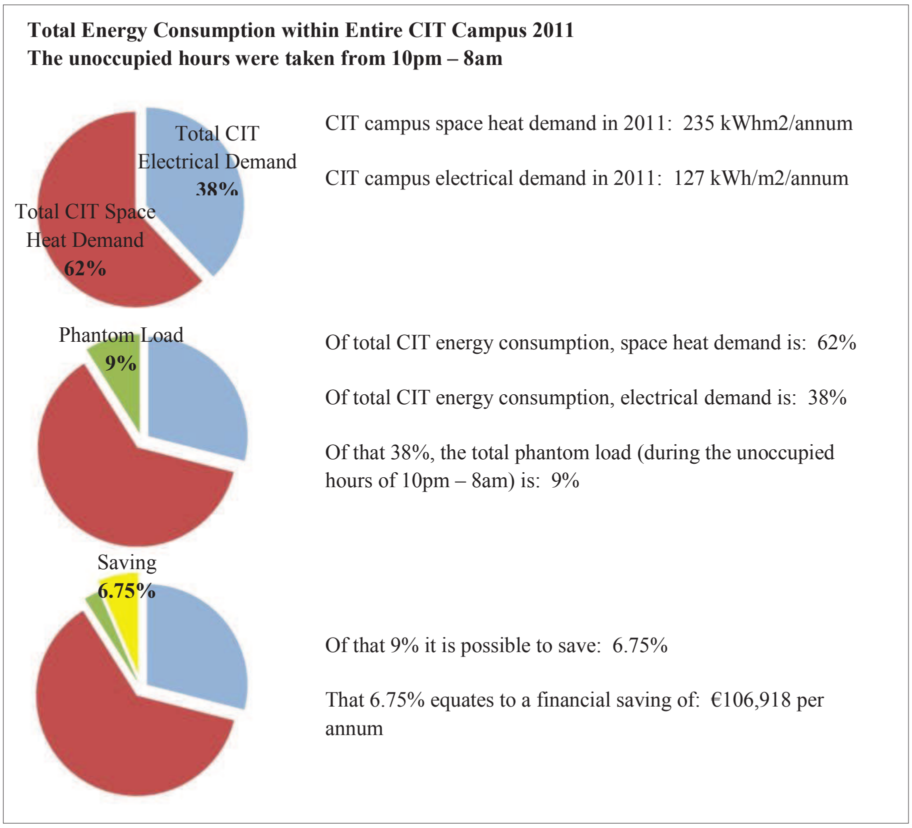

Figure 3.1 Entire CIT campus usage

3.2. Case Study: Research Office

A 24 hour monitoring of the plug loads of one of CIT's many post graduate research offices was conducted to test the plug meters, establish typical daily office device usage and identify any out of office or phantom usage. The office plug loads were monitored over a period of 30 days in December 2012 and an average 24 hour usage was established from this. Given this is a study conducted in a winter month, devices such as a space heater were prevalent within the overall usage. Currently a similar study is being conducted to establish a summer 24 hour usage. Below are the results of the winter case study.

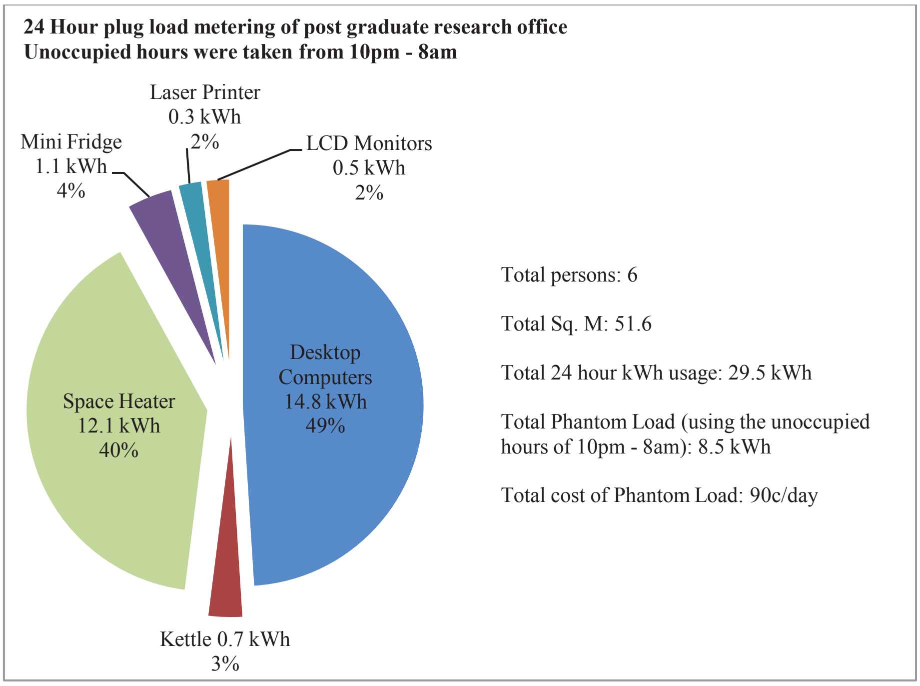

Figure 3.2 Post graduate office results

3.3. Case Study: 30 day metering of post graduate and purchasing offices

A 30 day period from 12/12/2012 to the 11/01/2013 was chosen for the second study, as this period would include the Christmas break. This allowed for the metering of plug loads during a prolonged period without occupancy. The two offices were chosen as they were similar in size, occupancy and use. Readings were taken daily over the 30 day period and this was monitored against office hours and out-of-office hours. The 14 day Christmas break was monitored separately and all staff were surveyed on their use of their relevant offices over this period: no members of staff occupied either office during this 14 day period. Some of the post graduate research staff members used remote access to access and use their computers from their homes. This is typical in many offices within Cork Institute of Technology and many other educational and commercial offices. The loads calculated during this 14 day period are still constituted as an unoccupied energy load. Of the total kWh usage monitored during this 30 day period the combined percentage of unoccupied/phantom plug load was a staggering 50%.

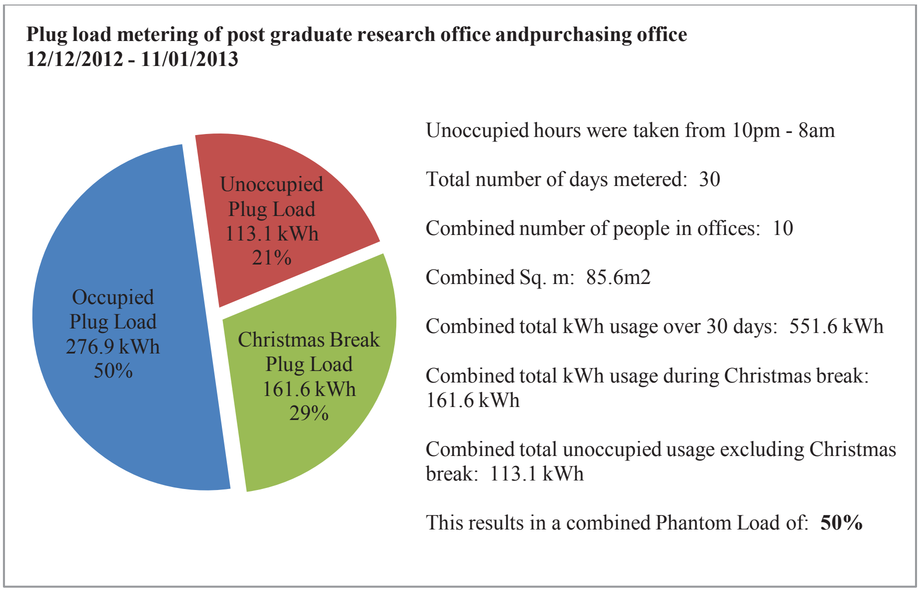

Figure 3.3 Post graduate office and purchasing office results

3.4. Case Study: Ongoing plug load analysis of CIT Zero Energy Test-Bed

The current phase of the case study is the undertaking of post occupancy evaluation of the Net Zero 20/20 Energy Test-Bed in CIT. Within this evaluation is the key component of the plug load analysis. The Net Zero Energy Retrofit 2020 Test-Bed project has upgraded approximately 290 sq. metres of the existing building with a view to achieving net zero energy by 2020. A net zero energy building produces as much energy as it uses in a year. The methodology is based on minimising consumption and supplementing the balance with renewable energy. Analysis of the unregulated energy loads is being undertaken as well as the establishment of a concise feedback loop to learn from the occupants themselves. This evaluation is fundamental to the collective aim of achieving a true low energy retro-fitted building. The plug load metering of the Zero Energy Test-Bed began on April 10 2013. This was the first stage in the post occupancy evaluation of the Test-Bed which utilises the established Probe Building Evaluation Method (Leaman and Bordass, 2001).

Having analysed plug loads in a standard building (CIT campus buildings), analysing the same loads in a Net Zero Energy building offers a comparative insight into any differences that may be evident. Do people behave differently in a Net Zero Energy building? Gaining an understanding of how much the human factor is responsible for poor operational energy performance in any building is vitally important, but given that plug loads can account for 50%+ of a Net Zero Energy building's energy load, in this case it is imperative. The metering of occupant electrical consumption at plug level will give hard data on actual electrical consumption at each electrical outlet twenty four hours a day. This is to be continued for a period of one year, providing data throughout each season. In identifying any problems or inefficiencies that exist within the interface, a clarification of whether design, the building management or other factors are at fault will emerge. In terms of energy use the plug is often the secondary interface between the occupants and the building - lighting being the often first. By metering plug loads together with monitoring space heat demand and lighting demand, performance patterns that are directly attributed to the plug interface will become evident.

Currently the results show almost identical patterns of usage and levels of kWh consumption to that of the existing non-retrofitted buildings of CIT. It shows high occupied usage and high levels of unoccupied loads. By conducting an initial survey it became evident that the occupants were uninformed of the objectives of the other ongoing research of the Test-Bed. They were not aware of the overall objectives and aims of the Test-Bed. This undoubtedly contributes to the occupants' behaviour in treating the building as they would any other. Below is the first set of results displaying a weekly average in a Net Zero Energy Building. The weekly average was calculated from a four month period of monitoring.

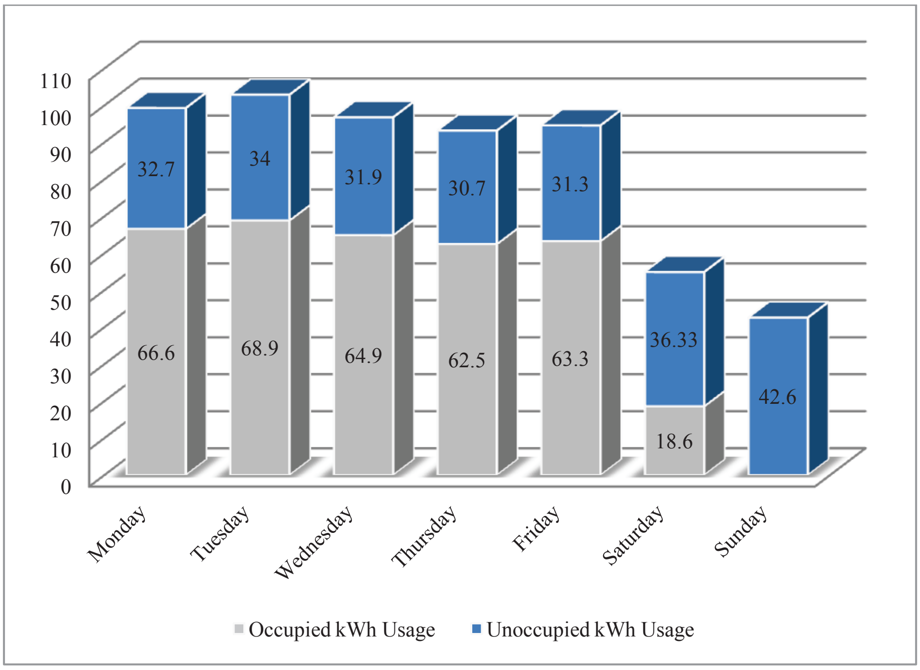

Figure 3.4 Occupied and unoccupied kWh usage with Zero Energy Test-Bed

4. Taking the next step

4.1. Evaluation

As large gaps exist between a building's pre-occupancy projected energy usage and post-occupancy actual energy usage, this has now seen the post occupancy evaluation (POE) methods that once focused primarily on health, comfort and productivity to evolve into evaluations that consider operational energy consumption. Today building performance evaluation (BPE) allows for making direct correlations between the occupants and the energy being consumed and emphasises that the evaluation should be constructed so that the returning data best informs the design process equally as much as it informs the building management (Mallory-Hill et al., 2012).

Architects, engineers, building managers and occupants must all be included in the operational performance of their buildings. Establishing an appropriately thorough POE, together with establishing a strong feedback-loop is an intrinsic part of good briefing and good building design (Mercier and Moorefield, 2011). POE is a way of providing feedback throughout a building's lifecycle from concept stage through to occupation. The information from established feedback-loops can inform future projects, whether it is information on the process of delivery or the technical performance data of the building. It serves a vital purpose. Coupled with this is the vital need to articulate to all stakeholders the potential to yield significant savings from reducing plug loads.

4.2. Managing operational energy loads

The proliferation of user appliances and poor user awareness of energy consumption is leading to increased daily electrical loads and increases in vampire loads. Vampire loads refer to the electrical loads of devices and appliances when they are on standby or in sleep modes. Within a work environment people care less about the energy they use. Including employees in the collective ethos of providing a low energy building is crucial. The monitoring and metering of electrical consumption must not be intrusive and must allow for variations, as people can change habits, increase or decrease the number of plugged-in appliances they use daily resulting in higher or lower energy consumption.

The choice of desktop computers, for example, within office or other commercial buildings can have a considerable bearing on the unregulated energy load of that building. Typical office desktops are of a higher performance level than needed for the computer's use. Incorporating desktops that are fit for purpose, for example low performance level computers for simple administrative programs, can substantially reduce the plug load from these devices.

The developments in occupancy sensors at outlet and circuit level, such as the Sensor Plug and the WattStopper DLM, respectively, hold potential to reduce plug energy load considerably. In dealing with Uninterrupted Power Supply (UPS) typically associated with server rooms, server Virtualisation is an emerging technology that will prove invaluable in the reduction of building energy load. Furthermore, the growing area of DC Microgrids, although costly, is direct response to high occupancy electrical use.

5. Conclusion

As the Energy Performance in Buildings Directive (EPBD 2010) is calling for all buildings to be Near-Zero Energy Buildings by the end of 2020 the building industry will need to position itself to achieve this standard of building. Understanding the considerable problem and the financial cost attributed to unregulated plug load energy demands in low energy buildings is necessary for designers to achieve true Zero Energy Buildings. The results of the case studies conducted for the purpose of this research reaffirm the considerable problem of unoccupied energy loads that exist within our buildings. Implementing this gained knowledge and applying proven energy saving solutions can contribute to the growing sector of low energy building design. In the case of a Net Zero Energy building, or any low energy building, it is vital to include the occupants in the overall ethos of low energy buildings. Educating the users is of upmost importance if a true low energy building is to be achieved, particularly in the commercial sector. Understanding the importance of the building's design interface with its users in terms of spatial and fit-for-use design is essential at design brief stage. It is key for building designers and managers to recognise that most of the problems associated with high operational energy use of buildings are behavioural rather than technical.

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