Social Networking Sites as Platforms to Persuade Behaviour Change in Domestic Energy Consumption

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ABSTRACT

Social Networking Sites as Platforms to Persuade Behaviour Change in Domestic Energy Consumption

This MSc project addresses the following research question – "Can online social networks such as Facebook facilitate the motivation and behaviour change to reduce energy consumption in the home?" An investigation into the role of social interaction in social networks provides evidence to support the research question. The project undertook an extensive literature review and identified a gap in current knowledge regarding energy monitoring systems that are socially enabled. A participatory design workshop was then held to generate initial concept ideas and prototype interfaces. A final system using the Facebook application platform was designed and implemented by the author called Wattsup. An experimental design was then developed to evaluate the system which involved recruiting eight households for an eighteen day trial. This was supplemented with a qualitative study of comments generated by users and also in semi structured interviews. The results indicate that the users of the Wattsup energy application integrated in Facebook assisted the participants in reducing their energy consumption. Types of energy information displayed in the application were both live and historical measurements as well as Co2 emissions, publicly viewable to participants and others on their personal Facebook friends list. Public viewing was implemented for comparison purposes as well as introducing peer pressure and competition amongst like-minded friends. Further analysis of the participant's social interaction activity with the energy application revealed higher awareness of their energy usage behaviour was present. Positive effects of the results were lower energy costs and fewer Co2 emissions released upon the environment from the participants by using the socially enabled energy application. To test the theory of a positive effect of social interaction on domestic energy consumption, two Facebook energy applications were developed by the author. One of the applications contained socially enabled features, while the other displayed only the participant's personal energy usage with no social features or capability to view other participant's energy information.

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1 INTRODUCTION

This Masters level Project investigates the potential to raise awareness in domestic energy consumption using persuasive technologies [41] that provide visual energy feedback to assist in changing behaviour and attitudes towards energy consumption in the home. The potential to change human behaviour is trialled through the user's experience of interacting with a persuasive technology in the form of a Facebook application developed for the project. This application will be referred to throughout this report as the WFA (Wattsup Facebook Application) or Wattsup.

With the shift of traditional HCI (Human Computer Interaction) moving over to UX (User Experience) from usability [53,10], this project follows this transition by focusing on creating an interactive environment that encapsulates an important contemporary issue within an influential social platform - Facebook. The choice of following a UX approach in no way suggests that usability performance and design techniques such as eye tracking or physiological measures are now irrelevant, but they don't adequately provide measurable design principles for UX in social environments such as the home and workplace [9]. As this project is based on technology in the home, it follows a user-centred methodology that uses the qualitative focus group method [81] involving participatory design to derive a fundamental basis for all user interfaces developed that facilitate the UX elements.

Raising awareness of the project's research issue - energy consumption in the home - is embedded in the WFA interfaces the user interacts with. Household energy usage with associated negative effects such as Co2 emissions is recognised as a contributor to global warming and subsequent climate change. Environmental issues such as rising Co2 levels are becoming ever more pertinent and demanding more media attention to raise consumer awareness of the possible environmental implications. With all of us responsible to a degree for our own carbon footprint, it makes sense for people to work together towards reducing domestic energy consumption collectively. Following this collective philosophy, in the WFA the user's experience is not limited to interacting with their 'personal and private' energy information, the energy data is integrated into the Facebook social platform allowing users to interact with their immediate friends and others if they choose to. This introduces a 'socially enabled' user experience entwined with domestic energy usage.

The context of this project's research is the use of social platforms to help raise awareness of domestic energy consumption, specifically through the massively popular Facebook social platform. Facebook has seen phenomenal growth in recent years and has in excess of 250 million active users, offering itself as an ideal deployment platform to raise awareness in large numbers of users given its viral nature in application proliferation [34]. Put another way, if Facebook's members were to reside in a country, it would be more populous than Russia. To create awareness in the domain of domestic energy consumption and to further investigate the sustainability of any behavioural change towards energy consumption two Facebook applications were created for end user participants. One application facilitated social interaction between friends, for example the sharing of energy usage data and the use of a ranking table for best and worst energy consumption between friends. The second application did not feature any social interaction and only provided a means for users to view their own detailed personal energy usage, effectively a closed system. Both applications received energy data via the Wattson energy monitor [26], which displays fiscal units as well as real-time energy usage data through its numeric and ambient display [79]. By conducting an experiment that compared the activity and energy usage between users of both applications, it provided an insight into the viability of social platforms to create and raise awareness of energy consumption. Both applications were identical in respect of their name, Wattsup, and their interface layout, the only difference was the disabling of application navigation tabs that direct the user to the social features in the non-social application.

1.1 Motivation

With energy consumption a global concern, both in industry and domestic settings, the scope of such a project to create awareness is challenging. This is an important area of study as the negative effects of global energy usage from the domestic setting as well as industry is having an impact on our planets climate according to multiple scientific peer reviews from the IPCC (Intergovernmental Panel on Climate Change), their latest synthesis report published in 2007 [54] . The IPCC reviews all the latest scientific and socio-economic data from around the world relating to climate change and produces reports of high scientific and technical standards. Indeed, in the UK alone, domestic energy consumption accounts for roughly one third of all energy consumed, according to official statistics from BERR (Department for Business, Enterprise & Regulatory Reform) [8]. In addition to this statistic, domestic energy consumption has *risen* 30% since the 1970's with damaging Co2 emissions hitting record highs.

As well as the obvious ecological motivating factors to conduct beneficial research that support raising awareness of energy consumption, it is wise to pursue a productive path for any such research given the scale of the task. As a result of this, one of the prime motivating reasons for using Facebook as a delivery platform is simply because of its huge success with its popularity continuingly soaring. In addition to this, it is particularly popular amongst the age group of 18-34 year olds, according to statistics supplied by alexa.com [3].This age group could make a potentially significant impact to climate change by raising their own personal awareness at an earlier time in their adult lives. Conversely, according to official Facebook statistics, the demographic of users who are 35+ are the fastest growing group of active users [34]. Many millions of people use social networking sites such as Facebook and MySpace on a daily basis; analysis of people's behaviour on such sites shows evidence that typical users are highly-motivated to read other peoples postings, play games, upload comments on photographs and add to their own 'profile' many times daily [55]. These sites provide a powerful means to deliver small, asynchronous applications to peer groups of likeminded real-world friends in a manageable and pleasant way. With Facebook actively advertising and continuingly developing its open API (Application Programming Interface) for developers of such applications, more developers are actively using it as it continues to grow with each iteration [72,35]. Subsequently, it may be said that there is great potential in leveraging the engaging, but persuasive, power of small applications such as ones that can display and share energy usage between friends, offering rich social interactive features that are readily built into social platforms such as Facebook.

Nowadays computers are being used as tools to facilitate behavioural change in the individuals and groups who use them. They now operate as social actors that fill the roles of teachers, sales people and health agents designed to influence and persuade our behaviour, aligning with the technologies' design ideology [41,40]. These social actors could play key roles in the delivery of intervention strategies for reducing domestic energy [2] by employing extensive use of social psychology to appeal to users.

Facebook is fundamentally built upon social psychology by facilitating key social interactions. Some psychological theories suggest these are interactions such as social validation (to belong, willingness to adopt behaviour if other, similar people are doing it) [6], group polarization (belief strengthening, such as joining a network with a common belief or theme) [69]; and reciprocal interaction [62] where people respond to each other by means of deeply integrated online social gestures such as 'poke' [55] or responding to other actions upon your online persona via instant and asynchronous messaging.

Assuming the previously discussed social psychology phenomena are embedded within the WFA, the potential may be realised for people to view their friends shared energy data and conform to the group norm by attempting to emulate their friend's energy consumption behaviour. Social norms such as peer pressure are powerful motivators in changing behaviour to align with the ideas or beliefs of peers [84].To better understand this concept, in terms of normative energy consumption among friends, *figure 1.1a* illustrates this.

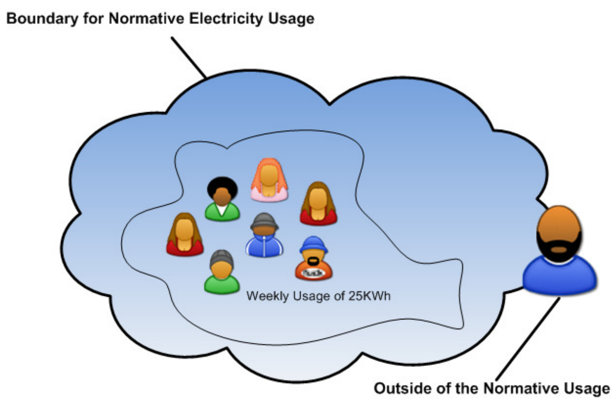


Figure 1.1-a - Normative energy consumption among friends

Group polarization may be present in the form of a network of friends who have voluntarily chosen to install and use an energy awareness Facebook application; therefore strengthening their beliefs around the common theme of reducing energy usage in the home. Reciprocal interaction may be both positive and negative, for example they may post a message of encouragement to a friend if they have reduced their energy consumption, but also post a reprimand if they are using an excessive amount. Social platforms such as Facebook provide built in mechanisms to quickly respond to friend's behaviour and actions such as the 'poke' feature. This type of feature may be characterised as a 'one-bit' piece of information [56] that facilitates intimacy between the sender and receiver, usually by conveying a personalised message of sorts.

By leveraging the aforementioned social features when interacting with other users, awareness and behavioural change could take place in relation to energy consumption in the home. Thus the motivating factor of the project is to have a possible positive effect towards the decline of global warming, realised through reduced energy consumption and Co2 emissions in households. The capability to appeal to large numbers of users is also a motivating factor driving the project, realised through the Facebook application platform.

1.2 Aims

With the scope of any project in reducing energy consumption almost limitless in strategies, a selected area of HCI for developing human awareness was targeted that could be delivered through computers in the home, namely persuasive technologies. The main aims of the project are to provide a persuasive technology in the form of the WFA to support users in reducing their energy usage, and to measure any potential effectiveness. The main deliverable of the project is to support the concept of energy monitoring by providing a socially enabled feedback mechanism allowing users to monitor their energy consumption in the home. It is anticipated that the action of monitoring their energy consumption could eventually lead to attitudinal behaviour change with regards to energy usage.

Central to the WFA conception and subsequent development was the concurrent collaboration between the developer and typical end users of such an application. This was to ensure that the aims of the project were continuously central to the project's focus by inspiring a user-based design throughout.

1.3 Objectives

1. Undertake literature search and literature review of domestic energy usage and historical/current methodologies that attempt to create awareness of domestic energy consumption

2. Carry out a user-based design methodology for software development

3. Identify, critique and select suitable toolsets for software implementation

4. Create and implement valid experimental designs that will give a comparison between experiment methods

5. Statistically analyse logged WFA and energy data

6. Provide an in-depth evaluation of results and present future work direction

1.4 Ethics

Consideration of potential ethical issues and their effect upon the project's development and experiment participants were addressed. This was to ensure the project's advancement and successful conclusion could be carried out. In the main, the project's experimental data is in a raw numerical form, from energy readings, and contains no identifiable personal information. The qualitative data collected via the Wattsup comment boards and semi-structured interviews was anonymised. Protecting any potential participant's confidential information is an important ethical consideration for any project, however there was deemed to be no confidential information required and therefore the participants' privacy would not be breached.

Permission was received from each selected participant for the hardware and software installations in their home and PC respectively. Informed consent was given from all participants who were individually briefed on the experiment's design, types of data collected and the tasks they were asked to carry out. With regards to the experiment's software application and the use of a third party platform in the form of Facebook, all participants had to agree to the terms and conditions of using a Facebook application before it could be applied to their personal profile. If a participant wished to withdraw from the experiment or not give authorization to the Facebook application to access their Facebook profile, they were informed that they could do so at any time.

All participants were over the age of 18 and were responsible for paying their household energy bill. With informed consent given by all participants there were no known ethical issues with the project.

1.5 Project Report Guide

The contents of this project report are described succinctly in the following paragraphs describing each chapter.

Chapter 2 discusses the research undertaken for the project in the form of a literature review. An extensive literature search was carried out in the style of a literature survey investigating a wide range of academic papers and organisational reports with a domestic energy theme.

Chapter 3 details the project's method to carry out testing the project's research question. The participants, materials and experiment procedure are discussed as well as confounding variables.

In chapter 4, the user-based design process of the two Facebook applications is described, mainly GUI (Graphical User Interface) design, as elicited through the project's focus group and previous research findings.

In chapter 5 the technical design and implementation of the project's Facebook applications is discussed. The programming languages utilised and application architecture diagrams are documented.

Chapter 6 describes the results of the project's experiment after data analysis.

Discussed in chapter 7 is the evaluation and critique of the project's research and experiment.

Chapter 8 discusses potential avenues for future work and further research. Several emerging concepts are discussed such as social and serious games to support behaviour change.

Chapter 9 summarises the project by concluding its findings.

Appendix A documents the programming code of the WFA main methods.

Appendix B includes the initial and final iterations of the project's Gantt chart from inception to completion.

Appendix C details some of the media coverage surrounding the project's research and use of a Facebook application to monitor energy consumption in the home.

Appendix D contains a submitted CHI 2010 conference paper directly derived from the work contained in this report, at the time of writing it was not known if the submission was accepted by CHI reviewers.

This introduction has served to describe the project's motivating factors, aims, and objectives in carrying out the project. The following chapter describes the project's research domain by discussing in detail the findings of an extensive literature review carried out to investigate the project's research question.

2 RESEARCH

2.1 Introduction

In this chapter the research undertaken for the core concept of the project's development is discussed. This includes literature research on historical and recent domestic energy consumption, technology-enabled feedback for energy consumption and the use of leveraging social platforms to assist with creating energy consumption and ecological awareness.

The concept of the project is encapsulated as providing a socially enabled interactive application to target reducing energy consumption. Primary research in this area was conducted through investigating historical studies in reducing domestic energy consumption as well as contemporary methods. As such, a timeline of literature ranging from the 1980's to the present day was researched. All of the core literature reviewed was in the form of peer-reviewed academic papers as well as governmental reports for agencies such as Office of the Gas and Electricity Markets (OFGEM) and Dept for Business, Enterprise; Regulatory Reform (BERR). The researched reports were carried out in collaboration with various university groups such as the Environmental Change Institute in the University of Oxford. Peer-reviewed academic papers from the Journal of Environmental Psychology and from Computer-Human Interaction (CHI) as published by the ACM Conference on Human Factors in Computing Systems are reviewed.

The following literature review discusses multiple studies of energy feedback in the home, workplace and communities through various methods, some using low-fidelity implementations such as reading your own meter and keeping a diary, information-rich billing and reporting your meter readings regularly through a telephone agent with targets set. High-fidelity contemporary methods that utilize home computers, energy monitors, social platforms and ubiquitous computing devices such as portable devices and ambient displays are also investigated.

2.2 Structure of this Chapter

This literature review was carried out to address the question of finding out what the current knowledge of energy consumption is in the domestic setting. It also looks into the state-of-th- art for interactive technologies created in response to energy consumption in the home, particularly from the HCI community.

In the first section of the literature review, 'Domestic Energy Consumption', statistical information on UK domestic energy consumption and appliance usage is presented in order to set the scene.

For the second section, ‘Energy Feedback & Monitoring’, three major UK household energy based reports from this decade form the basis of the review. Two were created by the Environmental Change Institute in the University of Oxford [21,20] the latter being produced for Department for Environment, Food and Rural Affairs (DEFRA) that provide an extensive insight into energy feedback in the home. The third report was compiled by the Centre for Sustainable Energy (CSE) [17] for OFGEM providing a detailed analysis of consumer preferences in energy feedback in the home. These reports produced a comprehensive analysis of past, current and future projections of consumer behaviour towards domestic energy consumption and the starting point for this projects further research in the domain of feedback for household energy consumption. Several peer-reviewed studies by the behavioural sciences are also investigated and critiqued giving an insight into human behaviour and attitudes towards various modes of energy feedback in the home.

Following the previous review section into various uses and effectiveness of feedback in energy consumption, the third section; ‘Technology-enabled Feedback’, discusses several studies that employed novel technology-enabled feedback. These studies encapsulate the use of prototype devices, robots and situated/direct displays to inform users of energy consumption and offer varying degrees of interactions with each system deployed. The use of social platforms to raise awareness of energy consumption is also researched. Currently available ‘off-the-shelf’ technologies such as home energy monitors are also discussed.

The final part of the literature review summarises the relevant work in this review and highlights the entry points of this project concept. This includes the research opportunities the project fits into by exposing the gaps in knowledge that other relevant work did not explore or develop. A cursory mention of the growing trend of green amateur enthusiasts building their own prototypes to monitor consumption in the home is also included.

2.3 Domestic Energy Consumption and its Importance

Current domestic energy consumption accounts for roughly 30% of all energy consumed in the UK. In the period of 1970-2000 it increased by 32% and in 1990-2000 it increased by 19% [8]. A pivotal question may be asked in why domestic consumption keeps rising. Recent studies suggest that population and economic growth, especially in relation to disposable income can all lead to increased consumption [2,27]. In particular, technology advances resulting in energy intensive appliances such as dishwashers, PC’s, large screen T.V’s, microwaves and a plethora of other gadgets such as mobile phones and laptops that require charging regularly all contribute to increased consumption. PC ownership has also risen significantly; in 1995 roughly 29% of households in UK owned one, compared to roughly 65% in 2006, an increase of more than double according to the latest available figures [71]. The PC is a good example of a product that has contributed to the growth of domestic energy consumption in recent times and is worth discussing in more detail.

Presently the power supply component of a PC is outputting approximately 300W, significantly more than computers of the mid 90's [83]. This may continue to rise as computer components become more complex and sophisticated with high-end components such as graphics cards and processors now each using around 60W and 250W under load respectively. Comparatively, these two components alone inside a PC would use the same amount of power as five 60W bulbs. PC component manufacturers are committing to producing parts that use less energy and in one case claiming up to 60kg of Co2 emissions reduced a year in the case of a single hard drive [97].

The introduction of the 'Netbook' computer in the last 18 months, designed for general computing tasks such as internet browsing and using office type applications, has brought about cheap affordable computing that consumes significantly less power. This is in part due to the integration of the low power Intel Atom processor that can operate using 10x less power than a desktop processor [7].The average desktop PC is normally over-powered for all but the most compute intensive tasks. If the adoption of the Atom processor technology contained in netbooks becomes more popular for desktop computers then it is likely to decrease energy consumption in households by a significant amount, particularly if the households computer is switched on for long periods of time. Some PC manufacturers now offer a type of mini desktop computer called a 'Nettop' that comes with significant power saving technology such as the Atom processor [ibid], with manufacturers even quoting, *"A traditional desktop operates on a minimum 220W power supply, but the Atom-based nettop requires a mere 30W."* . The 30W figure has been quoted even lower from another manufacturer, claiming 20W total power consumption for their latest Nettop [4].

With such a huge increase in ownership of the PC and its energy consumption being relatively high, studies have shown that even simple changes in behaviour towards using a PC can make a difference to consumption levels [91]. It may be seen as somewhat ironic that this project uses computers to attempt to reduce energy consumption. However, the possible gains by raising overall energy awareness in householders may outweigh this inherent flaw as there are many more devices and appliances in the home that householders can change their energy pattern behaviours with. One can easily imagine the scenario when both at home and at work there may be long periods of being physically away from the PC whilst it is switched on. Computers now have sophisticated energy saving profiles and it would be a simple task to put the computer into standby mode during these times - where it will only use approximately $1/20^{th}$ of the power of it being fully switched on. Resuming a PC from standby usually only takes a few seconds as the computer's complete state is suspended to fast memory - in a busy working environment users are unlikely to completely turn their machines off as it may take several minutes to fully boot up and login to resume work. Turning the computer completely off will use less power than using standby, but a trade-off between productivity and energy savings will likely be sought in the workplace.

An official UK governmental BERR report [8] also aligns its outlook with a previous study of interventions for reducing domestic energy usage [2] in that disposable income has increased by 30% since 1990, leading to increased ownership of appliances in the home. Another important factor according to the BERR report that has contributed to increased consumption is the rise in single occupancy households, from a proportion of 17% in the 1970's to

32% in 1990. More energy is consumed when two people live in different households than two people that live in the same household. The Co2 emissions created by UK households have also risen in relation to the energy consumed. A report from the Office for National Statistics (ONS), examined the ecological impact of UK households [42]. Findings indicated that Co2 emissions per capita, were lowest for households with 3 or more people, while single occupancy homes were highest. The Co2 emission findings are partly aligned with the BERR report [8] in stating that households with one occupant consuming more energy per capita than houses with two or more occupants.

2.4 Energy Feedback & Monitoring

The UK government has recently announced a £7 billion plan that will replace all current electricity meters in the UK with smart meters by 2020 [24]. Smart meters have displays that can communicate visual energy feedback such as current usage, personal carbon footprint, current energy tariff and possible per-appliance usage. This announcement, coupled with the huge investment, confirms there is a need for greater awareness in home energy consumption for the consumer. This level of investment will bring energy feedback into every home in the UK when complete. Feedback can be displayed on the smart meters own display and also through a display that can be situated anywhere in the home with energy data communicated via wireless technologies from the smart meter to the display. The visual content of such a display is of particular interest, as it is likely to be similar in presentation to the energy data displayed in the software applications developed for this project.

The displays of current basic electrical meters are not designed with the consumer in mind, usually only providing an energy measurement in kilowatts for usage to date. These have no additional information in what the measurement means financially or ecologically, with no comparative baseline measurement. Typical examples of these common basic meters are seen in *figure 2.4a,* illustrating the ambiguities of current energy meters and how easily perplexed a consumer could be when attempting to decipher the display.

Figure 2.4-a Domestic meters, older analogue meter on left, newer digital meter on right, photographed by author

A recent study revealed that users do not understand energy measurement units such as the kilowatt, rendering them meaningless when read from their electricity meter [15]. Conversely, another recent study found that live energy feedback using the same kilowatts measurement unit was effective in raising awareness of consumption in the home [106]. This may be attributed in the context of static versus dynamic feedback, with a static cumulative kilowatts reading on the meter not providing the same amount of perceived information as a live kilowatts reading from a direct display. In the case of dynamic feedback, a consumer can directly see the consequences of their energy usage change in real time, with the kilowatt unit's currently being used fluctuating up or down.

Older meters usually have a static analogue display while newer digital meters may be able to cycle the display showing data such as energy rates and a more granular description of usage. Even with digital displays offering enhanced detail, they are still akin to a monotone calculator display with difficult to interpret cumulative information. As such, it may be said that energy usage in the home is transparent to the user with no tangible or visible means to accurately and efficiently monitor it [20].

A new smart meter display can be seen in *figure 2.4b*, highlighting the major differences in the display of information compared to basic meters. Clearly, one of the main benefits of instantaneous feedback through a smart-meter display is that a consumer can effectively monitor their energy consumption in the home as it happens. They can see the cost implications as they switch appliances on and off around the home with the potential capability to view the carbon offset of individual appliances. Similar devices to a smart meter are currently available in the form of home energy monitors. These are not directly physically wired into a household's electricity circuit or directly to the energy provider. They operate by taking a current reading from basic electricity meters through a sensor clamped around the fuse box power cable which then sends the reading to a display in the home. Energy monitors are discussed in more detail later in this literature review under the 'Technology-Enabled Feedback' section.

Most consumers are not aware of their current energy usage as any kind of information feedback is usually only present on their electricity meter, which may not even be located in their own home depending on type of domicile. Electricity meters are generally locked away in a dark cupboard or basement with no real practical way to monitor the meter's display or interpret its information. The only kind of feedback normally accessible is the quarterly paper electricity bill, although this is changing with the advent of online energy billing and 'green' energy tariffs [29,28].

Figure 2.4-b Smart meter display showing live financial values for electricity and gas usage, reproduced by permission of EDF

Online billing with green tariffs provides a basic overview of a home's carbon footprint displaying self-comparative energy use and Co2 emissions, normally through a bar graph such as seen in *figure 2.4c.*

This is the current limit of consumer interaction and it does not provide a live reading or benchmark comparative of current energy usage in the home. Even for consumers who are not on a green tariff, it shouldn't present any difficulties for energy providers to supply this kind of information on all tariffs either by paper bill or online.

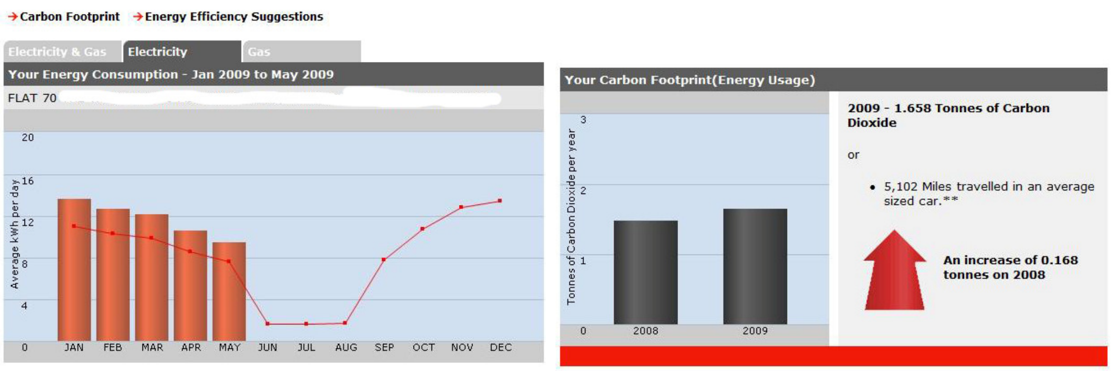


Figure 2.4-c Green Tariff billing displaying author's self-comparative and emissions data, produced by author

Studies into improving billing to create more awareness in the consumer have taken place, both in the UK and in Norway. These involved redesigning paper bills to show pertinent information that the consumer can understand derived from various consumer based focus groups and questionnaires that were sent with energy bills [17] [98]. Graphical representations such as pictorial images and graphs were used to enhance current bills by showing financial and normative comparisons. It may be considered somewhat ironic that such efforts should be concentrated on creating yet more paper in our efforts to reduce consumption. However, the aforementioned studies did take place in 1999 & 2004 respectively, there is now a much greater proliferation of households that have access to the internet, opening up a route to more effective online billing with the possibility of 'paper-free' billing. Perhaps the most striking comparison between both the UK and Norway studies of paper billing was the lack of interest from UK consumers for comparative feedback, such as comparing themselves to other households in the neighbourhood and also a distinct dislike for comparison to any normative average. The only kind of comparative feedback the UK consumers preferred was to compare their own historical energy usage, with simple bar charts given preference over pictorial images. In contrast, the Norwegian study received a high interest in comparative feedback with other similar households. Similarly, a recent study in the US [15] also revealed that consumers would like to benchmark their energy usage against others. Interestingly, the US study received feedback from participants regarding privacy issues and how other people, possibly in their own neighbourhood, could make inferences about their lifestyles by their energy consumption. This does raise legitimate ethical and privacy concerns, although comparisons to other households could be anonymised.

Enhanced billing could help raise awareness of consumption but its usefulness over the long term may be compromised due to long interval based feedback with billing cycles. It also does not provide continuous real time feedback. A UK based study found that frequent, continuous feedback over a long period is the best method for changing behaviours in the home towards energy consumption [37]. This preferred feedback is delivered through interactive systems such as energy monitor displays and PC's providing live feedback, a superior alternative to raising awareness over paper billing. As suggested in another study, live continuous feedback supplemented with informative billing offers a solid basis for promoting sustained energy reduction in the home [20]. This project tackles the problem of designing an interactive application to display energy usage, both current and historical, as well as social comparative data.

The notion of feedback in the home for energy consumption is a well documented area [21,20,37]. Different types of feedback have been categorised, with main categories such as *direct* and *indirect* [21] feedback as part of strategies such as *antecedent* or *consequence* strategies [2]. As both main types of strategy include at the core some form of feedback, it is suggested that following the headings of direct and indirect feedback provides a more simplistic taxonomy.

An ethereal type of home appliance operational feedback may originate from other people, or can be self-conceived in the form of folk theories or myths regarding appliance energy usage in the home [23]. One such theory is the incorrect use and subsequent operational feedback of the thermostat control in the home [57]. Following such unsubstantiated beliefs can be attributed to a lack of information on how systems such as the thermostat operate, leaving the occupant to develop a folk theory of their own or adopt someone else's. This type of self developed feedback may be critical in forming behaviours towards using appliances in the home, particularly as incorrect practical or recommendation advice may come from friends or colleagues who are influential sources [96]. As 58%

of all domestic energy consumed in the UK is from space heating in the home [8], incorrect use of the thermostat control through misconceptions of appliance operation can have a significant impact on consumption and subsequent Co2 emissions. It follows that the belief in folk stories regarding heating the home can be a very real issue. The operational use of the thermostat study conducted in 1987 estimated that between 25%-50% of American household occupants held an incorrect theory on how the thermostat operated, the theory was called 'Valve Theory' [57]. This theory harbours the misconception that if the thermostat control is set to a higher temperature than desired to heat a cold room up it will heat the room up quicker. As this mental model of system operation is incorrect, it is likely that more energy is consumed as the temperature will ultimately reach the higher temperature, with the occupant then turning it back down to the required temperature. An earlier study found that 62% of 38 households also stated they would turn the thermostat on full to heat a room up believing it to be quicker [74]. Although the studies discussed in relation to thermostat usage may be rather old, ranging from 1982-2000, the actual thermostat control on contemporary heating systems has not been through a major transitional change. Most modern systems still employ a rotary dial for temperature adjustment, while others use a digital display with numerical values that can be set up or down. An occupant may still go through the same application of 'Valve Theory' on a modern system by the same temperature adjustment method.

Further research into folk theories and myths regarding energy consumption was carried out in 2000 study [23] and exposes myths such as leaving lights, computers and televisions switched on consumes less energy than frequently turning them on and off. The seemingly widespread belief of folk stories surrounding energy consumption in the US, as evidenced through the aforementioned studies, illustrates that more awareness is required and can be realised through educating occupants and providing homes with a real time feedback mechanism.

In applying feedback to home energy consumption, direct feedback holds the most promise with potential reductions of 5-15% [20]. Examples of direct feedback are direct displays, computerised interactive feedback and smart meters. All of these types of feedback will display energy usage through PC monitors or an unobtrusive portable display in the home in an attractive, timely and easy to understand manner. Indirect feedback such as more frequent billing, or informative billing with historical feedback, offer potential energy reductions of 0-10% when used [20].

In order for direct feedback to be acknowledged and successfully delivered, the occupant must be able to *monitor* the feedback, preferably in an unobtrusive manner. A display which places a low cognitive load on the viewer is desirable in order for at-a-glance interpretation of the feedback. The Oxford Dictionary definition of monitor:

Monitor: *"A person or device that warns, checks, controls, or keeps a continuous record of something"*.

The definition interestingly states that it can be carried out by either a person or device. In most cases home energy monitoring requires the consumer to carry out the *physical* monitoring such as regulating or controlling the consumption. More sophisticated business-orientated monitoring equipment will be able to act on current consumption by adjusting appliances operating parameters. An example could be adjusting lights depending on time of day or adjusting thermostat dependent on temperature.

The home energy monitor may display feedback in the form of energy information or a warning regarding energy usage but it does not control the energy consumption by acting to reduce it, this is entirely the remit of the consumer to do something about it. Relevant literature describes a type of persuasive technology as 'self-monitoring' which "*allows people to monitor themselves to modify their attitudes or behaviours to achieve a predetermined goal or outcome*" [41]. When applied to energy monitoring it is not strictly self-monitoring in terms of monitoring your own physical state such as heart rate or progress for number of steps taken using a pedometer. It is more a state of monitoring your behaviour's impact on your home's environment based on feedback from an energy monitor. Pre-emptive monitoring of one's own behaviour towards appliance usage in the home can reduce the reliance on the feedback from the energy monitor itself. Through time the occupant could *learn* which appliances use the most energy through monitoring the feedback from the display, to the point where they begin to monitor their behavioural attitudes in the use of the appliances. Self-monitoring can take place instantly depending on the display's feedback at that time, for instance you may notice that energy usage is high and you subsequently monitor the immediate environment to see what may be causing the higher than usual consumption. Over time you may notice a pattern of high energy usage at certain periods of the day and may develop a strategy to combat it, ultimately by doing so the self-monitoring through the use of feedback may create a sustained behavioural change.

Although feedback may be instantaneous, possibly followed through by action by the user in the same immediate timeframe, this may not always be sustained due to the time estimated for sustained behavioural change. To continuously sustain behaviour that proactively reduces energy consumption, research has indicated it usually takes a minimum of 3 months for the positive behaviour to become more autonomous [20]. Even after the period of 3 months, sustainable behaviour still requires the feedback to be present as a reminder, albeit more infrequently [37].

Additional peer-reviewed studies from the Journal of Environmental Psychology have researched the role of feedback for reducing energy consumption both in the domestic domain [11] and the workplace [86]. The domestic study provided evidence that using computers to display current consumption as well as historical consumption was the most successful in reducing energy usage. This was compared to infrequent printed information detailing self-to-self and self-to-others comparisons. However, an improvement could be including multiple types of feedback such as incorporating self-to-self and self-to-others in the computer program as well, although this may not have been technically feasible at the time of the study. The self-to-others comparative feedback may have been more successful if applied through a computer connected to the internet, comparing other similar household's energy data by means of an online database. The workplace study highlighted group-to-group comparative feedback had the greatest effect in energy reduction when compared to a group that only had access to self-performance data. Feedback was only given during once-weekly meetings in the workplace, leaving scope for greater reductions if the feedback was more frequent, such as on a large screen that workers can view live energy data at any time.

The concept of using a large situated display to show energy usage to groups and individuals was recently researched [75]. The study primarily involved collecting and then comparing university campus dormitories energy usage using social-normative data which was then viewable on a website. The overall energy expenditure of each hall and energy used by each individual student member of the respective hall was displayed, allowing students to directly compare their own usage to their fellow students in the same hall as well as hall-to-hall comparison. However, the information was only updated bi-weekly with no instantaneous direct feedback, yet it still resulted in a reduction of 33,008 kilowatts of electricity and 724,322 gallons of water when compared to baseline usage of the 3 years prior to the study. The study suggested that by using the social-normative comparison method it contributed to the reduction.

Instead of the indirect, infrequent bi-weekly feedback used in the study, an improvement would be exposing the possibility of applying live direct and timelier feedback through a direct display or website application. The final user-centred iteration of the energy interface for the campus dormitory study is seen in *figure 2.4d.*

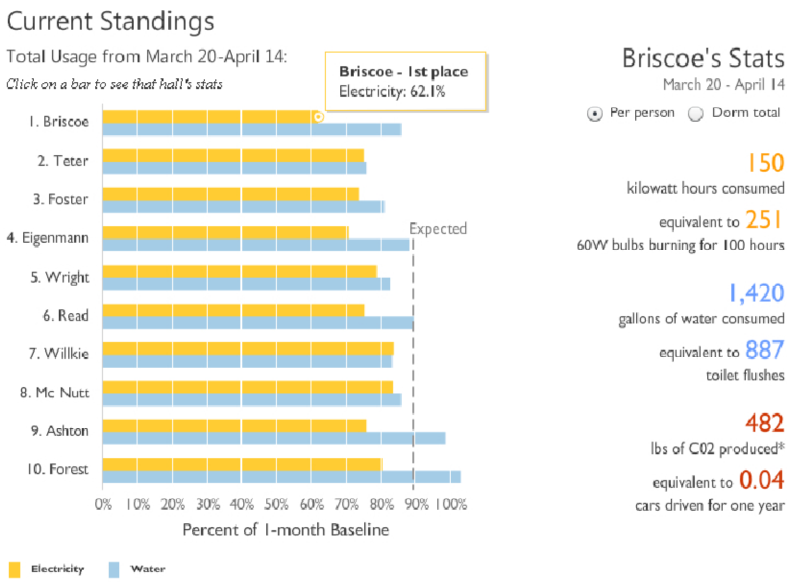


Figure 2.4-d Energy Awareness Challenge interface displaying social-normative data, reproduced by permission of Will Odom

Although social-normative comparisons can be made by viewing the interface, it is not a live measurement and some of the students in the same dorm may not even be part of the same immediate social network of friends. It is suggested that comparisons made between students who are not immediate friends or colleagues may not have a high influential or personal value; they are not likely to influence behaviour to a great extent as they do not belong to the same social group of friends or colleagues [58]. Belonging to the same social group of friends suggests students would be more likely to behave similarly by conforming to social norms and living up to the group's expectations [92]. Following this, students of the same social groups may be more likely to copy positive behaviour of other friends who are actively reducing their energy consumption as they value their social relationship. By leveraging a social platform such as Facebook, an application could be designed around displaying comparisons only with the people you have chosen to add as friends in your social profile. The most important element to incorporate is the highly valued social relationship variable, which has the power to orient behaviour to what is socially desired.

The creation of a social networking Facebook group was also facilitated for the university dormitory study but this did not have a high uptake. An improvement over a basic Facebook group could have been a Facebook application created to display the energy data, with personal student energy usage tied into each student's unique personal Facebook profile. Facebook applications provide a more personalised Facebook experience through access to the users profile, profile actions and news feed. Applications also utilise social data from the user's personal profile with access to their friends, photos and events such as birthdays and other events [46]. A Facebook group network can only be fed updates in the form of manually entered textual or static image posts with little guided or sophisticated interaction. Facebook applications can occupy portions of highly viewed webpage real estate, pages such as a user's personal profile page to display interactive information; they also provide direct interaction with other users of the application in a timely fashion, such as sending messages or acting upon others actions.

From this study, there appears to be a gap in the current knowledge of applying energy feedback, specifically through using social-norms *and* instantaneous direct feedback, delivered with an established online social platform such as Facebook. Feedback would be applied using a Facebook application for an up-to-date interactive comparison with other friends using the application as well as the capability to filter anonymous non-friend comparisons if desired. Other innovative household technology-based feedback studies have been carried out, but these also highlight a lack of up-to-date social-normative comparisons using social platforms which limit their scope over time. These studies are critiqued in the next section of this review.

2.5 Technology-Enabled Feedback

From the literature reviewed so far, several key points to realising the success of energy feedback have been presented. Firstly, the majority of studies identify the need for feedback in response to the invisibility of energy usage in the home, it cannot be perceived, and neither is it's ecological impact interpreted. Multiple study findings indicate that direct feedback through the use of a display can raise awareness and that self-to-self and self-to-others comparative feedback provides scope for the presentation of the energy data for a direct display. The determinant success of the received feedback is dependent on the quality of the display's presentation of consumption, such as measurement units and graphical embodiments of energy, as well as the types of normative comparisons used. Additionally, indirect feedback such as enhanced paper billing with an informative breakdown of usage over periods of time was found to be useful in raising awareness and reducing consumption. However, the qualities of enhanced paper billing could easily be implemented in an online computer application, providing anytime and real time access to energy consumption. Two substantial review papers investigating studies of energy feedback summarised:

"*Clear feedback is a necessary element in learning how to control fuel use more effectively over a long period of time and that instantaneous direct feedback in combination with frequent, accurate billing (a form of indirect feedback) is needed as a basis for sustained demand reduction.*" [20]

"*Successful feedback combines the following features: it is given frequently and over a long time, provides an appliance-specific breakdown, is presented in a clear and appealing way, and uses computerized and interactive tools."* [37]

From these two summary statements it is believed that instant and continuous feedback is necessary, with clearly presented energy data, ideally through computerised interactive tools. In other words, technology-enabled feedback is a positive way forward and a major concept this project has adopted. Current energy monitors provide a part solution to the summarised findings, particularly for overall household consumption. However, *comprehensive and granular* feedback at the per-appliance level is currently not a cost effective option. A stand-alone monitor for each appliance is required with the monitor situated next to the appliance; this is a costly approach which would mean the presence of multiple monitors around the home, not accommodating home aesthetics. However, it is not a difficult task for a consumer to *learn* how much energy an individual appliance is using by means of a simple observation and subsequent calculation. By simply turning an appliance on and off, the observed difference in wattage or cost on a direct display gives a rudimentary indicator of its consumption.

An innovative approach to per-appliance monitoring was investigated using a power-aware cord. [50] It utilised feedback in the form of ambient light alone emitting from the cord to indicate the appliances current consumption as seen in *figure 2.5a*. Although it does present instant and at-a-glance information it does not really provide any useful granular level of information such as an approximation of actual energy used or cost, both of which a direct display could provide. In addition to this, having power-aware cords attached to many devices in the home would actually increase energy usage through the cord requiring power itself and would likely present aesthetics problems with many glowing cables emitting light in a given area of the home.

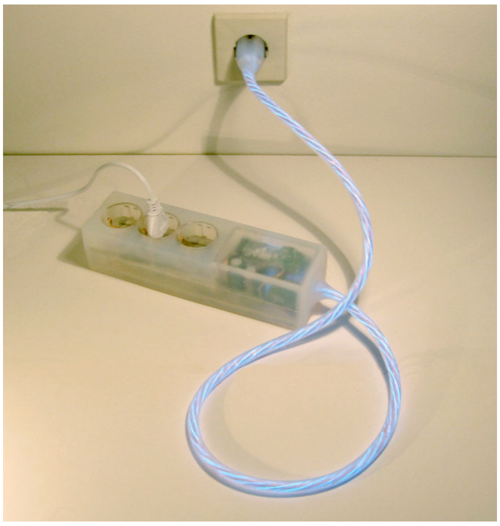


Figure 2.5-a The power-aware cord, emitting light to indicate energy consumption, kindly reproduced by permission of the Interactive Institute www.tii.se

Another recent study investigated the use of prototype portable and stationary, minimalist direct displays for the home [106], a significantly improved approach over the power-aware cord approach. In the study, it was found that occupants would move around the house and turn appliances on and off to monitor the change of feedback on the portable display they carried with them. This is akin to per appliance monitoring as the occupant is noting the feedback change that each appliance creates on its own merit. Qualitative feedback from the study indicated that users of the portable system enjoyed the somewhat 'playful' approach of roaming around the house checking individual appliance usage, trying to get the overall household usage as low as possible.

The two previously discussed studies did not employ the use of any normative feedback, social or otherwise. The study incorporating the portable and stationary displays received feedback from high-usage participants to this effect. The high-usage consumers desired some kind of normative feedback they could compare to. Although both study approaches were novel and had potential to create awareness of energy consumption, it is projected that any behavioural change would not be sustained without some form of normative feedback, such as friends or other households in the neighbourhood.

A currently available off-the-shelf home energy monitor embodies improved attributes of both the devices used in the power-aware cord and portable prototype studies, making it a worthy candidate as a home monitor. This device is called the Wattson and is seen in *figure 2.5b* [25]. It has an ambient light system embedded that provides light feedback dependent upon household energy usage as well as a numerical display that can show energy units such as watts and monetary units such as pounds. The display is fully configurable allowing the ambient light system to be turned off, used on its own, or in conjunction with the numerical display. An additional bonus is that it has a built in battery that can power it, allowing it to be carried around the home to see the effect of household appliances in different locations.

Figure 2.5-b The Wattson energy monitor from DIY Kyoto, photographed by author

Until aggregated displays are a reality, per appliance monitoring is not currently a viable option for domestic energy monitoring. There are technological stumbling blocks in providing a full household overview in conjunction with an appliance specific consumption. Another problem for instant comparative feedback is that there are currently no available domestic monitors that can send usage directly to the internet without the need of being connected to a PC. Currently, to facilitate online comparisons with other people's consumption requires a PC to be switched on continuously in order to share and remotely view live energy information on the web. There are some commercial trial systems currently being developed that are beginning to address these problems with the ability to display aggregated energy data in conjunction with a smart meter as seen in *figure 2.5c* [85].

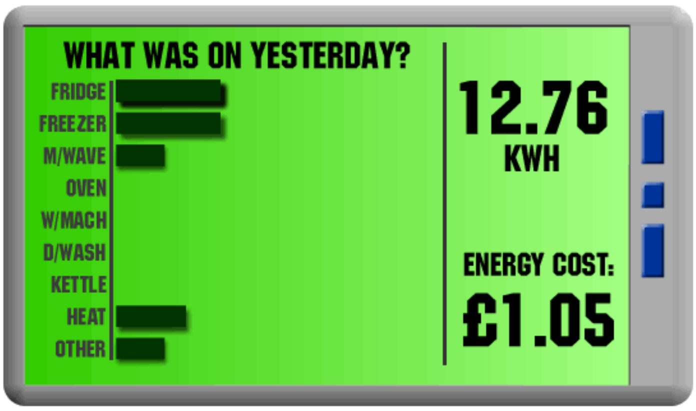


Figure 2.5-c Coracle energy feedback display system from SENTEC, reproduced by permission of SENTEC

In the UK, several other off-the-shelf energy monitors are currently available providing varying levels of interaction as well as diverse display presentation, these monitors are shown in *figure 2.5d.* It is suggested here and also by an investigation into design issues for energy feedback devices [38] that displays such as the Wattson are more aesthetically pleasing for fitting into the home than the somewhat austere displays in *figure 2.5d*, providing greater levels of interaction. Indeed, another study revealed that user's perceived usability of objects in the home may be variable simply by their design and condition [68].

Figure 2.5-d Current Cost & Owl Energy Monitors [19,1], Owl photographed by author, Current Cost image reproduced by kind permission of CurrentCost

Several studies have attempted to take the traditional approach of field studying domestic energy consumption into the lab for investigation using simulated energy usage [65, 51]. The latter study researched the use of a robotic agent to provide social feedback; the agent used was the iCat from Philips [78]. The iCat gave both positive and negative feedback through facial gestures and verbalisations to match the facial gesture. The participants utilised software that simulated performing washing machine cycles on screen. Depending upon the energy used, the iCat would respond correspondingly. Findings indicated that participants experiencing the social feedback through the iCat used less simulated energy than participants who where only shown feedback in the form of a bar chart for energy consumed. A criticism of this approach is that a robot such as the iCat is unlikely to be common place in households anytime soon; it is a sophisticated research-only device that costs in the region of £5000. Also, it would require monitors and sensors to be installed in every major appliance in the home with an elaborate software system to support it. In short, it is not a realistic study that could be taken from the lab and field-trialled in many homes. The iCat can be seen in *figure 2.5e.* An improved approach would be a software agent that could embody any type of entity, even a virtual human through the use of a direct display, negating the need for an expensive physical robot. Such software agents could even be installed on mobile devices, allowing interactive feedback wherever you are.

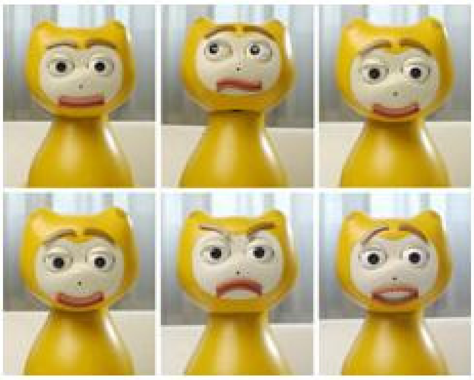


Figure 2.5-e iCat facial expressions that can be used to represent positive or negative energy consumption

The other lab study also adopted the use of simulated washing cycles on a mock washing machine control panel and tested their hypothesis of using a combination of simulated feedback and energy goal setting. This improves on the iCat study by adding another variable in the form of setting energy goals. Before commencing the experiment the goal setting group of participants selected a goal value, for example a target saving of 20%, then programmed the simulated washing machine control panel to commence their selected cycle of washes. Findings indicated that all groups who had feedback consumed less energy than the control group; further reductions were found when feedback was used in conjunction with goal setting. A possible further improvement on using self-goal setting could be the introduction of social interaction. Goals could be set in the form of competitive energy challenges that you can create against your friends in other households, this could be facilitated through a social platform such as Facebook using an energy application.

Some work has been carried out in using social platforms to motivate people to reduce their ecological impact [63]. The study investigated the use of creating social network groups that would feed members of such a group suggestions on how to reduce their carbon footprint. This employed the use of web widgets such as 'badges' that could be incorporated in various social platforms such as MySpace that can show personalised information such as their carbon footprint. However, their proposed implementation did not address the issue of collecting personalised domestic energy consumption automatically through technology. Instead they proposed that the user enter their consumption themselves, clearly this is a major detriment in the usability of such a system in that it relies entirely on the user to keep manually updating their consumption data. It also presents a similar approach to a previous study discussed in this review that investigated the use of socially enabled feedback in university dormitory communities [75]. The dormitory studies concept of using a social networking group on Facebook did not have a high uptake, it is suggested that a socially enabled application integrated with access to the user's personal profile data would provide greater scope of interaction. More positive aspects of the currently discussed study proposed that their system included goal setting and competitive challenges; again, the execution and success of these properties of the system rely completely on the user updating their own energy usage manually.

Overall, the concept behind the idea of using technology in the form of online application or websites that display household energy is not entirely new, although most websites already in place are self-reporting carbon-offset tools such as Microsoft's 'Hohm' and Oxford University's 'iMeasure' websites [66,76]. What these online applications do not offer is live autonomous recording of household energy usage through an energy monitor or integration into the online social networks that many millions of people regularly use, this is where some of the persuasive aspects of the project's Wattsup energy application are introduced, with participants exposed to social normative influences from their network of friends. One study however has integrated home energy monitors with an online website providing live energy readings through an AJAX driven energy dashboard [22]. It incorporated a form of normative measurement as it allows users to compare their energy usage to other users of the system, but not in a social context, as users of the system are anonymous. So we can see that there are some online persuasive systems out there that are designed to raise awareness of energy consumption, and ultimately assist people in reducing their energy consumption.

2.6 Summary

The literature review carried out exposes the current gap in knowledge of leveraging social platforms by embedding live, continuous energy data into a fully interactive socially-enabled energy application. The energy data would be uploaded automatically and presented within an application embedded in a well established social platform such as Facebook. Although several studies investigated social-normative comparisons for reducing domestic energy usage, none of these studies actually facilitated it through the use of popular, well established social platforms using their built-in requisite API's.

This review has informed the reader of the current state of domestic energy consumption in the UK and has investigated various studies in raising awareness through feedback from countries around the world. It has described various commercial and prototype technologies that are emerging to address the rising consumption levels in the domestic sector and has highlighted gaps in current knowledge of providing energy feedback at a social level.

The next chapter of this report describes the design of the project following a user-centred approach, including focus group results and interface designs.

3 METHOD

In order to ask this project's research question, "*Can social networks such as Facebook facilitate the motivation and support subsequent sustainable behaviour to reduce energy consumption in the home?*, a cycle of HCI requirements gathering and design was carried out. This includes the interface design, application development and testing of the research question by means of a scientific experiment.

Following the project's method allowed the testing of the project's experimental hypothesis leading to results that could be analysed statistically using quantitative measures, and additionally, through a qualitative research method. The following sections describe the project's method – and if followed in the same systematic fashion, allow the project's experiment to be duplicated.

3.1 Participatory Design

Creating good interface designs is not an easy feat, even more so if some of the target users of the interfaces do not have a hand in their design [73]. To this end a user-centred approach was taken to first choose the type of energy data they would like displayed and how this data would be visually presented. The approach used to elicit the requirements in the form of energy data categories and subsequent interface designs that includes these categories was a focus group. The focus group is a participatory design method [70] that facilitates requirements gathering in a social group context to aid in the design of an interactive system.

The focus group took place in an artificial home setting, more specifically a technologically advanced responsive home based in the University of York campus [18]. The focus group participants were shown a Wattson energy monitor and exposed to several domestic-energy related YouTube videos. The videos were shown to help inspire creativity in the participants to produce their own energy related images. Also given to participants was a paper materials pack containing pictorial icons and interface elements to start building interfaces.

Participants of the focus group were directed to produce paper prototype [12] interfaces displaying their own chosen energy data attributes. This eventually led to user-generated interface designs that satisfied the project's requirements and conceptual interface designs for the WFA.

Further details of the participatory design approach including the focus group results are discussed in chapter 4.

3.2 Facebook Application Development

After collating the focus group findings, the user-generated interfaces were selected for implementation into a Facebook application. Interfaces were selected based on their feasibility to implement, UX values and popularity from the focus group participants. Final selected interfaces are detailed in chapter 4, section 4.4, and are termed 'Personal', 'Friends' and 'Rankings' interfaces. The more elaborate interface designs detailed in chapter 4 would have taken considerable development time and resources beyond the scope of this project and were therefore not implemented. This ensured that the original designs as derived from the focus group would be present in the final WFA, providing the type of UX the participants sought.

The application was developed using multiple programming languages, and when completed deployed to the Facebook application platform. The languages utilised are detailed in chapter 5, section 5.3.

Once deployed, the application was manipulated as the independent variable in the project's experimental design as discussed in the next section.

3.3 Experimental Design

The main aim of the experiment was to compare the domestic energy usage between participants using a socially enabled Facebook application and a Facebook application with no social features. Both applications displayed energy data communicated via the Wattson energy monitor. The experiment took place in each participant's home in their own time offering a realistic environment to test the experiments hypothesis.

3.3.1 Design

The experiment followed a within subjects design [13] with each participant taking part in two conditions or *social modes*. Condition A was using the socially enabled Facebook application and condition B using the Facebook application with no social features. The reasoning behind choosing Facebook to deploy the application with no social features was to level the playing field, with the assumption that participants were more likely to interact with Facebook over a normal website.

A within subjects design was chosen because the participant sample size was small. Half of the participants started in condition A with the other half starting in condition B. The independent variable was therefore the Facebook application's social mode, either enabled or disabled. The dependent variable was the energy used in Kilowatt Hour units with a total measurement being taken in each condition for each participant.

3.3.2 Participants

Eight participants were recruited, each one the household representative responsible for paying the electricity bill. Selection of the participants followed the Purposive Sampling method [5]. This method was utilised as specific participant criteria had to be met in order to take part in the experiment. The criteria were that the participant must be responsible for paying their household electricity bill and be a daily user of the Facebook website.

The participants were also recruited in 4 pairs who resembled one another in circumstances as much as possible. For example if a participant belonged to a family of four then another participant belonging to a family of four was recruited. In total the participants belonged to households with 6 couples and 2 families of four. The selected participants had all been regular users of Facebook for at least one year and were all friends, being part of one another's Facebook friends list. Relevant demographical details of the participants are included in *table 3.3a* with pseudonyms used in place of the participant's real names.

Participant No.	Profession	Age	No. Household Members
Diane	Nurse	26	2
Alice	Nurse	23	2
Rachael	Office Administrator	49	2
Christopher	Programmer	32	2
Robert	Secondary School Teacher	41	2
David	Student	31	2
Richard	Student	20	4
Shirley	Writer	40	4

Table 3.3-a- Participant demographics

3.3.3 Apparatus

The experiment required hardware in the form of a Wattson energy monitor and a Windows based PC running the Powometer desktop software available from www.myenergyusage.org to collect energy data from the Wattson monitor. Also required is a compatible internet browser to view Wattsup running on the Facebook application platform. Internet Explorer versions 7,8 and Firefox 3 were tested and working at the time of writing this report.

3.3.4 Procedure

Each participant carried out the experiment in their own home after the role they would play in the experiment was fully explained and informed consent was given to the author. The experiment took place over a period of 18 days with 9 days in each condition. The experiment's purpose was explained to the participants as being an eco-study evaluating the effect of social platforms on household energy consumption. They were told that they would each receive a Wattson energy monitor which would be installed by the author at a convenient time to themselves.

The Wattson monitor was installed along with the required desktop software one week before the experiment officially began. This was done to assist in reducing any effects on participants' energy usage by initially using the Wattson on its own, as it was likely to receive attention with being the new gadget in the house. At this stage no Facebook applications were deployed and trialled.

When the experiment commenced, half of the participants started in condition A with the other half starting in condition B, swapping over after 9 days. This was to assist with reducing any order effect [13] with participants' UX with the WFA interfaces in conditions A and B. After 9 days the participants were sent an email through Facebook informing them of the changeover of conditions. The applications were then reprogrammed to perform in the alternative conditions with the relevant participants.

3.3.5 Data Collection

Data collected from the experiment had a safeguard of triple redundancy. Energy data as measured from each participant's fuse-box by the Wattson monitor was stored in 3 separate electronic mediums. The Wattson monitor stores 30 days of energy data within its dedicated memory and the same data also stored in an MS SQL mobile database using the installed desktop software. The third point of storage was online using the myenergyusage.org web service via a MySQL database. All participant energy data could then be queried in as required such as hourly, daily or weekly usage. A benefit of this approach was that all data was collected autonomously with no requirement for participant intervention.

An independent second set of data was collected using the Google Analytics service [48]. This allowed the number of Facebook application page views to be recorded for both experiment conditions as well as the average time spent viewing each of the applications features. Using this data could help expose the most popular features of the application and direct future work.

3.4 Wilcoxon Statistical Test

A non-parametric statistical test to analyse the experimental energy data was used called the Wilcoxon Matched-Pairs Ranks Test [77]. This test was chosen because the energy data collected would not be normally distributed. This assumption was made because of the huge variance in size of households in terms of number of rooms and occupants. However the two experiment groups created from the 8 participants were matched across as equally as possible. The test provided a means to statistically analyse the collected paired energy values for each participant in each condition.

3.5 Grounded Theory

As well as quantitative data gathering some qualitative data was collected. The first qualitative data collected was in the form of participant comments posted within the WFA comment boards embedded in the rankings interface. These posts offer up insightful information on how the participants interact with each other in relation to viewing each other's household energy consumption. A GT (Grounded Theory) [47] was completed based upon the classification of the participant comments data.

A second set of qualitative data was collected from a semi structured interview using open questions put to each participant at the end of the experiment. This took place when the author returned to the domiciles of each participant to collect the Wattson monitor and remove any software installed by the experiment on the participants PC. The following questions were asked:

1. What part of the experiment did you like best, condition A or B, and why?

2. Did you come across any problems whilst using the application or the Wattson?

3. Would you use a Wattson device or something similar for a longer time period?

4. Do you think a difference can be made by reducing energy both personally and for the environment?

Each participant's response was audio recorded after informed consent was given to do so. The audio data was then analysed to produce a grounded theory based on their experience of using both the Wattson monitor and the Facebook applications.

4 DESIGN

After identifying the relevant gaps in knowledge through this project's literature review, the test platform developed for the project's experimental hypothesis of raising awareness of energy usage in the home using social platforms would follow a user-centric design. The design first followed a participatory design methodology following the school of thought of communicating information about systems [81], in this instance on how to display energy information to householders. This was realised through a focus group with participants communicating their thoughts and ideas on energy consumption in the home.

Central to the focus group was the task for participants to produce graphical representations of what they felt were good and engaging images and metaphors relating to energy use in the home. As such, the bulk of this chapter is based around user generated material with supporting documentation in why the participants justified the representations. The subsequent findings of the focus group are utilised in the conceptual design [80] of the project's WFA interfaces and detailed later in this chapter.

Before the focus group and conceptual design content is discussed, it is worth describing the project's concept with a brief overview of how the concept will be technically feasible to design and implement.

4.1 Projects Concept

The concept of using social-normative comparisons to potentially sustain a reduction in energy usage is illustrated in *figure 4.1a*. In the diagram, norm activation takes place by observing energy feedback from a direct display showing the current energy usage in either monetary or kilowatts units. At this stage the observer may choose to control the level of current consumption by turning off appliances and also begin to think about what they consider to be a normal amount of usage at that time. This may motivate them to compare usage with their immediate social group of friends on a social platform such as Facebook through a rankings table, thereby initiating a social-normative comparison to see if they are still within the social norm of the group. Following this, they can evaluate their energy behaviour in relation to the social-normative comparison and choose whether or not take action if necessary. The question of whether or not the action stage is sustainable over time is projected to be positive. However, the sustainability of the behaviour may only be present for as long as the social-normative intervention is present.

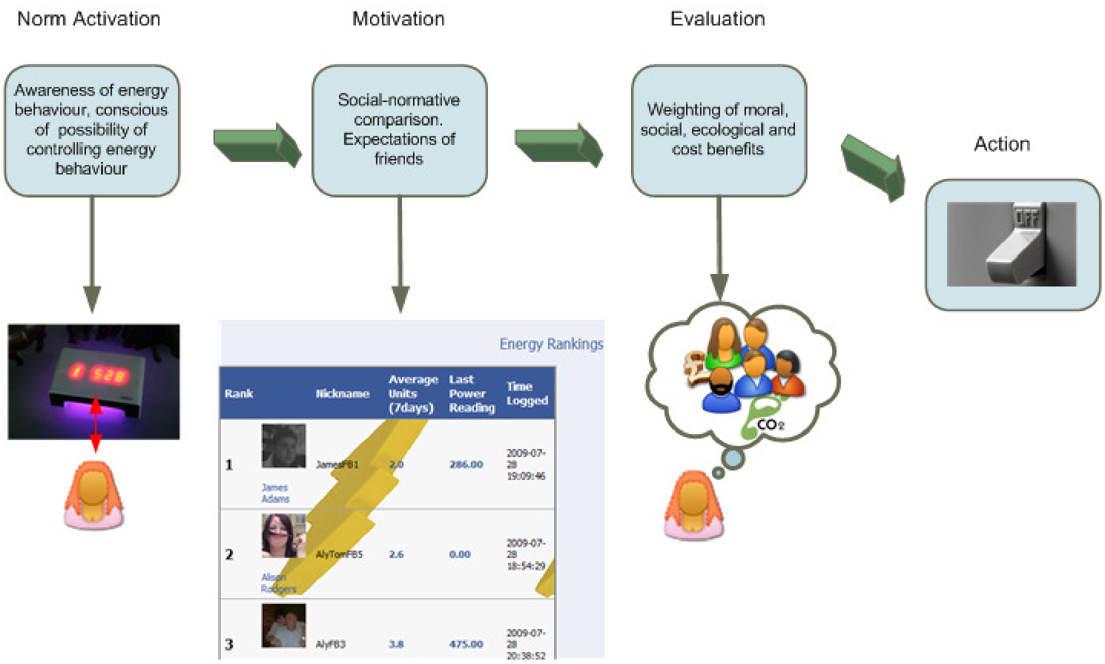


Figure 4.1-a Project concept cycle of social-normative comparison for energy consumed

It is possible to implement a potential solution to the shortcomings and subsequent gap in knowledge of the various technology-based feedback studies reviewed in this project's literature review. The project's social-normative concept is one such possible solution that is realistic and aesthetically pleasing for the home by using the Wattson device. Employing the use of the Wattson energy monitor offers continuous live direct feedback and the potential for socially enabled interaction through the Facebook social platform. To facilitate socially enabled interaction a Facebook application can be designed that displays live shared energy feedback to householders with the energy data polled frequently from the Wattson to the internet. An example scenario of social-normative energy comparison may be envisaged in a group of friends currently operating within the expected norms of the group, with each person using around 25 Kilowatts of energy per week and one friend in the group who has stepped outside of the group's normative range. This leaves the other members of the group in a position to playfully encourage their wayward friend to normalise their energy usage back in line with the group. This can be realised using positive or negative social feedback in the form of a poke, message or possibly an energy challenge as a motivator. It also puts the individual who is outside of the normative usage in a position where they have to dwell upon the fact their energy behaviour is outside of their friends. With conforming to the norm a powerful motivating factor, it is anticipated the individual in question will attempt to normalise their energy usage and fall back in line with the group.

The application when designed will be deployed through the well established and supported Facebook application platform with studies showing that users are willing to invest time in interacting with applications built for the platform [6].

With domestic energy consumption becoming more prevalent in the public eye, it has spawned a plethora of amateur enthusiasts who are designing their own prototype domestic monitoring systems, some linking them into the Twitter social platform [60]. The type of energy data displayed is basic in nature and presentation format and has yet to be developed into a complete socially-enabled interaction with more granular consumption data shared. No academic studies have taken place to date using these prototype technologies. With the encouraging growth of these prototype technologies, it is envisaged that different kinds of novel interaction may be designed by the enthusiast that could spill over into the commercial market when smart meters become a reality for most of UK householders.

4.2 Project Technical Design Overview

Upon completion of the design stage the findings were transferred over to the development and implementation of a Facebook application capable of displaying energy data communicated by the Wattson energy monitor. To afford the functionality of displaying energy data within a Facebook application, an elaborate application framework was designed and implemented as seen in *figure 4.2a*

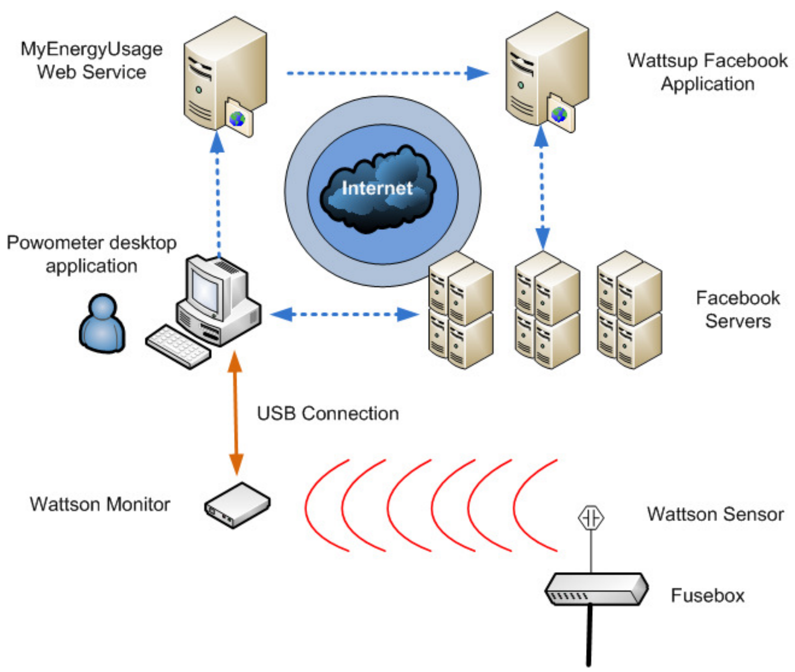


Figure 4.2-a Project's technical design overview showing the Wattsup Facebook application communication pathway

The starting point of communicating the energy data to the householder is the Wattson monitor's wireless sensor at the householder's fuse-box. From there its path follows various channels through the householder's home, onto the internet, and then communicated to Facebook using sophisticated data transportation methods facilitated by XML for the data exchange. An in-depth description on how this was achieved is presented in chapter 5.

4.3 Participatory Design

4.3.1 Focus Group Introduction

The aim of the focus group was to elicit participants' understanding of energy consumption in the home through user-generated paper-prototypes. Firstly, participants were directed to select the categories of energy related data they found to be relevant and easy to understand then integrate them into their own interface designs. The user-generated conceptual energy designs would be transferred into final physical designs. Additionally, the participant's viewpoints on the various scenarios they would encounter whilst using an application that provided energy information was discussed.

Four participants were recruited for the focus group with the author mediating and presenting materials. The participants were aged 23-38, one female and three males and were all responsible for paying the energy bill in their home. Participants were asked if they would consent to having the session audio recorded for future analysis, of which they all agreed to. The duration of the study was 1.5 hours after which all participants were thanked for giving their time and were suitably recompensed. The chosen venue for the focus group was the responsive home at the University of York, an ideal location as technology is at the forefront of the responsive homes design.

The structure of the session comprised briefly of introducing the concept of energy in the home, showing a novel video of energy use in the home created by the author followed by a selection of short energy-related videos from YouTube. The videos from YouTube were based around energy usage in the home - for example highlighting the importance of switching off devices when not in use and also on how electricity is generated and delivered to the home. After the videos were shown a paper-prototyping materials pack was handed out to each participant for creating their own designs and made up the bulk of the session with discussion ongoing throughout. Each part of the projects participatory design stage will now be discussed within their own sections.

4.3.2 Introduction Handouts

To set the scene, a brief paper handout was given to each participant with the author presenting the handout's content to the group. It comprised of pictorial metaphors of electricity in the home, showing objects that are commonly found in the home relating to energy, from a light switch to a fuse box. Following the pictorial metaphors, images of energy monitors were presented that can report how much energy is being used to the householder, providing an interesting comparison between energy used in the home and devices that are capable of displaying this energy usage. These handouts are seen in *figure 4.3a*.

Figure 4.3-a Focus group introduction handouts

With electricity being a service most of us take for granted, it was felt good practice to start the focus group by introducing the possibility of monitoring your energy usage in the home. A Wattson energy monitor was also placed on the table where all participants could see its shape, size and informational display. It was anticipated the Wattson monitor would be setup to display a live energy reading from the responsive home but unfortunately the homes fuse box was not designed to allow any contemporary monitor to take a reading.

4.3.3 Introductory Novel Video

A video showing a novel way in representing energy in the home was shown after the introductory hand-outs to help inspire the users to think differently about what energy is in the home. The video was called 'Wattson and Nabaztag' and is available for viewing on YouTube [105]. By moving away from traditional thoughts and concepts of what electricity is in a physical sense, such as light switches, cables, sockets and plugs it was hoped the participants would think out of the box and be more creative during the session. The video itself featured a Nabaztag device [94] communicating with the Wattson energy monitor to inform the householder of their energy expenditure. The Nabaztag is a socially interactive electronic device that is capable of communicating a wealth of information to a recipient using voice, lights and movement with all three usually combined. Types of information communicated can be reading aloud emails, displaying weather using colour schemes, reading out news and even assisting with teaching different languages such as French.

The Nabaztag has an open API [95] based upon making simple URL calls allowing developers to leverage the feature set available on different online platforms, leaving only their imaginations to provide the interaction qualities. In the video, the Wattson monitor is shown over a period of a few minutes displaying live home energy readings, from low to high when a cooker is switched on. Simultaneously, the Nabaztag responds upon receiving the high energy usage data and outputs a vocal message that a lot of energy is being used at that moment in time, in conjunction with the vocal message it also flashes various red lights in a synchronised fashion. By doing so it is indicating both vocally and visually that the householder's home is currently using a lot of energy, attempting to capture the householder's attention.

Also demonstrated in the video was the possibility of the Nabaztag to say aloud end of day readings such as total Co2 or energy used and comparing to previous usage. In all of the scenarios demonstrated in the video the Nabaztag is acting as a robotic agent [51] that may have the potential to help persuade the householder to reduce their energy consumption by raising awareness informatively. Being a unique approach to communicating energy consumption in the home, it set the tone of the focus group that practically any kind of interaction is viable for discussion, it was iterated to the participants that the more creative the better! A screenshot of the video is shown in *figure 4.3b* displaying high energy usage from the Wattson reflected in the red lights of the Nabaztag device.

A positive sentiment towards the video was communicated by the participant's with regard to the Nabaztag's humorous 'surreal' properties. This sentiment could be leveraged with a view of exploiting the immersive comical potential of the device thereby engaging users with fun, playful interaction.

Figure 4.3-b Screenshot of authors YouTube video showing Wattson and Nabaztag

4.3.4 Energy Videos on YouTube

Further selections of videos sourced on YouTube presented concepts such as 'energy conservation' and 'energy as a necessity for life'. The videos were produced in a number of different countries around the globe, comprising the US, UK and Dubai. In total 6 short videos [100,101,102,103,104,105] were shown to the participants running for a few minutes each with a discussion afterwards.

The videos offered a broad spectrum of viewpoints on energy usage across different countries and decades of time with content varying from how energy is produced before it arrives in the home to conserving it. Bizarrely, one of the energy videos was nothing more than what seemingly stated the obvious, that it powers all the common devices we have taken for granted for some time now including cookers, washing machines and even street lighting. This video was from the late 1980's in the UK, with a message that would have "*little meaning in today's times*", as echoed by one of the group members. Other comments on this video stated:

Participant B: *"....seemed like they are almost trying to sell it as some kind of desirable object"*

Participant D: *".....sounded a bit like a trailer for a movie"*

Indeed, this particular video appeared more like a commercial advert designed for advertising the latest washing powder

4.3.5 Prototyping Interface Designs

After the YouTube energy videos were shown, a materials pack was handed out to each participant that contained paper pictorial images of various interfaces elements such as user avatar icons, energy icons and Co2 icons.

Readymade prototype conceptual interfaces were also included as examples, shown in *figure 4.3c*, demonstrating the concept of viewing personal energy usage and comparing to friends. Plain interface templates cards were added to the pack enabling the participants to place the interface elements on the blank interface templates. Pencils, coloured pens, scissors and other craft materials were also provided allowing participants to create their own interface elements.

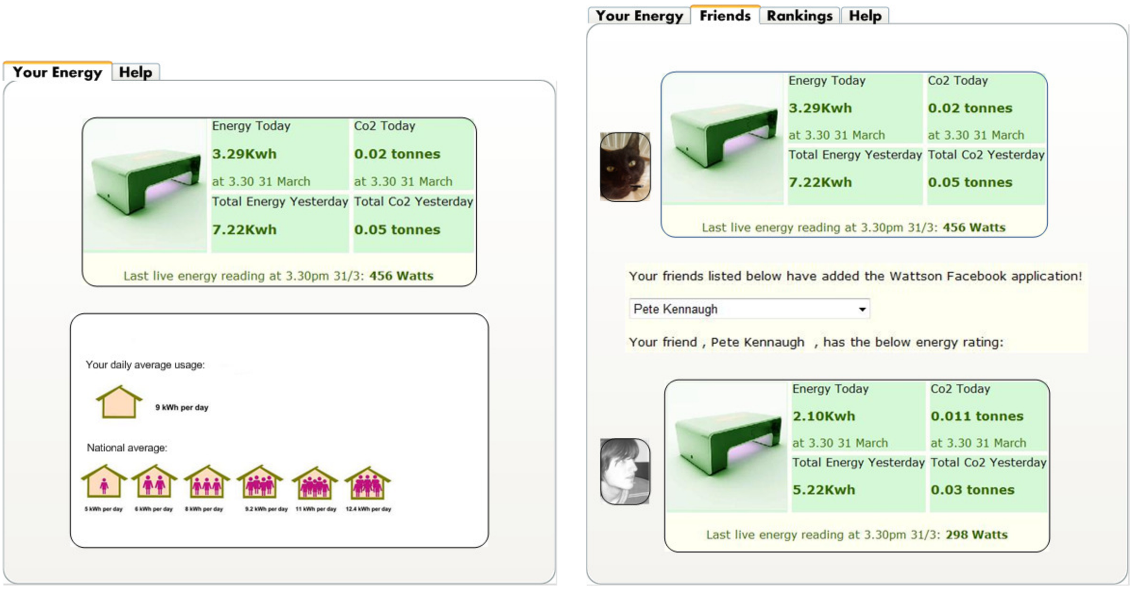


Figure 4.3-c Screenshots of author's prototype conceptual interfaces for focus group

To this end the participants were encouraged to be creative and produce their own representations of energy attributes such as metaphors for electricity and Co2. Examples of the interface element building blocks participants could use to create their own interfaces are shown in *figure 4.3d.*

Figure 4.3-d Examples of interface elements given to participants to create their own designs

After commencing the creative part of the focus group with participants becoming designers of interface metaphors, several important questions were raised by some of the participants:

Participant B: *"Who are the people it is being targeted for?"*

Participant C: *"Do the users have their own houses?"*

For the first question the answer may be as simple as encompassing everyone, in the sense that every home in the UK will be fitted with a smart meter in the coming years. All companies involved in designing and fitting smart meters will likely have to go through many focus groups and large scale trials to create a suitable interface for their many millions of customers. For this small project pilot study, potential users of the application were selected from a wide age group, 20-55 year olds, including couples and families. The second question brings to bear the caveat that potential users of the interfaces they are designing for are required to be responsible for paying their energy bill. Effectively this means they could either own their house or rent it, as long as the energy bill is paid by them.

Before the participants started to progress through creating their own conceptual designs, several interesting comments were made:

Participant B: *"I rent but I'm not bothered about efficiency as I don't own my home"*

Participant A: *"...are people actually interested in saving the planet?"*

These somewhat negative responses are interesting in that they show a polarised line of thinking between the two participants, it could be construed that by their own admission both participants were actually aware of energy issues. On the one hand participant B has used the word efficiency, hinting that they have knowledge of what this means in terms of energy, on the other hand participant A has created the impression of linking energy consumption to saving the planet.

Of the pre-made interface elements themselves there was a good amount of feedback. Overall the participants seemed to favour the idea of using a gauge or dial to display either energy or monetary usage:

Participant B: *".....would like to see a comparison over a week or a month maybe, to see how much I am using over time."*

Participant D: *"What the dials can do is give you a comparison, although they are very abstract, I can still tell if I have used loads of energy today."*

Participant A: *"On a good day you could show a few light bulbs for my usage, on a bad day you could show more light bulbs."*

Participant C: *"Only trouble with using colours to represent good and bad is that they mean different things in different countries, China for example, red is good and here it's not."*

As observed with the last comment above from participant C, there was a greater than average sensitivity to interface design issues. This is because most of the participants taking part in the focus group were HCI students and were in possession of a working knowledge of interface design.

At this point the participants were just beginning to create their own designs and the comments above showed their thinking was focused on how energy could be represented with some kind of contextual meaning. The comments regarding the use of gauges and bulbs inspired the creation of a prototype interface by one of the participants shown in *figure 4.3e.*

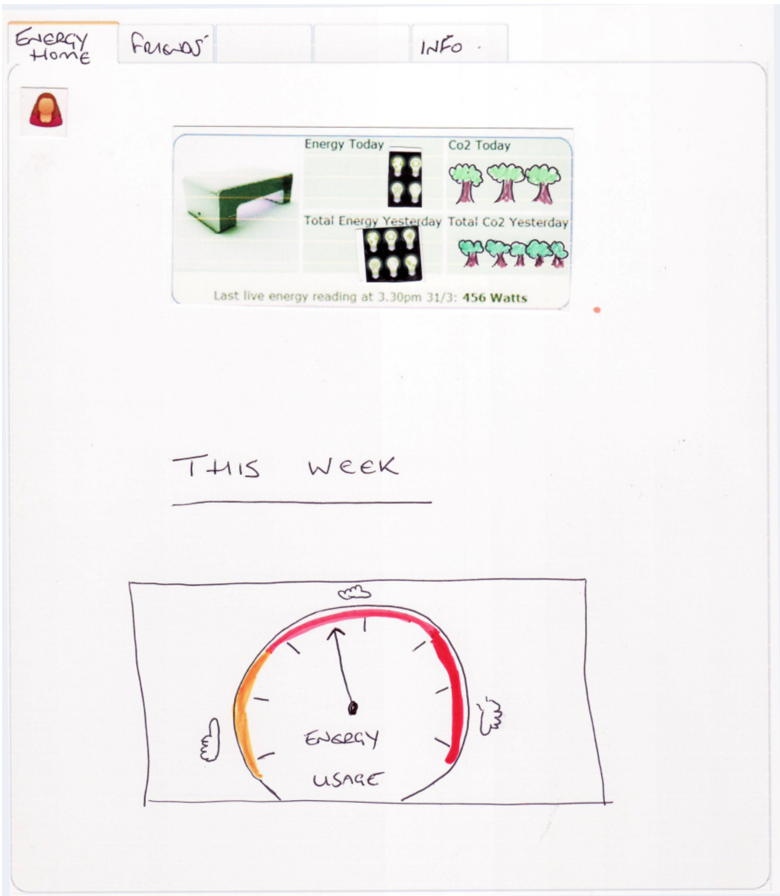


Figure 4.3-e Participant prototype design showing gauge and Co2 representations

With Co2 being represented graphically as trees in the prototype interface, it spawned several Co2 related participant discussions fuelled by the following comments:

Participant A: *"I like the idea of using trees, people do link co2 to trees."*

Participant C: *"...a lot of companies do say they plant trees to offset their products."*

A question raised from the group asked if Co2 was directly related to energy consumption. This highlights a potential lack of awareness of basic energy principles which may be common in the general population. The quality of informative energy material sent to consumers from energy providers with regards to Co2 emissions has not been investigated for this study. However, it may be debatable on who is responsible for supplying informative energy information to consumers, be that the UK government or the energy providers themselves.

Some more of the produced ideas were highly abstract and imaginative:

Participant B: *"I was thinking that to represent your usage you have a box with balls in it that move around, the more energy you use the more the balls bomb around in the box."*

Participant D: *"What about like a furnace, in a power station with blazing fires the more energy used"*

Participant B: *"....a saucepan of boiling water that simmers away nicely, but when you start using too much it boils over splashing about."*

Participant D: *".....a digital photo frame, if you aren't using much energy then see pictures of beautiful scenery or if using a lot some stark scenery, almost like a piece of art that changes over time."*

In practice these highly abstract ideas may be too far removed contextually for many of the potential users of an energy feedback application to understand easily. However, it was suggested by a participant that a whole range of themed skins could be offered to users of the application with the ability to select their favourite metaphoric theme. Abstracted concepts like the ones the focus group participants created could also be termed as 'Informative Art', where typically an attempt is made to beautify the presented information to make it more enjoyable to view or aesthetically pleasing [10].

Participant D: *"...you could choose your theme or skin like in windows media player that you like best."*

An important question directed to all participants by the author asked if they would prefer self-comparing or comparing to others with their energy data. As previously discussed in this reports literature review, there were substantial cultural differences from country to country on consumers viewpoints of sharing energy information with others.

Participant B: *"Maybe an average, not going to be looking at what my neighbour uses or my family."*

Participant C: *"..... you could set targets for yourself, rather than compete against other people"*

Participant C: *"The risk of failure in front of your friends."*

Participant B: *"You could add people you wanted to compare to."*

Participant B: *"...could use your face to block out other people's faces, like if you are using more power, like bouncing balls around the screen with a face in each ball...."*

The mixed reactions to this question show that potential users of the application may have concerns about sharing their energy data or a reluctance to do so. Interestingly, the concept of only adding the people you want to compare to was discussed, as well as a 'playful' compare-to-others method that used bouncing balls with pictures of the people inside the balls you are comparing energy to. This resulted in a rich prototype interface being created by a participant as seen in *figure 4.3f* that used only the participant's imagination, and none of the readymade interface elements.

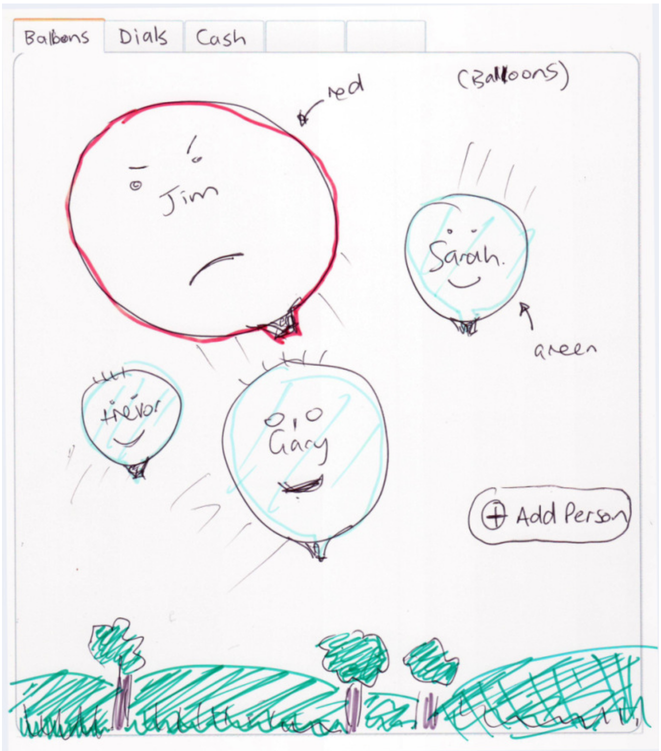


Figure 4.3-f Participant prototype design for sharing energy data

The notion of failure in front of your friends was seen as a negative issue by one participant, but it may be said that such powerful peer pressure to remain within a normative measurement of energy could be leveraged in a playful manner, such as the bouncing balls method.

Perhaps one of the most important concepts discussed was the use of either ecological or monetary metaphors as well as numerical or graphical measurement units. A large proportion of the focus group discussion was taken up by these points as the following comments show:

Participant B: *'Kilowatts, watts, I don't want to see any of that, money yes."*

Participant D: *'I completely disagree about the money thing, think it should be left out of it entirely'*

Participant A: *'Personally I would do it because I am interested in reducing my emissions'*

Participant D: *'Ecological is really strong, more than cash, especially in younger people'*

Participant C: *'I'm thinking a kind of erm some form of visual presentation....you'll see more trees over time in an image if you use less energy, see trees knocked down if you use more'*

Participant C: *'Would people consider ecological impact over financial costs before the recession kicked in?'*

The comments show that three of the four focus group participants appeared to favour the ecological viewpoint of representing energy and emissions. Another quirky representation discussed and favoured for both energy and Co2 emission was the use of cartoon like avatar faces. These were discussed in the context of using colour to represent good and bad based on the traffic lights system as seen in *figure 4.3g*.

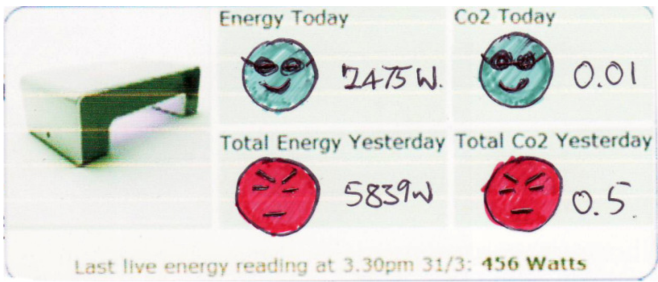


Figure 4.3-g User generated energy and Co2 indicators

The final discussion of the focus group was geared towards introducing a competitive element between friends to potentially drive a reduction in consumption. From the comments below the top discussion point was the use of a rankings table where friends could instantly see their consumption in comparison to many others.

Participant D: *'click on a prize if you move up a ranking'*

Participant A: *'I thought about a leagues table based on points, slightly competitive but not with pressure and a bit where people can discuss it'*

Participant A: '*Can see it working amongst a group of friends, but finding a way to notify users of the group of whats happening'*

Participant A: *'Maybe you could have about ten of your mates in competitive teams, where you join with your mates against other teams'*

The participants created several designs that manifested their thoughts on the form a ranking table could take as seen in figures *4.3h* and *4.3i*

Figure 4.3-h User generated podium style ranking system for energy consumption

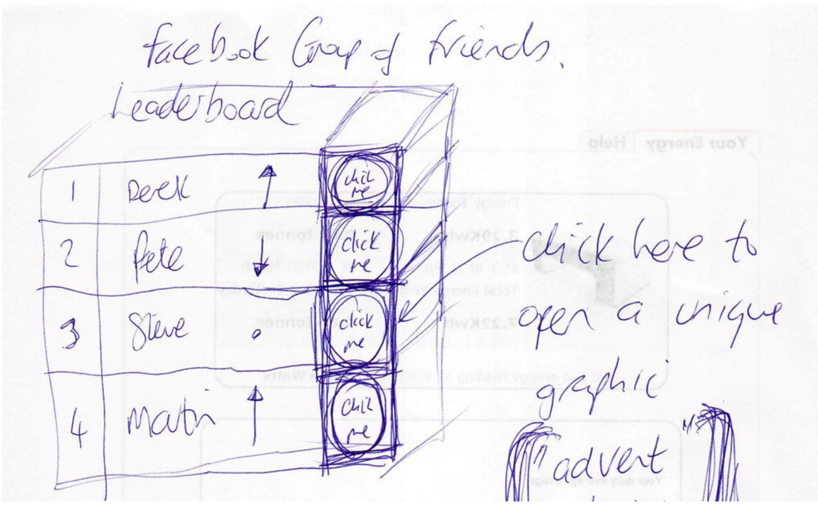


Figure 4.3-i User generated table style ranking system for energy consumption

Overall the focus group provided a vast array of qualitative data with both creative prototype designs and verbal discussions. It was felt by all involved that the group had generated a positive potential contribution towards representing household energy consumption.

An adequate amount of interface prototypes from the participants enabled moving onto the conceptual design of the energy applications interfaces as derived though the user generated material. Given the substantial amount of audio data collected from the focus group, further in-depth analysis could categorise and label the audio transcript with a view to capturing recurring themes of energy usage from the group. However, this was beyond the scope and time constraints of this project and may be completed at a later time.

The next section of this chapter will discuss the implementation of selected user-generated interface designs into operational conceptual designs.

4.4 Conceptual Design

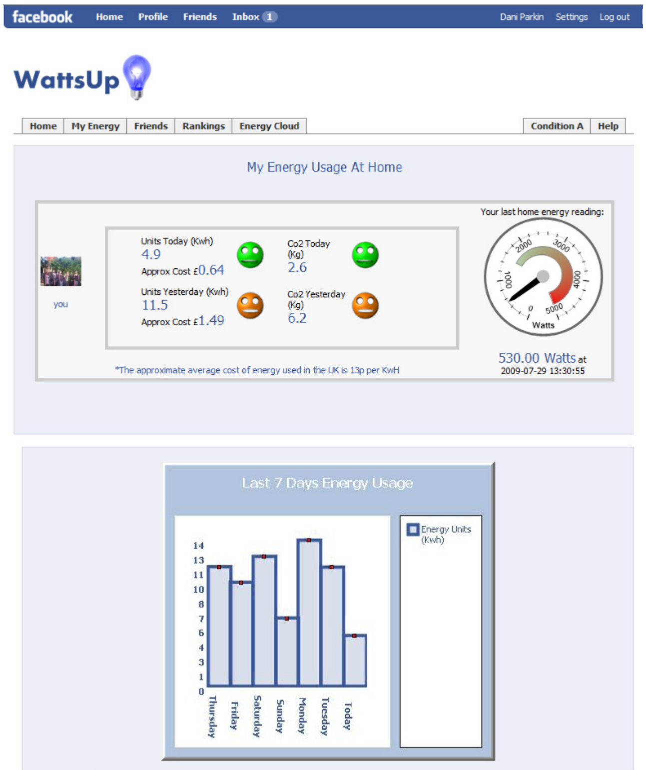
Transitioning from participatory design to the conceptual design stage was made relatively straight forward due to the high quality of user generated designs with clearly defined interface features. In this section, we discuss how the participant's suggestions and prototype designs were developed into final physical interfaces that would embody the WFA interfaces.

With the concept of displaying energy consumption in the home thoroughly covered by the focus group, the main interface attributes for displaying energy would be expressed in Watts and fiscal units as well as Co2 emissions measured by weight. In addition to numerical representations, a graphical representation was selected to display alongside both numerical values for energy and Co2 emissions in the form of the happy/sad face theme as discussed in the previous section.

Three core interfaces were developed to provide an engaging UX. These were from the focus groups user-generated content with the aforementioned energy, fiscal and Co2 measurements embedded. These three interfaces were themed with the following concepts:

- **My Energy**: Displays personal energy consumption, as well as a 7 day history bar chart
- **Friends**: Displays personal energy as well as that of friends, with individual friends selectable
- **Rankings**: A ranked table showing the highest and lowest energy consumption between users of the application

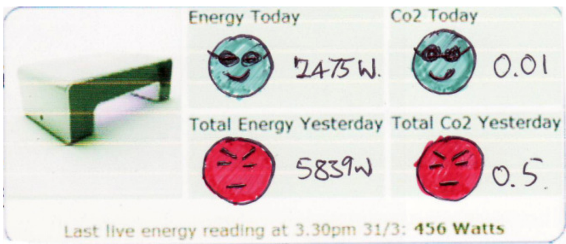
Shown from top to bottom in *figure 4.4a* are the final conceptual design, user comments and user-generated prototype designs that define the WFA 'My Energy' interface, clearly showing the relationship between prototype design and final conceptual design.



Participant D: *'What the dials can do is give you a comparison, although they are very abstract, I can still tell if I have used loads of energy today."*

Participant C: *"combine a bar chart with the last week's performance'*

Participant B*: "....would like to see a comparison over a week or a month maybe, to see how much I am using over time."*



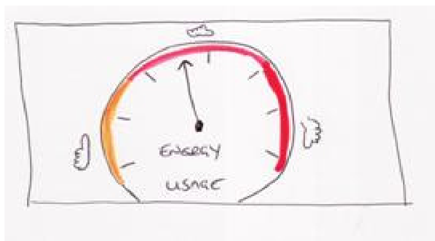
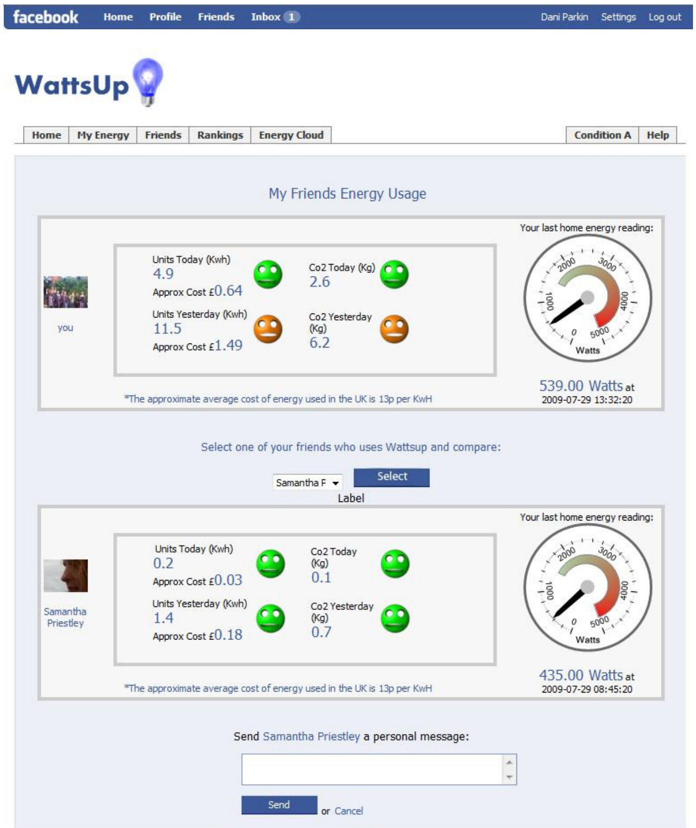


Figure 4.4-a My Energy interface from user-generated design to final conceptual design

The next interface shown in *figure 4.4b,* named 'Friends', follows on closely from the 'My Energy' interface using the same design to present the information except with a friends selector to choose a friends energy usage data to compare to. The participant comments inspired the design of this interface.

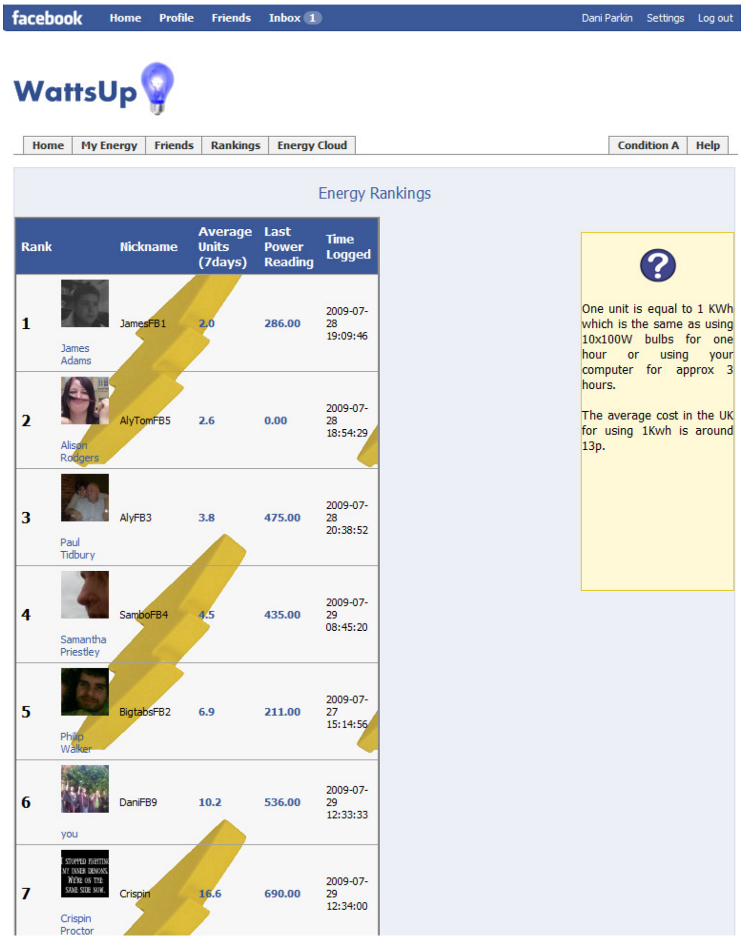


Particpant D: *'you could add people you wanted to compare to'*

Participant A: *'Can see it working amongst a group of friends, but finding a way to notify users of the group of whats happening'*

Figure 4.4-b Friend energy interface for comparing to other friends

The final core interface was the rankings interface shown in *figure 4.4c*; from top to bottom are the final conceptual design, user comments and user-generated prototype designs that define the WFA 'Rankings interface. There were two possibilities on how to implement the rankings table - on an individual or team basis - but due to limitations in participant numbers for using the application an individual basis was chosen for the rankings table.



Participant D: *'click on a prize if you move up a ranking'*

Participant A: *'I thought about a leagues table based on points, slightly competitive but not with pressure and a bit where people can discuss it'*

Figure 4.4-c Rankings table interface, from prototype to final conceptual design

An important interface element was included as an additional part of the rankings interface - the integration of a comments board. A rankings table allows users to visualise what their standing is against others but it does not facilitate friends commenting on personal or others energy consumption. A screenshot of the comments board is seen in *figure 4.4d* displaying a snapshot of conversational comments based on the rankings interface.

The comments illustrated playful interest in participants' personal energy usage as well as that of their friends by use of friendly banter. There is much scope to gather qualitative data collected from comment boards with the possibility of conducting a GT when enough data has been collected. Several GT's were carried out for this project based on user comments and directed open questions; these are documented in chapter 6. Facebook comment boards allow users to express themselves freely with the choice to post their comment to their profile, allowing all of their friends to read the message, even if they do not use the Wattsup application. It is this type of method that offers strong indicators in how Facebook applications can spread in a viral fashion by appealing to large numbers of users, facilitated by users either directly or indirectly.

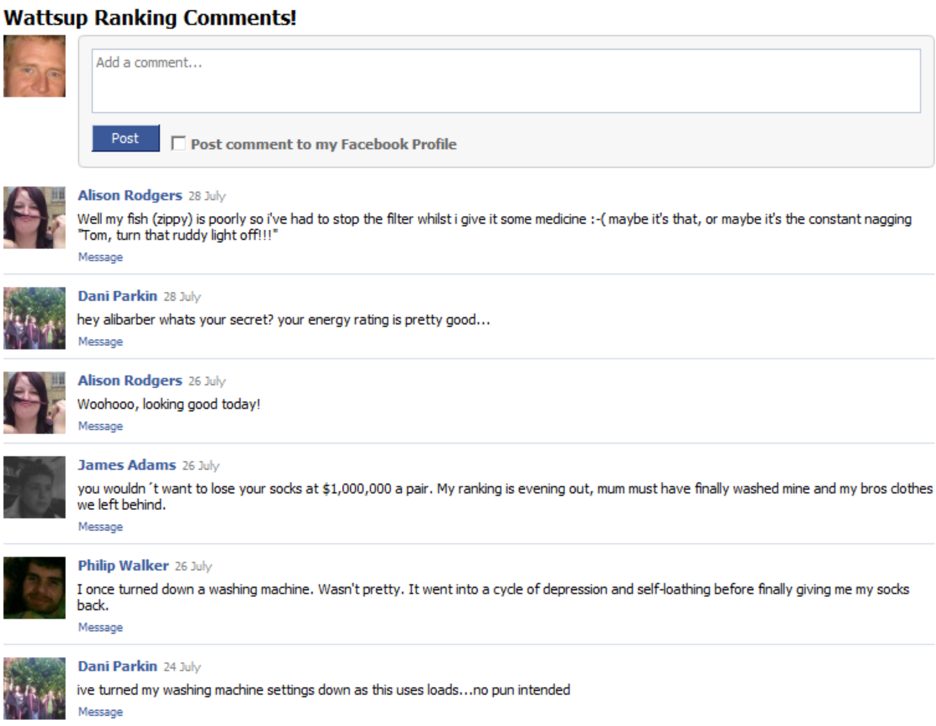


Figure 4.4-d Rankings interface sample comments board

An additional novel interface was designed which was indirectly derived from the focus group. An 'Energy Tags' interface was devised by the author who was inspired from a participant stating, '*I would like to see how much energy per appliance my home is using*'. Implementing per-appliance monitoring was not technically feasible for this project, although a creative approach was taken to partially include the concept.

The internet in its present form makes large use of tag clouds, usually accompanied by search functions. They visually display the most common search terms for a website by displaying the most frequent search queries as larger words. These are best described visually, as seen in *figure 4.4e* which shows multiple tag clouds.

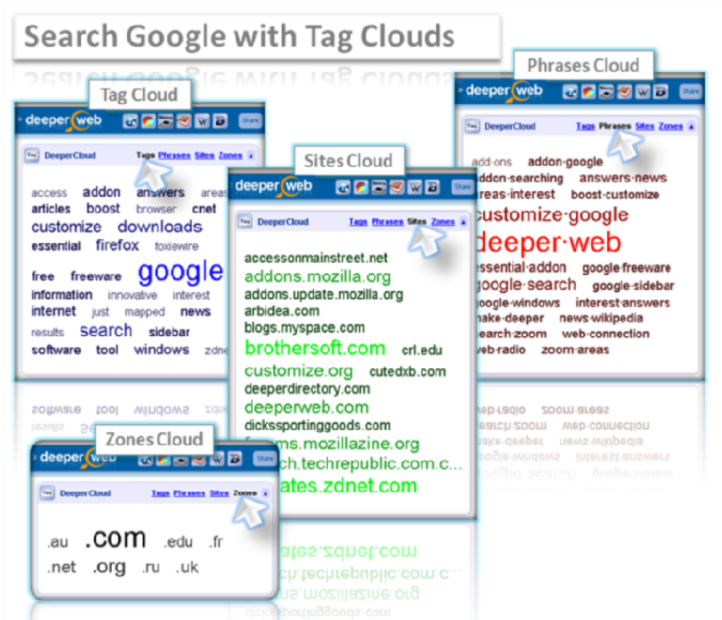


Figure 4.4-e Examples of Tag Clouds, image freely distributable under the Creative Commons Attribution ShareAlike 3.0 licence

The energy tags interface follows the same concept as standard tag clouds. The difference being that the tags aren't based on the number of times the word or phrase has been searched for. The tags are based on energy appliances in the home. The energy tags are entered by the user under the premise that the device or appliance the tag represents uses a lot of energy, based upon the user's opinion. Thus it is envisaged that an energy tag cloud will be generated by users displaying a tag collection of devices they think use the most energy in the home. If an appliance is entered multiple times, the tag will grow larger. In an attempt to stop users from simply copying what they see in the tag cloud they cannot view the cloud until they have submitted their own tag, hopefully inspiring originality in submissions to an extent. The collected tag data presents an opportunity to qualitatively assess householder opinions on what devices and appliances use the most energy in the home.

The final energy tags interface is illustrated in *figure 4.4f.* Also seen in the energy tags interface is the addition of a comments board designed to encouraged discussion of the energy tags in the cloud.

Figure 4.4-f Energy tags interface for Wattsup

The interfaces shown within this section were the final conceptual interface designs used in the technical development and implementation of the Facebook application. A substantial amount of technical development was required to move the designs generated from the focus group into fully working designs. However, there was also an additional collection of high quality ideas garnered from the focus group that did not find their way into the final designs due to restrictions on time and technical feasibility. These ideas have been documented, such as the team versus team league table and the highly abstract face-balloon interface example. It is hoped that by expanding on these unfulfilled concepts in the near future will pave the way for other studies presenting themed concepts for other focus groups.

The next chapter discusses the project's technical development details, defining the programming languages used in development and the applications architectural implementation.

5 TECHNICAL DEVELOPMENT

Central to the discussion of this chapter is the WFA technical design and implementation, detailing its constituent software components, external web-services, databases and architectural framework. With the WFA developed as a Facebook application, the use of several API's was required to produce a working application as well as utilising several programming languages. To note an important point, the development of a Facebook application is not streamlined in anyway and is a complex affair, mainly due to the eclectic mix of programming languages required and the perpetually evolving Facebook platform.

To better understand how the Wattsup application was developed and implemented, an overview of the various systems involved in moving the householder's energy data from the home and onto the internet are discussed in the first section of this chapter. Following this in brief is the software engineering methodology utilised for developing the application and the various technical toolsets used. The final section of this chapter details the technical function of each of the main interfaces including their data collection components through the use of XML data streams and SQL databases.

5.1 WFA Architecture

The supporting framework for the operation of the WFA is comprised of three main software components and one hardware component. The software components are a desktop application named Powometer that collects data from the Wattson monitor, a web service that stores the energy data online and the WFA. The three software components describe the high-level overview of the supported software system. At the core of the framework is the hardware component – the Wattson energy monitor - that supplies energy measurement data directly from the householder's fuse-box to the three software components in a consecutive fashion.

This project was solely responsible for the development of the WFA, with the other two software components readily available and developed by Crispin Proctor of www.myenergyusage.org. The author worked closely with Crispin to ensure the data collection functions of Wattsup were able to adequately call, query and store the relevant energy data from the myenergyusage.org web service via XML.

The myenergyusage.org web service is designed to be an open platform with energy data made available for services such as Twitter and Facebook or practically any kind of authorised website. An overview of how the Wattson monitor communicates with the myenergyusage.org web service is illustrated in *figure 5.1a*. The diagram highlights the capability of the myenergyusage.org service to take on the role of an energy data provider to multiple major services such as Twitter and Facebook application platforms.

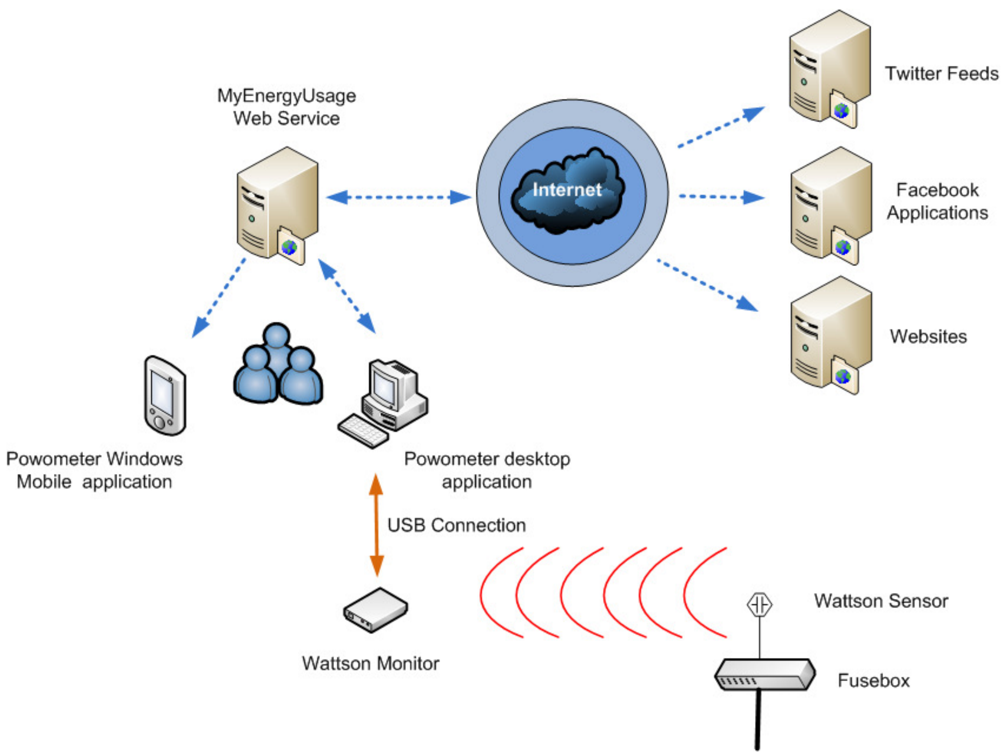


Figure 5.1-a Wattson monitor communicating with myenergyusage.org web-service

The diagram illustrates the Wattson sensor at the householders fuse box sending by radio signal the current energy reading to the Wattson energy monitor which stores the data in its 30 day dedicated memory. The Wattson is physically attached to a PC via a USB cable which transports the energy data from the Wattson to the PC via the Powometer application where it is stored in a local SQL mobile database. At configured intervals Powometer sends the stored energy data to the myenergyusage.org service via the internet where it is stored in multiple MySQL databases for redundancy. Once the energy data is stored on the myenergyusage.org databases it is then presentable to authorised applications to make use of it.

A comprehensive architectural overview diagram of the WFA showing more granular detail was presented previously in chapter 4, section 4.2, with the diagram illustrating how the myenergyusage.org web service is providing the WFA with queried energy data. In turn, the Facebook application platform parses all information that is communicated from Wattsup, including its HTML code before displaying content to the user within their logged in Facebook profile.

5.2 Software Development Methodology

The WFA technical design and implementation tasks were approached using a software engineering methodology termed Evolutionary Prototyping [82]. This quickly delivered a working application framework with each component being added into the framework when completed. By using this methodology, a reduced functionality application was available for demonstrating completed features throughout the projects development. As the user-generated designs required many different functions to be implemented, the assumed approach would be to implement them incrementally, one interface at a time. This would allow each function to be developed iteratively as an individual component then reviewed and tested. Overall this was deemed to be a practical and valid approach to the development of Wattsup, as it allowed easily recordable and documented progress during its development. An additional bonus of using the evolutionary prototyping approach is that the process allows the prototype to be constantly refined and additional functions added if required without major redesign.

The evolutionary prototype model is illustrated in *figure 5.2a* where we start at the communicative requirements stage which was initiated by the focus group. The focus group theme of gathering representations of energy was part of the plan to develop the user-generated interfaces which encapsulate both stages of 'Quick Plan Developed' and 'Modelling Quick Design' in the evolutionary prototyping process. Once the user interfaces are selected their development and subsequent testing commences. Finally the application is deployed and feedback recorded from users of the application.

Criticism of the evolutionary prototype model is also present, as with any software life cycle model. Difficulties in delivering a prototype quickly may rely on prior knowledge of toolsets to deliver a working prototype rapidly [45]. However, after carefully researched consideration, the evolutionary prototyping model appeared to be the most suitable methodology to developing the WFA and was the selected approach.

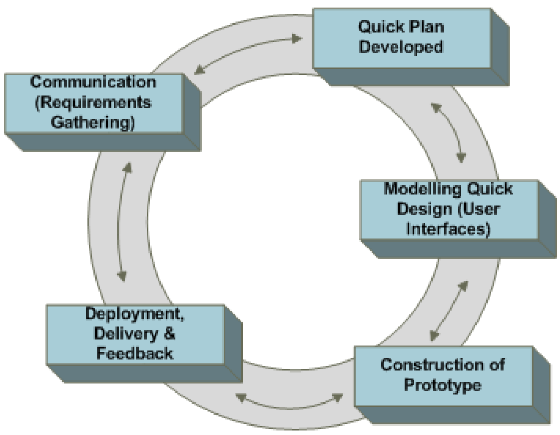


Figure 5.2-a Evolutionary prototype model. Adapted from Software Engineering, Pressman, R.S., 2005

5.3 Toolsets

The selection and use of multiple toolsets in the WFA development was central to its successful and timely development. Incorrect selection of toolsets could result in the application being stalled by time constraints with unforeseen difficulties or with an overhead in learning how to efficiently use a previously unknown complex toolset.

The language tools used for the WFA development comprise of programming and mark-up languages, all of which are listed.

- FDK (Facebook Development Toolkit) API [67]
- FBML (Facebook Mark-up Language) [44]
- ASP.NET [59]
- Microsoft C# [61]
- HTML/CSS [14]
- XML [16]
- MS SQL [99]

The development environment utilised was Visual Studio 2008 using the Microsoft .NET 3.5 SP1 framework with three additional open source client libraries added:

- WebChart control for ASP.NET [64]
- Cloud Control for ASP.NET [93]
- Gauge Control for ASP.NET [88]

As Facebook applications are principally web applications, the first choice a developer has to make is the client library to use, usually based on their current level of experience of the libraries on offer. The available Facebook API support is listed on the Facebook developers' wiki [32], with this project opting for the .NET Facebook Development Kit.

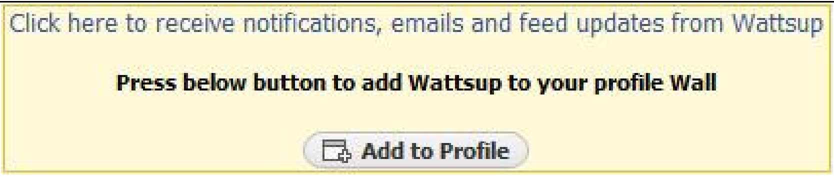
After the development languages and environment have been selected the next stage was to choose which type of Facebook application to develop, this is split into two distinctive categories, an FBML or iFrame application. An FBML application fully supports the use of Facebook's own FBML language integrated within HTML tags, with the Facebook platform parsing the FBML through its servers before presenting content to users. Selecting FBML also opens up a specialised feature set such as the Facebook FQL (Facebook Query Language) data store, similar to storage in terms of SQL databases. The full list of available up-to-date FBML tags is also available on the Facebook wiki [31].

An iFrame application uses the more conventional style of web development in that it cannot be used with FBML, restricting its feature set. An iFrame application may be considered easier to develop as the developer only needs to know the basics of typical web languages such as HTML, CSS and PHP. It may lead to a quicker development and deployment timescale but may not be as feature rich.

It should be noted that Facebook does not host any applications on its own servers. All third party applications are hosted by the developer and are parsed by Facebook servers for presentation on the Facebook application canvas page. The canvas page is the area where all applications render their content and is outlined in *figure 5.3a,* allowing an application to have a maximum width of 760 pixels.

Figure 5.3-a Facebook application canvas area for rendering content

The WFA was developed as an FBML application allowing it to use the many specialised functions provided by the Facebook platform. Example usage of the relatively powerful and quick development qualities of FBML in the WFA is giving the users the option of adding a small application box to their Facebook profile page that displays their current energy usage. It can also grant permissions to send and receive notifications from other users. These important features can be added simply by applying the code in *table 5.3a* which also shows the output with styling applied.




```
<fb:if-section-not-added section="profile">
<p>Press below button to add Wattsup to your profile Wall</p>
<div class="section-button">
<fb:add-section-button section="profile"/></div>
</fb:if-section-not-added>
```

Table 5.3-a Wattsup FBML example usage for profile box and permissions

Without access to FBML tags, separate code would have to be developed solely by using the .NET server side Facebook Development Toolkit API which would be more time consuming.

The principal web language used to develop the WFA was ASP.NET with C# behind code with styling applied through CSS. To concisely and adequately explain the applied use of the described toolsets in this section the three main interfaces will now be discussed with their constituent technical functions. These are the 'My Energy', 'Friends' and 'Rankings' interfaces. An additional interactive interface was developed which was not part of the core experience interfaces called 'Energy Tags', and is briefly discussed.

5.4 My Energy Interface Technical Design

The 'My Energy' interface was designed to display comprehensive energy usage data with some of the data kept private and not shared amongst others. The user is presented with a table outlining a today view and yesterday's total energy usage and Co2 emissions. In addition to this, they are also presented with a bar chart illustrating the past 7 days total energy usage for each day. These two features comprise the main functions for the 'my energy' interface and are illustrated in *figure 5.4a*.

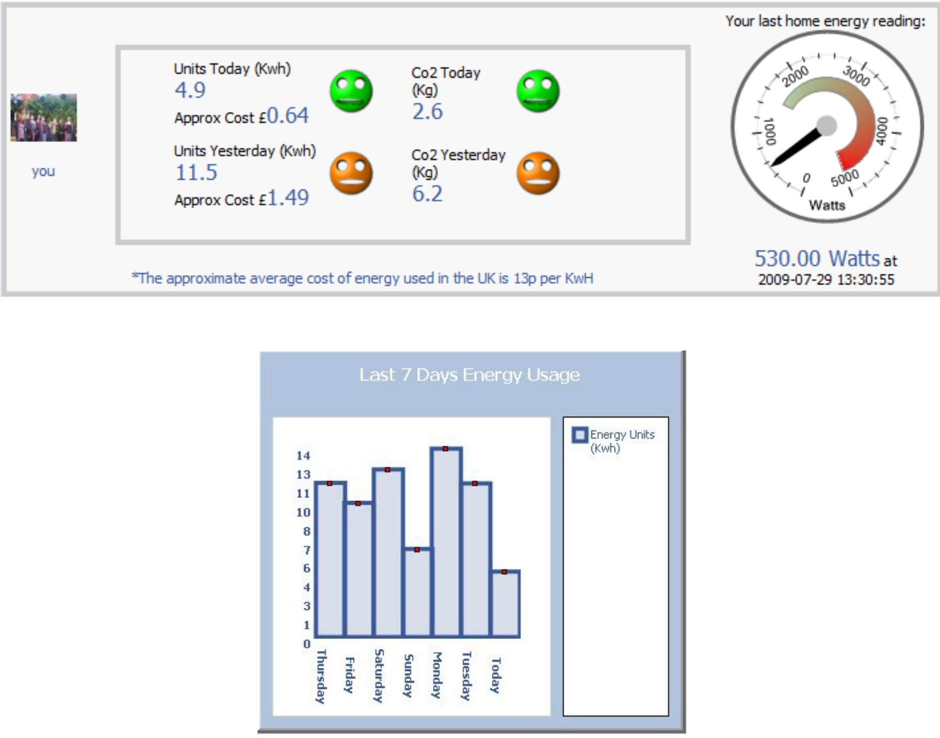


Figure 5.4-a My Energy interface main features

Upon the browser loading the 'my energy' interface, a PHP method call via a URL is made to the myenergyusage.org web service to retrieve the currently logged in Facebook user's energy data.

http://myenergyusage.org/pmonline/getusersummary.php?fbid=689529676


```
<?xml version="1.0" ?>
- <root>
<user screeName="Derek" todayUnits="0.00000" yesterdayUnits="0.00000"
todayCO2="0" yesterdayCO2="0" lastReading="2009-07-14 22:17:19"
lastPower="662.00" fbid="689529676">Derek</user>
</root>
```


Table 5.4-a- URL call to myenergyusage.org web service for user summary of energy data with resultant returned XML data

In *table 5.4a* the XML results of a call to fetch the personal summative energy data for the WFA user called 'Derek' are displayed. Authentication takes place by matching the logged in users unique Facebook user ID with the one stored in the myenergyusage.org web database. The energy data is returned in the form of an XML response which is written to a local file and stored for retrieval under a filename matching the users Facebook user ID. Once the XML is written to the local file the WFA is free to query the data using the .NET Xpath function [59] which is used to populate all energy and Co2 values within the interface. The method code for calling, writing to file system and querying the XML energy data is detailed in *appendix A-1.1*. The XML writing method is an important method and used throughout all of the applications main interfaces. The bar chart and energy dial components are also populated by querying the local XML file.

The chart and dial class libraries are freely available ASP.NET open-source packages that can be added to almost any ASP.NET web application using .NET framework version 2.0 and above. A quirk of the Facebook platform caused an error in rendering the bar chart within an FBML page, likely due to the bar chart being rendered dynamically. The only solution the author could provide was to embed the chart in an iFrame within an FBML page with the currently logged in Facebook users ID saved as a session variable and passed to the chart within the iFrame. This is an acceptable approach and is documented in the Facebook wiki for the iFrame component [33].

In order to match the 'smiley' images to the correct contextual value of the user's energy and Co2 usage a method was developed that allowed this. The method as it is currently implemented is not sophisticated enough to dynamically change dependent on the user's energy behavioural patterns. Instead, it is hard-coded based on average household energy consumption as derived from a UK Co2 emissions report [42]. It is anticipated it will be improved upon in the future by means of an intelligent algorithm. This method's code is detailed in *appendix A-1.2*.

5.5 Friends Interface Technical Design

The 'Friends' interface uses the same table format to display energy and Co2 readings as the 'My Energy' interface. This table appears in duplicate, top table to show the currently logged in user's energy data and the bottom table displaying the selected friend's energy data. Friends are selected from a dropdown list populated with Facebook friends who also use the WFA application.

Populating the dropdown list was possible by using direct API calls to the FDK, with the method code detailed in *appendix A-1.3*. The dropdown list should only contain a list of the logged in user's friends who have added the WFA to their Facebook profile. Although there is a readymade method to do this using FBML [36] , it was found to be unsuitable in that it does not display a list of their friends using Wattsup. It operates as a predictive friend selector requiring the user to start typing the name of a friend with the FBML control offering up possible friends beginning with the letters typed. This may be suitable for sending a message to a friend the user already has in mind and knows the name of, but unlikely a user will remember all of their friends who use the WFA application. The author's solution allows users to see a list of their friends who use the WFA without having to commit them to memory.

A social feature of the 'Friends' interface is the programmed capability to send a selected friend a personal message via a notification as seen in *figure 5.5a*. The message when sent is highlighted at the bottom right of *figure 5.5a* offering the sender a few seconds grace if they which to undo the notification.

Figure 5.5-a Sending a personal message from the Wattsup Friends interface

When the intended recipient is next logged on or is currently logged into Facebook at the time of the message being sent, the new notification will first be displayed as an alert box notifying the user they have received a new notification. They can then click on the notification alert to see the message the notification conveys. Both the notification alert and content are shown in *figure 5.5b* with the method code detailed in *appendix A-1.4.*

Figure 5.5-b Recipient receiving notification and message from Wattsup

5.6 Rankings Interface Technical Design

The Rankings interface was designed primarily to display the energy consumed by users of the WFA, with the user using the least amount of energy placed at the top of a rankings table. The table was populated using XML with the same code method as used by the other interfaces for reading, writing and querying the XML data as detailed in *appendix A-1.1.* The only difference this method has is in the call it makes to retrieve the data which requests a list of all the currently logged in user's friends and their energy data. The energy data displayed is the average usage for the past 7 days - the user with the lowest energy value for this will be ranked number 1 at the top of the table.

An ASP.NET Gridview control was used to create the table with the XML data bound to the gridview's fields using an XmlDataSource control [90]. The energy data saved to a local XML file requires formatting first before it can be displayed in the gridview due to a limitation in the XmlDataSource control treating all numerical values as strings. This was solved by converting the XML string values to a float value to one decimal place. A sample user in returned XML data for populating a row in the rankings table is shown in *table 5.6a* along with the row displayed in the table for the XML.

```
?xml version="1.0" ?>
- <root>
-  <users>
      <user screenName="SamboFB4" peopleInHouse="1" avgUnits="1.947830000"
      power="269.00"  logtime="1249714776"  logtime2="2009-08-08  07:59:36"
      isFriend="1"         publicKey="2f87a5c1-6d6b-11de-8824-e1f422cea1bc"
      isFollower="1" rank="1" fbid="559161354">SamboFB4
      </user>
</root>
```

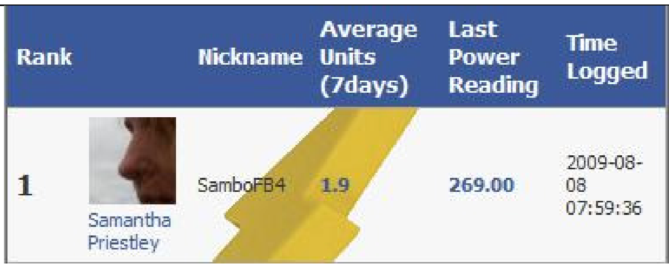


Table 5.6-a - Sample XML user data for rankings table with resultant row generated

The ranking XML data also returns the users Facebook ID which is used to generate the Facebook profile image of each user in the table. The code to create the profile image for the rankings table was done by using FBML embedded in the gridview as seen in *table 5.6b.*

```
<ItemTemplate>
<fb:if-is-app-user uid="<%# XPath("@fbid") %>">
<fb:profile-pic linked="true" size="square" uid="<%#XPath("@fbid")%>"/>
<fb:name  uid="<%# XPath("@fbid") %>"/>
<fb:else>
<asp:Image ID="blankpic" runat="server" Height="30px"
ImageUrl="http://wattsup.derekfoster.net/images/blankprofilepic.gif"
Width="41px"></asp:Image>
Not a Facebook User
</fb:else>
</fb:if-is-app-user>
</ItemTemplate>
```

Table 5.6-b FBML code to display profile image in ASP gridview

The other important interface element in the Rankings interface is the comments board which allows users to publicly post comments about other users energy consumption from the rankings table. This is managed by inserting a few lines of FBML which gives the comments board a unique ID as seen in *table 5.6c*. The Facebook application platform handles the storing and retrieving of all comments data automatically with no coding required by the developer.

```
<fb:comments xid="ranking_comments" canpost="true"  showform="true"
candelete="false" numposts="10"
returnurl="http://apps.facebook.com/wattsup/rankings.aspx">
<fb:title>Wattsup Ranking Comments!</fb:title>
</fb:comments>
```

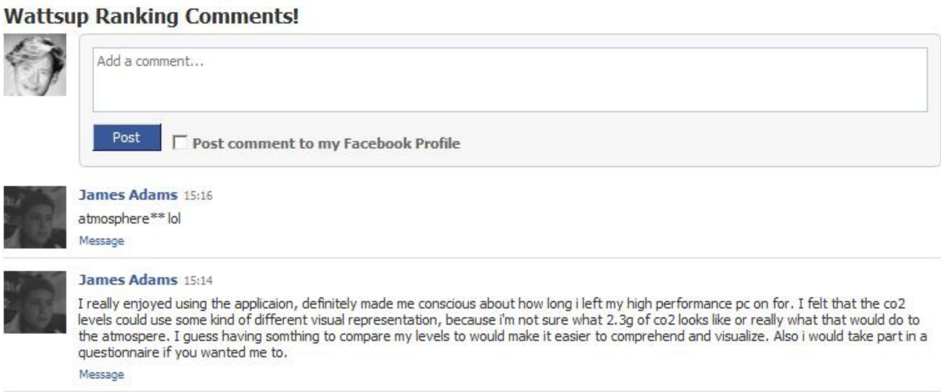


Table 5.6-c Wattsup comments board in Rankings interface with code creation

5.7 Energy Tags Interface

The energy tags interface was implemented using the freely available open source Cloud Control for ASP.NET [93], which provides a basic framework for building a tag cloud. Submitted energy tags were stored separately from the myenergyusage.org web service and were stored in an MSSQL (Microsoft Structured Query Language) 2008 database created by the author as well as the required SQL commands for handling energy tag submissions. Energy tags submitted are sized and displayed according to the number of times they have been submitted, with the standard deviation of all tags submitted calculated to determine each tags size. When an energy tag is submitted a check takes place to see if the tag already exists in the database, if true an SQL UPDATE command is executed instead of an INSERT command. The behind SQL code for submitting energy tags in the WFA energy tags interface is detailed in *appendix A-1.5*.

5.8 Gauge and Chart Controls

The gauge control is used in both the 'My Energy' and 'Friends' interfaces. As stated previously, the gauge used is a freely available open source ASP.NET control. The code to generate a gauge and populate the gauge pointer value is detailed in *appendix A-1.6*. As with the gauge control, the chart control is also a freely available open source ASP.NET control and is used in the previously discussed 'My Energy' interface. A bar chart is created using the control to display a user's energy consumption for the last 7 days with the code to generate this bar chart shown in *appendix A-1.7*.

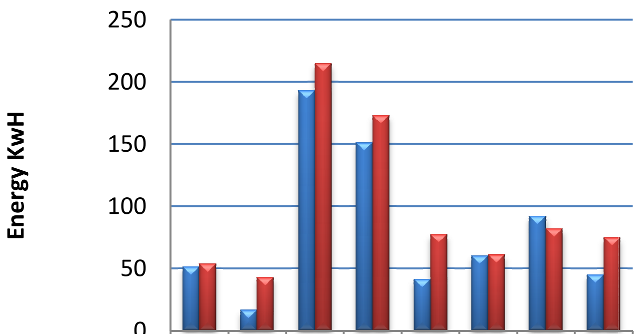
6 RESULTS

This chapter presents the results of the data analysis from the project's experiment. The experiment's alternate hypothesis of observing a reduction in energy consumption when using the socially enabled condition of Wattsup was proved to be positive. Therefore the null hypothesis was rejected with a total of 57Kwh units of energy saved by the participants in condition A as opposed to condition B, with condition A socially enabled.

Both the descriptive and inferential statistics results are presented as well as the qualitative findings of two grounded theories. The first grounded theory is derived from social interaction comments from the Wattsup rankings interface with the second theory based upon qualitative responses to a semi-structured interview with the participants at the end of the experiment. By using both quantitative and qualitative approaches to gathering data throughout the experiment it provided greater insight and understanding to the interpretation and meaning of the experiments results. The pseudonyms previously used to describe the experiment's participants in the method chapter are used throughout this chapter in some instances when referring to the participants.

6.1 Descriptive Statistics

The saving of 57KwH units of energy was equivalent to around 31 kg of CO_2 emissions in the 9 day period the participants were in condition A, with 7 out of 8 participants reducing their energy consumption whilst in condition A. Put another way, if the savings were sustained over a year then a reduction of around 1.2 Metric tonnes of CO_2 would be realised, requiring around 6 trees to offset the CO_2 if not saved and equal to the emissions of a medium sized car driving for 2404 miles. Illustrated in figure *6.1a* is each participant's total energy consumption in both experiment conditions.



	1	2	3	4	5	6	7	8
Condition A	51.3	16.5	193	151	41.3	60.3	92	45
Condition B	53.7	43	215	173	77.4	61.3	82	75

Figure 6.1-a - Total participant energy data in both conditions

Additional data collected from Google Analytics highlighted the differences in user interaction activity between both conditions. In terms of the number of times the participants visited Wattsup, condition A was significantly more popular than condition B with a total of 263 versus 51 page views respectively. A closer look at this data in *figure 6.1b* shows the number of page visits to the main features of Wattsup allowing an insight into features the participants may have favoured.

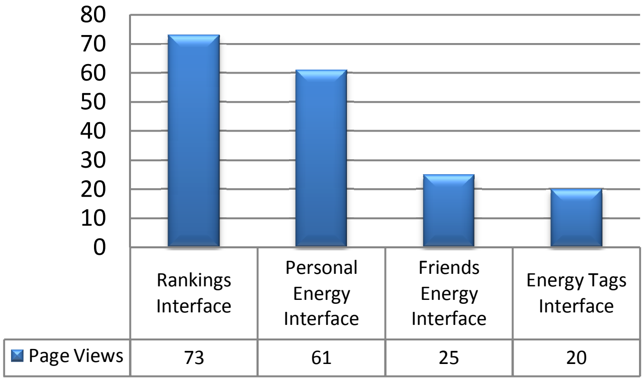


Figure 6.1-b Participant page views for Wattsup main interfaces

From the data it appears the participants preferred to view the rankings table and their own personal energy usage breakdown. They seemed less bothered about viewing a detailed breakdown of their friend's energy usage or in using the energy tags interface. Interestingly, the rankings table appeared to engage the users in an almost playful manner using friendly banter on the rankings comments board, more on this qualitative data in the grounded theory sections of this chapter. Data was also collected for the average amount of time participants spent on each of Wattsup main interfaces as seen in *figure 6.1c*.

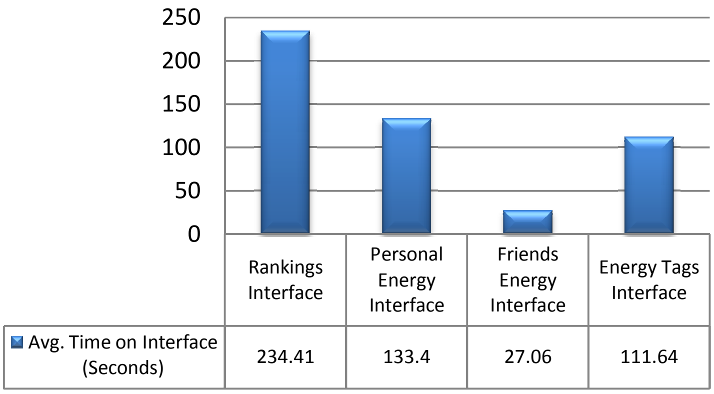


Figure 6.1-c Average participant time spent on Wattsup main interfaces

Participants spent the most time on the rankings interface viewing and commenting on the rankings table. It can be assumed that participants enjoyed this feature the most due to the collective amount of page views for rankings as well as the average time spent viewing it.

6.2 Inferential Statistics

The statistical test used to test the experiment's hypothesis was the Wilcoxon Matched-Pairs Ranks Test. The total energy used data for each participant in both conditions is shown in *table 6.2a*, which was entered into the SPSS software package [87] with the Wilcoxon test selected for the data analysis.

Participant	Condition A	Condition B
Diane	51.3	53.7
Alice	16.5	43
Rachael	193.1	214.8
Christopher	151.1	173.1
Robert	41.3	77.4
David	60.3	61.3
Richard	92	82
Shirley	45	75

Table 6.2-a - Total participant data for each experiment condition

The ranked results of the test and the subsequent probability value are illustrated in *table 6.2b*.

Ranks				
		N	Mean Rank	Sum of Ranks
ConditionB - ConditionA	Negative Ranks	1[a]	3.00	3.00
	Positive Ranks	7[b]	4.71	33.00
	Ties	0[c]		
	Total	8		

Test Statistics[b]	
	ConditionB - ConditionA
Z	**-2.100[a]**
Asymp. Sig. (2-tailed)	**.036**
a. Based on negative ranks.	
b. Wilcoxon Signed Ranks Test	

Table 6.2-b - Results of Wilcoxon test using SPSS

Results from the test indicate $p<0.05$ with $p=0.036$, providing supporting evidence the result is highly significant. However with such a low n value with the number of participants it is worth exploring further by analysing the qualitative data collected from the WFA comment boards.

6.3 Grounded Theory on Wattsup Social Interaction

Analysis on the qualitative data derived from the rankings interface was carried out using a small scale GT [89]. A theory describing the types of social interaction that took place with the main social interface on Wattsup, the rankings interface, was developed.

6.3.1 Open Coding

Eighteen comments from the rankings interface were analysed to produce the first stage of the social interaction GT - open coding. The descriptive label codes derived from the comments analysis are listed in *table 6.3a.*

Comment	Codes Generated
"you wouldn´t want to lose your socks at $1,000,000 a pair. My ranking is evening out, mum must have finally "washed mine and my bros clothes we left behind."	1. **Joking** to friends 2. **Justifying** ranking score
"Woohooo, looking good today!"	1. **Boasting** about ranking score 2. **Elation**
"hey alibarber what's your secret? your energy rating is pretty good..."	1. **Questioning energy usage** of friends
"good to see I'm higher in the table then you phil ha ha"	1. **Provoking reaction** from friend through **mocking** 2. **Ranking importance** upheld 3. Implies **competitiveness**
"Wow. Finally found a reason to like laptop PCs. You can leave 'em on all night downloading stuff for just 40 watts. :p"	1. **Surprised** at **energy usage** 2. Implies receipt of **new knowledge**
"Hey Sambo, how come you are at the top, cut down drastically on your cups of tea?"	1. Initiating **friendly banter** 2. **Questioning** friends **energy usage** in a **social context**
"I've been usurped"	1. Acknowledging **defeat** 2. Implies **competition** and **position of power**
"Left my main PC on the last two nights. Made a massive difference to my scores."	1. **Disclosure** of **personal energy habits** 2. **Ranking impact was justified**
"gone down in the rankings? I´m in Spain :S"	1. **Disbelief** of **ranking score**
"energy vampire...you clearly are!!"	1. **Provoking** a **response** from friend 2. **Jesting** about **energy usage** accusations
"I've turned my washing machine settings down as this uses loads...no pun intended"	1. Implies **informed knowledge** of **appliance energy usage** 2. Validates comment by means of friendly **jocular banter**
"I once turned down a washing machine. Wasn't pretty. It went into a cycle of depression and self-loathing before finally giving me my socks back"	1. **Elaborating** on **personal appliance usage** through banter
Well my fish (zippy) is poorly so I've had to stop the filter whilst i give it some medicine :-(maybe it's that, or maybe it's the constant nagging "Tom, turn that ruddy light off!!!"	1. Implies knowledge of fish filter **energy usage** 2. Involving others **socially** 3. **Speculating** about energy usage causes

Take's the top spot: D	1. **Gloating** at attaining **top ranking** 2. Implies **competition**
"My socks aren't that expensive! Leccy bill is on the up tho :(I NEED TO STOP PLAYING PUTER! (idontwanttoidontwanttoidontwantto)"	1. **Displeasure** over electricity bill 2. **Disclosure** of energy behaviour cause 3. **Reluctance** to reduce behaviour
"I cannot believe I am number 1. Cannot believe it."	1. **Disbelief** of ranking 2. Feeling of **superiority** 3. Implies **competitiveness**
"I really enjoyed using the application, definitely made me conscious about how long I left my high performance pc on for. I felt that the co2 levels could use some kind of different visual representation, because I'm not sure what 2.3g of co2 looks like or really what that would do to the atmosphere. I guess having something to compare my levels to would make it easier to comprehend and visualize"	1. **Enjoyed** using Wattsup 2. Implies **increased awareness** 3. **Confusion** on visual representations meaning 4. **Comparing** Co2 levels 5. Awareness of **high usage** devices

Table 6.3-a - Social interaction GT labels for rankings interface

6.3.2 Axial Coding

With the axial coding step of the GT, descriptive labels from the open coding step are grouped together under header categories with labels grouped based upon their relationships. The categories generated from the descriptive labels are shown in *table 6.3b.*

Banter	Engagement	Competition
gloating	enjoyment	competitiveness
social	comparing	superiority
elaborating usage	disbelief	top ranking
jocular	reluctance	energy usage
jesting	displeasure	provoking
boasting	disclosure	ranking impact
mocking	speculating	score
	personal usage	defeat
	informed awareness	personal standing
	responding	number 1
	questioning	
	justifying	

Table 6.3-b - Axial coding table generating from user comments

The banter category was defined as many of the codes derived from the user comments were specifically related to social banter they participated in within the rankings interface. For example, the 'mocking' label was deemed important as participants boasted about their rank standing and made inferences about their friend's energy usage. Some examples of these socially directed comments are:

Diane: *"energy vampire...you clearly are!!"*

Richard: *"good to see I'm higher in the table then you phil ha ha"*

These types of comments not only mock their friends in a light-hearted way, they can also provoke a response by motivating the recipient to perform better to beat their friend by reducing their own energy usage.

The engagement category relates to users experience of using Wattsup. Engagement through various social contexts was observed in the data, such as 'disclosing' energy usage behaviour and attempting to justify it by reasoning about it. Questioning others about their energy usage was also present, although in a somewhat subtle fashion, usually masked by humour as seen in the following comments:

Diane: *"Hey Sambo, how come you are at the top, cut down drastically on your cups of tea?"*

Robert: *"hey alibarber what's your secret? your energy rating is pretty good..."*

It is these types of social engagement that may appeal to users to interact with others based upon shared energy data. The engagement category showed that participants were willing to spend time comparing and responding to their friend's energy data, akin to the activity of a small close-knit virtual community.

Competition was a strong category that emerged with multiple labels identifying users being motivated to compete against each other, thereby attempting to elevate their ranking. The participants mentioned their personal ranking status many times in the comments as seen below:

Richard: *"Take's the top spot : D"*

Shirley: *"I cannot believe I am number 1. Cannot believe it."*

Richard: *"gone down in the rankings? I´m in Spain :S"*

Interestingly, participants commented upon their own rankings when both moving up and down the table, highlighting their success and failure. The 3 categories generated are intrinsically related in how they are supported and entwined with one another. The relationships between the categories are illustrated in *figure 6.3c*.

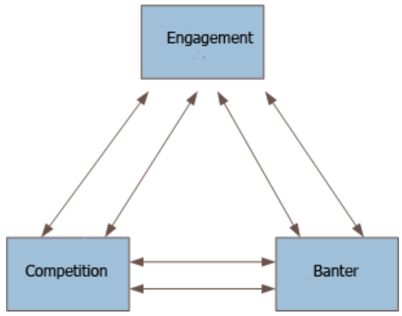


Figure 6.3-a - Axial coding categories relationship rankings interface GT

6.3.3 Selective Coding

The dominant core category was the engagement category, with the other two categories derivatives of it. The engagement category encapsulates all the user's main interactions and emotions which then branch off and develop into different contexts such as the banter and competitive elements.

The social interaction GT when applied to the Wattsup rankings comment board illustrates that users were motivated to be competitive, willingly spent time engaging with friends through the Wattsup interfaces and enjoyed the experience through using jocular nuances.

6.4 Grounded Theory on User Experience with Experiment

An ideal opportunity arose at the end of the experiment to elicit qualitative data in-situ regarding the participant's experiences of the experiment, of using the Wattson monitor and Wattsup together. Four open questions were put to participants when the Wattson was collected from their homes at the end of the experiment. The responses were analysed to produce a grounded theory on the participant's UX during the experiment. The questions asked were:

1. What part of the experiment did you like best, condition A or B, and why?

2. Did you experience any problems whilst using the application or the Wattson?

3. Would you use a Wattson device and Wattsup or something similar for a longer time period?

4. Do you think a difference can be made by reducing energy both personally and for the environment?

A short narrative on a scenario experienced by the author may offer an insight into what may encapsulate part of the meaning of UX for this projects experiment:

"It was observed by the author directly after installing the Wattson monitor in the home of the participant Richard that he instantly started moving from room to room in his home attempting to ascertain what he personally termed his 'baseline' energy usage was. Devices such as televisions and DVD players were switched off in a flash to view the change on the Wattson's display. He moved about the house in an excited and animated fashion intent on the task at hand – to determine his homes energy usage in an 'idle' state. The baseline measurement was interpreted by Richard as being everything but the essential appliances turned off, leaving appliances such as freezers and heating systems on."

Evidently, this positive engagement wasn't restricted to using the Wattson monitor itself. As discussed in the GT on the socially enabled rankings interface, participants actively engaged in fun and friendly banter on the Wattsup comments board embedded in the rankings interface, all generated from their own interactions with each other.

Before the grounded theory process is presented, we will briefly expand upon the four questions asked at the end of the experiment. The first question asked if they preferred Wattsup in condition A or B, effectively social or non-social mode. The participants responded with the anticipated answer that they all preferred interacting in the socially enabled condition A. Some of the responses for the first question were:

Diane: *"Good interaction to compare with others, to see where you were in the rankings. To see if any improvements you made improved your ranking. Fun to look at other peoples energy usage."*

Robert: *"I preferred the second one (socially) because I am quite competitive, it gave me further incentive. I think it putting a bit of fun in it is quite important."*

David: *"Preferred condition A because there was more interaction, encouraged more to look at the application because of the thought of other real people's information being there."*

When asked the second question with regards to problems and issues participants experienced with the Wattson and the Wattsup application during the experiment, several interesting responses were recorded. Some of these responses were:

Richard: *"I thought there could have been more stimulating visual representations used for Co2 levels."*

Robert: *"I wasn't always at home and Wattson needed to be kept plugged into the PC all the time."*

David: *"If I could have hooked it into an Ethernet or router or a Bluetooth device it could have worked wirelessly and I could have put it where I wanted, perfect."*

The third question asked if the participants would be interested in taking part in a longer study with the Wattson. Positive responses recorded:

Christopher: *"I would use it all the time and look at it on a regular basis."*

Richard: *"I would definitely love to have the Wattson in my Kitchen all the time as a constant reminder to save energy."*

Diane: *"I would absolutely use a Wattson device permanently. I would probably see it would take a couple of months of visual reminding to change my behaviour."*

The last question addressed what differences could reducing their energy make both personally and for the environment. The question was deliberately kept vague to see if the participants themselves would come out with the two most likely motivational drivers – cost and ecological. Some of the responses were:

Diane: *"Ecological issues are important to me and to reduce my emissions which can only be good for my bills."*

Richard: *"I think that everyone wins when people use less energy; house holds save money on their bills, less resources are needed to provide energy to national grid meaning energy companies have more time to develop other methods for energy production while still having an income, and the planet wins because less green house gasses are produced."*

David: *"I was very conscious of my electricity usage and my partner was, think we were turning things off a lot more."*

A summarised transcript of the user generated responses was then used to generate a grounded theory which is presented in the following sections.

6.4.1 Open Coding

Due to the large amount of data collected in response to the open questions, a summarised table of pertinent question responses with their descriptive labels are presented in *table 6.4a.*

Question Response	Codes Generated
"Condition A was preferred. Good interaction to compare with others, to see where you were in the rankings. To see if any improvements you made improved your ranking. Fun to look at other peoples energy usage."	1. Enjoyed the **social interaction** 2. **Fun** to make **comparisons** with other **people**
"I would absolutely use a Wattson device permanently. I would probably see it would take a couple of months of visual reminding to change my behaviour. It helps to have the visual feedback as a reminder. Although I do think it changes your behaviour subconsciously"	1. Eager to use **Wattson** permanently 2. Implies **behavioural change** will take place as a result of **visual feedback**.
"Ecological issues are important to me and to reduce my emissions which can only be good for my bills. I don't think everybody else on my friends list are ecologically motivated but they might be interesting in reducing their bills."	1. Implies **ecological** and **environmental** issues are important and potential motivators as well as **reducing bills** 2. Implies **uncertainty** of **friends motivation**
"Preferred condition A because there was more interaction, encouraged more to look at the application because of the thought of other real people's information being there. Interaction between people gives you more motivation. Didn't look at the Wattson display as much as I did the web one. Large benefit without having a separate display, just using your computer."	1. **Encouraged** more by the **social interaction** involving **real people** 2. States **motivation is improved** with **social interaction** 3. **Benefit** of using **web interface**

"Wattson design was problematic due to placement of the cable connections, caused problems for where I wanted to place it in my home. If I could have hooked it into an Ethernet or router or a Bluetooth device it could have worked wirelessly and I could have put it where I wanted, perfect."	1. Physical **designs issues** for **Wattson** 2. **Desired placement** of **Wattson** in **home** problematic
"I would use it all the time and look at it on a regular basis. Wish it was wireless though so I could place it where I wanted to."	1. Implies **eagerness** to use Wattson regularly over a **longer time** 2. Desired **extra features** on **Wattson monitor**
"I was very conscious of my electricity usage and my partner was, think we were turning things off a lot more. Plus it seemed like in our first week with the socially enabled part our energy was lower, it wasn't so much the competition for us, the social side of it drew us in. The more we looked at it the more we became aware of it and the more we changed our behaviour. Just the interaction on there was enough to make us more aware of what we were doing. Overall it had a positive effect on our energy usage. Was interested in interacting with the other people on the comments, just to see what they were saying, then there is the fact that we are all here and what are we all doing, it does help you to think about it. I liked the people and I wanted to join in."	1. Describes **consciousness** and **awareness** of **energy usage** 2. **Social interaction** made a **positive impact** but it was the **social aspect** and not the **competitive aspect** that **interested** us 3. Implies a **behaviour change** took place 4. **Interested** more in **interacting** with **people** for the **enjoyment**
"I preferred the second one (socially) because I am quite competitive, it gave me further incentive. I think it putting a bit of fun in it is quite important."	1. Preferred the **social** condition citing it was **fun** 2. **Competition** supported **incentive** to use
"I didn't look at the display much, problems with the cable popping out of the connector. The settings on the Wattson aren't clear and not easy to change. Didnt want to see the cost, just wanted to see the Watts. Problem because I wasn't always at home and Wattson needed to be kept plugged into the PC all the time."	1. **Wattson display** not important and **difficult to use** 2. Displaying **cost** was not an **incentive** 3. **Wattson poorly designed**
"I found that I was starting to turn things off, putting things on standby, several times. I felt I was motivated to do so, just the way I am. The question is, I think, are you doing it for the right reason? Think it would vary from person to person, I have been turning things off by habit now after only a few weeks. Some people may revert back to what they did before."	1. Implies **Behaviour change** by **turning off devices** by **feeling motivated** to do so 2. Raising question of **sustaining behaviour** change in themselves and others
"I preferred condition A, the social side of the WattsUp project because it provided me with motivation to monitor my energy usage more thoroughly. The ranking made saving energy more of a competition and therefore fun. Complimenting the rankings page was the comment section which worked great to share tips and taunt people into working harder to save energy"	1. **Social** condition **facilitated motivation** to raise awareness of energy usage 2. Implies **fun** and **competition** when using the rankings interface
"The non-social part of the project left me feeling a little lonely in my quest to save energy. I didn't really feel motivated to start the application and therefore to save energy, I noticed that my computer was on more and more. I think this was because I couldn't see how good or bad I was being compared to everyone else. Although the application had a visual representation to help me decided whether my energy usage was high or low, it wasn't as motivational and as fun as the social side."	1. **Unhappy** about using the **non-social** condition and therefore becoming **demotivated** 2. Implies **non-comparative** feedback created a **negative impact** on energy usage 3. Not as **fun** as the social condition
"In terms of technical problems with the software I did not encounter any problems. I had an issue with the hardware as the USB lead that came with the device was faulty. I thought that the Wattson device was a little tricky to use, the shake action to change from Watts to Pounds output was quite tricky to use as it would change back when I put the device down."	1. **Usability** of **Wattson monitor** a bit **poor, tricky**
"In terms of general problems with the application, I thought there could have been more stimulating visual representations used for Co2 levels. The same face four times on my personal energy usage page didn't really work for me. Perhaps a smiley face for good Co2 levels, a picture of a chimney for average levels and a power station for bad levels."	1. Implies better **visual representations** for **Co2** could have been more useful 2. **Smiley face** representation wasn't a good metaphor for their **energy usage**
"Yes, I would definitely love to have the Wattson in my Kitchen all the time as a constant reminder to save energy. However I think that it would get boring using the device after a long period, it would maybe get stuffed in the corner once the batteries ran out for the wireless transmitter. This is why I think that it would be almost essential for the Facebook application or something similar be available to accompany the Wattson to keep it fresh and interesting for the house hold."	1. Implies **pleasure** in using the **Wattson monitor** for the **long term** 2. Possibly **boring** to use the **Wattson** on its own with no supporting **Facebook application**
"I am a firm believer in making our energy usage more efficient, both in the	1. **Belief** in **efficient** of **energy usage** and

design of energy using devices and the use of them. I think that everyone wins when people use less energy; house holds save money on their bills, less resources are needed to provide energy to national grid meaning energy companies have more time to develop other methods for energy production while still having an income, and the planet wins because less green house gasses are produced. Therefore YES a difference can be made."	in the **design** of **devices** and **appliances** with a view to energy consumption 2. Implies **positive impact** on **households** and the **environment** when less energy is used 3. **Encouragement** is present in that a difference can be made
"I preferred condition A for several reasons. The first being that I could compare my usage to my friends, which I thought added a competitive element to it and gave me some incentive to want to improve my usage. The second being that there was a wall to post/comment on."	1. The **competitive** elements of the **social** condition gave **incentive** to improve **energy usage** 2. Another incentive was the **public wall** to **post comments** to
"It enabled me to monitor my usage in order to try to reduce our energy bills and identify which appliances use the most electricity."	1. Indicates **financially motivated** to **reduce bill costs** and to identify **high usage appliances**
"I think there are great benefits to reducing personal energy consumption, if this was repeated across the general population this could have a positive impact on our use of resources and enable us to make use of renewable energy sources. My motivation or incentives was the ability to convert the figures on the Wattson to pounds and also being in competition with others using the monitor."	1. Implies **benefits** to **reducing energy** for **everyone** 2. Indicates **awareness** of **renewable energy** 3. Motivated **financially** and **competitively**

Table 6.4-a - GT descriptive labels for UX with experiment

6.4.2 Axial Coding

The descriptive labels from previous open coding data analysis are grouped together under higher-level header categories. The four initial categories generated are shown in *table 6.4b.*

Motivation	Design	Environment	Usability
social interaction	web interface	consciousness	placement in home
fun	visual feedback	positive impact	design issues
comparisons	wattson monitor	turning off devices	tricky
real people	facebook application	sustaining behaviour	usability
friends' motivations	environmental	negative impact	boring
encouragement	home	awareness	non-comparative
eagerness	benefits	beliefs	de-motivated
competition	visual representations	efficient	unhappy
interested		high consumption	long term
enjoyment		renewable energy	
incentives		Co2	
pleasure		reducing energy	
bill reduction			
ecological			
finances			
behavioural change			

Table 6.4-b - Axial coding table generating from UX with experiment

The four categories were motivation, design, environment and usability. The motivation category describes labels such as competition, enjoyment and bill reduction, being some of the driving forces aiding their motivation to reduce energy whilst using the Wattson and Wattsup. The design category included design aspects of the Wattson and Wattsup, for example the components such as visual feedback representations and the Wattsup web interface. The environment category captured elements pertaining to the ecological impact of reducing energy such as beliefs and renewable energy; it also described labels such as turning off devices and sustaining energy behaviour. The final category created was usability which included mostly negative issues surrounding the usability of the Wattson monitor but also several negative labels describing the non-social condition of Wattsup such as de-motivated, unhappy and boring.

There appeared to be a degree of crossover between the usability and design categories so the two categories were merged, producing an amalgamated category retaining the name 'design' category. The remaining categories are illustrated in *figure 6.4a.*

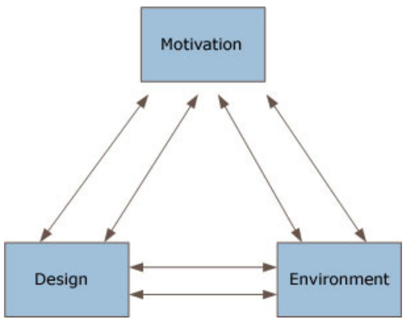


Figure 6.4-a - Axial coding categories relationship for UX with experiment

6.4.3 Selective Coding

The core category chosen for the GT was 'Motivation'. In the first instance the design category which includes the elements of visual energy representations and interfaces of Wattsup were directly inspired to facilitate motivation in participants to reduce energy. A direct consequence of their motivations to reduce energy and subsequently carrying it out were lower Co2 emissions on the environment. Reduced energy may have taken place through either ecological or financial motivation. Ultimately if the participants were motivated then energy would be saved, equally and just as importantly, if they were de-motivated then no energy savings would be made. This reasoning led to the selection of motivation as the core category.

The resultant theory derived reveals the importance of designing a persuasive system with the ability to facilitate and inspire motivation, central to the participants UX. The motivational elements were realised through social interaction as well as ecological and financial drivers, also embedded in the Wattsup interfaces. With no motivation present then it is unlikely that any behaviour change would take place with energy usage and certainly follows that it would not be sustainable.

6.5 Energy Tags

The energy tags interface was designed to elicit participants perceptions on the amount of energy a device may use. For example they were invited to input which devices they thought used the most energy in their home, when entered the tag for the device was displayed in a cloud along with all other energy tags submitted by other participants. The generated cloud is shown in *figure 6.5a*. If a tag had been entered multiple times by other participants it would appear larger in the cloud, therefore exhibiting a greater presence over the other tags.

Figure 6.5-a - User generated cloud tag for devices in the home

A larger tag meant more participants interpreted the device as using more energy. The number of times each energy tag was submitted is detailed in *table 6.5a*. Further discussion on the energy tags is presented in the next chapter.

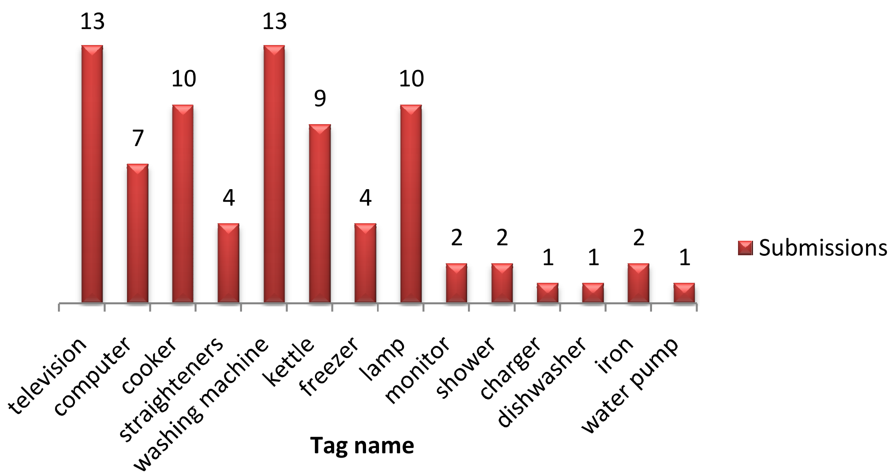


Table 6.5-a - Energy tag submissions by participants

7 DISCUSSION

With the energy experiment successfully completed and results analysed giving way to support the alternate hypothesis, this project's activities and results will now be evaluated and critiqued. The body of the evaluation section includes notable points and issues that occurred throughout each of the project's stages.

7.1 Project Evaluation

Before this discussion critiques the project's development, it is practical to start off by asking the project's research question again to review the concept of using persuasive technologies in social networks for monitoring domestic energy usage:

"Can online social networks such as Facebook facilitate the motivation and behaviour change to reduce energy consumption in the home?"

The results of the quantitative statistical test carried out provided evidence to support the experiments alternate hypothesis in the form of a low 'p' value, where $p<0.05$, suggesting that social networks play a role in assisting participants in reducing their domestic energy consumption. However the validity of the results may be called into play if the number of participants were scaled upwards, would the Wilcoxon statistical test produce another significant p value? The only way to answer this question would be a large scale experiment which also addresses another concern for the validity of the results in that did enough time elapse to adequately measure the energy data reliably.

A UK study claimed that behavioural change with domestic energy consumption was unlikely to alter until over 3 months had elapsed using targeted feedback, even after 3 months, the feedback had to be continued albeit at less frequent intervals [20]. The energy feedback delivered in the aforementioned study was not delivered within a socially enabled context; therefore it is possible the claim of 3 months minimum for energy usage behaviour change may not hold when a social platform is used to deliver the energy feedback. Due to time constraints and resources available this project could not address the experiment duration issue for sustained behaviour change. This project's findings may be viewed as a pilot study potentially leading onto a larger and more robust experimental design.

With the project's software application, Wattsup, falling into the category of persuasive technologies, visiting what this means again with the experiment completed may offer some retrospective evaluation. The inferential statistics results indicate that the Wattsup application was successful as a persuasive technology in that the participants were persuaded to reduce their energy usage. Additionally, the descriptive statistics suggest that there was a lot more activity with participants when in the socially enabled condition. The activity was measured in the number of visits to the Facebook application from the participants, with a fivefold increase of activity in the social condition over the non-social condition.

To further support the quantitative results two grounded theories were generated to assist in understanding the qualities that facilitated the engaging interaction between participants based around their energy usage, and why the socially enabled condition appeared to be more compelling to the participants. One GT was derived from user generated comments embedded in the rankings interface, creating a theory on the types of social interaction that took place when all of the participant's energy data was exposed in the rankings table. The second grounded theory was based upon audio data recorded during semi-structured interviews with the participants to collect the Wattson after the study was completed. Several open questions were asked to initiate conversation on the participants' experience of using the Wattson and Wattsup together during the experiment.

The first GT, based on user generated comments from the rankings interface, yielded strong descriptive data in the motivational and competitive drive of the participants. Three categories were derived from the comments analysis; these were **Banter**, **Engagement** and **Competition**. It is clear from these generated category definitions that the participants were actively engaged in monitoring their energy usage but also enjoyed the competitive aspect when pit against their friends. Supporting these defined types of categories were the significantly higher activity rates with participants when engaging in the socially enabled condition of Wattsup.

Competitiveness was clearly evident from the comments, and appeared to be a powerful driving force pulling the participants back to visit the application. The competitive elements of the rankings interface likely caused it to achieve the highest level of activity from the participants, in terms of number of page visits which was 73, the second best was 61 page visits for the 'personal energy' interface. Most of the social activity was centred on the rankings interface. Some comments illustrating the importance of competition between participants are seen below:

Diane: *"Hey Sambo, how come you are at the top, cut down drastically on your cups of tea?"*

David: *"I've been usurped"*

David: *"Left my main PC on the last two nights. Made a massive difference to my scores."*

Richard: *"gone down in the rankings? how is this possible I´m in Spain :S"*

The core central category derived from the rankings interface GT was 'Engagement', it follows that if the users were not engaging with their energy data and their friends then none of the other interaction would have taken place under the categories of banter and competition. It is safe to say that the participants found the socially enabled condition of the application 'fun' to use that led to immersive engagement. Given the relatively short length of the study, 18 days total, it would be interesting to see if the competitiveness nature exhibited when using Wattsup could be sustained over a longer period of time.

The second GT was based around the participants UX whilst taking part in the experiment. Responses to the semi-structured interview questions were recorded and analysed. The grounded theory gave a qualitative view of the participants overall experience whilst using the Wattson monitor and the Wattsup Facebook application. Three main categories were derived from the analysis; these were **Motivation**, **Design** and **Environment**. From these categories we can see that we have moved away from the more granular social interaction type categories of the first GT and have moved to a higher level of understanding in what the participant's core motivating factors to using the Wattson and Wattsup in the first place. It was evidenced in the data that both ecological and financial motivators were present in the participants as well as a higher awareness of energy usage with participants' conscious of Co2 emission impact and renewable energy sources.

From the three categories, the core category chosen was motivation. This was deemed to be the most important as without motivation participants would not be interested in using the Wattson or Wattsup and no energy savings would be experienced. They would have to be either motivated ecologically or financially with other factors such as competition and peer pressure supporting this. The design category was chosen because the physical interface designs of Wattsup would have to facilitate social interaction to support the participant's motivation.

It is clear from these generated category definitions that the participants were motivated from the design elements of Wattsup and as a result a positive impact was made upon the environment with less Co2 emission and greater awareness of 'green' issues such as renewable energy sources.

An important question may be asked - who would be interested in receiving feedback on their energy usage? And would they be interested in such data being presented in an online social setting? The first part of the question can be answered simply by stating we will all be receiver's of visual energy feedback in our homes in the near future in the UK, through the widespread government funded integration of smart meters. Following this, everyone with a smart meter will have to take some form of interest for informative reasons or otherwise in visual energy feedback, and learn to understand what the information means to them in relation to how they use energy in the home. As far as who would be interested in being presented with energy information in an online social network, exploratory workshops would need to take place to gather insights into the attitudes of various consumer demographics.

This project attempted to make energy conservation fun by targeting users of a major social platform – Facebook - with users already logging onto Facebook in the first instance for a pleasant social experience. Rather than being faced with a dull paper utility bill detailing energy expenditure, users can interact with an online system and if they so wish can engage in friendly competitiveness over their energy usage when comparing to their friend's. If competitiveness it not of interest to an individual then a fine grained personal breakdown of their energy or a normative comparison may prove useful to some.. A normative comparison could be the capability to view energy usage data from a home closely matched to their own in terms of number of people and rooms. Even if no normative comparison or social interaction is desired, there is still scope to interact with personal energy data in an online setting through using graphs for self-comparing purposes.

All of the aforementioned types of interaction with energy data such as personal, social or normative would all contribute to raising awareness of energy usage in the home. It could even be argued that by raising awareness of energy usage alone with no initial behaviour change, it could be branded an early success. Behaviour change could take place at a later date when the user is in a position to develop an attitudinal change with enhanced feedback, but awareness of their own behaviour must come first, and is the first step forward. Through the aforementioned optimistic assumptions, and the project's validated experimental findings, it is envisaged that people will be interested in sharing their energy data online in a social context on a larger scale, with privacy options available to opt out of certain social features.

So what appear to be the important persuasive requirements to assist in reducing energy consumption as observed from the project's experiment? The first requirement was to raise awareness of energy usage. This project chose to raise awareness through technology assisted visual feedback using the Wattson energy monitor and a Facebook application offering an alternative social way to display the energy data. When awareness was suitably raised through the Wattson and Wattsup application, the observed participant's energy behaviour changed, we then need to address the requirement of sustainability - could this project's concept of using social networks to reduce energy consumption be sustained over a much longer time by the participants? As stated previously, the only way to address this question adequately is through a longitudinal study. One of the questions put to the participants at the end of the experiment was if they would like to take part in a longer study of which they all agreed to with some comments below:

Alice: *"Yes, most definitely. It enabled me to monitor my usage in order to try to reduce our energy bills and identify which appliances use the most electricity."*

Richard: *"Yes, I would definitely love to have the Wattson in my Kitchen all the time as a constant reminder to save energy. However I think that it would get boring using the device after a long period..... think that it would be almost essential for the Facebook application or something similar be available to accompany the Wattson to keep it fresh and interesting for the house hold."*

Interestingly, one of the participants voiced their opinion that the Wattson device itself may become 'boring' after a while with a definite need of a supporting application. The same participant referred to keeping the interaction 'fresh', something a socially enabled application such as Wattsup is able to facilitate. A fresh perspective may always be available in new comment postings to catch up with and also checking to see how their ranking is currently standing.

As suggested by a recent persuasive technology paper, one of the fundamental caveats of creating a successful persuasive technology is not to be too ambitious with goal setting [39]. Individual behaviour patterns are difficult to change and any approach used is likely to yield greater success if it is small-goal orientated and as this project suggests, 'fun' to use. The projects goal, to reduce energy consumption, may be perceived as a majorly important ecological and financially motivated goal but it is by no means too ambitious. A little bit of energy saved can go a long way when part of a larger collective, consisting of like-minded people.

The same paper also goes on to suggest the lack of systematic design process for persuasive technologies because of its status as an emerging field. A similar comparison may also be made regarding HCI and its lack of defined design methodologies for creating quality UX in interactive systems. By working through this project's method it can be seen it follows an HCI UX approach of user-centred design with no persuasive technology specific processes used. Papers were consulted themed around the persuasive use of social networks for designing applications but none of them followed any tried and tested methodologies. This likely explains why persuasive technologies are usually interactive systems following their own bespoke design processes.

One of the main incentives to the use and success of the project was its simplicity. The participants had no difficult behavioural changing tasks to perform such as abstaining from smoking or eating more healthily. By informing them of their energy usage through visual feedback they could choose to try and reduce their household energy consumption by as little or as much as they were motivated to do. To reduce usage participants could actively turn off lights in the home when not required, switch off devices instead of using standby and be more mindful of their home's thermostat settings. All of these tasks are not difficult to perform and can make a positive impact to overall energy usage. Lending credence to the idea that tasks to reduce energy can be both engaging and fun in a playful manner are comments made by of two of the experiment's participants. Both stated they had fun going around the house turning everything off in an attempt to get the Wattson energy monitor reading as close to zero watts as possible as the following comments suggest from the semi-structured interviews at the end of the experiment:

Robert: *"Well, this morning we unplugged EVERYTHING one by one, room by room. The reading on the wattson went down by around 450 to 970 watts. Ha, we actually enjoyed investigating this though ;)"*

Richard: *"After hooking it up to fusebox outside, went around the house with mum and dad and turned everything off to see what was using what, quite enjoyed it"*

A help section within the Facebook application provided a short informative narrative on energy usage in the home and subsequent impact on climate change, informing them of the bigger picture. The benefits to the participant's reducing their energy are many, and under different schools of thought. A participant may be motivated ecologically or financially or a combination of both. The focus group findings presented mixed feelings on these viewpoints but with a slant towards stating ecological could be the greater motivator. Numerical and visual representations in the

Facebook application provided information to support both ecological and financial modes, an attempt to appease the different outlooks.

Further to the ecological or monetary motivating factors, participants of the experiment mentioned the motivating factors during the semi-structured interviews:

Diane: *"Ecological issues are important to me and to reduce my emissions which can only be good for my bills. I don't think everybody else on my friends list are ecologically motivated but they might be interesting in reducing their bills."*

Richard: *"I think that everyone wins when people use less energy; households save money on their bills, less resources are needed to provide energy to national grid meaning energy companies have more time to develop other methods for energy production while still having an income, and the planet wins because less green house gasses are produced."*

Alice: *"I think there are great benefits to reducing personal energy consumption, if this was repeated across the general population this could have a positive impact on our use of resources and enable us to make use of renewable energy sources. My motivation or incentives was the ability to convert the figures on the Wattson to pounds and also being in competition with others using the monitor.*"

An interesting observation from all of the above comments is that they address both ecological and financial perspectives with two participants mentioning alternative energy sources. This is encouraging in that the participants are already thinking of the implications of energy production as well as their own personal energy usage.

An additional interface was created to attempt to elicit their perceptions of which devices and appliances in the home use the most energy. An 'Energy Tags' interface was designed and implemented in addition to the three main core interfaces, please see *figure 6.5a* in chapter 6 for screenshot image. It was not directly derived from the focus group findings but was an explorative interface designed by the author. Participants submitted the names – energy tags - of devices they thought consumed a lot of energy in the home, with the tags possibly generated through their experience of observing the Wattson's dynamic display in their home or purely through their own knowledge. When the tag was successfully submitted they could then see the tag nestled in a cloud of other energy tags submitted by the other participants. Hovering the mouse over each tag allowed the participants to see the number of times it had been submitted. The more times the same tag was submitted, the larger the tag would become, taking up more space in the cloud. Metaphorically the larger the tag in the cloud, the more times it had been submitted and the more energy it was perceived to consume.

It was envisaged that the use of an energy cloud may help to raise awareness of energy usage in the home further, by making participants dwell on what specific devices use more energy in their home with the possibility of targeting those devices to be used less. Indeed when a participant is presented with the cloud containing all other energy tags submitted it may introduce a normative effect if the tags they have submitted have been submitted multiple times before.

Design issues were highlighted in the semi-structured interview responses in relation to the Wattson monitor – an immediate aesthetic problem was in order to stand the unit upright for easy viewing of the display you could not have the USB cable plugged into the PC, the unit has to be placed flat for the USB connection. This is not ideal as most users would like to see the display easily as well as being able to plug it into their PC, no energy data can be sent online if the USB cable is not attached. Secondly, as anticipated, requiring a USB connection meant the participants were restricted in that they could only send their energy data online when their PC was switched on. This is somewhat ironic for a device that is attempting to reduce energy consumption. However this is the state of the art for currently affordable home energy monitors. Ideally, the requirement by the Wattson monitor for a physical PC internet connection to send energy data online should be negated, as echoed by several of the participants in their previous comments. To do this would require a redesigned Wattson monitor that communicates data wirelessly through their home internet connection. Bypassing the need for a PC also deals with the problem of requiring the PC to be switched on to send data online and creating more Co2 emissions in the process. Currently, if the PC isn't switched on energy data cannot be sent until the PC is switched on again. It is anticipated in the near future that new home energy monitors and smart-meters will be designed to communicate energy data online without consumer intervention, making it a transparent process. A government funded report on smart meters suggests the possible use of community based mesh and mobile carrier networks for communicating smart meter data online [30].

There may be a value to experimental endeavours such as this project beyond an immediate and short term measurable net reduction of personal energy consumption. Such studies cannot help but raise awareness of energy consumption if only because of the Hawthorne effect [52], although the change in energy behaviour observed from the results in this study revealed that participants found using the Wattsup application pleasurable and an enjoyable experience, and unlikely to be the result of any Hawthorne effect. For ecological change to take place there must also be ideological change, however sustaining a change in a user's behaviour is a challenging task, but may be alleviated if the user's behaviour is subject to social norms and not just entirely the remit of the individual. This study generated a considerable amount of press interest, please see appendix C for press stories, which indicates that ecological sustainability is now a very real concern of users. Additionally, a full CHI 2010 conference paper was submitted based on work directly derived from this project, the full paper is presented in appendix D.

This discussion has served to critique the project's findings by evaluating the validity and context of the experiments results. The next chapter discusses possible avenues for future work in expanding the projects scope.

8 FUTURE WORK

Future work direction is best dictated according to the qualitative data from the participants who took part in the experiment as well as the focus group participants. Practical suggestions such as improvements to the Wattsup application are feasible to implement dependent upon their scope and content. The experiment participants also commented on several issues with the Wattson device itself such as placement of socket connections and its display output, but these are beyond the scope of any kind of future work and are solely the remit of the manufacturers of the Watson. However the design suggestions for the Wattson monitor hardware will be briefly mentioned at the end of this chapter.

The most likely direction of future work is a larger study to attempt to validate the initial statistical results further. A larger study would allow the formation of teams or cliques of friends to compete against each other and form league tables instead of the current individualistic rankings table. Using teams in the workplace to reduce energy was also highlighted in a study as being more successful than using individuals [43]. Additionally, this approach was suggested by the focus group participants and was manifested in some of their interface prototypes, but was not feasible to implement due to project constraints in time permitted and number of available Wattson monitors. At the end of the experiment several participants also put the same team based improvement forward suggesting that it could become even more 'competitive'.

Other future work direction would also include the implementation of game-play elements such as a points system with rewards in the form of virtual prizes. As all of the experiment participants enjoyed the experience of engaging with the application, it was felt that game-play features could enhance their UX further in a more playful manner.

Several participants also noticed that the colour coded 'smiley' images used to indicate how good or bad their energy and Co2 levels were actually fixed value points. This meant the appearance of the smiley images didn't dynamically adapt to their energy behaviour, in other words the fixed points applied to all users, regardless of number of people in a house or number of rooms. This meant that a family of four could constantly be shown a sad red smiley even although their energy usage is scaling properly for their circumstances. Naturally, they are likely to be using more energy than a small flat with a couple living in it. An algorithm could be developed to overcome this shortcoming, allowing energy readings to be normalised depending upon the number of people in a house as well as the number of rooms.

To summarise, the future work direction for the Wattsup application would include:

- Longer study with more participants
- Formation of teams with friends competing in leagues or cliques

- Introduction of game-play features to increase engagement and immersion

- Algorithm designed to normalise energy data for graphical smiley representation, eliminate fixed points

A potential future implementation of the Wattsup application would involve the link-up of smart meter energy data when they become more prevalent in UK homes. This may not present a significant challenge as far as software development is concerned. The difficulties may lie with gaining authorised access to the energy data if the energy providers introduce proprietary systems that effectively close data collection off to everyone but themselves. Closing off the ability collect energy data from smart meters may appear to defeat their purpose of being designed to raise awareness by opening up energy usage data making it more informative and presentable to the end user. It is desirable for energy providers to provide support for third party developers to design front-end web applications based on smart meter energy data.

As previously mentioned, but outside the remit of this project, there were some physical design issues with the Wattson. Several participants were dissatisfied with the cable connector placements. The USB cable port was placed at the side that allows the Wattson to free stand vertically giving an easy viewing angle for the display. With the project requiring the Wattson to be plugged into the PC via USB for the most part it was inconvenient with it having to be laid flat and creating an awkward viewing angle to read the display. This may have been attributed to a lack of proper participatory design on the manufacturer's part when designing devices for the home.

The next chapter concludes the project's findings.

9 CONCLUSION

The project has described the design, deployment and evaluation of a Facebook application designed to allow friends to compare their home energy consumption. Although it was a small and relatively short study the results are encouraging and indicate that social networking sites such as Facebook and Twitter may be able to play a role in reducing energy consumption in the home. It may be seen as a pilot study with a strong foundation for future work to build upon.

Following a participatory design methodology throughout, the project resulted in producing engaging interfaces that the participants could easily understand and engage with, creating an enjoyable UX. Ultimately the focus group inspired designs resulted in participants saving a total of 57KWh of energy when acting in the socially enabled condition of the experiment. If this were sustained over a longer period of time then significant savings would be made both in cost and Co2 emissions. For example if the savings were sustained at the same rate over a year then a reduction of 1.2 Metric tonnes of Co2 would have been made, equivalent to requiring 6 trees to offset the Co2 and equal to the emissions of driving a medium sized car for 2404 miles.

It could be argued that in terms of domestic energy consumption and using computers to assist in reducing it, computers are part of the problem and not the solution, with industrial power consumption also increasing in parallel to support our lifestyles and insatiable desire for gadgets in the domestic setting. This is an important argument and one that is likely to surface time again until scientists and manufacturers start seriously addressing the power requirements of technology itself, as well as consumers' understanding of it. The main question raised may be akin to this - Could using technology to solve a problem that technology itself has created be a productive path? A response in the form of a validated ecologically orientated answer remains to be seen with time; however a large scale deployment of technology designed to raise consumer awareness of domestic energy is already underway. The UK government's strategy of fitting a smart meter into every UK home by 2020 to the tune of £billions is a direct example of using technology to create awareness of yet more technology. It remains to be seen what the energy providers and the UK government will do with the energy data generated from smart meters and how they will inform and present this data to the consumer as some form of feedback. It is perfectly feasible to utilise the data from a smart meter in an application such as Wattsup.

Part of the reason for the massive increases in domestic energy consumption is the proliferation of computers and other energy intensive devices. Indeed to support the Wattsup application online it requires the use of a large complex networked infrastructure - the entity or social platform we call Facebook, no doubt requiring a very large amount of power. It may even be argued that we spend more time using our computers because of social platforms such as Facebook as we enjoy using them so much, with the negative side meaning our computers are switched on for longer.

The qualitative results of the study indicate that the participants enjoyed the experience of interacting with the Wattson and Wattsup, with several quoting that it was fun to use. The fun aspect may be considered to be vitally important when designing an interactive system which has an underlying serious theme to it, such as energy and climate change as manifested in Wattsup. People live busier lifestyles and are unlikely to be enticed by mundane computer applications with a serious theme. With people logging on to Facebook because they want to and because they will have a pleasant experience while logged in means the applications they will use must also be enjoyable.

Peer pressure and competition appeared to be the main motivating forces of the participants in their quest to save energy. Social platforms such as Facebook are built upon fundamental social psychology elements and are an ideal platform to deploy persuasive technologies. Further to this, when asked during the semi-structured interviews at the end of experiment which condition they preferred, all participants unanimously agreed on the socially enabled condition. From this we can see the combination of fun entwined within a social environment engaged the user's to the point where they willingly spent their free time using Wattsup and reduced their energy usage in the process.

Additionally, the participants were asked if they would like to take part in a longer study and all responded positively that they would be happy to do so. The author believes that in order to raise awareness of issues such as energy use in the home, it has to be presented in a compelling way to engage users. If done in such a way as to introduce the concepts of social interaction such banter, engagement and competitiveness as this project has done, it may pave the way for successful domestic energy interventions of a longer duration and scale.

The project was designed to address a gap in current knowledge surrounding the use of social networks to help reduce household energy consumption. It also addresses other elements lacking in many energy studies such as how to record energy data before it is presented as feedback. Most studies have involved the use of self-reporting techniques, which is a rather poor method of recording energy data resulting in participants having to pour over paper energy bills to decipher their energy consumption or even read their own energy meters and input the values into a software tool. It also means that no current up-to-date energy measurement is always available when using self-reporting. The Wattsup application used an elaborate software framework that facilitated the autonomous logging of energy data from each participant's home with no user intervention required. This transparent logging of energy data allowed the participants to easily take part in the experiment with no requirement of remembering to input an arbitrary energy reading at an appointed time each day.

As a persuasive technology Wattsup was a success in that it motivated the participants to save energy. It can therefore be said that the projects research question was proved positive in that social networks such as Facebook and Twitter can engage and motivate householders to reduce their energy consumption.

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APPENDIX A – CODE METHODS

1.1 XML Code Method

```
private void ReadXml()
    {
        //Create the WebRequest to myenergyusage.org for user’s energy summary
       WebRequest fetchXml =
       WebRequest.Create("http://myenergyusage.org/pmonline/getusersummary.php?fbid=" +
       Master.API.uid.ToString());

        //Create a Proxy
        WebProxy px = new
        WebProxy("http://myenergyusage.org/pmonline/getusersummary.php?fbid=" +
        Master.API.uid.ToString(), true);

        //Assign the proxy to the WebRequest
        fetchXml.Proxy = px;

        //Set the timeout in Seconds for the WebRequest
        fetchXml.Timeout = 5000;
        try
        {
            //Get the WebResponse
            WebResponse rep = fetchXml.GetResponse();

            //Read the Response into a XMLTextReader
            XmlTextReader xtr = new XmlTextReader(rep.GetResponseStream());

            //Create a new DataSet
            DataSet ds = new DataSet();

            //Read the Response into the DataSet
            ds.ReadXml(xtr);

            //Write response to physical xml file on with unique ID for filename
            string xmlFile = @"C:\Domains\derekfoster.net\wwwroot\wattsup\App_Data\" +
            Master.API.uid.ToString() +".xml";
            ds.WriteXml(xmlFile);
            //Bind xml to xmldatasource
            XmlDataSource1.DataFile = xmlFile;
        }
        catch (Exception ex)
        {
            throw ex;
        }
    }
```

1.2 GetPhoto Code Method

```
protected string GetPhotoPath(object todayUnits)
    {
        //Reset photoPath and convert todayunits to a double
        string photoPath = string.Empty;
        double todayUnitsConvert = Convert.ToDouble(todayUnits);
        //Check if units are less than 8 or less than 14 or above 14 and display image
        if (todayUnitsConvert < 8)
        {
        photoPath =  string.Format("http://wattsup.derekfoster.net/images/Smilies/happy.png",
        todayUnitsConvert);
        }
        else if (todayUnitsConvert < 14)
        {
       photoPath = string.Format("http://wattsup.derekfoster.net/images/Smilies/neutral.png",
       todayUnitsConvert);
        }
```

```
        else
        {
        photoPath = "http://wattsup.derekfoster.net/images/Smilies/sad.png";
        }
        return photoPath;
    }
```

1.3 Populate DropDown Box Method

```
IList<long> items = this.Master.API.friends.getAppUsers();
            //bind the list of friends using Wattsup, get name and FBID
            ListItem li = null;
            DropDownList1.Items.Clear();
            foreach (long friend in items)
            {
            li = new ListItem(string.Format("{0}     :{1}",   Master.API.users.getInfo(friend).name,
            friend));
            DropDownList1.Items.Add(li);
            SelectedUsersID.Text = DropDownList1.SelectedValue.Split(':')[1];
            }
```

1.4 Send Notification and Message Method

```
protected void Message_Click(object sender, EventArgs e)
    {
        //bind messageData data from form postback and store in myMessage
        var myMessage = Request.Form["messageData"];
        // save to hidden label then send through notificatioin
        hiddenMessage.Text = myMessage;
        Master.API.notifications.send(SelectedUsersID.Text, hiddenMessage.Text);
```

1.5 SQL Energy Tags Method

```
protected void Button1_Click(object sender, EventArgs e)
    {
        //Create new SQL connection with connection string
        SqlConnection thisConnection = new SqlConnection("Data Source=*******;Initial
        Catalog=projects;User Id=Derek;Password=******;");

        //Create new query command
        SqlCommand nonqueryCommand = thisConnection.CreateCommand();

        thisConnection.Open();
       //Execute query to check if tag already exists
        nonqueryCommand.CommandText = "SELECT name FROM cloud_tag WHERE name=@MyName";
        nonqueryCommand.Parameters.AddWithValue("@MyName", TextBox1.Text);
        string returnValue = (string)nonqueryCommand.ExecuteScalar();

       //If tag doesnt exist then use INSERT else use UPDATE
        if (returnValue == null)
        {
            nonqueryCommand.Parameters.AddWithValue("@newItem", TextBox1.Text);
            nonqueryCommand.CommandText = "INSERT INTO cloud_tag (name,title,weight)
            VALUES(@newItem, 1,1)";
            nonqueryCommand.ExecuteNonQuery();
        }
        else
        {
            nonqueryCommand.Parameters.AddWithValue("@updateItem", TextBox1.Text);
            nonqueryCommand.CommandText = "UPDATE  cloud_tag SET weight=weight+1,title=title+1 WHERE
            name=@updateItem";
            nonqueryCommand.ExecuteNonQuery();
        }
        thisConnection.Close();
    }
```

1.6 Gauge Generation and Data Binding Method

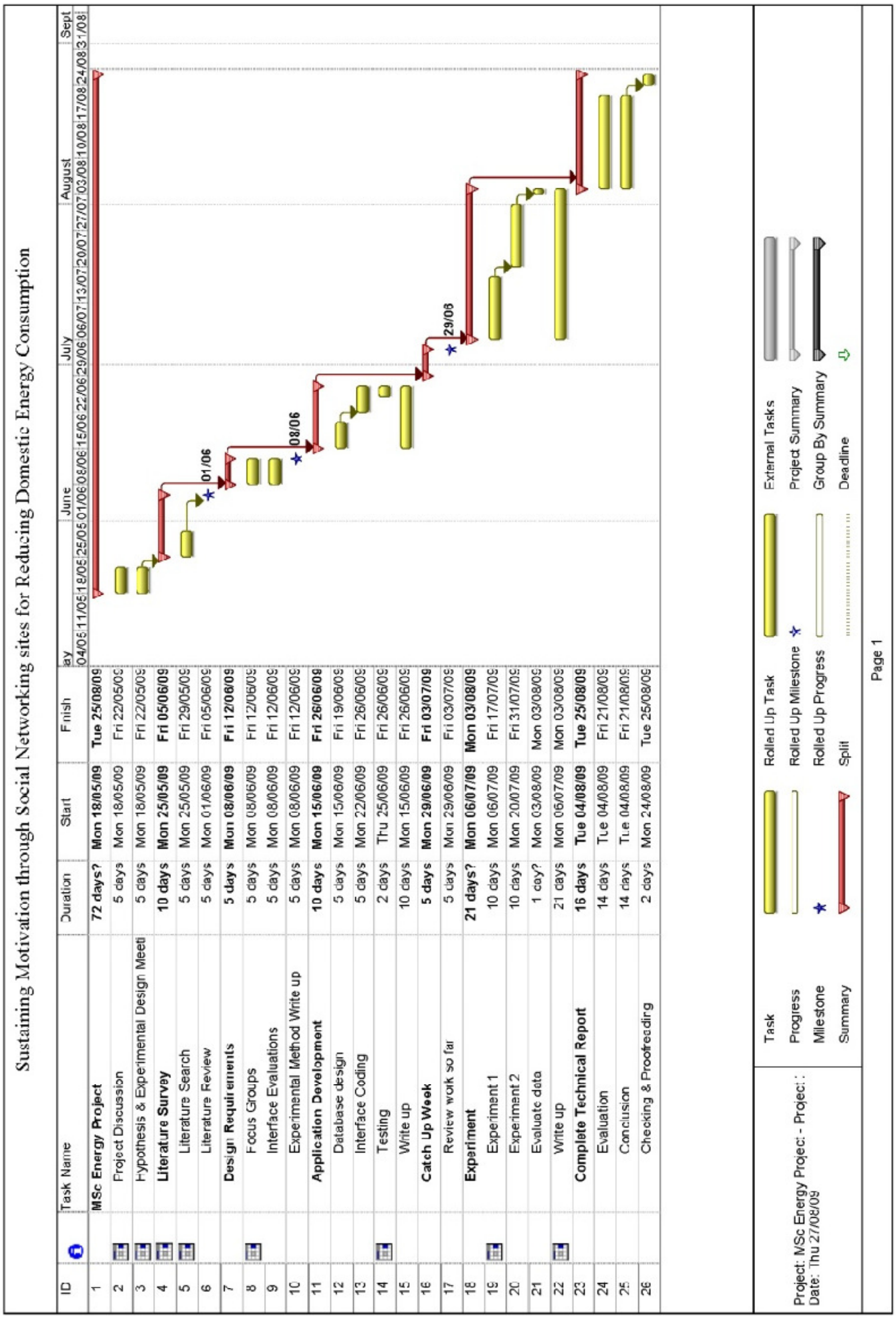
```
XmlDocument xmlDocumentInstance = new XmlDocument();
xmlDocumentInstance.Load(@"C:\Domains\derekfoster.net\wwwroot\wattsup\App_Data\" +
Master.API.uid.ToString() +".xml");
XmlNode power = xmlDocumentInstance.SelectSingleNode("root/user/@lastPower");
       //store XML power value to label then convert to double for gauge pointer
        Power.Text = power.Value;
        double gaugeValue = Convert.ToDouble(Power.Text);
        GaugeContainer1.CircularGauges["Default"].Pointers["Default"].Value = gaugeValue;
```

1.7 Chart Generation and Data binding Method

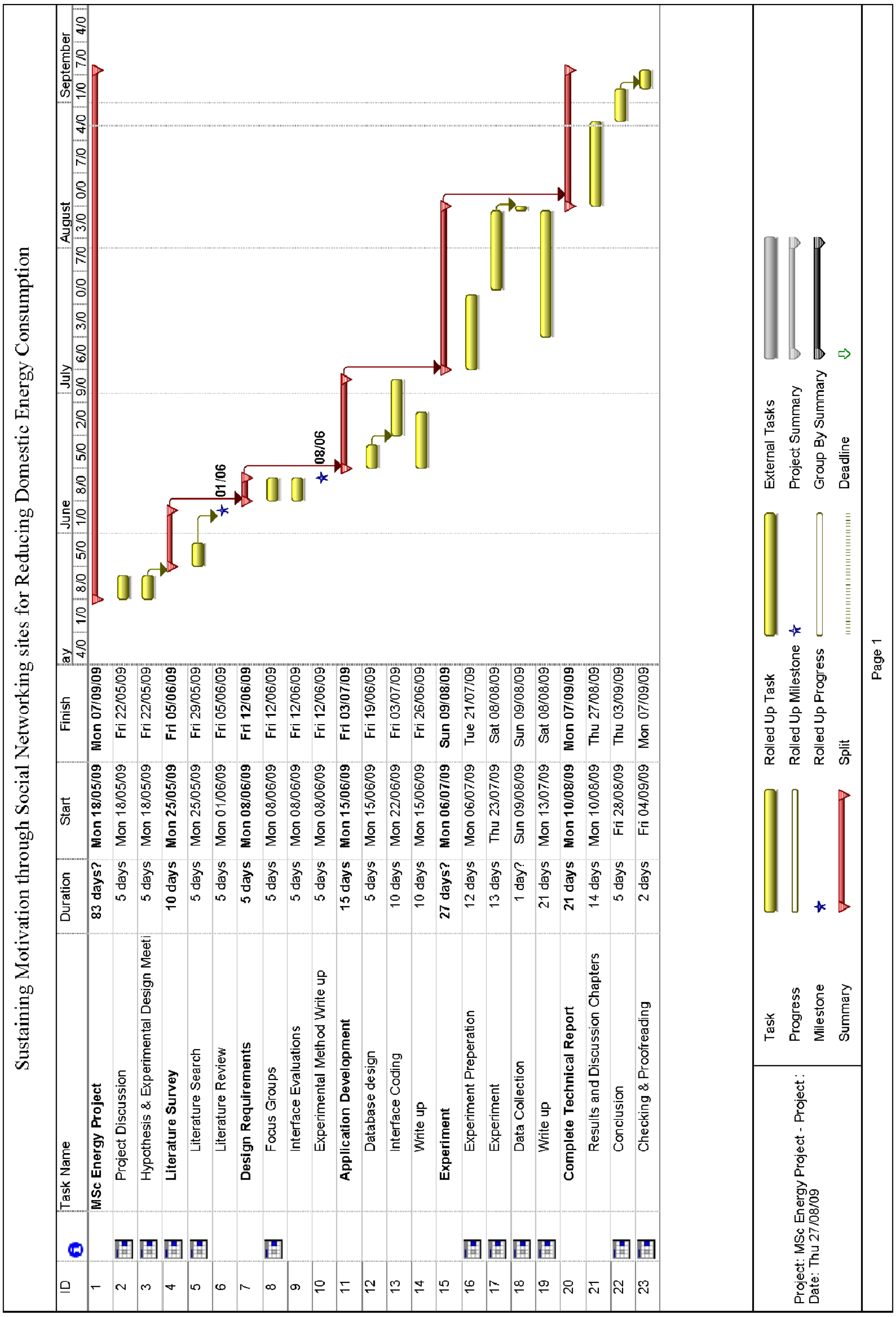
```
XmlDocument xmlDocumentInstance = new XmlDocument();
xmlDocumentInstance.Load(@"C:\Domains\derekfoster.net\wwwroot\wattsup\WebCharts\" +
Request.QueryString["id"] + ".xml");
//store XML value into day variables
XmlElement el = xmlDocumentInstance.SelectSingleNode("root/mpSD/*") as XmlElement;
XmlNode day0 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u0/@p");
XmlNode day1 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u1/@p");
XmlNode day2 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u2/@p");
XmlNode day3 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u3/@p");
XmlNode day4 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u4/@p");
XmlNode day5 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u5/@p");
XmlNode day6 = xmlDocumentInstance.SelectSingleNode("root/mpSD/u6/@p");
ColumnChart chart = new ColumnChart();
chart.Fill.Color = Color.FromArgb(50, Color.FromArgb(59,89,152));
chart.Line.Color = Color.FromArgb(59,89,152);
chart.Line.Width = 4;
chart.ShowLineMarkers = true;
chart.MaxColumnWidth = 30;
chart.Legend = "Energy Units (Kwh)";

float d;
//add new bar to bar chart with each daily power value from the XML values

DateTime myDateTime6 = DateTime.Now.AddDays(-6);
string day_6 = myDateTime6.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_6, day6 == null ? 0 : float.TryParse(day6.Value, out d) ? d : 0));

DateTime myDateTime5 = DateTime.Now.AddDays(-5);
string day_5 = myDateTime5.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_5, day5 == null ? 0 : float.TryParse(day5.Value, out d) ? d : 0));

DateTime myDateTime4 = DateTime.Now.AddDays(-4);
string day_4 = myDateTime4.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_4, day4 == null ? 0 : float.TryParse(day4.Value, out d) ? d : 0));

DateTime myDateTime3 = DateTime.Now.AddDays(-3);
string day_3 = myDateTime3.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_3, day3 == null ? 0 : float.TryParse(day3.Value, out d) ? d : 0));

DateTime myDateTime2 = DateTime.Now.AddDays(-2);
string day_2 = myDateTime2.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_2, day2 == null ? 0 : float.TryParse(day2.Value, out d) ? d : 0));

DateTime yesterday = DateTime.Now.AddDays(-1);
string day_1 = yesterday.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint(day_1, day1 == null ? 0 : float.TryParse(day1.Value, out d) ? d : 0));

DateTime today = DateTime.Now.AddDays(0);
string day_0 = today.DayOfWeek.ToString();
chart.Data.Add(new ChartPoint("Today", day0 == null ? 0 : float.TryParse(day0.Value, out d) ? d :
0));

ChartControl1.Charts.Add(chart);
ChartControl1.RedrawChart();
```

APPENDIX B – GANTT CHART

1.1 Initial Gantt Chart



1.2 Modified Final Gantt Chart



APPENDIX C – MEDIA ARTICLES

Various media articles appeared in both the paper press and online research news websites. A Selection of some the articles are listed here.

Student's 'green' use for online social networking

17 August 2009

A Computer Science student at the University of York has created a new Facebook application that uses the social networking website for monitoring home energy consumption.

Derek Foster developed the WattsUp application, which will also allow people to assess their carbon dioxide emissions, as part of his project for the MSc in Human-centred Interactive Technologies.

The domestic sector accounts for about 30 per cent of all energy consumed in the UK. The application aims to raise awareness of energy consumption in the home to both reduce usage and have a positive impact on climate change.

The WattsUp application records users' live and historical household energy consumption and carbon dioxide emissions, via a special energy monitor - the WATTSON monitor.

Derek said: "With so many people using Facebook now, it seemed like a novel approach to incorporate other elements of our lifestyle, such as our household energy consumption, into our online social profiles.

"By using Facebook as the delivery platform it introduces social psychology elements such as peer-pressure and normative behaviour between friends which can introduce competitiveness to reduce energy usage."

The developers of the Microsoft Facebook Development Toolkit selected WattsUp as a novel application finalist and are planning to publish an upcoming special article on the Microsoft Developers Network (MSDN).

Source: http://www.alphagalileo.org/ViewItem.aspx?ItemId=60203&CultureCode=en

Facebook applications go green

by Stephen Hurrell. Published Mon 17 Aug 2009 14:04, Last updated: 18 Aug 2009

People could soon be able to monitor their carbon emissions on popular social networking website Facebook.

The energy-conscious application is the brainchild of University of York student Derek Foster. The Computer Science student designed the WattsUp application as part of his Masters degree.

The application, which can be added to a Facebook profile, records live household energy consumption and carbon dioxide emissions and adds them to an archive. The emissions are recorded using a special energy monitor – the WATTSON monitor.

Foster said: "With so many people using Facebook now, it seemed like a novel approach to incorporate other elements of our lifestyle, such as our household energy consumption, into our online social profiles.

"By using Facebook as the delivery platform it introduces social psychology elements such as peer pressure and normative behaviour between friends, which can bring in competitiveness to reduce energy usage."

The application was selected as a novel application finalist by the developers of the Microsoft Facebook Development Toolkit – the program that allows users to design their own Facebook applications.

Household energy accounts for 30 percent of the UK's total energy use and Foster believes the application can reduce usage in the home, saving the user money and having a positive impact on the climate.

WattsUp will join other green Facebook applications such as 'Green My Ride', which offers carbon credits to the greenest car user and (lil) Green Patch, which has used sponsors donations to save 183,244,167 sq ft of the rainforest so far.

Source: http://www.clickgreen.org.uk/product/directory/12544-facebook-applications-go-green.html

Energy quest sparks comparison with friends

Published Date: 17 August 2009 By John Roberts Education Correspondent

A UNIVERSITY researcher is hoping to reduce people's energy consumption by exposing them to on-line peer pressure.
Derek Foster has created a computer programme which allows friends to compare how much power they use and how much carbon dioxide they emit from their homes.

The PhD student at York University has developed the system as an application on the social networking website Facebook.

The Wattsup Facebook pro-gramme uses a monitor to measure household energy consumption and then enters details into a series of league tables and charts to let people see how their electricity use and carbon footprint differs from their friends.

Mr Foster, 33, said: "I found that in the group where people knew their information could be seen they adjusted their energy consumption.

"The social interaction meant that people were motivated to reduce the amount of energy they consumed," added Mr Foster.

Source: http://www.yorkshirepost.co.uk/news/Energy-quest-sparks-comparison-with.5562074.jp

Competitive Carbon Counting: Can Social Networking Sites Make Saving Energy More Enjoyable?

First Author Name (Blank if Blind Review)
Affiliation (Blank if Blind Review)
Address (Blank if Blind Review)
e-mail address (Blank if Blind Review)
Optional phone number (Blank if Blind Review)

Second Author Name (Blank if Blind Review)
Affiliation (Blank if Blind Review)
Address (Blank if Blind Review)
e-mail address (Blank if Blind Review)
Optional phone number (Blank if Blind Review)

ABSTRACT

This paper reports on the design, deployment and evaluation of "Wattsup", an innovative application which displays live autonomously logged data from the Wattson energy monitor, allowing users to compare domestic energy consumption on Facebook. Discussions and sketches from a workshop with Facebook users were used to develop a final design implemented using the Facebook API. Wattson energy monitors and the Wattsup app were deployed and trialled in eight homes over an eighteen day period in two conditions. In the first condition participants could only access their personal energy data, whilst in the second they could access each others' data to make comparisons. A significant reduction in energy was observed in the socially enabled condition. Comments on discussion boards and semi-structured interviews with the participants indicated that the element of competition helped motivate energy savings. The paper argues that socially-mediated banter and competition made for a more enjoyable user experience.

Author Keywords

Sustainability, Persuasive Technology, Social Networking, Competitive Energy Saving, User Experience

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

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It is generally acknowledged amongst scientists and, increasingly, politicians and corporations that current levels of energy consumption are not sustainable [25]. Many people already know very well that they consume too much energy at home and fly too often. And yet they do next to nothing to change this. Indeed a recent article in the Ecologist on unnecessary travel was written on board a transatlantic Boeing 747 flight [30]. At the moment we want to cut carbon emissions without changing our lifestyles; we do not want sustainable technologies but perhaps we want to want them. How then can technologies designed to change behaviour become compelling, desirable and enjoyable?

It is increasingly recognised that interaction design must address issues of sustainability, e.g. [4, 24, 33]. There has been much work in HCI in the past decade on persuasive technology, e.g. [9, 18, 23]. However Fogg recently pointed out that persuasive technologies very often fail and urged practitioners to think small [19]. Monitoring technologies alone (e.g. pedometers) are often not enough to make meaningful changes in behaviour. This paper draws on previous work on persuasive technologies, e.g. [18, 19] in order to address environmental concerns over domestic energy consumption.

Households are responsible for 30% of the UK's total energy use [12]. Since 1970, household energy demands have grown by 32% [29] and still continue to grow. Energy demands have grown because of increases in home temperature and the proliferation of consumer electronics [14]. Ulrick Beck identifies increasingly individualized forms of living such as: "living alone, single parenthood, non-marital cohabitation, childless marriage, serial marriage" and "living apart together", where partners live in separate dwellings" [2]. The impacts of these trends are social but also environmental in that one person living alone uses more energy than two in the same household [3]. Rising energy consumption currently means increased CO_2 emissions so domestic energy consumption is very much a world problem e.g. [20, 46].

This paper reports on the design, deployment and evaluation of a Facebook application which aimed to encourage energy saving by using live and historical energy feedback in a social-normative context.

BACKGROUND

Numerous studies have demonstrated that energy usage falls when people know it is being monitored [46]. Studies in Environmental Psychology have shown that feedback on energy consumption can achieve behavioural change though it is not necessarily sustained without timely reminders [11, 37]. The goal of this project therefore, was not just to effect behavioural change but to demonstrate larger reductions in energy consumption through the addition of a social aspect in monitoring energy usage.

The desire to belong and willingness to adapt behaviour to follow what others are doing has been seen as a fundamental motivator [1]. Social norms such as peer pressure have also been seen as a means of changing behaviour to align with the ideas or beliefs of groups [41]. It has been argued that computers now operate as social actors designed to influence our behaviour, filling the roles of teachers, sales people and health agents and [40, 18]. Computers have, for example, been shown to help people overcome their fear of public speaking [43]. Recent work on persuasive technology has argued that reciprocal interaction through instant messaging and “pokes” can be effective strategies for persuasion [47]. Whilst there is insufficient space to give a full account of the psychological theories of social motivation, effecting behavioural change through computer mediated social networks seems promising.

Energy Monitors

In many homes, electricity meters are often difficult to access (located in cupboards or corners) and usually difficult to read. Energy measurements in kilowatts are difficult to make sense of either in terms of finance or ecological impact [15]. Dynamically updating kilowatt readings are however much more understandable [48]. Studies of paper electricity bills have also shown that awareness and understanding can be increased through graphical representations of financial and normative comparisons [17]. However bills do not provide frequent feedback and a recent study found that continuous feedback over a long period is the best means of changing patterns of energy consumption [37]. The importance of raising awareness about patterns of consumption can be illustrated with reference to still widely held but mistaken beliefs about domestic appliances. One study of mistaken folk theories of energy consumption found that there was still credence given to such myths as - turning a thermostat up higher than necessary heats a room up quicker, and - leaving computers and lights on consumes less energy than turning them on and off frequently [57].

The Wattson home energy monitor is a standalone device which is designed to raise awareness of domestic energy consumption. It is an off the shelf technology which takes readings from electricity metres and displays the information as real-time energy usage data. It has a light system that provides ambient feedback as well as a numerical display that can show units like watts and pounds sterling.

Figure 1: The Wattson energy monitor from DIY Kyoto

Smart monitors such as the Wattson are increasingly common and The UK government has committed to replacing all current electricity metres with smart metres by 2020. This is no guarantee that it will happen of course, but it indicates that the availability of such devices is likely to increase.

Facebook

The social networking site Facebook now has over 250 million active users [15]. If the site were a country its population would be greater than that of Russia. Studies of Facebook have demonstrated that users read other people’s postings, play games, upload comments on photographs and add to their own ‘profile’ many times daily [55]. These sites provide a powerful means of delivering small, asynchronous applications to peer groups of likeminded real-world friends in a manageable and pleasant way. There may then be potential in leveraging the engaging power of small applications, offering rich social interactive features to change behaviour.

Feedback Studies

In recent years there have been many studies of innovative ways of displaying energy consumption. The “power aware cord” offers per-appliance feedback in the form of a glowing power cord but does not indicate energy used or cost [50]. The use of portable and stationary, minimalist direct displays for the home was investigated in another recent study [48]. This found that occupants would move around the house turning appliances on and off to monitor the change of feedback on the portable display they carried and enjoyed this playful approach (*ibid*). The Phillips iCat study used a robot with happy or sad facial expressions corresponding to low or high energy use scenarios in a lab [37]. Although the study was limited to the lab and involved the use of a very expensive robot it indicated that participants responded more positively to the playful expression of the cat rather than a bar chart [51].

The two previously discussed studies did not employ the use of any normative feedback, social or otherwise. But some work has been carried out in using social platforms to motivate people to reduce their ecological impact. Mankoff [34] proposed the use of web widgets like "badges" showing carbon footprints which could be incorporated on platforms like MySpace but the proposed implementation relied on users self-reporting their energy information.

A recent study used a large situated display to compare energy consumption between dormitories of a university campus showing expenditure by both halls and individuals. The display was only updated bi-weekly yet resulted in massive reductions in electricity and water [36]. A Facebook group was created for the study but did not have a high uptake. A Facebook group network can only be fed updates in the form of self-reported textual or static image posts with little guided or sophisticated interaction. Facebook applications provide a more personalised experience through access to the users profile, profile actions and news feed. A Facebook application displaying personal student energy usage tied into each student's unique Facebook account profile may have been more effective.

This study aimed to address a gap in current work on leveraging social platforms by embedding live, continuous energy data into a fully interactive socially-enabled energy application. Using the Facebook Developers Kit (FDK) API, Wattson devices were linked to Facebook allowing us to investigate whether sharing such information between friends might make for further reductions in energy consumption.

DESIGN PROCESS

Focus groups were conducted with a convenience sample [40] of four Facebook users aged between twenty three and thirty eight. There were three males and one female and all were responsible for paying the energy bills in their homes. Discussions took place in a home lab on campus at a university and helped the participants focus on the home as a design space. It should be noted that as the participants were students on a Masters course in HCI they were more sensitive to issues of interface design than other groups might be.

Participants were shown the Wattson monitor and a selection of YouTube videos related to energy consumption. One video featured a Wattson monitor over a period of a few minutes displaying live home energy readings, from low to high when a cooker is switched on; simultaneously, a "Nabaztag" outputs a vocal message that a lot of energy is being used at that moment and flashes its lights.

Figure 2: Watsson and Nabaztag YouTube Video

Participants commented on the comic potential of the device and the possibility of fun, playful interactions. This generated general discussions around the concept design of a socially enabled home energy monitor and what that might look like.

Pencils, coloured pens, scissors and other craft materials were also provided allowing participants to create their own interface elements.

Figure 3: Initial Sketches developed in focus group

A large number of ideas were generated and discussed. Various graphical metaphors were suggested such as a mouse running in a cage turning faster or slower depending on energy consumption, balloons with user's faces on them were pictured being inflated larger or smaller and floating higher or lower to indicate ranked consumption rates (see figure 3. There were a number of interesting suggestions. For instance: "*a digital photo frame, if you aren't using much energy then you see pictures of beautiful scenery or if you're using a lot some stark scenery, almost like a piece of art that changes over time*". Smiley and sad faces were also suggested as simple but very easily understood graphical elements (see Figure 5).

The participants were then given a paper materials pack containing various paper interface elements such as user avatar icons, energy icons and CO_2 icons to help create prototype interfaces. Plain interface template cards were added to the pack enabling the participants to place the interface elements on the blank interface templates.

Figure 4: Interface elements given to participants

Much of the discussion revolved around the difficulty of relating to the kilowatt as a unit of energy measurement. "*Kilowatts, watts, I don't want to see any of that, money yes*." There were interesting debates about whether financial representations were more powerful than ecological ones "*I'm thinking a kind of erm some form of visual presentation....you'll see more trees over time in an image if you use less energy, see trees knocked down if you use more*" There were also interesting general discussions of issues such as privacy when sharing data raising concerns such as: "*The risk of failure in front of your friends*." However it was generally agreed that introducing a competitive element between friends who were free to opt in or out of the group might help drive a reduction in consumption.

IMPLEMENTATION

Moving on from the conceptual design stage was made relatively straight forward due to the high quality of the user generated designs. Following discussions in the focus group it was decided that the main interface attributes for displaying energy would be expressed in Watts and pounds sterling as well as CO_2 emissions measured by weight. In addition to numerical representations, a graphical representation was selected to display alongside both numerical values for energy and Co2 emissions in the form of the happy/sad face theme as previously discussed.

Three core interfaces were developed to provide an engaging user experience: **My Energy, Friends** and **Rankings**. The My Energy screen would show energy consumption with a dial visualisation and a seven day history bar chart.

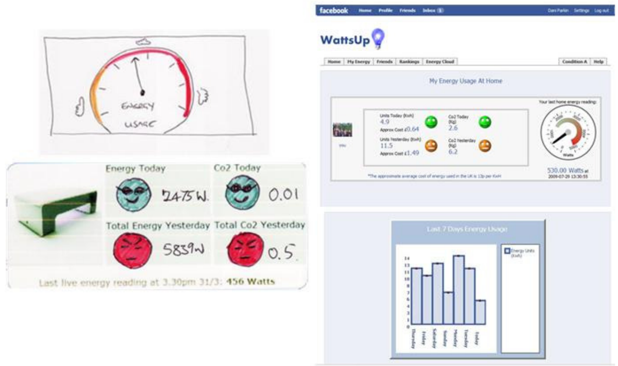

Figure 5: My Energy: Workshop sketches and final design

Sketches developed in the workshop (see the left hand side of figure 5) were developed into final designs (see the right hand side of figure 5). Workshop comments also informed the design e.g.: "*What the dials can do is give you a comparison, although they are very abstract, I can still tell if I have used loads of energy today.*" The final design then related quite directly to initial discussions.

The **Friends** screen would display personal energy consumption against selected friends.

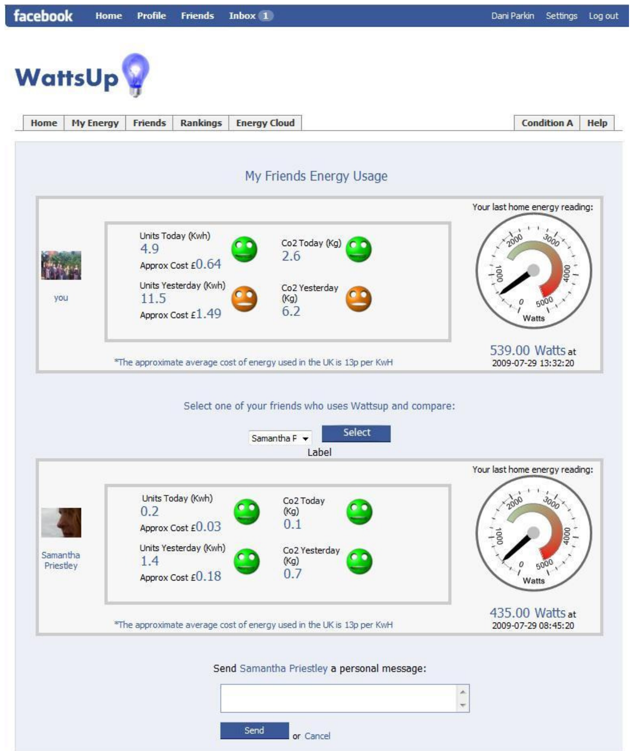

Figure 6: "Friends" screen final design

Again this final design built directly on ideas and comments from the workshop "*I can see it working amongst a group of friends, but finding a way to notify users of the group of whats happening*".

The **Rankings** screen would show a table of highest and lowest energy users of the application.

Figure 7; Rankings Screen, Initial workshops sketches and final design.

Again there was a very direct link between the final design and workshop suggestions such as "'*I thought about a leagues table based on points, slightly competitive but not with pressure and a bit where people can discuss it*'" and rough sketches such as those on the left hand side of Figure 7. The ranked pyramid of the heaviest consumers suggested in the workshop (see the bottom left hand side of Figure7) was simplified to a ranking table similar to that imagined in another workshop sketch (top left hand side of Figure 7).

Another important interface element was the integration of a comments board. The rankings table would allow users to visualise what their standing was against others but it would not facilitate friends commenting on personal or others' energy consumption. This feature was added following discussions of the importance of interacting with friends through such an application. A cloud tag feature was also added where users could note the devices they thought were high energy users.

As with any prototype design, choices were limited by time and material constraints. A number of interesting concepts were generated in the workshop which were not feasible within the scope of the project. As is well documented in the participatory design literature, the sketching process was invaluable not only in generating the final designs but also in recognizing a wider design space e.g. [6].

DEPLOYMENT

The application was developed using ASP.NET, Microsoft C#, HTML/CSS, XML, MySQL, Facebook Markup Language, and the FDK API. When completed it was deployed to the Facebook application platform.

To afford the functionality displaying live and recent energy data within a Facebook application, an elaborate application framework was designed and implemented as seen in Figure 8.

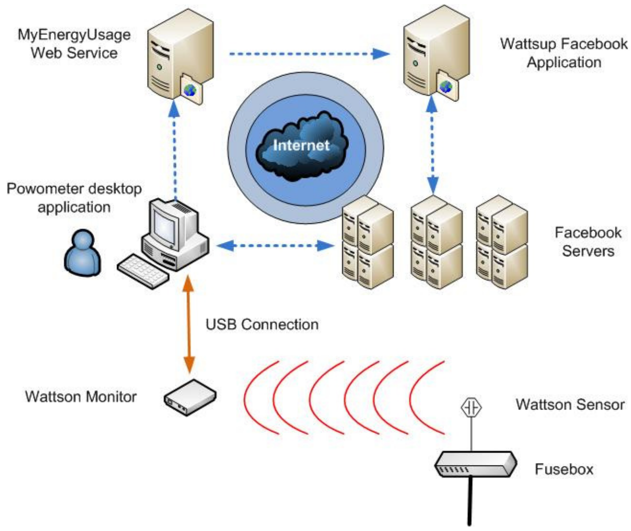

Figure 8: Technical Design Overview

The diagram illustrates the Wattson sensor at the householders fuse box sending the current energy reading by radio signal to the Wattson energy monitor which stores the data in its 30 day dedicated memory. The Wattson is physically attached to a PC via a USB cable which transports the energy data from the Wattson to the PC via the desktop "Powometer" application where it is stored in a local SQL mobile database. At configured intervals Powometer sends the stored energy data to the myenergyusage.org service via the internet where it is stored in multiple MySQL databases for redundancy. Once the energy data is stored on the myenergyusage.org databases it is then presentable to authorised applications to make use of it. The Wattsup technical design and implementation tasks were approached using Evolutionary Prototyping [38].

EXPERIMENTAL METHOD

Aim

The aim of the study was to see if energy savings could be increased by the addition of a social element to monitoring. As it is already known that monitoring can reduce energy consumption the focus was on the social element and we did not consider households without any energy monitors of any kind. To this end, we made a socially enabled version of the Wattson energy monitor via Facebook. The hypothesis was that less energy would be used whilst the Wattson was socially enabled than when it was not socially enabled.

Participants

Eight households were recruited to trial the prototype with each participant being the person responsible for paying the electricity bill. The number of participating households was limited by the number of devices available to the researchers. Selection of the participants followed a purposive sampling method [40]. The criteria for recruitment were that the lead participant in each household must be responsible for paying their household electricity bill and be a daily user of the Facebook website.

Participant	Profession	Age	No. Household Members
Diane	Nurse	26	2
Alice	Nurse	23	2
Rachael	Office Admin	49	2
Christopher	Programmer	32	2
Robert	School Teacher	41	2
David	Student	31	2
Richard	Student	20	4
Shirley	Writer	40	4

Table 1: Wattsup participant demographics

The participants were also recruited in 4 pairs who resembled one another in circumstances as much as possible. For example if a participant belonged to a family of four then another participant belonging to a family of four was recruited. In total the participants belonged to households with 6 couples and 2 families of four, so twenty people in all were involved in this study. The lead participants had all been regular users of Facebook for at least one year and were all friends who were on one another's Facebook friends list. Additional demographical information on the participants is detailed in Table 1 with pseudonyms used in place of the participant's real names.

Design

The experiment followed a within subjects design [7] with each participant taking part in two conditions or social modes. In condition A the Wattsup application was socially enabled, i.e. users could see their friends' data as well as their own, in condition B the Wattsup application was manipulated so that there were no social features i.e. users could only see their own energy usage.

The households were divided into matched groups and the conditions were counterbalanced between the groups to avoid ordering effects [7]. Group 1 started in condition A, group 2 in condition B and the groups switched conditions halfway through.

The independent variable was therefore the Facebook application's social mode, either enabled or disabled. The dependent variable was the energy used in Kilowatt Hour units with a total measurement being taken in each condition for each household.

Procedure

The experiment required hardware in the form of a Wattson energy monitor and a Windows based PC running the Powometer desktop software available from www.myenergyusage.org to collect energy data from the Wattson monitor. The Wattson monitor was installed along with the required desktop software one week before the experiment officially began. This was done to assist in reducing any effects on participants' energy usage by initially using the Wattson on its own, as it was likely to receive attention as a new gadget in the house (and, as previously noted, decrease energy consumption).

Each participant gave their informed consent and carried out the experiment in their own home. The experiment took place over a period of 18 days with 9 days in each condition. Half of the participants started in condition A with the other half starting in condition B, after 9 days the participants were sent an email through Facebook informing them of the changeover of conditions. The applications were then reprogrammed to perform in the alternative conditions with the relevant participants.

Data was collected in the Wattson device itself, a MS SQL mobile database using the installed desktop software and the myenergyusage.org web service via a MySQL database. The Google analytics service was also used to record the number of Facebook application page views for each interface.

RESULTS

The energy usage, in kWH, in both conditions for each household is summarised in Figure 9.

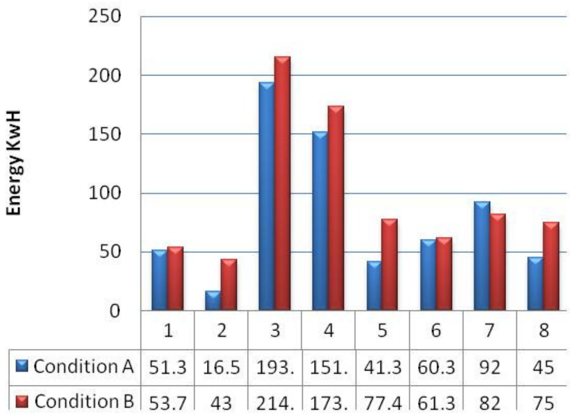

Figure 9: Wattsup participant energy usage in each condition

A Wilcoxon test, for comparing repeated measures of non-parametric data, showed that energy consumption was significantly lower when using the socially enabled application ($Z= -2.1$, $p=0.036$).

A total of 57Kw units of energy saved by the participants in condition A as opposed to condition B. This amount of energy would be expended by leaving a 60W bulb on for 4 days and result in Co_2 emissions similar to those produced by driving a medium sized car for 60 miles.

Additional data collected from Google Analytics highlighted the differences in user interaction activity between both conditions. In terms of the number of times the participants visited Wattsup, condition A was significantly more popular than condition B with a total of 263 versus 51 page views respectively. The number of visits to the Facebook application then showed a fivefold increase in the social condition. Participants spent most time on the rankings interface viewing and commenting on the rankings table. It can be assumed that participants enjoyed this feature the most due to the collective amount of page views for rankings as well as the average time spent viewing it

However with such a low number of participants it is worth exploring the result further by analysing the qualitative data collected.

QUALITATIVE DATA

In addition to the descriptive and inferential statistics qualitative data analysis was undertaken on the comments board and on semi structured interviews following the trial.

Comments board

The comments board proved to be a popular feature with participants and comments were analysed using a small scale grounded theory approach [44]. Three main categories of comment emerged: **banter, engagement** and **competition**. Banter included teasing such as "*how come you are at the top, cut down drastically on your cups of tea?*" And gloating "*good to see I'm higher in the table then you rob ha ha*" as well as provocations such as ""*energy vampire...you clearly are!!*"". This kind of banter extended to joking exchanges such as:

> Diane: "*I've turned my washing machine settings down as this uses loads...no pun intended*"
>
> Alice: "*I once turned down a washing machine. Wasn't pretty. It went into a cycle of depression and self-loathing before finally giving me my socks back*"

Engagement included disclosure of information such as "*Left my main PC on the last two nights. Made a massive difference to my scores*." And disbelief about energy usage "*gone down in the rankings? I´m in Spain :S*" Engagement could indicate enjoyment "*Woohooo, looking good today!*" but sometimes also mixed feelings of guilt and disinclination to change "*I NEED TO STOP PLAYING PUTER! (idontwanttoidontwanttoidontwantto)*".

Other comments indicated pleasure in the competitive aspect of the rankings "*Take's the top spot: D*" this seemed enjoyable even to those who were not necessarily winning "*I've been usurped*". This competitive element occasionally led to questions "*hey [name omitted] what's your secret? your energy rating is pretty good...*". Comments were made when participants moved both up and down the ranking table indicating engagement in the process throughout.

Semi-Structured Interviews

Participants took part in semi structured interviews about their experience with the study when the Wattson device was collected from their homes at the end of the study. They were asked: which condition they preferred and why, whether they had any problems using Wattsup and whether they would use it or something similar over a longer period of time.

All of the participants preferred the socially enabled condition "*I preferred the second one (socially) because I am quite competitive, it gave me further incentive. I think putting a bit of fun in it is quite important.*". All of the participants said they would be very interested in using the system over a longer period of time. With regard to problems using the device some suggested a more visual representation of Co2 emissions.

As with other energy reduction systems participants found monitoring itself quite enjoyable:

> "*Well, this morning we unplugged EVERYTHING one by one, room by room. The reading on the wattson went down by around 450 to 970 watts. Ha, we actually enjoyed investigating this though ;)*"

Although financial and ecological concerns may also be important factors this and other studies clearly indicate that fun should be taken seriously, eg [5].

DISCUSSION

One UK study claimed that sustained behavioural change with domestic energy consumption was unlikely to alter until more than 3 months had elapsed [11]. However, the energy feedback in that study was not delivered within a socially enabled context; therefore it is possible that the claim of 3 months minimum for energy usage behaviour change may not hold when a social platform is used to deliver the feedback. Due to time constraints and resources available this project could not address the experiment duration issue for sustained behaviour change. These findings then may be viewed as a pilot study potentially leading onto a larger and longer term study.

But the approach may be criticised more generally. It could be argued, for instance, that computers are part of the problem and not the solution. Part of the reason for the massive increases in domestic energy consumption is the proliferation of computers and other energy intensive devices. In 1995 29% of the UK population owned a PC, in 2006 this had more than doubled to 65% [71]. The power supply of today's computers is around 300w and growing as technology progresses, significantly more than computers of the 1990s [39]. Increasingly sophisticated components such as graphics cards and processors are using more energy with each subsequent generation.

It is difficult to find reliable figures estimating the carbon footprint of an entity like Facebook. Some estimates place the number of servers necessary as 10,000 with an additional 300,000 user PCs connected at any one time

[32, 42]. While all carbon footprint estimates are disputable the footprint of Facebook and its users is clearly large, perhaps, as some claim, the equivalent of a major city. The number of Facebook users is often compared to the populations of nations. If Facebook is a country you need a computer to live in it. Using Facebook to reduce energy consumption then may be rather like eating more pies in order to lose weight.

However there may be a value to endeavours such as this beyond an immediate and measurable net reduction of personal energy consumption. Such studies cannot help but raise awareness of energy consumption if only because of the Hawthorne effect. For ecological change to take place there must also be ideological change. This study generated a considerable amount of press interest [e.g. 45] which indicates that sustainability is now a very real concern of users. That said, the focus on individuals and personal energy consumption must not detract from larger political interventions. As Paul Dourish has argued we must raise awareness not just of the ecological consequences of leaving the lights on but the consequences of our decisions at the ballot box [13].

It has been argued that in an age of potential ecological catastrophe user centred design is no longer appropriate [e.g. 4]. The user's needs and preferences should not take precedent over the impact of their technologies on the environment. However this is to configure the user solely as a consumer. Users may also be considered as citizens. Although some scientists continue to doubt that global warming can be attributed to human activity it is clear that a great many users / citizens are now entirely persuaded and want to do something about it. The impact of our technologies is a real concern at the level of user experience. User experience is already broadly conceived in terms of social and psychological perspectives, it is becoming clear that it must be conceived in still wider terms to address the ecological challenges of the coming years.

Slavoj Zizek has argued that enjoyment is a political factor in any social structure, even, or especially if it is extremely repressive. The jokes and private satires against the party in communist states were no threat to the regime, indeed they were entirely necessary for its smooth running [49]. Lovelock has argued that if we were to take the ecological challenges that we face seriously then we would adopt systems of rationing much harsher than those of the second world war [31]. Even if the cataclysmic predictions of climate change are wrong it is clear that the way we consume energy must change. If harsh measures are to be endured then perhaps we must find ways to enjoy them.

CONCLUSION

The paper has described the design, deployment and evaluation of a Facebook application designed to allow friends to compare their domestic energy consumption.

The quantitative and qualitative analysis of the data collected from participants in this study suggests that social networking sites may be able to play a role in reducing energy consumption in the home by making monitoring more enjoyable.

This was a small scale study and only a larger investigation could conclusively determine how effective such applications may be. However, these results are encouraging. Competitive carbon counting appears to be both more enjoyable and more effective than individual monitoring.

The limits of how much any individual can achieve by changing their own lifestyles are often pointed out. But collective behaviour change even on a small scale is increasingly recognized as a key to tackling global warming. The International Energy Agency, for instance, estimate that devices on standby cause a full one percent of world greenhouse emissions, this is nearly equal to that of the entire aviation industry[46].

Social networking sites like Facebook and Twitter are increasingly being appropriated by users for political and social ends. Facebook is of course primarily for fun but it may be that the enjoyable aspects of the service make for effective platforms for persuasive technologies.

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