THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Energy Monitoring through Social Networks

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Abstract

Social networks play a significant role nowadays in changing people's behaviours. However, this is a fact of which only few of the energy monitoring system manufacturers have taken advantage. This thesis explores the use of social networking in monitoring and modifying household energy use.

The results of this study indicate that providing real-time feedback reduces the energy usage of the consumers and further reductions in energy consumption can be gained by involving the consumers in a competition to keep overall consumption down. Also, they indicated that there might be a correlation between strong affinity and social relations among members of a community and the speed of change in people's conservation behaviour.

This research contributes to a greater understanding of people's conservation behaviour. It is a part of a larger project (iDSLM project) aimed at providing techniques to better manage domestic electricity consumption without overtly affecting quality of life; this project involved developing a monitoring system on the Facebook platform to evaluate the influence of both real-time feedback and competition on changing consumers' conservation behaviour (University of Waikato, 2011-2012).

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1 Introduction

The overuse of the world's resources is threatening the environment. In fact, the electricity industry is harming the environment because a large percentage of electrical production comes from burning fossil fuels with the largest amount coming from the dirtiest source, coal ("the Power Behind our Lives," 2007-2012). Scientists and consumers alike have thus begun to worry about this alarming depletion of energy sources and to search for other power sources that do not affect the environment, such as sunlight or wind. Global warming caused by the combustion of fossil fuels has disastrous environmental consequences such as increasing temperatures, melting glaciers resulting in rising sea levels and increased flooding, hurricanes, and droughts (Socha, n.d.). Controlling power consumption is one important way to address global warming, conserve resources, and secure the future availability of energy resources (Williams, Matthews, Breton, & Brady, 2006).

A significant factor in the development and establishment of a sustainable energy system is the end-user. Household power consumption comprises about forty per cent of total energy use (Löfström & Palm, 2008). In 2007, 13 per cent of energy demand in New Zealand came from the residential sector (see Figure 1.1)(Ministry for the Environment [MfE], 2009), while in the United States in 2010, 23 per cent of total energy demand came from the residential sector (see Figure 1.2) (U.S. Energy Information Administration [EIA], 2011).

Figure 1.3 shows that although New Zealand domestic electricity demand has not grown as fast as demand in other sectors since 1975, it remains a significant component of overall consumption, at around 34 per cent of the national demand (Ministry of Economic Development [MED], 2011). The Household Energy End-use Project (HEEP) found that the average total power usage for all fuels per home was 11410 kWh/year with standard error ¼ 420 kWh/year (Isaacs, Saville-Smith, Camilleri, & Burrough, 2010). "HEEP was a multi-year, multidiscipline research project that involved detailed energy and temperature monitoring, occupant surveys and energy audits of some 400 randomly selected houses throughout the different climate regions" (Isaacs et al., 2010, p.471).

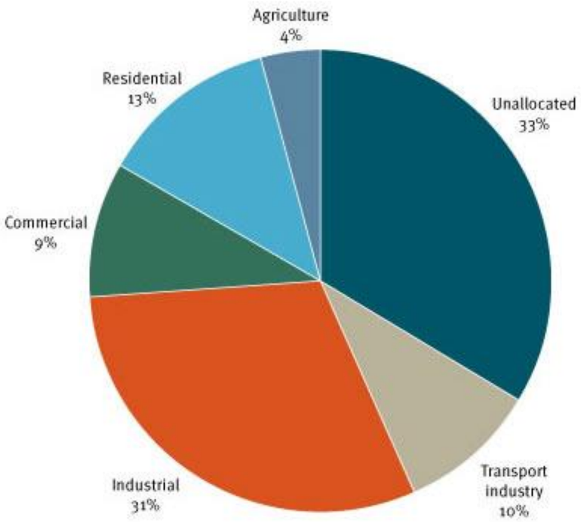

Figure 1.1: Consumer energy demand in New Zealand by sector, 2007 (Reproduced from MfE, 2009)

However, the time spent at home is likely to increase as a result of the increasing popularity of telecommuting and e-commerce (Williams et al., 2006). As a result, household power consumption will increase as well. Therefore many countries have taken actions to reduce power consumption; for example, the European Union's new energy policy (Commission of the European Communities, 2007). However, many of the political strategies for conserving electricity have failed. For example, in the United States the policies of aggressive emissions cutbacks have not affected the conservation behaviour (Holmes, 2007).

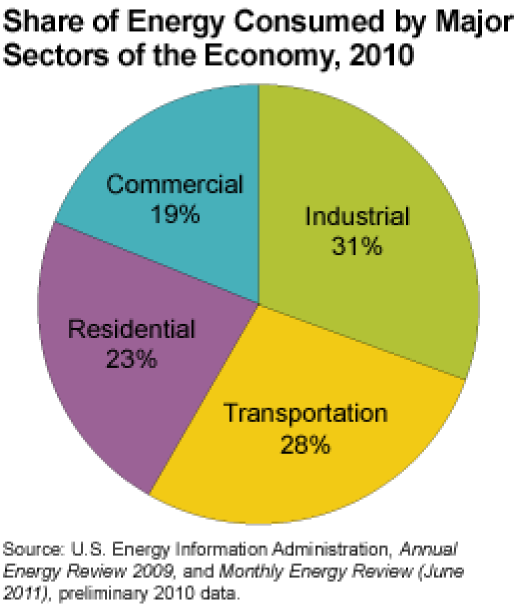

Figure 1.2: Share of energy consumed by major sectors of the economy, 2010 (Reproduced from EIA, 2011)

Increasing expenses make people think about reducing their consumption in many of the basic aspects of their lives such as fuel and electricity expenses. However, according to Weiss, Mattern, Graml, Staake, and Fleisch (2009), lack of information is a major hurdle for people who want to reduce energy consumption in their homes. Moreover, some studies (Weiss et al., 2009) have indicated that an electricity bill with monthly feedback is not sufficient for behaviour change. In order to adapt their behaviour more efficiently, users need to understand how much energy different appliances consume. Such feedback should be given to consumers to enable them to adjust their behaviour and conserve energy (Weiss et al., 2009).

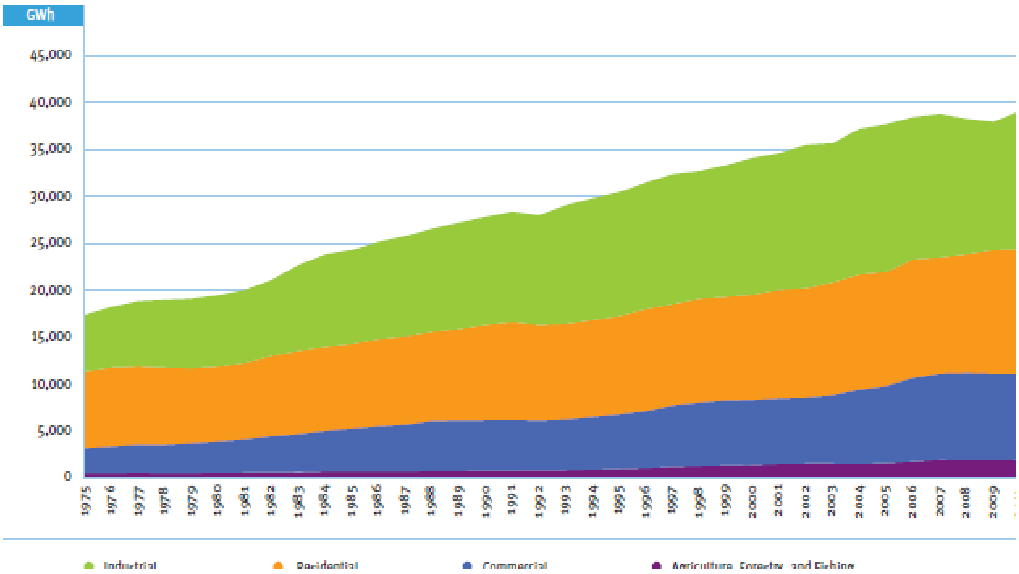

Figure 1.3: Observed Electricity Consumption in New Zealand by Sector (Reproduced from MED, 2011)

A survey reported by Abdelmohsen and Do (2008) showed that:

> "while 91.8% of U.S. homeowners are interested in increasing their home energy efficiency and expect their home heating bills to increase by 76.5%, almost half of these homeowners lack understanding of how their homes consume energy, and are not clear on which home improvement projects yield the largest energy saving benefits." (p.1)

One possible solution for monitoring electricity consumption that has been used widely in New Zealand is traditional electricity meters. These meters are usually placed outside the house or in some cases inside the garage. According to Abdelmohsen and Do (2008), homeowners tend to pay little attention to their meters because they do not provide any helpful information that might alter their consumption behaviour. Instead, they provide only an intuitive reading of power consumption status. Electricity use is represented by the moving speed of the dial, so the more kilowatts of energy are being consumed, the faster it moves.

Furthermore, the consumption of individual home appliance cannot be determined from these meters. Therefore the consumers cannot see what is on or what appliance is consuming more. The information provided by this type of meter does not offer homeowners real-time awareness of their usage nor a chance to adjust their behaviour patterns (Abdelmohsen & Do, 2008). Television, radio and print media have lost the interest of many people, particularly youth, as their interests have shifted to the internet where they spend much of their free time. "As different demographic groups become active via the plethora of mobile and Internet-based applications, social media is emerging as another powerful tool for behaviour change" (Beachy, 2009). According to Löfström and Palm (2008), behaviour changes can reduce total energy use by at least 10 per cent. "Recent projects are also showing that possibility of up to a 15-20 per cent reduction in energy use by behaviour change concerning lighting alone" (Löfström & Palm, 2008, p.1). Additionally, supplying consumers with detailed and immediate feedback is generally expected to result in a reduction in household energy consumption of between 5 and 15 per cent (Weiss et al., 2009). Therefore more actively informing end-users about their electricity consumption may raise their awareness and help them better manage their consumption (Löfström & Palm, 2008).

This thesis describes the development of an experimental setup for carrying out user evaluations of the effectiveness of providing real-time feedback and involving consumers in a competition to keep overall consumption down and reducing the energy usage of the consumers. Some of the materials from an earlier COMP591 project (Alrowaily, 2010) were used in this report. Chapter 2 first reviews previous work in the area and discusses some of the technology currently available. Chapter 3 then presents the hypothesis and the system design of this study. The development of our system is described in the system implementation chapter, Chapter 4. The actual experiment is described in Chapter 5, and the results are presented in Chapter 6 and discussed in Chapter 7. Chapter 8 then examines the implications of these results and makes suggestions for further work in the area.

2 Background

Modifying people's behaviours is not an easy task and in order to succeed in that we need more understanding about those behaviours. In particular, we need to gain more understanding about how they intend to use energy and what could help them to change their habits which affect their energy behaviours negatively.

One of the important determinants of the pattern of energy use was consistently found to be income; however it is not of the power conservation behaviour in reaction to feedback (Brandon & Lewis, 1999; Heslop, Moran & Cousineau 1981; Matsukawa, 2004 as cited in Allen & Janda, 2006). The possible reason for this may be because a further reduction cannot be made by low-income consumers in their energy use as they are unable to do that any further and one-time efficiency improvements are preferred by the high-income consumers rather than changing their energy usage habits (Cunningham & Joseph, 1978 as cited in Allen & Janda, 2006).

The concern about the environment could motivate some people to conserve energy. However, previous studies have shown some incompatibility between the claims of some people about their environmental concern and their own energy use (McMakin, Malone, & Lundgren, 2002). In some cases, strong conservation views were expressed by consumers who stated that they take a large number of conservation actions; however, the data measurement of their energy consumption indicated that these statements were to some extent exaggerated (McDougall, Claxton, Ritchie, & Anderson, 1981 as cited in McMakin et al., 2002).

In this chapter, the energy behaviour will be highlighted as well as some of the factors that could influence consumers' behaviour positively to conserve more energy; factors such as technical feedback and social comparison and competition factors. Additionally, some of the available hardware and the software technology for monitoring the energy use will be identified.

2.1 Energy Behaviour

Behaviour is defined by Oxford Dictionaries as "the way in which an animal or person behaves in response to a particular situation or stimulus." Since this definition of behaviour is wide, it is essential to identify what is meant by behaviour(s) in the context of this study and how these could possibly be categorised. In the context of this study, energy using behaviour(s) are defined as electricity and gas use in the home such as using electrical appliances including televisions, microwaves, dishwashers and personal electronics. Using lighting and setting the thermostat level are also included. Therefore, all actions in the home which have direct associations to gas or electricity which is being consumed at the point of usage are defined as energy consuming behaviours (Martiskainen, 2008). Becker, Seligman, Fazio, and Darley (1981) concluded that energy consumption is not a behaviour in itself, but rather a consequence of behaviours. It has been suggested by previous research that household energy conserving behaviours could be divided in the following two groups: efficiency and curtailment (see Table 2.1).

Table 2.1: Types of household energy saving behaviours (Reproduced from Abrahamse et al., 2005; Dwyer et al., 1993 as cited in Martiskainen, 2008)

Behaviour type	Examples
Efficiency	One-shot behaviours – Investment • loft insulation • cavity wall insulation • Double-glazing
Curtailment	Repetitive efforts – Operational • Turning lights off • Closing curtains • Turning appliances off

Abrahamse, Steg, Vlek, and Rothengatter (2005) found that there is a lack of evidence on whether curtailment or efficiency behaviours are more effective in producing energy savings. It has been argued by some researchers that actual behavioural changes are initiated by curtailment behaviours which can possibly be sustained for long-term (Martiskainen, 2008). However, it has been suggested by recent research that actual and larger energy savings are obtained more effectively by efficiency behaviours (Abrahamse et al., 2005).

Energy behaviours are affected by some internal aspects such as attitudes, beliefs and norms and external aspects such as cultural practices, regulations, institutions (Jackson, 2005). Both aspects influence behaviour and must be considered in order to modify consumer behaviours related to the environment (Gärling et al., 2002). Habits and routines are also part of our behaviour, they are the actions undertaken by people naturally without thought and these are particularly relevant to domestic energy use. In fact, habits and routines are the base of many of the behaviours related to domestic energy use, such as using appliances (e.g. boiling the kettle, using the washing machine) and heating systems (setting the thermostat level) (Martiskainen, 2008). Before being replaced, the old habits and routines need to be fragmented and then new habits and routine behaviours can be formed (Stern, 2000). However, as habits and routines are ingrained in people's behaviour, it can be very difficult to break them. Therefore, it can be challenging to choose the best actions for encouraging a behavioural change in domestic power use (Martiskainen, 2008).

When intrinsic behaviour controls are supported by feedback, constant savings will happen. That is, when new habits are developed by individuals and when controls have acted as an incentive for investment in efficiency measures. Additional help may be needed for consumers to change their energy habits and this is where well-considered power counsel can be applied. The behaviour change that is achieved from providing feedback in conjunction with incentives to save energy is likely to vanish when the incentive is gone (Darby, 2006).

The relationship between attitudes and the power usage behaviour of the users has been examined in the context of feedback effectiveness recently by Naesje, Andersen and Saele (2005 as cited in Allen & Janda, 2006)**.** Their study concluded that while some incentives may be essential to motivate power conserving attitudes, some other incentives are obviously wasted on consumers with non-power conserving attitudes. It has been suggested by previous studies that rewarding individual behaviour may not motivate consumers to make any reduction in their energy consumption (McCalley, 2003 as cited in Yim, 2011).

2.1.1 Feedback

The lack of handy feedback on electricity consumption indicates the need for a solution that provides the consumers with helpful and immediate feedback that will increase their awareness about their consumption. While monthly utility bills are the only feedback source on home electricity use for most people, its form remains a black box. This limits the user's options for reducing electricity consumption, thus making it a difficult task (Williams et al., 2006). Oxford Dictionaries (n.d.) defines "Feedback:[as] information about reactions to a product, a person's performance of a task, etc. which is used as a basis for improvement."

A typical range of energy savings from providing feedback of 10-15 per cent was suggested by recent evaluations in Canada and Japan (Parker, Hoak, Meier, & Brown, 2006). There are a number of different types of feedback, for example direct, indirect and historic feedbacks. The direct feedback, which is immediate feedback that comes from the meter directly or from a linked display monitor, can save, on average, from 5-15 per cent. Other existing studies show that providing direct, immediate feedback on household electrical demand can decrease energy consumption by 10-15 per cent, while indirect feedback ,which is feedback that has been processed before it reaches the consumers, can save from 0-10 per cent. Additionally, historic feedback, where previous captured periods of the users' energy consumption can be used for comparison, seems to have a greater influence than comparative or normative feedback where the comparison is running against other households, or with a target figure (Darby, 2006).

It has been emphasised by some researchers that one part of a learning process is feedback, where people represent the information processing system who vigorously make sense of the world around them (Ellis & Gaskell, 1978 as cited in Darby, 2006). An assumption based on theory and field research is that a better understanding of the patterns of energy use and the ability for changing them effectively would gain by exposing detailed and/or frequent information to residential consumers about their usage (Darby 2000; Van Raaij & Verhallen, 1983).

2.1.1.1 Real-Time Feedback

The first examination of the real-time energy feedback was by McClelland and Cook (1979 as cited in Allen & Janda, 2006). They found an average reduction of 12 per cent of residences with real-time energy use feedback compared with their neighbours without monitors (Allen & Janda, 2006). "A number of studies conclude that sophisticated utility meters and computers that display and analyse real-time electricity consumption in an easily accessible place within a residence can stimulate energy conservation" (Darby, 2000; Brandon and Lewis, 1999; Roberts and Baker, 2003 as cited in Petersen, Shunturov, Janda, Platt, & Weinberger, 2007, p.19-20). Darby (2000 as cited in Parker et al., 2006) suggested an average reduction of between 10 and 15 per cent in overall energy based on a compilation of available data on real-time feedback studies.

Anderson and White (2009) indicated that their participants learned rapidly about the differences in energy usage of the appliances in their households as a positive effect of providing real-time energy feedback on energy-related knowledge and behaviour. They suggested that their participants "were often aghast at what they found and, in most cases, this led to specific actions to reduce energy…such as changing light bulbs, or changes in on-going behaviour, such as only filling the kettle with the water that is needed" (Anderson & White, 2009, p.9). Real-time feedback has been shown by recent studies as a powerful stimulating factor for behavioural change when coupled with competition (Petersen et al., 2005 as cited in Allen & Janda, 2006) and visual displays (Matsukawa, 2004; Petersen et al., 2005; Ueno et al., 2006 as cited in Allen & Janda, 2006). Nine Japanese households were involved in a micro-level study conducted by Ueno, Sano, Saeki, and Tsuji, (2006). The participants were provided with a visualisation of their power consumption, divided into different end-uses. The prices of electricity, historic power consumption and previous bills were included in the computer display. As a result of installing the monitoring system, a reduction in power consumption by 9 per cent was noted. Also a reduction in using both displayed and non-displayed appliances by the monitor was caused by the increased knowledge about energy-saving behaviours (Allen & Janda, 2006).

However, few large scale research studies on the effects of the real-time energy feedback exist. One of them, conducted in Canada by Ontario Hydro, (Dobson & Griffin, 1992) concluded that displaying real-time energy feedback in 25 Canadian households resulted in overall reduction of 13 per cent of their energy consumption, which largely continued even after removing the devices. It is well-known that the reduction of energy consumption cannot be guaranteed by providing only technical and physical improvements in housing. It can easily differ between "identical homes, even those designed to be low-energy dwellings, can easily differ by a factor of two or more depending on the behaviour of the inhabitants" (Sonderegger 1978; Curtis 1992-93; Keesee, 2005 as cited in Darby, 2006, p.5).

2.1.2 Social factors

Creating social norms through information-based programs instead of monetary incentives was suggested by other studies as possibly leading to positive results (Schultz 1999; Cialdini, 2004 as cited in Yim, 2011). Neighbourhood use information has been included by a few pilot utilities programs in the monthly energy statement for consumers as decreasing energy use through social comparison e.g. "OPOWER company provide a software platform to utilities to generate such a monthly statement" (Allcot, 2010 as cited in Yim, 2011, p.2).

An assessment of the total effort level by aligning incentives with group outcome has been shown by literature in a large scale on group-based competition or tournaments (Yim, 2011). For example, Erev, Bornstein, and Galili (1993) found that a reduction on free riding in social dilemma and an increase of total effort levels has been shown by evidence from experimental and field studies on intergroup competition. Yim (2011) found that strong affinity among members of a community, such as in a Greek community, has a positive influence in reducing energy consumption, whereas in North Campus resident halls, energy consumption increased. Additionally, he found that social competition can be an effective approach to decrease energy consumption behaviour of students in the dorms each year. Also, he found that employing social incentives in engaging students can be more effective than monetary prizes. A first order evidence was provided by Yim's findings that monitoring and incentive based competitions are successful in producing energy reduction behaviour.

2.1.2.1 Social networks

The numbers of users of social networking websites such as Tweeter and Facebook have grown dramatically in a short period of time (Foster, Blythe, Lawson, & Doughty, 2009). According to Facebook (2012), it has currently more than 800 million active users. Additionally, more than 50 per cent of Facebook active users log on daily. The average number of friends that user has is 130 friends, the average number of community pages, groups and events that user is connected to is 80. Moreover, the numbers of objects that people interact with such as pages, groups, events and community pages are more than 900 million objects. Oxford Dictionaries defines “Social network: [as] a dedicated website or other application which enables users to communicate with each other by posting information, comments, messages, images, etc.." (n.d.).

Development tools such as Facebook Platform and OpenSocial, which are available for free make it possible for small software applications to be widely spread to huge numbers of users in a viral style (Foster et al., 2009). In addition, on average, 20 million photos and apps are uploaded and installed daily, respectively. Lastly, while there are more than 7 million apps and websites integrated with Facebook, there are more than 500 million people using those apps or experience Facebook Platform on other websites (Facebook, 2012). Some of the minor applications on Facebook were very popular and widely used by a large number of people and that indicates that people are keen to spend some time daily in interacting with the applications they install as well as providing some recommendations to their friends about these applications (Foster et al., 2009). Those previous statistics about the number of Facebook active users and their social connectivity indicate that persuasive applications can be delivered by a very powerful platform such as Facebook and that has been suggested by a number of researchers applications such as Mankoff, Matthews, Fussell, and Johnson (2007) and Nazir, Raza, and Chuah (2008). However, more exploration is still needed in this area for evaluating applications in an academic context for this purpose (Foster et al., 2009).

Social psychology can provide some answers about the powerful motivators in behaviour change which can be obtained by social platforms such as Facebook. Voluntarily, people are able to join Facebook and install apps to their Facebook profile. Providing the users with their own online networks of their selected friends is the core functionality of Facebook (Foster et al., 2009). According to Foster et al.:

> "There is likely to be more attitudinal change between friends when the friendship attributes of familiarity and attractiveness of other friend's qualities are present. Very recent investigations of Facebook have produced a series of named patterns that attempt to spread persuasive behaviour by embedding them in applications." (p. 2)

Some of the existing features of the Facebook platform, such as the friend selector and messaging features, may use these patterns for mitigating the distribution of an app through a social network in a viral style. "One such pattern is called 'Provoke and Retaliate' where one friend can take action on another friend, for example by sending a virtual gift or a graphical representation of encouragement" (Foster et al., 2009, p. 2). Then reciprocity will be applied because the receiver feels that being among friends makes them socially obligated to respond to the sender. By employing this notion, it can be assumed that reciprocal interaction can be applied by a power monitoring system where energy information can be shared between friends (Foster et al., 2009).

Another persuasive factor is cognitive dissonance. It is defined as "the state of having inconsistent thoughts, beliefs, or attitudes, especially as relating to behavioural decisions and attitude change" (Oxford Dictionaries, n.d.). Foster et al. (2009) expressed this term in the energy awareness attitude context as a person having two inconsistent beliefs such as knowing that (i) his/her power usage is having a negative effect on the environment, but also (ii) constantly keeping some appliances on even when there is no one at home.

Cognitive dissonance can be prompted by these conflicting notions. Creating more awareness could help to reduce the conflict. Therefore, people's behaviour and attitude can be changed. The behaviour that needs to be changed in this case is to prevent keeping the unused appliances on in order to align with their belief of power usage having a bad effect (Foster et al., 2009).

2.2 Technology Available

Several devices and supported applications for those devices have been developed to monitor household electricity consumption, and they can be divided into two groups. Some of them will be reviewed in this section. The first group is the hardware equipment used to monitor either the whole-of-house consumption or the individual appliance level. The second group is the applications that can be used to process the data coming from the energy monitoring devices and represent them either online or offline. Both are relevant to this project, which investigates both the hardware and software solutions.

2.2.1 Hardware solutions

A number of commercial solutions have been developed in the first category and they can be divided to two subcategories. The first focuses on visualising whole-of-house consumption, and the second allows monitoring at the individual appliance level (Weiss et al., 2009).

2.2.1.1 Solutions for monitoring whole of house consumption

Once the devices of this type are installed, they visualise the total energy consumption of the household on a central or portable display. However, these systems do not provide feedback on the energy consumption of single device (Weiss et al., 2009). Some of the most promising devices will be highlighted in this section. One of these devices, ‘Wattson’, (Figure 2.1) was listed among the top 10 gadgets of 2007 by *Stuff Magazine* (Viteri, 2008). Both direct and ambient feedback is integrated by Wattson to provide real-time feedback on total power use within the household (Pierce, Odom, & Blevis, 2008). The technology involves a transmitter device attached to the consumer's electricity meter and the freestanding Wattson device, which displays both numbers and colours to show much power homeowners are consuming (Viteri, 2008). As explained on the designers' website, "When there's a purple glow, you're using the average for your home. And when they're red, you're using more electricity than usual" ("How Wattson works," n.d.). Additionally, Wattson's LED display can show electricity use in different types of currency such as euro, dollar, yen or pound along with the colour representation to illustrate the amount of energy being consumed in real time.

Figure 2.1: Wattson (Reproduced from "How Wattson works," n.d.)

In addition, it is portable and can keep a record of power use for up to four weeks, which can be downloaded and used for analysis with software that is included (Viteri, 2008). Some studies have indicated that using real-time portable energy displays similar to the Wattson or Eco-Eye can reduce home electricity consumption by about 10 per cent (Pierce et al., 2008).

Another solution of the same type is the Onzo. The amount of data gathered, processed, and analysed can be increased by applying both Onzo's hardware and software. Combining both the hardware and software solutions can be effective; however, they can also work separately. The data are captured by Onzo's self-powered energy sensor, which is easy for customers to attach to meter tails, if available (Onzo, n.d.).

Figure 2.2: Touchpoints of Onzo (Reproduced from Onzo, n.d.)

Energy sensor data are retrieved by connecting the display to a computer with a USB cable. The touchpoints of Onzo (Figure 2.2) include its energy displays and website. The display provides simple and coherent information. In order to help consumers make decisions about their electricity use and change their behaviour, the data are stored and interpreted by the display device, using advanced learning logic. Smart bills and mobile apps can be provided by Onzo as two further consumer touchpoints (Onzo, n.d.).

Another existing device for monitoring total household electricity consumption is the PowerCost Monitor (Figure 2.3). According to the PowerCostMonitor website, many people from the United States and Canada depend on this device to save money on their electricity bill. At a glance, consumers can determine how much electricity their homes are using at any given time and in total. The monitor includes two components: a sensor unit and a display device. The sensor unit can be easily attached to the outside of the consumer’s electric utility meter. Once the sensor has been installed, the amount of electricity consumed in the household is read and transmitted wirelessly in real time to the display device located inside the home ("Power Cost Monitor," n.d.). The PowerCost Monitor display receives the data wirelessly with a range of up to 100ft. from the sensor unit. It provides important feedback such as the amount of electricity usage in real time, the cost of electricity as it is consumed, and the peak of energy usage in a 24-hour period.

Figure 2.3: PowerCost Monitor (Reproduced from "Power Cost Monitor," n.d.)

The display device has two different indicators: the battery indicator, which shows consumers when their battery power is low, and the signal indicator, which shows consumers the signal strength of the sensor unit ("Power Cost Monitor," n.d.).

Another solution available for monitoring the whole house energy consumption is CurrentCost ENVI Energy Monitor (Figure 2.4). It was designed by Current Cost. Information about the homeowners' electricity usages is provided through a wireless display panel by attaching the system to the house's electricity supply. The ENVI Energy Monitor consists of a sensor, a transmitter and a display unit. In order to install the system, the homeowners need to clamp the sensor around their live electricity feed (usually the cable coming out of the electricity meter in the house) and to connect the other end to the transmitter. Then all the data regarding the homeowners' energy usage will be sent by this transmitter to the wireless display unit, which allows homeowners to track their energy consumption up to 30 meters away from it (EnviroGadget, 2010). Many details regarding the homeowners' electricity usage are provided by the display unit. For example, it notifies the homeowners of the cost of the current electricity drain. The information can be provided in graph form by the display unit showing night, day and evening consumption. Additionally, the homeowners can be informed by the display about how this information differs to previous consumption and also stored information can be used to estimate daily, weekly and monthly consumption and costs (EnviroGadget, 2010).

Figure 2.4: Current Cost ENVI Energy Monitor (Reproduced from Smarter Products, n.d.)

The energy usage of individual appliances can also be shown by the ENVI Energy Monitor system and it can track up to nine individual appliances. Individual appliance modules (IAMs) are required for this function. They need to be plugged in the wall socket and have the appliance to be monitored plugged into them (EnviroGadget, 2010).

2.2.1.2 Solutions for monitoring the consumption of individual appliances

There are a number of commercial products available that provide feedback on the level of individual appliance consumption, mostly smart power outlets (Weiss et al., 2009). One of these devices is called Kill-A-Watt (KAW), manufactured by P3 International (Lipsett, 2003). The device, which acts as a meter, is placed between the item using the power and the power source, like a typical wall outlet. The LCD screen five rubberised buttons which are used to determine which of the information the KAW has collected to show: Volt/Amp, Watt/VA (Vrms Arms), Hz/PF (Power Factor), or KWH/Hour. To start using the device, it needs to be simply plugged into a wall socket and then the electronic device also needs to be plugged. According to the package documentation, all meter readings (volts, current, watts, frequency, power factor, and VA) will be displayed by the LCD of the Kill-A-Watt. KWH and power duration (in hours) will be recorded by the unit after power is applied (Lipsett, 2003).

Another device of this type is called the Energy Puppet interface, now a working prototype. Different modes of energy consumption with peripheral awareness for a single home appliance are displayed by the Energy Puppet. The coming data is assumed to be coming from a home appliance (e.g. microwave, refrigerator, etc.) using a 'kill-a-watt EZ electricity usage monitor' device. Manually, homeowners can monitor a kill-a watt device for a long period of time to record the maximum and minimum energy usage for the specific appliance plugged into the device. The data is presented by the Energy Puppet in a way that makes homeowners aware of the energy usage instead of having to continuously follow the consumption rates. The data is translated from the device by an analog potentiometer (Abdelmohsen & Do, 2008). The Energy Puppet interface shows different behaviour according to levels of energy consumption. The Energy Puppet consists of two eyes, two arms, and a mouth. The LED lights in the eyes change colour according to different consumption rates. When electricity consumption for a specific appliance is within normal ranges, a green light will glow from the device's eyes, and its arms will be raised. The device represents medium-range usage with blue eyes and somewhat lowered arms. When the Puppet's eyes glow red and roar with sound and its arms are lowered, electricity consumption has become too high (Abdelmohsen & Do, 2008).

2.2.2 Software solutions

There are a number of applications available and they can be divided into two subgroups: web-based applications and desktop applications.

2.2.2.1 Web-based applications

One of the web-based applications that has been developed for the Facebook users is Wattsup application (Figure 2.5). "Wattsup is an innovative application which displays live autonomously logged data from the Wattson energy monitor, allowing users to compare domestic energy consumption on Facebook" (Foster, Lawson, Blythe, & Cairns, 2010, p.1). Foster et al. (2010) were trying 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" (p.3). Additionally, they used the Facebook Developers Kit (FDK)

API to link Wattson devices to Facebook to investigate whether further reductions in energy consumption can be gained by sharing such information between friends. There are three core interfaces in the WattsUp application: My Energy, Friends, and Rankings.

Figure 2.5: WattsUp application (Reproduced from Foster et al., 2010)

The energy consumption is shown by the energy screen with a dial representation and a history bar chart for a week. Additionally, the comparison data is displayed by the Friends screen where users can view their personal energy consumption against that of selected friends. The Rankings screen presents the highest and lowest of the application's energy users in a table (Foster et al., 2010). It has been suggested by Foster et al. that employing a social platform to provide feedback would quickly drive a change in energy using behaviour, even though some previous studies indicated that the minimum period for energy using behaviour change is three months. Foster et al. also suggested that social networking sites can play a key role in decreasing power usage in the household by making the monitoring experience more enjoyable.

Another web-based application for monitoring the energy consumption was developed called Google PowerMeter (Figure 2.6). It was launched on October 5, 2009 as a free energy monitoring tool for raising people's awareness about the importance of getting access to their energy information via smart metering (Google, n.d.).

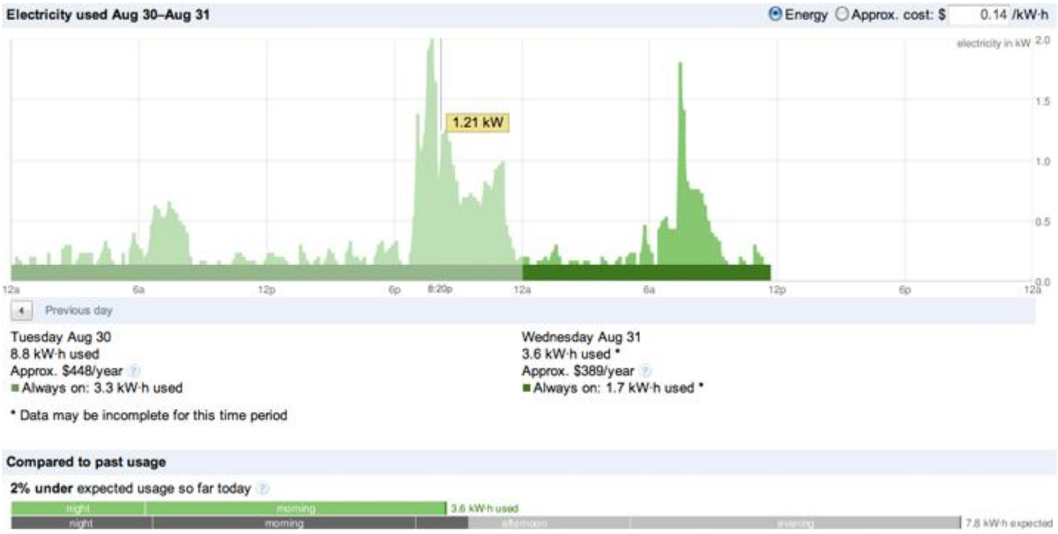

Figure 2.6: Google PowerMeter (Reproduced from Google, n.d.)

Additionally, some of the key features included by Google PowerMeter are, visualising users' energy usage, sharing information with others, and personalising recommendations to save energy. Fortunately, many device manufacturers and utilities around the world, such as Current Cost, are partnered with Google PowerMeter (Google, n.d.). In addition, Google PowerMeter could help to raise the perception property owners of their power consumption and use electricity more efficiently (Verne & Ryan, 2009). In fact, the captured data can be streamed immediately (low latency for the consumer); however, it is currently limited to uploads at 10 minute intervals. Unfortunately, it has been fully retired since Sept 16, 2011 ("Google PowerMeter API," n.d.).

Lastly, another web-based application for monitoring the energy consumption is Energy Tracking Analytics (Figure 2.7). "Energy Tracking Analytics is a web based modular application that provides real time access to current and historical energy usage data for analysis anytime, anywhere via the Internet using a web browser" (Energy Tracking, 2005-2011).

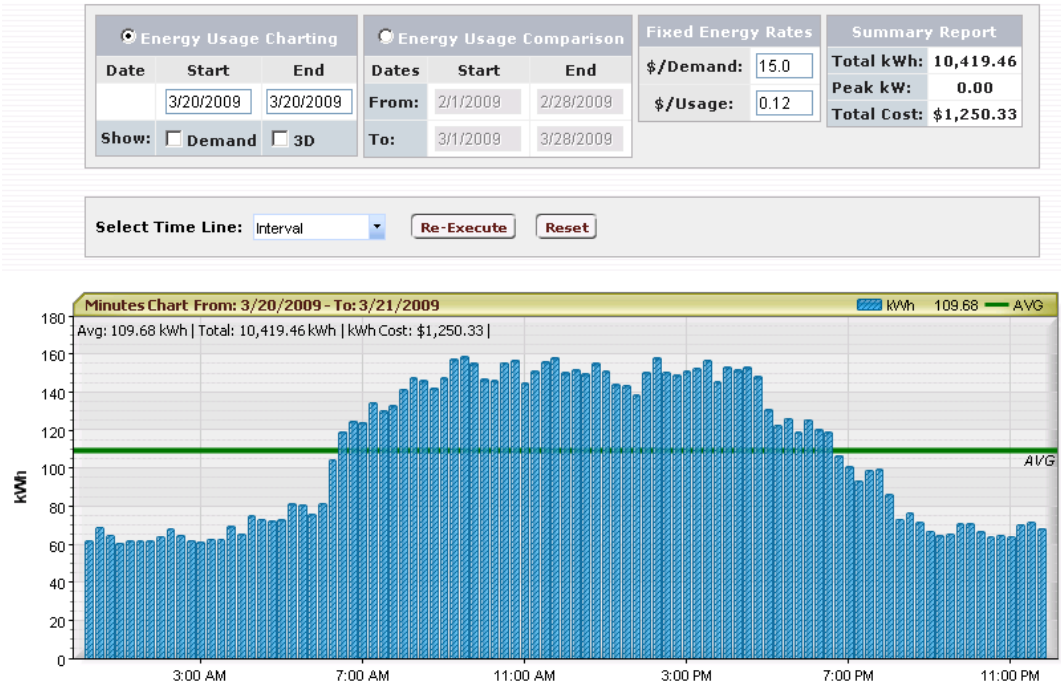

Figure 2.7: Energy Tracking Analytics - Interval Data Graph (Reproduced from Energy Tracking, 2005-2011)

Any time series data and power resources, such as electric, wind and oil can be used by Energy Tracking Analytics. It includes a number of features e.g., consumption and demand reporting, energy usage comparison and drill down capability with identification of peak usage and demand. It can also show exactly where, when and how much energy people's facilities have consumed and aid in energy management. Additionally, users are allowed to create tariffs and generate a bill (Energy Tracking, 2005-2011).

1 of 1 | 3 Items | 10 /Page | Go

Start Date	End Date	Tariff Description	Schedule Description	Demand Cost	Usage Cost	PDV Cost	Total Cost	Process Date
3/1/2009	3/15/2009	Weekdays: tou tariff Saturdays: tou tariff Sundays: tou tariff Holidays: tou tariff	Sked # 1	$2,542,367.30	$851,032.80	$41.00	$3,393,441.10	3/12/2009

Figure 2.8: Energy Tracking Analytics - Tariff & Billing (Reproduced from Energy Tracking, 2005-2011)

2.2.2.2 Desktop Applications

Some people are more confident in dealing with applications and store the data in their local storage more frequently than dealing with a web-based application where their data will be available to them online. Numbers of applications can be used to help homeowners for monitoring and analysing their home energy data.

One of those applications is called Energy@DeskTop (Figure 2.9). Energy@DeskTop is an “advanced and powerful application that presents real-time energy data from our meters and loggers” (Energy Tracking, 2005-2011). Energy usage data is displayed and stored by Energy@DeskTop software in a local database for later analysis. It is a application suitable for power management and a unique customization for charts, grids, names and colours which can all be changed to suit users’ needs. Also it is suitable for those for whom looking for low volume applications where sharing data is not required. The load profile, consumption and demand data is transmitted by its energy measurement meters via email. It is also can be sent via FTP from each meter. The load profile information presents in the form of a spreadsheet and the data of the last 24 hours is presented as chart immediately upon data being received via email or FTP (Energy Tracking, 2005-2011).

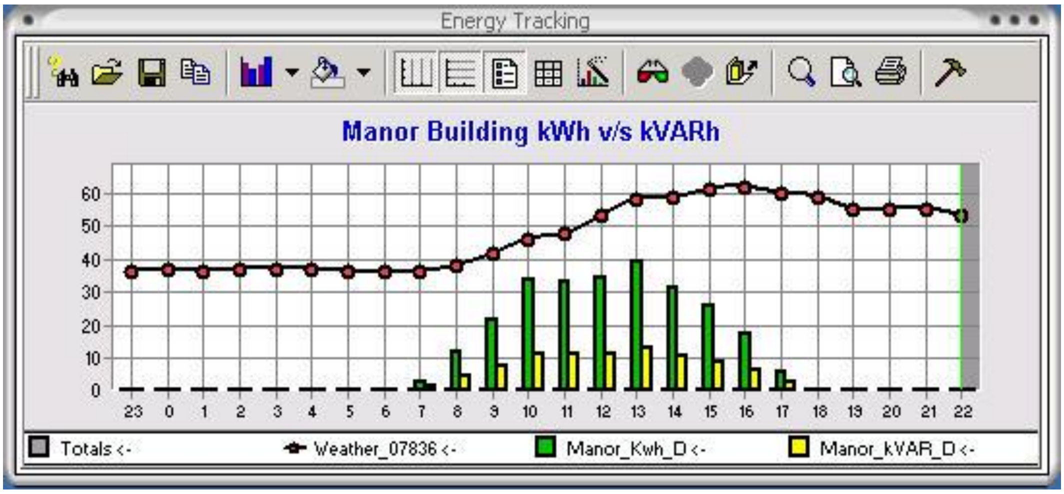

Figure 2.9: Energy@DeskTop Software (Reproduced from Energy Tracking, 2005-2011)

Another application displaying real-time information as well as historical data is called Techtoniq Energy Station (Figure 2.10). “Techtoniq is an independent software vendor and IT consultancy specialising in developing bespoke and off-the-shelf solutions for Microsoft Windows, with particular expertise in the field of real-time data” (Techtoniq, 2009-2011). The cost of the license for this application is around €9. It shows live information from the Current Cost device. Additionally, all Current Cost devices, including the US version, are supported.

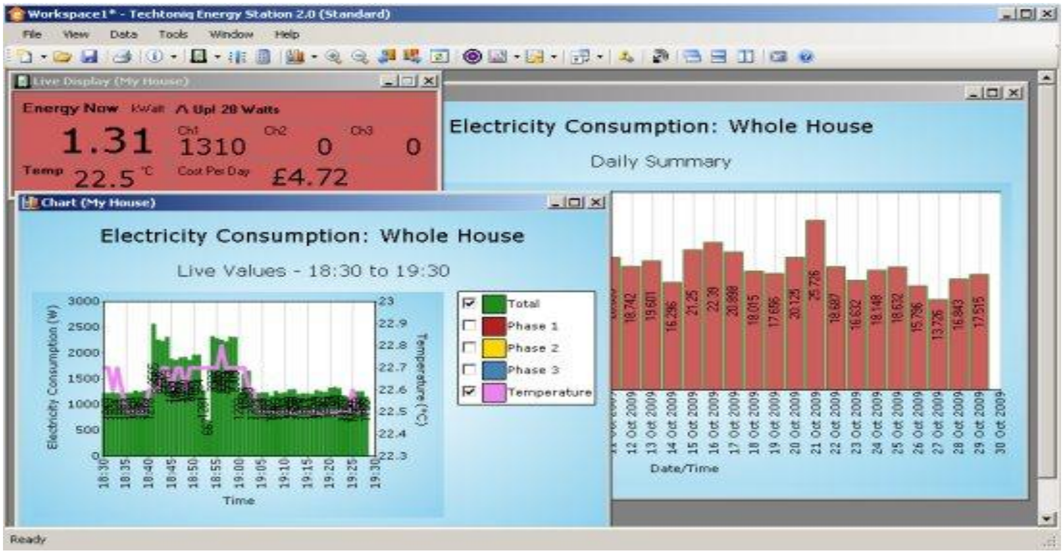

Figure 2.10: Techtoniq Energy Station application (Reproduced from Techtoniq, 2009-2011)

Representations, such as live display, live chart, historic charts, usage analysis and cost analysis, are displayed in the application. It also includes an alerting system which allows the set up any number of alerts monitoring the status of either the whole house appliance or any of the individual appliances, and when the alert condition is met, it passes an alert to one or more destinations. Currently the alerting system is capable of sending an alert to Twitter and FTP. However, they are working on supporting more destinations such as Email, SMS and Pachube (Techtoniq, 2009-2011). "Pachube is a realtime data infrastructure platform for the Internet of Things, managing millions of datapoints per day from thousands of individuals, organisations & companies around the world" (Pachube, 2008).

2.3 Summary

Allen & Janda (2006), Darby (2000), Anderson & White (2009), Weiss et al. (2009), and Dobson & Griffin (1992) found that the real-time energy use feedback results in a reduction in household energy consumption of between 5 to 15 per cent. Additionally, Yim (2011) found that a strong affinity among members of a community, such as in Greece, has a positive influence in reducing energy consumption, whereas in a North Campus resident halls, energy consumption increased. He found also that social competition can be an effective approach to decrease energy consumption behaviour of students in the dorms each year (Yim, 2011).

The work most relevant to this project is the CurrentCost ENVI Energy Monitor and Wattsup application. The bridge available of the CurrentCost ENVI Energy Monitor can be programmed to redirect the capture data to any destination, while the Wattsup application which has been developed for the Facebook users examined similar elements of this project such as employing social networks to motivate people to conserve more energy.

3 Hypothesis and System Design

This chapter presents the research hypothesis and the design stages of the system.

3.1 Hypothesis

As mentioned earlier, real-time feedback has been shown by recent studies to be a powerful stimulating factor for behavioural change when coupled with competition (Petersen et al. 2005) and visual displays (Matsukawa 2004; Petersen et al. 2005; Ueno et al., 2006 as cited in Allen & Janda, 2006).Therefore, we believe that providing real-time feedback will reduce the energy usage of the consumers. Further reductions in energy consumption can be gained by involving consumers in a competition to keep overall consumption down.

3.2 System Design

This part of the thesis describes the design stages of the system.

3.2.1 Scenario

Saeed is a student who lives in a two bedroom apartment with a flatmate. One day, Saeed received his bill from his electricity provider and when he opened the mail: he was shocked! The bill was over $400. He thought that the monthly bill was not enough for him to keep an eye on his electricity usage. While surfing Facebook, he found an app which could help him to track his electricity usage. He added that app and requested the equipment. The equipment was installed in his apartment and the system was ready to go. He was then able to monitor his electricity usage in real-time. Additionally, he was able to see what part of the day he was consuming the most and what was the peak hour in any typical day. He was also able to monitor this daily consumption. As a result of using the system, he reduced his energy consumption.

However, Saeed was not sure how efficient his electricity activities were. Therefore, he decided to invite some of his friends on Facebook to install the system so they could share their information and knowledge. Four of his friends had the system installed. By comparing his usage for a day or a month with a particular friend, the best of them or the average consumption, he found that he was consuming more electricity than most of his friends. Saeed and his friends had the opportunity to comment in the application to share their strategies to reduce their electricity monthly bills. They decided to have a competition between them to keep the overall usage down for a month. The competition started and they were able to see their overall ranking as well as the winners of the daily reward. The daily reward was a winning symbol with the Facebook profile picture of that winner. They were also able to share their winning with the rest of their Facebook friends by posting the winning symbol on their Facebook profile. At the end of the competition, Saeed and his friends was able to reduce their electricity usage even further.

3.2.2 System Architecture

This section explains the general concept of the system (Figure 3.1).

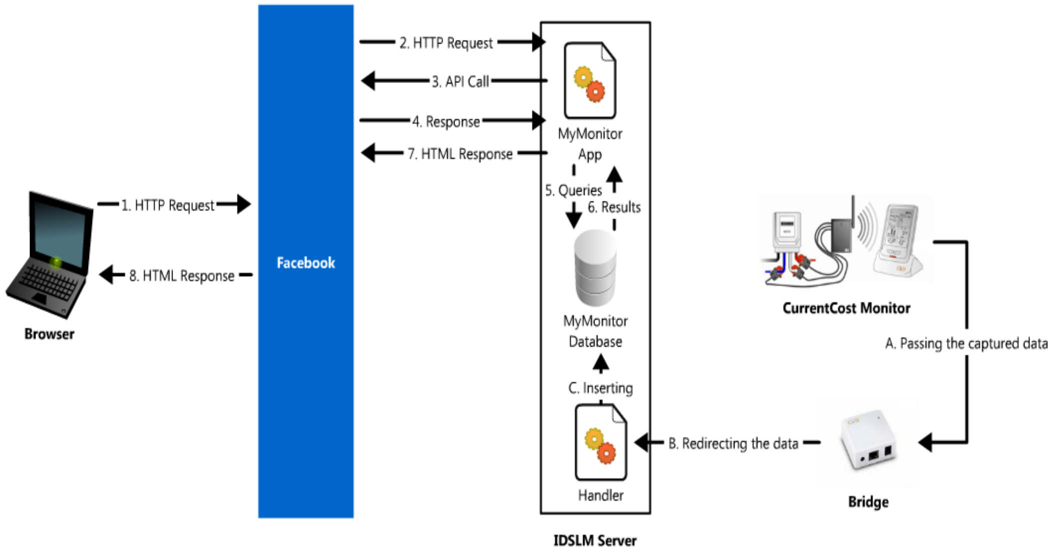

Figure 3.1: Our system architecture

In order to interpret Figure 3.1, a number of technical and non-technical terms will be explained briefly.

HTTP - hypertext transfer protocol: "The protocol is used to transmit and receive all data over the World Wide Web." (ComputerUser, 1994-2011).

HTML - hypertext markup language: "HTML is a collection of formatting commands that creates hypertext documents--Web pages, to be exact." (ComputerUser, 1994-2011).

API - Application Programming Interface: "Facebook API is a Web services programming interface to access the main Facebook services (profile, friends, photo, event) and the function of Facebook (login, redirect, update the view)" (Facebook Programming: Facebook Platform, n.d.).

IDSLM- Informed Demand-Side Load Management: this is a project at the University of Waikato that aims to optimise domestic electricity consumption (University of Waikato, 2011-2012).

There are two main procedures for the project system each work separately (see Figure 3.1). The first procedure is numbered numerically in (Figure 3.1), while the second procedure is numbered alphabetically. The first procedure is about retrieving, processing and presenting the data to the users, whereas the second procedure is about capturing and storing the energy usage data of the users.

In the first procedure, when the MyMonitor application on Facebook is opened by a user, an HTTP Request will be sent to the Facebook server. This request will be forwarded to the MyMonitor application on the IDSLM server. The application will request API calls to collect some information about the user (e.g. user ID, profile picture, list of friends) from the Facebook server. After that, the MyMonitor application will receive a response from the Facebook server with the requested information. Then the MyMonitor application will query the data requested (e.g.: the current Consumption of that use) from the MyMonitor database. The database will then send back the requested data to the MyMonitor application. The data will be processed by the MyMonitor application and sent the document in a HTML format to the Facebook server. Then the HTML document will be forwarded by the Facebook server to the user browser.

In the second procedure, the transmitters attached on the users' meter box send the total power usage to the display unit inside the home. Then the display unit passes this data to the bridge by a short cable connecting the two devices together. After that, the bridge sends this data to the Handler script on the IDSLM server. Finally, the data reach their final destinations as the Handler script captures this data and inserts it into the CurrentCost table on the MyMonitor database.

3.2.3 Data Flow Chart

In this section, the data flow of the system will be highlighted in detail. The data-flow diagrams (DFDs), were introduced and widely spread by Gane and Sarson in the late 1970s for structured analysis and design (Ambler, 2004). The flow of data from external entities into the system can be shown by DFDs as well as the data movement between processes and its logical storage. Generally, each component has a common symbol (see Figure 3.2) and serial levels may be needed for describing the data flow chart.

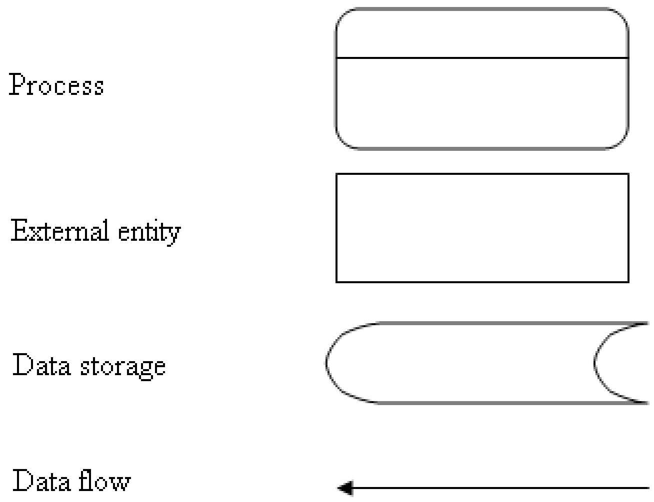

Figure 3.2: Symbols of data flow chart

The MyMonitor system interacts with two factors: user and Facebook server. Every factor represents an external entity in the data flow chart at its level zero (Figure 3.3). This level of the data flow chart comprises the general processes of the system, the external entities, and the data between them.

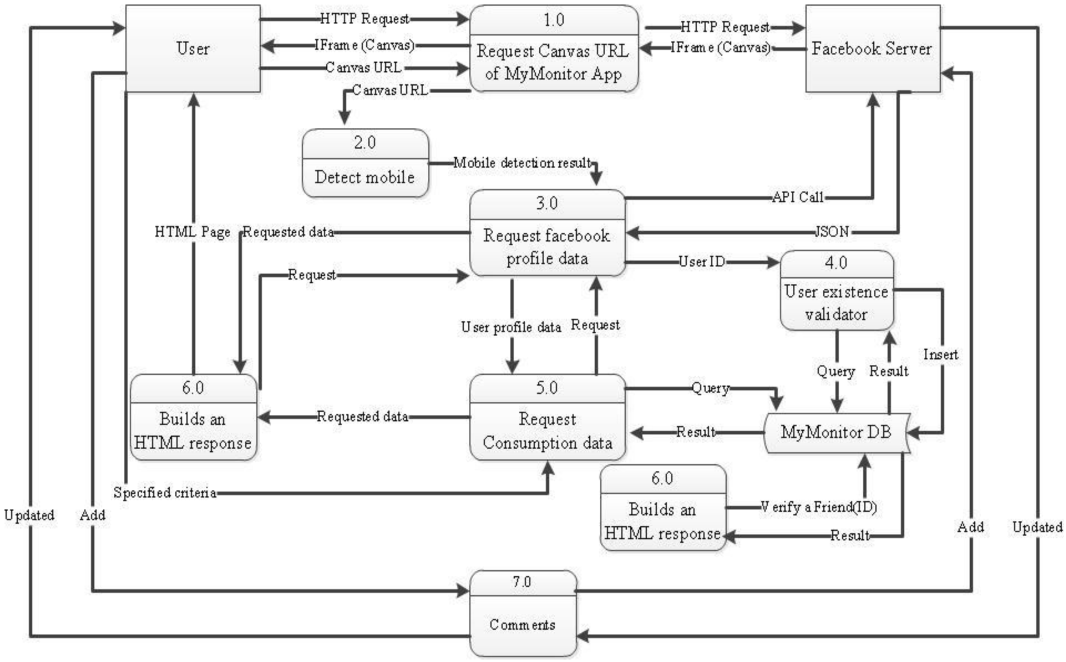

Figure 3.3: Level 0 of the data flow chart of MyMonitor system

Canvas URL: The URL link for the actual location of MyMonitor app.

When the user opens the MyMonitor application on Facebook, a HTTP request is sent to the Facebook server. An HTML code with the Facebook chrome and the IFrame are then returned to the user by Facebook. After that, the IFrame requests the Canvas URL to our server. The first process that MyMonitor will do is to detect mobile browsers, then forward them to the mobile version of the application. Both the desktop and the mobile versions of the system share the level 0 diagram and they differ in the sub-processes of the 3, 5 and 6 processes. Therefore, for both cases in process 3, our system asks for the current user's name and ID for the Graph API. After that, our system receives a response from Facebook server in JSON format. In process 4, the user ID is used to verify the user existence in our database. If the user does not exist on our database, his ID number will be stored in MyMonitor Database. After that, the application queries the database in process 5 to collect the requested consumption data of the current user. Then the database sends back the results of the queries and they will be taken to process 6 to build an HTML response to show the requested consumption data of the current user in the IFrame. However, sometimes process 6 requests some more data from the Facebook server, such as a user's name, profile picture or friends ID list through process 3 before it finalizes the HTML page.

Furthermore, when process 6 gets the current user's friends ID list, it matches this list with the ID list existing in our database. Then only the friends of the current user who added our application will be listed in the friend list of the application.

Additionally, in some cases the current user profile data will go directly to process 6. Then a HTML response will be built with some forms to collect the specification from the current user for the consumption data wanted, such as the consumption data for a certain day or month in process 5. Finally, the result will be returned to process 6 to build the HTML response for the requested data.

Finally, the users can also have some dialogue with each other. Therefore, when they add a new comment it is stored in the Facebook server under our application account in Facebook. Then the Facebook server will update the application's dialogue box with the new comment to be visible for the friends of the current users who have already added the application.

3.2.3.1 Level one of data flow chart the desktop application

In level one of data flow chart of the desktop application, processes 3, 4, 5, and 6 will be highlighted.

3.2.3.1.1 Facebook API

Process 3 (Figure 3.4) mainly deals with the Facebook API calls to those required from our application to collect some information about the users and their friends.

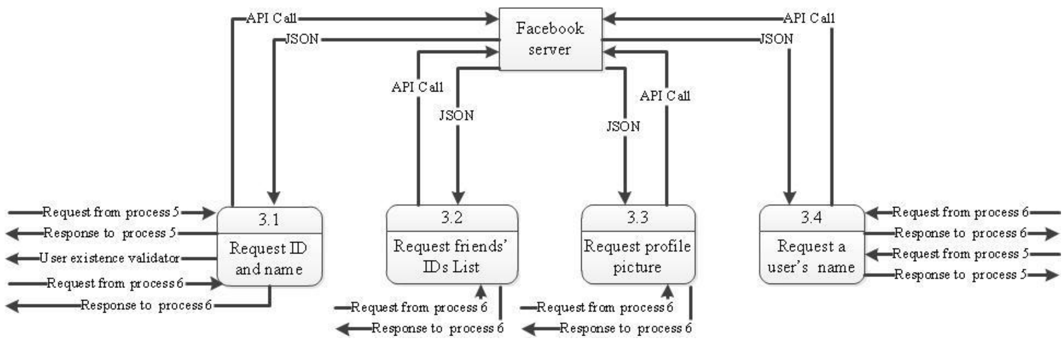

Figure 3.4: Level 1 of data flow chart of process 3 in the desktop application

Both processes 5 and 6 request an API call in process 3.1 to collect the ID number and the name of the current user. Therefore, they both collect the requested data in JSON format. Additionally, the ID number is transferred to the user existence validator in process 4. In some cases, process 6 requests a list of ID numbers of the current user's friends in process 3.2. Therefore, process 3.2 responds with the ID numbers of all the friends of the current user and then process 6 will try to identify who is already added the our application of those friends. Process 6 in 3.3 process requests also the profile pictures of some users to process these pictures and merge them in order with the background image of the best consumers in total. Finally, process 3.4 sometimes receives some requests from processes 5 and 6 to collect the name of a specific user by supplying process 3.4 with the ID number of that user.

3.2.3.1.2 User existence validator

There are two sub-processes in process 4 (Figure 3.5). The first subprocess 4.1 receives the current user ID number from process 3 and then queries the *users* table in the MyMonitor Database to verify the user existence in our database. If the user does not exist in our database, the sub-process 4.2 inserts his ID number in the *users* table. The rest of the *users* table attributes where the ID number of the new user is stored, are filled with the default values and they are modified manually by the study organizer.

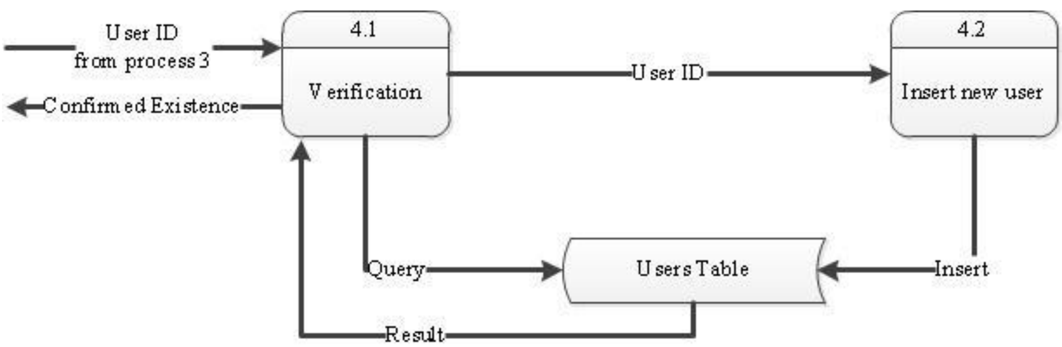

Figure 3.5: Level 1 of data flow chart of process 4 in the desktop application

However, if the user already exists, the sub-process 4.1 will confirm their existence and then the process 4.2 will not be applied.

3.2.3.1.3 Requesting consumption data

All the consumption data are retrieved and processed by process 5 (Figure 3.6). The consumption data are either requested directly (sub-process 5.1) or indirectly (sub-process 5.11) by the users. When the current users request their or their friend's consumption data for a specific day, such as in sub-processes 5.1 and 5.3, these requests go through the sub-process 5.5 which will generate hourly requests for that day. For example, if the users request their energy consumption for a day, the sub-process 5.5 will generate 24 requests for each hour of that day to the subprocess 5.8. Then the sub-process 5.8 queries the *CurrentCost* table in the MyMonitor Database to collect the energy consumption for the hour requested in that day.

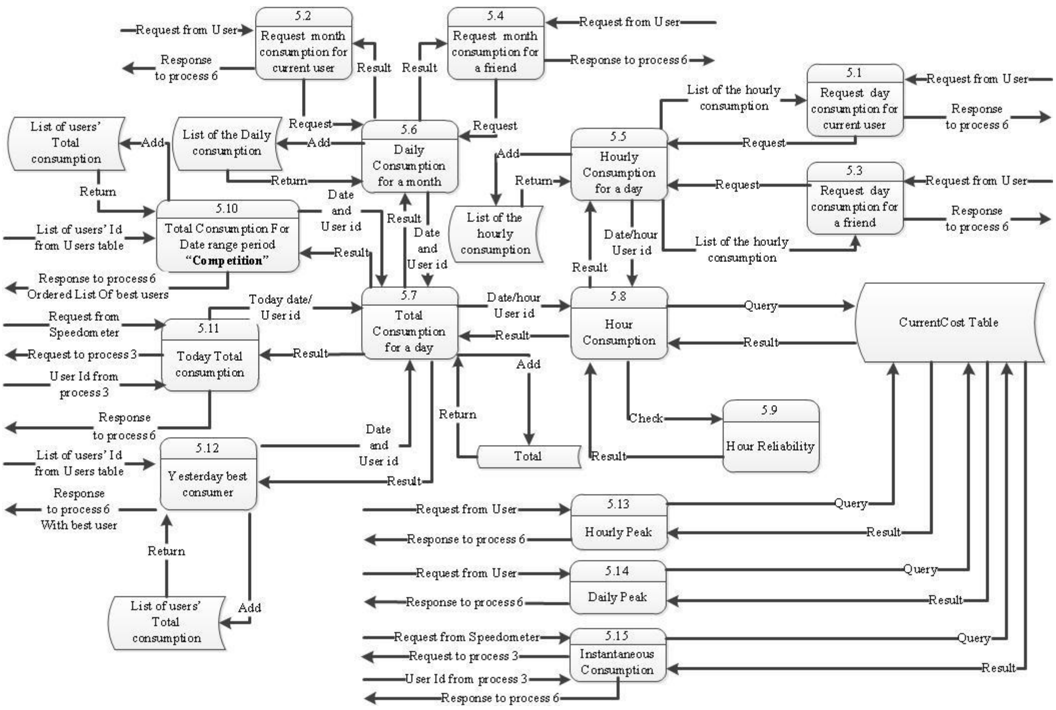

Figure 3.6: Level 1 of data flow chart of process 5 from the desktop application

The reliability of that hour will be tested in the sub-process 5.9. If it passes this test, it will be sent back to the subprocess 5.5. After that, the result is added to a list of the hourly consumptions of that day. Then the sub-process 5.5 will continuously request each following hour until it reaches the last hour of that day. Finally, the completed list of the hourly consumption of that day will be sent to process 6. However, sometimes when the sub-process 5.9 finds that there are no adequate energy feeds from the users' equipment for a specific hour, that hour will be replaced with the average consumption of the same hour and day of the previous two weeks.

Another type of direct request from users is requesting the energy consumption for a certain month. When the current users request their or their friends consumption data for a specific month such as in sub-processes 5.2 and 5.4, these requests go through the sub-process 5.6 which will generate daily requests for that month. The sub-process 5.6 will send these requests day by day to the sub-process 5.7 and then 24 requests will be generated by the sub-process 5.7 for each hour of that day and pass them to the sub-process 5.8. The sub-processes 5.8 and 5.9 will deal with these requests as has been described earlier. The running result of each hour will be gathered in the *Total* variable by the sub-process 5.7. After that, the total consumption of that day will be added to a list of the daily energy consumption of the requested month by the sub-process 5.6. Finally, when the list is completed, it will be sent to process 6 through the sub-processes 5.2 and 5.4.

Additionally, when the competition page of the MyMonitor application is opened by the current user, the ID number of the current user and his/her friends will be sent to the sub-process 5.10. The range date of the competition has already been set up by the study organizer. Therefore, the sub-process 5.10 requests the total consumption from the beginning date to the final date of the competition for each user. Those requests will go through the sub-process 5.7 and they will follow the previous process. Sub-process 5.10 will calculate the total energy consumption of each user during the competition and then the ID numbers of the best users will be added in a list in ascending order. Finally, this list will be sent to process 6. In addition, another sub-processes will be fired, when the competition page of the MyMonitor application is opened. Sub-process 5.12 receives the list of the users' ID numbers and requests the total energy consumption for every user for the previous day from the sub-process 5.7 and when it receives the result, it adds that value to the user in a list. Once all the requests to all the users have been collected, the full list of the users with their consumption will returned to sub-process 5.12. Finally, sub-process 5.12 arranges the list in ascending order and sends the ID number of the first user to process 6.

When the current users request their, or their friends', energy consumption data for a day or a month, sub-process 5.13 the hourly peak, or sub-process 5.14 the daily peak, respectively, will be requested. Therefore, when sub-processes 5.13 and 5.14 receive the requests, they will query the *CurrentCost* table in the MyMonitor Database to collect either the hourly peak or the daily peak for the current users and their friends. Finally, the result will be sent to process 6.

Additionally, the home page of the MyMonitor application has a speedometer and that speedometer requests some of the energy consumption data of the current user. One of these requests that speedometer makes is for the today total energy consumption from sub-process 5.11. When sub-process 5.11 receives the request, it requests the ID number of the current user from process 3. After sub-process 5.11 receives the current user's ID number, it requests the current day's total energy consumption from sub-process 5.7, which deals with this request. Additionally, the speedometer requests the instantaneous energy consumption of the current user from sub-process 5.15. Sub-process 5.15 requests the current user's ID number from process 3 and then process 3 replies to the sub-process 5.15 with the ID number of the current user. After that, sub-process 5.15 queries the *CurrentCost* table in the MyMonitor Database to get the latest update of that user. Finally, sub-process 5.15 responds to process 6 with this result.

3.2.3.1.4 Preparing visualisations

This process (Figure 3.7) prepares the requested data to be presented to the current user. The energy consumption data is visualised in different forms, in flash format such as in sub-processes 6.1 and 6.2 and in image format such as in sub-processes 6.3 and 6.4. Subprocess 6.1 receives the energy consumption data of the current users and their friends for a day or a month and renders it in animated chart. The FusionCharts free component is used in sub-process 6.1 for generating dynamic flash bar charts. It is a data visualisation component that can be used to generate dynamic Flash charts and those dynamic charts can be embedded in web and desktop applications (FusionCharts, 2012). When the data is rendered, the flash bar chart will be embedded in sub-process 6.5. Finally, the HTML page is sent to the current users.

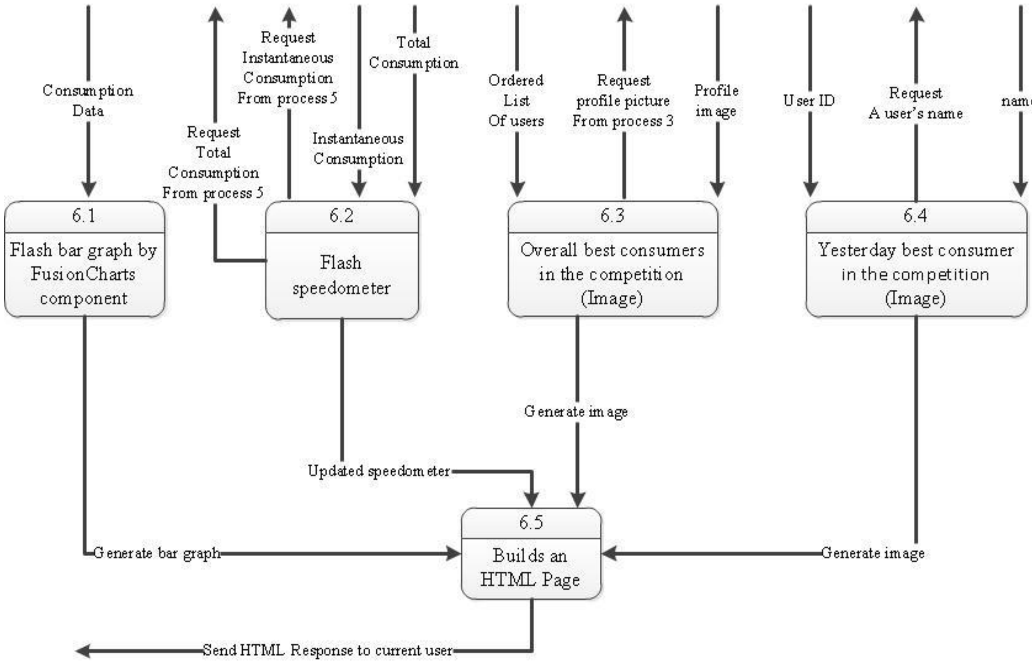

Figure 3.7: Level 1 of data flow chart of process 6 in the desktop application

Additionally, the instantaneous energy consumption and the current day's total consumption of the current users are requested by sub-process 6.2. The flash speedometer has been developed by the study organiser and it requests those data for every six seconds then the speedometer will be embedded in an HTML page in sub-process 6.5 and HTML response will be sent to the current users.

Another type of visualisation that has been implemented to visualise competition data running between users to keep the overall energy consumption down and winning the individual award for the best consumer for yesterday has been created in image format. There are two images presented in the competition section of the MyMonitor application. The first is generated by sub-process 6.3. Sub-process 6.3 receives a list of ID numbers of top users in total during the competition. After that a request is sent by sub-process 6.3 to process 3 to collect the profile picture of each user. When sub-process 6.3 receives all profile pictures of the users, it merges all these pictures with a background picture to represent the ranking of the best users in total during the competition. After that, the picture generated is sent to sub-process 6.5. Finally, sub-process 6.5 deals with this picture as previously explained.

Additionally, another picture is generated beside the previous picture by the subprocess 6.4. The subprocess 6.4 receives the id number of the best user for yesterday. Then, it requests the name of that user from process 3 by passing the id number to it. When the name is received, it will be merged with a background picture to generate and represent the user name with this award. Then, the created picture reaches its final destination “the current user” through subprocess 6.5.

3.2.3.2 Level one of data flow chart of the mobile version

The mobile browser version of our system is a light version and does not provide the full functionality of the desktop browser version.

3.2.3.2.1 Facebook API

This process (Figure 3.8) handles the Facebook API Call. When the users login using their mobile devices, they will be redirected to the mobile version of our application. Our system then sends an API call to the Facebook server to obtain the ID number and the name of the current users.

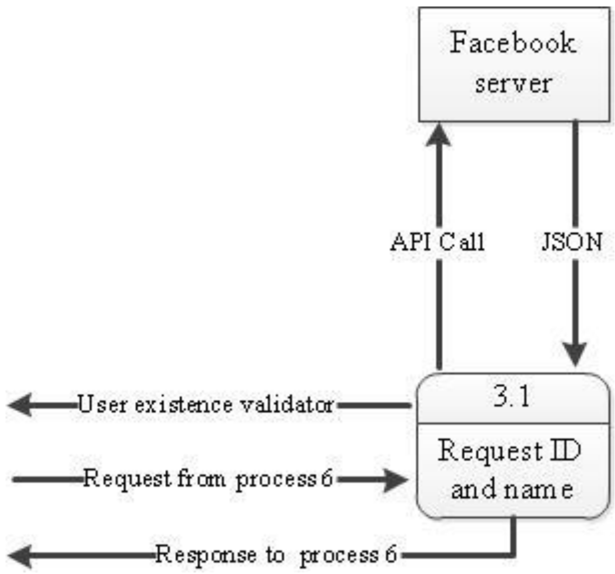

Figure 3.8: Level 1 of data flow chart of process 3 in the mobile version

Sub-process 3.1 receives the result in JSON form and extracts the ID numbers and sends these to process 4 to verify the users’ existence in our system. Additionally, the ID numbers and the names of the current users are sent to process 6.

3.2.3.2.2 Requesting consumption data

The users can only monitor their instantaneous energy consumption in the mobile version. Therefore, sub-process 5.1 (Figure 3.9) receives a request from process 6 with ID numbers of the current users to collect their instantaneous energy consumptions.

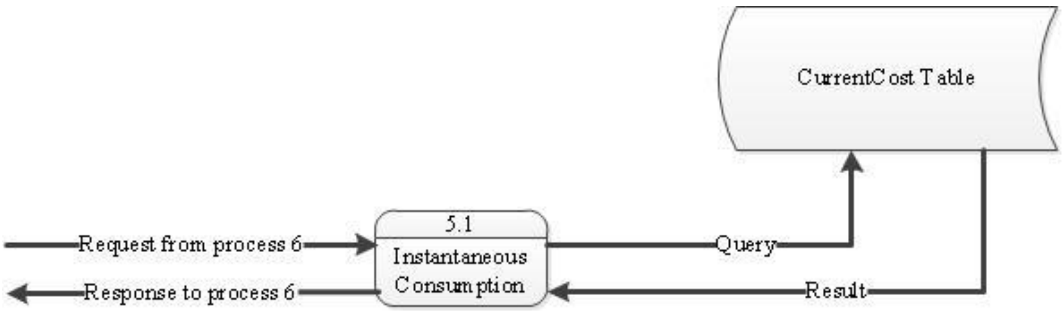

Figure 3.9: Level 1 of data flow chart of process 5 in the mobile version

The subprocess 5.1 queries the *CurrentCost* table in MyMonitor Database to get the latest update of the current users. Finally, the subprocess 5.15 responds to process 6 with this result.

3.2.3.2.3 Preparing visualisations

As most mobile browsers support JavaScript, the flash speedometer is replaced with a speedometer made by JavaScript. Sub-process 6.1 (Figure 3.10) requests the current users' ID numbers from process 3. As soon as it receives the ID numbers, it sends another request to process 5 to collect the instantaneous energy consumption of the current users. When it receives the result, it updates itself with the new value and then the updated speedometer will be embedded in sub-process 6.5. Finally, the HTML page is sent to the current users.

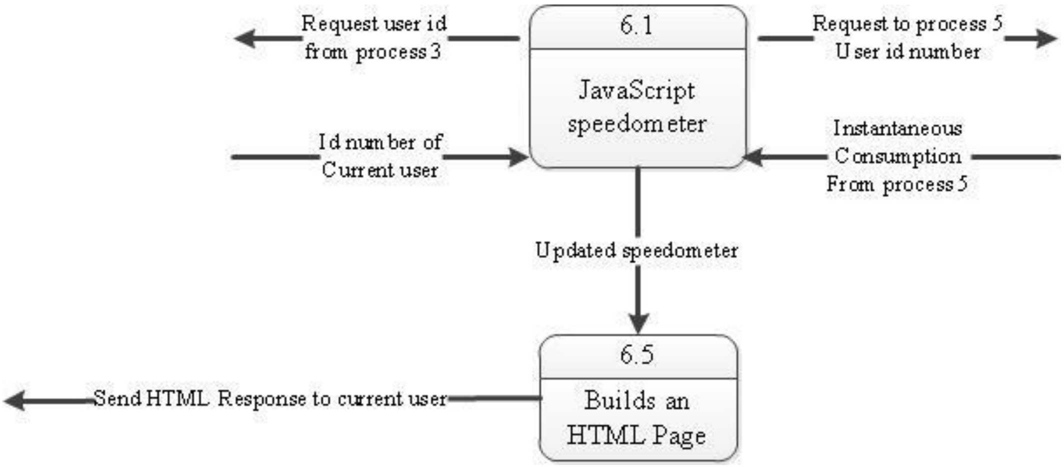

Figure 3.10: Level 1 of data flow chart of process 6 in the mobile version

3.2.4 Entity-relationship diagram of MyMonitor database

"[An] Entity-relationship model (ER model) is an abstract and conceptual representation of data. Entity-relationship modelling is a database modelling method, used to produce a type of conceptual schema or semantic data model of a system, often a relational database, and its requirements in a top-down fashion. Diagrams created by this process are called entity-relationship diagrams or ER diagrams" (Wikipedia, 2012).

The MyMonitor database was designed and created for the purpose of this study; therefore, it had only the most needed entities and attributes to keep it as simple as possible. The ER diagram (Figure 3.11) represents the schema of the MyMonitor database.

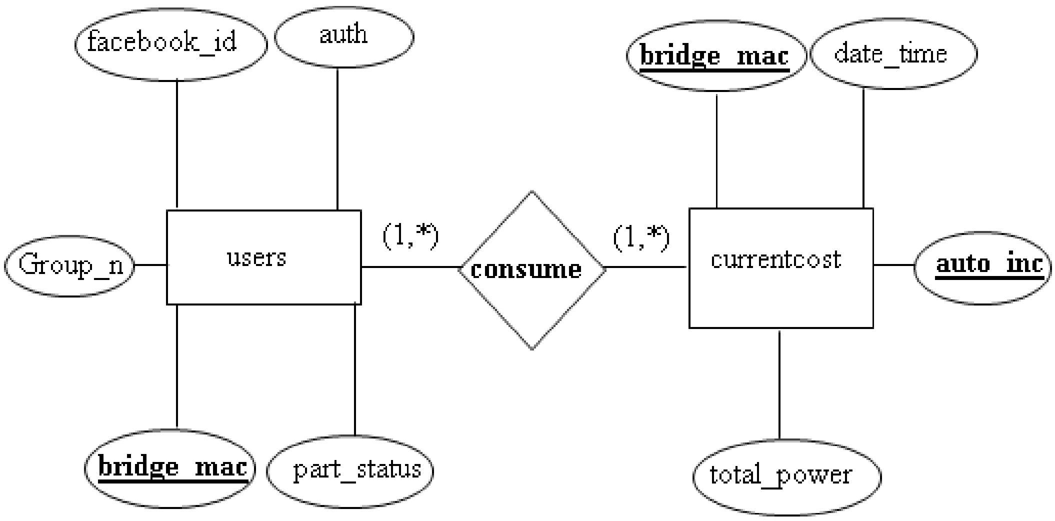

Figure 3.11: Entity-relationship diagram of MyMonitor database

There are two entities in the MyMonitor database: *users* and *CurrentCost* tables. The *users* table has a number of attributes such as facebook_ID, auth, group_n, bridge_mac and part_status. The descriptions of these attributes are described below.

> **Facebook_id:** is the Facebook ID number of the user. The data type of this attribute is BIGINT(20).
>
> **Auth:** is the authority level of the user. It is used to make sure that only authorised users have access to certain sections of the MyMonitor application. The data type of this attribute is INT(1).
>
> **Group_n:** is the group number of the users. It is used to set the users into a certain group. The data type of this attribute is INT(1).
>
> **Bridge_mac:** is the mac address of the bridge at the user's house. It is the primary key of this table. The data type of this attribute is VARCHAR(20).
>
> **Part_status:** is the participation status of the user. It is used to keep the debugger users out of the study. The data type of this attribute is Boolean.

There is no need for any personal information about the users, such as their names and dates of birth, to be stored in our database because all this information and more can be gathered using the Facebook Graph API.

The *CurrentCost* table has four attributes: auto_inc, bridge_mac, date_time and total_power. These attributes are described below.

> **Auto_inc:** is the auto increment number of the record. It is the primary key of this table. The data type of this attribute is BIGINT(30).
>
> **Bridge_mac:** is the mac address of the bridge at the user's house where the data has come from. It is the foreign key of this table. The data type of this attribute is VARCHAR(20).
>
> **Date_time:** is the date and time when the data was received. The data type of this attribute is DATETIME.
>
> **Total_power:** is the reading of the total power of the user's house for a specific date and time. The data type of this attribute is INT(11).

The corresponding data stored in MyMonitor database are shown in separate tables below.

Table 3.1: Example data of users

facebook_id	auth	bridge_mac	part_status	group_n
12345678	1	00:08:DC:DF:FB:61	1	1
23456789	2	00:08:DC:AA:23:A5	1	2

Table 3.2: Example data of CurrentCost

auto_inc	bridge_mac	date_time	total_power
1612568	00:08:DC:DF:FB:61	2011-05-25 12:49:17	2000
1612569	00:08:DC:AA:23:A5	2011-05-25 12:49:19	1500

4 System Implementation

This chapter describes the approach that taken to implement our system. This chapter consist of our implementation environment, algorithms, social features, user interface and technical issues and solution.

4.1 Implementation Environment

There were two implementation environments. The first was for the development stage and the second for the production stage. Both environments had the same properties. The reason behind this choice was to keep the production environment clean as possible and do all the changes and tests on the development environment.

4.1.1 Hardware

Both servers of the development and production stages share the same properties. Therefore, both have 200 GiB hard disk and 4 GiB RAM. Additionally, they both run on Dual-core CPU.

4.1.2 Software

The operating system of both servers is Ubuntu Server 11.04 64-bit and they have Apache 2, PHP 5 and MySQL 5.0 installed. An application called Putty 0.60 was used for SSH tunnelling to the server. For transferring the file to the server over Secure Copy (SCP) protocol WinSCP 4.3.2 was used. Another application, employed to control and query the database, is MySQL Workbench 5.2 CE. Finally, Notepad++ 5.9.2 was used to write the code of our system.

4.2 Social features

A number of social features were implemented in our system such as sharing energy data with friends, post feed and share comments.

4.2.1 Friends List

The users are able to share their energy data with their friends on Facebook. Through MyMonitor they can access a list of friends who have already installed the application. Then they can compare their energy data with a particular friend from the list as well as compare themselves with the average consumption of all their friends. Basically, the application compares the list of ID numbers of those on the application database with the ID numbers of the current users' friends to get a list of ID numbers of the current users' friends who have installed the application.

4.2.2 Post feed

The winner of the daily reward is able to share this reward by posting the reward picture in his/her profile. Then his/her friends will be able to leave comments in his/her post picture.

4.2.3 Comments plugin

Comments box is a social plugin provided by the Facebook platform that enables users to comment anywhere in your application. Its available features are moderation tools and distribution. Social signals are used by the comment box to surface the highest quality comments for each user. The most relevant comments for the current users, which are comments from friends, friends of friends will appear first to them, while comments marked as spam are hidden from view. Automatically, the mobile version of the comment box will show up when a mobile device user agent is detected (Facebook, 2012). In the MyMonitor application, only the users who participated in our study were able to use this feature.

4.3 Ready components, software development kit (SDK) and classes

The MyMonitor application was developed using PHP scripting language while the database of the application was created in MySQL. However, there are a number of available free licensed PHP components, SDK and classes which have been used in our system.

4.3.1 Calendar component

The calendar component was written in PHP script by TriConsole website. Two modes are contained in this component: normal display calendar (Figure 4.1) and date picker (Figure 4.2) (TriConsole, 2009).

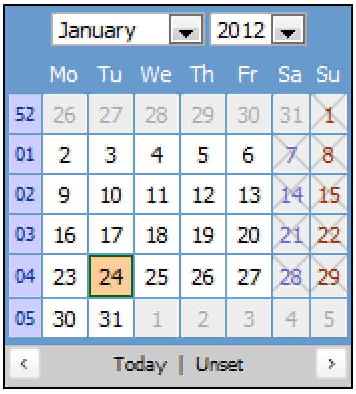

Figure 4.1: Normal display calendar (Reproduced from TriConsole, 2009)

Figure 4.2: Date picker style (Reproduced from TriConsole, 2009)

In order to display the calendar in a webpage, the following code needs to be included in the header tag of that webpage:

```
<script language="javascript" src="lib/calendar/calendar.js"></script>
```

Additionally, a class needs to be included in the webpage:

```
require_once('lib/calendar/classes/tc_calendar.php');
```

Moreover, instantiate class needs to be made and the properties of the calendar also need to be set.

```
$myCalendar = new tc_calendar("date1", true);

$myCalendar->setIcon("images/iconCalendar.gif");

$myCalendar->setDate(date('d'), date('m'), date('Y'));
```

Finally, the output code of the calendar can be then used.

```
$myCalendar->writeScript();
```

4.3.2 FusionCharts Free component

Data-driven and animated charts can be rendered in web-based applications, desktop applications and presentations by FusionCharts Free which it is an open-source Flash charting component. This cross-browser and cross-platform solution can be used with different scripting and programming languages and applications such as PHP, ASP, ASP.NET, JSP, ColdFusion, Python, RoR, simple HTML pages or even PowerPoint Presentations (FusionCharts, 2012).

A number of basic charting requirements with the essential chart forms and features are covered by FusionCharts Free. There are 22 popular charts, including Column, Line, Pie, Bar, Area, Stacked, Candlestick and Funnel Charts. All the charts are animated and support a number of interactive features like tooltips and drill-down. Moreover, all the charts are able to retrieve data from any source of database and they all also support AJAX (FusionCharts, 2012).

The data of the FusionCharts Free can be provided in xml file or it can be added using the FusionCharts Free classes. The FusionCharts Free can be used as follows (FusionCharts, 2012):

- The file FusionCharts_Gen.php needs to be included in the webpage. This file contains FusionCharts PHP Class codes.

```
include('../Class/FusionCharts_Gen.php');
```

- Then the Column3D chart object needs to be created:

```
$FC = new FusionCharts("Column3D","300","250");
```

- The chart type, chart width and chart height properties of the object are initialized by the invoked constructor of the FusionCharts PHP Class.

```
$FC = new FusionCharts("Column3D","300","250");
```

- Then the path of the chart SWF files needs to be set using `setSwfPath()` function. This path is where the chart SWF files are loaded.

```
$FC->setSWFPath("../FusionCharts/");
```

- All desired chart attributes are then stored in the $strParam variable and then the chart attributes need to be set using setChartParams() function.

```
$FC->setChartParams($strParam);
```

- Now, the chart data needs to be provided using the `addChartData()` function. The value is passed first and then category name against each value as a parameter i.e., `name=Week 1` etc.

```
$FC->addChartData("40800","name=Week 1");

$FC->addChartData("31400","name=Week 2");
```

- Next, `FusionCharts.js`, which is a FusionCharts JavaScript Embedding Class, should be included in the webpage header tag.

```
<script language='javascript'

src='../FusionCharts/FusionCharts.js'></script>
```

- Finally, the chart can be displayed using `renderChart()` function.

```
$FC->renderChart();
```

However, complex charts such as multi-series charts can be generated as well. Multi-series charts are used to plot multiple datasets. For more information about the full functionality of the component see the documentation section of the FusionCharts website (FusionCharts, 2012).

4.3.3 Facebook PHP SDK

The Facebook PHP SDK v.3.0.1 was employed in this project. However, the latest version of the Facebook PHP SDK until writing this report is v.3.1.1. A rich set of server-side functionality is provided by the PHP SDK for operating API calls on the server-side of Facebook. These include all of the features of the Facebook Graph API, Facebook Query Language (FQL), and the Deprecated REST API. Typically, the SDK provided for PHP developers is used for performing processes on behalf of an app administrator; however, it can also be used for performing processes on behalf of the current sessions' users. The process of authentication and authorizing users for Facebook apps is simplified greatly by the PHP SDK, because the need for managing access tokens manually is removed. The Facebook PHP SDK can be downloaded from GitHub website (Facebook, 2012).

In order to install the PHP SDK, the downloaded files need to be extracted and copied to a directory on the server where the Facebook app is hosted, for example, php-sdk. Then the SDK can be used by including php-sdk/facebook.php and instantiating a new Facebook object with, at a minimum, the app id and app secret ("Facebook PHP SDK," 2012):

```
  require ' php-sdk/facebook.php';
  $facebook = new Facebook(array(
'appId'  => 'FACEBOOK_APP_ID',
'secret' => ' FACEBOOK_APP_SECRET',
));
// Get User ID
$user = $facebook->getUser();
```

For making API calls ("Facebook PHP SDK," 2012):

```
if ($user) {
  try {
    // Proceed knowing you have a logged in user who's authenticated.
    $user_profile = $facebook->api('/me');
  } catch (FacebookApiException $e) {
    error_log($e);
    $user = null;
}
}
```

For more information about the Facebook PHP SDK see the Facebook developer documentation (Facebook, 2012).

4.3.4 Mobile Detect class

Most of the popular mobile platforms can be detected by this simple PHP class; for example, Android, iPhone, Blackberry, Opera Mini, Palm, Windows Mobile, as well as other generic platforms (Stanciu, 2011).

The class file “Mobile_Detect.php” needs to be included and an instance object of that class is created to be able to use this class (Stanciu, 2011).

```
include("Mobile_Detect.php");
$detect = new Mobile_Detect();
```

Checking for a specific platform is very simple (Vic Stanciu, 2011):

```
if ($detect-> isIphone()) {
// code to run for the iPhone platform
}
```

There are a number of available methods: isAndroid(), isAndroidtablet(), isIphone(), isIpad(), isBlackberry(), isBlackberrytablet(), isPalm(), isWindowsphone(), isWindows(), isGeneric(). Alternatively, if the interest is only for detecting any mobile device without caring for a specific platform, the isMobile()method can be used (Stanciu, 2011).

```
if ($detect->isMobile()) {

// any mobile platform

}
```

4.4 User Interface

4.4.1 Desktop interface

When the users open the MyMonitor application through Facebook, they are taken to the index page which is the "My energy" page (see Figure 4.3). In this section of the application, they will be able to monitor their own instantaneous and historical energy usage data. They can monitor their instantaneous energy consumption through the speedometer.

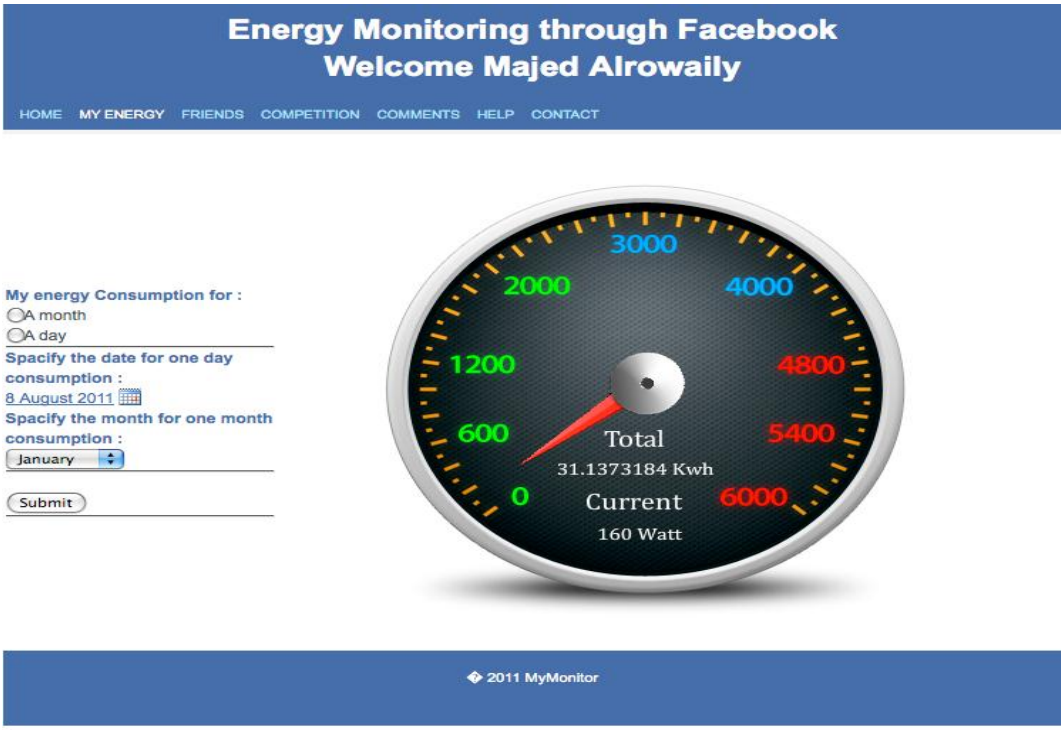

Figure 4.3: MyMonitor application - My Energy page in desktop version

Also, they can monitor their energy consumption for a particular day or month. Their energy consumption data, for either a day or a month, will be represented in a dynamic flash bar graph. The bar graph will show the total energy consumption for each hour or day with the peak of that hour or day.

Another section of the MyMonitor application is the Friends section (see Figure 4.4). In this section, the current users can compare their energy consumption data with their friends. MyMonitor collects the friends list of the current users who have installed the application. Then the current users specify the comparison option either for a month or a day, then they chose a friend of theirs. Finally, their energy consumption data, for either a day or a month, will be represented with their friend's data in a dynamic flash bar graph. The bar graph will show the total energy consumption for each hour or day. They can compare their energy usage with the best consumers or with the average consumption among themselves.

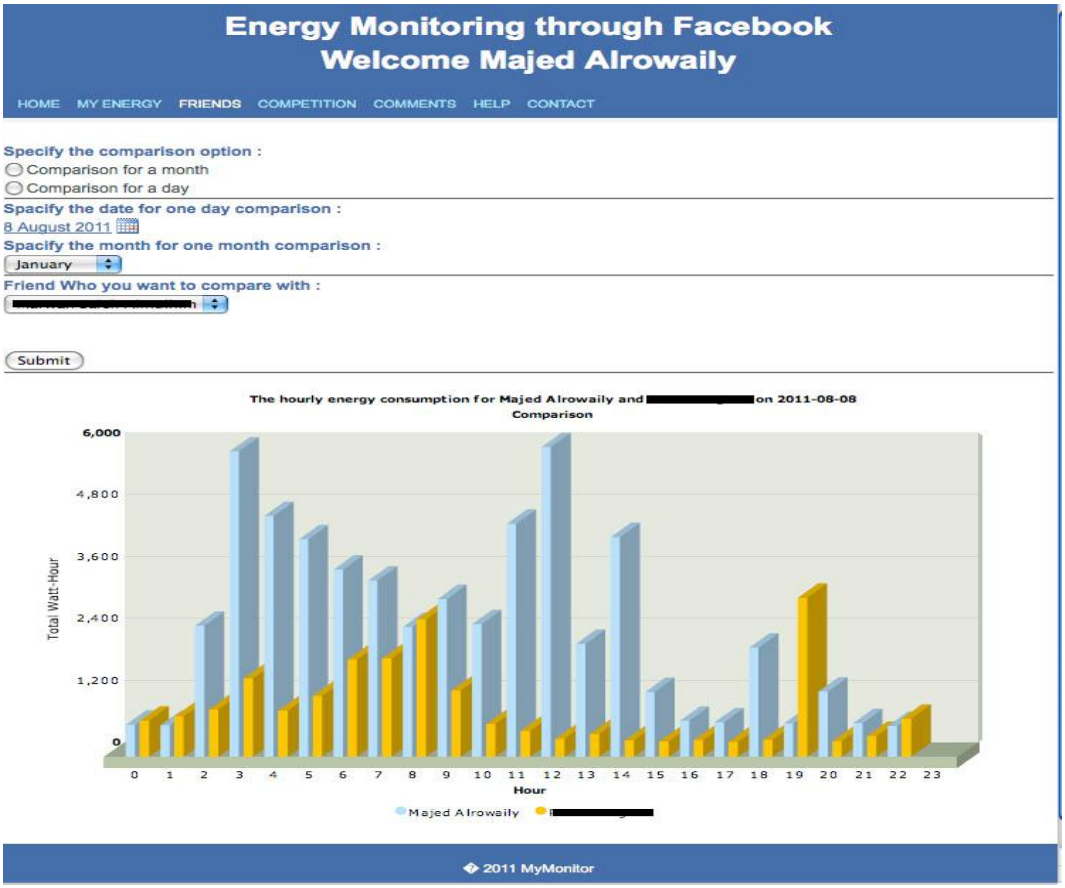

Figure 4.4: MyMonitor application – Friends in desktop version

The next section of the MyMonitor application is the competition section (see Figure 4.5). In this section, users can see the best consumers among their friend list in total during the competition. Additionally, they will be able to see the best consumer for yesterday and that consumer will have the option of posting the winning picture in his/her profile and shareing it with his/her friends. The profile picture of the winner users will be used in this section for the representations. The profile pictures of the top five users will be requested to be merged with the ranking background picture. Moreover, the name of the winner of the daily reward will be also merged with the winning sample.

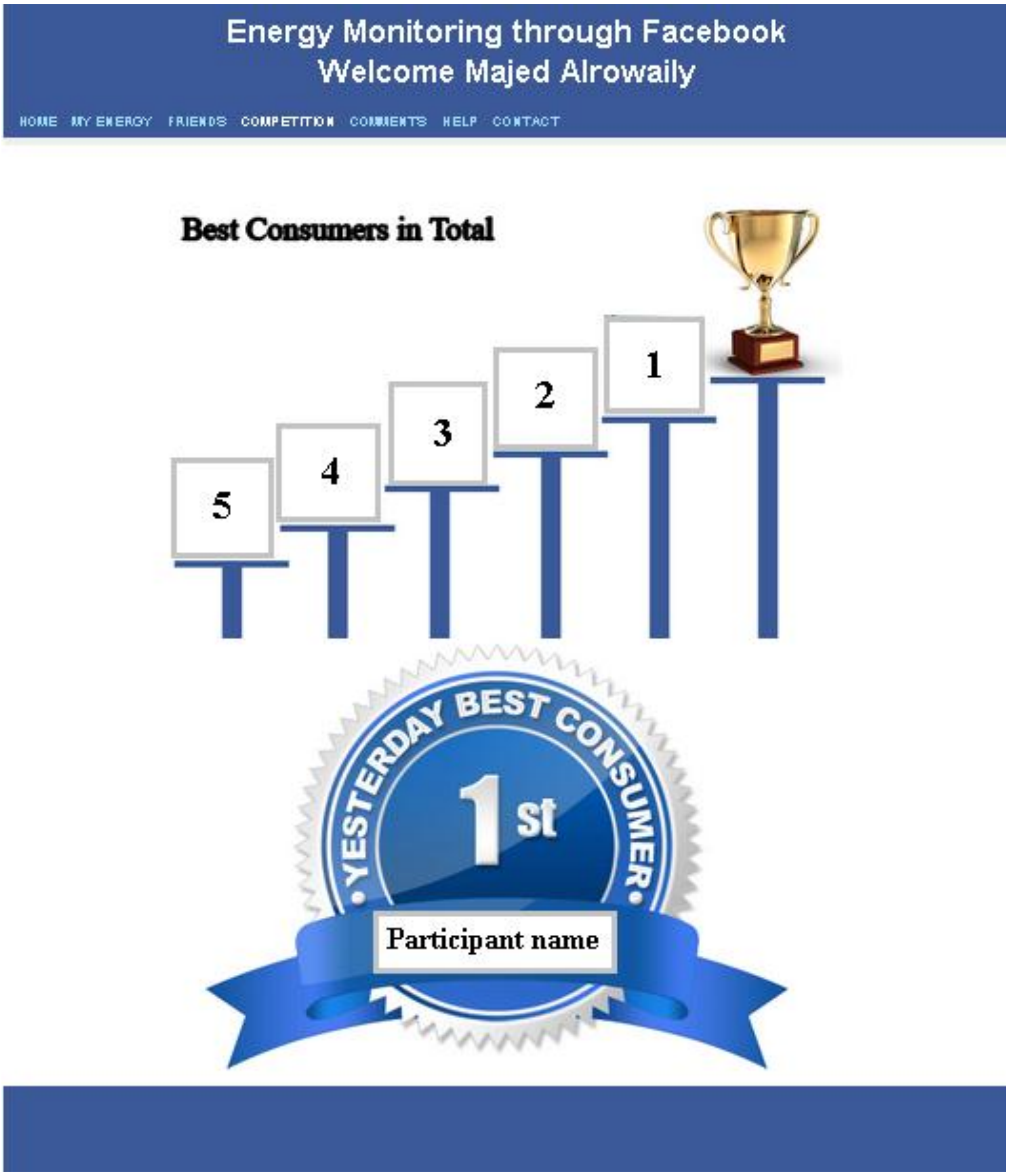

Figure 4.5: MyMonitor application – Competition in desktop version

The last section of the MyMonitor application is the comment box (see Figure 4.6). In this section, users are allowed to communicate and learn from each other's experience. There are a number of options which can be used to customise the comment box. One of these options is moderation mode. Using this option, the new post can be automatically made public or need an approval before it appears. Also, the standard Facebook word restrictions can be used to block the blacklisted words. Finally, a grammar filter can be used to automatically correct common grammar mistakes.

Figure 4.6: MyMonitor application - Comment box in desktop version

4.4.2 Mobile interface

In the mobile interface there were only two features available. The first was monitoring instantaneous energy consumption through the speedometer in Figure 4.7. It is the home page of mobile version of the MyMonitor application. This speedometer was created using JavaScript as the speedometer of the desktop version was created using flash and that was not supported in mobile platforms.

Figure 4.7: MyMonitor application - My energy page in mobile version

The last section of the mobile version of MyMonitor application is the comment box (see Figure 4.8). In this section, users are allowed to communicate and learn from each other's experience. There were two comments in this comment box and as it can be noticed in Figure 4.8, the comment box supports most languages. Therefore, the users will be able to use their own language to communicate with each other.

Figure 4.8: MyMonitor application - Comment box in mobile version

4.5 Technical issues and solution

A number of technical issues have been encountered during the development of this project resulting in some missing data from some users' homes.

4.5.1 Missing data

There were a number of scenarios of this problem. The first scenario is that the wireless transmission between the transmitter and the Envi is not reliable; therefore, the data can be lost. The problem is worse when the distance is larger, or has obstacles in the way. The second scenario is that the UART baud rate for the link between the Envi and Bridge is specified as 57600 bps, but in reality is quite variable and sometimes leads to corruption. The last scenario is that the Bridge is based on the Arduino platform, and the TCP/IP library does not appear to behave in a normal manner. Sometimes the firmware gets into a bad state, and stops forwarding data to our server. Additionally, the Bridge sends an ARP request for every packet it sends, which may cause problems with some routers. The true cause of the problem has not been found, but in any case the identical firmware works fine in some networks but not in others.

A number of solutions have been applied for tackling the previous issues. The first solution is that a watchdog timer was used to detect the bad state of the Bridge firmware and then restart it. The second solution is that, sometimes the physical relocating of Envi may be necessary to get better reception from the transmitter. The last solution is that the reliability of the result of each hourly energy request that comes to the MyMonitor application will be examined. If there are no adequate energy feeds from the users' equipment for that hour, it will be replaced with the average consumption of the same hour and day of the previous two weeks.

5 Social metering system: User study

5.1 Introduction

The purpose of this study is to examine the effect of real-time feedback and competition between consumers on changing their conservation behaviour. At this stage we were seeking indicative results rather than comprehensive statistical evaluations. Consequently, the user study involved a relatively small sample and took place in an actual environment the participants' household. This research sought qualitative (questionnaires) and quantitative (energy readings) results. The ethical approval is in Appendix A, while Appendix B contains the participant workbook which consists of a participant information sheet; a research consent form for participants; an initial questionnaire, phase two questionnaire; and phase three questionnaire.

5.2 Inviting Participants

Five of the participants were invited by the study organizer by talking to them directly and requesting their participation. The rest of the participants were invited by my supervisor by talking to them directly and by email.

5.3 Subjects

Ten households were selected for the study and they were divided into two separate groups. The criteria and characteristics chosen for the participants to be qualified to participate in this study were:

- Over the age of 18;
- Household size between 2 to 5 people;
- An available Broadband connection;
- An adequate computing background; and
- A Facebook account.

Table 5.1: Subjects of group A

Subject number	Age group	Gender	Household size	Average monthly Bill
A1	20-29	Male	2	$100-$150
A2	30-39	Male	2	$150-$200
A3	20-29	Male	2	$100-$150
A4	20-29	Male	2	$150-$200
A5	20-29	Male	2	$100-$150

In Table 5.1 all of the participants in group A were couples except, participant 1 who lives with a flatmate. They shared similar characteristics and all were Saudi students.

Table 5.2: Subjects of group B

Subject number	Age group	Gender	Household size	Average monthly Bill
B1	40-49	Male	> 3	$100-$150
B2	40-49	Male	> 3	$100-$150
B3	> 50	Male	> 3	$150-$200
B4	40-49	Male	> 3	> $200
B5	40-49	Male	> 3	$150-$200

In Table 5.2, all of the participants in group B live with families with some children. They shared similar characteristics and all were staff members at the University of Waikato.

5.4 Physical setup

5.4.1 Hardware setup

A CurrentCost Monitor was installed in each of the participants' houses. The equipment includes a Transmitter, Envi (a display screen) and NetSmart (a bridge). The transmitter is attached to the meter box for transferring the energy usage to the Envi. The Envi receives the data and passes it to the NetSmart. Finally the

NetSmart is programmed to send the data through the internet connection of the participants to our server and then the server stores it in a database.

5.4.2 Software setup

The participants were required to add the the MyMonitor application to their Facebook accounts. Their Facebook IDs were recorded automatically on a table called *users* on the application's database. The participants' data on the *users* table needed to be updated manually with the mac addresses of the NetSmart and the right permission for the current phase. Lastly, the participants were required to add each other as a friend on Facebook to communicate with each other in the third phase of the study.

5.5 Design

This research sought qualitative and quantitative results. The qualitative results were collected using questionnaires, while quantitative results were collected using our metering system. Two main independent variables were evaluated in this project including real-time feedback and competition of conservation behaviour.

The study had three consecutive stages: first, second and third.
First stage: the householders' electricity activities were recorded without giving them any feedback.

Second stage: the participants saw their consumption but not share their consumption with others. They saw three types of information:

- Real-time data for the current consumption;
- The Hourly consumption for a day; and
- The daily consumption for a month.

Third stage: the participants competed with each other to keep overall consumption and the peak down. Via social network software, they compared three types of information:

- The hourly consumption for a day with friend, the best user or the average usage;
- The daily consumption for a month with friend, the best user or the average usage; and
- The top five participants in the competition part.

5.6 Procedure

The participants were not asked to perform any set tasks as we wanted to collect data of real life situations. An initial questionnaire (see Appendix B) seeking background details was given to the participants. After the installation of equipment and our monitoring system, the first phase was run for about two weeks. At the end of the first phase, the participants' permissions on our monitoring system were modified to move them to phase two. This phase was run for about four weeks. At the end of the second phase, the participants were given the second questionnaire to fill in. After that, the participants' permissions on our monitoring system were modified again to move to phase three. This phase, also, was run for about four weeks. At the end of the study, the participants were given the third questionnaire to complete.

5.7 Ethical Considerations

Before we were able to carry out this study, ethical approval was required because our study involves real people in a real environment. The ethical approval was obtained from Human Research Ethics Committee at Department of Computer Science at University of Waikato (see Appendix A). The signatures of the participants were collected on the Information Sheet and Consent Form before any study conditions to make sure that the participants are aware about the aims of the research and inform about their rights and their possible involvement.

5.8 Data collection

The data were gathered from two different sources: the questionnaires completed by the participants and the participants' electricity consumption activities: these were captured remotely and stored in the application database.

6 Findings

The previous chapter discussed the design of the approach and the methods which were used to collect data about participants' energy consumption before introducing them to our metering system and after introducing them to the real-time feedback of their energy consumption and competition to keep their overall consumption down. In this chapter, the findings obtained from the study are presented. Section 6.1 presents the qualitative results while the quantitative results are presented in section 6.2. The next chapter will discuss these findings and what has been learned from this study.

6.1 Qualitative result

There were three questionnaires in this study. Firstly, section 6.1.1 presents the demographic information of the participants. Secondly, the participants' energy background and attitudes toward energy conservation is presented in section 6.1.2. Thirdly, section 6.1.3 presents the results of introducing real-time feedback. Lastly, the results of introducing competition between the participants is presented in section 6.1.4.

6.1.1 Demographic information of the participants

The initial questionnaire, covering some of demographic information, was given to the participants before beginning the study.

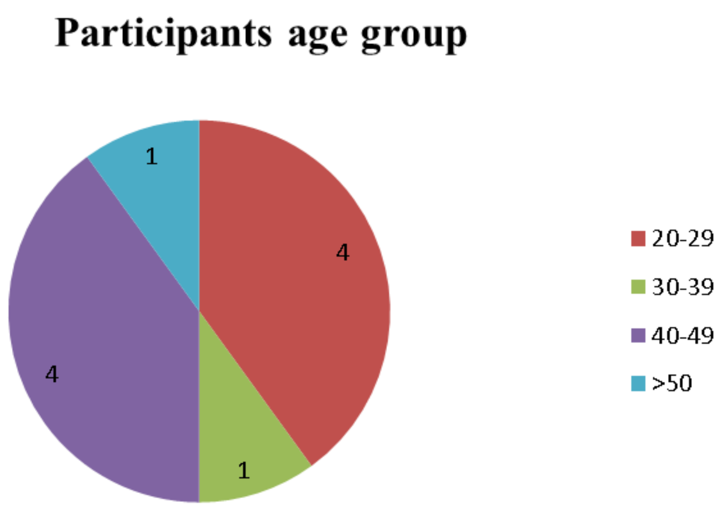

Figure 6.1: Participants' age group

The age groups of the participants of this study are shown in Figure 6.1. The majority of the participants were from two age groups: 20-29 and 40-49. There were four participants of each of these age groups, while two of the participants were divided equally between 30-39 and >50 age groups.

The size of the participants' household of this study is presented in Figure 6.2. The household size of five of the participants was two; four were more than three family members. Only one of the participants was living in a household of three family members.

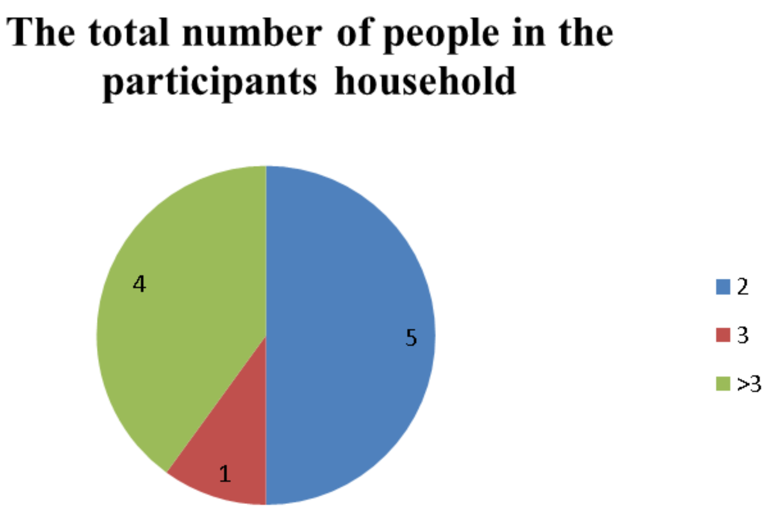

Figure 6.2: Total number of people in the participants' households

The participants' average monthly bill for their electricity consumption is illustrated in Figure 6.3. Five out of ten participants paid, on average, from NZD100 to NZD150 monthly for their electricity usage. The monthly payment of four of the participants for their energy consumption was from NZD150 to NZD200. Only one of the participants was paying more than NZD200 monthly for his electricity consumption.

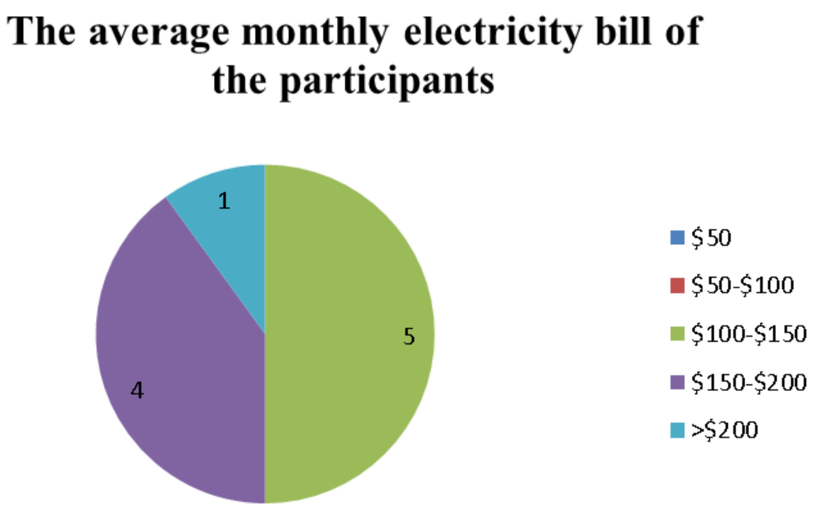

Figure 6.3: Average monthly electricity bill of the participants

6.1.2 Participants’ energy background and attitudes

The rest of the questions of the initial questionnaire were mainly examining the participants' understanding of energy. Firstly, they were asked about commonly used unit for measuring the power.

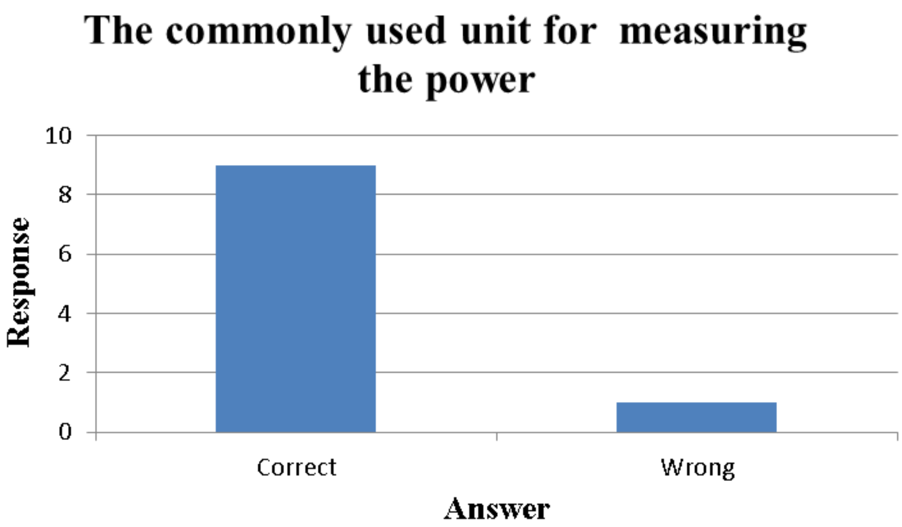

Figure 6.4: Commonly used unit for measuring power

Figure 6.4 shows that nine out of ten participants were able to answer this question correctly. Only one participant was not able to identify the correct answer of this question. Secondly, they were asked about the commonly used unit for measuring the total energy usage in the monthly electricity bill.

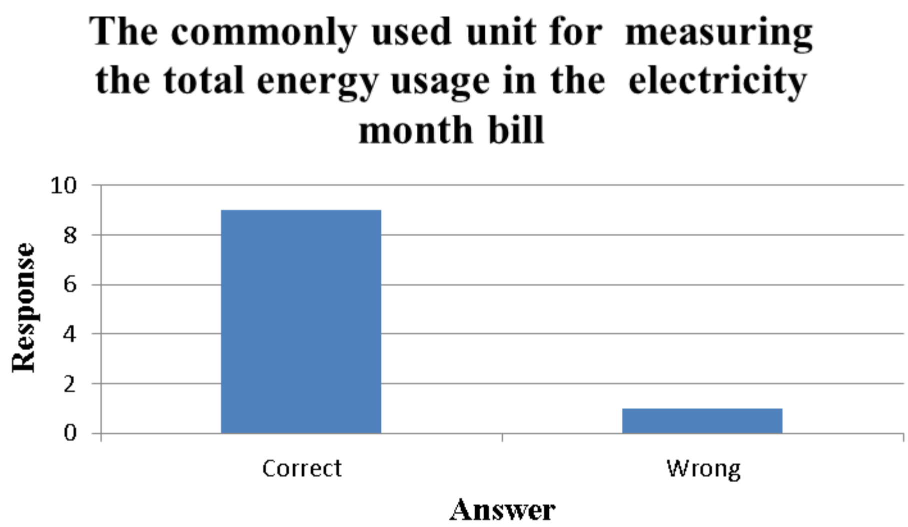

Figure 6.5: Commonly used unit for measuring the total energy usage in the monthly electricity bill

Finally, the participants were asked a question on their understanding about the consumption activities and their impact on their total energy usage.

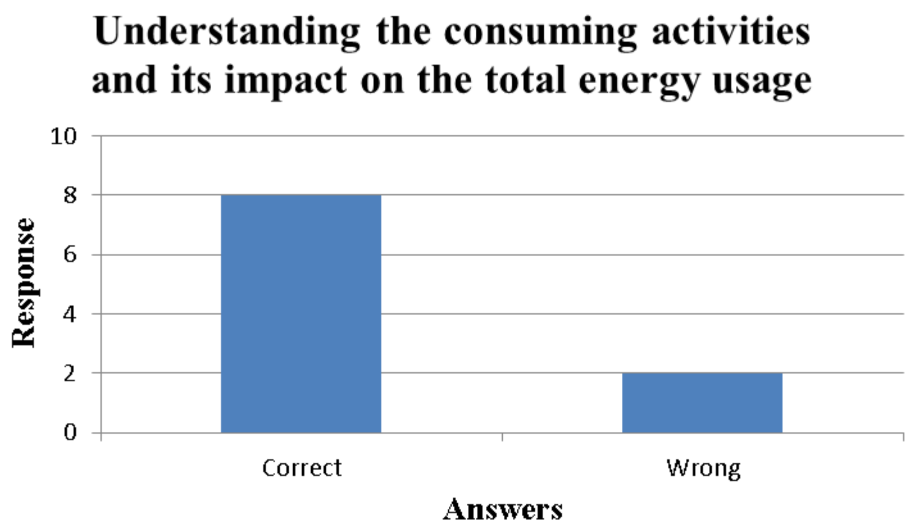

Figure 6.6: Understanding the consumption activities and their impact on the total energy usage

Figure 6.6 shows that eight in ten participants have a good understanding about the impact of different consumption activities on their total energy usage. Only two of them were not able to figure that out correctly. Additionally, the participants were asked about their attitudes and views towards energy conservation. Firstly, they were asked about their general attitude towards improving their energy conservation.

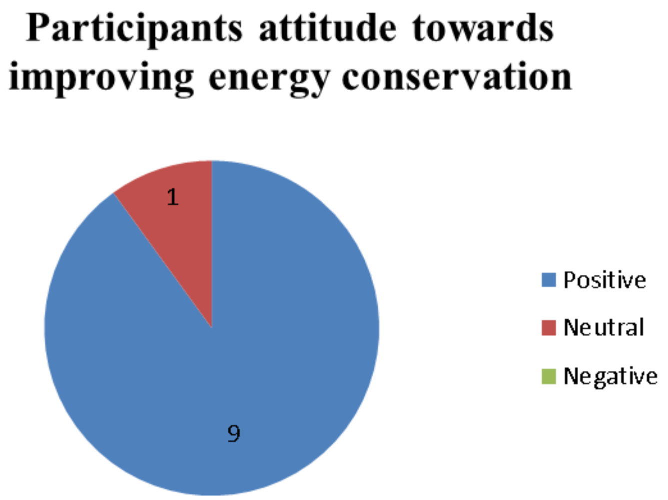

Figure 6.7: Participants' attitude towards improving energy conservation

Figure 6.7 illustrates that nine out of ten participants have positive attitudes; while one participant has a neutral attitude towards improving his energy conservation. Lastly, they were also asked about their point of view about the lack of effect of energy conservation on the comfort of our lives.

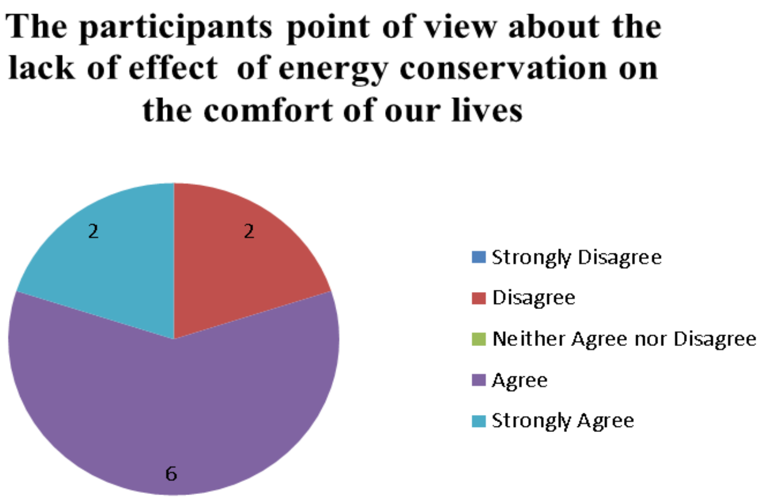

Figure 6.8: Participants' point of view about the lack of effect of energy conservation on the comfort of our lives

Figure 6.8 shows that six out of ten participants agreed that energy conservation does not affect the comfort of our lives. Two of the participants strongly agreed about the previous statement. However, two of the participants disagree with the previous statement and they think that the energy conservation does, in fact, affect the comfort of our lives.

6.1.3 Introduction of real-time feedback

The second questionnaire was given to the participants at the end of the second phase of this study. They were firstly asked about whether or not they were surprised by the data provided about their energy consumption. Nine of the participants were surprised by the data provided by the MyMonitor system. Only one participant was expecting the amount of energy consumption that was recorded by our system, therefore, he was not surprised.

Using a scale of 1 to 5, the participants were asked to rate the motivation for modifying their electricity usage habits created by the information provided by our metering system. A high rating indicates a high level of motivation.

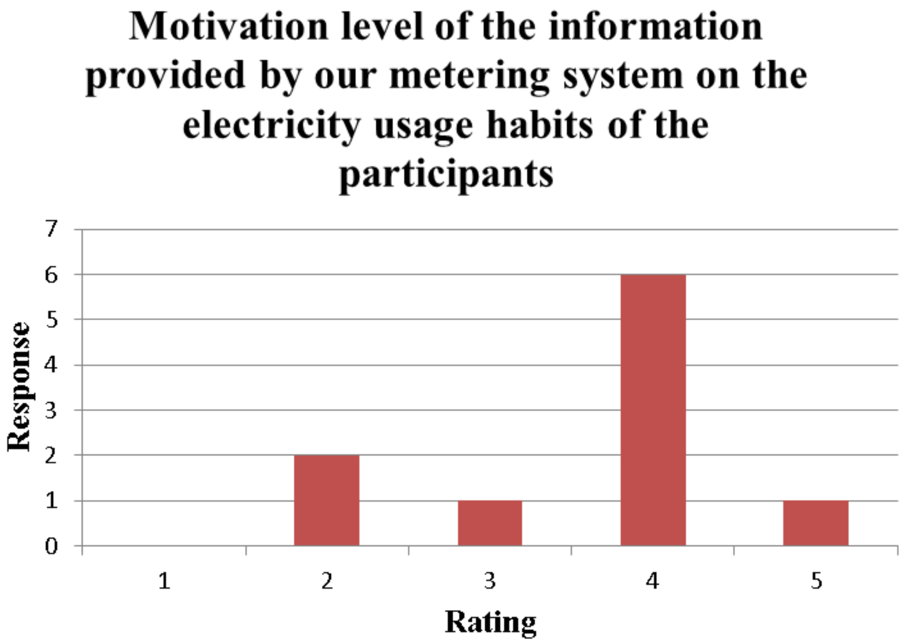

Figure 6.9: Motivation level of the information provided by our metering system on the electricity usage habits of the participants

Figure 6.9 shows that the information provided by our metering system was given high rates by seven of the participants as motivator for them to change their electricity usage habits. However, two of the participants indicated they rated the information provided at a low rate.

Finally, the participants were asked again about their point of view about the lack of effect of energy conservation on the comfort of our lives. Figure 6.10 illustrates that eight out of ten participants agreed that the energy conservation does not affect the comfort of our lives. One participant strongly agreed about the previous statement. However, one participant also disagreed about the previous statement and he thinks that the energy conservation does, in fact, affect the comfort of our lives.

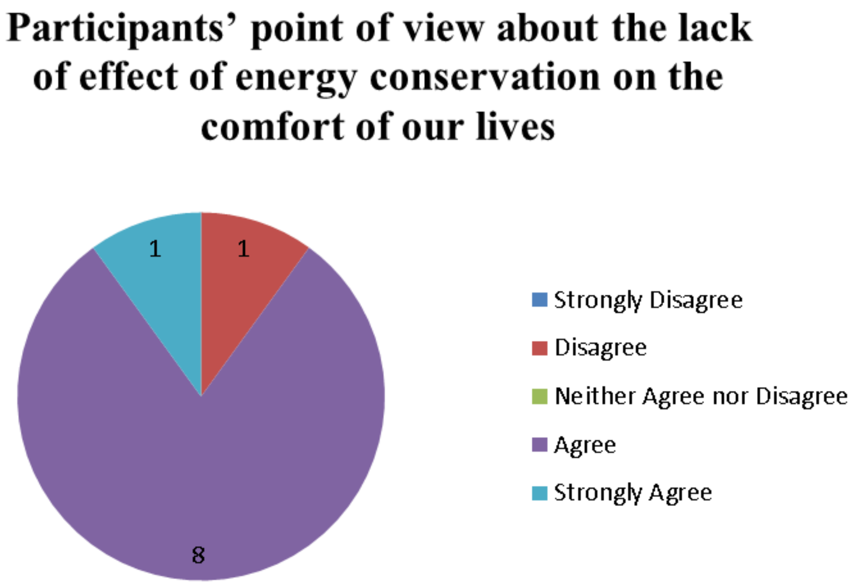

Figure 6.10: Participants' point of view about the lack of effect of energy conservation on the comfort of our lives after phase two

6.1.4 Introduction of competition

The last questionnaire was given to the participants at the end of the study after they finished the third phase which is involving a competition running between them. The motivation level of the information provided by our metering system on the electricity usage habits of the participants was examined again after this phase.

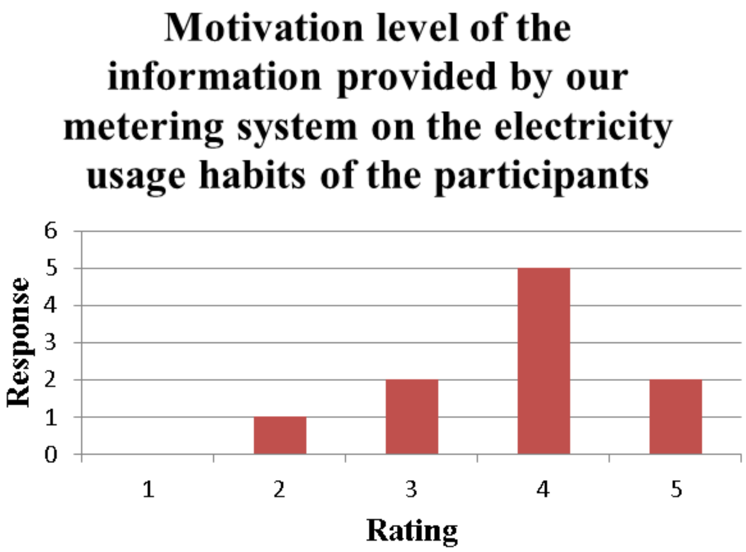

Figure 6.11: Motivation level of the information provided by our metering system on the electricity usage habits of the participants after phase three

Figure 6.11 shows the information provided by our metering system was given high rates by seven of the participants as motivator for them to change their electricity usage habits. Two participants think that it was very motivating. Only one of the participants gave the information provided a low rate.

Using a rating of 1 to 5, the participants were asked about whether or not they were motivated by the competition that they were engaged in with others to change their conservation habits. The high rating indicates a high level of motivation.

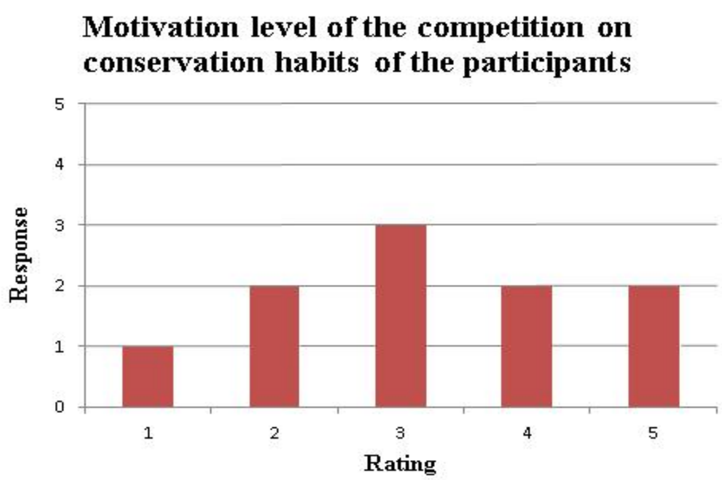

Figure 6.12: Motivation level of the competition on conservation habits of the participants

Figure 6.12 shows that three participants were rating the competition level three as a motivator for them to change their electricity usage habits, while six participants divided their rating equally about competition as motivator between levels two, four and five. Only one participant rated the competition at level one.

Nine of the participants were interested to see their energy usage compared with others and also interested to continue to use a monitor system like ours. Only one of the participants was not interested in both previous statements.

6.2 Quantitative results

As it has been mentioned earlier this project consisted of three phases. The results of each phase will be presented for each group in this section. The results of all phases for both groups will be also presented in this section.

6.2.1 Phase 1

In this phase, the participants were not given any type of feedback. The weekly average energy consumption of the participants of group A for the first phase are presented in Figure 6.13. This phase was run for two weeks for all participants of this group.

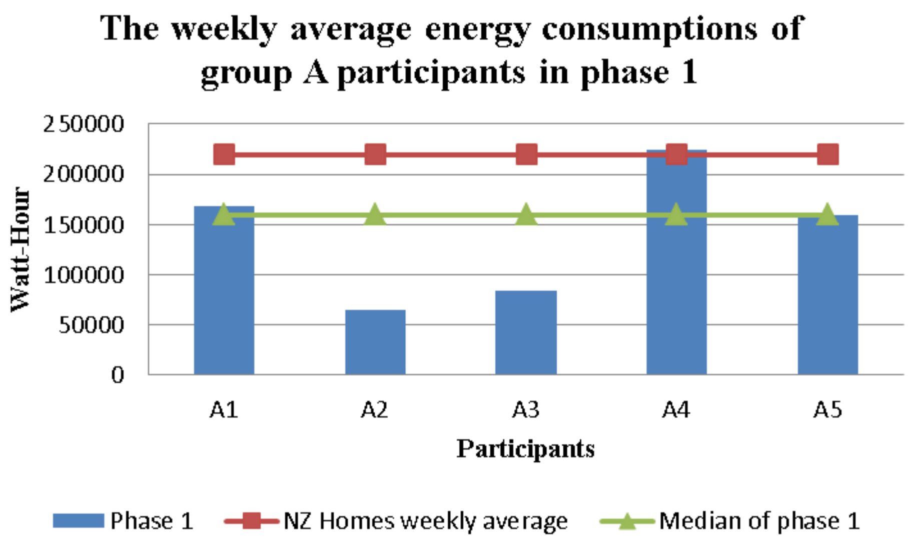

Figure 6.13: Weekly average energy consumption of group A participants in phase 1

Figure 6.13 shows that the weekly average of total energy consumption of group A participants in phase one were mostly below the New Zealand homes weekly average which is around 219420 Watt-Hour (Isaacs et al., 2010). However, one of the participants of this group, A4, was just above the New Zealand average. Two of the participants, A2 and A3, were well below the New Zealand average and the median of their group. The rest of the participants of this group were around the median of this phase. The most efficient participant in consuming less electricity in this phase was A2. He was consumed just above 65,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity was A4. He was consuming around the weekly average of New Zealand homes, 219,420 Watt-Hour.

The weekly average energy use of the participants of group B for phase one is presented in Figure 6.14. This phase was run for two weeks for three participants of this group, B2, B3 and B4; however, this phase was extended for B1 and B5 to be in total four weeks. The reason for extending this phase for those participants was that there were some missing data for the first two weeks; therefore, this phase was extended to guarantee the reliability of the energy consumption data of those participants.

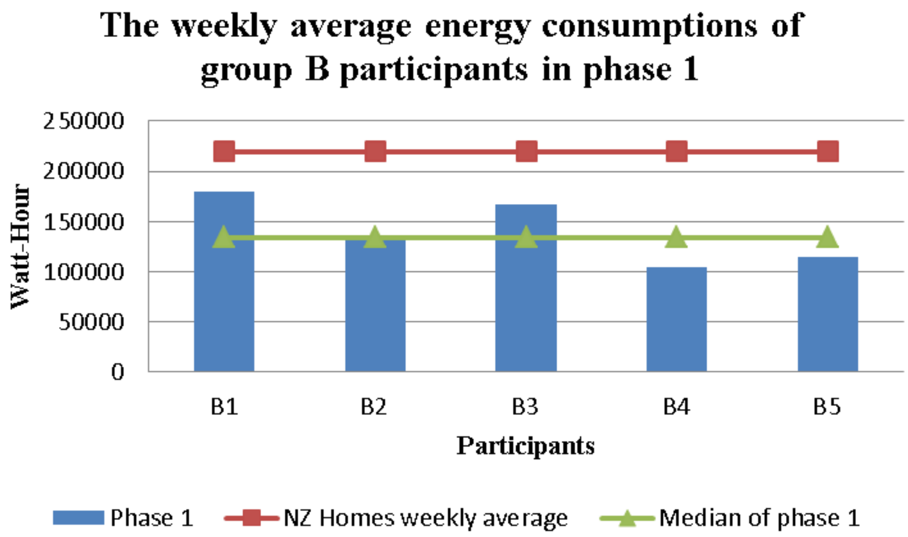

Figure 6.14: Weekly average energy consumption of group B participants in phase 1

Figure 6.14 shows that the weekly average energy use of all the participants of this group is below the New Zealand homes weekly average energy use. The weekly average energy consumption of two of this group's participants, B4 and B5, were well below the New Zealand homes weekly average energy use, around 100,000 Watt-Hour/week. The weekly average energy consumption of all the participants of this group were around the median of phase one of this group. The most efficient participant in consuming less electricity in this phase was B4 who consumed just above 100,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity was B1. He was consuming around 180,000 Watt-Hour.

6.2.2 Phase 2

In this phase, the participants were only allowed to monitor their own energy usage data. The weekly average energy use of the participants of group A for phase two is presented in Figure 6.15. This phase was run for four weeks for all of the participants of this group.

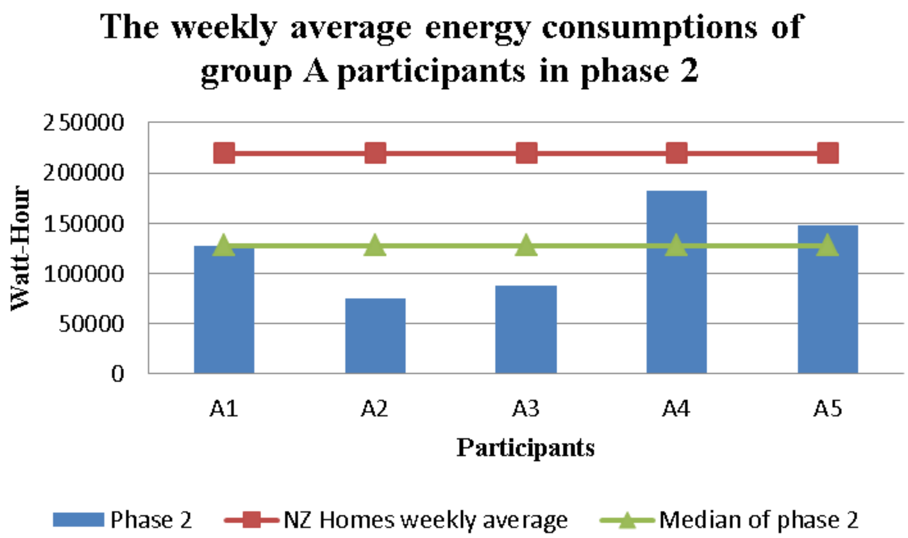

Figure 6.15: Weekly average energy consumption of group A participants in phase 2

Figure 6.15 illustrates that the weekly average energy consumption of all participants of this group was below the New Zealand home weekly average energy usage. Also, two of these participants, A2 and A3, were well below the New Zealand home weekly average, they were around the median of phase two of this group. The most efficient participant in consuming less electricity in this phase was also A2. He consumed just above 75,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity was A4. He was consuming around 180.000 Watt-Hour.

The weekly average energy use of the participants of group B for phase two is presented in Figure 6.16. This phase was run for seven weeks for three participants of this group B2, B3 and B4; however, this phase was run for five weeks for participants B1 and B5 who had some missing data in the earlier phase. The reason for extending this phase for seven and five weeks for others was that B1 and B5 participants were shifted later to phase two from the rest of the group. Also, participants B1 and B5 had some missing data for several days and phase three required for all participants to start together; therefore, this phase was extended for all participants to guarantee the reliability of the energy consumption data of those participants.

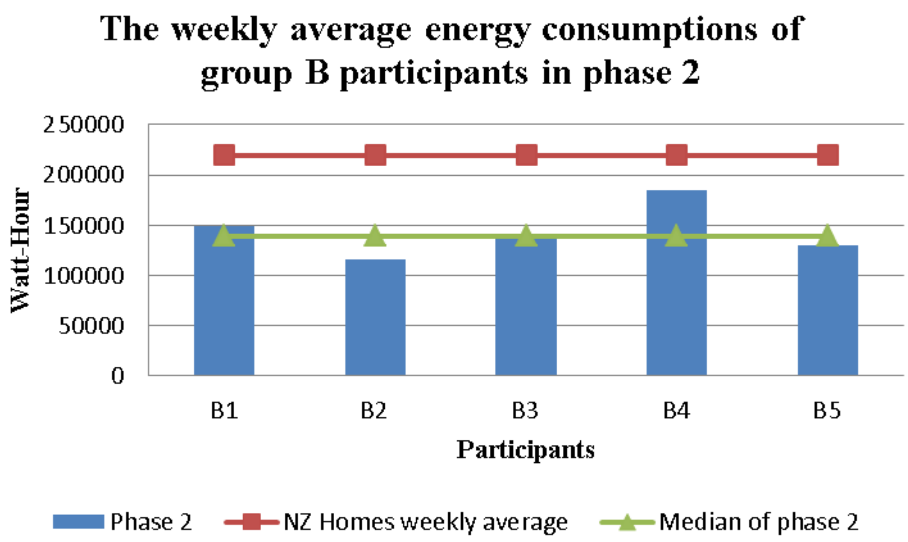

Figure 6.16: Weekly average energy consumption of group B participants in phase 2

Figures 6.16 presents the weekly average energy usage of all the participants of this group that were still below the New Zealand home weekly average energy consumption. The energy consumption of B2 was well below the New Zealand home weekly average energy use, around 100,000 Watt-Hour/week. Their weekly energy consumptions were around their group median of phase two. The most efficient participant in consuming less electricity in this phase was B2. He consumed around 100,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity B4. He was consuming around 185,000 Watt-Hour.

6.2.3 Phase 3

In this phase, the participants were involved in a competition against each other. The weekly average energy consumption of the participants of group A for the third phase are presented in Figure 6.17. This phase was run for four weeks for all participants of this group.

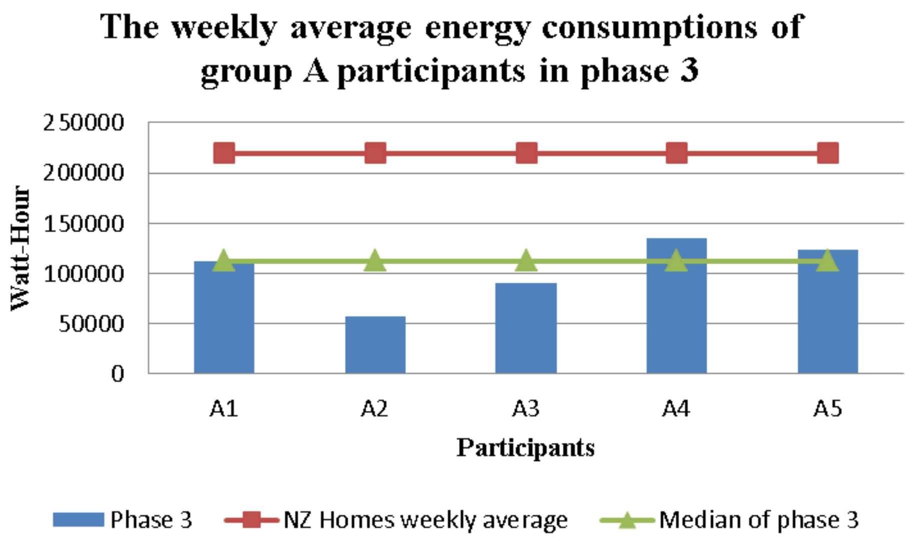

Figure 6.17: The weekly average energy consumptions of group A participants in phase 3

Figure 6.17 shows that the weekly average energy usage of all participants of this group dropped significantly below the New Zealand home weekly average energy use. One of the participants, A2, was consuming significantly well below the New Zealand average and the median of his group. They were almost all around the median of phase three of this group. The most efficient participant in consuming less electricity in this phase was A2. He consumed just above 50,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity was A4. He was consuming around 140.000 Watt-Hour.

The weekly average energy consumption of the participants of group B for phase three are presented in Figure 6.18. This phase was run for four weeks for all participants of this group.

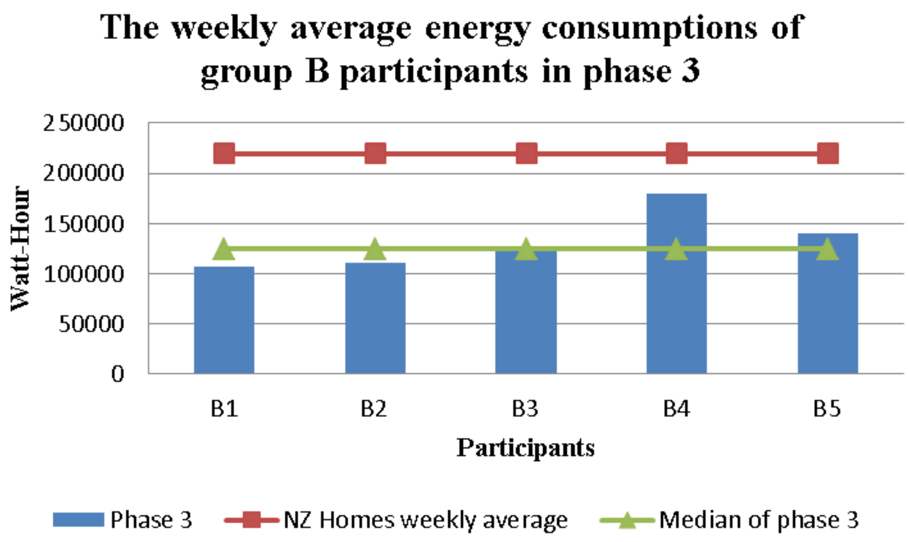

Figure 6.18: Weekly average energy consumption of group B participants in phase 3

Figure 6.18 shows that the weekly average energy consumption for all the participants of this group were still below the New Zealand home weekly average. The energy consumption of B2 was still well below the New Zealand home weekly average energy use, around 100,000 Watt-Hour/week. They were all around their group median of phase three. The most efficient participant in consuming less electricity in this phase was still B2. He consumed around 100,000 Watt-Hour/week. The participant who had least efficiency in consuming electricity was still B4 participant. He was consuming around 180,000 Watt-Hour.

6.2.4 Comparison between all phases

In this part, the weekly average total energy consumption for groups A and B and the reduction and the increase level across all phases are highlighted. The weekly average energy consumptions of the participants of group A for phases one, two and three are presented in Figure 6.19. The duration of all phases was ten weeks.

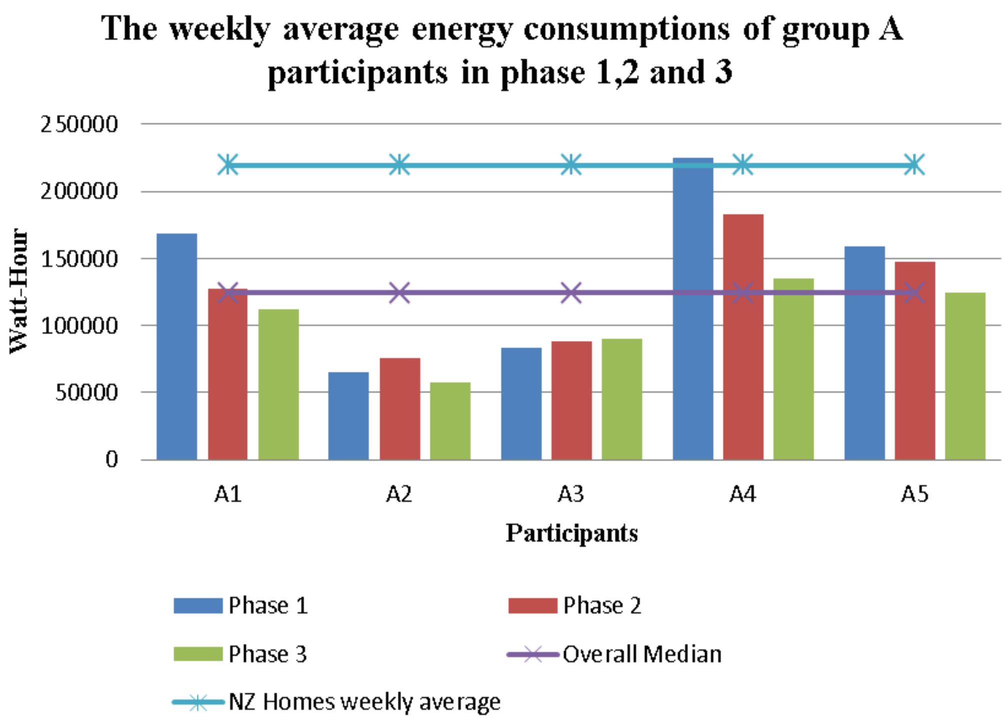

Figure 6.19: Weekly average energy consumption of group A participants in phases 1, 2 and 3

Figure 6.19 shows that the weekly average energy usage of group A for all phases were almost all below the New Zealand home weekly average energy consumption. Two of those participants, A2 and A3, were significantly well below the New Zealand home weekly average across all phases. It can be noticed that there were some reductions in energy consumption in phases two and three for three of the participants, A1, A4 and A5, while participants A2 and A3 were not able to reduce their energy consumption except A2 in the third phase. Also, their weekly energy consumption was dispersed around their group overall median to some extent. The most efficient participant in consuming less electricity across all phases was A2, while the participant who had least efficiency in consuming electricity across all phases was A4.

The weekly average energy usage of the participants of group B for phases one, two and three is presented in Figure 6.20. The duration of all phases was thirteen weeks.

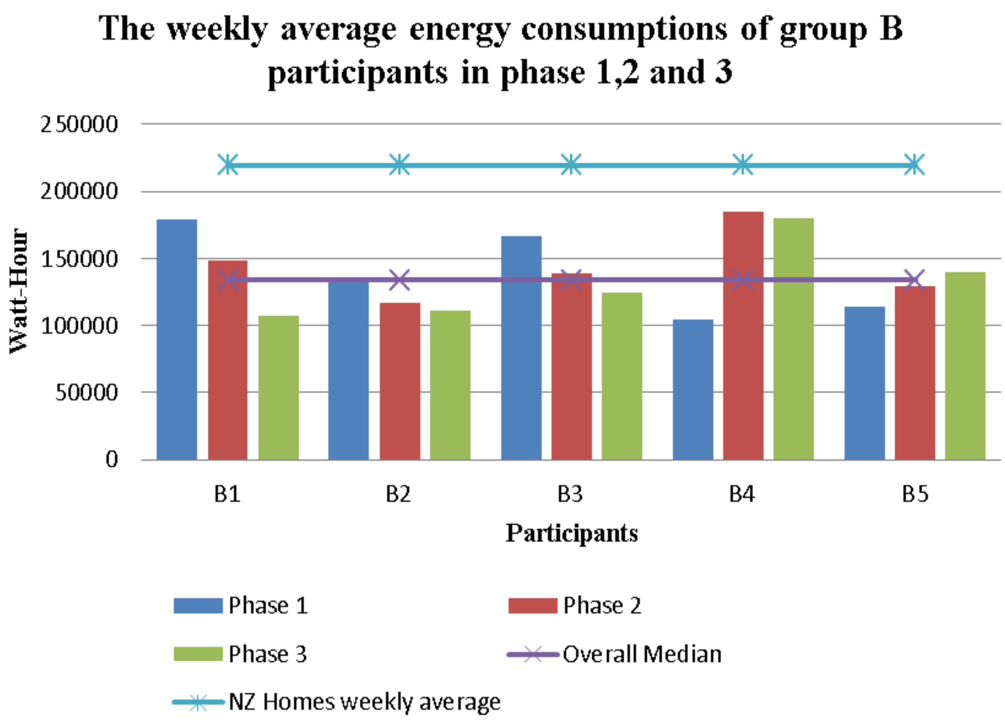

Figure 6.20: Weekly average energy consumption of group B participants in phases 1, 2 and 3

Figure 6.20 demonstrates that the weekly average energy usage of group B participants for all phases was all below the New Zealand home weekly average energy consumption. It can be noticed that there were some reductions in energy consumption in phases two and three for three of the participants, B1, B2 and A3; while participants B4 and B5 were not able to reduce their energy consumption, except in the third phase of participant B4 there was a slight reduction. Also, their weekly energy consumption was, to some extent, convergent around their group overall median. The most efficient participant in consuming less electricity across all phases was B2, while the participant who had least efficiency in consuming electricity across all phases was B4.

The weekly energy consumption for all participants is presented in Figure 6.21 which shows that six of the participants reduced their electricity consumption gradually to be around 100,000 to 150,000 watt-hour/week and their energy consumption steadied around that throughout the study. The electricity usage of participant B4 was around 100,000 watt-hour/week for the first two weeks, then it increased sharply to reach 200,000 watt-hour/week in week three. After that it dropped in week six and then increased gradually to around 200,000 watt-hour/week. Finally, it dropped gradually from week ten until the last week of the study. The energy usage of participant A1 was around 220,000 watt-hour/week for the first three weeks and then it significantly decreased to reach around 150,000 watt-hour/week in week five. After that it continued to decrease gradually till week nine. Finally, it increased in the last week of the study of group.

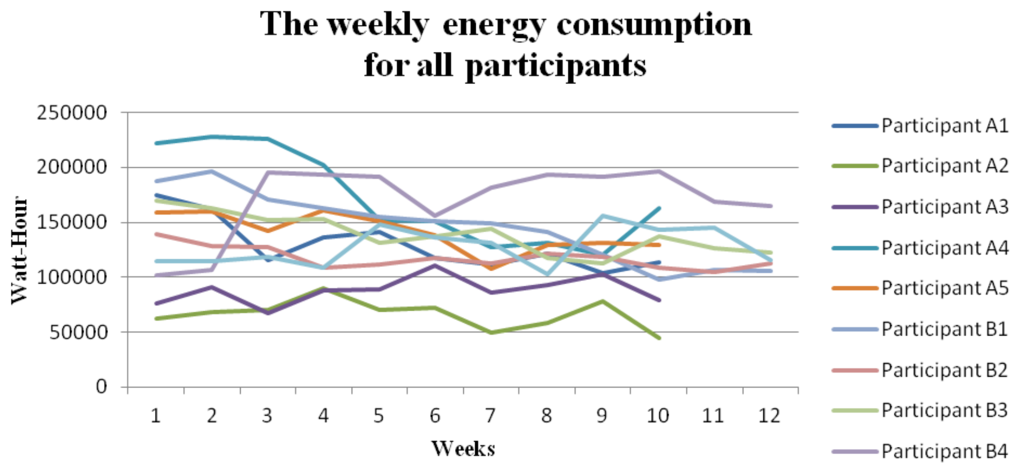

Figure 6.21: Weekly energy consumption for all participants

The reduction and increase percentages of the electricity consumption of group A participants across all phases are presented in Figure 6.22, which shows that three of the participants of this group, A1, A4 and A5, were successfully able to reduce their electricity consumption during phases two and three. In contrast, one participants, A3, was not able to reduce his electricity consumption at all.

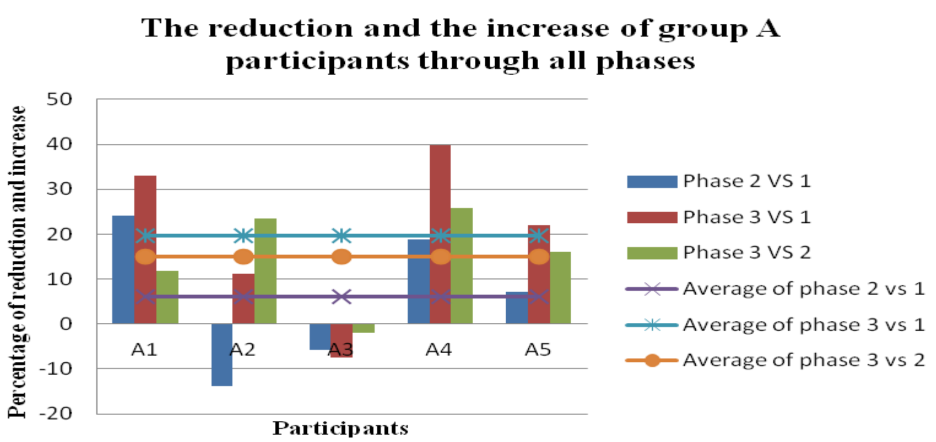

Figure 6.22: Reduction and increase percentages of the electricity consumption of group A across all phases

Three in five participants were able to reduce their energy consumption in phase two. Four out of five participants were successfully able to reduce their energy consumption even more in the third phase. The average of the reduction percentage between phase two and phase one was around six per cent. While, the average of the reduction percentage between phase three and phase one was about 20 per cent. Moreover, by comparing the reduction of electricity consumption between the third and second phases, it was found that the participants of this group reduced their electricity consumption in phase three by about 15 per cent more that of the second phase. The maximum reduction in the energy consumption was gained by participant A4 in the third phase; while in opposite the maximum increase in the energy usage was gained by participant A2 in the second phase.

The reduction and increase percentages of the energy usages of group B participants across all phases are presented in Figure 6.23.

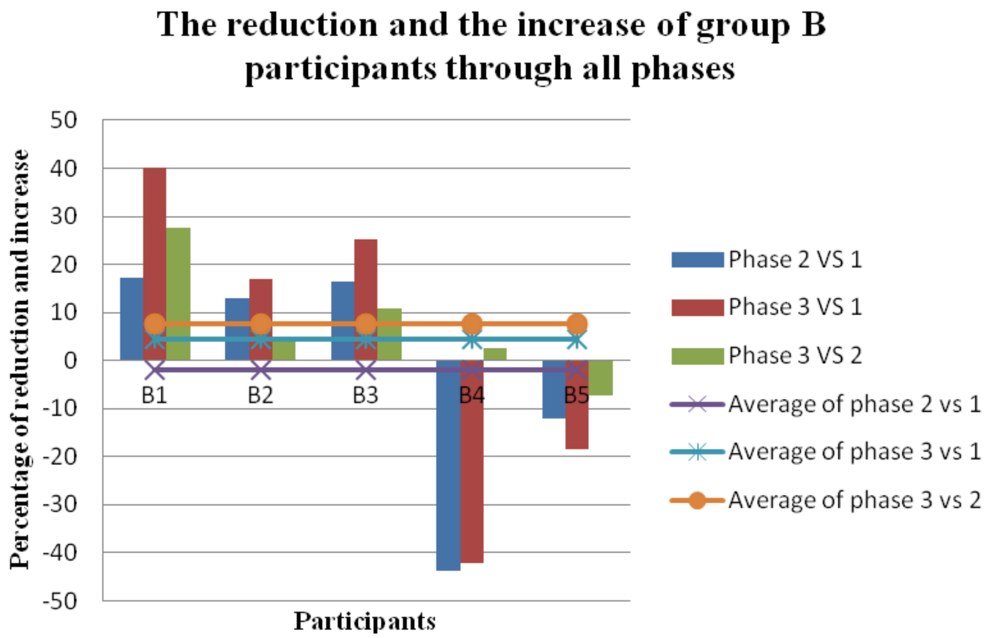

Figure 6.23: Reduction and increase percentages of the electricity consumption of group B across all phases

Figure 6.23 illustrates that three of the participants of this group, B1, B2 and B3, were successfully able to reduce their electricity consumption during phases two and three. In contrast, two of the participants, B4 and B5, were not able to reduce their electricity consumption during phases two and three compared to phase one.

However, participant B4 was able to reduce his electricity consumption in phase three in comparison with phase two.

Three in five participants were successfully able to reduce their energy consumption in phases two and three. The average of the reduction percentage between phase two and phase one was increased by around 2 per cent, while the average of the reduction percentage between phase three and phase one was about 4 per cent. By comparing the reduction of electricity consumption between the third and second phases, it can be found that the participants of this group reduced their electricity consumption in phase three by about 3 per cent more than the second phase. The maximum reduction in the electricity consumption was gained by participant B1 in the third phase; while the maximum increase in the energy usage was gained by participant B4 in the second phase.

The overall reduction and increase in the energy use for all participants across all phases is presented in Figure 6.24.

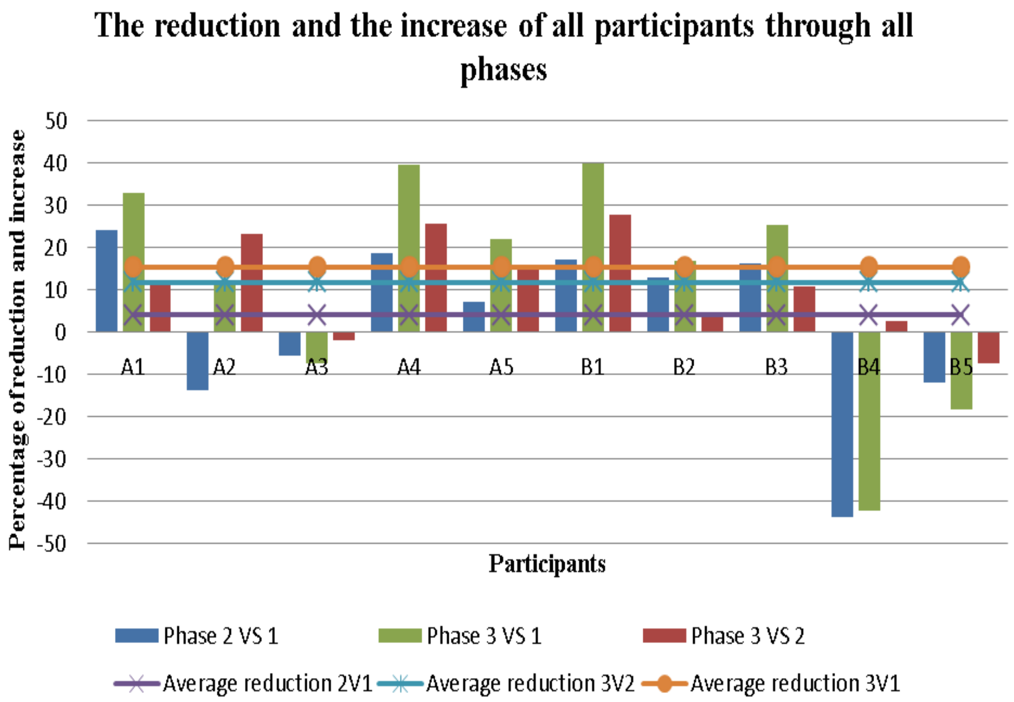

Figure 6.24: Reduction and increase across all phases

Figure 6.24 shows that six out of ten participants of both groups were successfully able to reduce their electricity consumption during phase two; while seven in ten were able to reduce their energy use during phase three. In contrast, three out of ten participants, A3, B4 and B5, were not able to reduce their electricity consumption at all, instead their energy usage increased during phases two and three compared to phase one.

The overall average reduction for both groups between phase two and phase one was around 4 per cent; while the overall average reduction between phase three and phase one was about 14 per cent. By comparing the reduction of electricity consumption between the third and second phases, it is found that the participants of both groups reduced their electricity consumption in phase three by about 10 per cent more than in the second phase. The maximum reduction in the power use was gained by participant A4 in the third phase; while the maximum increase in the energy consumption was gained by participant B4 in the second phase.

6.2.5 Facebook insights about MyMonitor application

Metrics around the contents of Facebook Platform developers and Facebook Page owners are provided by Facebook insights (Facebook, 2012). Some of those results will be presented in this section.

Most of the participants were allowed to use the MyMonitor application from the beginning of week three of the study; however, two users started using the application from the fifth week which started from 9/19/2011.

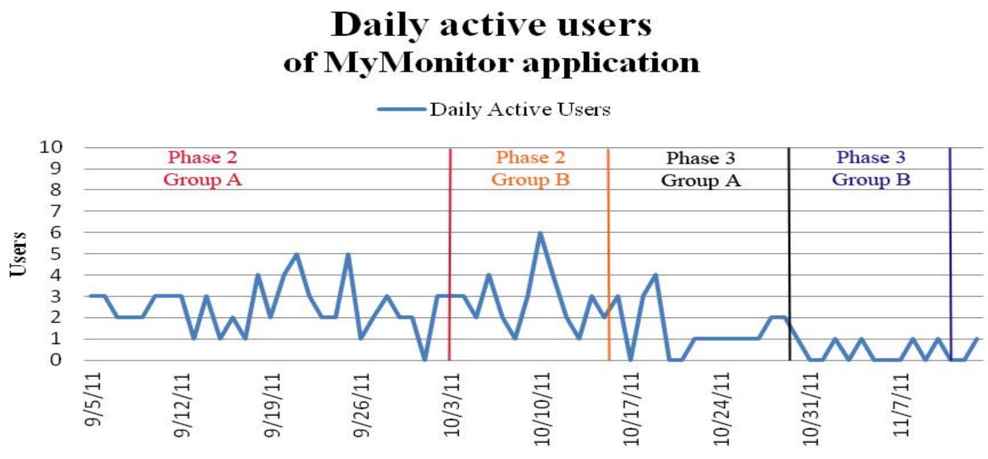

Figure 6.25: Daily active users of the MyMonitor application

Figure 6.25 shows that the number of users of the application for the first two weeks of the second phase of group A and B fluctuated around one to three users. The fluctuation continued and the number of users increased to five users. After that, the number of users decreased between 26/09/2011 and 3/10/2011 at the end of phase two of the group A. When phase three of group A began, the number of active users started to increase again until it reached the peak number which was six users on 10/10/2011 and also, during that time phase two of group B was still running. Then the number of users decreased again to be one daily user every couple of days after the peak especially when phase three of group A was over.

During the third phase where the competition was running between the participants, the participants were allowed to publish their winning symbol of the daily reward in their Facebook profile page and share their winning with their friends.

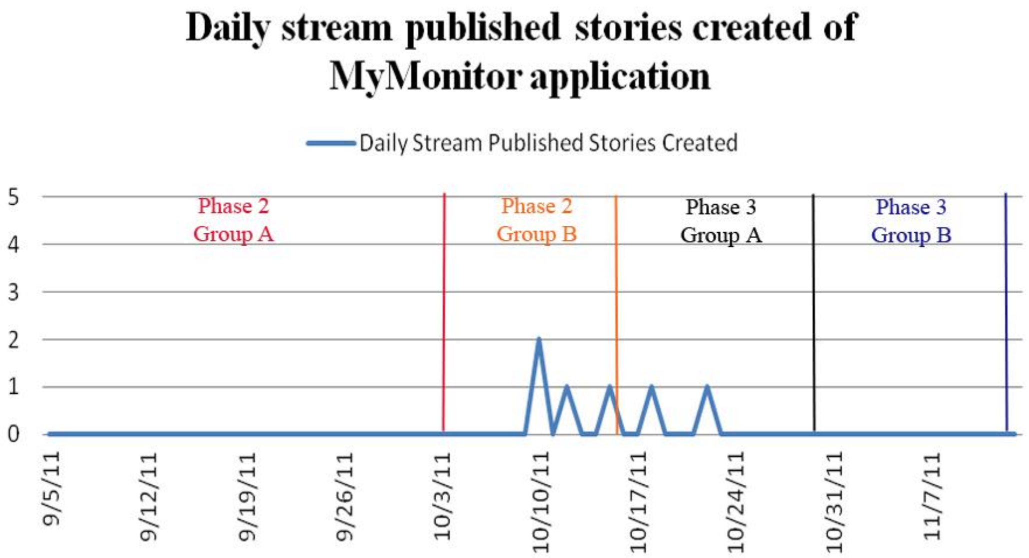

Figure 6.26: Daily stream of published stories created by MyMonitor application

Figure 6.26 illustrates that there were two posts published on 10/10/2011 during the third phase of group A. Then there was one post fed every couple of days between 10/10/2011 to 24/10/2011. Four posts were published for sure by the participants of group A because the third phase of group B started on 16/10/2011. Only two posts were being published during phase three of group B and the rest of time on the third phase of group A.

7 Discussion

This study aimed to explore the effect on the energy conservation behaviour of the participants of providing real-time feedback and involving the participants in a competition to keep overall consumption down. This chapter will further evaluate a selection of the study results that were previously presented in chapter six. Finally, a number of the study's limitations will be highlighted at the end of this chapter.

7.1 Lessons learned

Monitoring participants' energy consumption over long period of time has produced a massive amount of the data, which needs to be evaluated and interpreted. A selection of results will be used to highlight the general and important issues related to research issues. This chapter will focus on three main interlocutors: the reflection on providing real-time energy data, involving the consumers in a competition; and having strong affinity among members of a community on changing consumers' conservation behaviour.

7.1.1 Real-time feedback

In section 3.1, it was stated that we believe that providing real-time feedback will reduce the energy usage of the consumers. The findings prove our first hypothesis and show that more than half of the participants reacted positively to the real-time data and they changed their energy conservation behaviour; therefore, they were able to reduce their energy usage. These results agree with all previous works: Allen & Janda (2006), Darby (2000), Anderson & White (2009), Weiss et al. (2009), and Dobson & Griffin (1992) where the effects of the real-time feedback on the energy conservation behaviour of the consumers were strongly emphasized. However, the average reduction that was gained in the second phase for all participants which was about 4 per cent (see Figure 6.24) is below the average reduction that was found in most of the previous work which was between 10 and 15 per cent.

There are a number of explanations for the gap between our average reduction result and the result of most previous studies. Firstly, our research sample was small for collecting comprehensive statistical results to be representative results of the population. Therefore, if a relatively large sample was involved in this study, then the reduction results were gained by providing real-time feedback to the participants would reach the range of the average energy reduction that was indicated by most previous studies. The reason for choosing to have a relatively small sample was that indicative results only were sought by this study.

Secondly, the length of phase two might be inadequate for the participants to be fully adapted to the new behaviours which were obtained from providing real-time feedback. Figure 6.21 provides clear evidence of the previous assumptions where six of the participants reduced their electricity consumption gradually until week six, then their energy consumption steadied to around 100,000 watt-hour/week to 150,000 watt-hour/week. Therefore, if the second phase was run for a longer time, the reduction results of the second phase would reach the range of the average energy reduction that was indicated by most previous studies.

7.1.2 Competition

It has been stated also in section 3.1 that we believe that further reductions in energy consumption can be gained by involving the consumers in a competition to keep overall consumption down. The findings of this study have shown a significant reduction, about 15 per cent (see Figure 6.24) in the participants' energy consumption during the third phase, the time when the competition was held. Additionally, the average reduction while providing real-time feedback was about 4 per cent and when the participants were involved in a competition, the average reduction increased up to 15 per cent compared with phase one. Figure 6.24 also shows that the average reduction between phase three and phase two for all participants was around 12 per cent. Therefore, our assumption is proved by these results and also agrees with all previous studies such as Allen & Janda (2006) which found that competition improves the effect of real-time feedback when coupled with it, and becomes a powerful stimulant for behavioural change. Also it agrees with Yim's (2011) findings that social competition can be an effective approach to decrease energy consumption behaviour.

7.1.3 Affinity among members of a community

The participants of group A (all from the Saudi community) interacted very positively with our system and they were able to significantly reduce their electricity consumption to around 6 per cent in phase two where they were provided with real-time feedback (see Figure 6.22). Additionally, they gained a huge reduction of about 20 per cent in the third phase where they were involved in a competition. The significant success behind that is that the participants of this group where all members of the same social group and they knew each other very well. As can be seen in Figure 6.25, the number of daily active users of the MyMonitor application dropped to only one active user after the end of phase three of group A which was on 30/10/2011. Additionally, most, if not all, of the daily stream published stories (Figure 6.26) were by group A participants. Therefore, these are indications for which group was using our system more frequently.

In contrast, the interaction of group B participants was slow. In phase two, their energy consumption increased on average by about 2 per cent (see Figure 6.23). However, their energy consumption in phase three reduced on average by about 4 per cent. The reason for the slow changing in the conservation behaviour of this group is that these participants were individuals. They were all staff members at the University of Waikato and they do not know each other very well. Therefore, they were less social than the other group.

In summary, strong affinity and social relations among members of a community have a great influence in changing people's conservation behaviour and the change will happen sooner than if the social relations are weak. This finding agrees with Yim (2011) who found that strong affinity among members of a community such as in Greece has a positive influence in reducing energy consumption, whereas in North Campus resident halls, energy consumption increased. Despite the fact that group B was less social than group A, the energy usage behaviour change was gained by both groups in less than three months. This finding agrees with the finding of Foster et al. (2010) that the claim of three months minimum for energy using behaviour change may not be necessary hold when a social platform is used to deliver the feedback.

7.2 Recommendations

User behaviours and thoughts in three different conditions have been studied to explore the effect of real-time feedback and competition through social networks on people's energy conservation behaviour. The empirical evidence from the study, as well as the insights from related studies, will be used to make suggestions to be considered for use in the next stage for developing social energy monitor.

- Making the monitoring experience through the social networks more enjoyable would encourage users to use the monitoring system more frequently and to be connected with their trusted friends to share their thoughts and experiences. That agrees with Foster et al.'s (2010) findings which suggested that social networking sites can play a key role in decreasing energy consumption in the home by making monitoring more enjoyable.

- The technological revolution in the smart mobiles increase the number of people who are surfing the internet though their phones because they are providing an easy access to the internet as they are carried by people most of the time. Therefore, creating a social monitoring system that fully supports mobile devices would result in reducing energy usage further.

- Making users contribute more effectively in the social monitoring system by allowing them to add consuming events and presenting these added events in the representations would result in increasing users' understanding of the changes presented in their energy consumption.

- Allowing users to make their own challenges would encourage them to be deeply involved in the competition to win these challenges. For example, the users could be allowed to post a challenge card to their Facebook friends to invite them to a competition and make the competition result available to all users' friends to get the needed support and encouragement.

7.3 Study limitations

This study was limited by two main limitations: time and technical issues. The development of the monitoring system of this study took more time than expected; therefore, we were running of time to do the experiment before the end of B semester as the participants of group A were international students and most of them were planning to go back to their home country during the summer holiday. Also the other group were university staff members and it would be difficult to catch up with them during their summer holiday. Therefore, the original plan was modified to make sure that we finish the study before the end of B semester for the student group and before the summer holiday of the staff members group. This modification in the original plan could have had a negative influence on our results.

The technical issues that were explained earlier in section 4.5 could also have had a negative influence in our results, especially in the first phase. We chose to make the first phase shorter than the others because of the limitation of available time. This phase was the most appropriate phase to modify its length because we were not expecting any changes in participants' behaviours. However, the technical issues had an opposite effect on this modification.

8 Conclusion and Further Work

Global warming and climate change have caused people all over the world to think about reducing the sort of activities that make this problem worse. Therefore there are many devices on the market that can monitor household electricity consumption. Those devices represent total household electricity consumption, consumption on the appliance level, or both. Representing electricity consumption at the whole-of-house and appliance levels makes the visualisation even more powerful than representing just one of them. Most of those existing solutions did not consider taking advantage of social networks. However, a few of these existent solutions have employed the power of the social networks and created applications on them for allowing the users to monitor and share their energy data with their friends. For example, there is an application on Facebook that was developed by Current Cost Ltd where this application works with the CurrentCost dashboard to view and share the same data in Facebook (Current Cost Technical Blog, 2011).

A key role can be played in energy use behaviour change by social networking sites to decrease the power use in the household by providing an enjoyable monitoring experience. Therefore, the energy conservation behaviour change can be gained in less than three months and that was confirmed in our findings. Moreover, we have found that providing real-time feedback reduces the energy usage of the consumers and also further reductions in energy consumption can be gained by involving the consumers in a competition to keep overall consumption down.

Social relations are patterns of relationships between individuals who share a common culture and institutions which characterize our human societies; a given society may be described as the sum total of such relationships among its constituent members (Wikipedia, 2012). We found that strong affinity and social relations among members of a community have a great influence in changing people's conservation behaviour and the change will happen sooner than if the social relations are weak.

An obvious next step in this work would be to use a large-scale sample to re-evaluate the hypothesis of this study to obtain comprehensive statistical results to be representative of the population. Also, in the further work all the recommendations in section 7.2 should be taken into account when we develop the new version of our Facebook app which is called MyMonitor.

Finally, we cannot claim that this project is truly completed; however, we hope to proceed with some of the proposals in the future work section to deal with limitations that were encountered.

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Appendices

Appendix A

Ethical Approval

Computing and Mathematical Sciences
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THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

8 August 2011

Majed Alrowaily
C/- Department of Computer Science
THE UNIVERSITY OF WAIKATO

Dear Majed

Request for approval to conduct a research study involving human participants and in-home installation of power monitors

I have considered your request to conduct a study for your research project "Power usage monitoring through social networks". Your project will measure the effectiveness of conducting a competition between consumers through installation by a qualified electrician of Current Cost domestic electricity monitors in participants' homes and monitoring over a period of three months, for the purpose of evaluating the effect of a set of independent variables.

The procedures described in your request are acceptable.

I note your statement that confidentiality and participant anonymity will be strictly maintained. The data gathered from participants will be accessible only to you and your supervisor and at a later stage shared with all those in the group participating. No names or other identifying characteristics will be stated in the final or any other reports.

The research participants' information sheet, consent forms and questionnaires meet the requirements of the University's human research ethics policies and procedures.

Yours sincerely,

LA Hunt

Lyn Hunt
Human Research Ethics Committee
Faculty of Computing and Mathematical Sciences

Appendix B

Participant workbook

Research Consent Form

Ethics Committee, School of Computing and Mathematical Sciences

Power usage monitoring through social networks

Consent Form for Participants

I have read the **Participant Information Sheet** for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that I am free to withdraw from the study before 15 November 2011, or to decline to answer any particular questions or require removing the current cost monitor during the study. I understand that I can withdraw any information I have provided up until the researcher has commenced analysis on my data on 15 November 2011. I agree to provide information to the researchers under the conditions of confidentiality set out on the **Participant Information Sheet**.

I agree to participate in this study under the conditions set out in the **Participant Information Sheet**.-
I also agree to have the other participants in the study see and have access to my energy activity data.

Signed: ____

Name: ____

Date: ____

I agree / do not agree to have the current cost monitor installed in my house.

I agree / do not agree to my responses to my energy activity be recorded.

Signed: ____

Name: ____

Date: ____

Researcher's Name and contact information: Majed Abdullah Alrowaily

majed_m9@hotnail.com

Supervisor's Name and contact information: Dr. Mark Apperley

m.apperley@cs.waikato.ac.nz

Bridge Mac Address:

Initial Questionnaire

This questionnaire is aimed at gathering general information about the household, as well as establishing what basic knowledge the subject has of electricity, power and energy concepts

1. Please answer the following general questions to your best ability: (Please circle)What is your age group?

a. < 20 b. 20-29 c. 30-39 d. 40-49 e. >50 f. refuse

2. Gender:

a. Male b. Female

3. What is the total number of people in your household

a. 1 b. 2 c. 3 d. > 3 e. refuse

4. What is the average monthly electricity bill?

a. < $50 b. $50-$100 c. $100-$150 d. $150-$200 e. > $200 f. refuse

5. Do you know the unit commonly used as measure of power?

a. Km b. M c. Ampere d. Watt e. No idea

6. In your electricity bill, what is the unit used to measure your total energy usage for the month?

a. Watt b. Kilowatt hour c. Kilowatt d. Voltage e. No idea

7. Can you suggest which of the following activities would consume the most energy

a. 100 Watt lamp used for 17 hours b. 1500 Watt oven used for 1 hour

8. What is your general attitude towards improved energy conservation?

a. Positive b. Neutral c. Negative

9. What is your view of the statement “energy conservation need not affect the comfort of our lives”?

a. 1 b. 2 c. 3 d. 4 e. 5

Strongly Disagree Neither Agree nor Disagree Strongly Agree

Bridge Mac Address:

Stage two questionnaire

This questionnaire is aimed at gathering information about the household expectation, as well as establishing any change of the subject attitude towards improved energy conservation after being informed about their energy usage during this stage.

Please answer the following questions to your best ability: (Please circle)

1. Were you surprised by the data provided about your energy consumption ?

a. Yes b. No

2. To what extent has the information provided by the metering system motivated you to change your electricity usage habits?

   (Please rank: 1 = not at all motivating and 5 = very motivating)

a. 1 b. 2 c. 3 d. 4 e. 5

3. What is your general attitude towards improved energy conservation?
   a. Positive b. Neutral c. Negative

4. What is your view of the statement “energy conservation need not affect the comfort of our lives”?

a. 1 b. 2 c. 3 d. 4 e. 5

Strongly Disagree Neither Agree nor Disagree Strongly Agree

5. You have been provided with real-time information about your energy consumption, as instantaneous power demand and total hourly and daily energy consumption during this stage. Is there additional information that you would have found useful in this context?

Bridge Mac Address:

Stage three questionnaire

This questionnaire is aimed at gathering information about the household expectation, as well as establishing any change of the subject attitude towards improved energy conservation after being informed about their energy usage and others' as well.

Please answer the following questions to your best ability: (Please circle)

1. Were you surprised by the data provided about your energy consumption in comparison with other's energy usage?

   a. Yes b. No

2. To what extent has the information provided by the metering system motivated you to change your electricity usage habits?

   (Please rank: 1 = not at all motivating and 5 = very motivating)

   a. 1 b. 2 c. 3 d. 4 e. 5

3. To what extent did the information about others' energy usage motivating you to change your conservation habits?

   (Please rank: 1 = not at all motivating and 5 = very motivating)

   a. 1 b. 2 c. 3 d. 4 e. 5

4. To what extent did the competition that you were engaged in with others motivate you to change your conservation habits?

   (Please rank: 1 = not at all motivating and 5 = very motivating)

   a. 1 b. 2 c. 3 d. 4 e. 5

5. To what extent did reading others' comments about their experince in their energy conservation behaviour motivate you to change your conservation habits?

(Please rank: 1 = not at all motivating and 5 = very motivating)

a. 1 b. 2 c. 3 d. 4 e. 5

6. Did you find it interesting to see your energy usage compared with others?

a. Yes b. No

7. Would you like to continue to use a monitor like this?

a. Yes b. No