School of Engineering and Information Technology

Department Electrical Engineering, Energy and Physics

Bachelor of Engineering Honours (H1264)

Majors: Electrical Power Engineering & Instrumentation and Control Engineering

Demand Response Implementation Into Residential Sector

ACADEMIC SUPERVISOR ENDORSEMENT

I am satisfied with the progress of this thesis project and that the attached report is an accurate reflection of the work undertaken.

Signed

Date

DECLARATION

This thesis is presented for the Bachelor of Engineering Honours degree of Murdoch University, and submitted in January 2016. I declare that this thesis is my own work and all sources of information used in this thesis have been fully acknowledged.

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iii. ABSTRACT

In the current financial climate, focus on energy saving within the home has intensified by the desire to reduce costs. Western Australian residential electricity prices are expected to increase in 2016 and 2017. Between 2015 and 2017 the cost of supplying electricity is predicted to increase annually by 7% (Australian Energy Market Commission 2014, 57 -63). Fossil fuel savings, lowering average carbon emissions, as well as a permanent fall in electricity prices, are all significant incentives for the residential sector to look at different methods to reduce its power consumption.

In Australia, the residential sector contributes about 25% of the total energy consumption but can incorporate up to 45% of Peak Demand. Pricing techniques and enabling technologies offer various possibilities for lowering Peak Demand by encouraging consumers to participate actively in power Demand Response. Our power networks are designed to meet Peak Demand to avoid equipment failure and service disruptions; this provides excellent opportunities for energy savings. Reducing Peak Demand will benefit consumers and suppliers by reducing power system costs. Suitable Pricing techniques can be applied in the residential sector, which could lead to consumer savings on electricity bills.

Due to its complexity, the introduction and integration of pricing schemes into the different Energy Markets entails a comprehensive approach, including consideration of the functional energy performance, economic and environmental aspects, from conceptual design through to design realization. This report defines some enabling technologies such as smart meters, appliances, and tools which provide an opportunity for consumers to respond at short notice to a variety of signals. For example electricity price, by changing their energy consumption.

The pricing techniques are divided into several basic pricing schemes and the effectiveness of each programme in Demand Response implementation into the household sector will be explored. The pricing tariffs are systematically examined, and proper cost analysis is performed to determine the practicality of implementation. Existing pricing schemes and pilot studies, smart appliances and meters, in-home displays and smart energy measuring devices are first introduced to estimate the suitability of the introduction of pricing schemes into the residential sector.

Multiple scenarios with comparable pricing tariffs is recommended for a comprehensive evaluation of Demand Response implementation in the residential area and the selection of the optimal pricing technique. The proposed general pricing schemes are also applied to solving a real problem. Namely, the introduction of pricing schemes in two typical residential households in the suburbs of Thornlie and

Ferndale in Perth, Western Australia to verify consumer shift in energy consumption behaviour.

iv. ACKNOWLEDGEMENTS

Foremost, I wish to express my sincere gratitude to my advisors Dr Gareth Lee and Dr Sujeewa Hettiwatte for their continuous support of my undergraduate honours study and research. Dr Hettiwatte was a tremendous help in the planning and development of the project. I am disappointed that Dr Hettiwatte couldn’t remain at Murdoch University for the whole duration of the project, but I do wish him all the best in his new position and future endeavours. Dr Lee proved to be invaluable in providing direction with his insight and practical advice to guide the project to its completion.

I am very grateful and indebted to Dr GM Shafiullah and Mr MD Moktadir Rahman (Ph.D. student) for their guidance and support. They encouraged me to push harder and go the extra mile. I thank you both for the time end effort you have put aside for my project.

I would like to acknowledge Geoff McCarron-Benson and Michael O'Connell from Power Tracker for partaking in numerous requests and discussions on the functionality of their equipment, which helped me improve my knowledge and understanding of the captured measurement data.

Last but not least, I would like to thank my husband, family and friends for their support and encouragement throughout my years of study. Your understanding

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1 INTRODUCTION

Electricity prices are always on the increase due to aging infrastructures, increase in population and new technologies, just to name a few uncontrollable causes. The residential sector, which accounts for about 25% of total energy consumption, can make up to 45% of Peak Demand in Australia. An essential aspect of Australian energy consumption patterns is the rapid growth of Peak Demand relative to average demand. In the time between 2005 and 2011, the peak demand significantly increased at a rate of about 1.8% annually compared to only a percentile growth of 0.5 for total energy (Australian Energy Market Commission 2012, 26 -27).

Our power networks need to meet peak demands to avoid equipment failure and service disruptions. It would require investment in the expansion of power generation, transmission and distribution capacity to meet the increase in peak demand.

If consumer consumption can be reduced during peak periods, it could result in substantial savings on total power generation and distribution costs (Australian Energy Market Commission 2012, 26 -27). Currently, the majority of the consumer sector is on flat tariffs, with no incentives or information provided to them to encourage any change in their consumption behaviour.

Demand Response techniques may assist in curbing electricity price hikes and avoid network expansion costs. Demand Response techniques can be actions such as peak demand shifting, changing consumer behaviour, appliance energy efficiency and installation of renewables. The increase in renewable energies has proven to reduce total energy demand but has not had a significant impact on peak demand. This study will explore some pricing techniques the electricity retailer can employ to encourage consumers to shift peak loads or reduce it all together.

Some trials that have been successful in shifting demand with pricing techniques, such as Real Time Pricing (RTP), Time of Use Pricing (TOU) and Critical Peak Pricing (CPP), will be investigated in this report. Financial incentives, enabling technologies and education programs on benefits and impacts are other methods that can be used to encourage participation in Demand Response (Faruqui, Hledik and Tsoukalis 2009, 1-15). This study will research the different strategies employed in Demand Response pricing techniques to establish which techniques will prove to be successful within the Western Australian market. The validity and limitations of the various techniques will be established based on the Australian consumer traits and needs.

Innovative use of information technology could permit users to access their power usage and other informative data. Some pilot studies indicate that if customers are provided with direct feedback on their power consumption, it induces a change in their consumption behaviour. The studies will be examined more in-depth within the report.

This study will also explore available tools such as smart meters, In-House Displays and smart appliances, that will enable residential consumers to partake in Demand Response. The smart devices allow the consumer to make a conscious decision of changing their electrical consumption behaviour. It has been proven that In-House displays together with dynamic pricing schemes lead to increased demand response. (Faruqui, Sergici and Sharif 2009, 1-10) This study will try to develop a more strategic and organised approach to enhance consumer knowledge by looking at preconceptions and energy usage within the consumer sector. If customers are provided with the right tools and information, they will be encouraged to shift their behaviour due to an increased awareness of efficient energy consumption.

2 Time or Price Based Demand Response Programs

Pricing schemes such as time or price-based demand response programs are employed to guide consumer behaviour in their electricity usage to match power generation. These systems are valuable in balancing energy, especially during peak times. Time-based electricity price programs such as Time of Use Pricing (TOU) or Real Time Pricing (RTP) encourages consumers to voluntarily adjust their consumption behaviour.

2.1 Background

Focus has been placed on increasing demand response in the energy market. One way is to involve the customer in the wholesale fluctuation of electricity expenses. This could be achieved by introducing dynamic (RTP) or variable time pricing (TOU) to the consumer.

On average, TOU programs have led to a mean reduction of 4% in peak usage, while CPP programs can reduce peak usage by 17%. CPP programs supported with enabling technologies reduce peak usage by 36% (Faruqui and Sergici 2010).

2.2 PRICING SCHEMES

2.2.1 REAL TIME PRICING (RTP)

RTP is the simplest form of dynamic pricing where electricity prices are adjusted according to fluctuations in the wholesale cost of electricity on an hourly or sub-hourly basis. Consumers are made aware of the tariffs on a day-ahead or hour-ahead basis (Ahmad, Hledik and Tsoukalis 2009, 1-15). A drop in electricity price, will cause consumers to increase their demand. This results in increased aggregate demand and higher generation costs which are then reflected in a increased electricity price. The change in off-peak consumption may not equal the change in peak use, but an overall usage decrease may be observed resulting in overall energy savings for the day (Widergren, Marinovici, Berliner and Graves 2012). RTP could be combined with other programs to avoid increased aggregate peak demand.

However, if certain consumption activities cannot be interrupted once started, it could mean that consumers will receive higher electricity bills with RTP. Interruptible activities, on the other hand, may introduce fluctuations in the system, which potentially could be dangerous and hard to control (Rostami, Mehdi and Safaee 2012).

To avoid having some consumers being concerned about the high volatility of the electricity price, part of their bill could be fixed for a baseline consumption level, and then usage above that level could be billed according to the RTP.

An important aspect of the design of an RTP program is the time interval between announcing the price to the consumer and the actual consumption. A long time lag would result in a less precise reflection of wholesale cost, which then may require a balancing of the power system. A shorter time lag would give a truer reflection of what is happening in the electricity market but would make it harder for the consumer to plan their consumption (Steen, Tuan and Bertling 2012).

RTP with 5-minute pricing signals alongside automated energy management systems have the potential to optimize the consumer's use and reduce peak loads. RTP programs hold benefits not only in peak shaving but also increases the system's flexibility to respond to a generator outage and local distribution system capacity limiting circumstances (Widergren, Marinovici, Berliner and Graves 2012). The demand shifting due to RTP could also support the increase of renewable energy sources available.

2.2.2 TIME OF USE RATES (TOU)

TOU rates are more generally employed and can be viewed as an RTP with the wholesale cost of electricity production being adjusted over an extended time interval. The average day is divided into two or more time periods to reflect variations in power generation costs. Consumers will be charged higher tariffs during peak load periods and reduced fares for off-peak periods. TOU rates are not dynamic rates and are an inadequate reflection of the wholesale cost. Around 14% of the wholesale price difference would be exhibited in the TOU rates as opposed to RTP rates. TOU rates might thus not capture the total peak demand in the power system (Steen, Tuan and Bertling 2012). It also limits the support for the integration of the ever increasing but fluctuating renewable energy sources.

TOU rates are easy to implement, and they remove uncertainty, for customers have the security of knowing what the rates would be for each period and can plan their energy consumption accordingly. Studies have shown (Ahmad, Hledik and Tsoukalis 2009, 1-15) that TOU pricing is efficient, and customers do respond to pricing techniques, which results in shifting demand. The demand response varies from modest to substantial and is due to variation in tariffs and enabling technologies. TOU rates prompt a decrease in peak demand ranging from 3 to 6 %. However, this impact is significantly enhanced when combined with enabling technologies (Faruqui, Ahmad and Sergici 2010, 193-225).

Energy management systems allow consumers to optimise energy usage by comparing costs with the different load plans and make decisions accordingly. Thus, TOU rates lead to customers saving energy and reducing their electricity bills. However, it has been shown that optimizing individual consumption may result in a shift of the aggregate demand to form an even steeper and higher peak in the off-peak period. Tiered pricing provides the need to delay consumption but not to reduce it in total (Matteo, Schuelke-Leech and Rizzoni 2014, 546-553).

Due to the evolution of the electrical system more sophisticated techno-economic solutions would be required to address peak shifting and anxieties about market volatility caused by price-based demand response programs. This will be investigated in more depth in this research project.

2.2.3 CRITICAL PEAK PRICING (CPP) WITH TIME OF USE RATE (TOU)

This is a time-varying rate structure, where during a few hours of the year, critical rates are charged. These periods can be referred to as Super Peak times. It is intended to reflect the electricity wholesale cost during desperate times such as extreme weather conditions or significant events. Customers will be charged higher rates during peak periods and lower rates during off-peak periods compared to standard flat tariffs. This CPP with TOU rate will provide a more accurate representation of the market wholesale cost of electricity generation.

This pricing scheme will provide the consumer with the opportunity to save on electricity bills by lowering their Peak Demand (Ahmad, Hledik and Tsoukalis 2009, 1-15).

2.3 Pilot Studies

California State-wide Pricing Pilot (SPP)-

The object of the pilot concluded by Ahmad, Hledik and Tsoukalis (2009, 1-15), was to investigate any changes in consumer consumption behaviour if their flat tariff electricity plans were changed to a time of use (TOU) structure. Over 2500 residential and small businesses participated in the study which spanned more than two years. The principal outcome of the study was Peak Demand reductions of between 1 and 9 % produced by the time-varying rate structure.

Perth Solar City –Western Autralia (PSC)

The Perth Solar City 2012 pilot programme was conducted between 2009- 2012 and over 16000 residential customers took part in the study. The programme was a five-part programme: the Smart Grid Trial; the Air Conditioning Trial; the In-Home Display trial; the Time-of-Use Trial and the Solar Photovoltaic Saturation Trial.

The Smart Grid Trial: Over 9000 smart meters were installed in residential areas. It was shown that providing households with the smart meters contributed to lowering Peak Demand and increased network efficiencies.

The In-Home Display (IHD) trial: Families were given an IHD, which provided real-time power usage statistics, facilitated by smart meters. This test resulted in a 1.5% reduction in total electricity consumption and 5% reduction of Peak Demand.

The Time-of-Use Trial: Used the variable time pricing structure called Power Shift (PS1). See sections 2.4.3 and Appendix 9.1.3 for a breakdown of the tariff. The households had the ability to inspect their energy consumption in real-time on the IHD, which was enabled by the smart meter, and could make informed decisions about their behaviour. The trial proved that the pricing scheme caused about 9% reduction in Peak periods, but when combined with an IHD this figure increased to about 13%.

Canada/Ontario – Hydro One time-of-use pilot:

Hydro One time-of-use pilot (Faruqui, Ahmad, Sergici, and Sharif 2010, 1598-608) was conducted in 2007 over five months during the summer period. The aim of the trial was to examine the effects of TOU pricing schemes with real-time feedback. Four different scenarios were tested:

- 153 customers were placed on TOU rates and provided with IHDs,
- 177 customers were placed on TOU rates alone but rewarded with $50 at the end of the trial
- 81 customers were just provided with an IHD with no pricing structure changes or financial incentives
- 75 customers were the control group with no incentives, IHD or TOU rates

The trial demonstrated that by just providing families with real-time power usage facilitated by IHD, total energy consumption was lowered by 6.7%. The group with a IHD and subject to TOU reduced their consumption by 7.6%. The group placed only on a TOU structure lowered their usage by 3.3%. This programme revealed that TOU rates and IHD are very effective tools for conserving electricity. Furthermore, IHDs perform better in regard to energy conservation than TOU prices. The study found that the combination of TOU and IHDs shifted 5.5 percent of load from on-peak to mid-peak and off-peak hours.

2.4 Synergy Residential Pricing Schemes

Synergy is Western Australia's electricity supplier-retailer within the South West Interconnected System (SWIS). Synergy offers five types of tariffs that residential consumers can choose from. Four of these plans will be applied to verify what cost effects the different pricing techniques will have on this particular load profile. The four tariffs are:

1. Home Plan (A1) Plan (2016)
2. Smart Home (SM1) tariff (2016)
3. Power Shift (PS1) Plan (2009-2012)
4. Smart Power (SP1) tariff (2015)

2.4.1 The Home Plan (A1) tariff:

The consumer is charged a flat rate for their electricity consumption regardless of the time of day they use electricity or how much they use. See Appendix 9.1.1 for a detailed breakdown of the tariff.

2.4.2 Smart Home (SM1) tariff:

The Smart Home tariff is a variable rate or a TOU pricing scheme. This tariff has four different time periods, namely Peak, Off-peak, Weekday shoulder and Weekend shoulder periods. However, the weekday and weekend shoulder periods are currently charged at the same rate. During the peak period, electricity consumption is charged at the highest rate, while the three other periods are charged at lower rates compared to the Home Plan (A1) tariff. To be able to select this tariff, a smart meter or TOU meter is required to record the amount of energy and what time of day the energy was consumed. See Appendix 9.1.2 for a detailed breakdown of the Smart Home tariff.

2.4.3 Power Shift (PS1) tariff:

This tariff is also a TOU pricing scheme but is divided up into three time periods namely peak, off-peak and super-peak periods. The Peak period times are different for weekend and weekdays. The Super peak weekdays charge is a CPP, which tries to account for unusual occurrences when exceptionally high peak demand is expected.

See Appendix 9.1.3 for a detailed breakdown of the Power Shift tariff. This pricing scheme was also employed in the Perth Solar City trial.

2.4.4 Smart Power (SP1) tariff:

The Smart Power tariff was a variable rate or a TOU pricing scheme offered by Synergy in 2015. This tariff had four different time periods namely Peak, Off-peak, Weekday shoulder and Weekend shoulder periods. The Smart Power tariff was very similar to Synergy's Smart Home tariff. The difference is that the SP1 tariff charged higher rates for the weekday shoulder time of day but less for the weekend shoulder time of day than the SM1 tariff. The peak period was also more expensive that the current SM1 tariff. During the peak period, electricity consumption also was charged at a higher rate and the three other periods were charged at a lower rate compared to the Home Plan (A1) tariff. To be able to select this tariff a smart meter or TOU meter was required to record the amount of energy and what time of day the energy was consumed. See Appendix 9.1.4 for a detailed breakdown of the Smart Power tariff.

3 Smart Devices & Enabling Technologies

3.1 Background

Results of studies conducted revealed that pricing techniques are successful in reducing peak demand. However, pricing schemes enabled by smart technologies amplify the reductions significantly.

3.2 Smart Appliances

Over the last few decades, improvements and advancement in technologies have meant that smart technologies can be incorporated into standard household appliances. Devices can be controlled and managed remotely. It is hard to come by a washing machine these days that does not have a simple timer. The consumer can take control of their Peak time consumption by changing the time of use for appliances such as the washing machine or dishwasher simply by setting a timer or managing it from afar.

3.3 SMART METERS

Placing a high-performance Power Quality meter on the main incomer to a facility allows for real-time energy monitoring. A smart meter is a more advanced meter that records total energy consumption and is capable of capturing usage in half hour intervals. The meter is capable of two-way communication and meter readings are automatically sent daily to Western Power.

Western Power had planned to use Smart meters to create a Smart Grid by integrating data and communication to the existing infrastructure. These smart technologies will make the grid more flexible and adaptable to changes in the power system. These meters are no longer being installed; see the Perth Solar City (PSC) trial.

Western Power is currently installing only Bi-directional meters. Bi-directional meters measure a customer's energy consumption and energy generation. Anyone who has installed a system which generates energy into Western Power's grid must have a bi-directional meter fitted.

Models

EM1000: standard electronic accumulation meter; single phase (<100 A); programmable for all time & TOU metering/tariffs; bi-directional; capable of storing interval data

EM3330: standard electronic accumulation meter; 3phase installation (<125 A); programmable for all time & TOU metering/tariffs; bi-directional; capable of storing interval data – This meter is only available for commercial and residential customers which are heavy energy users due to higher cost of capturing and administering data to customers (special data team involved in issuing data)

U3300: latest standard electronic accumulation meter; 3 phase (<125A); programmable for TOU metering; bi-directional

3.4 IN-HOME DISPLAYS (IHD)

In-Home Displays, which are easy to install and use, provide the user with information on their energy consumptions and cost. Useful information which can be displayed to the household includes:

- The present rate of use (dollars or kWh)
- The amount of power used yesterday (dollars)
- The amount of energy used last month (dollars)
- The amount of electricity/cost so far in the current month
- Cost projections for the month
- Current date and time

- The current energy usage period: the IHD changes colour to reflect different periods: blue for off-peak hours, green for on-peak hours, flashes red a couple of hours in advance of a critical peak event, and turned solid red for critical peak hours.
- The particular device/appliance in use and its typical energy usage

3.5 Smart energy measuring devices

One of the reasons why so few people economise on their power consumption is that they simply are not aware of how much energy their appliances can consume. Smart energy measuring devices are valuable tools for observing and decreasing electricity consumption within a household. The smart tools provide useful and real-time feedback on power consumption and other informative data. With advances in technologies, there are many models with different functionalities that are available on the market. The key to choosing between these models is to evaluate all the energy options and then select the best-integrated technologies that provide the consumer with the greatest end solution.

See Section 4.1 for the smart measuring devices used in real-time data capturing for a typical residential household.

4 DATA COLLECTION

Residential load profiles can be used to form some knowledge about consumer consumption patterns. To investigate the success of demand response implementation in the residential sector, access to real load data from ordinary households was required. This was made possible by Murdoch University providing smart energy measuring devices manufactured and designed by Power Tracker Pty Ltd (Power Tracker Pty Ltd 2011-2015).

4.1 TOOLS

Power Tracker's wireless smart devices are very durable and easy to install. The devices can be monitored and controlled online or via Power Tracker's free mobile phone app. Power Tracker wireless products could be integrated with other smart devices. The web platform provides home energy information such as:

- Real-time energy consumption monitoring
- Daily, weekly, monthly and yearly historical information
- Comprehensible charts and graphs
- Cost predictions

The devices can be used to monitor solar system performance, control appliances remotely and provide power surge protection.

To get started, you need one Smart Energy Gateway, which is an all-in-one router which allows secured wireless internet access for real-time power management. The Gateway receives data wirelessly from the smart devices and sends this to the server. You can connect up to 30 smart devices to one Gateway but the system is scalable, and you can connect as unlimited number of Gateways. See in figure 1 for an image of the SG6200NXL Smart Energy Gateway (POWER TRACKER PTY LTD, 2011 – 2015, Products).

Figure 1 The SG6200NXL Smart Energy Gateway (POWER TRACKER PTY LTD, 2011 – 2015, Products)

The Smart Clamp can monitor an entire premise including hard-wired appliances such as an air conditioner, solar system or lighting. The clamp is installed into the distribution board to the house. The device can measure electricity in both directions to determine if a house is consuming or exporting electricity. See figure 2 for a picture of the SG3010-T3 Smart Clamp.

Figure 2 The SG3010-T3 Smart Clamp (POWER TRACKER PTY LTD, 2011 – 2015, Products)

The Smart Appliance can be used to control and measure the power consumption of individual appliances. These devices provide not only the ability to turn devices on and off remotely but they also provide power surge protection. It is simply an extension of the appliance you require to control and measure. See figure 3 for an image of the SG3010-T1 Smart Appliance.

Figure 3 The SG3010-T1 Smart Appliance (POWER TRACKER PTY LTD, 2011 – 2015, Products)

The data captured by the smart devices were power demand [W] with sampling interval times of approximately sixty seconds. The data is exported to Microsoft Excel spreadsheets. The area under the power vs. time graph gives the total energy consumption of an appliance over the course of a day. See Appendix 9.2.9 for the calculation of energy consumption from a power curve.

4.2 Case study 1

Power Tracker smart measuring devices were installed in a private house in the suburb of Ferndale in Perth.

4.2.1 Domestic household profile

The Ferndale house is a small three bedroom, one bathroom villa. Power consumption data was collected over a seven-day period from 20 November to 26 November 2015. Monthly, quarterly and annual usage and cost estimations were calculated from consumption data collected over this seven-day period. The household is on the standard Synergy Home Plan (A1).

The weather during that week ranged from mid twenty degrees Celsius to mid thirty degree Celsius. Sunday the 22nd of November was the hottest day recorded over the seven-day period when the temperature reached 35.3 degrees Celsius (Elders, 2016). The weather was atypical to the summer month of November and the load profile should reflect a typical domestic summer load profile. Seasonal variations in electricity demand needs to be considered since typically, demand is higher in winter than in summer.

Five people occupied the premises.

4.2.2 APPLIANCES MEASURED

One Gateway (SG6200NXL), three clamps (SG3010-T3) and ten smart devices (SG3010-T1) were fitted. The three clamps were separately wired into the distribution board of the house by an electrician. One clamp monitored the main incomer, the second clamp monitored the air conditioner and the third clamp monitored the oven.

The smart appliances were connected to the following appliances:

- Refrigerator
- Washing Machine
- Kettle
- Dishwasher
- Television
- Vacuum cleaner
- Bedroom 1 bedside lamps (2 lights bulbs)
- Bedroom 2 bedside lamp (1 light bulbs)
- Bedroom 3 bedside lamp (1 light bulb)

4.2.3 RESULTS

The household's typical daily energy consumption pattern can be represented by the load profile for the 21st November which can be seen in figure 4. Case Study 1 showed that the household's typical daily consumption was characterised by morning cyclic patterns then afternoon peaks followed by similar cyclic patterns as in the morning and then late night peaks again.

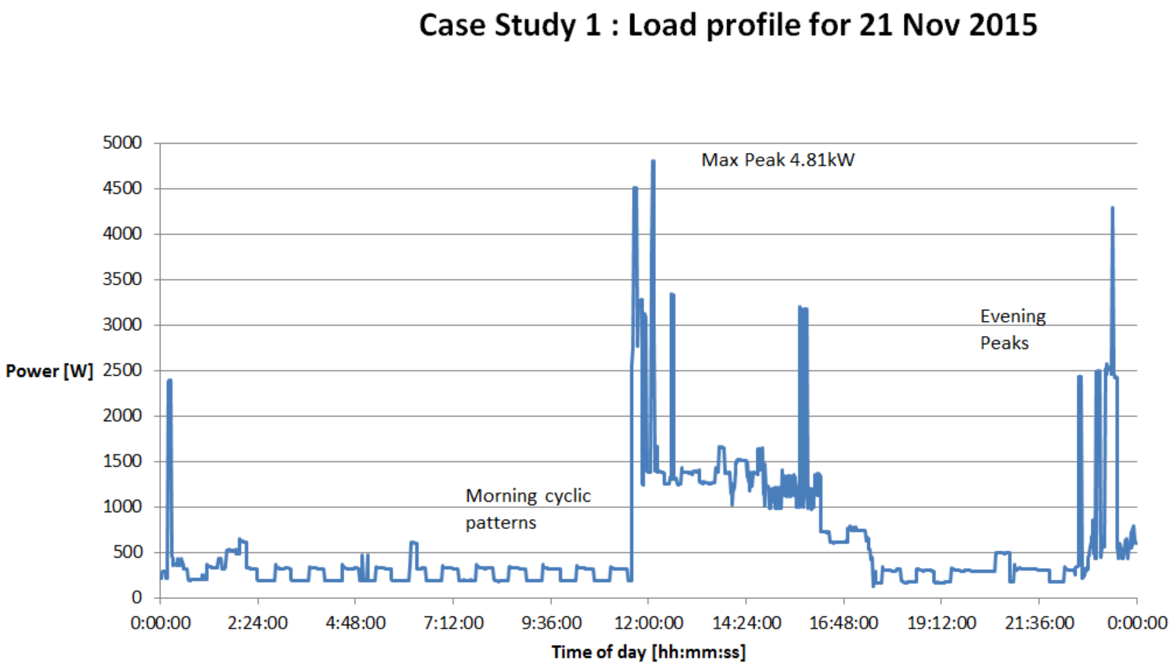

Figure 4 Case Study 1 load profile for 21 November 2015

The morning recurring pattern is caused by the cyclic behaviour of the refrigerator's compressor switching on and off; this will be discussed in detail in section 4.2.3.3 below.

The afternoon peaks were caused by using the air conditioner, oven and kettle. Each appliance's effect will be discussed in more detail in sections 4.2.3.1, 4.2.3.2 and 4.2.3.5 respectively.

The evening peaks can be explained by the functioning of the refrigerator, washing machine and kettle. This will be discussed in detail in sections 4.2.3.3, 4.2.3.4 and 4.2.3.2 respectively.

4.2.3.1 AIR CONDITIONER CHARACTERISTICS

The air conditioner (AC) was turned on at 11:45 am on the 21st of November 2015 and remained on for four hours twenty-eight minutes and eighteen seconds. The power demand of the AC for this day can be viewed in figure 5.

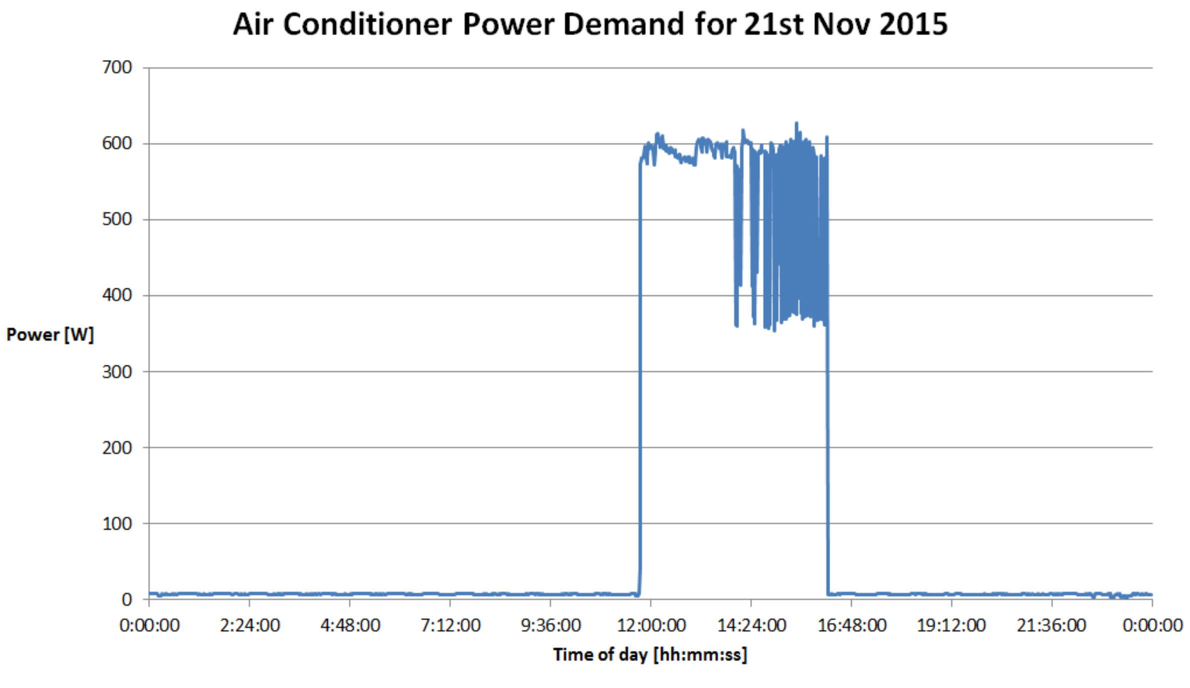

Figure 5 The air conditioner's power demand for the 21st of Nov 2015

The AC is rated to have a power capacity of 6.2kW and an input power demand of 1.72kW. It is estimated from the power measurements taken that the AC consumes 47.8kWh of energy a month of which 4.44kWh is for stand-by energy. The AC has an average stand-by power demand of 7.56W and contributes 9.3% of the total monthly

AC energy used. The duty cycle of an AC is influenced by factors such as household activity and extreme weather changes. The duty cycle and stand-by power loads can be viewed more in detail in Appendix 9.2.2.

4.2.3.2 OVEN CHARACTERISTICS

On the 21st of November, the oven was used for about fourteen minutes and twelve seconds at 11:36 am. The power demand of the oven for this day can be viewed in figure 6.

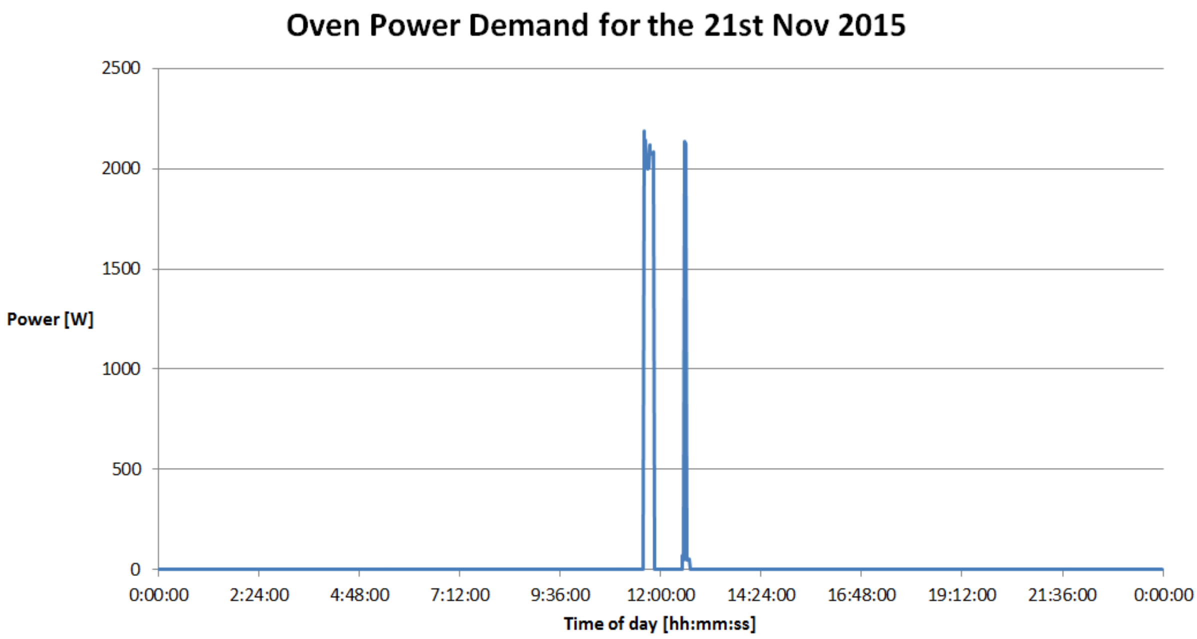

Figure 6 Oven Power Demand for the 21st Nov 2015

The monthly energy consumption estimated from the power measurements is 3.54kWh.

4.2.3.3 REFRIGERATOR CHARACTERISTICS

On the 21st of November 2015, the refrigerator repeated a cyclic pattern until its power demand increased to a peak pulse until an average dissipation of 327.6 W at around 8:31 pm for an interval time of 20 min and 41 seconds. The Refrigerator's cyclic behaviour is due to the duty cycles of constant pressure difference on the compressor (Seong-woo, Park and Pecht 2011). The daily power demand for the refrigerator can be viewed in figure 7. The peak in the evening can be attributed to the opening of the fridge which causes the compressor to work harder in lowering the temperature to the set point temperature. The demand of the refrigerator never falls below 2.53W.

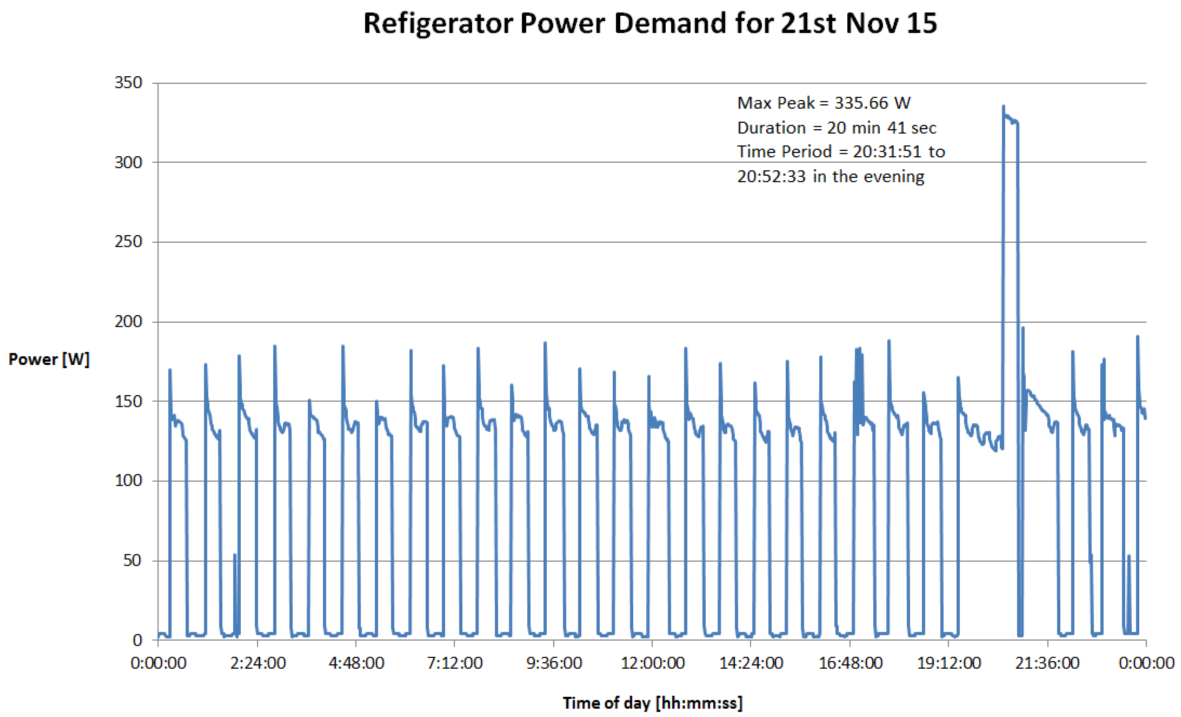

Figure 7 Characteristics of a refrigerator

The compressor for this particular refrigerator turns ON for an average of 19 minutes and 28 seconds and switches OFF for an average 27 minutes and 21 seconds. The examination of the compressor's duty cycle can be seen in Appendix 9.2.

From the power measurements taken, the refrigerator is estimated to consume 62.7 kWh of energy per month, which equates to about 752.4kWh of energy over a year. The refrigerator's energy rating is 916kWh/year. The disparity indicates that the actual energy use and running costs will depend on how the appliance is used.

4.2.3.4 WASHING MACHINE CHARACTERISTICS

On the 21st of November 2015, the washing machine was in stand-by mode until it was used at 10:31 pm for an operation cycle of around 1 hour 27 minutes. See figure 8 for the daily power load for the washing machine.

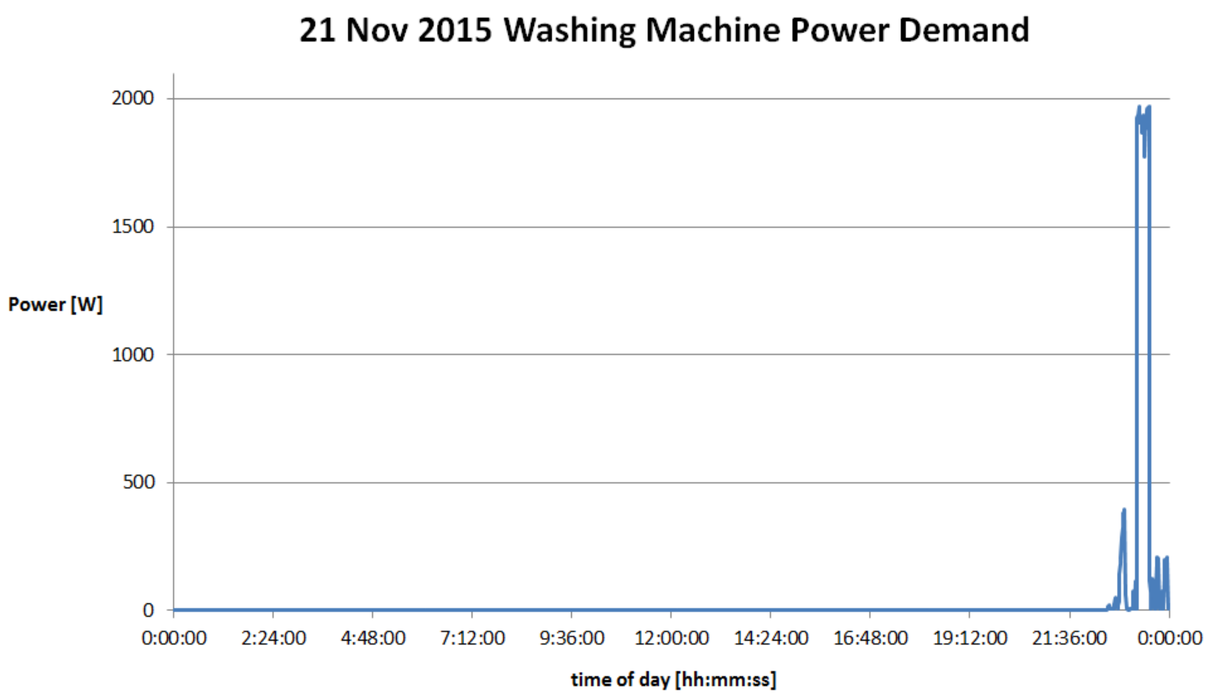

Figure 8 Washing Machine Power Demand for the 21st of Nov 2015

The average stand-by power demand for the washing machine is 0.58 W. The washing machine consumes an estimated 4.54kWh of energy a month, of which 0.39kWh is for stand-by energy. The stand-by energy works out to be 8.5% of the total monthly energy used.

4.2.3.5 KETTLE CHARACTERISTICS

The kettle was used numerous times on the 21st of November 2015. See figure 9 for the daily power demand of the kettle.

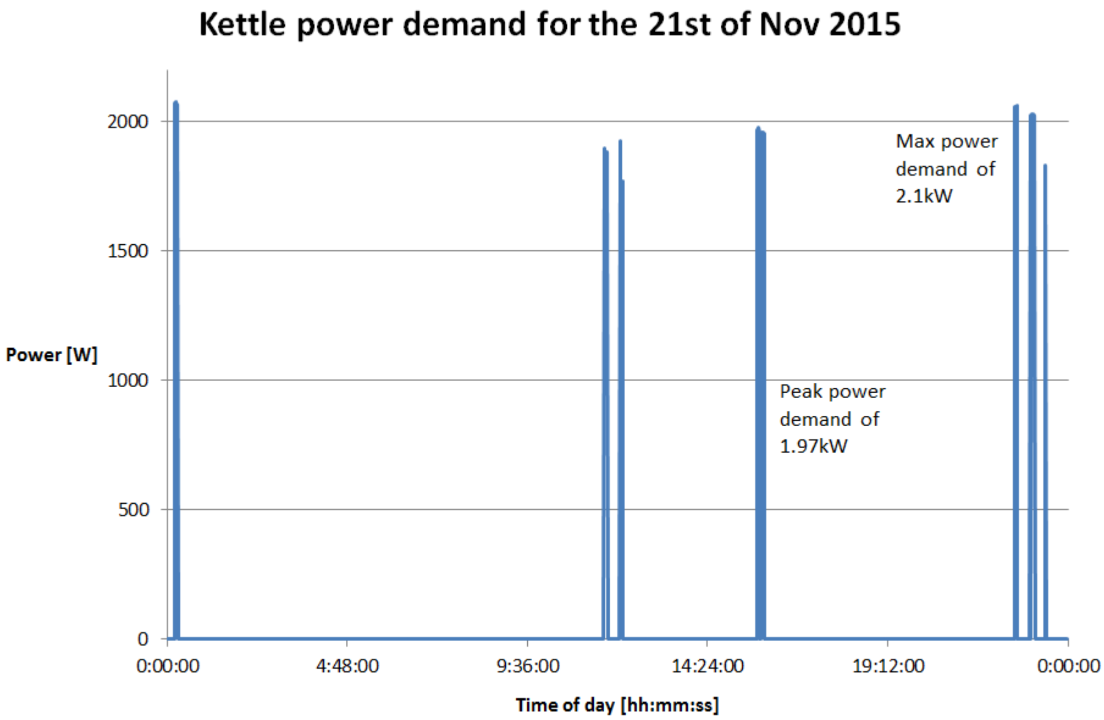

Figure 9 Kettle power load for the 21st of Nov 2015

The kettle's rating, ranged from 1850 to 2200 W. On this particular day the maximum peak for the power demand was 2100W. The monthly energy usage for the kettle is estimated to be 15.6kWh. It takes an average of 4 min to boil the kettle. The power demand is very high for very short time intervals.

4.2.3.6 DISHWASHER CHARACTERISTICS

The dishwasher was not used on the 21st of November 2015 but consumed stand-by energy. The power demand for the day can be viewed below in figure 10.

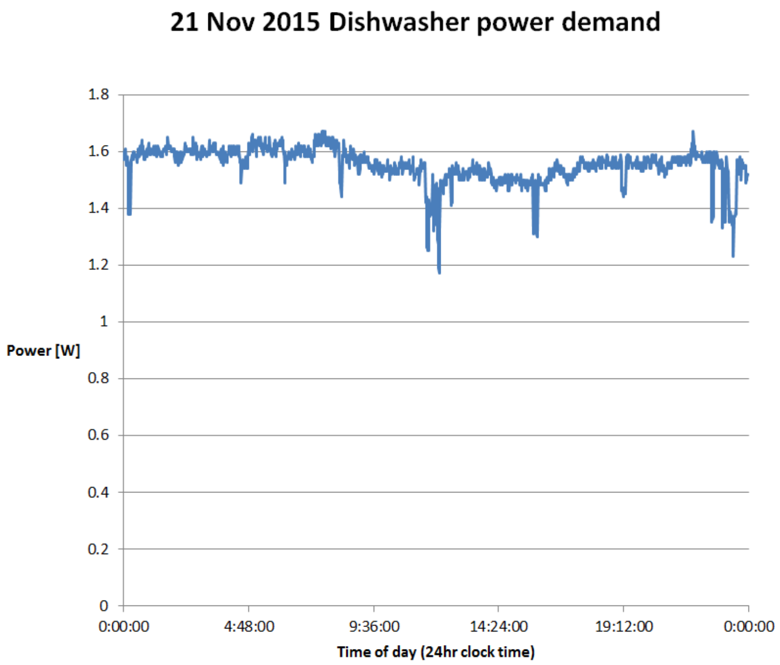

Figure 10 The dishwasher power demand for the 21st of Nov 2015

The dishwasher was only used three times during this week. The average stand-by power demand is 1.6W. The monthly stand-by energy calculates to 1.1kWh, which is 7.4% of the total energy consumption of 14.9kWh. The expected total annual energy consumption is thus calculated to be 179.1kWh and is half of the rated annual energy consumption of 400kWh. Once again it proves that the actual energy use of an appliance depends on individual consumer behaviour. The operation of the dishwasher is investigated in depth in Appendix 9.2.4

4.2.3.7 Television characteristics

The television (TV) was not used on the 21st of November 2015 and only consumed stand-by energy. The average power demand for this day was 0.68W as can be seen in figure 11.

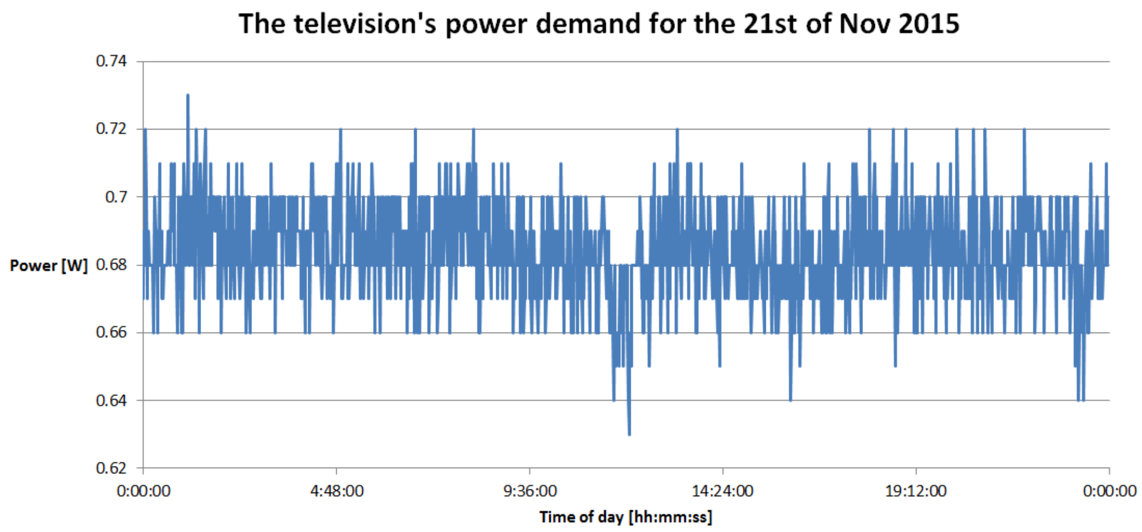

Figure 11 Power demand of the TV for the 21st of Nov 2015

The monthly stand-by energy is estimated to be 0.47kWh, which is 5.5% of the total energy consumption for the month which is 8.54kWh. The TV's operational characteristics are discussed in detail in Appendix 9.2.5. The TV is rated for 300W power demand.

4.2.3.8 VACUUM CLEANER CHARACTERISTICS

There was no consumption for the vacuum cleaner on the 21st of November 2015. The vacuum cleaner was only used three times during the week. The vacuum cleaner is rated at 1600 to 1800 W. For consumption patterns based on this week's power measurements, it is estimated that the monthly energy consumption should be 2.27kWh. A closer inspection of the operation of the vacuum cleaner is available in Appendix 9.2.7.

4.2.3.9 ROOM 1 BEDSIDE LIGHTS CHARACTERISTICS

The bedside lamps were only used three nights during the week when monitoring took place. There were two bedside lamps and both were investigated with the one smart appliance. No energy consumption was recorded for the 21st of Nov 2015. The total energy consumption was calculated to be 0.51Wh based on the consumption patterns observed during the seven-day observation.

4.2.3.10 ROOM 2 BEDSIDE LIGHTS CHARACTERISTICS

There is only one bedside lamp in room 2 with a light bulb rated at 25W. The bedside light in room 2 was not used on the 21st of November 2015 and was only used three nights of the week. However, on this day, the bedside lamp did draw stand-by energy as seen below in figure 12.

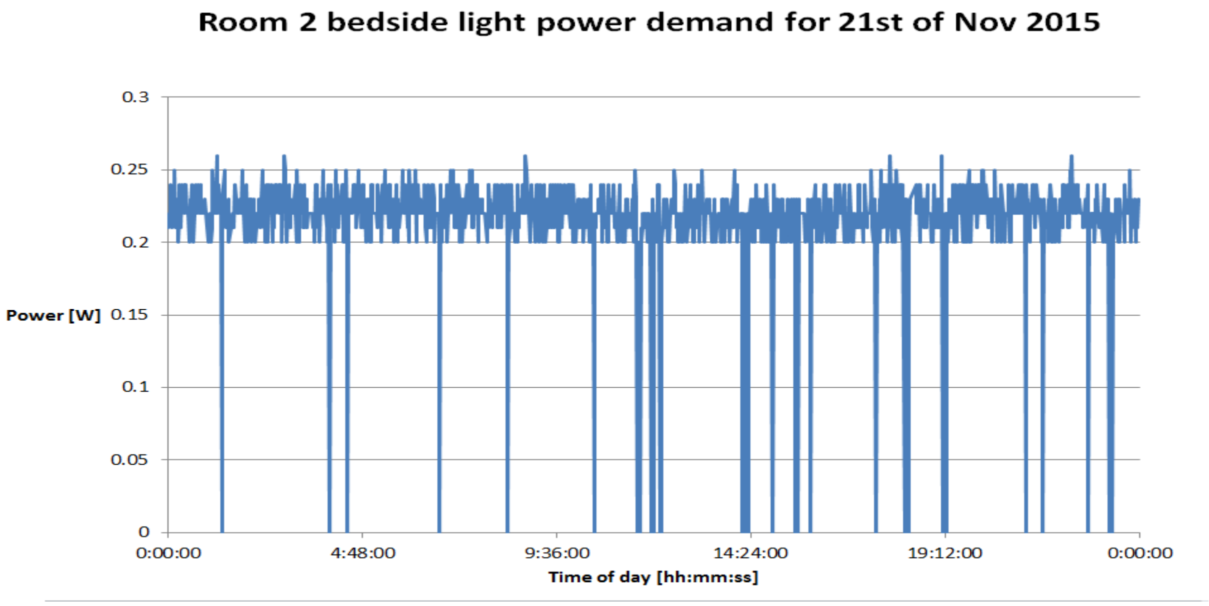

Figure 12 Room 2 bedside lamp drawing stand-by power on the 21st Nov 2015

The average power demand for this lamp was 0.22W. The total monthly energy consumption is 0.32kWh. The monthly stand-by energy was determined to be 0.15kWh, which makes up 47.8% of the total energy consumption of the lamp. See Appendix 9.2.8 for a more in-depth look at a time when the lamp was in operation.

4.2.3.11 Room 3 bedside lights Characteristics

The bedside light in room 3 was never used during the seven-day period of investigation.

4.2.4 Cost Analysis

The total energy consumption recorded over the seven day period equalled 69.5kWh. The weekly power demand and energy consumption values were then used to calculate estimated monthly values. See figure 13 for the comparison of the daily energy consumption during this week.

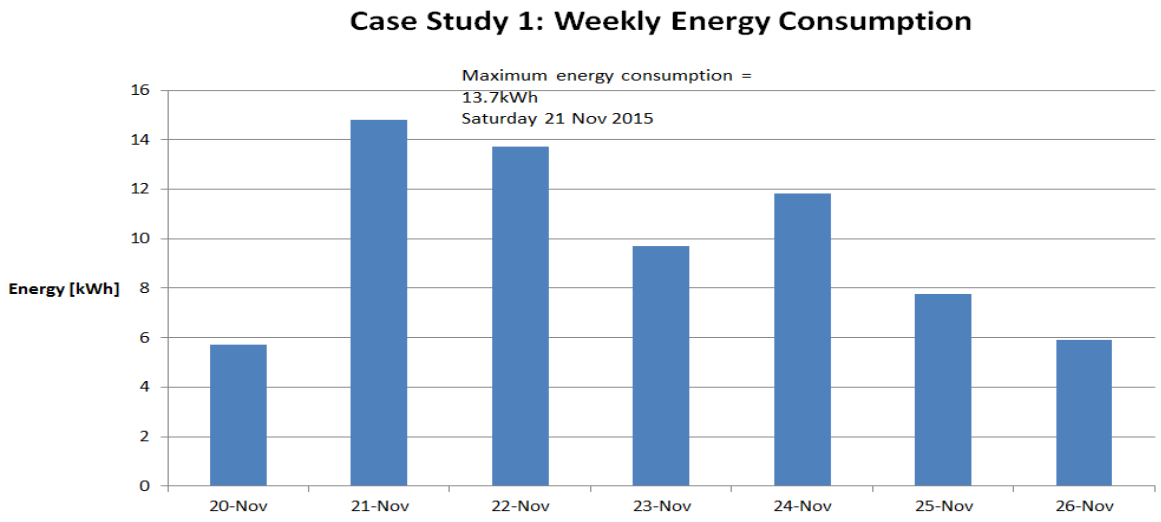

Figure 13 Case Study 1's weekly energy consumption

The highest consumption days were Saturday the 21st Nov and Sunday the 22nd Nov with daily totals of 13.7kWh and 9.70kWh respectively. The differences could reflect the fact that the consumers were at home for the weekend and were not working away from home, which resulted in higher energy usage.

Over this week period, the total energy consumption of the different appliances are also compared. See Appendix 9.2 for the total amounts and figure 14 below for the pie chart comparison of energy usage between the appliances.

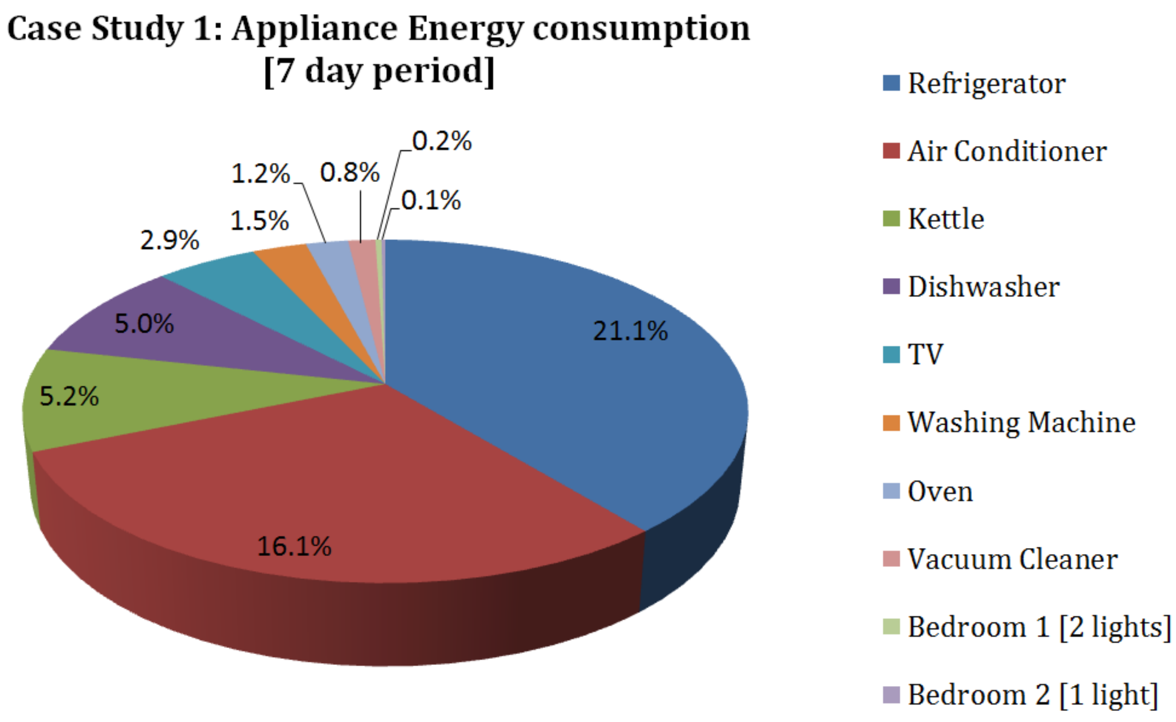

Figure 14 The pie chart comparison of energy consumption for different appliances in case study 1

As can be seen from the pie chart the refrigerator, AC and kettle were the three top energy consumers in the household. They were followed by the dishwasher, TV and washing machine. A family can't change their behaviour much when it comes to the refrigerator, AC or kettle but they have the option to buy smart and efficient appliances and also look at lowering the temperature setting of the AC to reduce household bills. However, the household can save money by avoiding stand-by energy costs with the dishwasher, TV and washing machine. Additionally, the family can look at using the dishwasher and washing machine in off-peak periods if they are on time-of-use tariffs.

To investigate whether avoiding stand-by energy and changing consumer behaviour will lead to savings for a residential household, a more detailed cost analysis was done using real-time data accumulated with different Synergy residential pricing schemes. The family in case study 1 is on the Synergy Home Plan (A1) tariff. The Synergy bill was received for the supply period 10 November 2015 to 11 January 2016 (63 days). The total units used were 940 which resulted in a total payable amount of $272.20. See Appendix 9.1.4 for the bill.

The percentage error between estimated monthly energy consumption and the real-time consumption equalled 4.98%. See Appendix 9.2.10.1 for the calculation of the percentage error.

Cost analyse were then done for four different scenarios by comparing three different Synergy tariffs: the Home Plan, the Smart Home Plan and the Power Shift Plan. The first scenario just compared the cost differences between the plans. See Appendix 9.1.1 for the different Synergy tariff costs and Appendix 9.2.10.1 for the unit totals and cost calculations. Options 1, 5 and 9 in Table 1 are the results of the cost comparisons between the different plans.

Secondly, the costs of the various programmes were compared when stand-by energy was omitted. See option 2, 6 and 10 for the association cost in the table below. The unit totals and cost calculations can be viewed in Appendix 9.2.10.2

Thirdly the costs for the different plans were compared when the consumer have changed their behaviour and moved the time of use of the dishwasher and washing machine to off-peak periods. See option 3, 7 and 11 for the comparison rates in the table below. The unit totals and cost calculations can be viewed in Appendix 9.2.10.3.

Lastly, the costs for the different plans were compared when the consumers have changed their behaviour (dishwasher and washing machine only) and eliminated stand-by energy (dishwasher, TV and washing machine). See option 4, 8 and 12 for the comparison rates in the table below. The unit totals can be viewed in Table 1 and cost calculations can be inspected in Appendix 9.2.10.4.

Table 1 Cost analysis of four different scenarios with three comparative tariffs for Case Study 1

	Option1	Option 2	Option3	Option4	Option5	Option6	Option7	Option8	Option9	Option10	Option11	Option12
Plan	A1	A1	A1	A1	PS1	PS1	PS1	PS1	SM1	SM1	SM1	SM1
Stand-by Power	×	✓	×	✓	×	✓	×	✓	×	✓	×	✓
Behavioural Change	×	×	✓	✓	×	×	✓	✓	×	×	✓	✓
Monthly Bill	**$90.68**	**$90.14**	**$90.68**	**$90.14**	**$88.61**	**$88.13**	**$86.87**	**$86.55**	**$90.64**	**$90.13**	**$89.35**	**$89.01**
Montly savings [$]	**$0.00**	**$0.54**	**$0.00**	**$0.54**	**$2.07**	**$2.56**	**$3.81**	**$4.13**	**$0.05**	**$0.56**	**$1.33**	**$1.68**
Quaterly savings [$]	**$0.00**	**$1.63**	**$0.00**	**$1.63**	**$6.22**	**$7.67**	**$11.44**	**$12.40**	**$0.15**	**$1.67**	**$4.00**	**$5.03**
Annual savings [$]	**$0.00**	**$6.51**	**$0.00**	**$6.51**	**$24.89**	**$30.68**	**$45.76**	**$49.61**	**$0.58**	**$6.69**	**$16.00**	**$20.12**
Montly percentile savings [%]	0.0	0.6	0.0	0.6	2.3	2.9	4.3	4.7	0.1	0.6	1.5	1.9

It can be seen in the Table that the consumers will achieve the greatest savings by changing their standard Home Plan (A1) to the Power Shift Plan (PS1). Option 8 will provide maximum saving and is due to the consumer changing their policy away from A1 to PS1 and then shift their time of use for the washing machine and dishwasher to off-peak times. However, the Power Shift plan is no longer a valid program offered by Synergy.

4.3 CASE STUDY 2

Power Tracker smart measuring devices were also installed in a private house in the suburb of Thornlie in Perth.

4.3.1 DOMESTIC HOUSEHOLD PROFILE

The Thornlie dwelling is a four bedroom two bathroom house. Power consumption data was collected during the period 3 November to 9 November 2015.

The weather during that week ranged from mid twenty degrees Celsius to thirty degree Celsius. On Tuesday the 9th of November, the hottest day was recorded, when the temperature reached a maximum of 30.9 degrees Celsius (Elders, 2016).

Five people occupied the premises.

4.3.2 APPLIANCES MEASURED

With Case Study 2, no data could be collected for the main incomer, air conditioner and electric hot water system. The total household consumption could not be recorded which meant that an exact daily load profile could not be obtained. However, it is known that the air conditioner was not used during the observation time interval but it would have still have drawn stand-by power.

One Gateway (SG6200NXL) and ten smart appliances (SG3010-T1) were fitted. The smart devices were connected to the following machines:

- Refrigerator
- Washing Machine
- Kettle
- Television
- Microwave Oven
- Oven
- Hair Dryer
- Toaster
- Laptop charger
- Portable Fridge

4.3.3 RESULTS

Case Study 2's appliance characteristics for the oven, refrigerator, washing machine, kettle, television are very similar to that of Case Study 1's features and won't be revisited. See sections 4.2.3.2 to 4.2.3.5 and 4.2.3.7 previously.

4.3.3.1 HAIR DRYER CHARACTERISTICS

On the 6th of November 2015, the hair dryer was in stand-by mode until it was used at 11:22 pm and was in operation for around 1 minute. See figure 16 for the daily load for the hair dryer.

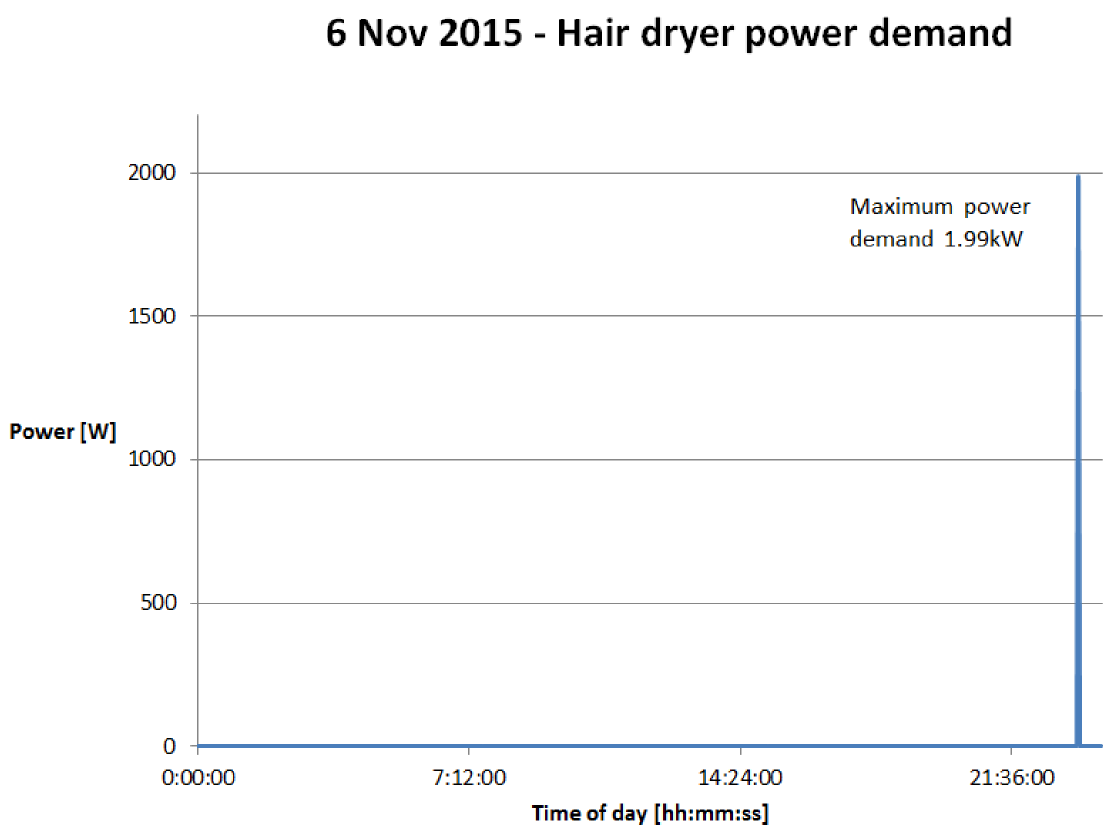

Figure 15 Power demand for hair dryer on 6 Nov 2015

From the graph it can be seen that the hair dryer is characterised by very high power demand over a very short time interval.

During a period of non-use, the appliance has an average stand-by power demand of 0.26W. The total monthly estimated energy consumption is 0.48kWh. The monthly stand-by energy was determined to be 0.19kWh, which makes up 38.9% of the total energy consumption. See Appendix 9.3.1 for a more in-depth exploration of the stand-by power requirements.

4.3.3.2 TOASTER CHARACTERISTICS

The toaster was used twice, early in the morning on Friday 6th of November 2015. The toaster was working for a minute each time with a minute delay between operations. See figure 17 for the power demand graph.

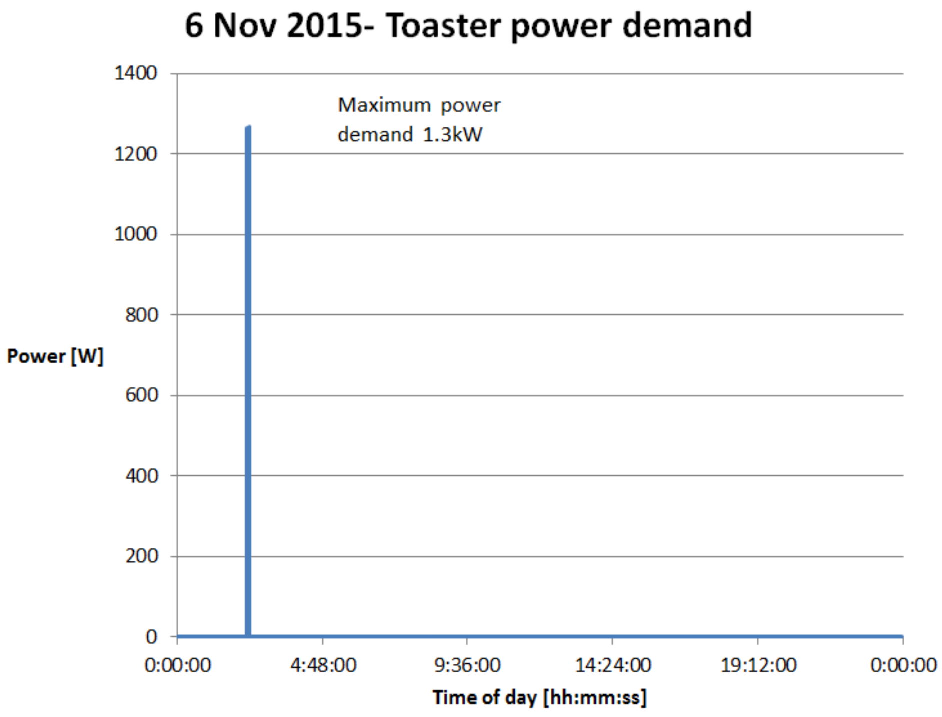

Figure 16 The toaster's power demand for the 6th Nov 2015

The total monthly estimated energy consumption of the toaster is 3.56kWh. There was no stand-by energy consumption.

4.3.3.3 LAPTOP COMPUTER AND CHARGER CHARACTERISTICS

When the laptop computer's battery is not hundred percent fully charged it draws power through the laptop charger to bring it up to charge. See figure 18 for the power demand for the laptop and charger for the 6th of November 2015.

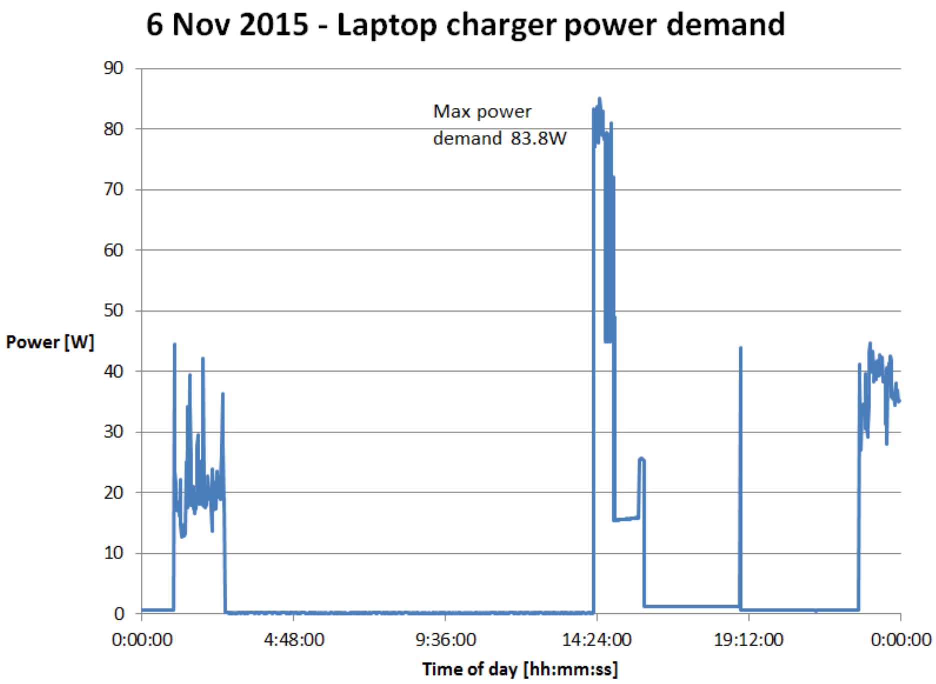

Figure 17 The laptop & charger's power demand

If the laptop is not plugged into the charger, the charger still draws stand-by power. See Appendix 9.3.2 for a closer look at the stand-by requirements for the charger of the laptop computer.

The total monthly estimated energy consumption is 4.31kWh. The monthly stand-by energy was determined to be 0.15kWh, which makes up 3.5% of the total energy consumption.

4.3.3.4 PORTABLE FRIDGE CHARACTERISTICS

A portable refrigerator was used as additional freezer space for the household. See figure 19 for the power demand requirements for the portable refrigerator.

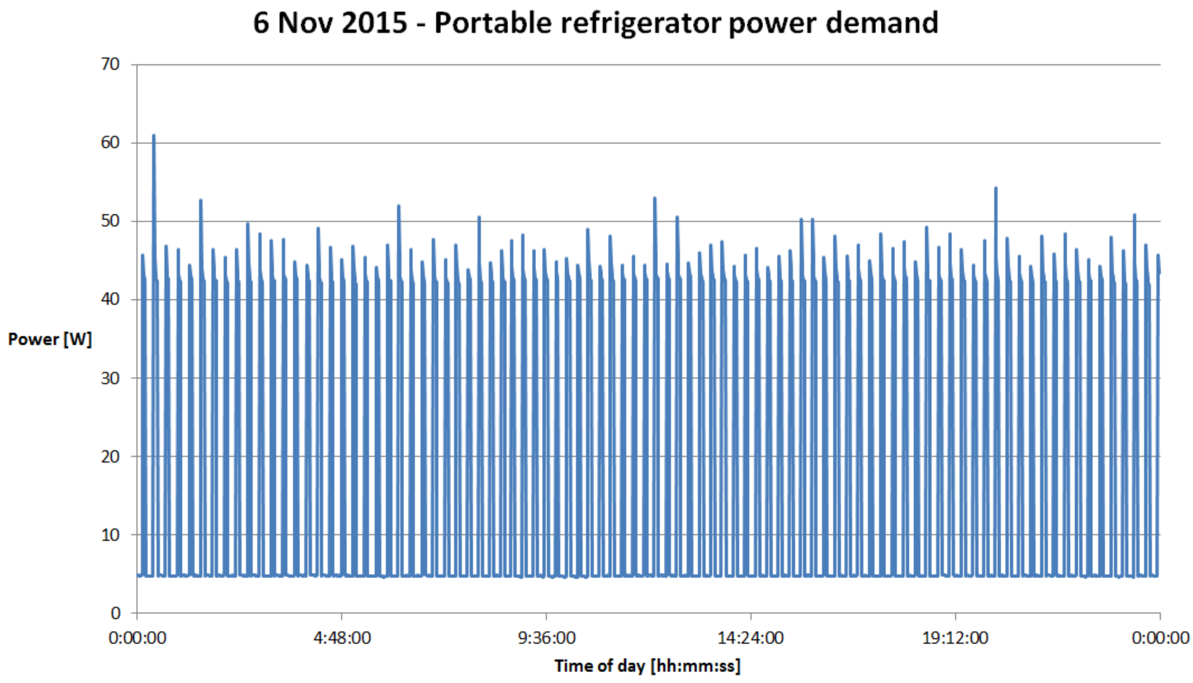

Figure 18 The portable refrigerator's power demand

The compressor for this portable refrigerator turns ON for an average of 3 minutes and 32 seconds and switches OFF for an average 10 minutes and 57 seconds. The refrigerator's demand never falls below 4.67W. From the power measurements taken, the refrigerator is estimated to consume 11.9kWh of energy per month which equates to about 143.0kWh of energy over a year.

4.3.4 Cost Analysis

The total energy consumption recorded over the seven day period equalled 35.1kWh. The weekly power demand and energy consumption values were used to calculate estimated monthly values as was done in Case Study 1. According to the derived values, Case Study 2 has half the energy consumption as Case Study 1. This was due in part to the fact that electrical consumption of the electrical water heating system was not considered in this study. See figure 20 for the daily energy consumption patterns for Case Study 2 over the week 3 Nov to 9 Nov 2015.

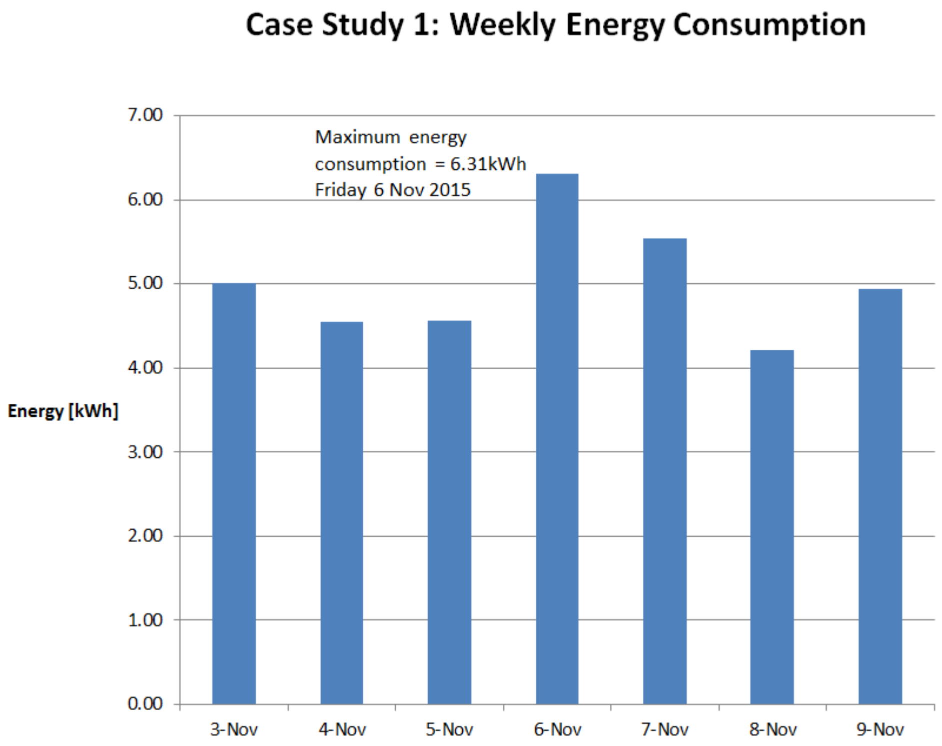

Figure 19 Case Study 2's weekly energy consumption

The highest consumption days were Friday the 6th Nov and Saturday the 7th Nov, with daily totals of 6.31kWh and 5.53kWh respectively. This could reflect the fact that the consumers were home for the weekend, which resulted in higher energy usage.

Over this week period, the total energy consumption of the different appliances were also compared. See Appendix for the total amounts and figure 22 for the pie chart comparison of energy usage between the appliances.

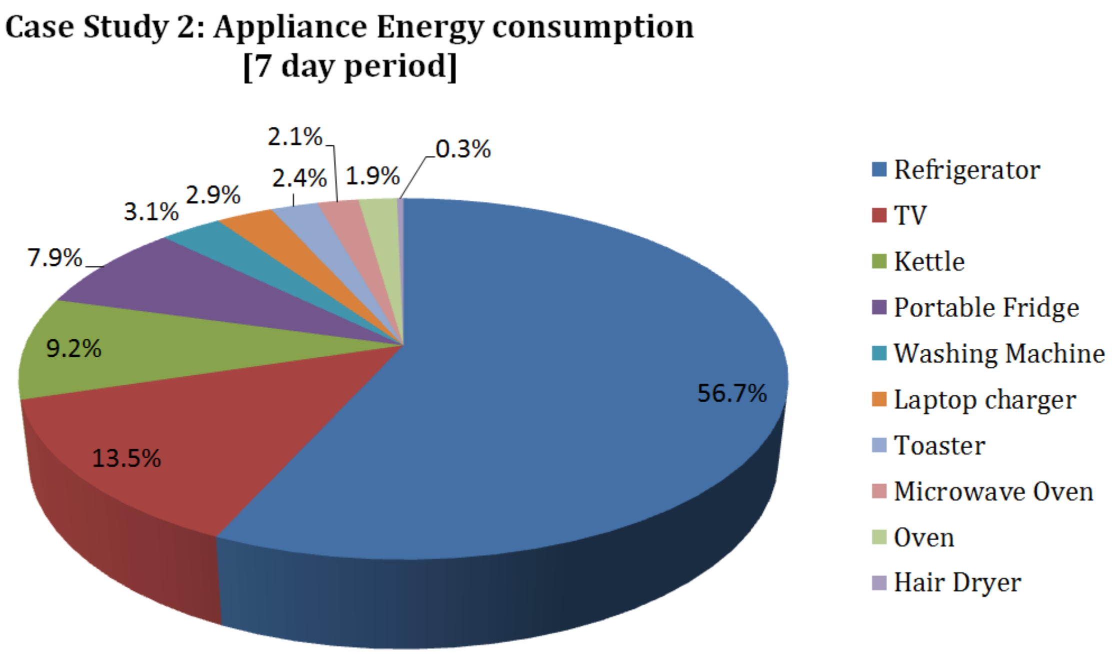

Figure 20 The energy consumption comparison for different appliances in case study 2

As can be seen from the pie chart, the refrigerator, television and kettle were the three top energy users in the household. They were followed by the portable refrigerator, washing machine and the laptop computer and charger. A household can't change its behaviour much when it comes to the refrigerator, kettle or a laptop computer and charger. This household could look at purchasing a smart and efficient refrigerator with a larger capacity for storage to avoid utilising the portable refrigerator. The family can also save money by avoiding stand-by energy costs associated with the hair dryer, television, microwave oven, oven, laptop charger and washing machine. Additionally, the household can look at using the dishwasher and washing machine in off-peak periods if they are on time-of-use tariffs.

To investigate whether avoiding stand-by energy and changing consumer behaviour will lead to savings for a residential household, a cost analysis was done using real-time data accumulated with different Synergy residential pricing schemes. The family in Case Study 2 was on the Synergy Home Plan (A1) tariff but changed to the time of use (TOU) Smart Power (SP1) tariff on the 29th October. A meter reading was taken on the 29th of October and then again on the 12th of November. The family moved out of the house on the 11th of November. The hot water system, oven and air conditioner system should have been the only appliances drawing power after the 11th.

The Synergy bill was received for the supply period 16 September 2015 to 12 November 2015 (58 days). The total units used were 1085 of which 277 units were consumed during the last 15 days when operating under the TOU tariff. The total payable amount was $376.20 of which $82.23 were under the TOU tariff. See Attachment 1 for the Synergy bill. Cost analysis for Case Study 2, conduct cost analysis, using the Synergy rates as seen on the bill for the Home Plan (A1) and Smart Power (SP1) using.

Cost analysis was then done on four different scenarios by comparing two different Synergy tariffs; the Home Plan and the Smart Power Plan. The first scenario just compared the cost differences between the plans. See Appendix 9.1.4 for the Synergy Smart Power tariff costs and Appendix 9.3.2.1 for the unit totals and cost calculations. Options 1 and 5 in Table 2 are the results of the cost comparisons between the different plans.

Secondly, the costs of the various programmes were compared when stand-by energy was omitted. See options 2 and 6 for the association expenses in the table below. The unit totals and cost calculations can be viewed in Appendix 9.3.2.2.

Thirdly the costs for the different plans were compared when the consumers have changed their behaviour and moved the time of use of the washing machine to off-peak periods. See options 3 and 5 for the comparison of rates in the table below. The unit totals and cost calculations can be viewed in Appendix 9.3.2.3

Lastly, the costs for the different plans were compared when the consumers have changed their behaviour (washing machine only) and excluding stand-by energy (hair dryer, television, microwave oven, oven, laptop charger and washing machine). See options 4 and 8 for the comparison of rates in the table below. The unit totals and cost calculations can be viewed in Appendix 9.3.2.4.

Table 2 Cost analysis of four different scenarios with two comparative tariffs for Case Study 2

	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6	OPTION 7	OPTION 8
Plan	A1	A1	A1	A1	SP1	SP1	SP1	SP1
Stand-by Power	×	✓	×	✓	×	✓	×	✓
Behavioural Change	×	×	✓	✓	×	×	✓	✓
Monthly Bill	$156.55	$155.40	$156.55	$155.40	$164.45	$163.52	$148.86	$147.94
Montly savings [$]	$7.90	$9.05	$7.90	$9.05	$0.00	$0.93	$15.60	$16.51
Quaterly savings [$]	$23.71	$27.16	$23.71	$27.16	$0.00	$2.80	$46.80	$49.54
Annual savings [$]	$94.86	$108.65	$94.86	$108.65	$0.00	$11.20	$187.18	$198.17
Montly percentile savings [%]	4.9	5.7	4.9	5.7	0.0	0.6	10.0	10.6

It can be seen from the table that the consumer has paid more for their energy bill. If they had remained on the standard A1 plan, they would have saved $23.71 on their Synergy bill. The consumer would have achieved the greatest savings on the Smart Power programme (SP1) if they changed the time of use for the washing machine plus switching off appliances which draw power when not in operation. Note, the Smart Power Plan (SM1) is no longer a valid plan offered by Synergy.

4.4 DATA COLLECTION ISSUES

Several issues arose while collecting data. With Case study 1, the first problem was that no data was recorded for the microwave due to the device not syncing with the Gateway. The smart appliance was connected to the microwave but had to be installed at the back of the built-in fridge in order to reach the power socket. This could have affected the connectivity of the device to the Gateway.

The second difficulty was that the electrician installed the clamps monitoring the air conditioner (AC) and the main incomer upside down in the distribution board. This resulted in negative results/ measurements being documented. However, the issue was promptly resolved by the Power Tracker IT department who fixed the problem remotely, circumventing the need for the electrician to attend the site again.

The Power Tracker smart devices sample the active and apparent power every minute. Fluctuations within the sample points might be missed. This is not normally a problem and will have no effect if the device is stable.

PERIOD data can be downloaded in big data blocks but it has already been processed. PERIOD data is first broken into 10 minute blocks and then averaged. Those averages are then combined to create the hourly and daily data. It is desirable that the average of the ten minute blocks to be as close to the real average as possible, the grouping of data provides this. The average power is delivered to the customer in hourly periods.

RAW data is sampled minute-by-minute. If it is preferred to see any peaks in power usage, RAW data needs to be retrieved and not PERIOD data. The issue is that this provides vast amounts of data and big data blocks can’t be downloaded without some data corruption. Small data blocks need to be selected, which means it is fairly time consuming to download the entire required big data block.

5 CONCLUSION

The TOU pricing schemes are designed for energy to cost more during peak periods to encourage the consumer to change their consumption behaviour and use electricity during cheaper off-peak periods. This will lead either to peak load reductions or shifting the peak load to a different time periods where the peaks can be managed to a higher degree. Also, TOU pricing schemes compared to fixed rates are intended to be a cheaper option if a consumer makes the effort to restructure their consumption behaviour. It is a clear incentive for consumers to change their tariff option to a more dynamic option such as a TOU rate.

Consumers will be more likely to select an alternative to fixed tariffs if enabling technologies are employed. The customer can allow a smart device and/or smart grid to calculate the optimal consumption pattern which will result in the lowest cost.

IHDs as well as TOU rates contributed to both energy savings and demand response effects. However, the results suggested that IHD usage has a stronger impact on energy conservation (impact of 4.3–6.7 percent) than on demand response (1.8 percent).

Together with enabling technologies, personalized newsletters and internet/email communications could encourage and educate consumers further about energy conservation.

The demand response results from pilot trials and Case Study 1 and 2 indicate that pricing techniques could implement demand response in the residential sector. However, differences in success rates with the different rate structures are dependent on the use of enabling technologies. Results from experiments reveal that customers do respond to price. However, the magnitude of demand response induced by dynamic pricing rates varies from modest to substantial. These variations are likely due to the variations in rates that have been observed in the experiments and also due to the difference in enabling technologies. Additional changes may also come from differences in experimental design, demography and other factors that are difficult to control.

6 FUTURE WORK

Future work can focus on broadening the scope of pricing schemes. It can investigate the effect of combining some of the pricing techniques mentioned in this report, but it could also look at other methods not investigated in this study. For example, there are block schemes where customers are rewarded for low energy consumption and charged large amounts for heavy usage.

Electric hot water systems and lighting contribute significantly to the overall energy consumption of a household. It might be instructive to do a real-time study looking at these systems.

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8 APPENDIX

Appendix 9.1 lists different Synergy residential plans and their associated costs. Appendix 9.2 looks closer at Case Study 1's results, cost analysis and appliance characteristics whereas Appendix 9.3 looks closer at Case Study 2's results and cost analysis.

8.1 SYNERGY TARIFFS & BILLS

Synergy List of residential tariffs: 1 unit equals 1kWh

(Extracted from www.synergy: https://www.synergy.net.au/Your-home/Energy-plans)

8.1.1 SYNERGY HOME PLAN TARIFF (A1)

The consumer gets charged a flat rate of their electricity consumption regardless of the time of day they use electricity or how much they use. See Table 3 for the rates charged for the Home plan. These values are GST inclusive.

Table 3 Synergy Home Plan (A1) tariff (Synergy 2015)

Synergy Home Plan (A1) tariff	Unit price [cents]
Supply charge [cents per day]	47.1834
Electricity charge	25.7029

8.1.2 SYNERGY SMART HOME PLAN (SM1)

See Table 4 for the rates charged for the Smart Home plan. Price is GST inclusive.

Table 4 Synergy Smart Home Plan (SM1) tariff (Synergy 2015)

Smart Home (SM1) tariff	Unit price [cents]
Supply charge [cents per day]	47.1834
Peak	
Weekdays 3pm-9pm	47.85
Off-Peak	
All days 9pm-7am	13.1817
Shoulder	
Weekday 7am-3pm	25.0603
Weekend 7am-9pm	25.0603

8.1.3 SYNERGY POWER SHIFT TARIFF (PS1)

See Table 5 for the rates charged for the Power Shift plan. Price is GST inclusive.

Table 5 Synergy Power Shift Plan (PS1) tariff (Synergy 2015)

Power Shift (PS1)	Unit price [cents]
Supply charge [cents per day]	47.1834
Super Peak	
Weekdays 2pm-8pm	44.0703
Peak	
Weekday 7am-2pm	23.7643
Weekday 8pm-10pm	23.7643
Weekend 7am-10pm	23.7643
Off-peak	
All days 10pm-7am	12.1295

8.1.4 Synergy Smart Power tariff (SP1)

The Smart Power tariff is very similar to Synergy's Smart Home tariff. The differences are that the new (2016) Smart Home tariff has the same charge for the week and weekend shoulder. The SP1 tariff charged higher rates for the weekday shoulder time of day but less for the weekend shoulder time of day. The peak period was also more expensive that the current SM1 tariff. See Table 6 for the rate comparison between the two tariffs.

Table 6 Rate comparison between current SM1 tariff and last year's SP1 tariff

Smart Power (SP1) tariff	Smart Power (SP1) Unit price [cents] excluding GST	Smart Power (SP1) Unit price including GST [cents]	Smart Home (SM1) Unit price including GST [cents]
Supply charge [cents per day]	42.894	47.1834	47.1834
Peak			
Weekdays 3pm-9pm	46.1169	50.72859	47.85
Off-Peak			
All days 9pm-7am	11.9834	13.18174	13.1817
Shoulder			
Weekday 7am-3pm	23.0231	25.32541	25.0603
Weekend 7am-9pm	19.0788	20.98668	25.0603

8.2 Case Study 1 Results

8.2.1 Refrigerator Characteristic

The refrigerator has a repetitive behaviour due to the compressor switching on and off. See Figure 22 for the cyclic nature of the operation of the fridge.

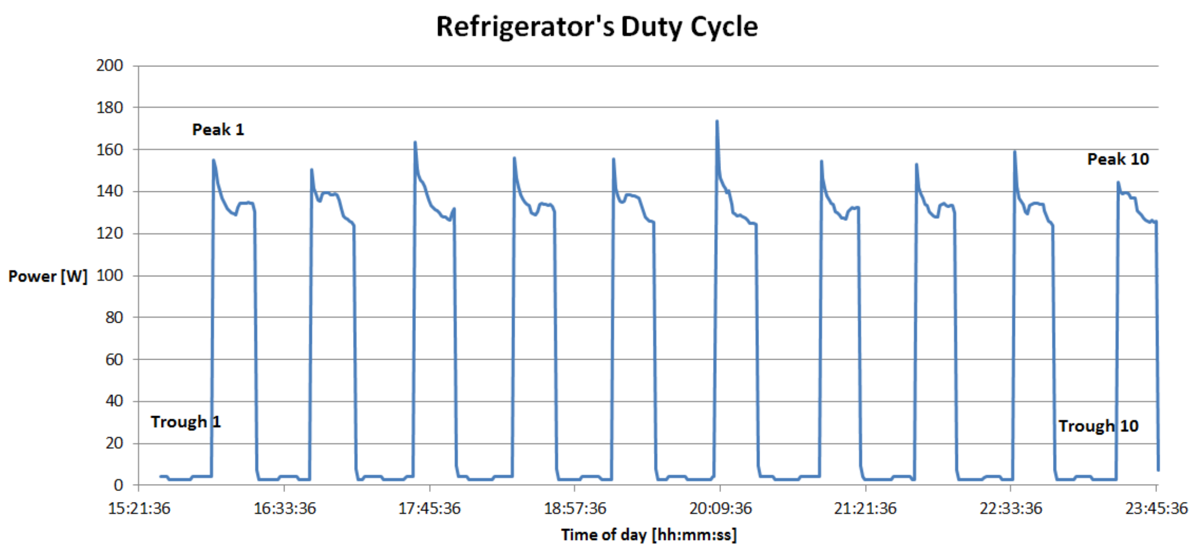

Figure 21 Refrigerator's Duty Cycle

In Tables 7 to 10 the peaks and troughs were inspecting on a finer scale.

Peaks

Table 7 Peak values of a refrigerator's duty cycle

Peaks	1	2	3	4	5	6	7	8	9	10
Maximum Power Demand [W]	155.0	150.4	163.6	156.1	155.6	173.6	154.3	153.2	159.2	144.7
Average Power Demand [W]	135.7	135.2	136.3	135.4	135.2	134.7	134.0	134.1	133.7	133.0
Duration of peak [hh:mm:ss]	00:20:42	00:20:48	00:19:37	00:19:38	00:19:43	00:19:36	00:18:33	00:18:30	00:18:42	00:18:52

The averaged values of the peaks can be seen in Table 8.

Table 8 Averaged values of the peak cycles of a refrigerator's duty cycle

Averaged Maximum Power Demand [W]	156.6
Average Power Demand [W]	134.7
Duration [hh:mm:ss]	00:19:28

Throughs

Table 9 Minimum values of the refrigerator's duty cyle

Troughs	1	2	3	4	5	6	7	8	9	10
Minimum Power Demand [W]	2.61	2.57	2.57	2.6	2.58	2.56	2.58	2.58	2.56	2.56
Average Power Demand [W]	3.53	3.36	3.55	3.71	3.34	3.39	3.75	3.45	3.28	3.08
Duration of peak [hh:mm:ss]	00:24:57	00:26:20	00:28:08	00:27:54	00:27:19	00:28:52	00:24:51	00:26:48	00:28:08	00:30:12

The averaged values of the troughs can be seen in Table 10.

Table 10 Averaged minimum values of the refrigerator's duty cycle

Averaged Minimum Power Demand [W]	2.58
Average Power Demand [W]	3.44
Duration [hh:mm:ss]	00:27:21

8.2.2 Air conditioner Characteristics

In figure 23 the duty cycle of the air conditioner is explored more in depth. It can be verified that the compressor cycles on for a minute and then off for a minute. It continues this cycle until the controller detects that the room temperature is above the nominal set temperature, and the compressor remains on for longer until the temperature is lowered back to the set temperature. The controller does set point checks ever minute. As can been seen in figure 23, the compressor turned on for a minute after which it was determined the temperature is still not at the desired set temperature. The compressor then remains ON further for a minute and thirteen seconds.

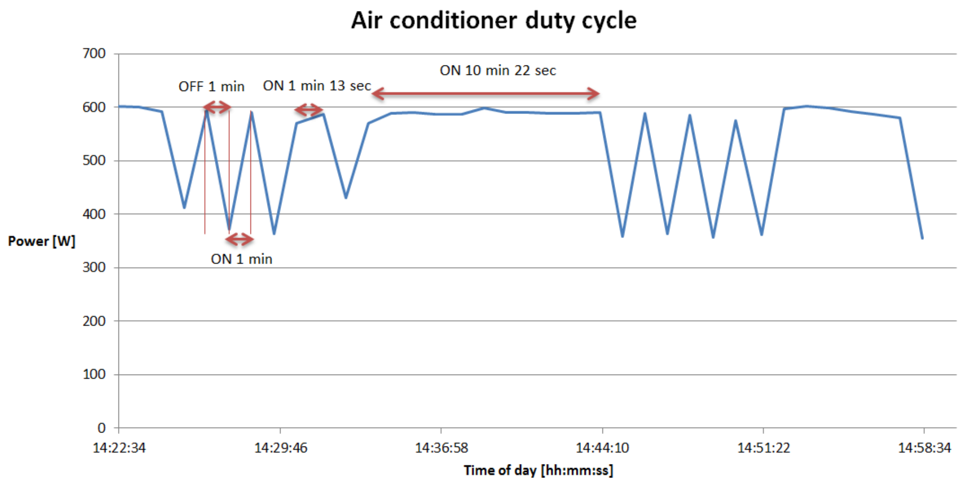

Figure 22 A closer look at the AC's duty cycle

The AC has an average stand-by power demand of 7.56W. The graph of the air conditioner on stand-by mode can be viewed in figure 24.

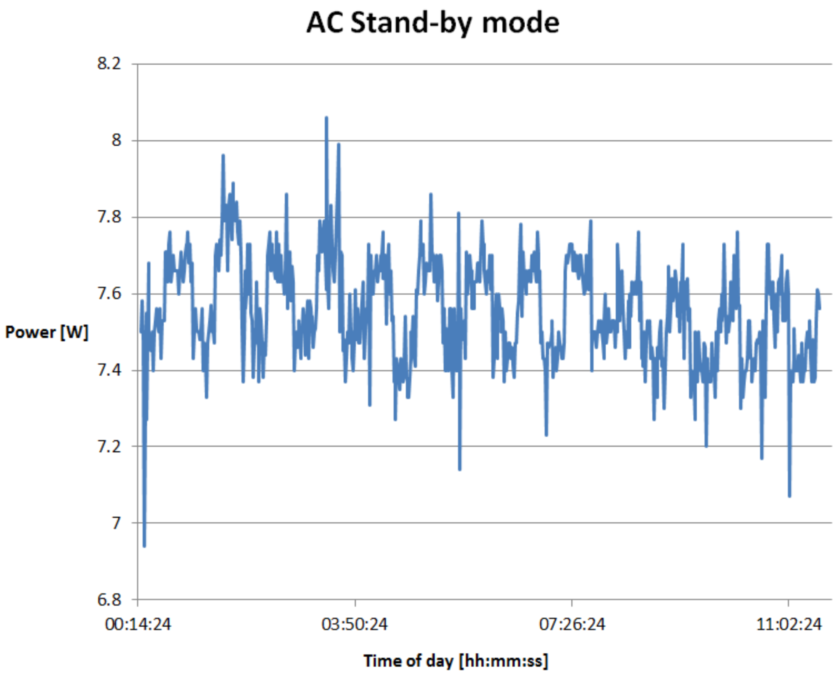

Figure 23 The air conditioner stand-by power demand

The AC consumes an estimate of 47.8kWh energy a month of which 4.44kWh is for stand-by energy. The stand-by energy makes up 9.3% of total monthly energy used.

8.2.3 Washing Machine Characteristics

The washing machine uses stand-by power when it is not in operation. The graph of the stand-by power demand can be viewed in figure 25.

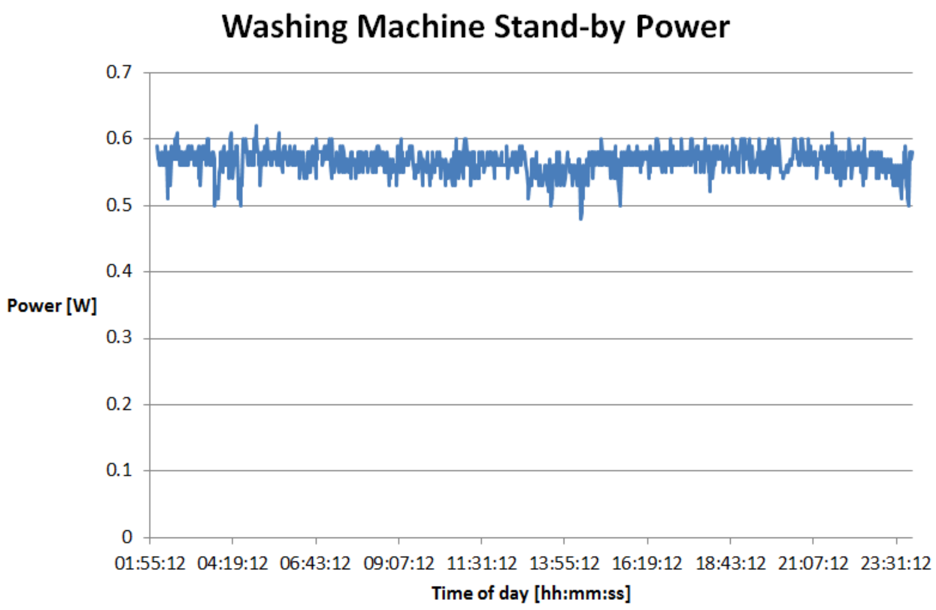

Figure 24 Stand- by power demand of the washing machine

The average stand-by power demand for the washing machine is 0.58 W. The washing machine consumes an estimate of 4.54kWh energy a month of which 0.39kWh is for stand-by energy. The stand-by energy works out to be 8.5% of the total monthly energy used.

8.2.4 Dishwasher Characteristics

The dishwasher was used on the 22nd November 2015 at 7:22 pm. The dishwasher cycle lasted for at least 1 hour and twenty-five minutes. It is the quickest program for this particular model of dishwasher. The daily power demand can be viewed in figure 26.

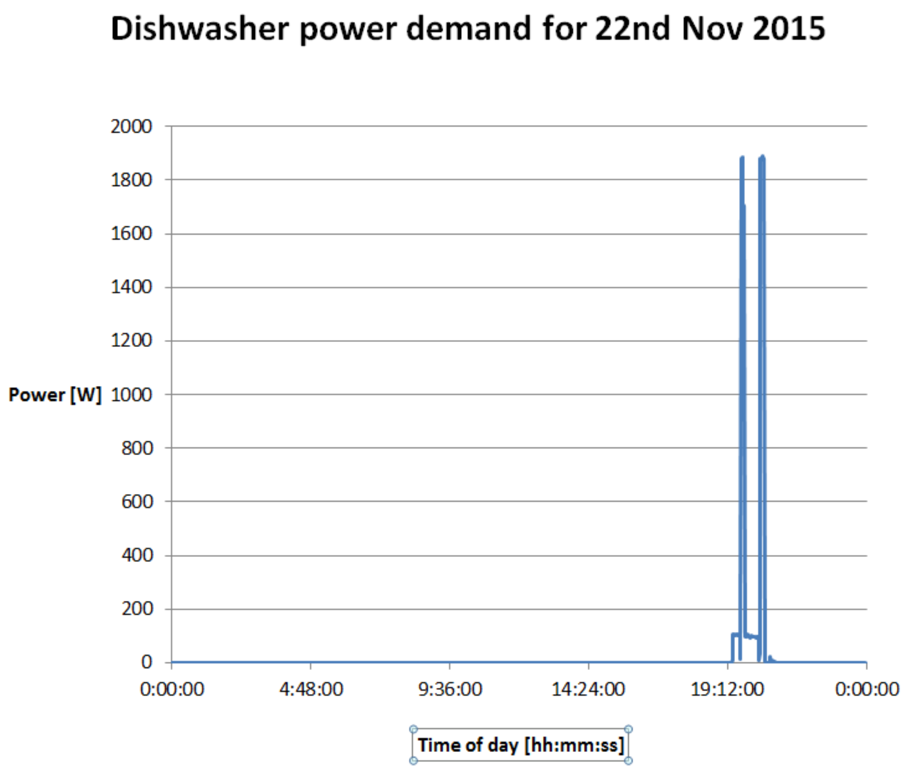

Figure 25 The power demand for the dishwasher on the 22nd Nov 2015

Focussing just on the dishwasher being in operation mode can be seen in figure 27.

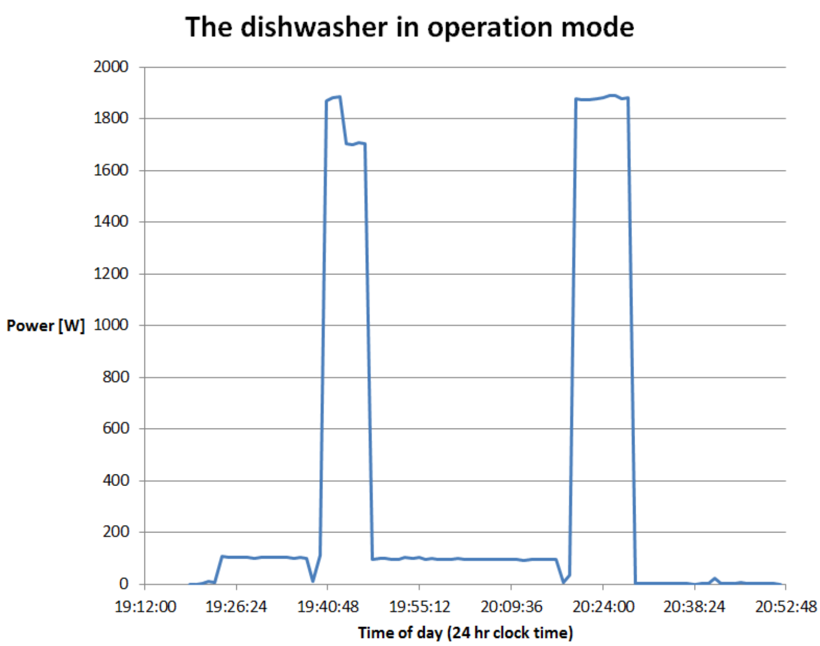

Figure 26 The dishwasher in operation mode

The first peak in the operation is due to the water being heated for the warm water wash and the second peak is due to the steam cycle.

8.2.5 TV Characteristics

The 24th of Nov was the TV had the highest energy consumption. See figure 28 for the power demand for the day.

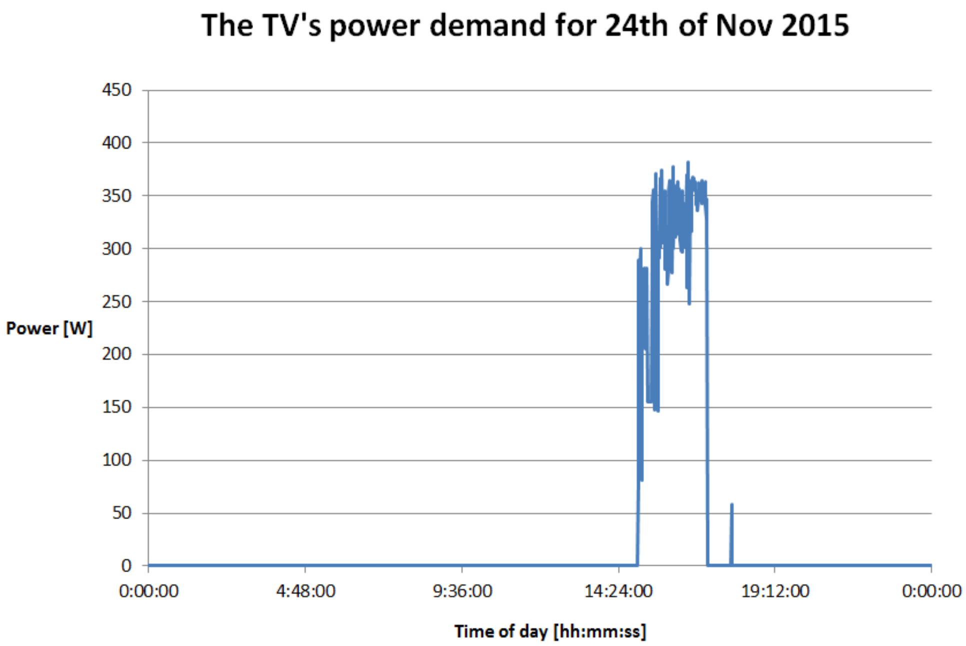

Figure 27 The TV's power demand for the 24th of Nov 2015

The TV was on for about two hours and six minutes. For this day the total energy consumption was 0.66kWh.

8.2.6 Vacuum cleaner Characteristics

The vacuum cleaner was only used on the 23rd and 24th of Nov. See figure 29 for the power demand for the Vacuum cleaner on the 24th.

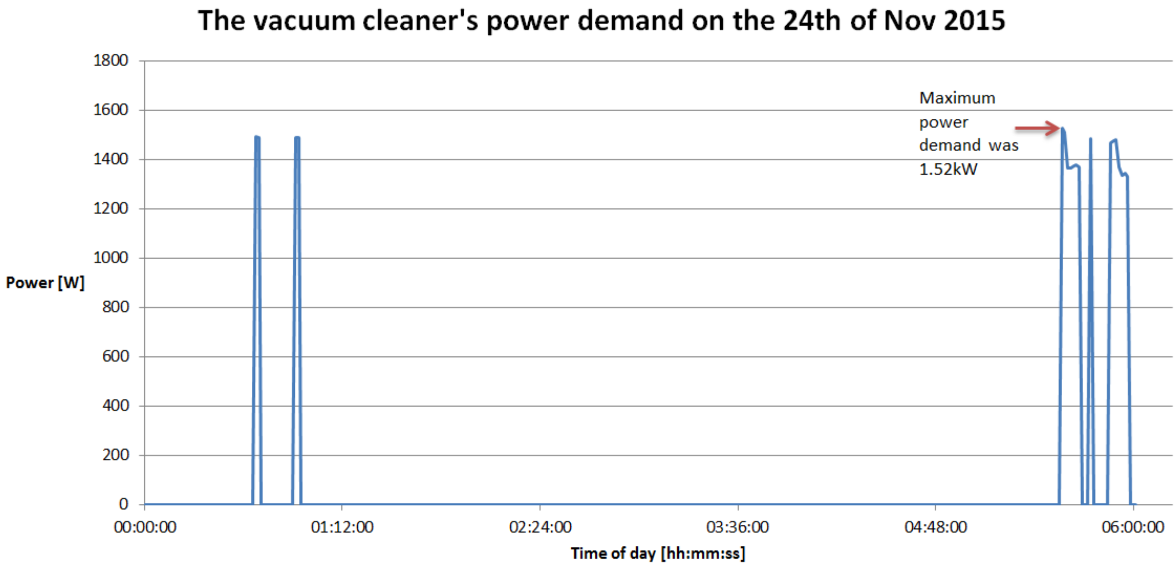

Figure 28 Vacuum cleaner's power demand for the 24th of Nov 2015

The vacuum cleaner is rated for a maximum power demand of 1.8kW. The highest power demand reached during operation on this day was 1.52kW.

8.2.7 Room 1 bedside light Characteristics

The consumer only used the bedside lights three nights of the week. The evening of the highest energy consumption was on the 24th of November 2015. See figure 30 for the power demand for the day.

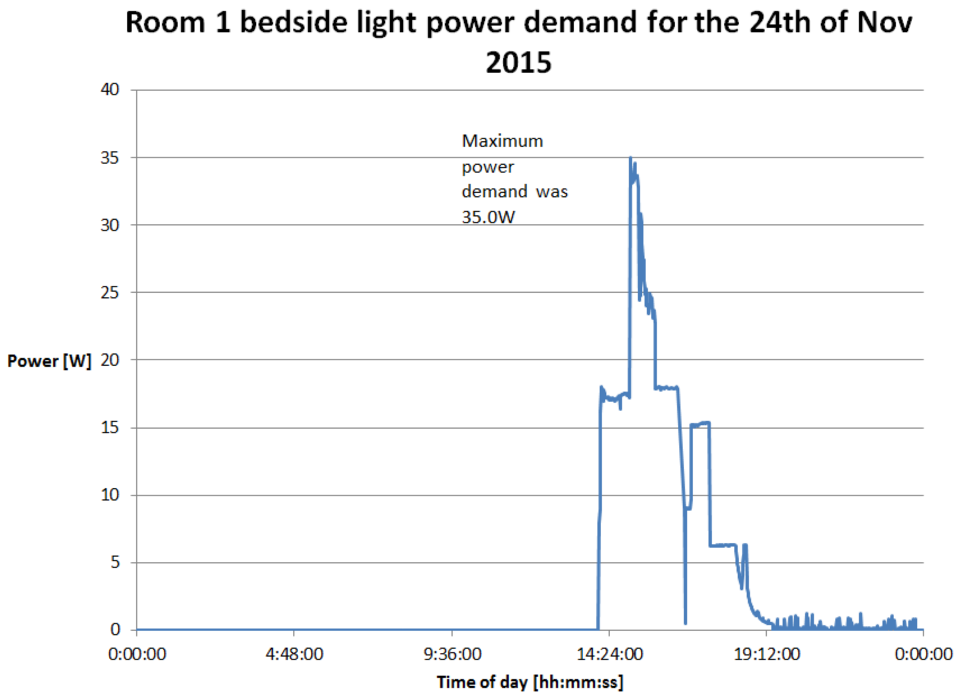

Figure 29 Room 1 bedside light's power demand- 24 Nov 2015

The lights were left on for about nine hours and thirty-nine minutes. The total energy consumption for this day was 0.07kWh.

8.2.8 Room 2 bedside light Characteristics

The bedside lamp in room 2 had a power demand with a maximum of 8.22W on the 25th of November 2015. See figure 31 for the daily power demand. The light was left on for about two hours and thirty three-minutes.

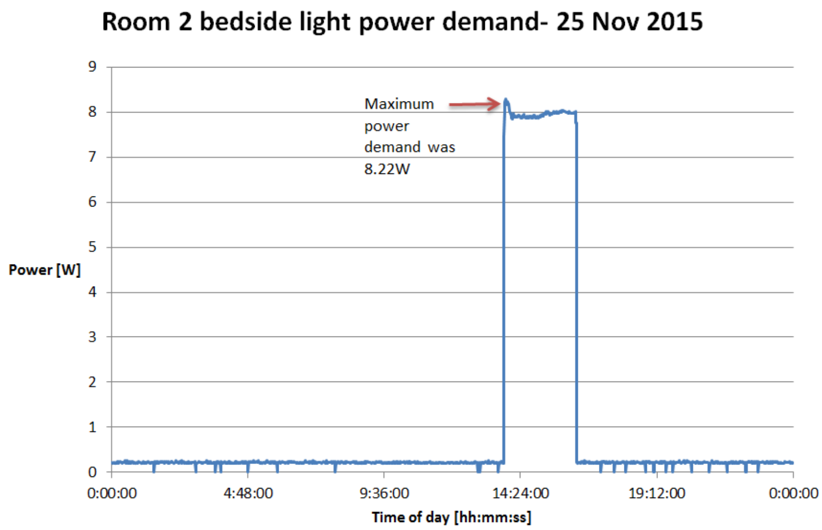

Figure 30 Room 2 beside lamp power demand – 25 Nov 2015

The daily energy consumption was 0.03kWh.

8.2.9 Energy derived from power curves

The data captured by the smart devices were power demand [W] with sample times being about sixty seconds. The data was exported to Microsoft Excel spreadsheets. The area under the power vs. time graph needed to be calculated to determine the total energy consumption of an appliance over the course of a day. The area under a curve can be approximated by adding up the areas of geometrical rectangles. Excel code was written to use the rectangular Riemann sums method to find the area under the curve. Since the sample times were uneven, a good approximation was found by finding the midway points between the sample points and adding them to form the width of the rectangles. See figure 32 for the graph to illustrate how the energy calculations were performed.

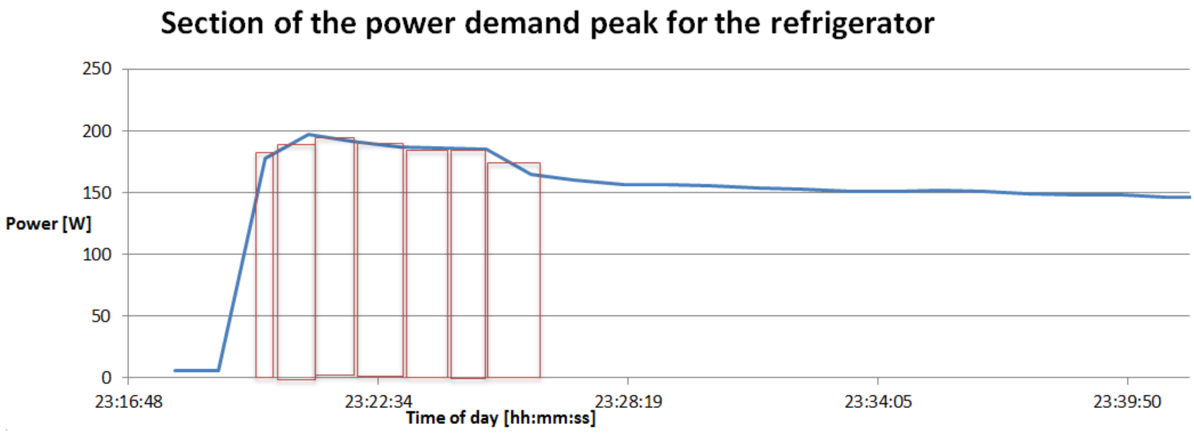

Figure 31 Graphical illustration for the definition of Riemann Sums for calculating energy from power curves

8.2.10 Case Study 1 Cost Analysis

8.2.10.1 Cost Analysis: Comparing plans with real time power data collected

The total weekly energy total calculated was 69.5kWh, which is 69.5 units in Synergy terms. See Table 11 for the weekly totals for each appliance.

Table 11 Appliance energy consumption compared

Case Study 1: Appliance Energy consumption [7 day period]	Weekly Total Enegy Consumption [kWh]	Appliance percentile usage compare to total household usage [%]
Refrigerator	14.6	21.1
Air Conditioner	11.2	16.1
Kettle	3.6	5.2
Dishwasher	3.5	5.0
TV	2.0	2.9
Washing Machine	1.1	1.5
Oven	0.8	1.2
Vacuum Cleaner	0.5	0.8
Bedroom 1 [2 lights]	0.1	0.2
Bedroom 2 [1 light]	0.1	0.1
Miscellaneous	32.0	46.0
Total	**69.5**	**100**

The associated monthly costs were calculated using the Synergy Home Plan (A1), the Synergy Smart Home Plan (SM1) and the Synergy Power Shift plan (PS1) using the weekly recorded power measurements,

See Table 12 for the Synergy Home Plan values and costs.

Table 12 Synergy Home Plan Cost Analysis

Synergy Home Plan (A1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Electricity charge	**25.7029**	**69.5**	1785.7
Total 7 day period units & cost [cents] respectively		**69.5**	**2,116**

The monthly costs were calculated by using the formula:

$$\text{Monthly cost} = \frac{\text{Total weekly cost}}{7 \text{ days}} * 30 \text{ days}$$

It equates to a monthly cost of $90.68

See Table 13 for the Synergy Home Plan values and costs.

Table 13 Synergy Smart Home Plan Cost Analysis

Smart Home (SM1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Peak			
Weekdays 3pm-9pm	**47.85**	13.2	632.2
Off-Peak			
All days 9pm-7am	**13.1817**	21.7	285.9
Shoulder			
Weekday 7am-3pm	**25.0603**	12.3	307.6
Weekend 7am-9pm	**25.0603**	22.3	558.9
Total 7 day period units & cost [cents] respectively		**69.5**	**2,115**

It equates to a monthly cost of $90.64

See Table 14 for the Synergy Power Shift Plan values and costs.

Table 14 Synergy Power Shift Plan Cost Analysis

Power Shift (PS1)	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Super Peak			
Weekdays 2pm-8pm	**44.0703**	15.70	691.7
Peak			
Weekday 7am-2pm	**23.7643**	8.52	202.5
Weekday 8pm-10pm	**23.7643**	2.42	57.41
Weekend 7am-10pm	**23.7643**	22.86	543.4
Off-peak			
All days 10pm-7am	**12.1295**	19.98	242.3
Total 7 day period units & cost [cents] respectively		**69.5**	**2,068**

It equates to a monthly cost of $88.61

To investigate how accurate the above values calculated were the quarterly energy consumption was estimated and compared with the Synergy bill for the period. The quarterly consumption totals were calculated by using the formula:

$$\text{Quarterly energy consumption} = \frac{\text{Weekly energy consumption}}{7\text{ days}} * 30\text{ days} * 3\text{ months}$$

$$\text{Quarterly energy consumption} = \frac{69.4736}{7\text{ days}} * 30\text{ days} * 3\text{ months}$$

$$\text{Quarterly energy consumption} = 893.2\text{ units}$$

The Synergy bill stated the total units used over the period 10 November 2015 to 11 January 2016 were 940.

To calculate the percentage error the following equation was used:

$$\text{Percentage error} = \frac{|\text{Approximate Value} - \text{Exact Value}|}{|\text{Exact Value}|} * 100\%$$

$$\text{Percentage error} = \frac{|893.2 - 940|}{|940|} * 100\%$$

$$\text{Percentage error} = 4.98\ \%$$

8.2.10.2 Cost Analysis: Comparing plans with real-time consumption excluding stand-by power consumption

Investigating the costs a consumer could expect when on different Synergy Plans and excluding stand-by power. The only appliances considered to switch off during times of non-usage were the TV, washing machine, dishwasher and room 2's bedside lamp. See Table 15 for the Synergy Home Plan values and costs.

Table 15 Synergy Home plan plus excluding stand-by power consumption

Synergy Home Plan (A1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Electricity charge	**25.7029**	**69.0**	**1773.0**
Total 7 day period units & cost [cents] respectively			**2,103.3**

It equates to a monthly cost of $90.14

See Table 16 for the Synergy Smart Home Plan values and costs.

Table 16 Synergy Smart Home plan plus excluding stand-by power consumption

Smart Home (SM1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Peak			
Weekdays 3pm-9pm	**47.85**	13.1	628.1
Off-Peak			
All days 9pm-7am	**13.1817**	21.5	283.1
Shoulder			
Weekday 7am-3pm	**25.0603**	12.2	304.7
Weekend 7am-9pm	**25.0603**	22.2	556.8
Total 7 day period units & cost [cents] respectively		**68.98**	**2,103.0**

It equates to a monthly cost of $90.13

See Table 17 for the Synergy Power Shift Plan values and costs.

Table 17 Synergy Power Shift Plan Cost Analysis

Power Shift (PS1)	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Super Peak			
Weekdays 2pm-8pm	**44.0703**	15.61	688.0
Peak			
Weekday 7am-2pm	**23.7643**	8.42	200.0
Weekday 8pm-10pm	**23.7643**	2.39	56.69
Weekend 7am-10pm	**23.7643**	22.78	541.3
Off-peak			
All days 10pm-7am	**12.1295**	19.79	240.1
Total 7 day period units & cost [cents] respectively		**69.5**	**2,056**

It equates to a monthly cost of $88.13

8.2.10.3 Cost Analysis: Comparing plans with real time consumption and changing consumer behaviour

Investigating the costs a consumer could expect when on different Synergy Plans and changing consumer behaviour. The only changes in consumer patterns considered were shifting the time of use for the washing machine and dishwasher to off-peak periods. See table 18 for the Synergy Home Plan values and costs.

Table 18 Synergy Home plan with optimal changed consumer behaviour

Synergy Home Plan (A1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Electricity charge	**25.7029**	**69.5**	**1785.7**
Total 7 day period units & cost [cents] respectively			**2,116.0**

This equates to a monthly cost of $90.68

See Table 19 for the Synergy Smart Home Plan values and costs.

Table 19 Synergy Smart Home plan with optimal changed consumer behaviour

Smart Home (SM1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Peak			
Weekdays 3pm-9pm	**47.85**	12.8	612.8
Off-Peak			
All days 9pm-7am	**13.1817**	23.4	308.8
Shoulder			
Weekday 7am-3pm	**25.0603**	11.6	290.1
Weekend 7am-9pm	**25.0603**	21.7	542.9
Total 7 day period units & cost [cents] respectively		69.47	**2,084.9**

It equates to a monthly cost of $89.35

See Table 20 for the Synergy Power Shift Plan values and costs.

Table 20 Synergy Power Shift plan with optimal changed consumer behaviour

Power Shift (PS1)	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Super Peak			
Weekdays 2pm-8pm	**44.0703**	14.70	648.0
Peak			
Weekday 7am-2pm	**23.7643**	8.42	200.0
Weekday 8pm-10pm	**23.7643**	2.39	56.90
Weekend 7am-10pm	**23.7643**	22.22	528.1
Off-peak			
All days 10pm-7am	**12.1295**	21.74	263.6
Total 7 day period units & cost [cents] respectively		**69.47**	**2,027**

This equates to a monthly cost of $86.87

8.2.10.4 Cost Analysis: Comparing plans with consumer behavioural as well as excluding stand-by power consumption

Investigating the costs a consumer could incur when on different Synergy Plans and changing consumer behaviour and avoiding stand-by appliance energy. The only changes in consumer patterns considered were shifting the time of use for the washing machine and dishwasher to off-peak periods. The TV, washing machine, dishwasher and room 2's bedside lamp stand- by energy were then exclusion from the changed of behaviour values. See Table 21 for the Synergy Home Plan values and costs.

Table 21 Synergy Home plan with optimal changed consumer behaviour and excluding stand-by power

Synergy Home Plan (A1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Electricity charge	**25.7029**	**69.0**	**1773.0**
Total 7 day period units & cost [cents] respectively			**2,103.3**

It equates to a monthly cost of $90.14

See Table 22 for the Synergy Smart Home Plan values and costs.

Table 22 Synergy Smart Home plan with optimal changed consumer behaviour and excluding stand-by power

Smart Home (SM1) tariff	Unit price [cents]	Total TOTALS [units]	Total Costs [cents]
Supply charge [cents per day]	**47.1834**		330.3
Peak			
Weekdays 3pm-9pm	**47.85**	12.8	611.6
Off-Peak			
All days 9pm-7am	**13.1817**	23.0	303.4
Shoulder			
Weekday 7am-3pm	**25.0603**	11.5	289.2
Weekend 7am-9pm	**25.0603**	21.6	542.3
Total 7 day period units & cost [cents] respectively		**68.98**	**2,076.8**

It equates to a monthly cost of $89.01

See Table 23 for the Synergy Power Shift Plan values and costs.

Table 23 Synergy Power Shift plan with optimal changed consumer behaviour and excluding stand-by power

Power Shift (PS1)	**Unit price [cents]**	**Total TOTALS [units]**	**Total Costs [cents]**
Supply charge [cents per day]	**47.1834**		330.3
Super Peak			
Weekdays 2pm-8pm	**44.0703**	14.68	647.0
Peak			
Weekday 7am-2pm	**23.7643**	8.39	199.3
Weekday 8pm-10pm	**23.7643**	2.39	56.69
Weekend 7am-10pm	**23.7643**	22.20	527.5
Off-peak			
All days 10pm-7am	**12.1295**	21.33	258.7
Total 7 day period units & cost [cents] respectively		**68.98**	**2,019.5**

This equates to a monthly cost of $86.55

8.3 CASE STUDY 2 RESULTS

With Case Study 2 no data could be collected for the main incomer, air conditioner and electric hot water system. The total household consumption could thus not have been monitored, and an exact daily load profile could not be compiled. However, it is known that the air conditioner was not used during the observation time interval but would have still had drawn stand-by power.

8.3.1 Appliance Characteristics

8.3.1.1 Hair Dryer Characteristics

The hair dryer uses stand-by power when it is not in operation. The graph of the stand-by power demand can be viewed in figure 33.

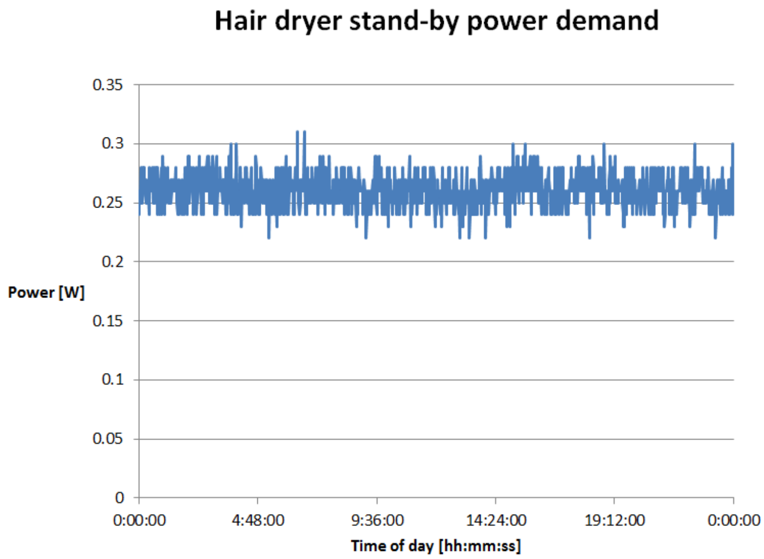

Figure 32 Stand-by power demand for the hair dryer

The average stand-by power demand for the hair dryer is 0.26 W.

8.3.1.2 Laptop Stand-by Characteristics

The laptop charger draws cyclic stand-by power as seen in figure 34.

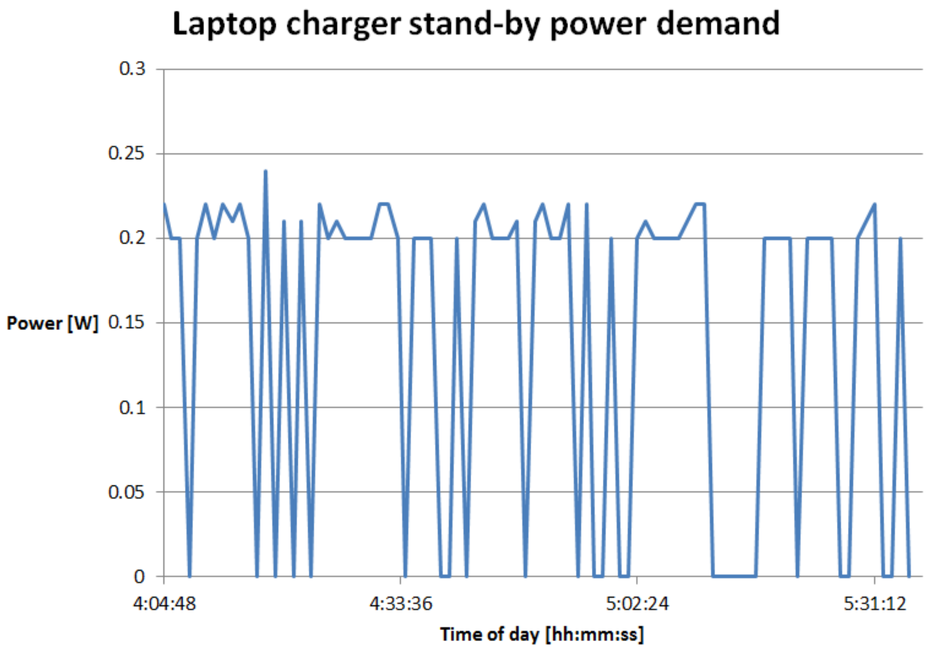

Figure 33 Laptop charger stand-by power demand

As seen in the figure, the laptop charger draws power which spikes to predominately maximums of 0.22 W but then the power demand drops back to 0W demand.

8.3.2 Case Study 1 Cost Analysis

8.3.2.1 Cost Analysis: Comparing plans with real time power data collected

The total weekly energy total calculated was 35.1kWh. See Table 24 for the weekly totals for each appliance.

Table 24 Appliance energy consumption compared

Case Study 2: Appliance Energy consumption [7 day period]	Weekly Total Enegy Consumption [kWh]	Appliance percentile usage compare to total household usage [%]
Refrigerator	19.9	56.7
TV	4.7	13.5
Kettle	3.2	9.2
Portable Fridge	2.8	7.9
Washing Machine	1.1	3.1
Laptop charger	1.0	2.9
Toaster	0.8	2.4
Microwave Oven	0.7	2.1
Oven	0.7	1.9
Hair Dryer	0.1	0.3
Total	**35.1**	**100**

The last 15 days under the TOU tariff the Synergy bill received by the household indicated for the total energy consumption was 277 units. To investigate how accurate the above values calculated were the quarterly energy consumption was estimated and compared with the Synergy bill for the period. The monthly consumption totals were calculated by using the formula:

$$\text{Monthly energy consumption} = \frac{\text{Weekly energy consumption}}{7\ \text{days}} * 30\ \text{days} * 3\ \text{months}$$

$$\text{Monthly energy consumption} = \frac{35.1}{7\ \text{days}} * 30\ \text{days} * 3\ \text{months}$$

$$\text{Monthly energy consumption} = 150.4\ \text{units}$$

The Synergy bill stated the total units used over the period 29 November 2015 to 12 December 2015 were 277. It calculates be around 554 units of energy consumption over a month period. It is quite a significant difference. It needs to be noted again that the water system, air conditioner and other appliances were not measured which could have significantly added to the total consumption of the house. The real total energy consumption of 277 units for 15 days will be used in the cost analysis of changes in consumer behaviour calculated just by measurements taken from the appliances mentioned in section 4.3.2 above.

Thus using the weekly recorded power measurements the monthly associated costs was calculated using the Synergy Home Plan (A1) and the Synergy Smart Power Plan (SP1).

See Table 25 for the Synergy Home Plan values and costs.

Table 25 Synergy Home Plan Cost Analysis

Synergy Home Plan (A1) tariff	Unit price [cents]	Real energy consumption TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	47.1834	15 days	707.8
Electricity charge	25.7029	277	7119.7
Total 15 day units [kWh] & costs [cents], respectively		**277**	**7827.5**
Total 15 day cost [$]			**$78.27**
monthly totals [$]			**$156.55**

The monthly costs were calculated by using the formula:

$$\text{Monthly cost} = \frac{\text{Total weekly cost}}{15 \text{ days}} * 30 \text{ days}$$

This equates to a monthly cost of $156.55

See Table 26 for the Synergy Smart Power Plan (SP1) values and costs.

Table 26 Cost analysis with Smart Power tariff

Smart Power (SP1) tariff	Smart Power (SP1) Unit price [cents] excluding GST	Smart Power (SP1) Unit price including GST [cents]	Real energy consumption TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	42.894	47.1834	15 days	707.8
Peak				
Weekdays 3pm-9pm	46.1169	50.72859	64	3246.6
Off-Peak				
All days 9pm-7am	11.9834	13.18174	72	949.1
Shoulder				
Weekday 7am-3pm	23.0231	25.32541	83	2102.0
Weekend 7am-9pm	19.0788	20.98668	58	1217.2
Total 15 day units [kWh] & costs [cents], respectively			**277**	**8222.7**
Total 15 day cost [$]			**$75.45**	**$82.23**
monthly totals [$]				**$164.45**

It equates to a monthly cost of $164.45

8.3.2.2 Cost Analysis: Comparing plans with real-time consumption excluding stand-by power consumption

Investigating the costs a consumer could expect when on different Synergy Plans and excluding stand-by power. The appliances considered to switch off during times of non-usage were the TV, washing machine, oven, microwave oven, laptop charger and the hair dryer. See Table 27 for the Synergy Home Plan values and costs.

Table 27 Synergy Home plan plus excluding stand-by power consumption

Synergy Home Plan (A1) tariff	Unit price	Stand-by TOTALS [kWh]	Energy consumption minus stand-by TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	47.1834			707.8
Electricity charge	25.7029	2.235596	274.7644	7062.242
Total 15 day units [kWh]				**7770.0**
Total 15 day cost [$]				**$77.70**
monthly totals [kWh]				**$155.40**

It equates to a monthly cost of $155.40

See table 28 for the Synergy Smart Power Plan values and costs.

Table 28 Synergy Smart Home plan plus excluding stand-by power consumption

Smart Power (SP1) tariff	Smart Power (SP1) Unit price including GST [cents]	Stand-by TOTALS [kWh]	Energy consumption minus stand-by TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	47.1834			707.8
Peak				
Weekdays 3pm-9pm	50.72859	0.28	63.7	3232.3
Off-Peak				
All days 9pm-7am	13.18174	1.31	70.7	931.8
Shoulder				
Weekday 7am-3pm	25.32541	0.36	82.6	2093.0
Weekend 7am-9pm	20.98668	0.28	57.7	1211.3
Total weekly units [kWh]		**2.235596393**	**274.8**	**8176.0**
Total weekly cost [$]				**$81.76**
monthly totals [kWh]				**$163.52**

It equates to a monthly cost of $163.52

8.3.2.3 Cost Analysis: Comparing plans with real-time consumption and changing consumer behaviour

Investigating the costs a consumer could expect when on different Synergy Plans and changing consumer behaviour. The only changes in consumer patterns considered were shifting the time of use for the washing machine to off-peak periods. The Synergy Home Plan values remain unchanged as the flat tariff is charged for all units.

See Table 29 for the Synergy Smart Power Plan values and costs.

Table 29 Synergy Smart Power plan with optimal changed consumer behaviour

Smart Power (SP1) tariff	Smart Power (SP1) Unit price including GST [cents]	Changed behaviour TOTALS [kWh]	Energy consumption minus changed behaviour TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	47.1834			707.8
Peak				
Weekdays 3pm-9pm	50.72859	0.01	64.0	3245.874358
Off-Peak				
All days 9pm-7am	13.18174	0.74	13.5	178.4219972
Shoulder				
Weekday 7am-3pm	25.32541	0.32	82.7	2093.819765
Weekend 7am-9pm	20.98668	0.02	58.0	1216.901108
Total weekly units [kWh]		**1.092483854**	**218.2**	**7442.8**
Total weekly cost [$]				**$74.43**
monthly totals [kWh]				**$148.86**

It equates to a monthly cost of $148.86.

8.3.2.4 Cost Analysis: Comparing plans with consumer behavioural as well as excluding stand-by power consumption

Investigating the costs a consumer could incur when on different Synergy Plans and changing consumer behaviour and avoiding stand-by appliance energy. The only changes in consumer patterns considered were shifting the time of use for the washing machine to off-peak periods. The TV, washing machine, oven, microwave oven, laptop charger and the hair dryer stand-by energy were then exclusion from the behaviour changed values. The Synergy Home Plan benefits and costs will be the same as above when just the stand-by energy was excluded.

See Table 30 for the Synergy Smart Power Plan values and costs.

Table 30 Synergy Smart Power plan with optimal changed consumer behaviour and excluding stand-by power

Smart Power (SP1) tariff	Smart Power (SP1) Unit price including GST [cents]	washing machine stand-by energy [kWh]	Changed behaviour for Stand-by energy TOTALS [kWh]	Changed behaviour plus exclusion of Stand-by energy TOTALS [kWh]	Total Costs [cents]
Supply charge [cents per day]	47.1834				707.8
Peak					
Weekdays 3pm-9pm	50.72859	0.01489106	0.27	63.7	3232.261449
Off-Peak					
All days 9pm-7am	13.18174	0.030883224	1.36	12.2	160.515118
Shoulder					
Weekday 7am-3pm	25.32541	0.017557401	0.34	82.3	2085.206109
Weekend 7am-9pm	20.98668	0.015549488	0.27	57.7	1211.262649
Total weekly units [kWh]		**0.078881172**	**2.235596393**	**215.9461436**	**7397.0**
Total weekly cost [$]					**$73.97**
monthly totals [kWh]					**$147.94**

This equates to a monthly cost of $147.94.

8.4 CASE STUDY 1& 2 SYNERGY BILLS

Case study 1 is on the Synergy Home Plan(A1) tariff. The Synergy bill was for the supply period 10 November 2015 to 11 January 2016 (63 days). The total units used were 940 which resulted in a total payable amount of $272.20.

See Attachment 1 for the Synergy bill.

9 ACRONYM GLOSSARY

AC – Air Conditioner

ACT - Air-Conditioner Trial

CT - Current Transformer

DM - Direct Marketing

DR - Demand Response

DRED - Demand Response Enabling Device

HAN - Home Area Network

HW - High Voltage

IHD - In Home Display

kW - Kilowatt

kWh - Kilowatt Hour

KPIs - Key Performance Indicators

LV - Low Voltage

MW - Megawatt

MWh - Megawatt Hour

NMI - National Meter Identifier

NMS - Network Management System

PQ - Power Quality

PV - Photovoltaic

RF - Radio Frequency

SWIS - South West Interconnected System

TOU - Time of Use

TV - Television

V - Volts

W - Watt