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Energy Management & Automated Analytics

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Disclaimer

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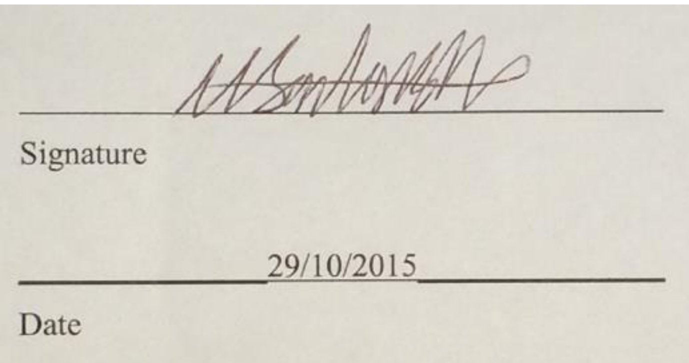

Abstract

Electricity bills are an inherent cost to any household or business. In recent years, the commodity as a whole has risen significantly in price placing greater demand on our society to reduce on energy costs.

The principle of energy management explores the energy behaviours of a given site or premises in order to create consumer awareness and alter their energy behaviours. By gathering and distributing more information regarding the consumption of a site or premises, consumers can grasp a better understanding of their energy consumption and make justified decisions in order to reduce their energy consumption. This concept can deliver significant long-term results but can often be a time consuming and expensive process to implement.

This research project aims to deliver the energy management process in a more time and cost efficient manner. Energy management is only viable if it benefits the end consumer and economic viability is placing significant constraints on developments within the energy management field. Finding time and cost efficient energy management processes will not only allow consumers to reduce their energy consumption in shorter time frames but will also allow for the possibility of benefitting more energy consumers across residential, commercial and industrial energy markets.

Acknowledgements

I would like to extend my greatest thanks to Dr. Narottam Das who has been extremely supportive throughout the entirety of this research project. His genuine interest in my project has pushed me above and beyond my normal capabilities and it has helped me to realise my full potential on this project.

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Most of all, I would to thank my family and friends for their support throughout the duration of my degree. They always assisted me through the tough times and it is something for which I will be forever grateful.

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List of Acronyms

CPR	Cardiovascular Pulmonary Resuscitation
EIS	Energy Information Systems
EMCS	Energy Management and Control System
EMS	Energy Management System
EEO	Energy Efficiency Opportunities
LAN	Local Area Network
LVR	Low Voltage Rescue
HVAC	Heating, Ventilation and Air-Conditioning
kWh	Kilowatt Hour
NABERS	National Australian Building Environment Rating System
ROI	Return on Investment
UK	United Kingdom
UCSB	University of California Santa Barbara
UQ	University of Queensland
VSD	Variable Speed Drive

Chapter 1: Introduction

1.1 Project Background

One of the most common problems among energy consumers is that their electricity bills do not come equipped with sufficient information for a standard consumer to understand how electricity is being consumed within their given premises. Electricity bills are a growing pain point amongst numerous electricity consumers within the domestic, commercial and industrial energy markets. In 2013, 24,000 homes in Queensland were disconnected from the network grid due to the fact that they could not meet the pressures of the rising electricity costs (Senior Australian, 2015). These rising costs have also placed significant financial stresses on businesses as well, with some small business owners moving their operations to their home because they cannot meet the cost demand of a second electricity bill.

The energy management concept aims to deliver more information regarding electricity consumption to assist consumers in reducing energy costs within their given premises. This project will explore energy management as a concept as well as deliver an innovative method of implementing the energy management process. It will explain the theoretical and technical aspects of energy management as well as deliver a practical assessment using standard electricity consumers.

Australia consumes approximately 10,719 kWh's per person per year (Trade Economics, 2015), which equates to an annual consumption of approximately 250 terawatt hours. A 5% saving across the country would provide enough energy to power 280,000 homes in Queensland for one year and would save the average consumer approximately $100 per year (Energy Made Easy, 2015). Although 5% within one premises is only a relatively small saving, it is the scalability of what these small changes across a larger number of consumers can achieve that can assist in making Australia a more energy efficient country to live in.

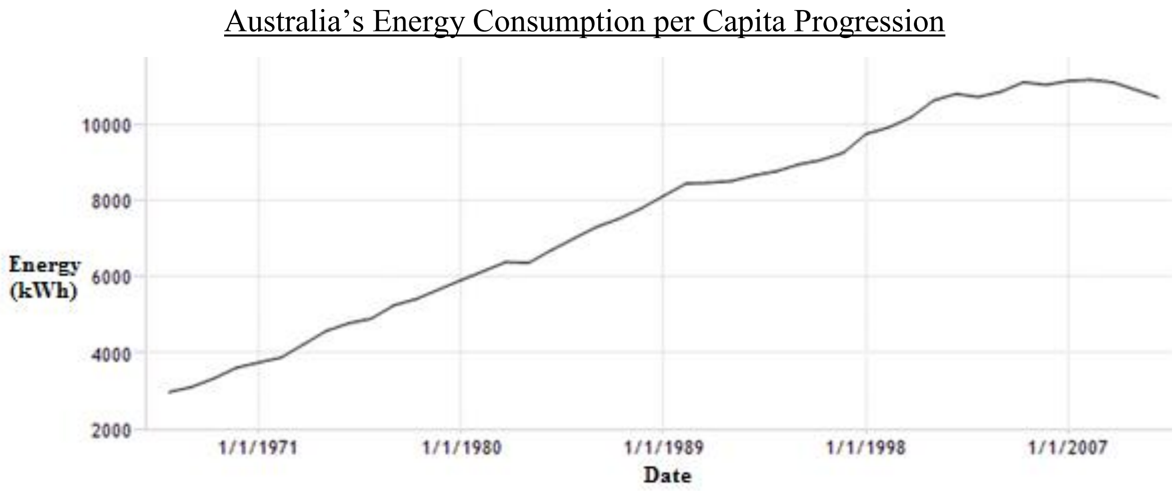


Figure 1.1: Electricity Consumption per Capita – Australia (Trade Economics, 2015)

1.2 Project Objectives

There are two main objectives that this research project will aim to achieve. The first is to justify the viability of the energy management concept. Energy management, although not a simple process to implement, has been well known to provide great results toward energy reduction for electricity consumers (Energy Efficiency Exchange, 2013). Energy management is still a relatively new concept as far as the general electricity market is concerned however with electricity bills rising constantly and climate change becoming a constant growing worldwide issue, energy management is becoming more popular within our society as a means of an energy reduction strategy.

One of the great challenges of energy management is investing the right amount of funding for the optimal return on investment (ROI). Energy measuring technology can be expensive to install and the time spent in analysing data and implementing control measures can raise initial capital costs quite dramatically, sometimes to the point where implementing an energy management system (EMS) is not viable. Some corporations have full time energy managers employed who are solely responsible for making their premises more energy efficient, placing bigger overheads on the running of the business. This adds an element of risk to the energy management process with no guarantees of an ROI for money saved versus money spent. A solution to this problem is the second objective of this project which aims to find a more cost and time efficient manner in which to analyse data and implement control measures that come under the energy management process - saving both time and money for the end consumer.

1.3 Project Implementation

The implementation of this project will be based around the three major steps of energy management. Figure 1.2 is a representation of the energy management process (Santarossa, 2015).

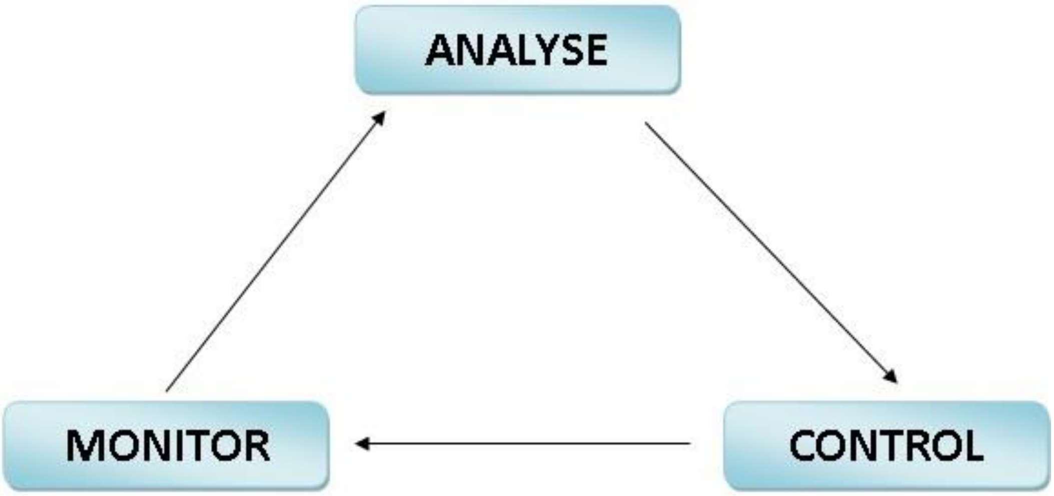


Figure 1.2: Energy Management Process (Santarossa, 2015)

The first step involves gathering a significant amount of data regarding the energy consumption of a given site or premises. This is achieved by installing energy measuring/monitoring devices, acquiring previous electricity bills and establishing communication directly with the consumer. After sufficient data has been gathered, it is analysed to find where energy is being consumed in order to better understand the consumer’s energy behaviours. A plan is then devised to implement control measures in an effort to reduce the amount of energy consumed within the given site or premises. This process is then repeated and reviewed in order to gauge if the control measures put in place were successful as well as attempting to find more ways to increase the energy efficiency of the site or premises.

1.4 Project Overview and Timeline

This research project will run over the course of two semesters based on the University of Southern Queensland's semester timetable. The full project timeline is represented as a Gantt chart in Appendix B of this report.

1.5 Project Safety Considerations

This project is to be performed in the interest of safety to ensure the protection of all members involved, the general public and property. Although this is a research project, safety concerns still need to be taken into consideration throughout the course of the project. Risk and hazard assessments will be undertaken throughout the entirety of the project with any imminent safety concerns to be further assessed if the need arises. Part of this project will involve performing an installation around electrical equipment. This, along with all installations, will be performed by licenced and qualified personnel within the correct safety guidelines as required.

1.6 Project Structure and Content

The following is a list of the dissertation chapters as well as a brief explanation of the content within each chapter:

Chapter 1 - Introduction: a brief overview of what the project entails as well as how it is going to be implemented.

Chapter 2 - Background Information: an in-depth explanation of energy management and an outline of the concepts behind energy management that make it a viable process.

Chapter 3 - Literature Review: explores how energy management has been utilised in a practical environment and how it has reduced energy consumption for given consumers. This chapter will be utilised as a base measure for comparison with the methodology.

Chapter 4 - Methodology: explains and delivers an innovative practical assessment of the energy management process tailored for the purposes of this research project.

Chapter 5 - Results: discusses the findings of the practical assessment. This will provide the required information to be able to discuss the successes and shortcomings of the project.

Chapter 6 - Discussion: evaluates the results and highlights the positives and negatives of how the project was implemented. The discussion will ultimately justify the viability of the energy management process.

Chapter 7 - Conclusions: a summarisation of the project as a whole.

Chapter 2: Background Information

2.1 Chapter Overview

This chapter will provide a detailed explanation of the theoretical background of the energy management concept and how it is implemented in a practical environment. It will also discuss briefly some of the historical developments of energy management within our society.

2.2 Energy Management Definition

2.2.1 Planning

Every EMS begins with a plan. This assists in conceptualising the goals of what the consumer wishes to achieve regarding reductions of their own energy consumption and also allows a consumer to understand how the process is going to work. An EMS may contain, but is not limited to, the following criteria (Energy Efficiency Exchange, 2015):

1. A list of all parties involved in the process
2. A benchmark for savings
3. A budget and time frame
4. Monitoring technologies
5. Analysis strategies
6. Controlling strategies
7. Areas for savings
8. Predicted savings

The above criteria lay the platform for a quality EMS. It is highly important during the planning phase to justify the feasibility of implementing an EMS as the budget must give an ROI over a defined time period. This will not become completely clear until the EMS implementation has begun but still needs to be accounted for nonetheless.

2.2.2 Monitoring

The planning phase will encompass the selection and installation of monitoring equipment that will capture data relating to the energy consumption of a given premises. There are inherent difficulties in justifying the quantity of monitoring equipment in which to acquire. If there is an insufficient amount of equipment installed, then inadequate data will be captured for the analysis phase of the process. However if the amount of equipment installed is overcompensated, it can become a costly assignment which may make the process less viable from a financial perspective.

More often than not, the best strategy is to not over-invest in monitoring equipment in the initial stages of the energy management process. Monitoring devices can be expensive to both purchase and install. Ultimately, the monitoring technology selection is limited to the EMS budget, the amount of data required to be captured, the resources of the given premises and the desired outcomes of the site consumer.

2.2.3 Data Analysis

Of all the stages of the energy management process, analysing the data can often be the most challenging from an engineering perspective. It is during the data analysis phase that all of the data gathered from the monitoring system is to be correlated and presented into a format that a regular consumer can understand. However every consumer site, and as well as a consumers understanding of energy consumption, is different and this can make the data analysis process difficult to execute.

Once the monitoring equipment is installed, the site consumer is committed to investing both funding and time into the EMS. Unlike the fixed pricing of installing monitoring equipment, the analysis process can vary significantly in price. A fixed price for data analysis will often come in the form of a standard report and this may not be enough information as a one off transaction for a site consumer to utilise for controlling their energy consumption over a long-term period. This project will attempt to implement a more time and cost efficient method to deliver the analysis phase of the energy management process to ensure better results for the end consumer.

2.2.4 Controlling

The control phase of the energy management process is implemented when action is taken toward physically reducing energy consumption. When executing strategies for controlling energy consumption, the following items must be taken into consideration:

- The reduction strategies must not compromise on the correct operation of the site or premises.
- Acquisition and installation of new equipment must be financially justified.
- Reduction strategies requiring large capital must come with a calculated return on investment time frame.

Producing a quality report during the data analysis phase will make the controlling phase simpler to implement. As well as having reduction strategies, the report should also have within it predicted outcomes for every strategy listed. Although this is mostly an estimate, it is a clear indication that there are areas for savings as well as quantifies what those savings could potentially be.

2.2.5 Review

Reviewing the energy management process after a given time period will provide a measure on whether the system was a success or if there were any short comings. It is then the responsibility of all parties involved to find out why the EMS implemented either succeeded or failed and how it can be better executed once the process is repeated.

Occasionally, consumers will only have sufficient funding to perform the energy management process once. However in order for an energy consumer to fully benefit from an energy management process, it is typically a long-term project. Regardless of the success or shortcomings of the process after the first review, a typical EMS will be an on-going process, aiming to find more ways to reduce both energy consumption whilst eliminating the potential for complacency. A standard consumer is most likely to be motivated to part-take in an energy management process when their electricity bill arrives. It is important for a consumer not to slip into a state of complacency toward their electricity bill once they have started the energy management process. Control measures can easily be forgotten due to simple complacency so it is critical to keep reviewing the energy management process to ensure energy costs are kept to a minimum.

2.3 Energy Management History

Although it is still a developing concept, energy management has still in part been utilised as a means of reducing energy consumption over the past 40 years. The United Kingdom (UK) began creating an energy saving mentality during the oil crisis of 1973 (Fawkes, 2001). Lack of fuel meant that energy costs rose dramatically throughout the 1970's and energy management was looked upon by organisations and people alike throughout the country as a means of energy reduction. During this time the energy management concept was also adopted throughout other parts of the world, with the University of Michigan receiving funding from the Department of Education (DOE) to perform energy audits of their campus beginning in the late 1970's (University of Michigan, 2013).

By the 1980's, it was becoming more evident that societies electricity would inherently be generated off non-renewable sources for a long time to come and this was having dramatic effects on the environment. Inflation and other costs associated with generating and distributing electricity continued to rise and with it came a greater demand of reducing energy consumption. During this time period, energy management started to become its own discipline throughout the UK, with the UK government assisting regional energy management organisations in distributing information regarding the need to reduce energy and how this could possibly be achieved (Fawkes, 2001).

Another great development throughout the 1980's was the development of energy measuring technologies that assisted in capturing energy data. This time period saw a dramatic rise in the personal computer industry and with it came an abundance of technological advancements that could be utilised within the energy management field. Monitoring and Targeting (M&T) systems were starting to be utilised throughout the UK. This meant they could begin to monitoring and control heating and cooling systems throughout large buildings, allowing for better energy information gathering possibilities. It also allowed for automated systems which reduced the requirement of human effort to decrease energy consumption (Fawkes, 2001). With this came the demand for more specialist personnel to run energy management projects and organisations started to hire full-time Energy Managers/Engineers to meet this demand (University of Michigan, 2013). Over the years these technologies have continued to develop and the market now offers a wide range of solutions in the energy management space, everything from self-implemented energy monitors to energy management companies who will establish their own EMS's for third party consumers.

In this day and age, there is a heavy focus on climate change by worldwide organisations and governments alike. As renewable energy technology has developed, society is seeking to find a solution to this problem of rising energy costs whilst reducing the impacts that non-renewable energy sources have on our environment. However be it that fossil fuels still power majority of the network grid and that the generation/distribution model offered by our electricity provider is still one of the most cost efficient solutions to generate and distribute electricity, energy management can still have a significant impact of our society in producing energy efficient behaviours and reducing energy consumption.

Chapter 3: Literature Review

3.1 Chapter Overview

This section of the report will discuss pre-existing instances of energy management processes as well as how the concept is being both utilised and implemented within society. Climate change and rising energy costs have increased the demand for energy management processes and it is utilised across the residential, commercial and industrial energy markets. This section of the report will discuss instances and occurrences of energy management across these markets, covering a broad spectrum of energy management in generalised terms.

This literature review will also discuss two real-world case studies of energy management at a greater depth. The case studies discussed will demonstrate how consumers implemented their own EMS's and will provide the outcomes of their given processes. Each case study had their own energy management challenges and hence had their own EMS implementation.

3.2 Energy Management Scope

Energy management is designed to protect the climate, conserve resources and save consumers on energy costs (Wikipedia, 2015). The global energy market is a six trillion dollar per year industry and the generation of electrical energy can have adverse effects on our environment (Commerce Gov, 2015). Demand to reduce energy consumption in this day and age is prevalent across all types of consumers be it residential, commercial or industrial and each type of consumer has their own energy management challenges.

3.2.1 Residential Energy Management

One of the greatest challenges of energy management within the residential market is that emotion is generally tied to a person’s behaviours. With household budgets growing tighter, consumers are searching for more ways to reduce their general expenditures and one area within the household where people are looking to save money is through their electricity bill. Energy reduction can be realised through simply turning an appliance off. However, people generally justify why they utilise particular appliances which makes it difficult to persuade a consumer into reducing their consumption.

Within the marketplace, there is copious amounts of information available that gives a consumer better ideas on how to save on their energy costs. Research has proven that behavioural science can be utilised to assist in reducing energy consumption (Allcott, 2010). Opower is an industry leader in energy management having saved the average consumer within their customer base 2.5% on energy consumption (Wikipedia, 2015). This is achieved by analysing data from over 400 billion meter reads across 50 million energy consumers throughout the world (Opower, 2015).

Research lead Opower to prove that saving money, becoming energy conscious and reducing carbon emissions were not proven motivators in making people responsive to reducing their energy consumption. Instead, they began informing their customers of how their energy consumption compared to that of their neighbours, after which people began to respond to the energy management information that was delivered to them (Opower, 2015). It thus proves that human beings need to be nudged in the right direction rather than persuaded and that the right information holds the highest level of importance for motivating a consumer to take action toward reducing on their electricity bill (Allcott, 2010).

Opower's research and their energy information system (EIS) is not the only proven approach toward educating consumers about their energy consumption. The Queensland government utilised real time monitoring technologies to show residential consumer's how their energy consumption changed as they turned particular appliances off and on in their household's (Efergy, 2015). The Climate Smart Home Service scheme was a program that ran throughout the state of Queensland for four years and reduced 344,000 homes an average of $400 per household totalling to 3.173 GWh's. Similar results were delivered in Sabadell Spain, with in-home energy displays assisting in producing energy efficient behaviours and reducing the average consumer 14.3% in energy costs (Efergy, 2015). This program was delivered by Sabadell City Council and helps to prove the theory that more information can assist in reducing a consumer's energy consumption.

3.2.2 Commercial Energy Management

The commercial energy market is one of the greatest areas of potential for implementing energy management practices. On top of reducing carbon emissions, it makes logical sense to implement energy management processes from a business operations perspective. The University of Queensland (UQ) began researching possible ways to make their St. Lucia campus more energy efficient in 2010. This was heavily influenced by the Energy Efficiency Opportunities (EEO) program run by the Australian Government (Energy Efficiency Exchange, 2013). Through implementation of EMS's, employing campus staff and thoroughly planned retrofits, UQ predicted campus-wide savings of 20% with a payback period of two years (Energy Efficiency Exchange, 2013).

Energy reduction policies can also assist in motivating commercial building owners and operators to acquire an EMS. The National Australian Building Environmental Rating System (NABERS) accreditation sets a benchmark for the efficient operation of commercial buildings and also offers this type of consumer other possibilities of becoming more energy efficient (OEH, 2012). NABERS accreditation also encompasses the capabilities of acquiring an energy management/information system which assist's in the continual implementation of the energy management process. There are numerous opportunities within a commercial building to reduce energy consumption especially within the monitoring and optimisation of heating, ventilation and air-conditioning (HVAC) systems (Berkeley Lab, 2015). The implementation of EMS's are more financially viable in today's energy market and must be considered when constructing or re-fitting any type of commercial building.

3.2.3 Industrial Energy Management

As electrical infrastructure demand increases for the operation of a particular plant, so too does the cost of running such a plant. The historical rise of electricity prices in the early 1990's gave the industrial energy market within Australia a major incentive to start implementing energy management processes (The Warren Centre for Advanced Engineering, 2015). Development of automation technologies have proven vital in optimising the operation of industrial plants throughout the world. With the ever growing demand to reduce energy consumption, these same technologies can be utilised to better manage the energy consumption of a given industrial plant (The Warren Centre for Advanced Engineering, 2015).

Variable speed drive (VSD) technologies are a typical example of automating a process to optimise the energy efficiency of electrical infrastructure and eliminating the requirement of human effort. A VSD allows an electric motor to run at speeds slower than normal operating speeds. Lowering the operational speed by 20% can reduce energy running costs of an electric motor by 50% and this notion has been adopted by farmers in New South Wales to reduce the energy costs associated with the irrigation of a farm (NSW Farmers Association, 2013).

The industrial market has also utilised data analytics to manage energy consumption. Reducing energy consumption can be achieved through the energy management process by understanding how particular industries operate and where the potential for reductions can occur (Climate Works, 2013). The greatest inherent challenge with energy management in the industrial energy market is justifying reduction opportunities as most high energy consuming machinery is required for the correct operation of the plant. However industrial plants can operate within their correct means and still be energy efficient, as the potential for $1.2 billion of energy savings could be realised throughout industrial plant operations within Australia alone (Climate Works, 2013).

3.3 Case Study 1: University of California - Santa Barbara (UCSB)

3.3.1 Case Study 1 Overview

The University of California, Santa Barbara (UCSB) met the right criteria as a particular site that could part-take in an energy management process. The university had already proven to be proactive in energy management processes that were undertaken across the campus. On top of already having a full-time energy manager who was highly motivated in reducing the campuses carbon impacts on the environment, it also had a pre-existing EIS that they utilised for gathering energy data. Being so motivated to reduce their energy consumption, UCSB raised a sum of capital to invest funding into the energy monitoring infrastructure to expand upon their pre-existing EMS (Motegi, Piette, & Kinney, 2003).

3.3.2 Case Study 1 Incentive

One of the great advantages UCSB had in their favour to implement an EMS was their pre-existing energy management control system/energy information system (EMCS/EIS). It provided the base technological infrastructure to implement an EMS and allowed the university to capture a significant amount of data regarding the campuses energy consumption. This data would assist in providing vital information during the data analysis phase of the project. Be it that UCSB is a large university campus, a significant amount of data was required to be captured in order to perform a thorough analysis.

Many electricity consumers are unable to implement an EMS due to the fact that they do not have a full-time energy manager, one of the benefits UCSB had in their favour. It was their responsibility to run the energy management project, analyse the incoming data with the assistance of other campus staff and implement control measures to reduce energy consumption. Energy management is still a developing concept and specialists in the area can prove difficult to employ. UCSB's energy manager displayed enthusiastic behaviour toward energy management at the campus which is a great advantage to the university or any organisation undertaking any form of energy management project (Motegi, Piette, & Kinney, 2003).

3.3.3 UCSB Monitoring System

UCSB had a great deal of pre-existing energy management infrastructure prior to developing their tailored EMS. Figure 3.1 (Motegi, Piette & Kinney, 2003) displays a diagram of the overall energy monitoring and controlling infrastructure at UCSB.

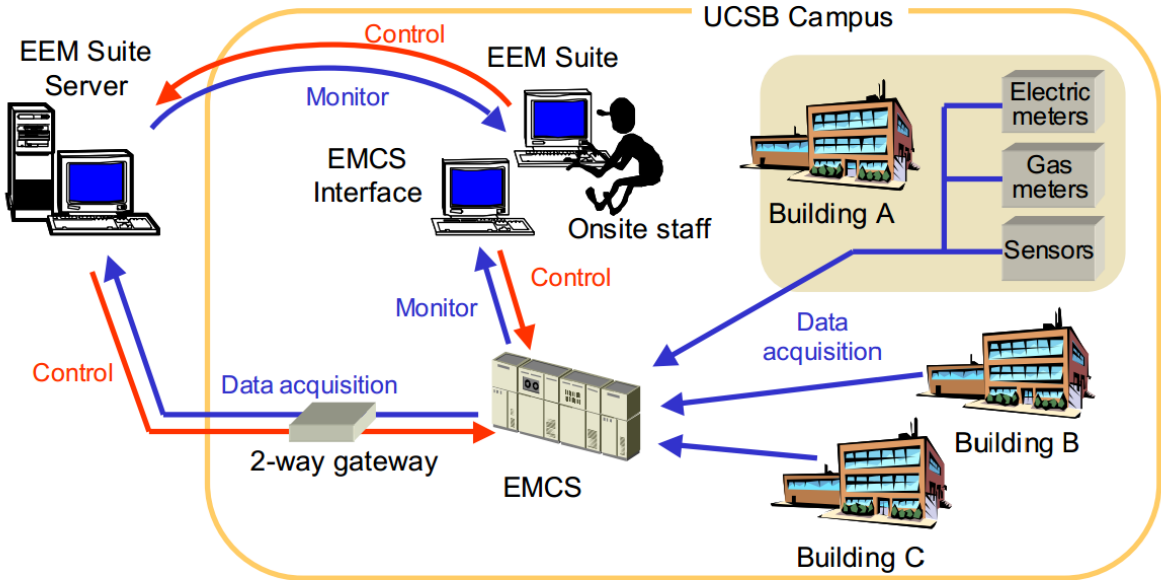


Figure 3.1: EMS Diagram for UCSB Campus (Motegi, Piette, & Kinney, 2003)

The EMCS was the central unit for the existing EIS. All measuring instrumentation (electricity meters, gas meters and sensors) within each building communicated back to the EMCS where the energy data was captured. Once at the EMCS, the data was displayed through computers/servers utilised by campus staff to analyse and review all of the energy data. Certain electrical infrastructure could also be controlled from the computers/servers (Motegi, Piette, & Kinney, 2003).

Along with the already existing technologies at the campus, the university added 30 electricity meters and 20 gas meters to the system in order to capture more data regarding their energy consumption. Also added onto the EMS were additional computer systems with monitoring software and licencing fees. Extending the EMS monitoring system cost UCSB approximately $341,000 in capital expenditure, $226,000 of which was provided by public funding (Motegi, Piette, & Kinney, 2003). The additional monitoring infrastructure captured more information on energy consumption within the UCSB campus which would become highly important during the data analysis phase of the process.

3.3.4 UCSB Data Analysis Process

UCSB had a full-time team of employees that were responsible for the energy management of the university campus. The staff consisted of, but were not limited to, the following personnel:

- One energy manager
- One facility manager
- Several zone managers

The energy manager, along with the assistance of the facility manager, are responsible for running the energy management process at the UCSB campus. They utilised the EIS and EMCS on a regular basis to optimise the efficient running of the site campus. Once the energy data has been analysed, the energy manager can then delegate specific energy management responsibilities to the zone managers. The zone managers are responsible for system operations and troubleshooting of their buildings within their specific zones (Motegi, Piette, & Kinney, 2003).

Although there were numerous staff involved in the operations and maintenance of the campus, the energy manager was solely responsible for the data analysis portion of the energy management process. He would spend at least 30 minutes per day analysing energy data captured by the EMCS. This time would be extended when control measures were put into place to find if they were reducing energy (Motegi, Piette, & Kinney, 2003).

Essentially the energy manager utilised summaries of data created by the software to identify where within the campus the energy was being consumed. He was then able to cross-correlate data between buildings to clearly identify why some buildings were consuming more energy than others. The software also provided data on energy consumption on an hourly, daily, weekly and monthly basis, shorter time frames with which to test control measures against rather than waiting for the next electricity bill.

3.3.5 UCSB Control Measures

Control measures that were executed at UCSB included, but were not limited to:

1. Reduction of physical science building fan runtime
2. Reduction of chemistry building fume hood runtime

Reducing the fan runtime in the physical science building began soon after the EMS was implemented at the UCSB campus. The energy manager became pro-active in implementing control measures to reduce energy consumption. After analysing the data captured regarding the energy consumption in the physical science building, it was found that the exhaust fan system, totalling 262 kW, was running 24 hours a day at 100% load, even though the building was unoccupied at night.

Under normal circumstances, the runtime of the exhaust fan system would already be controlled by a setback system. However the setback system was disabled by building staff to ensure sufficient air quality throughout the building. This presented the energy manager with one of the significant challenges of energy management, which is to implement control measures that do not compromise on the correct operation of the building.

After consulting the building staff, the energy manager convinced the staff to run the fans at 50% between the hours of 12am to 7am. As a result, UCSB saved $92 per day in energy consumption, all within a few short months of undertaking the energy management process. The air quality was still sufficient within the building so reducing the load to 50% was one strategy that reduced energy consumption.

Reducing the fume hood operation time in the chemistry building took place after the energy manager found they were left open every night. He asked students to close the fume hoods whenever it was feasible. It resulted in a slight reduction in energy consumption however it is a control measure that requires on-going human effort and can be easily forgotten due to simple energy management complacency.

These two control measures that were applied at UCSB provide very important insight into the feasibility of energy management. With VSD and automation technologies, reducing the fan speed is a relatively simple control measure to execute. The facility manager just has to set the values into the system and energy is reduced with minimal on-going human effort required. However the fume hood is a different control measure, where every day, students are to remain pro-active in closing the fume hoods in order to reduce energy. This can easily be forgotten due to simple complacency and is proof that not every control measure is going to be simple to execute or even prove successful in reducing consumption.

3.3.6 Results from the UCSB EMS Project

UCSB recorded electricity cost savings of $430,000 in general consumption and $160,000 in demand costs. From all of the data analysis performed at the UCSB campus, the energy manager was able to provide valuable insight that 50% of energy savings came from optimising the operation of electrical infrastructure within the building. This could be implemented due to the information provided by the EIS. The total savings that were attributable to the EIS within the first year was $295,000, which meant there was a payback period of 1.2 years (Motegi, Piette, & Kinney, 2003).

These savings were realised through control measure strategies such as those listed in section 3.3.5, thoroughly planned retrofits and installation of energy efficient lighting. From constant data analysis, the energy manager was able to focus on key areas where energy could be saved and as a result, it reduced energy consumption costs by 10.8% in 12 months. This is the typical result of a successful EMS and thus proves both the importance and viability of the monitoring, analysis and controlling process.

3.4 Case Study 2: Sysco Corporation

3.4.1 Case Study 2 Overview

Case study 2 was an energy management project that was undertaken by Sysco Corporation throughout the United States of America and Canada. Sysco are a multi-national marketing and food distribution corporation. They were able to part-take in the energy management process due to the fact they had people involved who were highly engaged with energy data and in energy management, they were aggressive toward energy reductions and high-efficiency performance and they were willing to participate in 3-4 hours of site visits (specific site would be chosen at the time) and interviews, opening the door to the thorough communication that an EMS requires when different parties are involved (Granderson, Piette, & Ghatikar, 2010).

3.4.2 Case Study 2 Incentive

Sysco set themselves a company-wide target of a 25% energy reduction across 143 of their distribution sites. As well as making the business more profitable, the energy reduction strategies across all of the sites gave Sysco a positive company image with the general public. It was heavily assisted from a technical perspective by a third party engineering firm with whom they already had a services contract.

Site visits were conducted by the engineering firm with assistance from Sysco employees in the initial stages of the energy management project. The EIS was then tailored for the specific energy reduction targets that Sysco were trying to reach. All of this action was followed by constant on-going communication between Sysco management, the engineering firm's engineers and the elected Sysco on-site energy champions. This re-iterates one of the most important aspects of energy management - that it is an on-going process with a high-level of commitment required by all parties involved in order to achieve positive results.

3.4.3 Sysco Monitoring System

Energy data from Sysco sites is captured via pulse outputs from electricity utility meters and is captured in a central database. The engineering firm has the ability to upload data to a server regarding Sysco's energy consumption to keep track of whether or not the goals are being met. Sysco's site EIS has reporting capabilities which also assist the Sysco employees during the analysis phase of the energy management process. The Sysco monitoring system was simpler to implement and more affordable to acquire due to the fact they required less monitoring hardware invested in the early stages of the energy management process. Be it that they had 143 sites to analyse, the engineering firm along with Sysco management decided it would be more beneficial to invest a small amount of funding across a large number of sites.

3.4.4 Sysco Analysis Process

Data analysis for the Sysco sites is performed by a combination of both Sysco staff and the corporation's third party engineering contracting firm. Each site has an energy champion who is responsible for the energy consumption of that given Sysco outlet. This employee is able to acquire and analyse the data and then liaise with the engineering firm and Sysco management in order put forward the best plan to optimise energy efficiency throughout the Sysco site.

This differs from the analysis process implemented in case study one. The energy management process that was undertaken at the University of California Santa Barbara campus had a much larger site with many more variables present. Analysing data across the Sysco sites was a shorter process, leading to the implementation of control measures in a shorter time frame. A second advantage Sysco Corporation had in their favour was that they had 143 distribution sites all holding similar electrical infrastructure. This meant that a control measure implemented at one site could be implemented across most sites, allowing for scalable reductions across the entire company.

3.4.5 Sysco Control Measures

When deciding on the best course of action to take to reduce energy consumption, Sysco focused heavily on their refrigeration units that held the stock that was sold to customers. Staff found that the stock was able to tolerate temperature changes within a specific range for a certain period of time. The company believed it viable for the energy champion to spend their mornings adjusting these temperature settings to reduce refrigeration costs. An important aspect to consider regarding this control measure was the extra overhead it could potentially place on the operation of the company. Although there was potential for reductions, this control measure required human effort which may take employees away from other operations within the business. However, be it that refrigeration was such a dramatic cost in electricity toward the running of the business, they believed it viable to utilise company staff to implement such a control measure.

The energy champion also focused on unexplained spikes that would assist in reducing the overall demand of the buildings. Energy spikes do not consume a large amount of energy. However depending on the arrangement between the site consumer and their energy provider, these spikes can cause major inefficiencies and also increase demand on the network grid.

Sysco believed it to be viable to investigate such spikes in an attempt to find what electrical infrastructure was causing such a problem.

3.4.6 Results from the Sysco EMS Project

Adjusting the temperature of the refrigeration units assisted in reducing Sysco Corporations energy consumption. The effort the energy champion at each site went through to adjust the temperature settings was worth it as it reduced energy costs significantly throughout numerous Sysco sites. There was one time period where one particular energy champion was on holidays and that specific site increased their energy consumption back to the point it was at before the refrigeration control measure was implemented. Accounting for the spikes also allowed for other energy reductions and increased site efficiency with Sysco seeing energy reductions of 35%.

Without taking the effort to implement an EMS, Sysco would have continued to waste electricity, placing larger costs on the running of their business. A company such as Sysco can take particular strategies utilised at one store and use those same strategies throughout other stores. This goes a long way in not only making the Sysco business more viable but also building a positive company image with the general public. Until such a day arrives that all energy can be run off renewable sources, utilising human effort to reduce energy consumption can go a long way in reducing societies energy demand.

3.5 Methodology Incentive

3.5.1 Financial Benefit

The case studies of UCSB and Sysco Corporation are large scale projects that require significant capital in order to be economically viable. Funding for this type of venture is justified as the amount of energy (and hence money) saved is scalable and makes the long-term running of the sites and buildings more efficient. However on a smaller scale, it is difficult for a home or small business owner to justify investing funding into an EMS. The costs and time involved in implementing an EMS make it less viable to perform the energy management process at a standard consumer level. However as this is a research project and all componentry is a low end cost, there is no financial risk from a consumer perspective to invest a small amount of time and resources into an EMS.

3.5.2 Process Implementation Comparison

As this research project is a smaller scale energy management project, the way in which the process is implemented differs significantly from the UCSB and Sysco Corporation case studies. Although it still follows the standard monitor, analyse and control paradigm, the way in which the project was implemented varies significantly.

UCSB and Sysco invested significant funding into monitoring hardware to ensure there was a large amount of energy data captured. This funding came from third party investors as well as income that was generated internally by the organisations themselves. Although they were investing funding back into an EMS, it was justified to make their organisations more energy efficient. A significant difference between the methodology and the above mentioned case studies was the amount of monitoring hardware that was acquired for the project. A major incentive for this research project was the overall aim of doing more with less and it begins with the acquisition of monitoring equipment.

A reduction in monitoring hardware meant that the data analysis phase had to be more robust and efficient. UCSB and Sysco had a full-time team of staff whom were fully or partially responsible for the energy analysis portion of the energy management process. This is less viable in a low-end cost consumer market. Small businesses and home owners do not have within their site or premises the same potential or scalability for savings that make it justifiable to hire an energy manager to spend time analysing their energy data. The energy manager at UCSB spent a great deal of time (at least a half an hour each day) analysing energy data which can easily increase the overheads of the business.

The analysis phase of the methodology will explore the information that consumers respond to that can be potentially compiled through an automated system utilising computer technology. Once there is modularity to the information and it is beneficial to the consumer, it can be easily duplicated and distributed in an efficient manner with less time spent reading energy data. This projects scalability is a smaller margin so it has to be performed more efficiently time-wise than a larger scale project such as the UCSB and Sysco Corporation's energy management projects.

Controlling strategies also need to be taken into account when comparing this projects methodology to the control strategies implemented by both UCSB and Sysco Corporation.

Every business or household run differently and different consumers utilise their electricity in different manners. The energy controlling strategies in the methodology are going to differ to that of a large corporation as how and when they consume their electricity is going to differ significantly. However the basic human behaviour principle still exists in that people can take better control of their energy consumption if they are equipped with the right information.

3.5.3 Methodology and Case Study Similarities

Although there are significant differences in the way the methodology and case studies are implemented, there are also similarities between any large and small scale energy management processes. The major incentive for any energy management process is that be it a small or large building, from an end user perspective, electricity bills are still unequipped with vital information to help consumers understand where their energy is being consumed. The reason a site consumer invests time and funding into an EMS is that they are wanting to find out more information regarding their energy consumption so they can find ways to reduce energy over the long-term.

The basic principles and motivations of energy management hold true across both the methodology and the literature review of this project. It is a growing concern for home and business owners alike that electricity prices have risen significantly in recent years and are continuing to do so as time goes by. They are a financial strain on any household or business and any reduction is a saving in both money and carbon emissions, even if it is only a relatively small saving. It is becoming increasingly important to understand electricity consumption and that is the same for any consumer be it a university, a large food corporation, a small business or even a common household.

Chapter 4: Project Methodology

4.1 Chapter Overview

This section will discuss the practical assessment that was undertaken throughout the research project. It will follow the standard monitor, analyse and control process of an EMS. The process will be tailored to the needs and demands of the energy consumer's premises' where the EMS was implemented.

4.2 Planning

Two test sites were utilised to facilitate the EMS process for the methodology. Test site number one was a seven day a week business whose operating hours were from 7:00am to 5:00pm. The business has a cafe and also sells grocery items which make up the combination of their main line of business. Electricity is a significant overhead for the business with energy consumption being one of the biggest expenditures toward the running of the business only second to wages. An agreement was put in place with the site consumer to conduct research at the premises to allow for sufficient information gathering as required.

Test site number two was a standard three bedroom household owned and occupied by a family of four (two adults and two children). This site was chosen due to the fact that the home owner's energy consumption was approximately three times more than that of the Queensland state average. Electricity is a large cost to the family of four and the consumers were highly motivated to investigate possible methods to reduce their energy consumption.

4.3 Consumer Motivation

The owners of the two consumer test sites were chosen due to the fact that they were motivated to take action toward reducing their energy costs. Both consumers indicated that they wished to know more about their consumption and explore the possible avenues for reducing their energy costs but were willing to do this through an energy management process. They were willing to undertake the learning procedures involved with energy management which made them ideal candidates for this research project.

4.3.1 Information Incentive

Without being equipped with the right information it is extremely difficult for a consumer to understand why their electricity is so high and how this consumption can be reduced upon. Ergon Energy, the electricity network provider for regional Queensland, do provide their consumers with energy reducing information to assist them in adopting energy efficient behaviours through television advertising, delivery of pamphlets in the mail and also on their company website. However whether this information is received and understood is questionable as both consumers who undertook this project EMS had at some stage in the past taken it upon themselves to contact their provider to try and understand why their electricity bills were so high and how it could be reduced upon. The extra information the consumers were to receive from the process would be beneficial for making better informed and justified decisions toward their energy consumption.

4.3.2 Financial Incentive

The obvious reason any consumer would part-take in an energy management process would be for financial benefit. However this financial benefit cannot be reached without first understanding how energy is being consumed within a premises. Numerous small businesses and households alike in today's world run on very tight budgets and for some people, even the smallest of savings can go a long way in assisting consumers live better lives. It is this financial incentive that can help motivate a consumer to part-take in an energy management process and implement actionsin that will assist reducing their energy consumption. The other significant aspect of this energy management process is that there was the inherent opportunity to assist consumers in reducing on their energy costs without having to invest up-front capital costs by either purchasing new equipment or investing in alternate sources of energy such as solar power.

4.3.3 Societies Benefits

Although it is not the greatest motivator, one of the adverse effects of energy management is that it allows participants to become a better citizen within our society. All of the energy saved also reduces society's carbon emissions and this is achieved through human behavioural changes. Energy management industry leaders Opower had predicted savings in 2013 of approximately two terawatt-hours which equates to approximately half of the United States solar industry (Opower, 2013). This goes to prove the scalable effects that energy management can have in creating a more energy efficient society. By contributing toward reducing on their electricity bill, a citizen is also helping to reduce carbon impacts on the world.

4.4 Acquisition of Monitoring Equipment

Acquiring the correct monitoring equipment for this research project presented two major challenges. The equipment had to gather sufficient data in order to conduct a thorough analysis whilst ensuring the project would remain economically viable. In the early stages of the project, and being that this project was self-funded, time was dedicated to testing the monitoring hardware to ensure it would perform to a specific standard for the purposes of this project.

After researching different types of energy monitoring technologies, the monitoring equipment chosen for this project was the Efergy Engage Hub Kit pictured in figure 4.1. The Engage Hub Kit was utilised across both test sites. At a retail cost of $199.95 including batteries, the Engage Hub Kit has no on-going maintenance costs or subscription fees, making it an affordable solution for the purposes of this research project.

Figure 4.1: Efergy Engage Hub Kit (Santarossa, 2015)

As well as being a low cost solution for gathering energy data, the Efergy Engage Hub Kit was also chosen for the following criteria:

1. Real-time feedback capabilities
2. Energy data logging with a one minute resolution
3. Hourly, daily and monthly data logging
4. Data download capabilities for MATLAB integration
5. Simple installation with no interference of wiring required

There are three separate components of the Engage Hub Kit. These have been split into electrical, communication and software to further explain the operation of the product.

4.4.1 Electrical Component

Data captured by the Engage Hub Kit is displayed numerically in units of either power, energy or cost. This data is captured by utilising the following mathematical equations:

$$\text{Energy (kWh)} = \text{Power} * \text{Time} \quad (1)$$

$$\text{Power (kW)} = \text{Voltage} * \text{Current} \quad (2)$$

The time is constantly monitored by a computer system and is multiplied to the power input from the kit in order to calculate the value for energy. Equation (2) is calculated from a constant value and a variable value. Current varies between consumer sites and is measured from the current transformers (CT's) pictured on the right-hand side of figure 4.1.

The CT's are clamped around the mains cable (where the mains are 25mm^2 or less in cross-sectional area size) with the tails plugged into a transmitter pictured on the left-hand side of figure 4.1. Installation of the engage hub kit will be explained further in section 4.4.4.

Voltage is considered a constant (240V Australian Standard) and is a programmed value within the software platform. This presents an accuracy issue. Although 240V is the Australian standard, the legal requirement for voltage supply in Australia allows for a 5% buffer that means the supply voltage at a particular site or premises can vary between 228V and 252V. For the purposes of this research project, a 5% error margin is considered feasible to account for without having to acquire more expensive and accurate monitoring hardware. The data captured by the Engage Hub Kit can also be calibrated during the analysis phase by comparing its data to the data captured by the electricity provider.

4.4.2 Communication System

Similar to any EMS, the Engage Hub Kit has its own communication system that binds all of the hardware together to ensure the data reaches the end user in an efficient manner. As well as supplying products that have data logging capabilities, Efergy also manufacture products with real-time feedback where the data is transmitted directly to an in-home energy display monitor. However the benefits of historical allow for better information correlation as well as graphical analysis and comparison. There is much more versatility in gathering historical data but in order to do so, a robust and efficient system must be implemented in order to ensure that quality data is being gathered.

The tail end of the communication system is in the mains switchboard of the site or premises being monitored. A battery powered transmitter is located in this switchboard and gathers the current consumption data measured from the CT's. Sometimes this componentry can be placed in a sub-distribution board if the mains switchboard is physically too far from the premises being monitored. Obstacles and distance can be another issue that may need accounting for as the transmitter must communicate to another Engage Hub Kit component known as the hub.

The hub, which is pictured in the centre of figure 4.1, is the central component of the EMS. All of data gathered by the transmitter is transmitted to the hub at 433MHz in either 6, 12 or 18 second intervals. This wireless transmission is what can cause communication problems. Ideally the hub and the transmitter should be no more than 50 metres apart from each other with minimal obstacles for clear transmission. Low quality batteries in the transmitter can also cause communication problems so these are all important considerations when performing installation of the Engage Hub Kit. If a quality installation is not performed, parts of data can be missed and this can be critical from a data analysis perspective. Fortunately for this research project, both test sites did not have any major distance or obstacle issues which made for quality data transmission between the transmitter and the hub.

Once the data has reached the Engage Hub Kit, it is required to get stored in a central database so all of the data can be logged and transferred as required. This data transfer is done via the hub. The hub is connected to the local area network (LAN) via an Ethernet cable. The LAN of a monitored site usually comes in the form of a standard internet router and is the gateway for the hub to transmit its data to a central database. Each individual hub stores its data into the database where it can either be downloaded by individual users or utilised by software developers to create platforms to neatly display the data. Although there are added complexities in transmitting data in such a manner rather than just offering real-time feedback through a display monitor, all of this historical data can offer much more versatility in the types of data that can be delivered to a consumer. A visual representation of the overall communication system can be found below in figure 4.2 of this report.

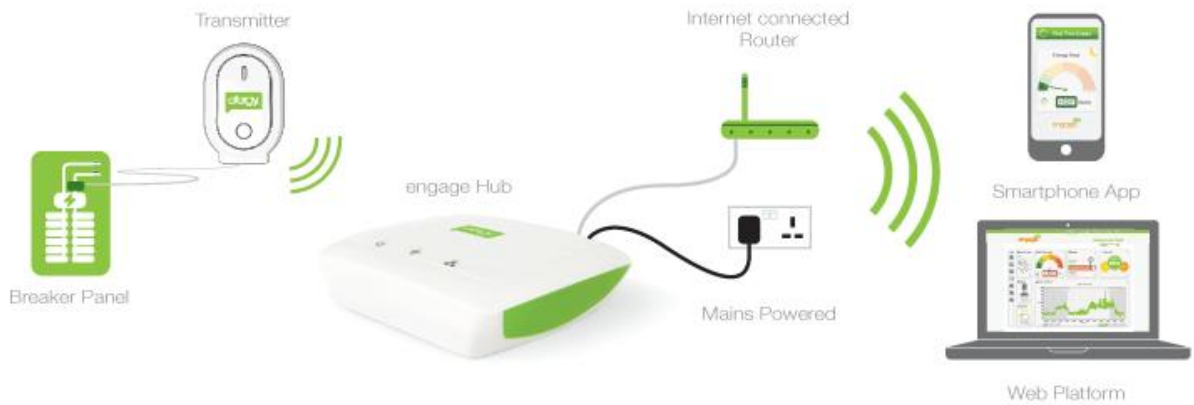


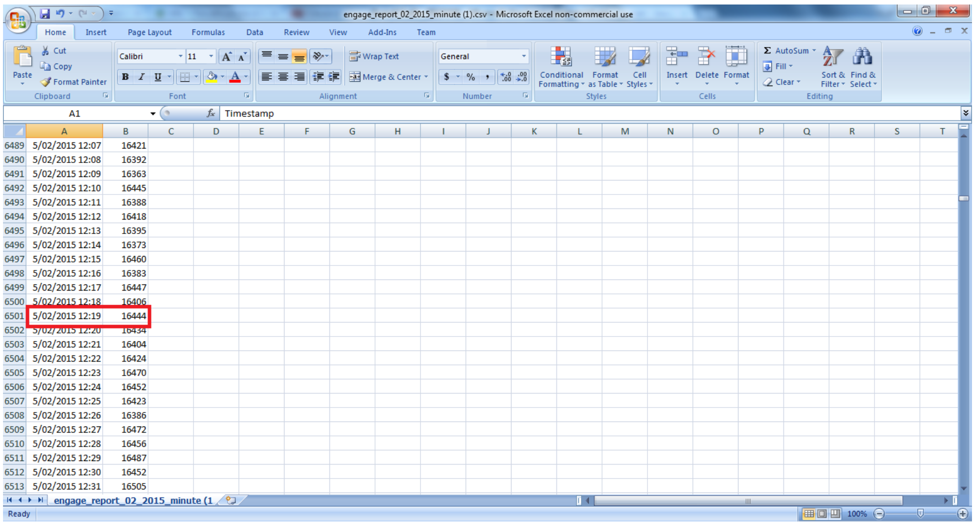
Figure 4.2: Engage Hub Kit Communication System (Efergy, 2015)

4.4.3 Software Platform

All of the data transmitted from the hub is captured in Efergy's databases which can be privately accessed by an individual user. Each hub is identified to the user by a Mac Address, which is a unique tag for each individual hub. The data is then compiled through Efergy's software platform to display the relevant information regarding energy consumption of the given premises. The typical engage software platform is displayed below in figure 4.3 (Efergy 2015).

Figure 4.3: Efergy's Software Platform (Efergy, 2015)

The software platform provides limited information for the consumer and was not the main focus for the data analysis phase of the energy management process. The important feature of the engage platform was the reporting tool. This allowed .csv files to be downloaded which could be then copied into an excel spreadsheet for further analysis. Figure 4.4 displays an example of the downloadable .csv file with an average kW value for a one minute period and a corresponding timestamp.



	A	B
6489	5/02/2015 12:07	16421
6490	5/02/2015 12:08	16392
6491	5/02/2015 12:09	16363
6492	5/02/2015 12:10	16445
6493	5/02/2015 12:11	16388
6494	5/02/2015 12:12	16418
6495	5/02/2015 12:13	16395
6496	5/02/2015 12:14	16373
6497	5/02/2015 12:15	16460
6498	5/02/2015 12:16	16383
6499	5/02/2015 12:17	16447
6500	5/02/2015 12:18	16406
6501	5/02/2015 12:19	16444
6502	5/02/2015 12:20	16434
6503	5/02/2015 12:21	16404
6504	5/02/2015 12:22	16424
6505	5/02/2015 12:23	16470
6506	5/02/2015 12:24	16452
6507	5/02/2015 12:25	16423
6508	5/02/2015 12:26	16386
6509	5/02/2015 12:27	16472
6510	5/02/2015 12:28	16456
6511	5/02/2015 12:29	16487
6512	5/02/2015 12:30	16452
6513	5/02/2015 12:31	16505

Figure 4.4: Downloadable Report (Efergy, 2015)

4.4.4 Monitoring Equipment Installation

The monitoring equipment acquired for this project was required to be installed onto both test sites. Part of the installation process required working around live electrical conductors. For this reason the installation was performed by a licenced and qualified electrical tradesperson with the assistance of a safety observer and the correct personal protective equipment (PPE). The following is a list of the qualifications required in order to perform the installation.

- Certificate III in Electrotechnology (QLD Electrical Licence, Tradesperson only)
- CPR/LVR Training

Figure 4.5 displays the hierarchy of controls when undertaking a risk assessment regarding a given job or task.

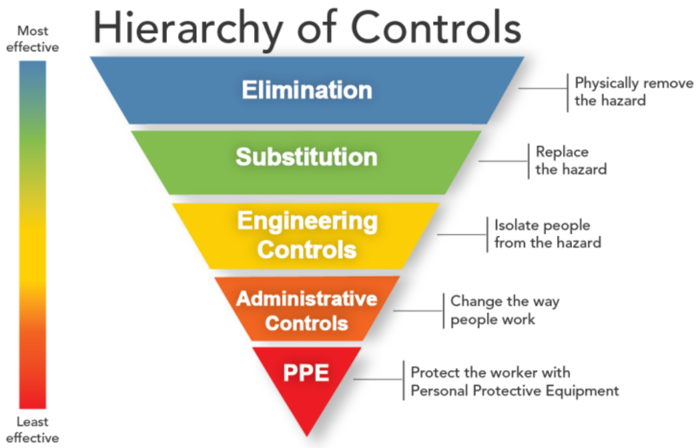


Figure 4.5: Hierarchy of Controls (CDC, 2014)

Installation had to be performed during business operational hours and as a result, isolation of electrical equipment was not feasible for the given procedure. However with the correct safety pre-cautions in place and after a thorough assessment of all potential risks and hazards associated with performing such tasks, it was deemed safe to perform the installation as long as all safety measures were accounted for. A full copy of the job hazard analysis (JHA) can be found in Appendix C of this report.

4.5 Data Analytics Process

Modern technology has allowed for a more efficient and robust means of capturing energy data. For the purposes of this project, a computer software program was utilised to efficiently analyse all of the captured data from the Engage Hub Kit. The data could be analysed through custom built code via a software program in order to compile and correlate the energy data into a tailored format for a regular energy consumer to be able to understand. The program chosen to analyse the data was MATLAB, a high level technical computing language which is utilised mainly by university students throughout the world for engineering coursework. It has a high level of functionality however it was mainly chosen for its ability to read data from an excel spreadsheet and output data in a neat and efficient manner.

The main goal of the data analysis process is to present the data in such a manner that it is easily understood by a regular energy consumer. A full-time energy manager will be able to understand different levels of energy information compared to that of a standard consumer. This is why the data analysis phase for this project has such a high level of importance placed upon it. The data needs to be presented back to the end client in a user friendly manner so they can make the best possible decisions in reducing their energy costs.

The data that is logged in the downloadable .csv file, such as that displayed in figure 4.3, is the average power consumption of the given site or premises over a one minute interval for every minute of a given month. For a standard 30 day month, there are 43200 data points to consider for analysis, 44640 for a 31 day month and 40320 for the month of February. It is the ability to re-structure this data by utilising the MATLAB software platform that allows information to be compiled into such a format that is beneficial for a standard electricity consumer to evidently show areas where electricity is being consumed, how they can save money or if the consumer's behavioural changes are having a positive effect. The type of data displayed to the consumer as well as how this data is beneficial to a consumer will be explained further in section 4.7 of this report.

4.6 Control Measures

The report delivered to the consumer had within it further information on energy consumption which opened discussion for potential control measures and areas for savings. Referring back to the basic principles of energy management, energy reducing strategies cannot be implemented if they compromise on the correct operation of a home or business. Examples of this might be an electric deep fryer that consumes a large amount of energy but may turn over a large amount of inventory cooking food such as fish and chips that are sold to the customer. Although it consumes a high amount of energy, the cost is justified in the sale of the food items cooked within it. Another example is turning the air conditioners down or even off which may compromise on the comfort of the customer experience and could potentially turn away more business.

All potential control measures discussed with the business and home owners were only general recommendations based on the information presented. The site consumers were ultimately responsible for implementing the controls measures recommended from the reporting portion of the process. This may differ from other EMS's where a third party consultant may be responsible for both analysing data and implementing control measures.

4.7 Report System

4.7.1 Report Content

Daily operations within a small business differ from that of a standard household. The type of data a household consumer may find beneficial can differ significantly from the information required by a small business owner. The difficulty in the reporting section of the energy management process is ensuring the data is transparent so that a regular consumer can understand it. In order to be able to implement justified control measures, the consumer must be able to firstly understand areas where they can potentially save themselves energy without compensating on the standard operations of the business or household. The purpose of the report is to make these potential areas evident and teach the consumer more about their energy consumption than what they already know.

Another consideration that must be taken into account during the reporting phase is the time frame that the report is to be delivered back to the consumer. For the purposes of this research project, information regarding the energy consumption had to be presented in a short enough time frame so that the consumer could remain pro-active toward their energy management process and find out whether or not the control measures implemented were viable whilst not becoming too great a distraction from other important aspects of their business or general lifestyle. For this reason, the reporting system went through a number of iterations throughout the course of the project to ensure the consumer was benefitting from the information that was presented to them.

The iterations of the report also meant that the original content that was delivered to the consumer differed significantly to the content that is required in an on-going report. There were two major causes for the continual change in content within the report. Reason number one involved the amount of time that a standard electricity consumer has to consider learning more about their electricity bill. Day-to-day operations make it difficult for a home or business owner to spend time researching how they can potentially reduce the cost of their electricity.

This idealism also holds true within a household, with many general consumers leading very busy lifestyles with work, household chores and leisure on the weekends that allowing time to spare learning more about their electricity consumption is often scarce. For this reason, the content delivered had to resonate with the consumer with very little explanation to ensure the time invested in learning more about their electricity bill was justified.

Reason number two for the iteration of the content came from the on-going learning process involving both the consumer and the content provider. As time went on throughout the research project, both the site consumer and content provider learnt more about the sites' energy consumption. This meant that new ideas arose as to how to gather and deliver more information. It also meant that the content became more of a comparative tool, with the site consumer being able to see whether or not improvements were made. Comparative information allows a consumer to ultimately see whether or not their efforts are rewarded by evidently displaying the results from the control measures implemented.

The report content included a combination of the following criteria for both the small business and the household:

1. Generalised trend consumptions
2. Daily consumption vs. night-time consumption
3. Base load consumption
4. Monthly comparison
5. Hourly breakdown per month

These will each be explained further in order to discuss how this information was compiled and what the benefit is of knowing this information from a consumer perspective.

4.7.2 Generalised Trend Consumptions

In the beginning of the energy management project, the data delivered to the consumer was more generalised than comparative. Displaying general data trends to an end consumer allowed them to conceptualise how particular appliances were contributing toward their electricity bill. In order for a consumer to understand how to save money on an electricity bill, they must first familiarise themselves with how they are currently consuming their electricity. The kilowatt-hour (kWh) is the amount of power consumed over a one hour time period. If a consumer is able to familiarise themselves with this concept, they can better focus their time and energy in particular areas to save energy.

For example, a kettle is a high powered appliance that if boiled twice a day consumes approximately 12kWh's over the course of one billing period (Santarossa, 2015). This equates to a cost of approximately $4 (based on Queensland electricity prices) and is the equivalent of running one standard three blade ceiling fan for approximately 200 hours. Explaining how energy is consumed by utilising visual aids is designed to change the thinking of the consumer and to eliminate any assumptions or pre-conceived notions they have regarding their energy consumption. It gives a consumer knowledge they may not have otherwise possessed, all of which is required to assist them in reducing energy consumption.

4.7.3 Daily Consumption vs. Night Time Consumption

Comparing daily and night time energy consumption was one of the first pieces of information within the energy data report. Sampled data was taken from the hours of 6:00am-6:00pm for daily consumption and 6:00pm-6:00am for night time consumption. This information allows a consumer to better understand where their electricity is being utilised. From a household perspective, especially when there is both school and work to attend to, it allows the consumer to quantify the amount of energy utilised during the day when the house is unoccupied versus the amount of energy utilised during the evening upon the arrival home of all occupants. This information is also strongly beneficial to a small business owner as well. A small business owner is able to quantify the amount of energy it takes to run the business even when the doors are not open compared to the time when the business is fully operational.

4.7.4 Base Load Calculation

The base load calculation is the amount of energy utilised by an energy consumer when their site or premises is unoccupied. It is found from taking a sample of data (at least 6-8 hours in time) where the premises is unoccupied, calculating the total consumption and then scaling that figure out to one billing period. The benefit of understanding the percentile of base load consumption is that it clearly identifies what the essential items within the premises are costing as a percentage against all other appliances. It also indicates what the site or premises is consuming in energy before running other appliances in a household (e.g. lights, cooking equipment, air conditioning etc.).

Although this appears to be accounted for by the daily vs. night time consumption, there is a slight difference with the data that is unaccounted for within the household. The operation hours of the small business are 7:00am - 5:00pm with staff arriving no earlier than 6:30am to begin their shifts. Be it that between the hours of 6:00pm - 6:00am the business premises is unoccupied, the base load can easily be calculated from the night time consumption and then be scaled out to the one month billing period in which the business gets charged for their energy consumption.

However the occupants of the three bedroom household vacate the premises at approximately 8:00am and then arrive back at approximately 5:00pm on a regular day, meaning there is still energy usage other than base load during those day time hours. This means that the household base load had to be measured at a time when the house was actually unoccupied.

4.7.5 Monthly Comparisons

The monthly comparisons provided a visual aid for the consumer to see if changing their habits improved their energy consumption. Utilised as a comparative tool, this data came in the form of a standard bar graph encompassed with numerical figures such as that displayed in figure 4.6. Monthly comparsion data is simple to implement and provides excellent assistance in analysing the progress of the energy management process.

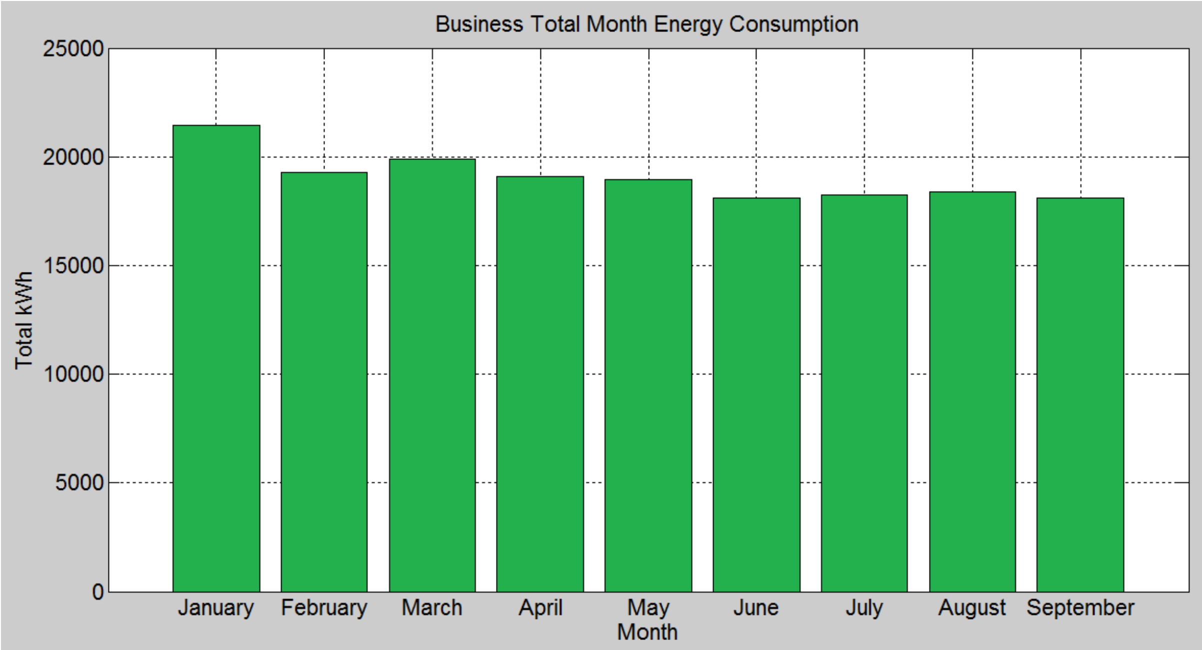


Figure 4.6: Monthly Comparison Example (Santarossa, 2015)

4.7.6 Hourly Breakdown per Month

This data is a table that displays the total energy consumption over each one hour time period for every day of a given month. The table has 24 columns, one for each hour of the day and either 28, 30 or 31 rows for each day of the month.

Comparing each hour of the day allows a standard consumer to see significant differences for given hours on specific days. It is designed to get a consumer considering what could possibly be causing the changes and how they can possibly alter it. For example, it was found that the small business can potentially have a 20kWh difference in energy operations between the hours of 6:00am - 7:00am on any given day. This can cost up to $3.00 for that time period alone which scaled can potentially lead to greater energy saving's.

Chapter 5: Results

5.1 Chapter Overview

This chapter will present the results of the methodology. It will quantify the energy consumption for the test sites over given time frames that will ultimately highlight whether or not the energy management process was beneficial in reducing energy consumption.

5.2 Results Structure

Once the data was analysed, the results that were delivered to the consumers were displayed using both graphical tools and numerical values. The energy management process began in January and ran over a nine month period during the 2015 calendar year. It was important that the information was transparent so a standard consumer could understand how they were utilising their electricity, why their energy consumption was so high and how they could possibly alter their behaviours to reduce consumption. This was also followed up with progress reports that highlighted whether or not any changes in behaviour were actually reducing energy consumption.

5.3 Energy Consumption Results (Business)

5.3.1 Energy Monitoring Results (Business)

Since the energy management process began in January 2015, it was found that there were minor reductions in energy consumption within the business test site. Figure 5.1 displays the monthly energy consumption for the business consumer that was compiled from the data captured by the energy monitor. Figure 5.2 displays the average daily consumption for the business over the given month. These results are also tabulated numerically in table 5.1.

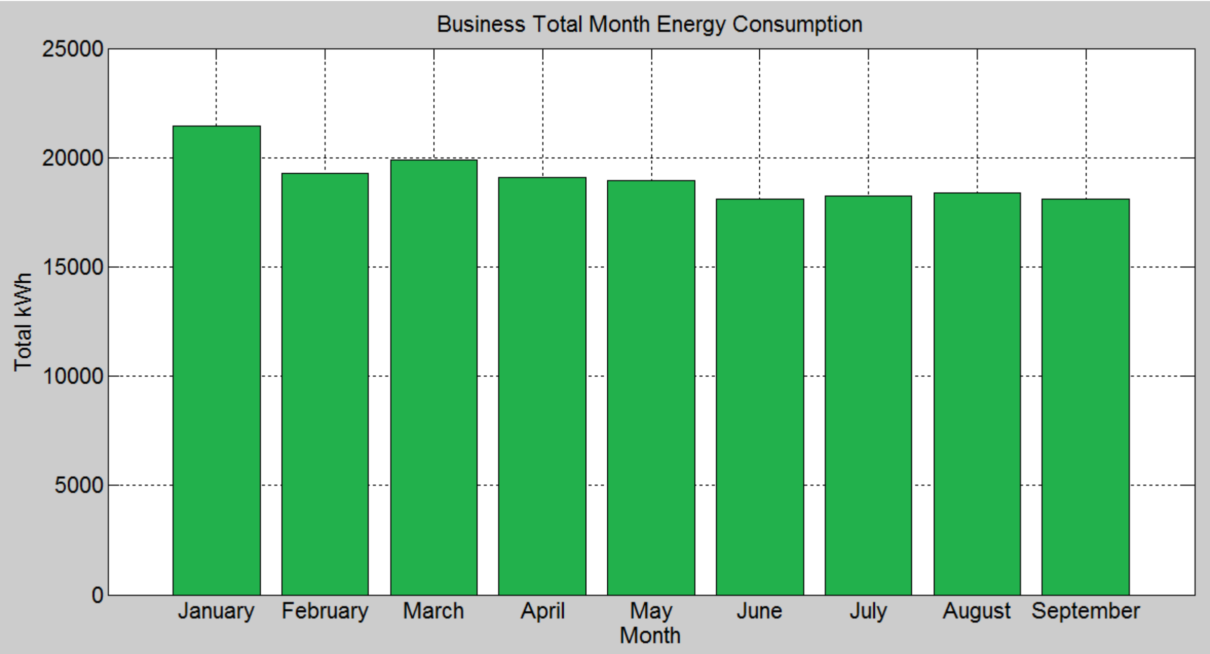


Figure 5.1: Business's Monthly Energy Consumption (Santarossa, 2015)

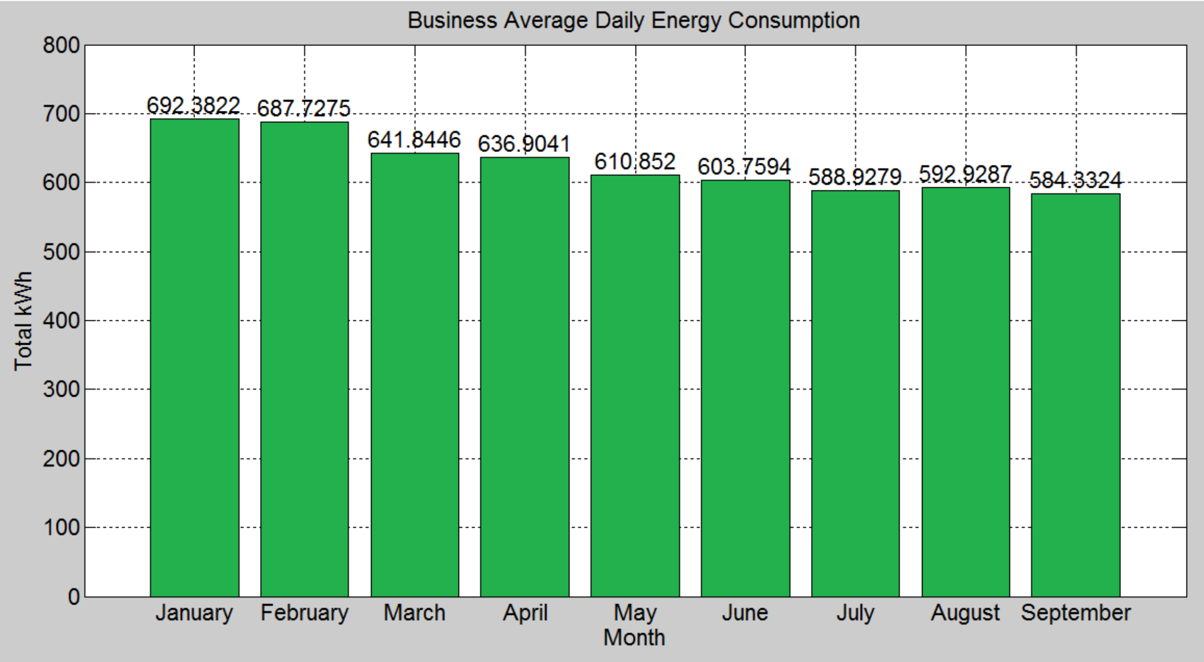


Figure 5.2: Business's Monthly Average Energy Consumption (Santarossa, 2015)

Table 5.1: Business's Monthly Energy Consumption

Month	**Monthly Consumption (kWh)**	**Average per day (kWh)**	***Percentage Reduction (%)**
January	21463.71	692.38	0
February	19256.37	687.73	0.67
March	19897.18	641.84	7.30
April	19107.18	636.90	8.01
May	18936.41	610.85	11.78
June	18112.78	603.76	12.80
July	18256.76	588.93	14.94
August	18380.79	592.93	14.36
September	18114.30	584.33	15.61

*Percentage reduction for each month is calculated in comparison to the starting month of January.

There are two important aspects to consider when analysing the data displayed in figure 5.1, figure 5.2 and table 5.1. Figure 5.1 displays the overall monthly consumption but does not take into account the fact that there are less days in particular months. For example, February displays a 9.66% reduction in energy consumption compared to the month of January however it also has three days less than the month of January. That is why in order to analyse the data correctly, the number of days in any given month must also be taken into account which is done in figure 5.2 and in column three of table 5.1. This average daily consumption allows for a better comparison between each month to see if reductions were actually present.

From the above results, it is evident that there were reductions in energy consumption throughout the energy management process. January through to February showed very little reduction with the average daily consumption not showing any significant changes for the first two months. However as time continued throughout the energy management process, the average daily consumption decreased as is evident from column four of table 5.1.

After an in-depth analysis and discussions with the site consumer, there were several apparent reasons for this reduction in consumption. The first reason comes from the high-powered heating appliances that were utilised within the kitchen for cooking and the cleaning of dishes. It was found that these appliances were getting turned on straight away upon opening in the morning and were getting turned off just before closing. Once the lunchtime rush was over, there wasn't as many food items being sold and this meant appliances were running and consuming energy without being viable for the business. A slight change in how these appliances were utilised meant that they were no longer left on if the café was not doing business and ended up saving themselves money on electricity.

A second consideration were appliances that were left on overnight that did not have to be. These were appliances such as the coffee machine and slushee machine that were left running after operational hours. Staff began to turn such appliances off at the end of every day and turned them back on upon opening to assist in reducing energy consumption.

One major aspect that needs to be taken into account is the weather patterns that were present throughout the course of the project. Refrigeration and other base load costs account for approximately 40-50% of the energy consumption costs within the business and temperature differences can have a significant bearing on how the cold rooms and refrigerator units consume energy. The average temperature for the month of January was 29℃ with the average for June being 23.7℃ (Weatherzone, 2015).

Figure 5.3 displays the average load profile for the least efficient month (January) versus one of the most efficient months (June) during the energy management process and the difference in the two lines at night clearly indicates a drop in night time consumption. This could potentially be due to the fact that refrigeration units cycle less during the colder months of the year and it must also be considered as a possibility as to why energy consumption reduced throughout the energy management process.

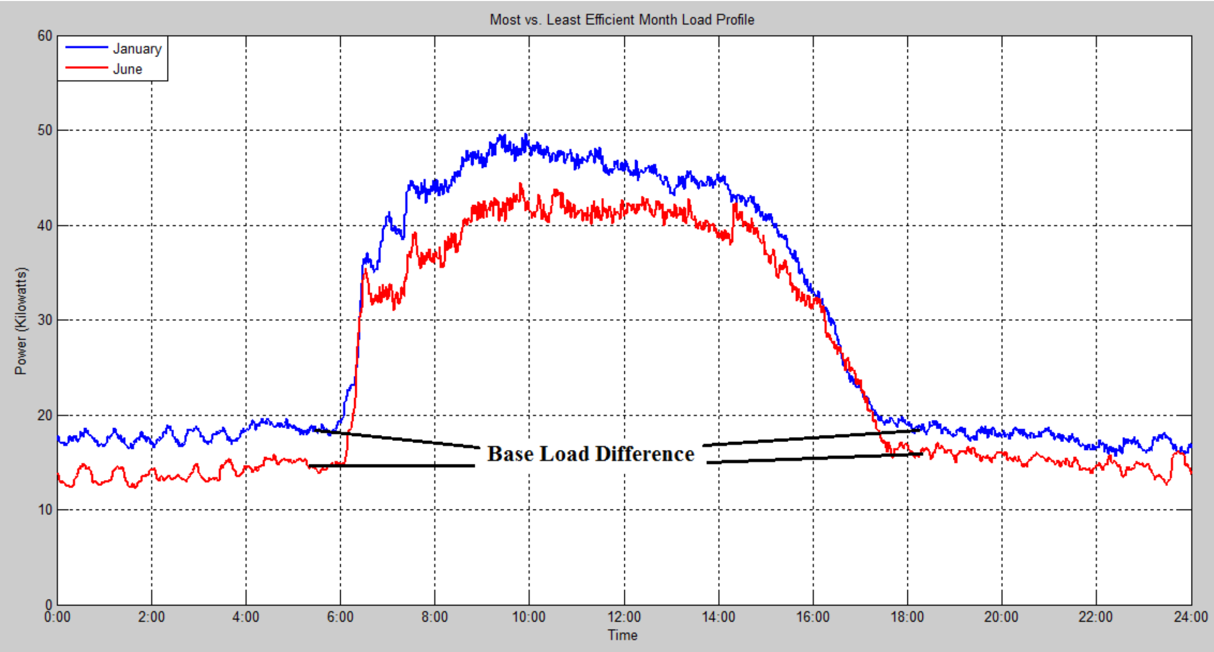


Figure 5.3: Businesses Load Profile Inefficient Vs. Efficient Month (Santarossa, 2015)

5.3.2 Energy Utilities Bill Results (Business)

As well as utilising the data from the secondary monitor that captured more data relating to the energy consumption of the premises, the consumer's electricity bill was also used as a second source of information to ultimately prove the viability of the energy management process. Figure 5.4 displays the average daily energy consumption for each month according to the utilities data for 2015 versus the same time period of the 2014 calendar year.

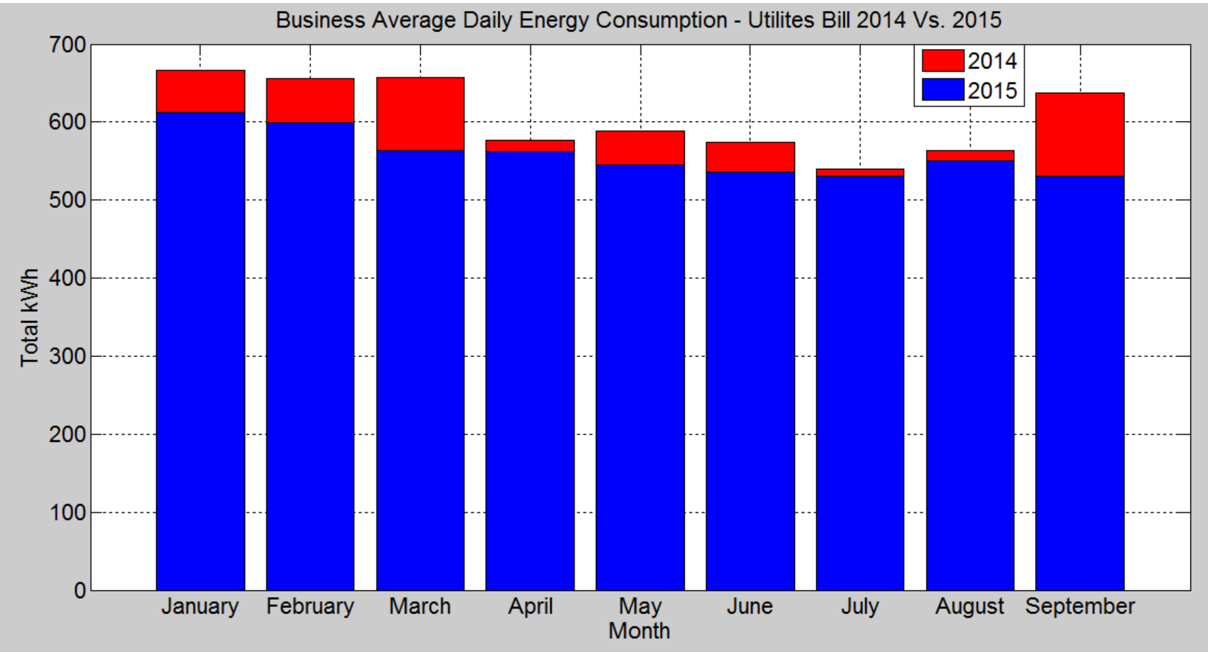


Figure 5.4: Business Utilities Measuring Consumption 2014 vs. 2015 (Santarossa, 2015)

Table 5.2: Business's Monthly Average Energy Consumption

Month	**Avg. Daily Consumption 2014**	**Avg. Daily Consumption 2015**	**Percentage Difference (%)**
January	667.0	611.7	8.29
February	655.8	599.8	8.54
March	657.6	563.0	14.39
April	577.0	561.7	2.65
May	588.7	545.2	7.39
June	535.5	530.0	1.03
July	574.7	540.0	6.04
August	563.4	550.9	2.22
September	638.0	530.5	16.85
Total	5457.7	5032.8	7.78

Although seasonal factors are to be considered as a factor as to why energy consumption reduced throughout the course of the project within the business, figure 5.4 and table 5.2 clearly indicated that implementing an EMS assisted in reducing energy consumption. The month of March and September showed an average daily consumption difference of 94.6 kWh's and 107.5 kWh's respectively which is considered to be caused by behavioural changes. The information from the utilities bill is vital in proving the viability of the energy management process which indicates a total energy reduction of 7.78% for the entirety of the project.

Overall, in communicating with the owners of the business test site, it was evident that they felt that small changes in their behaviours as a result of the data they received made them more energy conscious and allowed them to make better decisions regarding their energy consumption on a daily basis. The changes were not overly large, however it assisted in the economic viability of the business and saved them vital funding that they would have otherwise spent on wasted electricity. The consumers also made clear that being a part of an energy management process was beneficial as they acquired better knowledge for business making decisions regarding their energy consumption and felt more motivated to reduce on their consumption.

5.4 Energy Consumption Results (Household)

5.4.1 Energy Monitoring Results (Household)

Similar to the business owner in section 5.3, the household consumer also evidently showed energy reductions throughout the energy management process. The average daily consumption peaked during the month of February with a result of 62.91 kWh. This however started to reduce during the month of March and continued to reduce as the months progressed. These reductions are displayed graphically in figure 5.5 and figure 5.6 and are also tabulated in table 5.3.

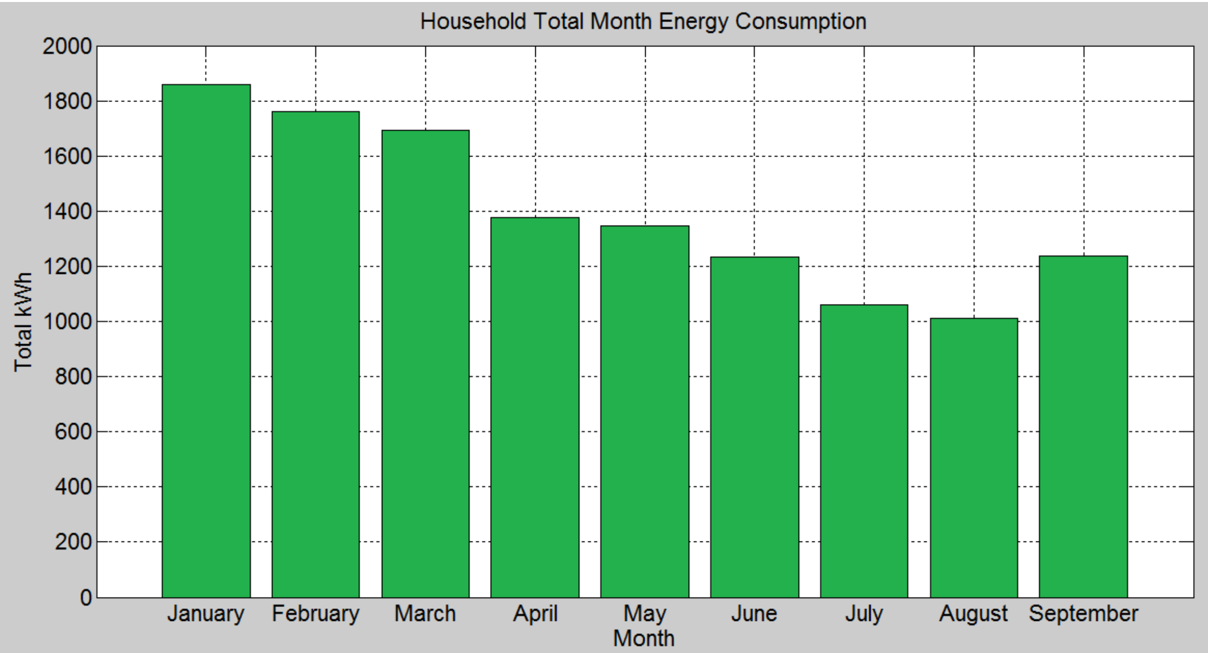


Figure 5.5: Household's Monthly Energy Consumption (Santarossa, 2015)

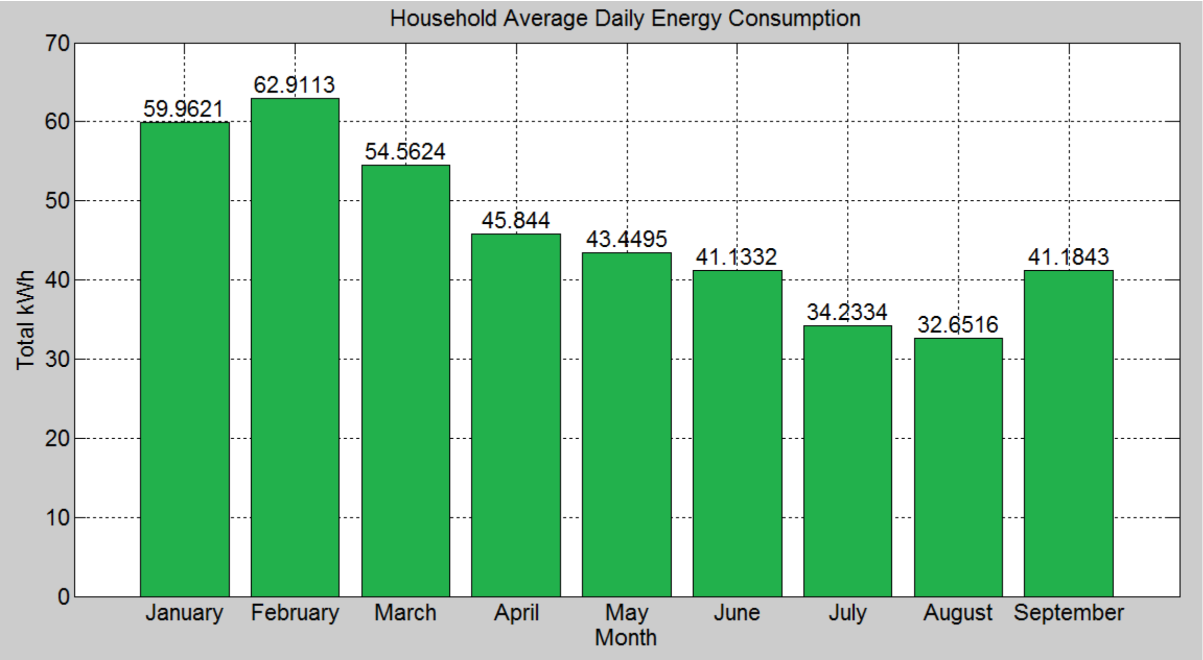


Figure 5.6: Household's Monthly Average Daily Energy Consumption (Santarossa, 2015)

Table 5.3: Household's Monthly Energy Consumption

Month	Energy Consumption (kWh)	Average per day (kWh)	Percentage Reduction (%)
January	1856.81	59.90	0
February	1761.52	62.91	-5.03
March	1691.44	54.56	8.91
April	1375.32	45.84	23.47
May	1346.94	43.45	27.46
June	1234.00	41.13	31.34
July	1061.24	34.23	42.85
August	1012.20	32.65	45.49
September	1235.53	41.18	31.25

*Percentage reduction for each month is calculated in comparison to the starting month of January.

Before the energy management process begun, the home owners would turn their box air conditioning system on during the afternoon hours of the day in the warmer time periods of the year, leaving it run for approximately 3-4 hours before going to bed. This type of air conditioning system is significantly inefficient in comparison to a standard split system air conditioner and was costing the consumers valuable money. They decided not to turn the systems on when arriving home and left them off until half an hour before going to bed. This was one area where the consumer could identify that they could alter their behaviour in order to reduce energy consumption.

Seasonal changes must also be taken into consideration as to why energy consumption reduced throughout the course of the process. Figure 5.7 displays the average load profile for the month of January verses the month of June for the household from the energy management process. It clearly shows a difference between consumption that was caused by seasonal changes as refrigerator consumption is varied by the temperature conditions in which it is surrounded by.

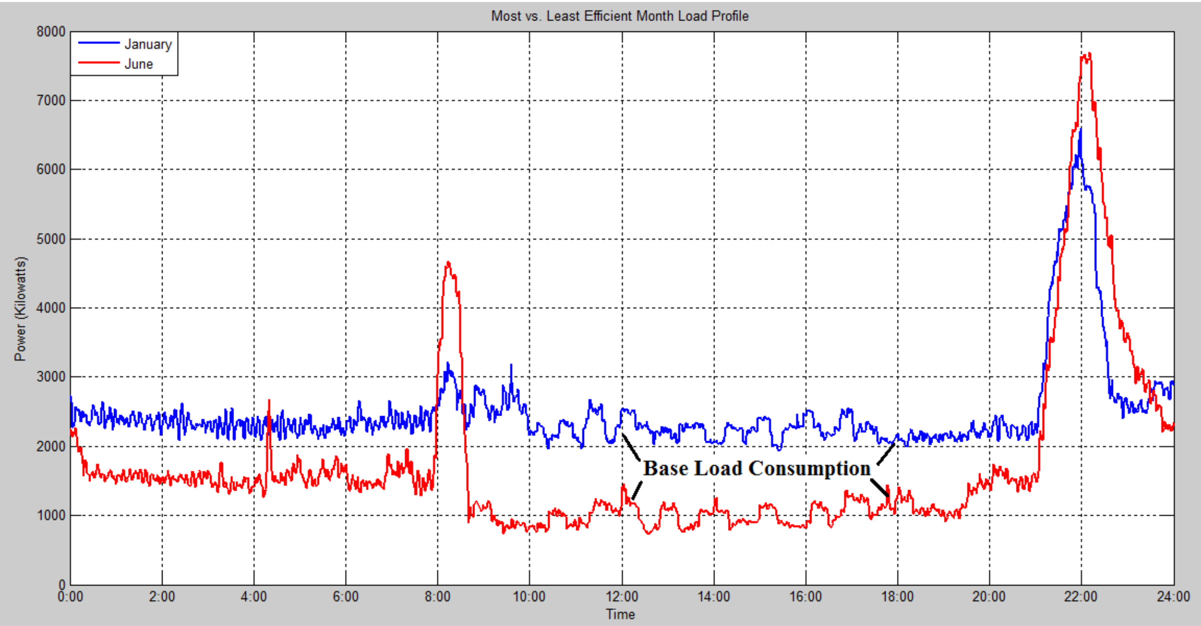


Figure 5.7: Households Load Profile Inefficient Vs. Efficient Month (Santarossa, 2015)

However even taking into account seasonal factors, the energy reduction in the household over the course of the energy management process was as a result of lifestyle choices rather than operational based energy consumption. The summer months in Far North Queensland are renowned for being relatively humid and this can make for very discomforting sleeping conditions. As a result, numerous households have air conditioning installed to allow for a more comfortable sleep. The particular test site that was monitored as a part of this project had box air conditioning systems. Table 5.3 displays a 45.49% reduction in the average daily consumption when comparing the month of January to the month of August. Regardless of how these figures compare to the consumption in the previous year, it is still a dramatic reduction in the scheme of lifestyle choices and goes to prove just how much these lifestyle choices can influence the cost of an electricity bill.

5.4.2 Energy Utilities Bill Results (Household)

The household consumers were less responsive in the initial stages of the energy management process however they became more adapt as time went on. They had an overall reduction of 3.07% as is indicative from the information compiled from the utilities energy bills in able 5.4 and figure 5.8. These savings were not as high percentage wise in comparison to the business however it was still a reduction nonetheless. The results also showed that the consumers started to see even greater reductions as time went on further throughout the process.

Table 5.4: Business's Monthly Average Energy Consumption

Month	Avg. Daily Consumption 2014	Avg. Daily Consumption 2015	Percentage Difference (%)
January-April	57.5	58.5	-1.74
April-July	42.4	39.9	5.90
July-September	36.8	34.1	7.34
Total	136.7	132.5	3.07

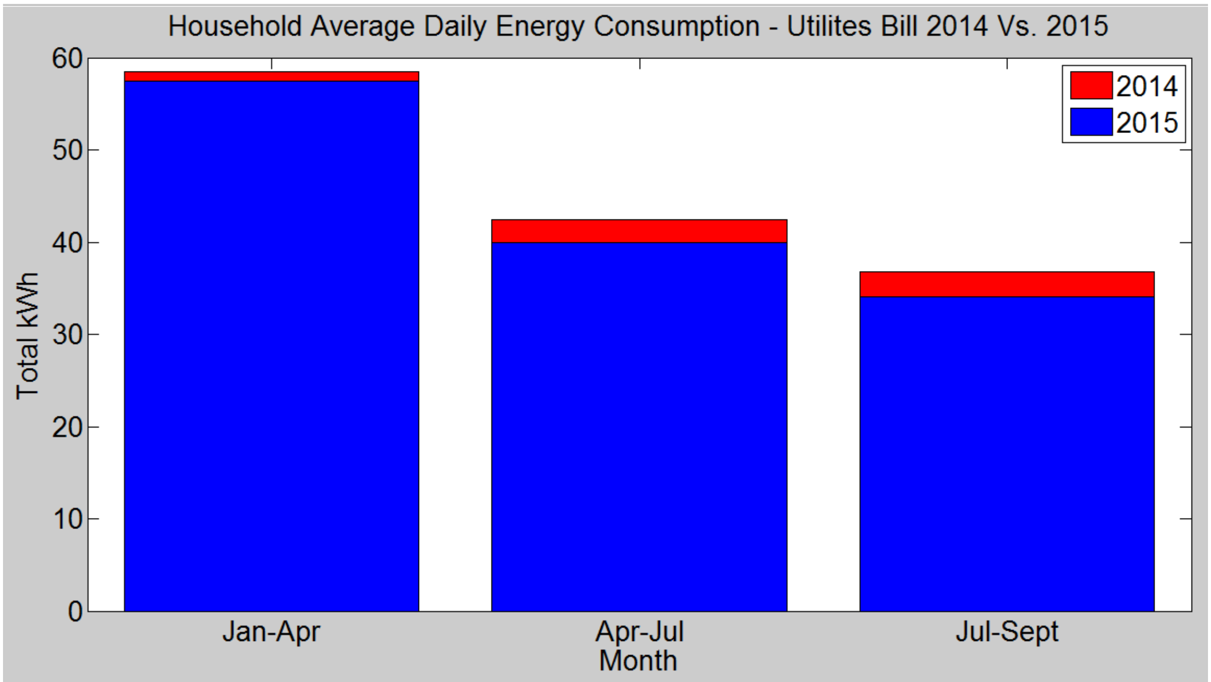


Figure 5.8: Business Utilities Measuring Consumption 2014 vs. 2015 (Santarossa, 2015)

These energy reductions were, like the business consumer, attributable to minor changes in behaviour. There was no capital outlay to realise these reductions and the consumers felt it would be better to have reduced something than to have not reduced at all. The consumers felt that they could have engaged in the process more if it was implemented in a different manner. Although satisfied with the assistance they received, they indicated it would have been more beneficial to them to be able to analyse and review information on their own terms and in their own time frame.

Overall, the household consumer found that the information they received was vital in making better informed decisions regarding their energy consumption. It became evident that they acquired more knowledge regarding their electricity consumption than what they had previously and as a result were able to financially justify how they utilised particular electrical appliances in their household.

Chapter 6: Discussion

6.1 Chapter Overview

This chapter will discuss the outcomes from the methodology and the project as a whole. The Discussion will identify the successes and shortcomings of the project in order to be able to draw conclusions and outline possible recommendations for the improvement of future implementations and research of energy management processes.

6.2 Consumer's Initial Perspective

Although the type of site between the two consumers differed, there were inherent similarities between the two consumers regarding their feelings toward their electricity bill, their motivations toward reducing it and how they responded to, and reacted toward, the energy management process. During the planning stages of the energy management process, both consumers indicated that the ultimate desired outcome would be to eliminate their electricity bill altogether. Be it that electricity is a commodity that all consumers purchase as a service to help improve their daily lives, this possibility was deemed to be impossible. The electricity bill is an inherent cost for any household or business owner and with current technology as it stands today, it is unfeasible to eradicate the cost of electricity altogether, at least not without spending a large sum of capital investment.

However with both consumers understanding that electricity bill eradication was not a feasible option, they were both responsive to utilising their premises as a test site to implement an energy management process. It was evident that both consumers were motivated to at least try and reduce their bill provided there was no capital outlay. Be it that this project was implemented for research purposes only, this was considered feasible for both of the consumers.

Another aspect that was similar across both consumers was the idealism that there were no possible means of being able to reduce their electricity bill. Although both consumers were willing to part-take in the process, it was their initial belief that they were already behaving as efficiently as possible. This is a reflection of the lack of quality information available for energy consumers as they had both contacted their energy provider to find out why their electricity bill was so high or if there was anything they could possibly do to reduce their bill. At the end of the contact they had established with their electricity provider, they finished the communication process feeling no more informed about their electricity consumption.

Time was a highly important consideration to account for in order for the consumer to part-take in the energy management process. From a consumers perspective, although electricity is still a part of the cost of running a household or business, time spent accounting for the cost of electricity can be limited for either a business or home owner. Both consumers indicated that although interested in learning more about their electricity bill, it was important that it did not take them away from general operations of running their business or household.

All of the aspects discussed above are extremely important in understanding the consumer's perspective for how they regard their electricity bill. Although there are inherent similarities between consumers regarding their feelings toward an electricity bill, how a consumer responds to the information as well as the action taken after they receive the information are going to differ between individual consumers. This is because every electricity consumer has different habits and motivations toward their electricity consumption and ultimately has different justifications as to why they use specific electrical appliances. Being able to gain the consumers perspective both during the planning phase and throughout the course of the energy management process was of the upmost importance for report compilation as it would allow the content provider to present data that would be beneficial for the consumer.

6.3 Reduction Identification

The results from the energy management process clearly indicate a reduction in energy consumption for both consumer's. There were numerous apparent reasons as to why the consumer reduced consumption with no one reason providing a clear indication as to why energy consumption reduced throughout the process.

6.3.1 Changes in Weather

Seasonal changes are an uncontrollable variable in reducing energy consumption. However, it still must be considered as a possibility as to why energy consumption reduced throughout the course of this project. Figures 5.3 and 5.7 from the Results section of this report represent the average load profile for the most efficient month and one of the least efficient for the business and household. These figures clearly indicate differences in base load consumption.

Table 6.1: Average Temperature for Each Month - Mossman

Month	January	February	March	April	May	June	July	August
Avg. Temp.	29℃	28.5℃	28.2℃	27℃	25.3℃	23.7℃	25.8℃	23.1℃
Avg. Daily Consumption (Business)	692.38	687.73	641.84	636.90	610.85	603.76	588.93	592.93
Avg. Daily Consumption (Household)	59.90	62.91	54.56	45.84	43.45	41.13	34.23	32.65

Table 6.1 displays the average monthly temperature for the Mossman area for the 2015 calendar year. It is evident from the table that the reduction in energy consumption for the months of the year followed a pattern of reduction along that was in unison with the changes in the average monthly temperature for both consumers. Freezer and refrigeration units can adjust their cycle of operation depending on whether or not the condenser can expel the heat it produces during the heat exchange process of a refrigeration cycle (WhitegoodsHelp, 2015). The higher the ambient temperature is that a refrigerator or freezer is being exposed to, the more likely it is to increase its cycle time and this can make a significant difference in the efficient running of the appliance. Be it that both consumers had a significant number of refrigeration appliances in their premises', the seasonal changes can certainly assist in explaining why there was a reduction in energy consumption.

6.3.2 Appliance Qualification and Quantification

In communicating with the energy consumers from both the household and business test sites, it became apparent that a standard consumer was unable to quantify how much particular appliances individually cost in energy consumption. Discussions indicated that both consumers had their own predictions in this regard however it was assumed that a standard energy consumer would not be able to quantify exactly how much any particular appliance consumes over the course of their billing period. Being able to qualify and quantify particular areas where energy consumption can be reduced is extremely important when implementing an energy management process as the consumer could potentially lose motivation if they are not seeing any reward for their effort.

A kettle or coffee machine can cost approximately $5.00-$15.00 per quarter to operate for any given consumer depending on how often the appliance is utilised over the course of a billing period. Alternatively, a consumer who enjoys coffee can purchase a coffee from a coffee shop rather than running their kettle or coffee machine which would cost approximately $3.00-$5.00 every time a coffee is purchased. It would be hard for a coffee drinker to qualify not using their kettle in order to save money on electricity however operating under the assumption that a standard consumer is not aware of the quantity of energy a kettle costs over a particular billing period, it makes it an important aspect to make this transparent to a standard consumer.

Although quantifying the exact cost of every appliance in a household or business was outside of the scope of this project, being able to show areas of difference became an important piece of information for a consumer to justify turning particular appliances on or off. One particular instance of this aspect was the business consumer who at peak load is consuming approximately $20-$25 worth of electricity per hour. If the café portion of their business is not particularly busy, then the business owner can justify turning particular appliances off to try and reduce energy consumption. It may only be a small saving every time this happens, however these minor adjustments can lead to better consumption habits that will ultimately assist in making a consumer more energy conscious.

Another example was the air conditioner consumption from the household consumer. By indicating that a boxed air conditioner is more inefficient than a standard split system, the household consumer was able to justify investigating how they could reduce their electricity bill in this particular area. It was made apparent that the consumer did not wish to purchase a new split system air conditioner due to the fact that it would be a substantial cost to their household budget. However in realising that this was a large consuming appliance in their household, the consumers were able to justify keeping this appliance off until just before going to bed and as a result it assisted the consumer in reducing their energy consumption.

Every energy consumer is different, showing different energy behaviours as well as having different justifications for why and how they utilise their energy consumption. By being able to assist a consumer in understanding how particular appliances operate and consume energy, they themselves can justify whether or not they wish to keep utilising those appliances in the manner they do. That is why it is particularly important to both qualify and quantify how different appliances operate for a consumer to make their own decisions as a person is more likely to respond to a nudge in the right direction rather than an attempt at persuasion (Allcott, 2010).

6.3.3 Consumer Assistance

From implementing the energy management process, both consumers said that they felt more knowledgeable about their energy consumption and felt that they became more energy conscious throughout the energy management process. There were instances in the past where both consumers had contacted their energy provider to find if there was anything they could possibly do to reduce their energy consumption. They both felt that the energy provider offered them no useful information and hence were unable to perform their own energy control measures.

This is indicative of another energy reducing aspect from the energy management process. It is considered that another reason for the reduction in consumption was that both consumers were more motivated to implement control measures simply because they were receiving assistance. Both consumers discussed that there was reasoning in their behaviours and they felt more motivated to reduce consumption since they had received more information and assistance. Although these two consumers do not speak on behalf of every consumer who utilises electricity in society, it goes a long way in proving that a standard consumer lacks vital information and proves that information can motivate a person to reduce energy consumption.

6.4 Business vs. Household Comparison

The results indicate that the business consumer was far more responsive to the energy management process than the household consumer's. Neglecting the character of the consumers and their motivations towards savings, there are relevant reasons as to why this difference was achieved. The business consumers could make small changes with less efforts that would result in greater reductions on their energy consumption. This is evident from the results of comparing the 2014 and 2015 average daily consumptions for both consumers with the business seeing an overall reduction of 7.78% as opposed to the households 3.07%.

Although the energy management process was more beneficial for the business, this research project also goes a long way in proving how operational energy expenses differ from lifestyle energy expenses. The business consumer went to extra efforts to trial control measures to reduce their bill which they achieved. However significant changes in their consumption could not be achieved due to the fact that the large energy consuming items are highly important to the correct operation of the business. To achieve significant changes in energy consumption would have meant compromising on the correct operation of the business and as a result they were unable to go any further with their reductions.

This differs from the household consumer whose energy consumption is largely lifestyle based. The month of August saw a dramatic 45.49% reduction in energy consumption compared to the month of January. Seasonal changes meant it was comfortable enough for the household consumers to sleep at night without air conditioning and this was a contributing factor to the household's energy reduction throughout the course of the energy management process. Although this was a consumer choice to utilise air conditioning, this concept goes a long way in identifying how lifestyle choices can influence an electricity bill. If a consumer can receive better information regarding these influences, they can make better decisions in order to reduce on their energy consumption.

6.5 The Consumer Learning Process

It is of the highest important during the data compilation phase of the energy management process to be able to correlate the data into a format that can be easily understood from a standard consumers perspective. Research has shown that the average person can only focus on up to four things at once (Moskowitz, 2008). If you consider the daily activities of the standard home owner or manager of a business, it is assumed they know very little about the topic of energy consumption. With this in mind, overloading this type of consumer with a large amount of information could be detrimental toward their energy reduction motivations.

One of the biggest learning experiences throughout the energy management process was that consumers responded better to smaller amounts of information over larger time frames. A successful energy management process should inherently make a consumer more energy conscious over the long-term. It was proven that it took numerous discussions before a consumer began to take action in implementing successful control measures. These meetings also assisted the consumer in feeling better about their bill as they were able to evidently see whether the changes were assisting in consumption reduction. The small amounts of direct information that were delivered over longer periods of time assisted in the consumers overall energy consciousness and motivation toward reducing their energy consumption.

6.6 Consumer's Final Perceptions

Interviews were conducted at the completion of the project to identify the final perceptions of the energy management process from the consumer's perspective. Technological advancements have allowed society to make major progressions within the energy management field but the technology is only as valuable as the responsiveness of the consumer. The interviews gave significant insight into the consumer's thoughts regarding how they felt toward their electricity bill since they had undertaken the process.

Although the energy reductions were not as great as what both consumer's had wished for, there was still an indication of satisfaction toward increasing their own energy consumption knowledge. Feedback was also presented which indicated room for possible energy management process improvements.

6.6.1 Time Frame Responsiveness

It was indicative throughout this research project that consumer's wish to take action and respond to their electricity consumption but on their own terms and in their own time frames. There are certain times when a consumer is thinking about their energy consumption over a given billing period however with general business operations to attend to as well as busy lifestyles lead by consumers, the time allowed to attend to energy tracking is minimal and has to be created by the consumer.

Feedback from the household consumer's indicated that electronic correspondence would have been more viable as there are certain time periods throughout the course of the billing period where they would follow information regarding their bill to see their progress. The business consumer however indicated that reminders and tracking results on a given time frame would be more feasible as during the busy working week, considerations toward their energy consumption can be lost due to other business matters and energy can be wasted. It was also indicated by both consumers that something that would assist them to at least investigate their energy consumption would be utilised as they considered electricity to be a significant cost to their business and household.

This feedback makes evident two important points regarding the energy management concept. One is that although electricity is a cost to given any household or business, consumers will consider ways to reduce upon it if they can be assisted. The correct information is vital and if delivered correctly, a consumer will become more motivated to learn more about their energy consumption to reduce on their bills. Secondly, they need to do this on their own terms when it suits them. Energy management processes will be undertaken by consumers to improve their lives if it can be done on in their own time and if it will be beneficial so the process can be improved by tailoring it for a consumer’s lifestyle.

6.6.2 Consumer Comparison

Feedback from the consumers indicated that their feelings toward their energy consumption was heavily influenced by comparing themselves to other energy consumers. This was especially the case within the household with the consumers pointing out that they had spoken to other consumers, comparing costs as well as appliances in their household and indicating that they did not understand why their bill was so high. The business consumer has also spoken with other business owners about power consumption and the possibility of installing a solar power system as it had proven to reduce energy costs for other businesses. Consumer comparison is another proven motivator for consumer responsiveness toward reducing their energy costs and being able to see what worked for other people will allow a consumer to consider ways to reduce on their energy costs outside of the information they receive.

6.6.3 Process Viability

Both consumers believed in the viability the energy management process undertaken in this research project. The business owner now carefully considers what appliances the business utilises and considers his energy costs as a vital expense consideration toward the running of the business. They also indicated that an energy management process can be adopted by other business owners to optimise the energy and cost efficiency of their own businesses. The household consumers were also strong believers in the energy management process and also considered electricity as a significant cost toward the running of their household. If an energy management process could be utilised across more households, they believed it would help more regular energy consumers.

One similarity between both the business and the household was that they both believed that an energy management process needs to be undertaken over the long-term to be viable. It needed to involve more tracking and trialling on shorter time frames but on the consumer's own time. A regular consumer only has minimal time to consider learning about their energy consumption and that time spent has to be useful in getting them to understand their consumption. A system such as this one where a consumer was receiving more information in short increments over a longer time period is a more effective method to reduce energy consumption and create consumer awareness.

Chapter 7: Conclusion

7.1 Chapter Overview

This chapter will summarise the project as a whole. As well as drawing conclusions regarding this project, the conclusion will also discuss recommendations for future research in this area.

7.2 Project Findings

7.2.1 Consumer Energy Challenges

As part of this research project, one of the most significant findings was how little a standard consumer understands about their electricity consumption. This is to be accepted as the norm as a standard consumer of energy knows very little about electricity no different than a standard vehicle operator knows about the car they are driving. Although electricity knowledge is lacking in a standard consumer, it is difficult for a standard consumer to justify investing both time and resources learning about how electricity operates in order to reduce energy and save money. However if the time spent learning about their electricity consumption is justifiable for particular consumers that wish to learn more, energy reductions are possible and it can lead to the efficient running of a household or business in the long term.

This project has assisted in proving that consumers are willing to adopt energy efficient principles and change behaviours if those principles are justified. However this project has also proven that although there is a great requirement for this information infrastructure, it does not exist, at least not here in the greater part of regional Queensland consumers. Both consumers of the test sites had contacted their energy providers in the past to find out if there were possible ways to reduce their electricity consumption.

There is a great deal of generalised energy information that currently exists for a standard consumer. Government and private organisations alike provide energy saving tips that can assist in reducing energy consumption. There are also electronic devices that can display information and these devices are designed to help a person reduce consumption like the Engage Hub Kit.

However one of the most significant proven aspects from this research project was that although the energy market already offers particular avenues for a consumer to learn more about their electricity consumption, what is lacking is energy information that appeals to each individual consumer. Information that is important for one energy consumer may not be necessarily useful for another consumer. This is where basic energy saving tips or a modular energy information platform may not be enough to help a consumer reduce energy. The information tailored to the consumer was extremely beneficial as they were then able to justify their behavioural changes to reduce energy consumption. Although this information is inherently lacking within society, this research project helped to provide great insight that if this infrastructure for providing this information does exist, the standard consumer can reduce energy consumption.

7.2.2 Energy Management Requirement

The development of renewable energy sources have assisted in reducing costs for some particular consumers. However there are numerous consumers within the energy marketplace that do not have access to funding to afford such systems and majority of consumers are still utilising the generation/distribution network grid system that is offered to society by the energy providers. While the energy providers have ownership of this system and are charging a consumer to build and maintain such an infrastructure, there will come with it the inherent need to reduce upon it from a consumer perspective.

7.3 Recommendations

Although deemed to be a successful research project, there are many areas where further research could be undertaken in order to improve on the findings of this project. Electricity is a commodity that cannot be seen and the more that is done to find where electricity is being consumed, the greater potential there is for savings. There was a great deal learnt from this project from both a researcher’s and a consumer’s perspective. However it was only as time went on that both parties were getting closer toward a level of optimal operation where the electricity costs are justified for either a business or household. If a business or household consumer is utilising information they did not previously have to reduce consumption, it could save these consumers small in the short-term but large in the long-term and in doing so can also reduce carbon emissions.

This project aimed to prove the viability of the energy management process. For this reason, a small number of consumers were utilised to allow for more time being spent with each consumer. Different sites and consumers present different energy management challenges. A smaller number of consumers allowed for more time to be focused on those consumers. It ensured that the consumers were getting optimal attention for the learning purposes of this project.

However to make a bigger impact within the energy management field, a more scalable solution needs to be implemented. This project required a great deal of time interfacing directly with the consumer and is a model that would not be economically viable for the greater part of society. There are possible avenues to further implement the energy management process with each part of the process having its own possible solutions to further improve the energy management process.

7.3.1 Monitoring Improvements

The Engage Hub Kit was an affordable solution for a monitoring technology for the purposes of this project. It was very affordable and captured energy data in one minute intervals, a time frame short enough to show inherent changes in site behaviours at specific times. However a large majority of electricity consumers are not going to pay the recommended retail price for such a device as with it comes the inherent risk of not reducing any energy consumption. The Engage Hub Kit also requires installation by a licenced and competent electrician which is a cost that needs to be covered by the end consumer. In order to benefit more consumers through an energy management process, a better monitoring solution needs to be acquired.

Digital meters have an infrared pulse output sensor which can assist in capturing more energy data for a consumer. A pulse output sensor does not require installation by an electrician making it more manageable and user friendly. For this reason, people will be more inclined to part-take in an energy management process as the installation time and costs are reduced. However there is still an inherent cost with acquiring this type of hardware and maintaining such a product can still be a pain for the end consumer.

The ultimate goal for a monitoring system as it stands with modern technology would be to utilise smart meters that are powered by the consumer load with no on-going maintenance required. Energy management industry leaders OPower have been able to leverage from the infrastructure created by utilities worldwide that are capturing energy data to benefit consumers. Their information system has saved a large number of consumer’s energy without charging these consumer’s any premium cost for the service which takes away the risk factor involved with implementing an EMS. For every person that will pay for an EMS there are a larger number of people who would be willing to try it for free and this is one of the proven ways to get consumers proactive toward reducing on their electricity bills.

7.3.2 Data Analytics Process

The MATLAB software platform was a simple and user-friendly tool to compile data for the purposes of this project. This type of program is designed for university students for its ability to solve complex problems without the need of being a highly skilled software developer. However from an end users perspective, the functionality MATLAB comes equipped with would not appeal to a regular consumer. The numerical figures and graphical models created in MATLAB can be simply implemented with other technologies that could be easily display information for standard consumers.

If multiple consumer sites are being monitored with useful information being distributed, there is the potential for the distribution of modular information to a larger number of consumers. Web-based technologies have proven to be a valuable resource of distributing information. If a web-based platform was created with tailored and beneficial energy information for an individual consumer, there is potential to serve a larger number of consumers and reduce even more energy. However working with consumers directly on this project has certainly assisted in finding what type of information appeals to a consumer.

The type of information that appeals to a consumer takes a great deal of trial and error. However as time went on throughout this project, new and innovative ways were practiced to find data that would appeal to an end consumer. Further research would bring with it better ideas and implementations to find out more about a consumers energy usage. Energy reduction will be a constant on-going challenge for the majority of energy consumers. It is with this that comes the inherent requirement to find better ways to compile energy data which could be realised through further research.

7.3.3 Control Measures

One of the greater difficulties with implementing control measures in an energy management process is justifying which appliances or electrical infrastructure can and cannot be controlled. This project has assisted in proving that the information delivered to a regular consumer has to be delivered in a simplistic manner for a standard consumer to understand and that ultimately, the control measures implemented should be consumer responsibility. From understanding this information a regular consumer can then have a better game plan for what electrical equipment they wish to keep utilising and how they wish to utilise it. It is important from an engineering perspective to create a quality system to give the consumer the best possible options for energy reduction.

Within the residential energy market, the energy reduction idealism is both operational and lifestyle based. For example, a family running a fridge in the kitchen to keep food cold is an operational expense which is standard for most households. If the same family were to acquire a secondary fridge for the patio, this is more of a lifestyle choice as not every family has a second fridge. This is opposed to the commercial and industrial energy market where energy consumption tends to be more operational based rather than lifestyle based. A second fridge may be required in a small business as it may need to hold food stock that is to make food for customers.

There are both pros and cons when comparing operational and lifestyle expenses. A lifestyle choice in a house is simpler to reduce consumption on however emotion tends to be tied to it and this can be a difficulty to overcome especially in explaining energy consumption to a regular consumer. Nonetheless in any energy market the rules of energy management still hold true in that possibilities will not become apparent if the monitoring and analysis process is not undertaken. A consumer will have a better chance of reducing their energy consumption if they follow the process and explore the possibility. These possibilities arise with new ideas and people can change their habits over given time to assist in reducing their energy consumption.

7.3.4 Self Sufficiency Possibilities

Although beyond the scope of this research project, there are possible suggestions that arose throughout the process with how EMS's can be made to be more self-sufficient from a consumer perspective to eliminate the need for third party assistance. The costs involved with implementing an EMS will always be one of the greatest challenges a consumer faces when choosing to invest in an EMS or not. Engineering, especially innovative engineering, can and must be utilised to create better EMS's for the benefit of the consumer. However with the aspect of engineering also comes with it heavy costs and this may end up being a detriment to a consumer rather than a benefit.

One aspect that can be considered when implementing future energy management processes is creating an energy management process that carries a consumer through their electricity consumption learning without the on-going assistance requirement of an engineer. A self-sufficient system implemented correctly could allow a consumer to assist themselves in reducing consumption and this will allow for a more cost efficient process. Cost efficiency holds a high level of importance within the energy management field. Through creation of more innovative EMS's, cost efficiency can be improved upon and adapted to assist even more consumers.

7.4 Consumer Benefits

The ultimate reason that energy management processes are in existence is because of the financial and environmental benefits they can contribute to society and energy consumers alike. With all of the technical aspects involved with not only creating but improving the energy management process, the one aspect that holds the highest level of importance above all others is ability to view the energy management process from a consumer's perspective. There is often a gap between how an engineer designs and implements a particular product and how an end user utilises that product. An engineer may believe that something is important that may not necessarily be important to a consumer who needs to not only use but benefit from the product.

This is related to a paradigm called 'eating your own dog food' which is believed to have originated from Microsoft back in the 1980's (Jevanyn, 2009). The idea behind the paradigm was that software developers within the company were made to utilise their own software products they had created to be able to evidently find out whether or not it was going to be beneficial to the end user. Since then the principle has been adopted by other companies in order to be able to find out whether what they are creating is going to be beneficial from an end users perspective. It is this ability to walk in the consumers shoes that will ultimately benefit the consumer when developing an energy management process. Without being able to visualise the information from an end consumer's perspective whom has very little understanding of energy consumption, energy management information will tend to not be adopted by energy consumers.

Tailoring information can also go a long way in improving the energy management process adopted in this report. Budgets, motivations and behaviours can vary between any two given consumers. This raises concern that modular information may not necessarily be enough to reduce a consumer’s energy consumption. Further research can be conducted to find more tailored information that will help a consumer make better justified decisions toward reducing their energy consumption. Being able to separate appliances can go a long way in assisting a consumer make decisions about how they utilise their electricity, no differently to when a citizen of society goes shopping at the supermarket and justifies their food purchases based on the displayed price.

References

Allcott, Hunt, *What Behavioural Science has to Say About Energy Consumption*, 2010, Available: http://www.rff.org/Publications/WPC/Pages/What-Behavioral-Science-Has-to-Say-About-Energy-Conservation.aspx, Accessed: July 7th, 2015.

Berkeley National Laboratory, *Building Energy Information Systems and Performance*, 2015, Available: http://eis.lbl.gov/smallcomm.html, Accessed: July 10th, 2015.

Centre for Disease and Control, *Controls for Noise Exposure*, 2014, Available: http://www.cdc.gov/niosh/topics/noisecontrol/, Accessed: June 28th, 2015.

ClimateWorks Australia, *Industry Energy Efficiency Data Analysis*, 2013, Available: http://www.climateworksaustralia.org/project/current/industrial-energy-efficiency-data-analysis, Accessed: July 10th, 2015.

Commerce.Gov, *The Energy Industry in the United States*, 2015, Available: http://selectusa.commerce.gov/industry-snapshots/energy-industry-united-states, Accessed: July 10th, 2015.

Efergy, *Efergy Engage*, 2015, Available: https://engage.efergy.com/dashboard, Accessed: April 15th, 2015.

Efergy, *Sabadell City Council Project*, 2015, Available: http://corporate.efergy.com/customers/public-sector, Accessed: July 10th, 2015.

Efergy, *Savin' Bundles with the ClimateSmart Home Service*, 2015, Available: http://efergy.gr/en/portfolio/climatesmart-home-service/, Accessed July 10th, 2015.

Energy Efficiency Exchange, *Commercial and Services*, 2015, Available: http://eex.gov.au/industry-sectors/other-sectors/commercial-and-services/, Accessed: July 10th, 2015.

Energy Efficiency Exchange, *Establishing an energy management system*, 2014, Available: http://eex.gov.au/energy-management/establishing-an-energy-management-system/, Accessed: April 4th, 2015.

Fawkes S., *History of Energy Management*, 2001, Available: http://www.vesma.com/thefivep.htm, Accessed: May 30th, 2015.

Granderson J., Piette M., Ghatikar G., *Building energy information systems: user case studies*, 2010, Available: http://eis.lbl.gov/pubs/beis-case-studies.pdf, Accessed: March 15th, 2015.

Kranz, Dr. J., *When is a Fridge More Efficient, the Summer or Winter*, 2015, Available: http://www.madsci.org/posts/archives/2003-01/1043077841.Ph.r.html, Accessed: July 11th, 2015.

Llewellyn, C., *Opower Surpass 400 Billion Meter Reads Worldwide*, 2015, Available: http://opower.com/company/news-press/press_releases/119, Accessed: July 11th, 2015.

Michigan Creative, *History of Energy Management*, 2013, Available: http://energymanagement.umich.edu/about-us/opsteam-history/, Accessed: May 2nd, 2015.

Moetegi N., Piette M., Satkartari K., *Case Studies of Energy Information Systems and Related Technology: Operational Practices, Costs and Benefits*, 2003, Available: http://btus.lbl.gov/sites/all/files/lbnl-53406_0.pdf, Accessed: March 7th, 2015.

Moskowitz, C., *Minds Limit Found: 4 Things At Once*, 2008, Available: http://www.livescience.com/2493-mind-limit-4.html, Accessed: July 11th, 2015.

Office of Environment and Heritage, *Energy Management Guide for Tenants*, 2012, Available: http://www.nabers.gov.au/public/WebPages/DocumentHandler.ashx?docType=3&id=66&attId=0, Accessed: July 10th, 2015.

Queensland Council of Social Service (QCOSS), *Electricity concessions needed for low-income earners*, 2013, Available: http://www.qcoss.org.au/electricity-concessions-needed-low-income-earners, Accessed: May 10th, 2015.

Senior Au., *Queensland prices to sky-rocket 21.4 per cent*, 2013, Available: http://www.seniorau.com.au/index.php/more-seniorau-news/3501-qld-electricity-prices-to-sky-rocket-214-per-cent, Accessed: May 10th, 2015.

The Warren Centre, *Energy Management in the Process Industries*, 2015, Available: http://thewarrencentre.org.au/projects/past-projects/energy-management-in-the-process-industry/, Accessed: July 10th, 2015.

Trade Economics, *Electric Power Consumption (kWh per capita in Australia)*, 2015, Available: http://www.tradingeconomics.com/australia/electric-power-consumption-kwh-per-capita-wb-data.html, Accessed: March 4th, 2015.

Trigg, A., *How are Fridges and Freezers Affected By Room Temperature*, 2015, Available: http://www.whitegoodshelp.co.uk/how-are-fridges-and-freezers-affected-by-the-room-temperature/, Accessed: July 11th, 2015.

Wikipedia, *Energy Management*, 2015, Available: https://en.wikipedia.org/wiki/Energy_management, Accessed: July 10th, 2015.

Wikipedia, *Opower*, 2015, Available: https://en.wikipedia.org/wiki/Opower, Accessed: July 7th, 2015.

Appendix A: Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	**MATTHEW SANTAROSSA**
TOPIC:	ENERGY MANAGEMENT AND AUTOMATED ANALYTICS
SUPERVISOR:	Dr. Narottam Das
ENROLMENT:	ENG4111 – S1 D. 2015 ENG4112 – S2 D. 2015
PROJECT AIM:	This project will aim to prove the viability of the energy management concept as well as research a more innovative way to perform the energy analysis process.
SPONSORSHIP:	N/A – own project
PROGRAMME:	**Issue A, 18th March 2015**

1. Research background information regarding energy management and the concepts behind why it is utilised among electricity consumers.
2. Research literature review to find where energy management has been utilised and outline why it succeeded/failed.
3. Devise own Energy Management System (EMS), outlying all equipment required as well as how each step will be carried out.
4. Review EMS and repeat analysis and control measure processes in an attempt to find better results.
5. Compile all information (background information, EMS design and results from performing EMS) into dissertation.

As Time Permits:

6. Innovate data analysis process to shorten the time frame between information gathering and report delivery.
7. Innovate data analysis process to deliver better quality information.
8. Perform extra research on appliance behaviour for consumer awareness.

AGREED:

______________________________ (Student) __/__/__

______________________________ (Supervisor) __/__/__

Appendix B: Project Timeline

	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15
Test Montoring Equipment												
Research for Test Sites												
Preliminary Proposal												
Set-up test site												
Initial Data Analysis												
Project Proposal					**(15th)**							
Project Specification					**(18th)**							
Finalise Project Specification						**(2nd)**						
Prelimnary Report Submission								**(3rd)**				
Partial Dissertation Submission											**(16th)**	
Project Presentation											**(24th)**	
Analysis/Reporting to Consumer												
Final Dissertation Submission												**(29th)**

Appendix C: Job Hazard Analysis

JOB HAZARD ANALYSIS

Job #: 0001			**Job Title:** Installation of Engage Hub Kit		
Job Location: Front Street, Mossman			**Job Date:** December 15th, 2014		
Job Leader: Matthew Santarossa			**Job Type:** Electrical Installation		
PERMIT CHECKLIST FOR JOB					
	Yes	**No**		**Yes**	**No**
Confined Space		✓	**Working at Heights**		✓
Hot Works		✓	**Chemical Work**		✓
High Pressure Works		✓	**Steam Works**		✓

HAZARD IDENTIFICATION CHECKLIST		
	Yes	**No**
Are there any hazards associated with the job/task? If yes, please provide a brief explanation.	✓	
Brief Explanation: Installation of the Engage Hub Kit is required to be installed around live electrical conductors. Correct procedures are required to be implemented in order for the safe installation of the equipment.		
	Yes	**No**
Can the hazards be eliminated?		✓
Can the hazards be substituted?		✓
Can the hazards be accounted for with engineering controls?		✓
Can the hazards be accounted for with administrative controls?		✓
Can the hazards be accounted for with personal protective equipment (PPE)?	✓	
If no has been answered for every question, consult other personnel for further advice. If yes has been answered, please indicate below		

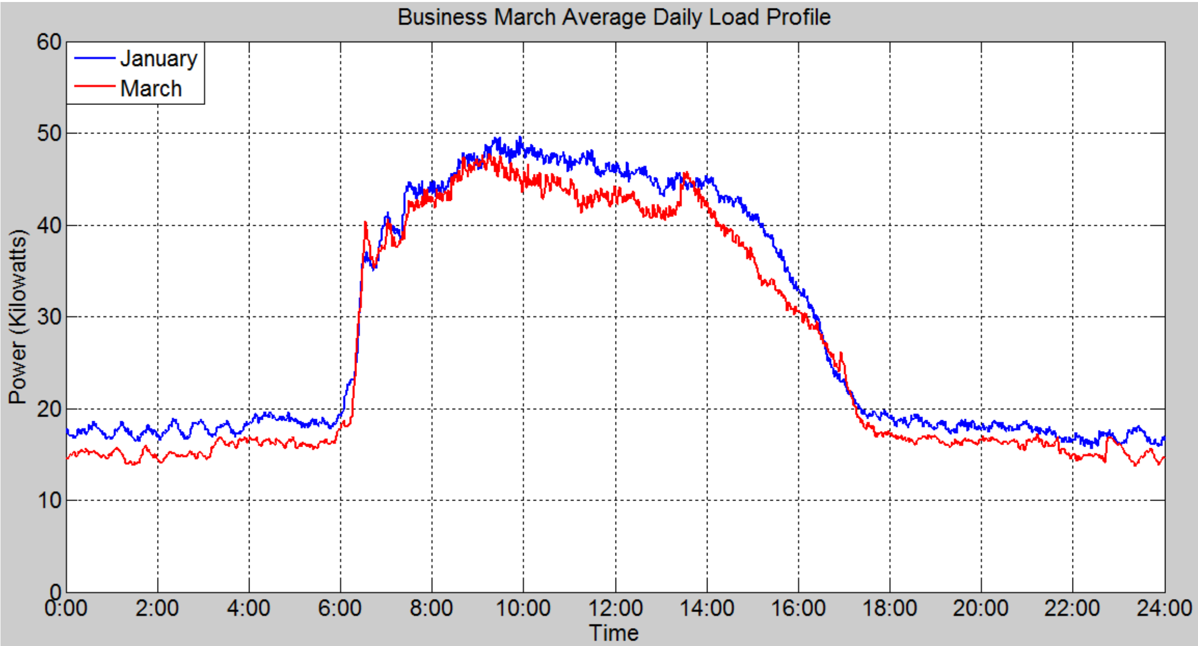
JOB STEPS		
Indicate below the steps required for each job, the hazards involved with each step and how the hazard can be controlled.		
Job Step	**Hazard**	**Control**
Check all safety equipment and locate isolation point in case of emergency.	N/A	N/A
Open electrical switchboard panel and locate mains cable.	Electrical Shock	PPE*, Safety Observer**
Clip current transformers around mains cables (one for each phase).	Electrical Shock	PPE*, Safety Observer**
Plug tails of current transformers into the transmitter.	Electrical Shock	PPE*, Safety Observer**
Mount transmitter in a safe manner so as to ensure no interference with other electrical equipment	Electrical Shock	PPE*, Safety Observer**
Close panel and tidy area	Electrical Shock	PPE*, Safety Observer**
***PPE items listed in tools for job**		
****Safety observer is CPR/LVR trained as required**		

TOOLS REQUIRED FOR JOB
Low voltage rescue kit (1000V insulated crook, gloves, torch, fire blanket, dressing) 1000V insulated pliers & side cutters Cable ties 1000V insulated screw drivers

Employees Involved: Matthew Santarossa, Mitchell Lyle.

Appendix D: Report Example

Overall Monthly Report (Business) - March



Item	Value
Base Load Consumption	11478.9 kWh's (57.69%)
Average Daily Consumption	453.01 kWh's (6:00am-6:00pm)
Average Night Time Consumption	188.83 kWh's (6:00pm-6:00am)
Peak Load	50.67 kWh's (March 3rd, 8:00-9:00am)
Most Efficient Weekday	642.58 kWh's (Thursday March 12th)
Least Efficient Weekday	699.52 kWh's (Monday March 3rd)

Major Points:

- Difference in most and least efficient days was 183.71 kWh's. This equates to approximately $24.62 is savings for the day.
- Base consumption accounted for more than half of all total consumption for the month.
- Consumption is reduced 50.54 kWh's per day since January.