ENERGY MANAGEMENT AT A SOUTH AFRICAN HIGHER EDUCATION INSTITUTION: A CASE STUDY

By

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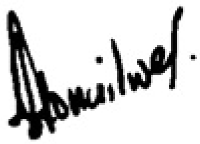
DECLARATION/AFFIDAVIT

I, **Othusitse Gideon Lokailwe (Student No.: 210167556)**, declare that the contents of this thesis represent my own unaided work and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.



05 February 2021

Signed **Date**

ABSTRACT

To date, student accommodations have received little attention in the published literature regarding energy consumption and energy efficiency. With their unique operating and building characteristics, these buildings have diverse opportunities for analysis in regards to building's energy usage and occupant's comfort. With the lack of research focus on these types of buildings (student accommodations), it can be concluded that the perspective is that student accommodations have overall lower average energy intensity, therefore they rarely receive energy assessments.

South Africa is currently faced with energy crises which have led to a continuous load-shedding and increased tariffs, for this case, there is a need for energy-saving models to be implemented mostly across the institutions of higher learning student accommodations.

This presented case study (thesis) focussed on the energy management at the CPUT's student accommodation (Catsville residence) through a preliminary energy audit, data logging (using a Fluke 1730 power analyser), electricity bill analysis and occupants (student) survey to fulfil the main aim of establishing whether the energy management strategies can be applied to the student accommodations to effect the cost and energy efficiency.

The work presented in this thesis is the first step towards making the CPUT student accommodations the most energy-efficient buildings. A preliminary energy audit which included metering was performed to determine if there is a need for a comprehensive energy audit. Based on the audit results, a comprehensive energy audit was recommended as it is more informative than the preliminary audit. The results from the audit determined that there are several energy conservation opportunities (ECONs) available such as retrofitting of existing equipment and there is also a need for energy management systems to be deployed.

Based on the electricity bills, the university spends just under R4 million per annum on electricity and if the energy conservation measures and energy management systems could be implemented, there is a prospect that the cost will reduce significantly. The electricity bill is expected to almost double by 2025 based on the assessment of the annual increases of about 8% based on the period under study (2017 to 2019).

The metering (data logging using the Fluke 1730 power meter) established the consumption profile which showed that the electricity in the residences is consumed even though there is no occupancy, this has also strongly suggested the need for energy management interventions. The profile shows that during recess, the consumption is low when compared

to the in-session (school time) period. The hard lockdown period was of interest as it also showed that the university had a bill of almost half of what they would normally pay, based on the data obtained from the data logger, this implied that there was the usage of electricity even though it was virtually unoccupied.

The data logger (Fluke 1730) has capabilities of measuring power quality issues such as voltage imbalances, current surges, power factor, frequency and harmonics. The data showed that the voltage is fairly balanced, however, there were voltage spikes noticed when power is restored after load shedding. The currents showed that the red phase is heavily loaded when compared to the other phases. Power factor was averaging about 0.8 lagging which is less than the 0.9 lagging recommended by Eskom. The frequency and harmonics were found to be within the limits as recommended by the NRS 048 – 2 and IEEE 519 respectively.

Over 100 residence students participated in the student awareness survey. The survey suggested that the students need some education or awareness when it comes to energy-related matters, from saving energy, cost of energy and energy efficiency. This will make students to be more energy conscious and therefore play their part in saving energy.

The study concluded that the energy efficiency at the residences has not been taken seriously and this requires the hostel and the university management at large to act swiftly as this can be seen as the cost and GHG emission saving opportunities

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Finally, I wish to thank all those who dedicated their precious time to help me, they might not be mentioned here but their efforts will never go unnoticed.

Go lona botlhe, ke re: "Kamoso le kamoso o mongwe, le direng fela jalo le mo go ba bangwe"

Ke lo leboga go menagane!!!

DEDICATIONS

*This thesis is dedicated to my late Father, **Mr MF Lokailwe**. Before his untimely passing, he ensured that he sets up a perfect platform for me to be able to complete my studies since undergrad as he had a dream that I will one day become the first graduate in my family. For that, I will always be indebted to him and I trust he is proud of my academic success.*

*I also dedicate this work to my mother, **Miss KP Phuduhudu**. She has always wanted the best for me and has never given up supporting me through it all, to this date, she still does. I don't know what would have been my destiny in her absence*

Finally, I dedicate this work to all those who were forced to abandon their studies due to life circumstances and to those who are still hoping to enter the doors of a university. I have a belief that they will one day realise their dream.

*To them: **May His Grace and Light shine upon you and if it doesn't he might take his time but he will definitely come through for you***

"There is nothing impossible to him who will try."

Alexander the Great

"Education is the most powerful weapon which you can use to change the world."

Nelson Mandela

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Definition of Terms

1. Energy management is defined as the strategy implemented to adjust and optimise energy usage using systems and procedures to reduce the energy consumption at the same cost or reduced costs (Bureau of Energy Efficiency, 2015b)
2. Energy Audit is a comprehensive, scientific evaluation of the energy-using systems and equipment at a facility to understand costs, identify reduction opportunities, compare with design values or industry values (Terra Firma Academy, 2013)
3. Energy efficiency is using less energy to perform the same task, this can be achieved by reducing energy losses (Feng & Wang, 2017).
4. Power quality is the measure of how voltage, frequency and waveform of the power supply system conform with the established standards (Bollen, 2010)

ACRONYMS/ABBREVIATIONS

AC:	Alternating Current
AP:	Authorised person
ASHP:	Air Source Heat Pump
BEE:	Bureau of Energy Efficiency
CB:	Circuit Breaker
CFL:	Compact Fluorescent Lamp
CoCT:	City of Cape Town
CPUT:	Cape Peninsula University of Technology
DC:	Direct Current
DME:	Department of Minerals and Energy
DOE:	Department of Energy
DSM:	Demand Side Management
EA:	Energy Audit/Energy Auditor
ECO:	Energy Conservation Opportunities
EM:	Energy Management/Energy Manager
EMP:	Energy Management Program
EMS:	Energy Management Systems
ENCON:	Energy Conservation
FM:	Facilities Management
HVAC:	Heating, Ventilation and Air Conditioning
kVA:	Kilo-Volt-Amp
kW:	kilowatts
kWh:	kilowatt-hour
LCC:	Life Cycle Cost
NEES:	National Energy Efficiency Strategy
PCC:	Point of Common Coupling
PPE:	Personal Protective Equipment

RMS:	Root Mean Square
RP:	Responsible Person
RSA or SA:	Republic of South Africa or South Africa
SABS:	South African Bureau Standards
SANS:	South African National Standards
SHE:	Safety Health and Environment
SPD:	Surge Protection Device
TDD:	Total Demand Distortion
THD:	Total Harmonic Distortion
TOD:	Time of Day (rates)
TOU:	Time of Use (traffic structure)

KEYWORDS

- Energy Management
- Energy efficiency
- Energy audit
- Power Quality

CHAPTER ONE

1 INTRODUCTION

Chapter 1 introduces the idea behind the study and lays down the purview of the research topic. It will also present, in a sequential manner, the research problem statement, aim of the study, objectives of the research, research questions, study approach, importance of the study and the structure of the presented study

1.1 BACKGROUND

The electricity supply crisis is perhaps the most obvious of South Africa's current energy security crises, with emergencies in supply being declared in 2008 and once again in early 2014 (Trollip et al., 2014)

During 2008, the energy crisis was declared in the South African energy fraternity where major electricity blackouts in the country were experienced. As a countermeasure, the Department of Energy decided to demonstrate the importance of energy efficiency issues by releasing the first National Energy Efficiency Strategy (NEES) review in the same year (Krupa & Burch, 2011).

NEES was first established in 2005 as part of the resolutions from the white paper on energy policy of 1998, its mandate was to implement energy efficiency programmes to reduce the national energy consumption. Due to the energy crisis of 2008, the NEES programme was fast-tracked hence the NEES review of 2008 (Department of Energy, 2013).

(Laher et al., 2019) also reported that South Africa's power crisis continued even in recent years (2018 & 2019) where the communities experienced continuous load shedding (power outages) because the electricity supply could not meet the demand (Laher et al., 2019).

Load shedding is an intentional and temporary power cut as a measure of last resort implemented by Eskom (South Africa's state-owned power utility) when the supply fails to meet the demand and if not implemented, the results could lead to total countrywide power system collapse. Load shedding is implemented through a strategic rotational electricity shutdown on parts of the network (national grid) in a controlled manner to reduce the demand (Eskom, 2020a).

Eskom has not been able to meet the demand since 2008 because of several reasons such as poor maintenance in the existing power plants, failure to successfully synchronise the newly built power plants, maladministration and allegations of corruption (Laher et al., 2019).

In addition to this, minimum investments in the country's electricity supply also contributed to these power crises (Laher et al., 2019).

The increase in this demand is mainly caused by the economic growth through industrialisation coupled with the electrification of the rural areas, studies show that the demand will be doubled in 2030 (SAinfo, 2012).

These energy problems that South Africa is currently facing require professors, doctors, engineers, scientists, technologists, technicians and all men and women with technological knowledge to perform extensive research and studies on how electrical energy can be produced and consumed for sustainable development. There has been a lot of literature aimed in addressing these energy crises, some looked into alternative and sustainable energy supply (such as renewable energy technologies) as well as demand-side management which includes energy efficiency, energy management, energy audits, energy savings and energy consumption reduction.

1.1.1 ENERGY-SAVING OPPORTUNITIES AND CONSUMPTION IN SOUTH AFRICA

The energy savings can be achieved when focusing mostly on the large energy-consuming sectors such as industrial, residential, built environment (commercial institutions etc.), mining, agriculture and others (transport etc.). Figure 1.1 below shows the energy consumption by each sector as according to (Terra Firma Academy, 2013)

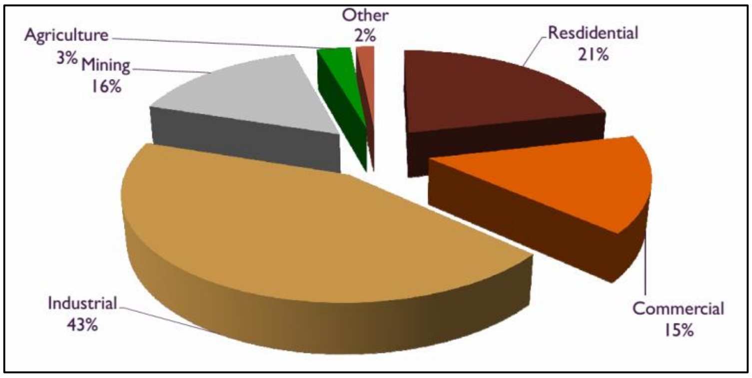

Figure 1.1: Electricity Consumption by Sector (Terra Firma Academy, 2013)

According to figure 1.1, the large consumers of electricity are industrial at almost half (43%) followed by residential at 21%. The mining industry is the third-largest at 16% then on fourth is the commercial at 15%. Most of the literature shows that the commercial and the residential have not received the much-needed attention in terms of saving energy, therefore, help alleviating South Africa's problems

In the built environment, commercial and institutional buildings are the largest consumers mostly during the hours when in operation. Most institutional (in this case, the South African universities) buildings were constructed over 30 years ago and energy efficiency was not taken into consideration as it was not a problem then than today (Maistry et al., 2012).

Based on the study by (Maistry et al., 2012) and (Govender, 2005) whom both performed the energy consumption studies at the University of Johannesburg and the University of KwaZulu Natal respectively came to the same conclusion that institutions of higher learning are energy inefficient and they cost universities a fortune and this is not just the university's problem but for the country as the more energy inefficient the consumers are, there more energy crises persists.

Buildings are considered to have lower average energy usage, such as student accommodations, religious buildings etc. and they do not necessarily receive the much-needed attention in terms of energy consumption assessments as they should. Although there is a perception that the total contribution to energy usage by these types of buildings is insignificant, the energy intensity of any particular building must be considered (Terrill & Rasmussen, 2016).

1.1.2 ENERGY MANAGEMENT

Energy Management is the process of trying to be efficient with energy (using less energy) for the same or even increased output. It's highly regarded as a powerful tool for reducing the Greenhouse gas (GHG) emissions produced as part of the industrial process (International Energy Agency, 2013). Energy efficiency does not only reduce GHG emissions, but a successful energy efficiency program also reduces the electricity bill (International Energy Agency, 2013).

According to (Bureau of Energy Efficiency, 2015b), Energy management is defined as the strategy implemented to adjust and optimise energy usage using systems and procedures to reduce the energy consumption at the same cost or reduced costs. The basic objectives of energy management are: to achieve and maintain the optimum systems energy purchasing and utilisation, to reduce the energy cost while maintaining the same production levels and to minimise the environmental effects.

1.1.2.1 ENERGY MANAGEMENT SYSTEM(EMS)

EMS is possible for the industrial or commercial sector companies by developing a framework for their production equipment which will manage its energy consumption and identify possible opportunities to save energy and to adopt the energy-saving techniques which include costless opportunity. EMS ensures that energy savings don't just happen once but continuously to optimise efficiency. Energy management must be supported by the executive management of the company such that it can be successful (Jelić et al., 2010).

On these bases, the study will look at whether it is possible to apply Energy management systems at the Cape Peninsula University of Technology student accommodation to determine if the usage of electricity, as well as the related costs, can be reduced.

Universities spend a lot of money mostly on the student accommodation buildings which therefore constitutes a considerable percentage of the annual operational costs. Energy cost is not only the factor, but energy usage is also key as it contributes to the electricity shortage, the depletion of natural resources and environmental issues associated with energy production (Maistry et al., 2012; Govender, 2005).

1.2 Problem Statement

In buildings, energy can be consumed in several ways and this depends on the building construction, climatic conditions and building services such maintenance (Harris, 2012). Figure 1.2 below outlines the typical consumptions on a building, it can be seen from the figure that the large consumers are lighting (27%), fans and pumps (24%) as well as heating (19%) and cooling (13%). The rest of the equipment (office equipment, catering and other) are the least consumers and consume about 17% combined

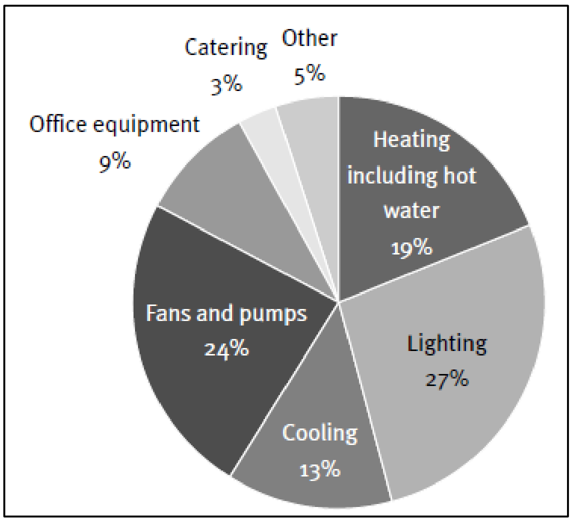

Figure 1.2: Typical energy consumption on an office building based on the British weather (Harris, 2012)

According to studies by (Maistry et al., 2012) at the University of Johannesburg and (Govender, 2005) at the University of KwaZulu Natal, the institutions of higher learning buildings are the most energy-inefficient of all consumers because they are old and at the time of construction, energy-efficiency was not a factor.

The Cape Peninsula University of Technology, like any other South African University, industries, households and business is faced with an increased pressure to regulate, manage and curb the demand of electricity and cost by embarking on energy efficiency programs. This will assist in addressing financial and generation capacity constraints.

Between 1994 and 2007, electricity consumption has increased by 50% while between 2008 and 2014 the cost of electricity has increased by over 200% implying that universities are faced with escalating energy costs. (Maistry & McKay, 2016).

There is no sufficient literature to suggest that the energy efficiency at the CPUT student accommodation has been tested before, therefore, based on this and the studies by (Cao et al., 2016), (Asmar & Tilton, 2015), (Maistry et al., 2012), (Maistry & McKay, 2016) and (Govender, 2005) which were focussed on the energy consumption and energy efficiency at their respective institutions of higher learning and coupled with the fact that CPUT buildings are over 50 years old (Cape Peninsula University of Technology, 2005), there is reason enough to believe that there is a need for a study to be carried out to determine the energy efficiency and energy is consumption profiles at the CPUT's student accommodations and make necessary recommendations based on the findings. If there is a need, possible interventions will be recommended on how to reduce the energy usage and cost, therefore, minimising negative effects of high energy consumption.

The study is necessary for awareness in terms of energy management to ensure that institutions of higher learning such as CPUT form part of a closed circle of energy conservation and demand-side management

1.3 RESEARCH QUESTIONS

1. What are the major consumers of energy at student accommodations?
2. Can the implementation of energy management programs at the South African Higher Institutions of learning contribute to minimising energy consumption?
3. Are there any energy conservation measures in place in the South African Higher Institutions of learning?

4. How does an increase in the electricity cost impact on the South African Higher Institutions of learning's fiscal?

1.4 AIM OF THE STUDY

To determine if student accommodations at CPUT are **energy efficient** and establish if the implementation of the **energy management strategies** can be a possible solution if there are any energy inefficiency issues.

In line with the principal aim, the study will focus on the objectives as outlined in the "objectives of the study" below

1.5 OBJECTIVES OF THE STUDY

1. Survey literature relating to the built environment energy optimisation focussing on:
   a) Energy consumption
   b) Energy efficiency
   c) Energy Audit
   d) Energy management
   e) Power Quality
2. To investigate and analyse the energy consumption at the CPUT buildings (student accommodation) through:
   a) Energy Audit and
   b) Data logging (obtaining the consumption profile through metering)
3. To establish a database of the historical energy consumption on CPUT through:
   a) Logged Data analyses
   b) Electricity Bills analyses
4. Investigate major energy users as well as causes of inefficiencies (if any) and therefore quantify their consumption patterns and identify trends where possible through
   a) Energy Audit results analyses
   b) The Student Survey Analyses
5. Investigate the building's power quality and other related electrical issues.
6. Recommend the energy-saving opportunities and also make recommendations on any other energy-related issues identified.

1.6 METHODOLOGY

Following the agreement with the CPUT's facilities department, Catsville residence (student accommodation building) was made available for the study to be conducted. Interviews were arranged with the Catsville residence supervisors to assist with data collection and the related building information.

This study will investigate the state of energy efficiency and energy management strategies deployed at the university's student accommodation (Catsville residence) if there are any. The findings of this study in conjunction with other studies done at other universities will give the Department of Education, Eskom (the national electricity utility), Department of Energy and all other interested parties an idea on how to approach the universities in terms of energy efficiency.

An energy audit and data logging (using Fluke 1730 power analysers) at the Catsville Residence was performed. Qualitative and quantitative methods were used to analyse the results obtained.

A questionnaire which was given to the residence occupants (students) at the early stages of the study provided additional information regarding appliances used at the residence. The CPUT's facilities department also provided the detailed building layout, however, there was no data on individual equipment and this strongly necessitated the energy audit

1.7 STUDY AREA

The study area is the Catsville residence situated in Browning Road, Observatory, Cape Town, Western Cape. The area is situated in the Northern Suburbs about five kilometres (5 km) outside Cape Town. Figure 1.3 below shows the zoomed-in Observatory to show the exact location of Catsville residence.

Figure 1.3: The Observatory map highlighting the Catsville residence location (Courtesy of Google.com)

The complex consists of 10 buildings, four of the buildings namely Block G, Block H, Block K and Block E are for accommodating students, they accommodate approximately 250, 250, 150 and 150 students respectively. During the analysis of the complex architectural drawing and visits to the complex, it was established that Block G and Block H are identical whereas Block K and E are also identical. The other six blocks are mostly for the CPUT support staff namely, the residence/complex manager's office/house, security booth (guardhouse), etc., whereas others are for student support systems in places such as kitchen services, laundry area, media centre (study rooms and computer rooms) as well recreational rooms.

This study's focussed mainly on Block G (Data collection, metering and energy audit) and the energy bills analysis focussed on the entire complex. Figure 1.4 below shows the aerial view of the Catsville residential complex as obtained from google.com.

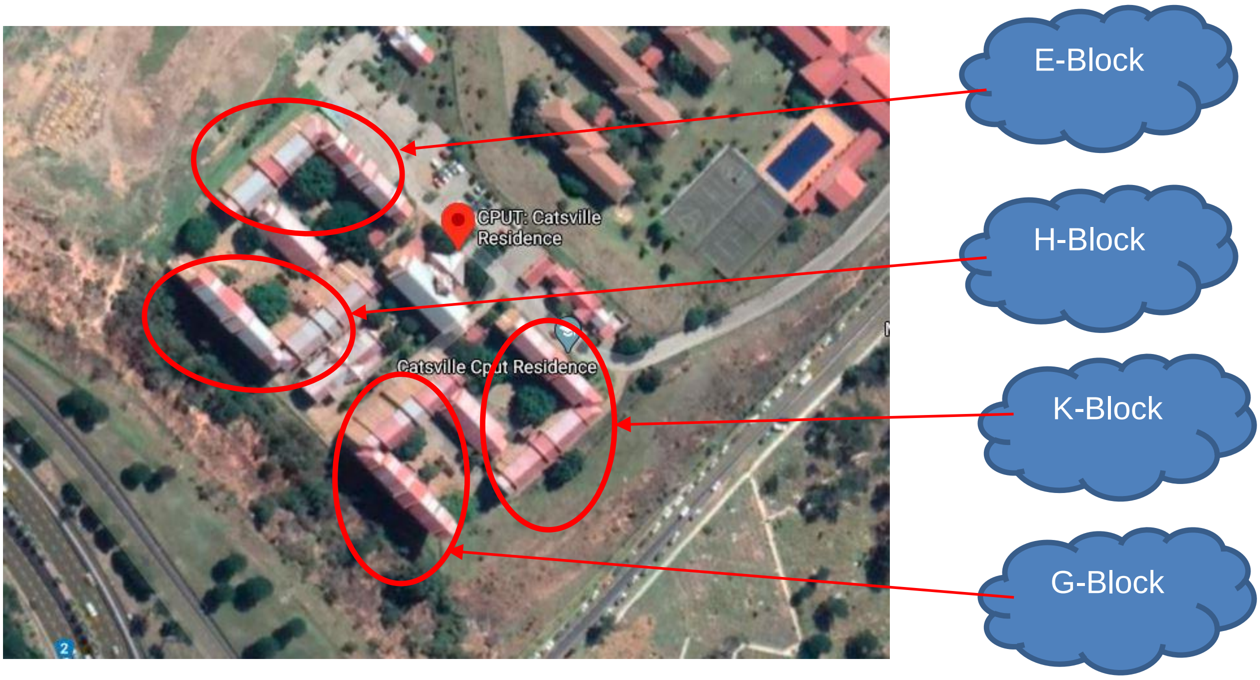

Figure 1.4: Catsville Residence Aerial view (Courtesy of Google.com)

1.8 LIMITATIONS

The study is only limited to the Cape Peninsula University of Technology's selected building (Catsville Residence). The results or recommendations of the study were not implemented due to time and financial constraints. This study will remain available to allow upcoming researchers who are interested in this field to further the study and implement the recommendations.

The study mainly focussed only on one building from the complex namely G-Block, this is because of time constraints, equipment and resource limitations. Furthermore, Block G was chosen as the main focus because it offers large occupancy. The analysis from this block will be used as the base or the sample to provide an idea of what is happening in the student accommodation in terms of energy usage.

1.9 ASSUMPTIONS

- It is assumed that all participants on the study through questionnaires and interviews will have much knowledge about the subject. Further assuming that they will be available, cooperative and respond accurately without prejudice to the questions asked
- It is assumed that reports and records that will be provided regarding the concerned buildings will be accurate and participants will afford correct information
- It is assumed that there will be unlimited access to the proposed buildings, as agreed with the facilities department.

1.10 Ethical Considerations

To protect the image and views of participants in the study, individuals were not recorded on this document. No compensation was paid to any respondent or participant in the study and quality assurance was done through the following monitoring aspects:

- Quality of Data Capturing
- Accuracy in data interpretations
- Accuracy in calculations

1.11 Significance of the Study

It is posited that the outcome of this study could assist the Cape Peninsula University of Technology to make decisions regarding electricity consumption and associated costs more especially at the student accommodations. This is a small (limited scope) research but it can, however, paint a picture of the status of energy in the student accommodations, lessons learnt may be of value to other researchers or the institution if they wish to embark on the energy efficiency programs.

The research sought to somehow integrate or build a link between the facilities (operations) department of the university and the research department. The diurnal consumption patterns obtained can be used as the baseline for future research or comparisons. With profiles metered from the supply during the academic calendar and recess periods, the active, quieter and inactive phases of the university can be established. This gives a clear understanding of peak demands periods. With this data, systems can be implemented to actively manage peak demands and lead to the creation of the energy savings financial model which can assist when motivating energy efficiency or energy savings interventions.

1.12 Outline of the Thesis

This thesis is divided into TEN (10) chapters and they are explained as follows:

1. **Chapter 1: Introduction**

   This chapter (current chapter) introduces the idea of the study in a context of energy management at higher institutions of learning. The foundation of the research is clearly outlined in a form of:

   a) Problem statement with the conceptualisation
   b) Research questions
   c) Aims of the study

d) Objectives of the study
e) Brief on methods
f) Study area
g) Scope and limitation
h) Ethical considerations and
i) The significance.

2. **Chapter 2: Literature Review (Theory) related to the present study**

   Chapter two provides a general literature review on the theoretical background of major concepts involved in the study, namely: energy management, energy efficiency and energy auditing as well as their applications. A theory from previous related research was reviewed with relevant initiatives and interventions highlighted.

3. **Chapter 3: Methodology**

   Chapter 3 presents the methods and research techniques of data collection and instruments used as well as the approach to the analyses of the results. The justification of these research methods is explained including the shortcomings of the research.

4. **Chapter 4: Results: Energy Audit**

   Chapter 4 is the first chapter of the presentation of the results; the chapter presents the energy audit results. The audit was performed at the student accommodation and this gives an idea of how energy conservative or energy-efficient the facility is based on the equipment and processes deployed.

5. **Chapter 5: Results: Energy Consumption**

   Metering was also performed using the FLUKE 1730 power meter, the devices monitored the electricity entering the building. This chapter presents the metering results where energy consumed and power consumed it analysed.

6. **Chapter 6: Results: Power Quality**

   Using the metering results presented in Chapter 5, this chapter examines the power quality based on what was obtained by the data logger. Power quality issues such as voltage imbalances, voltage dips and swells, phase loading in terms of current, frequency, harmonics and power factor are analysed as per the NRS 048-2 and IEEE 519-1992 standards.

7. **Chapter 7: Results: Electricity Bills Analyses**

   In this section, 2-year monthly bills (2018 and 2019) were analysed to determine how much is spent on electricity annually, monthly and daily. Furthermore, this painted a picture of how much energy is consumed by the entire complex, this is of significance as it can bring in the comparison between the consumption profile of one block and the entire complex.

8. **Chapter 8: Results: Student Energy Awareness Survey**

   Chapter 8 analyses the results from the student survey, the survey was given to the students who reside at the Catsville residence. The results here established the perception from the students in terms of commitment, behaviour and awareness with regards to energy efficiency.

9. **Chapter 9: Discussions**

   This chapter describes and interprets the results as obtained from the results chapters, namely Chapter 4, 5, 6, 7 and 8. The chapter explores the results in-depth and goes into detail about the meaning of the findings.

10. **Chapter 10: Conclusions and Recommendations**

    Chapter 10 offers a summary of the thesis, establishes whether the research questions have all been answered and provides the conclusion to the thesis. Furthermore, recommendations towards energy efficiency or energy management at the CPUT residences are outlined with suggestions on future research.

1.13 CONCLUSION

Chapter 1 was introducing the study in terms of what the study wants to achieve and how. The problem statement was established as well as the objectives and the aim of the study

CHAPTER TWO

2 LITERATURE REVIEW

2.1 INTRODUCTION

It is common practice that when the research is conducted, a look on the literature or the existing theory on the subject to be studied is thoroughly looked into to learn of previous work done on the study.

This chapter will look and lay down the theoretical overview of major concepts of the study namely – energy management and its aspects more especially on public and commercial buildings including university infrastructures. This will include energy auditing, the safety requirements when performing an energy audit, energy efficiency, energy cost and billing as well as power quality. Thereafter it will also present the methods or characterisation of these concepts.

2.2 OVERVIEW OF THE SOUTH AFRICAN ENERGY SECTOR

Eskom is the main supplier of electricity in South Africa, supplying about 96% in South African and just over 45% to Africa (Eskom, 2017). The wording “mix” refers to the fact that Eskom uses different technologies to generate electricity.

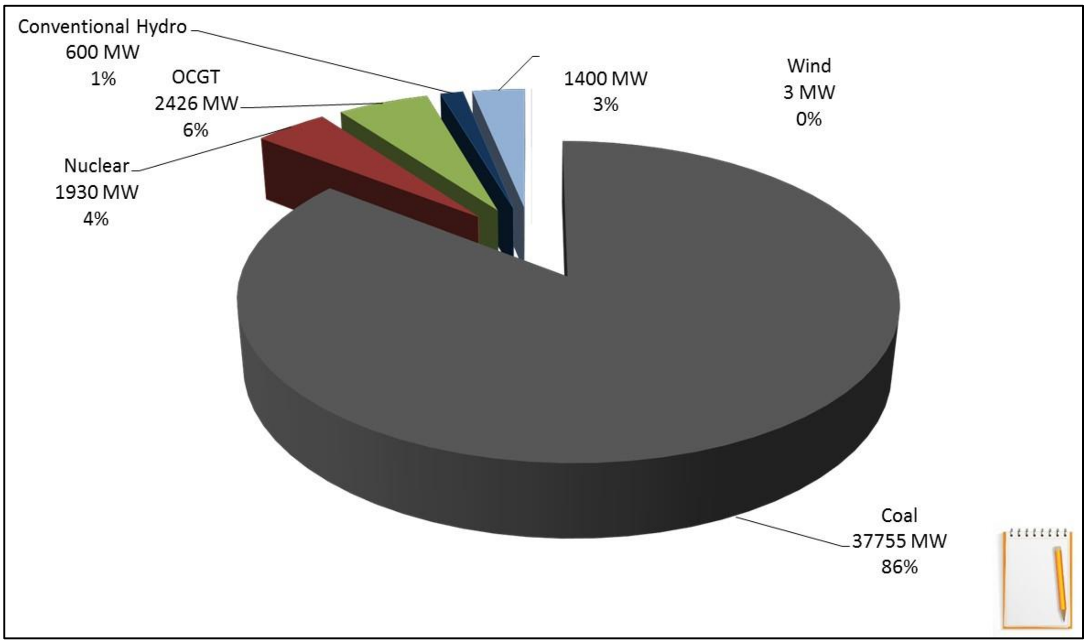

Figure 2.1: South African Energy Mix (Eskom Ltd., 2011)

Figure 2.1 above graphically shows the South African energy mix where coal-fired plants are the largest contributors contributing 38 548 MW. The 14 coal-fired plants run 24 hours

a day to meet the demand, therefore, they are referred to as baseload power stations. The monumental Koeberg Nuclear Power Station, the first in African (currently the only Nuclear plant in Africa) is also referred to as a baseload power plant, produces 1 940 MW from its twin pressurised water reactors daily (Eskom Ltd., 2011; Eskom, 2017).
Adding to the energy mix, Eskom also has the following:

i. Two conventional hydroelectric power stations,
ii. Three hydro pumped storage schemes
iii. Four Open Cycle Gas Turbines
iv. One Wind Farm renewable project contributing 100MW

The Eskom's installed capacity is sitting at 46 246 MW, the two new-builds Kusile and Medupi are still under construction which will each provide additional 4.8 GW to the national grid, the new plants are steadily synchronising with the grid as per completed units (Eskom Ltd., 2011; Eskom, 2017).
With so much power, there are at times where these gigawatts do not meet the demand and this calls for a phenomenon called energy management which will be discussed in the next section.

2.1 ENERGY MANAGEMENT (EM)

2.1.1 INTRODUCTION TO ENERGY MANAGEMENT

This the process of trying to be efficient with energy (using less energy) for the same or even increased output. It's highly regarded as a powerful tool for reducing the Greenhouse gas (GHG) emissions produced as part of the industrial process (International Energy Agency, 2013). According to (Capehart et al., 2005), energy management is the effective use of energy at minimum cost while maximising the profits, this is the main objective of the EM idea.

Successful energy management consists of the following aspects as shown in figure 2.2 below.

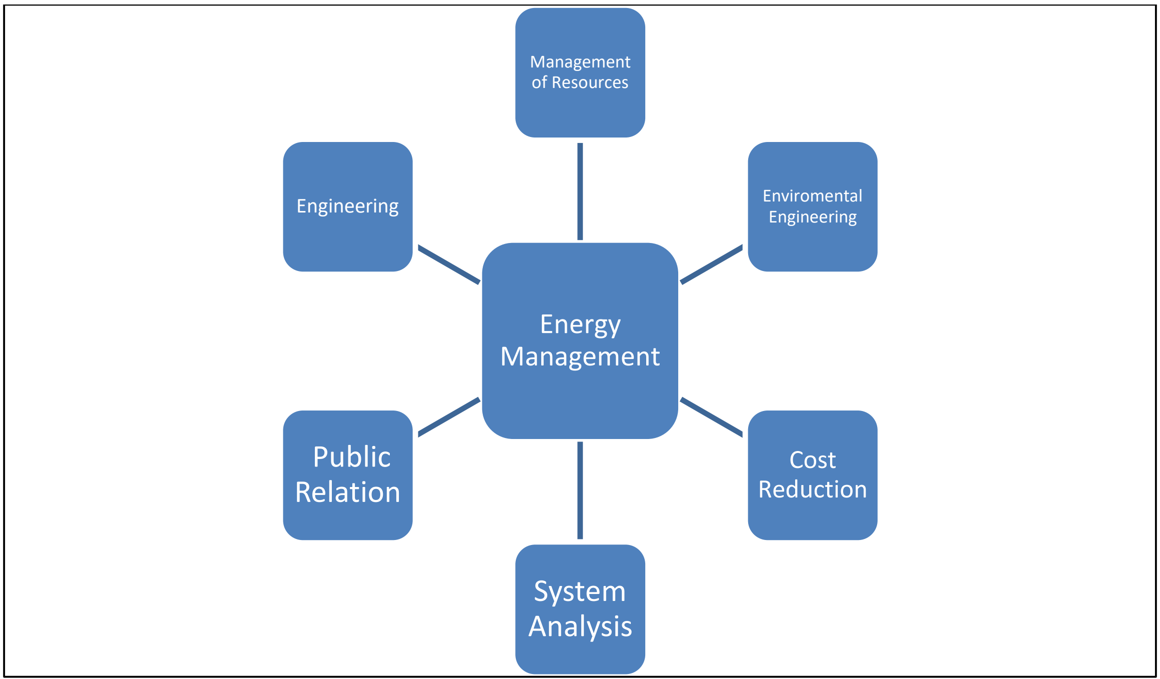

Figure 2.2: Aspects that are necessary for Energy management (Govender, 2005)

(Turner, 2006), explains that energy management is a continuous process and has to be done regularly because:

- Direct cost returns
- Equipment or machinery rapid technological changes, therefore, constant monitoring of new energy-saving opportunities is essential
- Energy security, the contingency plan in case of temporary power outages

2.1.2 ENERGY MANAGEMENT SYSTEM (EMS)

EMS is possible for the industrial sector companies by developing a framework for their production equipment to manage its energy consumption and identify possible opportunities to save energy and to adopt the energy-saving techniques which include costless opportunity. EMS ensures that energy savings don’t just happen once but o a continuous basis to optimise the efficiency. Energy management must be supported by the executive of the company such that it can be successful (Jelić et al., 2010).

2.1.3 ENERGY MANAGEMENT PROGRAM (EMP)

An energy management program is a tool used in conjunction with the relevant stakeholders to meet the set or desired energy-related goals such as improving the energy efficiency on the campus buildings to reduce costs and reducing greenhouse gas emissions (Govender, 2005).

Normally an energy management program consists of three parts namely, **energy audit**, **energy target** and **energy plan** (Bureau of Energy Efficiency, 2015b).

Energy auditing is a process where the energy consumption profile is obtained and then identify the energy-saving opportunities or any energy-saving improvements.

Energy target is the process used in conjunction with the energy audit in terms of identifying the energy-saving opportunities. This energy target is simply an objective of the energy audit such as percentage of energy savings or energy improvement. These targets can only be achieved by assessing the outcome of the energy audit.

Energy planning is the detailed energy efficiency improvement plan which includes energy policies, organisational structures and executions. These processes of energy management program (energy audit, target and plan) are all interconnected.

In addition to this, the energy management program can be measured by three aspects namely, **organisational structure, compatibility of performance indices** and **engineering support.**

2.1.3.1 ORGANISATIONAL STRUCTURE

The organisational structure is very important to a successful energy management program when it offers the required support. The support could be the implementation of relevant policies, regulations, incentives, awards, penalties and human sensitization can greatly stimulate the sustainable energy management program. Policies and regulation can include the time-of-use tariff structures which will provide the load shifting during peak hours therefore the improvement of efficiency on the network. The organisation can also establish human sensitisation measures to support and promote energy management programs such as awareness campaigns, energy alert programs, procedural guidance of workflow, skill training, production exhibition and appointment of energy managers (Turner, 2006)

The organisational structure will have an **organisational plan** as explained below:

The organisational plan should be developed to deal with implementing and monitoring specific EM programs (Govender, 2005). The plan should have the structure that consists of the Energy Manager, Energy team and employees as shown in figure 2.3 below (Turner, 2001).

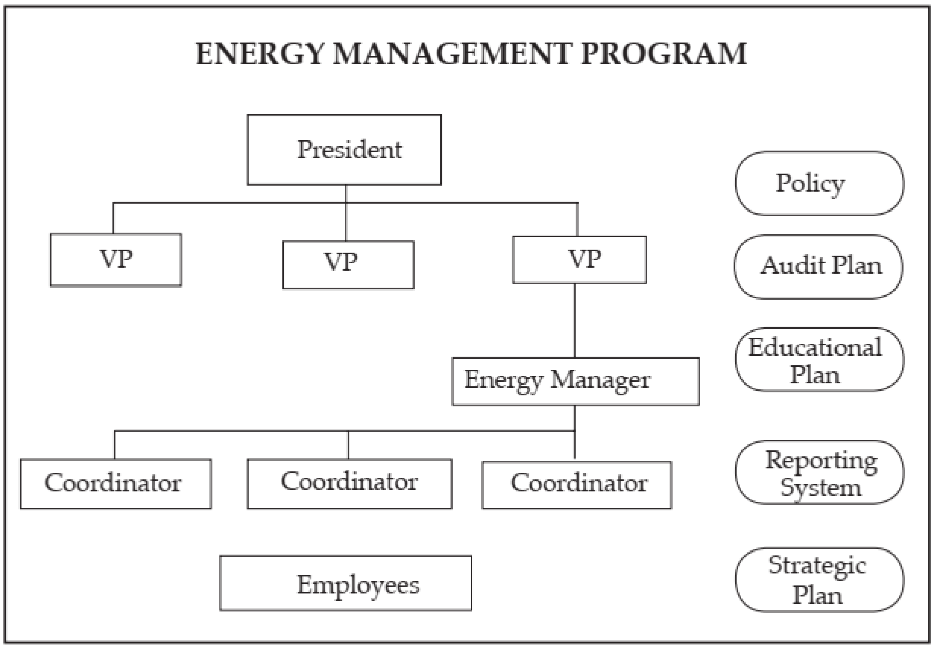

Figure 2.3: Energy Management Organisational Structure (Turner, 2006)

Below are some points that the organisational plan must address:

- Appoint and define the duties of the EM committee or coordinator
- Establish an effective communication strategy between coordinator between the departments and staff
- Design the energy monitoring system
- Motivate and educate the staff and students.

2.1.3.2 COMPATIBILITY OF PERFORMANCE INDICES

Energy system performance efficiency indicators can be classified into engineering and socioeconomic indices. Engineering indices will include energy security, energy sources, energy consumption and other technical indicators. The socioeconomic index will comprise of production, energy cost, labour and environmental impact. These two indicators can sometimes contradict each other, for instance, the purpose of saving energy contradicts the idea of production increase and sustainability (Turner, 2006; Bureau of Energy Efficiency, 2015b).

2.1.3.3 Engineering Support

Engineering analysis, modelling and optimisation are important to provide technical feasibility of an energy system. Energy solutions will be more reliable and provide more sustainability if engineering support is part of the energy management program (Turner, 2006; Bureau of Energy Efficiency, 2015b).

2.1.4 Successful Energy Management

The energy management program can be summarised as shown in figure 2.4 below with points that are regarded as guidelines to successful energy management, this plays an important role such that the energy manager can do his or her work accurately.

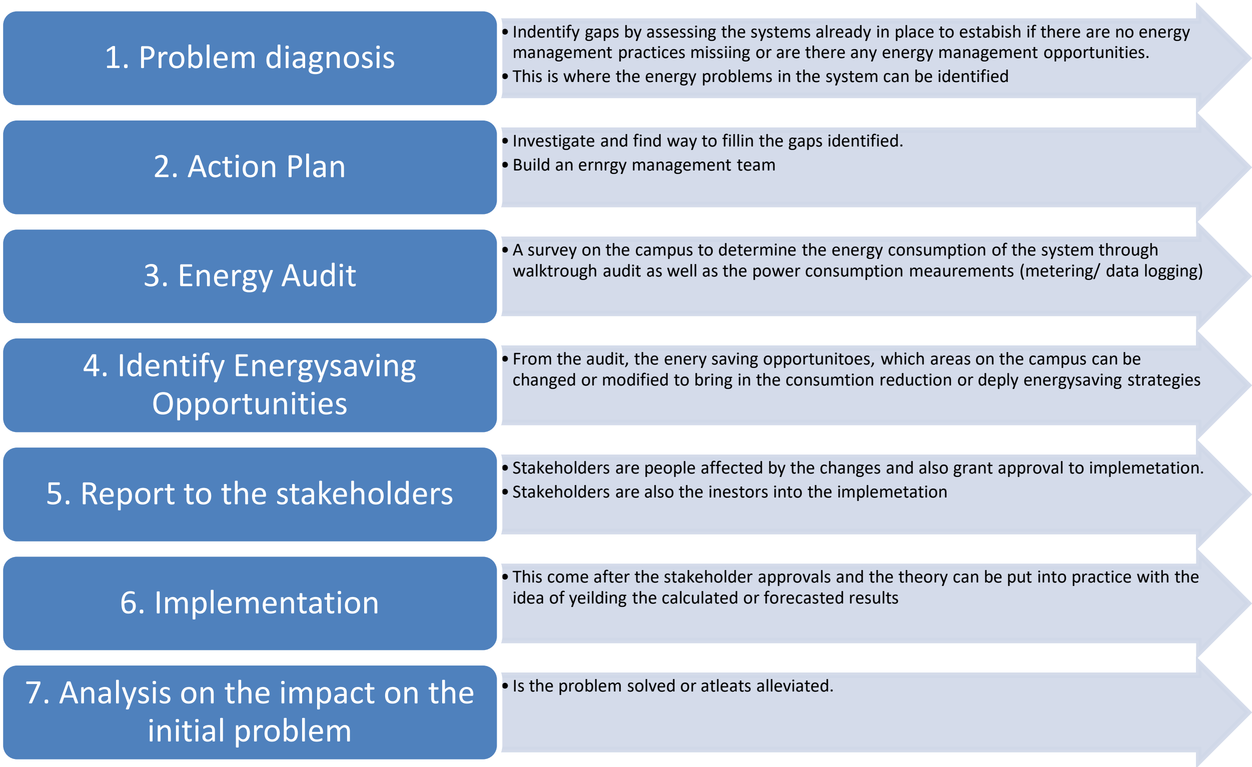

Figure 2.4: Energy Management Program (Govender, 2005; Turner, 2006)

2.2 Energy consumption

The energy consumption refers to all equipment in a system that uses energy to perform the desired functions. Energy consumption is not necessarily limited to one source; it accounts for all possible energy consumed in a particular system as there is a misconception regarding this because in most cases when energy consumption is assessed, only electricity is considered, however, this will not be a true reflection of the energy consumed as there could be many energy sources in the system (Teba, 2020).

Energy usage can be in either residential (domestic), industrial and commercial. According to (Cao et al., 2016), the global primary energy consumption has risen by 85% between 1980 and 2012 with an annual increase of 2% while emission rate increased by 75% at the annual increase rate of 1.7% in the same period.

In the modern-day, most people spend their daily lives indoors and rely on mechanical heating and air-conditioning hence buildings are considered the biggest energy consumers worldwide. in the US, the energy consumption in buildings has risen from 33.7% to 41.1% between 1980 and 2010 (Cao et al., 2016).

2.3 ENERGY EFFICIENCY

Energy Efficiency is by definition the ratio of the output energy to the input energy. This phenomenon is normally used to determine the reasonable use of energy and it is used commonly in energy management programs (Xia & Zhang, 2010).

According to literature, energy efficiency can be summarised into four (4) components namely, Performance efficiency, Operation efficiency, Equipment Efficiency and Technology efficiency. These components are therefore acronymic as POET. hence the acronym POET (**P-performance, O-operation, E-equipment, T-technology**).

The following sections will explain the components of POET in detail.

Performance Efficiency – is another form of energy efficiency measure determined by external factors but deterministic system indicators like energy production, cost, energy sources, environmental impact and technical indicators (Xia & Zhang, 2010; Xia et al., 2012).

Operation efficiency – this type of energy efficiency is measured by evaluating various coordination of system components. The coordination of system components consists of three parts namely, physical, time and human. These parts can also be indicated by sizing and matching (physical), time control (time) and skills level (human) (Xia & Zhang, 2010; Xia et al., 2012).

Equipment efficiency – is the measure of the components energy output of individual energy equipment in terms of input energy and equipment technology design specifications. When the equipment efficiency is evaluated, the equipment should not be connected with other equipment or the system components. The equipment efficiency is evaluated by considering specific indicators, namely, capacity; specifications and standards; constraints;

and maintenance. Constant maintenance and standard compliance are more critical to equipment efficiency (Xia & Zhang, 2010; Xia et al., 2012).

Technology efficiency – this is the measure of energy conversion efficiency, processing efficiency, transmission efficiency, and usage efficiency. This is also in line with the law of conservation of energy. The following indicators are normally used to evaluate the technology efficiency: feasibility, life cycle cost and return on investment and coefficient of the conversion, procession and transmission rate (Xia & Zhang, 2010; Xia et al., 2012).

2.4 ENERGY AUDITING

It is a comprehensive, scientific evaluation of the energy-using systems and equipment at a facility to understand costs, identify reduction opportunities, compare with design values or industry values (Terra Firma Academy, 2013). According to (Harris, 2012), energy auditing is very critical in energy management.

An energy audit provides information regarding the system's current consumption, potential energy-saving opportunities and interventions based on the audit results (Terra Firma Academy, 2013).

The Indian Energy Conservation Act of 2001 (INDIAN MINISTRY OF LAW & JUSTICE AND COMPANY AFFAIRS, 2001) defines energy audit as, " *The verification, monitoring and analysis of the use of energy and submission of technical report containing recommendations for improving energy efficiency with cost-benefit analysis and an action plan to reduce energy consumption."*

In addition to this, (Bureau of Energy Efficiency, 2015b) defines energy auditing as monitoring, verification and analysis of the use of energy in a particular system including of drafting of a technical report containing recommendations on energy-saving opportunities with an ultimate goal of reducing consumption and energy costs while maintaining the same production level.

In countries like the United States, an energy audit is referred to as an energy assessment (Hasanbeigi & Price, 2010). Furthermore, (Hasanbeigi & Price, 2010) explains that the energy audit can be classified into two types, preliminary audit (Walkthrough) and detailed audit (diagnostic)

Most literature and guidebooks conclude to the same definition of the energy audit,

2.4.1 OBJECTIVES OF ENERGY AUDIT

In most cases, the objective of energy audit varies from the application or electrical system to another, it can either be industrial, commercial or residential audits. However, the most common objective of the energy audit is to understand energy usage in the system and find opportunities or room for energy savings improvement. All these contribute to the main objective which is to reduce cost (Hasanbeigi & Price, 2010).

(Terra Firma Academy, 2013) literature is in agreement with (Hasanbeigi & Price, 2010) as they list the following as the aims and objectives of the energy audit in an organised manner:

- Understanding costs
- Identify reduction opportunities
- Benchmark against design values or industry values

2.4.2 TYPES OF ENERGY AUDITS

There several types of energy audit and the type of energy audit to be deployed depends on the type of industry, the scope of what must be audited and the potential and magnitude of the desired cost reduction. The five types of energy audits are **preliminary audit, targeted audit** and **detailed audit** (Bureau of Energy Efficiency, 2015b)**.**

Preliminary energy audit

Also referred to as the walkthrough audit and diagnostic audit is a quick exercise that uses the readily available or easily obtainable data. The scope of the said audit is as follows:

- Establishing energy consumption (probable sources: energy bills and invoice
- Obtain related data to what consumes energy
- Estimate the Scope of the energy savings
- Identify the most likely energy saving opportunities (e.g. lights, temperatures etc.?)
- Identify the immediate and low/no-cost energy efficiency improvements opportunities
- Setup the consumption baseline of the energy consumption
- Identify areas that will require a detailed audit/study/measurements

Targeted energy audit

It is often the results of the preliminary energy audit findings, they provide a detailed analysis and data on specific targeted projects or appliances. Projects may be a lighting system as a target with a view of effecting energy efficiency or energy savings. This audit has to be detailed about the targeted projects, details include surveys of the targeted subject and analyses of the energy flows and costs associated with the targets. The outcome of this audit will be the recommendations on actions to be taken.

Detailed Audit

This is the combination of preliminary audit and targeted energy audit (both explained above) as it is a **comprehensive energy audit** and the outcome is a detailed energy project implementation and execution plan since this type of audit covers all the energy-consuming equipment in the system being audited. It is also considered a more accurate audit when it comes to energy savings and cost. It further includes detailed energy cost savings and the projects implementation and execution cost.

When the energy manager conducts a detailed energy audit they aim to obtain an energy balance through an inventory of energy-using systems, assumption of current operating conditions, measurements and calculation of energy usage.

A detailed energy audit is carried out in three phases namely**: Pre-audit phase, audit phase** and **post-audit phase**. Section 2.4.6 explains how these three phases of an energy audit are conducted and section 3.5.2 shows how energy audit was conducted in this document.

The diagram is shown in figure 2.5 (on the next page) shows the flowchart that depicts the proposed work procedure for energy audits in buildings. From this diagram, the energy auditor can be able to determine if he/she should continue with other levels of energy audit after performing the preliminary energy audit and this decision depends entirely on how well the investor was convinced.

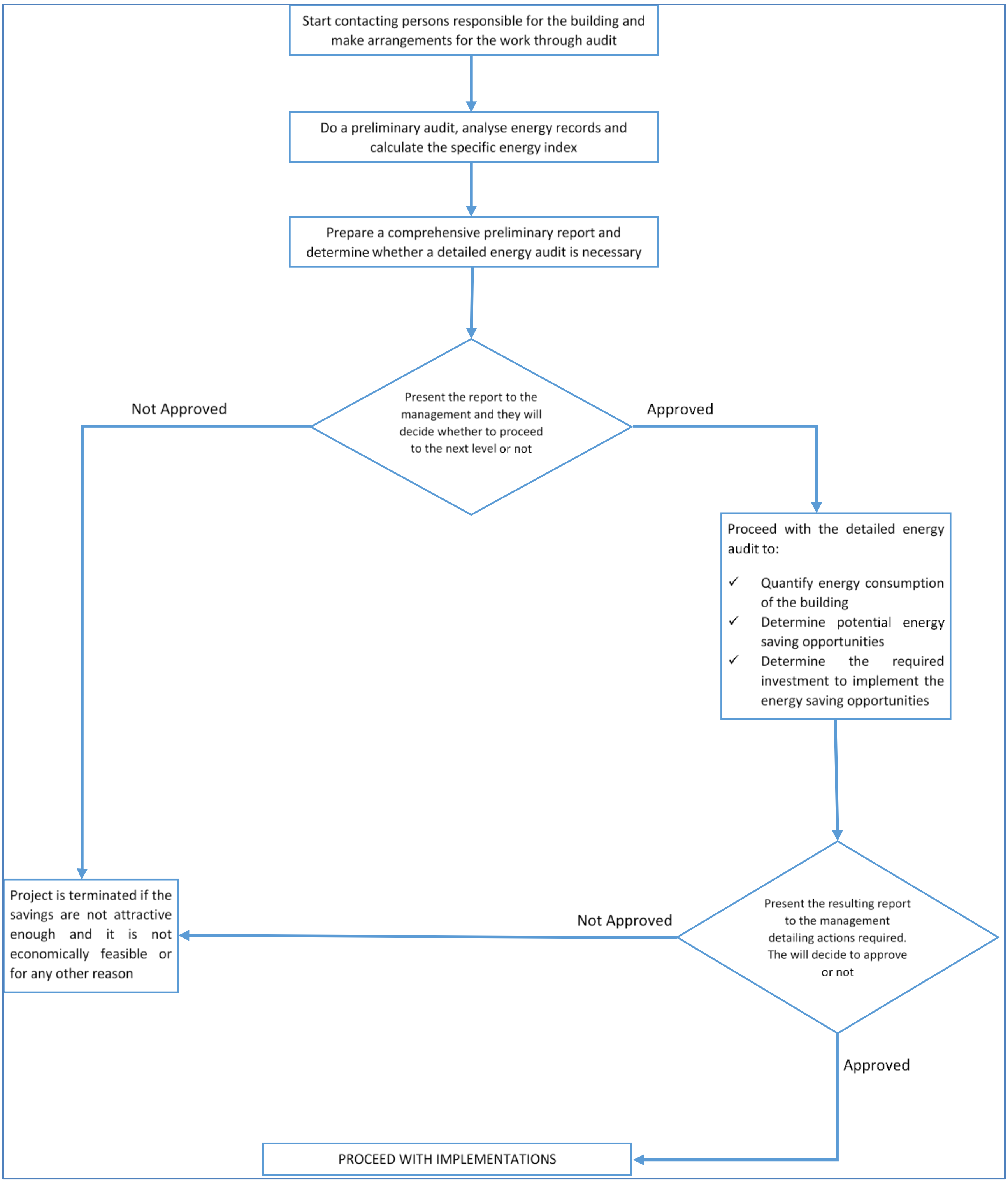

Figure 2.5: Flowchart on how to conduct Energy Audit (Govender, 2005)

2.4.3 INDUSTRIAL ENERGY AUDITS

The industrial energy audit is the energy audit carried out in large industrial enterprises to collect all the company's energy consumption profile. In the case of major industrial enterprises, the energy audit must be carried out regularly as energy-savings can be significant for the company's development. In some countries, energy audits in industrial sectors are governed by rules and policies (Hasanbeigi & Price, 2010)

Industrial audits are commonly complicated because there is a large variety of equipment that must be considered for audit. Equipment that can be found in the industries ranges from large chillers, boilers, ventilating fans, water heaters, coolers and freezers, to extensive lighting systems. These types of equipment can also be found in large office buildings or shopping centres (large office buildings and shopping centres fall under the commercial sector which will be discussed in the next section). Industries will also have small cogeneration systems which are also common in the commercial sector (Capehart & Spiller, 2001).

The fundamental difference between the industrial and commercial sector (in terms of equipment to audit) is those specialised types of equipment that are used for specialised industrial processes and operations. This specialised industrial equipment becomes one of the huddles the energy manager or energy auditor will experience as they have to learn how these machines operate and their function so that they can come up with improvements to processes and suggest the best way to improve the efficiency of these types of equipment or suggest any other equivalent that is efficient so that they can save energy, therefore, the cost (Capehart et al., 2010).

2.4.4 COMMERCIAL ENERGY AUDITS

Commercial audits range from very simple energy audits of small office areas to a very complicated multi-story building or large shopping complexes, centres or malls. Complicated commercial energy audits are performed similarly to those of industrial. Commercial audits consider structural envelope features of the facility as well as large or specialised equipment at the facility. The building envelope of malls, office buildings, shopping centres is very complicated when being examined and evaluated. Building materials, insulation levels, door and window construction, bay windows, and numerous other envelope features must be considered to identify candidate ECO's (Capehart et al., 2002).

Commercial buildings do have large equipment such as chillers, space heaters, water heaters, refrigerators, heaters, cookers and bulk of office equipment such as computers, laptops and copy machines. In addition to this, some commercial buildings like schools, universities and hospitals do have small cogeneration systems. In the commercial sectors, potential ECOs are improving the efficiency of heating equipment (reduce lost heat) and/or operational changes to use less expensive and energy-efficient equipment among others (Capehart & Spiller, 2001)

2.4.5 RESIDENTIAL ENERGY AUDITS

Energy audits of large multi-story apartments (block of flats) can be very similar to that of commercial audits as outlined above. In the single-family residences, audits are fairly simple. This type of audit (on a single-family residence), mainly focuses on the thermal envelope and the appliances such as the heater, air conditioner, water heater (e.g. geysers), lighting and plug loads (e.g. kettles. Television set, Laptop and phone chargers, microwave). To begin, the auditor needs to obtain past energy bills and analyse them to determine if there are any patterns or anomalies.

On the actual audit visit, the structure is examined for the level of insulation, the conditions of the seals on doors and windows and the ducting integrity. Forms of heating such as water heater, space heater and/or air conditioning are also inspected as well as lighting then their size, age and efficiency levels are recorded for analysis.

After these analyses, the auditor can now make a recommendation on the possible ECOs such as adding insulation, adding double-pane windows, window shading or insulated doors, and changing to higher efficiency lighting, heaters, air conditioners, and water heaters. With this in mind, the auditor then calculates the cost-benefit and the breakeven point as well as the payback period for the owner of the house to evaluate.

2.4.6 OVERVIEW ON HOW TO CONDUCT COMPREHENSIVE BUILDING ENERGY AUDITS

Energy auditing consists of three distinct parts or phases, namely, **phase 1 – pre-audit** (pre-survey data collection) **phase 2 – Audit** (the building survey), **phase 3 – Post Audit** (data analysis, identifying energy-saving opportunities and results report) (Turner, 2006). The diagram in figure 2.6 below outlines the process graphically.

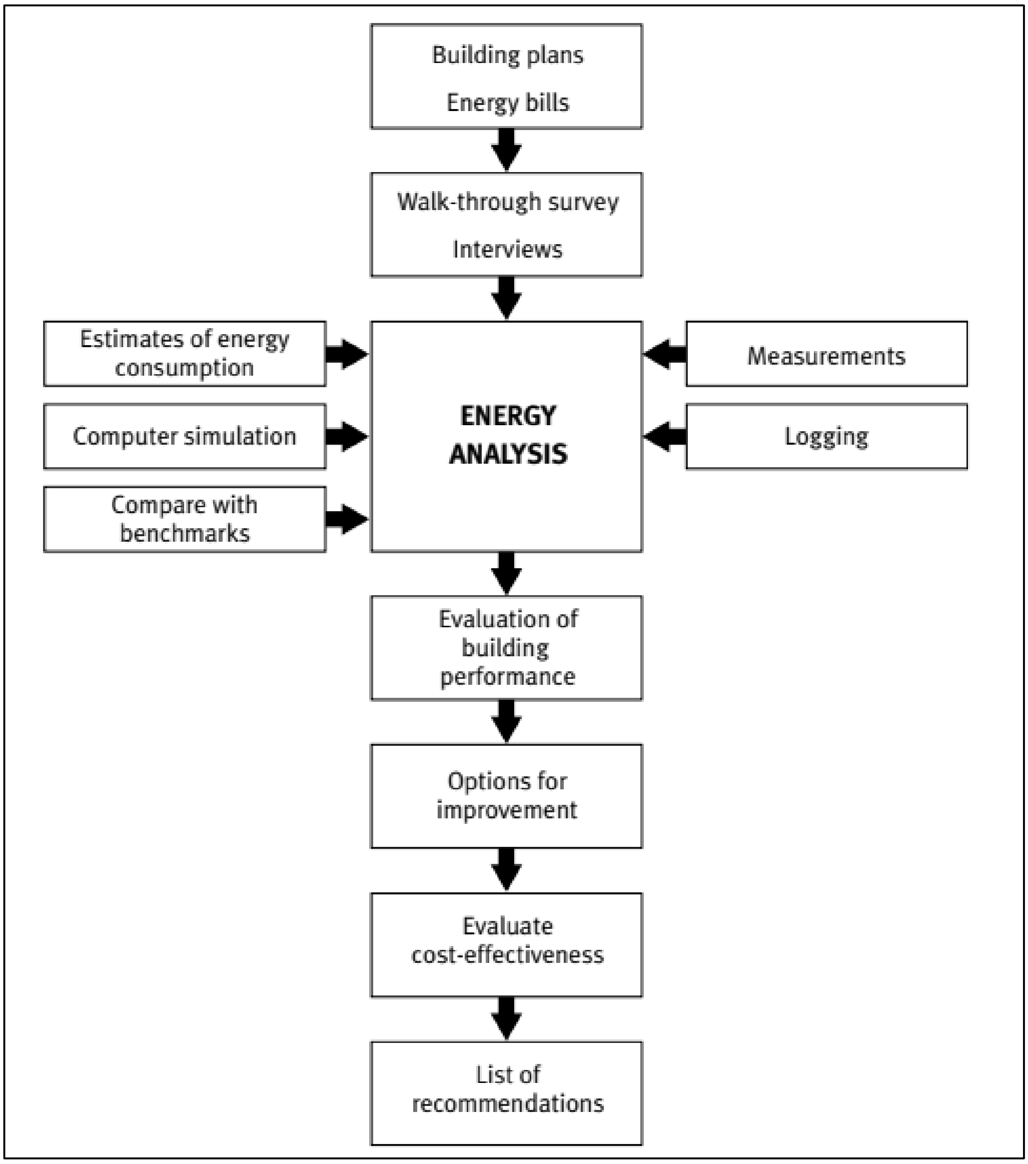

Figure 2.6: Energy audit process summarised (Harris, 2012)

As aforementioned in section 2.4.1 above, a detailed/comprehensive energy audit is the combination of the preliminary audit and target audit and it consists of three phases namely, **pre-audit, audit and post-audit**. The next section will unpack these three phases.

2.4.6.1 Phase 1 – Preliminary Audit/Pre-Audit

The preliminary energy audit consists of the following aspects:

- Planning and organising
  - Establish the energy audit team
  - Make arrangements for needed instruments and set time frames
- Informal Interviews
  - with Energy manager/building manager (or production/plant manager in a case of the industrial energy audit)
  - Issue questionnaires tailored for each department of particular interested
- Walkthrough energy audit
  - Collection of Data
- Results analysis
- Specific energy consumption index calculations
- Conclusion and recommendation. These recommendations will outline if there is a need for a comprehensive audit or not.

2.4.6.2 Phase 2 – Detailed Audit

The type of audit consists of the following aspects:

- Collection Detailed data and information
- Energy recording over a specific period
- Results analysis
- Identification and development of Energy Conservation (ENCON) opportunities or potentials
- Computation of the total energy savings and related capital cost
- Cost-Benefit Analysis
  - Assessment of the technical feasibility, economic viability and prioritisation of ENCON options for implementations
- Reporting and presentation of recommendations to relevant stakeholders

2.4.6.3 Phase 3 – Post Audit

This phase is all about recommendations to the relevant stakeholders. The recommendations include the following:

- It outlines the energy management decision and directions that the company must embark on
- capital improvements
- Measuring of results achieved and the relevant control measures necessary for
- ongoing energy management.

2.4.7 Measurements, Instrumentation, And Data Collection (Basic Components Of An Energy Audit)

Energy auditing can be classified in terms of measuring equipment. According (Terra Firma Academy, 2013) and (Turner, 2006), there are five categories of measuring equipment, namely:

1. Electrical Performance
    a. Voltage
    b. Current
    c. Power Quality
    d. Lux meter
    e. Demand profiles (Data-logger)
2. Temperature Measurements
    a. Infrared thermometer
    b. Infrared camera
    c. Thermocouple probe
    d. Surface pyrometer
3. Humidity Measurements
    a. Psychrometer
4. Combustion Measurements
    a. Oxygen
    b. Carbon dioxide
5. Pressure Measurement
    a. Manometer
    b. Draft gauge
    c. Bourdon gauge
6. Leak detection (Steam Compressed air)
    a. Ultrasonic leak detector

Below is the explanation of some of the tools/equipment that are required to measure the categories above (Turner, 2001; Bureau of Energy Efficiency, 2015b):

- Measuring tape: This tool is essential for obtaining the dimensions of walls, ceiling, windows and possibly the length between appliances (for cases where two light fittings are fitted in one room)
- Lux meter: for measuring the illumination levels to allow direct comparison between the required lighting according to standards and the already installed lighting. The auditor will, therefore, be in a position to determine the exact energy-efficient light to recommend
- Thermometers: To generally measure the temperature of the room or the area
- Infrared camera: To check overheated wires, connections, neutrals, motors, transformers etc.
- Voltmeter: To measuring the voltages on equipment, this tool is versatile for cases where the nameplate of the equipment has worn out
- Ammeter: preferably a clamp-on meter as there are no connections required. This is used to measure current drawn by each equipment
- Wattmeter/Power Factor meter: To measure the consumed power and the power factor of individual reactive components.
- Data logger: To record the energy or power consumption events for a set period.
- Safety equipment: The use of PPE (personal protective equipment) is very important when performing energy audits. A good pair of safety glasses and the safety boot are very essential to wear.

2.5 ENERGY POLICIES, CODES, STANDARDS AND PROTOCOLS

2.5.1 ENERGY EFFICIENCY POLICIES IN SOUTH AFRICA

This section discusses the energy policies that were implemented by the South African government

2.5.1.1 THE WHITE PAPER ON ENERGY (1998)

South Africa's White paper on Energy policy of 1998 states that energy security must be strengthened using the primary resource available in the country. Furthermore, electricity generation must be increased to accommodate economic growth and social progress. This must be achieved while climate change conscious (Department of Minerals and Energy of the Republic of South Africa, 1998).

The policy paper had five objectives as follows (Bukula, 2008):

- **Increase access to affordable energy services –** promotion of access to electricity for disadvantaged households, small businesses, small farms and community services
- **Improving energy governance –** clarification of various government institutions roles in the energy sector as well as consultation with the relevant stakeholders on implementing energy policies
- **Stimulating economic growth** – creating an investor-friendly climate by allowing competition in the energy markets
- **Managing energy-related environmental and health impacts –** making sure there is a balance between using fossil fuels and environmental or health issues it comes with
- **Securing supply through diversity –** the diversity of supply through various available primary energy carriers
- **In terms of energy efficiency –** the government at the time knew that there is a significant existing potential for energy efficiency improvements in South Africa.

The government through this paper outlined the following (Department of Minerals and Energy of the Republic of South Africa, 1998):

- The paper recommended that energy efficiency policies be implemented while mindful not interfere with the energy markets.
- The papers also stated that the government recommended/encouraged energy efficiency be a norm across both the commercial and industrial sectors
- The government will establish norms and standards for commercial buildings and industrial equipment as well as guidelines for the thermal performance of housing.
- The paper also recommended the domestic appliances labelling programmes (rating specifications) as well as ensuring the purchasers of the appliances know what exact purpose of the appliances through publicity campaigns
- Promote improved combustion techniques for fuelwood and other traditional fuels.
- Government to implement energy efficiency programs to reduce energy consumption in its buildings
- Set targets for industrial and commercial energy efficiency improvements as well as monitoring

- The government will establish an institution that will be mandated to implement energy efficiency strategies.

The following section looks at the energy efficiency strategies

2.5.2 NATIONAL ENERGY EFFICIENCY STRATEGY (NEES - 2005)

As stipulated in the white paper on energy policy of 1998, the department of energy (currently known as the Department of Mineral Resources and Energy) was mandated to pursue the energy efficiency programmes as they are seen as the cost-effective option of reducing energy consumption (Department of Energy, 2013).

The department of energy (DOE) came up with National Energy Efficiency Strategy (NEES) which was first endorsed by the cabinet in 2005 and it was established to explore the potential for improved energy usage through reducing the national energy consumption, therefore, reducing GHG (greenhouse gas) emissions (Department of Energy, 2013; Dme, 2005).

The NEES targeted the energy consumption to be at 12% in 2015 and the following sectors were seen as the potential for improving efficiency (Department of Energy, 2013; Dme, 2005):

1. Industrial and mining – target reduction of 15%
2. Commercial and public buildings – 15%
3. Residential – 10%
4. Transport (10%)
5. Power Generation sector (15%)

Each sector above had its 10 years (2005 – 2015) forecasted targets drawn up based on the year 2000 baselines as well as the economic development and population growth (Department of Energy, 2013; Dme, 2005).

The NEES of 2005 vision was Reducing the energy intensity of the economy through energy efficiency"

2.5.2.1 NEES REVIEWS

Amid the 2008 energy crises, the NEES of 2005 went through its first review but it was not favourable to most stakeholders based on the outcome of the public consultation process. The stakeholders needed more radical alterations including clear definitions of energy efficiency, monitoring system and baseline information (Department of Energy, 2013)(DME, 2009).

The NEES review rested on three goals: 1) Social Sustainability, 2) Environmental Sustainability and 2) Economic Sustainability.

The three goals are explained below (DME, 2009):

Social Sustainability:

1. **Improving the nation's health** – energy efficiency reduces the emission of harmful substances to human health
2. **Job creation** – studies show that jobs will be created by the spin-off effects of energy efficiency implementation
3. **Alleviate energy poverty** – If homes are energy-efficient, they make provision for increased supply of energy to more households in the community at affordable prices

Environmental Sustainability:

4. **Reduction of environmental pollution** – energy efficiency reduces the emission of harmful substances to the environmental health
5. **Reduce CO_2 emissions** – energy efficiency is an effective way of reducing GHG emissions

Economic Sustainability:

6. **Improve industrial competitiveness** – most cost-effective ways of maximising profitability are the adoption of appropriate energy efficiency measures
7. **Enhance Energy Security** – energy efficiency will significantly reduce import of primary energy sources such as crude oil.
8. **Reduce the necessity for additional power generation capacity** – Energy efficiency is an integral part of managing electricity shortage.

In 2011 the second round of NEES review was conducted and it mainly focussed on formulation on required legislations, regulations and standards (these standards are discussed in the next section). The 2011 review was endorsed and gazetted in 2012 (Department of Energy, 2013).

In the 2014's review, the energy efficiency target and monitoring system was established to mainly monitor the progress on meeting the original targets which were set in 2005. The results showed that there was significant progress made between 2000 and 2012 and most sectors exceeded expectations (DOE, 2016).

Table 2.1 below shows the improvements (DOE, 2016).

Table 2.1: The improvements on the NEES

Sector	2015 target (based on 2000 baseline)	Performance in 2012
Economy wide	12%	23.7%
Industry	15%	34.3%
Residential	10%	28.2%
Commercial & public	15%	0.3% (electricity only, 2003-13)
Transport	9%	14.1%
Power Sector	15%	26% (estimate by Eskom)

In 2016, the DOE released the post-2015 NEES which aimed to build on the achievement as on table 2.1 above with an idea of stimulating further energy efficiency improvements by combining fiscal and financial incentives as well as the robust legal and regulatory framework. The strategy was drafted such that it will complement the policies and strategies of the following Departments: Environmental Affairs, Public works, Science and Technology, Trade and Industry, transport as well as National treasury (DOE, 2016). The NEES came with the standards as discussed in the next section

2.5.3 SA'S ENERGY EFFICIENCY MANAGEMENT STANDARDS

The following are standards regarding energy efficiency in South Africa.

Building Environment Design – Energy efficiency: This is SANS 16818 of 2010. This standard deals with the design of energy-efficient buildings. It can also be used for retrofitting on existing buildings (SABS, 2010a).

Measurement and verification (M&V) of energy savings: the SANS 50010 of 2011. This standard deals with harmonising or standardising the M&V such that all entities seeking to achieve energy efficiency can have a similar approach yielding uniform results (SABS, 2011b).

The energy efficiency of electrical and electronic apparatus: SANS 941 of 2014. This standard was designed in line with the white paper of 1998 and NEES of 2005 which required the households to be energy efficient. The standard, therefore, covers the energy efficiency requirements, measurements methods and energy efficiency labelling of several household appliances which are stipulated in the SANS 941:2014 (SABS, 2014c)

Energy Audits – Requirements with guidance for use: the SANS 50002 of 2014. This standard sets a minimum set of requirements for the identification of energy performance improvement opportunities. The energy audit is the detailed energy performance analyses of an organisation, equipment, or processes (SABS, 2014b).

The energy efficiency of electric lamps for household use measurements methods: SANS 50285 of 2010. This standard deals with test conditions and measurement methods of luminous flux, lamp wattage and lamp life as given on a label on the lamp packaging as well the procedure for verification of the declared values (South African Bureau of Standards, 2010).

Energy efficiency in buildings: SANS 204 of 2011. This standard deals with requirements for energy efficiency in buildings and services in buildings with natural environmental control and artificial ventilation or air conditioning systems (SABS, 2011a).

Energy performance certificates for buildings: SANS 1544 of 2014. This standard specifies the requirements for developing energy performance certificates for new/existing buildings that compare the energy performance of the building with a reference energy consumption (SABS, 2014a).

Building Environment Design – Guidelines to assess the energy efficiency of new buildings: SANS 23045 of 2009. This standard is to assist building designers and practitioners when collecting and providing useful data that are required for energy efficiency. The standard applies to new buildings and is mainly for space heating/cooling equipment and the heating plant (SABS, 2009).

2.5.4 ELECTRICAL SAFETY STANDARDS

This will be done in accordance to the Electrical Installation Regulations, 2009 from Occupational Health and Safety Act, 1993 by the Department of Labour which states that "The purpose of the Act and specifically the Electrical Installation Regulations, 2009, is to ensure the safety of persons in so far as electrical installations and the performance of installation work is concerned and makes provision for

- the compulsory use of an approved health and safety standard for electrical installations;
- safety aspects relative to electrical installation work;

- the registered persons who exercise general control over electrical installation work and those persons who have to inspect electrical installations;
- the inspection and test of electrical installations by suppliers, persons registered with the Engineering Council of South Africa, competent persons and approved inspection authorities, only in so far as it is necessary and practical and in the interests of safety" (Department of Labour, 2012)

2.5.5 SANS 204:2011 SOUTH AFRICAN NATIONAL STANDARD: ENERGY EFFICIENCY IN BUILDINGS

This South African standard was approved by National Committee SABS SC 59G, Construction standards Energy efficiency and energy use in the built environment under procedures of the SABS Standards Division, in compliance with annexure 3 of the WTO/TBT agreement.

2.5.6 NATIONAL BUILDING REGULATIONS

SABS 0400·1990 is the South African standard on building regulations. According to (Nedbank Sustainability Institute, 2011) these are some of the regulations quoted from the policy:

- XA1 – buildings are to use energy efficiently and reduce greenhouse gas emissions following a set of requirements.
- XA2 – not more than 50% of the annual volume of domestic hot water should be supplied through electrical resistance heating, i.e. 50% or more of hot water used must be heated by energy sources other than electricity.
- XA3 – compliance with the XA1 Regulations must be achieved by one of three methods. If practitioners build per SANS 10400–XA, the buildings will be 'deemed to comply' with National Building Regulation XA1.

(Nedbank Sustainability Institute, 2011)

2.5.7 COMMON ELECTRICAL HAZARDS

2.5.7.1 ELECTRICAL SHOCK

As it is common knowledge to the personnel in the field of electrical engineering, electricity is extremely dangerous because it is not visible to the human eye (Atkinson-Hope, 2000). It is therefore impossible to tell if the conductor or terminal is alive or dead by just looking at it, to avoid the electrical shock, the terminal or conductor must be tested first by using an appropriate, calibrated, approved and functional tester. Thereafter it should (must) be made safe by de-energising it and making sure that no one else can re-energise it (Gass, 2009). According to (Atkinson-Hope, 2000) the is known procedure commonly used in the industry named “Gang Lock” which is used for energising and de-energising circuits men are to work on.

2.5.7.2 Electrical Burns

When dealing with any circuits with Low voltage (50 to 1000V), medium voltage (2.4kV to 69kV), High Voltage (115kV to 230kV), Extra High Voltage (345kV to 765kV) or Ultra High Voltage 1100kV, it no necessary to touch live conductor or terminals to get burned (Brown, 1989; Gass, 2009). Sometimes when a person comes very close to the conductor that is not properly insulated, air can be ionised and break down then form a conducting path between them and earth. This can also happen when dealing with energy storing devices like capacitors or inductors when they are not properly discharged after de-energisation (Gass, 2009)

2.5.7.3 Fire and Explosion

When working with voltages mentioned above in 2.6.4.2, there is a great danger of fire and explosion due to large fault currents that can flow in the system. Oil circuit breakers (OCBs) and oil mini substations (MSS) and ring main panels (RMPs) pose a particular threat. In not so uncommon cases, the human error can also cause faults which can result in fire and explosion, for example, and an operator can mistakenly power up the system while the other end is earthed (Gass, 2009).

2.5.7.4 Heat Build up

When wires are coiled, they behave like an inductor and generate unnecessary extreme heat which can also result in insulation degradation (Atkinson-Hope, 2000). In other cases, the path or route the cables take (like across aisles and under mats) can be starved of air as a coolant and also result in heat (Gass, 2009).

2.5.8 Safety when conducting Energy Audit (Metering and/or Data logging)

When metering is performed, personnel are at risk as they will be dealing with electrical switchboards where electrical faults can occur unexpectedly and can cause harm to the personnel. These faults can occur due to failed insulation, accidental contact with live systems, protective devices failure (e.g. Circuit Breakers – CB –) and/or energising faulty circuits (Department of Mines Industry Regulations Safety, 2017).

According to (SABS, 2010b) only the authorised person (AP) or responsible person (RP) must perform any work on the electrical switchboards. This said AP must have received quality training before being certified as an AP, further when this AP carries out any duty, they must be supplied with personal protective equipment (PPE) that is recommended by regulations for that particular switchboard. To determine which type of PPE to be used when AP is working (live maintenance, metering, cleaning or any type of work) on a switchboard or distribution board, the calculations of the electrical energy released during typical electrical arc conditions must be performed. The results will then be looked up into the relevant table in the NFPA 70E (Standard for Electrical Safety in the Workplace) to determine the correct PPE required and the safe working distance, this information must be specified on the company working procedures and they must be clearly depicted on the switchboard access door.

Personal Protective Equipment (PPE)

PPE for any electrical work (including testing and fault finding) must be suitable for that particular job, it must be properly tested and maintained to be sure that it is always in the working order. The AP and their assistants or anyone involved in the job must be provided with training on how to select, fit, use and care of the PPE to make sure of the effective usage (Department of Mines Industry Regulations Safety, 2017).

Below are the typical PPEs required when working with electricity, however, the selecting depends on the type of work to be performed and the risks involved:

- Face Protection: Used when there is a potential of high current and arcing
- Eye protection: it is recommended that they are worn every time but metal spectacle frames must not be worn
- Gloves: If the circuit is live, an appropriate glove which can withstand the highest voltage expected must be worn. If the circuit is de-energised, the normal working gloves can be worn
- Clothing: When working on a live circuit, non-synthetic clothing of non-fusible material and flame resistant to the required thermal rating must be worn, however, the clothing must not have any conductive material or metal threads on them. When the circuit is completely dead, the normal working PPE can be worn.

- Footwear: Non-conductive footwear must be worn that complies with the country's standards

2.6 Economic Analysis

The study of economic systems is therein referred to as economic analysis (Mishkin, 2007). The objective of the analysis is to determine the effectiveness of the change in systems, it can be production or government policy (McAfee, 2009).

According to (Centers for Disease Control and Prevention, 2008) on the paper about 'introduction to economic evaluation' in the context of public health, it refers to economic analysis as the powerful tool that can be used to determine if resources are used to the maximum, affordability and cost-effectiveness when changes are to be implemented including the breakeven point as well as the return on investment (RIO).

In the context of this research (energy management), this section looks at the capital investment (energy-related) which is one of the focus areas when dealing with economic analysis. Capital investment decision arises in many contexts and the base idea is that the revenue generated is greater than the cost incurred. In addition to this, the other factor is time (years) taken to accumulate revenue while considering inflation (Pratt, 2007). Therefore, the considerations of costs over the entire life cycle of the investment over the given period bring up an economic analysis aspect: 'life cycle cost' (Capehart & Spiller, 2001) which will be discussed in the following section.

2.6.1 Life Cycle Costing (LCC)

According to (Department SPORT AND RECREATION Government Of Australia, 2005), is a key asset management tool as it takes all the lifecycle implications of the assets from its planning, acquisition, operation, maintenance to disposal costs. The process looks at the asset's costs of ownership and management and that include the following:

- Costs of concept and definition
- Cost of design and developments
- Cost of manufacturing and installation
- Maintenance cost
- Support services costs
- Retirement, remediation and disposal costs.

The life cycle can be summarised or calculated using the formula below where **AC** is acquisition costs, **TD** is tax depreciation entitlements, **OC** is operating and maintenance costs, **RC** is the replacement/disposal/upgrade costs and RV is the residual value.

$$LCC = (AC - TD) + (OC + RC) - RV \quad 2.1$$

Life cycle costs analysis mainly focuses on assets and can be applied to the public or private business sector as well as personal financial planning. (Department SPORT AND RECREATION Government Of Australia, 2005; Capehart et al., 2002).

The typical example of the lifecycle cost of an asset is shown in figure 2.7 below where the estimated costs (in US – dollars (US$)) of owning and operating the oil-fired furnace designed to heat a 2000 ft^2 (185.806 m^2) house in the northeast of the United States. It can be noticed that the initial cost is only 23% which is relatively low when compared to the operating cost which is 68%.

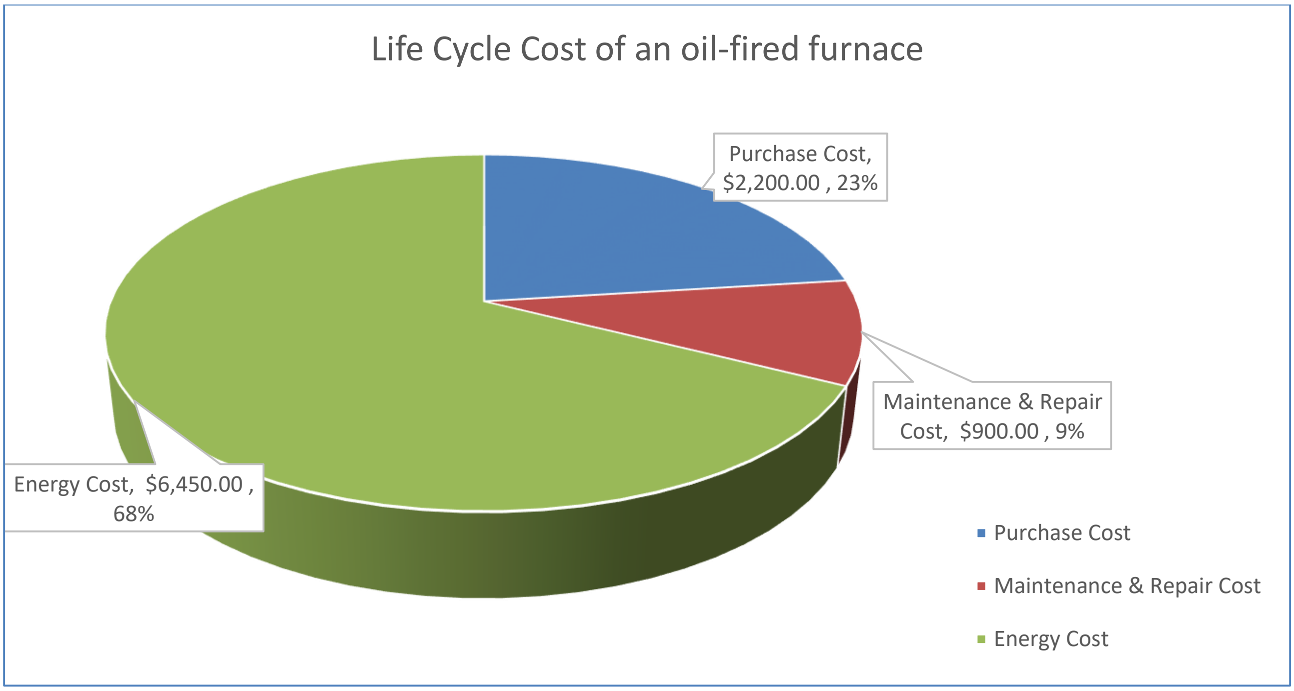

Figure 2.7: 15-Year life cycle costs of an oil-fired furnace (Capehart & Spiller, 2001)

The life cycle cost analysis is a perfect tool for an energy auditor or manager to use when recommending changes to an existing asset or structure after performing an energy audit of the facility. These changes or recommendations can include evaluation of alternative building structural designs which will have its own initial costs, operating and maintenance cost. The EM or EA could also recommend changes or improvements to the thermal performance of an existing building (wall or roof insulation, window glazing); or evaluation of alternative heating, ventilating, or air conditioning systems. All these will require a thorough LCC analysis (Turner, 2006).

In conclusion, the LCC analysis is a tool necessary to evaluate the cost-effectiveness of recommendation by the EA or EM (Capehart & Spiller, 2001).

2.7 ENERGY PURCHASING/BILLING AND COST

Energy costs are not a fixed overhead, there can be room for savings by introducing energy-saving measures, therefore understanding the energy costs and energy-saving opportunities is vital for any consumer. In the case where the energy metering is not done, the invoices can provide a detailed record of energy consumption (Bureau of Energy Efficiency, 2015b).

The billing of electricity is divided into two categories namely, demand drawn and the energy drawn. The demand is measured in Kilovolt Amps (kVA) or Kilowatts (kW) and energy in kilowatt-hour (kWh) (Bureau of Energy Efficiency, 2015a), kVA is apparent power and KW is the true power (Chikuni et al., 2008).

2.7.1 POWER COST

In many countries like India, electricity cost varies from city to city and customer to customer even though they all purchase the same commodity, electricity. The difference is due to many factors that considered, factors such as:

- Maximum demand charges, how rapid is the electricity used (in kVA)
- Energy charges, how much energy is used (in kWh)
- Time of Day (TOD), when is the electricity being used, peak and off-peak hours
- Power factor (PF) charges
- Type of tariff clause and rate of various categories such as industrial, commercial and residential, government, agricultural
- Tariff rates for rural and urban areas (developed and underdeveloped)

2.7.2 ENERGY RATE STRUCTURES

When performing an energy audit and the energy auditor is interested in learning about the cost energy, they must understand the rate structure under which that energy consumption is billed. Each energy usage has its structures and they are different, the electricity is complicated as various rates can be charged like customer charge, energy charge, demand charge, power factor charge and other miscellaneous charges that vary monthly. With the electric rate structures so complex, most consumers (customers or businesses) don't understand how they work, however, this brings the opportunity for an energy auditor to exploit as they can become handing to those consumers (Turner, 2006).

Electrical Demand Charges: This charge is based on the maximum power in kilowatts (kW) that the customer demands every month. The utility meters are normally set to average the power readings over fifteen to an hour intervals so that short fluctuations do not affect the customer. Hence why the customers are billed for a demand for a month based on the maximum value of a fifteen-minute integrated average of their power usage (Capehart & Spiller, 2001). However, according to (Maistry et al., 2012) and (Bureau of Energy Efficiency, 2015b), the maximum demand charge is based on the maximum power in kilo-volt-amps (kVA) but the process are the same as usage (Capehart & Spiller, 2001) outlines above.

Discounts and Penalties: Electrify supply utilities normally offer discounts (on energy and power rates) to customers who are supplied at high voltages and provided that they have a transformer on site. Customers also experience penalties if they have power factor less than 0.9 hence most customers try to regulate their power factor to be above 0.9 by implementing power factor correction measures (Capehart et al., 2005).

Water charges: municipalities do charge customers for water and wastewater use, therefore, energy auditors will also include these charges into the total cost when doing the cost analyses. These costs are often related to as part of the total energy costs (Capehart et al., 2010).

Energy bills should be broken down into components that can be controlled by the facility, the electricity bill can be broken down into power demand costs per kW per month, and energy costs per kWh. Upon compiling the final figures, the energy manager must include the taxes, the fuel adjustment costs, the fixed charges, and any other costs so that the true cost of the controllable energy cost components can be determined (Capehart & Spiller, 2001).

2.7.2.1 INDUSTRIAL ENERGY RATE AND STRUCTURES

The industries do have their rates; each energy source will have its rate structure. Electricity and steam have complex rate structures as they are normally differentiated into fixed customer charge, a demand charge, and an energy charge. In most cases, gas, steam and electric energy are often charged at the time of day rate or the interruptible rate that provides much cheaper energy service with the understanding that the customer may have his supply interrupted (stopped) for periods of several hours at a time. If the utility were to interrupt power, the industry will be notified in advance and the number of times the customer can be interrupted per period is limited (Capehart & Spiller, 2001).

2.7.2.2 Commercial Energy Rate Structures

Rate structures are separated in terms of small commercial customers and large commercial customers. Small commercial customers are billed on a per unit of energy basis while large commercial customers are billed under complex energy rate structures such as rate of energy (power) used, time of day or season of the year, power factor and other related elements. When conducting an energy audit in the commercial sector is to firstly establish the rate structures for all sources of energy used and perform analyses of one to two years' worth of energy bills and this information should be tabulated and presented graphically to obtain a better picture.

2.7.2.3 Residential Energy Rate Structures

According to (City Power, 2018), the residents are billed based on various factors and customers are divided into categories of **how much energy they use**, **the payment method** and **the type of electricity their electricity connection** (three-phase or single-phase). Customers are classified into a prepaid single-phase, pay after us single-phase, seasonal tariffs single-phase, seasonal tariffs three-phase, time of use (TOU) single-phase and TOU three-phase. In these categories, customers are also classified on the demand (in kWh), there is a rate for 0<500 kWh, 501<1000 kWh, 1001<2000 kWh, 20001<3000 kWh and >3001 kWh. Table 2.2 shows how prepaid customers are billed.

Table 2.2: Typical residential rate structure (Courtesy of City Power, Johannesburg)

RESIDENTIAL TARIFFS: Prepaid		
Energy (kWh)	Energy Charge R/Month Summer/Winter	Unit
0<500	124.49	c/kWh
501<1000	141.43	c/kWh
1001<2000	151.86	c/kWh
2001<3000	171.55	c/kWh
>3001	185.91	c/kWh

The municipal residential tariffs are reviewed annually and then increased by a certain rate that is in line with the budget guidelines (City Power, 2018).

2.7.3 ENERGY ACCOUNTING AND BENCHMARKING

Energy benchmarking is an important tool of energy management as it gives the energy manager a bigger picture or a pattern in other similar facilities. Energy benchmarking is a process where the energy performance of an individual facility or an entire sector of similar facilities is contrasted against a common metric that represents the standard or optimal performance.

2.8 ENERGY TARIFFS AND BILLS

Energy is supplied to different sectors in different forms, in the industrial sector Electricity, Gas, Coal, Heavy Fuel Oil, Purchased Steam, Diesel etc. are required. In terms of Commercial, Electricity, Gas, Diesel etc. are required (Terra Firma Academy, 2013).

2.8.1 TYPES OF TARIFFS

The individual approach of each energy company to tariff structure and provision means that a perfect definition cannot be applied to all tariffs within a given type (United Kingdom Government, 2012).

2.8.1.1 HOME FLEX TARIFF

This is a new structure that was introduced by Eskom to the residential sector.it is suitable for medium to high consumers of electricity in urban areas (suburbs) since it's a Time of Use (TOU) tariff type. The term TOU simply means the customers are charged differently depending on the time of the day as the electricity is consumed. This helps Eskom to alert residential customers at what times it is more expensive to use electricity at a certain time of the day than the other (Eskom, 2012).

At least Eskom believes this type of pricing encourages customers to change their behaviour on using electricity as they will be trying to lower their bills (Eskom, 2012).

2.8.1.1.1 Benefits of Home flex

- Savings on the bill if the electricity usage is optimised
- Time of Use tariff are billed remotely per month to avoid/reduce bill estimations
- Customers are provided with electricity at their respective homes and messages from Eskom can be viewed through the in-home display.
- Wireless communication with customers
- It is free to convert to TOU (No charges payable) (Eskom, 2012).

2.8.1.2 THE DOMESTIC TARIFF

This type of tariff applies to customers who receive more than 450 kWh on average per month but they are calculated using a twelve-month average (City of Cape Town Electricity Services, 2015).

2.8.1.3 THE LIFELINE TARIFF

It is aimed at customers who received less than 450 kWh per month on average as calculated on a twelve-month average (City of Cape Town Electricity Services, 2015).

2.8.1.4 BUSINESS AND COMMERCIAL

Applicable to customers using more than 100 kVA (City of Johannesburg, 2015).

2.8.2 TYPES OF TARIFF RATE STRUCTURES

- Flat rate
- Demand rate
- Demand charge
- Demand ratchet
- Time of use rates (TOU)
- Promotional rates
- Interruptible rates
- Seasonal rates
- Real-time pricing (Terra Firma Academy, 2013)

2.8.3 ENERGY BILLS

The energy bill will always contain the following aspects:

- Consumption amount (kWh, litres, tonnes etc.)
- Energy rate per unit consumed
- Customer cost
- Energy cost (kWh)
- Energy consumed in the billing period
- Demand Cost (kVA)

- Maximum total power demand in the period affected by the power factor of a factory (Terra Firma Academy, 2013).

The typical CoCT electricity bill will be shown in appendix B.

2.9 Power Quality

Eskom, the main South African electricity Supplier, will use reasonable resources to supply the customer with reliable and continuous power and maintain quality of supply in compliance with the NRS 048-2 (NERSA's power quality standard) as revised from time to time (Eskom, 2007).

2.9.1 NRS 048: 2: 2003, ELECTRICITY SUPPLY — QUALITY OF SUPPLY Part 2: Voltage characteristics, compatibility levels, limits and assessment methods

This part of NRS 048 covers voltage quality parameters that might affect the normal operation of the electricity-dependent processes of customers (NERSA, 2003).

Notable requirements from NRS 048 Part 2 of 2003

- Voltage measuring equipment must comply with the requirements of either SANS 6100-4-3 (in the case of Class A measurements) or NRS 048-5 (in the case of Class B measurements). NRS 048-5 is also a national standard and will be replaced by SANS 1816. NRS 048-5 forms part of the NERSA standards series regarding Electricity Supply – Quality of Supply.
  - Class A measurements are those which require precision (also requires a continuous 3 seconds measurements to capture the transients such as voltage dips, swells or interruptions, voltage harmonics and interharmonics as well as power frequency instabilities).
  - Class B measurements are those which require less precision
- The low voltage (LV) networks shall have 230V (single-phase) or 400V (three-phase) as the reference voltage as stipulated in the Regulations of the Electricity Act of 1987 (known as Act number 41 of 1987)
- In the case of Medium Voltage (MV), High Voltage (HV) and Extra High Voltage (EHV), the reference voltage must be the nominal voltage or the fixed voltage agreed to between the customer and the utility which may be higher or lower than the nominal voltage. It is recommended that the fixed voltage is within 5% of nominal voltage.
- All phases of the supply must always be closely monitored. In the case where transformers are solidly earthed on the neutrals, the phase to earth voltage must be

monitored as well. In the case of delta connected systems, the phase to phase voltages must be monitored.

- **Assessment period** – The voltages shall be assessed for at least one week (seven consecutive days starting at 00:00 on day 1 to 00:00 after the seventh day)
- Determine the lowest and the highest voltage magnitude (10 minute RMS value) and the value must not be exceeded for more than 95% of the week.
- **The magnitude of the Supply Voltage (voltage regulation)**
  - LV customers must receive a standard voltage of 400 V phase to phase and 230V phase to neutral.
  - MV, HV, EHV customers shall receive the voltage as per nominal or fixed voltage levels agreed between the customer and utility. The table below shows the Maximum voltages for supplies to customers in MV, HV and EHV

Table 2.3: The magnitude of the Supply Voltage (voltage regulation)

Nominal voltage kV	**Maximum voltage kV**
400	420
275	300
220	245
132	145
88	100
66	72,5
44 and below	Nominal voltage + 10 %

- **Compatibility levels**
  - For voltages, less than 500V, the ±10% tolerance is allowed and voltages from 500 V will have a ±5% tolerance.
- **Voltage Limits**
  - Table 2.4 (next page) shows the maximum/minimum deviation from standard or declared/fixed voltages.
  - In case of faults, these voltage limits can be extremely exceeded but this event should be treated as an interruption.

Table 2.4: Voltage Limits

Voltage Level (V)	Limit (%)
< 500	±15
≥ 500	±10

- **Under voltage event**
  - When the voltage drops to 0.85 pu of the standard or declared voltage for more than 3 seconds on one or more phases, this is deemed an under-voltage event.
  - However, if this drop is due to a fault of failure at the point of supply, this is not deemed as an under-voltage event but an interruption.
- **Frequency**
  - The standard south African frequency is 50 Hz
  - The compatibility levels are such that the grid can have a ±2% (±1 Hz) tolerance and ±2.5% (1.25 Hz) in the case of islands.
- **Frequency Limits**
  - The supplier might deviate from the standard frequency but must not exceed the limit of ±2.5% (±1.25 Hz) and ±5% (±2.5 Hz) for the grid & Island respectively
- **Voltage imbalance**
  - **Compatibility levels** – for LV, MV, HV and EHV three-phase networks, the compatibility level of voltage unbalance across the phases must be 2%. However, on the networks where there is a predominance of single-phase or two-phase customers, a compatibility level of voltage unbalance shall be 3%
  - **Voltage unbalance limits –** At the moment, there are no limits specified.

2.9.2 IEEE 519:1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

The standard states that, "Harmonic currents in the AC power system can cause interference with communication circuits and other types of equipment. When reactive power compensation, in the form of power factor improvement capacitors, is used with these nonlinear loads, resonant conditions can occur that may result in high levels of harmonic voltage and current distortion when the resonant condition occurs at a harmonic associated with nonlinear loads. (Static power converters, arc discharge devices, saturated magnetic devices, and, to a lesser degree, rotating machines) (IEEE, 1992; IEEE, 2014)".

Notable requirements from IEEE 519:1992 (IEEE, 1992; IEEE, 2014)**:**

Recommended Voltage Harmonic Distortion Limits

Recommended harmonic voltage limits at PCC (point of common coupling, normally) for different voltage levels are shown in the table below. It must be noted that the high voltage systems can have up to THD of 2.0% which is commonly caused by the HVDC terminal whose effects will have attenuated at points in the network where future users may be connected.

Table 2.5: Harmonic Voltage Distortion Limits

Bus Voltage (V) at PCC	Individual harmonic (%)	Total Harmonic Distortion – THD – (%)
V≤1.0 kV	5.0	8.0
1 kV < V ≤ 69 kV	3.0	5.0
69 kV < V ≤ 161 kV	1.5	2.5
V > 161 kV	1.0	1.5

For low voltage systems (below 1 kV), the application can determine the maximum Total Harmonic Distortion (THD), these limits are shown in table 2.6 below.

Table 2.6: Harmonic Voltage Limits (lower than 1.0 kV)

Low Voltage Systems (below 1.0 kV)	
Application	**Maximum THD (%)**
Special Application (e.g. Hospitals and Airports)	3.0
General Systems	5.0
Dedicated Systems (exclusive converter load)	10.0

Recommended Current Distortion Limits (120V to 69 kV)

IEEE 519 also has a recommendation on currents. The table below shows the current distortion limits for general distribution systems rated at 120V to 69 kV). It must be noted that the table only shows the odd harmonics, the even harmonics current distortions are limited to 25% of the odd harmonic currents limits as in the table. Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

Table 2.7: Current distortion limits for systems rated 120 V through to 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual Harmonic Order (odd harmonics)						
I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	TDD (%)
<20	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20

All power generation equipment are limited to these values shown on the table above regardless of actual I_{SC}/I_L values.

I_{SC} is defined as the maximum short circuit current at PCC

I_L is the maximum load demand current at the fundamental frequency (i.e. 50 Hz in the case of South Africa) at PCC under normal operating conditions of the load,

2.10 POWER (APPARENT, TRUE AND REACTIVE)

Power in terms of the definition is the rate at which work is done (Lewin & Goldstein, 2011) but in terms of electricity, power is the product of the current and the voltage supplied and there is DC power and also AC power (Serway & Jewett Jr, 2010). In electrical engineering, AC power is divided into three components namely, true/real power, reactive power and the apparent power (Boylestad, 2003).

True/Real Power (Symbol: P)

This the power that does the actual work or it is the power that is consumed by the resistive load.it is measured in Watts (W) (Serway & Jewett Jr, 2010).

Reactive Power (Symbol: Q)

This power only exists when there are reactive components on the circuit (the inductor or the capacitor), it represents the energy stored in the magnetic field of the inductor or the energy stored in the electric field of the capacitor. This energy is stored in the reactive component momentarily and then it flows back to the supply (grid). These reactive components do not consume electrical energy (ideal cases), however, they create a significant electric current. It is measured in Volt-Amps-Reactive (VAR) (Boylestad, 2003).

Apparent Power (Symbol: S)

This is the total power drawn by the circuit and it is the vector sum of the real power and reactive power (i.e. $\vec{P} + \vec{Q} = P + jQ$). The apparent power determines the total power required by the circuit and it is measured in Volt-Amp (VA), the relationship of these three types of AC power can be shown through a power triangle (Hughes, 2008).

Power Triangle

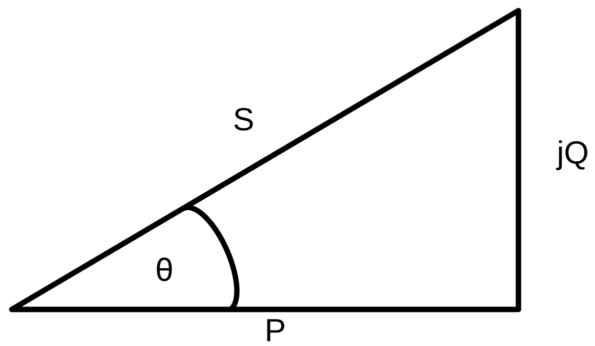

Figure 2.8: The power triangle (Walser & Borril, 2005)

The power triangle in figure 2.8 above shows the relationship between the three AC electrical powers. Since this is a right angle triangle, the relationship can be explained using the Pythagoras theorem i.e. $S^2 = P^2 + Q^2$. The angle theta represents the phase angle between the voltage and current, the angle also determines the power factor (i.e.: $PF = \cos\theta = S/P$) (Walser & Borril, 2005)

The reactive power is deemed the unnecessary power as it does not do the actual work, this brings in the phenomena known as power factor.

2.11 POWER FACTOR CORRECTION

Power factor

Power factor is defined as the ratio of real power to apparent power, it determines the efficiency of the system in terms of how much power is drawn from the supply compared to how much is used. Since the power factor is a ratio, it does not have units and it can only be between -100% and +100%. The power factor is negative on a capacitive load (named a leading power factor) and it is positive on the inductive load (named a lagging power factor). The purely resistive load will have unity (+100% where apparent power and real power are equal) power factor and the purely inductive or capacitive load will have a power factor of zero (Hughes, 2008).

Power Factor Correction

This is the process where the power factor is improved to be as close as possible to unity (100%) by reducing the reactive power. The reactive power is reduced by introducing an additional reactive component which absorbs the reactive in the opposite sense to that of the load (i.e. if the load is inductive, the capacitor is introduced and vice versa) (Voss, 2016).

The Power Factor comes with the benefit of saving costs; most industries are billed the apparent power (kVA) they consume instead of real power (kW) they actually use). However, the process is expensive therefore a thorough economics analysis must be performed to determine if it is feasible to deploy the power factor correction schemes (Chikuni et al., 2008). In some countries, poor values of power factor (typically below 90%) incur a hefty penalty, therefore, forcing the companies to regulate their power factor.

There is a famous analogy of a glass of beer with the foam. Real power is what the person consumes, the glass represents apparent power and it must be large enough to contain liquid beer and its foam. The froth represents the reactive power and the analogy is shown in figure 2.9 on the next page (Terra Firma Academy, 2013).

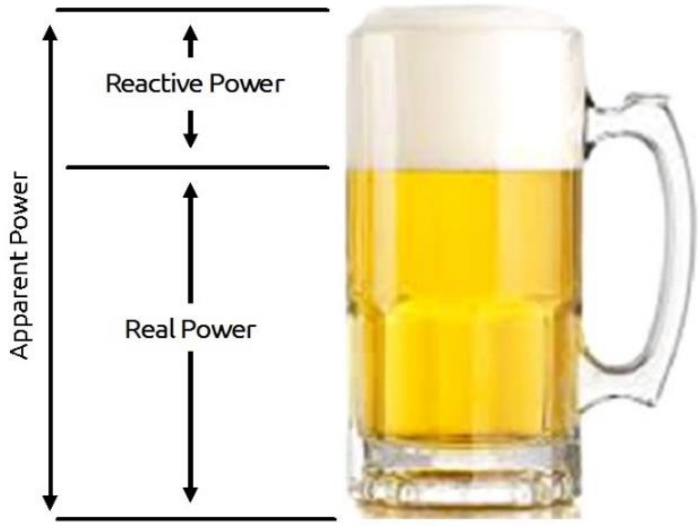

Figure 2.9: The power factor correction beer analogy (Terra Firma Academy, 2013).

The power factor correction can be imagined as the process of removing the foam (which comes naturally with beer) and therefore reducing the size of the glass.

2.12 CONCLUSION

South African which is currently facing the energy-related issues where the energy continuously fails to meet demand which leads to load shedding. The literature shows that there are possible ways to reduce energy demand. The literature also shows what is being done in South Africa as efforts to alleviate energy crises through the promotion of energy-efficient measures highlighted in the built environment with the focus on the public and commercial buildings. The literature established possible methods to deploy when dealing with energy efficiency and energy management. The in-depth approach to energy management and energy auditing were looked into, this included data collection and the related safety requirements. Based on the literature, power quality issues such as harmonics must be considered when embarking on energy efficiency measures. The implementation of energy efficiency and energy management strategies require capital investments, the literature also outlines the finances involved when dealing with energy management.

The following chapter presents the methods deployed to fulfil the aim and objectives of the study.

CHAPTER THREE

3 METHODOLOGY

3.1 OVERVIEW

This chapter is divided into six parts namely, introduction, study site, research design, phases (or parts) of the study and data analysis. The chapter unfolds the approach to the research including methods and procedures for consistent and systematic data collection and the type of data collected

3.2 INTRODUCTION

This study focuses on energy management at the Catsville residence which is a CPUT's student accommodation. Based on the studies by (Maistry et al., 2012), (Cao et al., 2016), (Asmar & Tilton, 2015) and (Vadodaria, 2014), there is a need for awareness in terms of energy management to ensure that institutions of higher learning form part of a closed circle of energy conservation and demand-side management. This chapter focuses on the process this study followed to determine the energy consumptions and energy consciousness of the users (CPUT students). The results will be interpreted through appropriate methods and necessary recommendations will be made.

The basic idea is to examine energy usage and make recommendations based on the findings. A detailed exercise to evaluate other options with the involvement of the utility and manufacturers of equipment can be considered based on the results and recommendations of the study.

3.3 STUDY SITE

The research was conducted at the Cape Peninsula University of Technology's Catsville Student residence. The residence is located in the suburb of Observatory in Cape Town (see section 1.7. Study Area, for geographical information of the study area).

Most of the study will be conducted at G-Block, which is used to accommodate students. This particular building consists of six floors (ground floor to the fifth floor) with an external area of approximately 890 m^2 and internal area of 775 m^2 per floor making an overall building internal area of 4600 m^2 and external area of 5300 m^2. Figure 3.1 (on the next page) shows the façade view of G-Block and it can be seen that it has six floors (including the ground floor), additionally, the building is in a form of an L-shape (see figure 1.4 of section 1.7 on page 9).

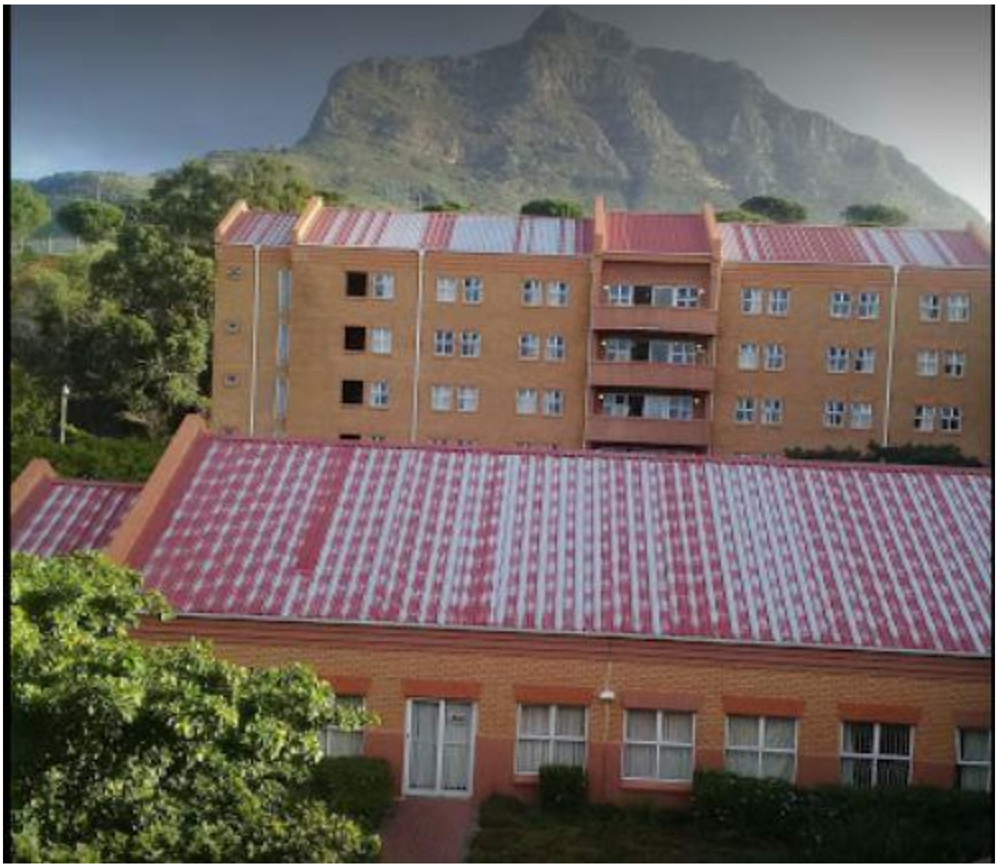

Figure 3.1: The façade of the building (Lokailwe, 2019)

According to the architectural information, each floor has the following:

Single rooms – 24

Double Rooms – 17

Recreation Room – 2

Kitchen – 2

Restrooms – 4

From this, it can be determined that G-block can accommodate 246 students. Appendix C shows the floor plan

3.4 RESEARCH DESIGN

The methodology outlines the process that the whole research project will follow. It is the plan of action developed to show how the problem will be investigated, how and what information will be collected and how will this information be analysed to reach the conclusion and recommendations (Oliver, 2008).

According to (Watkins, 2016) research design can be defined as " the logical sequence that connects the empirical data to a study's initial research question and ultimately to its conclusions. Colloquially, a research design is an action plan outlining plans of getting from here to there, where 'here' may be defined as the initial set of questions to be answered, and 'there' is some set of conclusions (answers) to these question".

The problem investigated in this study is energy management at the student accommodation of a higher institution of learning (Cape Peninsula University of Technology). Both qualitative and quantitative methods were used in this study. This study consists of five parts (or phases) as the methods to fulfil its objectives

3.4.1 PARTS OF THE STUDY

The study is divided into five (5) phases

Part 1: Literature Survey

Part 2: Energy Audits (walkthrough) at Catsville Residence – Block G

Part 3: Data logging – Instrumentation and Measurements at Catsville Residence – Block G

Part 4: Electricity Bill Analyses (Catsville Residence – The Entire Complex)

Part 5: Student energy awareness questionnaire/survey (Catsville Residence residents)

3.4.1.1 PART 1: LITERATURE SURVEY

This part of the research is the review of literature which is relevant to the subject that is dealt with in the research, it is often the longest in the thesis. The literature review is primarily about research writing which is connected with the main subject matter of the research study or thesis. The literature review is normally not connected with the methodology of the study. The word "review" does not mean the researcher must provide details and analysis of the book or article but simply summarise the broad content of the research article or the book and also indicate any linkages with other studies in that field (Oliver, 2008).

The researcher achieved this part of the thesis by the use of published books, journals, conference papers, newspaper and internet articles, manuals, interviews, lecture notes and all other accredited materials

3.4.1.2 PART 2: ENERGY AUDITS

This part of the research is an important tool in energy management. It is the actual analysis or investigation of the power entering and exiting the building. This helps with finding the exact areas where energy is used, both efficiently and inefficiently as well as a possible improvement to the system. These improvements include building fabric, services, controls and management (Harris, 2012).

For this study, a **preliminary energy audit** will be conducted in terms of **SANS 50002:2014 (SOUTH AFRICAN NATIONAL STANDARD: Energy audits — Requirements with guidance for use)** and based on the findings, further robust energy audits such as **targeted or detailed** audit will be recommended if deemed necessary. This energy audit will be conducted to obtain the details of the building's (CPUT student accommodation – Catsville Residence) energy-consuming equipment. The details of all energy-consuming equipment will be documented, the typical appliances that are expected to be documented are, heating equipment, lighting, cooling equipment, fans, pumps, cooking appliances, refrigerators, low power equipment (computers, copiers, fax machines, home entertainment, etc.), larger items such lifts and escalators.

The audit process will be carried out in the following manner:

- Pre-survey information and data collection
- The building survey (walkthrough)
- Analysis of the data collected/results
- Formulation of energy-saving solutions
- Reporting of results (conclusions and recommendations)

3.4.1.3 PART 3: DATA LOGGING (INSTRUMENTATION AND MEASUREMENTS)

The saying goes, 'if you can't measure it, you can't manage it', an energy audit can provide an idea of the expected energy bill but it is not the actual but an estimate (Air Force Civil Engineer Support Agency, 1998).

It is, therefore, necessary to take measurements and use that information to understand the state of the building electricity network and energy consumption. This can be achieved by a short or long term continuous monitoring for generating the best consumption profile. Data loggers and sensors are the relevant equipment for this purpose (Air Force Civil Engineer Support Agency, 1998). The measurement of interest in this research is that of electrical power.

It is understood that in most buildings, the electrical consumption is generally metered but it is unusual to find appliances metered separately. According to (Jorge, 2010), to measure on the circuit's individual item of plant or equipment, a current clamp is used; the current induced in the clamp is proportional to that in the primary circuit and can be fed to a data logger. For items drawing constant power, hours-run meters can be used, although they give no information on the timing of the power consumption.

3.4.1.4 PART 4: ELECTRICITY BILL ANALYSES

The 2-year electricity bills were obtained from the City of Cape Town, these 2-year bills were from December 2017 to November 2019 and gave an insight in terms of:

- Energy Consumption (kWh)
- Customer cost (service costs in Rand)
- Energy cost (Rand)
- Energy consumed during the billing period (kWh)
- Demand Cost (kVA)
- Tariff Structure

3.4.1.5 PART 5: STUDENT QUESTIONNAIRE/ SURVEY

When the researcher is collecting data from large populations, a survey is an instrumental tool to achieve this (Denscombe, 2003). There are two types of survey, namely, cross-sectional and longitudinal (Maistry et al., 2012). Both the surveys are observational studies, therefore, this implies that the researcher records data about their research topic without manipulating the study environment. Cross-sectional study/survey compares different population groups at a single point in time whereas, in the case of the longitudinal study, the researcher looks at several observations of the same subject for a given period, sometimes this period could be a couple of years (Institute for Work & Health, 2015).

For this research, the cross-sectional survey method was used as the form of data collection, the survey mainly focussed on the attitude, knowledge, viewpoint and behaviour towards energy from the students of the Cape Peninsula University of Technology who reside at the Catsville residence. In the survey, most of the questions were closed-ended for a better quantitative analysis. Some questions were looking at the student’s understanding of energy usage and energy efficiency.

This questionnaire was designed based on the previous surveys that were conducted either for universities or residential areas. The following three studies were used:

- The workings of (Maistry et al., 2012) which were about the energy efficiency study at the University of Johannesburg APK campus and some of the questions were adopted exactly as asked in (Maistry et al., 2012),
- The two outstanding studies by the late CPUT professor, Prof Phillip Lloyd,
  - The first one was (Lloyd et al., 2004) which surveyed the energy profile of the rural community of Nkweletsheni located in the southwest of KwaZulu Natal and
  - The second one was the (Lloyd, 2014) which was the same study as (Lloyd et al., 2004) but this time the focus was on the informal settlement of Samora Machele outside Cape Town, Western Cape.

For this research, the online survey was designed as it was seen as the best and convenient way to access the students. The survey questions are shown in appendix A

3.5 Details On Execution OF The Five Parts OF The Study

This section explains in detail how the five parts of the study (as mentioned above) were executed.

3.5.1 Literature Survey (Part 1)

There was little literature about energy management at the South African institutions of higher learning as compared to international literature. Because of the unavailability of literature about energy consumption or energy management at CPUT, it was therefore concluded that there was no such study conducted at the Cape Peninsula University of Technology before. However, there was a vast amount of literature on general energy management on buildings (commercial and residential) both in South African and internationally.

3.5.2 Energy Audits (walkthrough) at the selected building (Part 2)

PRELIMINARY AUDIT

For this study, the preliminary audit was conducted and the outcome will determine if the more intense audit (targeted audit or detailed audit) is necessary. The objective was to gather enough information about the building’s energy-consuming equipment during the walkthrough audit to estimate and evaluate whether there are possible energy and cost savings.

The preliminary audit consists of gathering information and physical investigation of the design and the layout of the building including the equipment. This physical investigation is known as a walkthrough phase of the energy audit. The next phase will be the analysis of the acquired information.

The walkthrough phase of the preliminary audit consists of a comprehensive daytime investigation and a condensed night-time and cleaning phase. This phase has the purpose of establishing a reasonable feeling regarding the energy-consuming systems in the building as well as their energy efficiency. The steps followed to accomplish the preliminary audit are outlined below:

3.5.2.1 DATA COLLECTION/DOCUMENTATION

The first step is to obtain the documentation of the following:

- Energy accounts and maintenance costs records (monthly) for a period of 3 years but a minimum of 1 year is still acceptable. These accounts will provide a clearer picture of the energy consumption patterns. This data will then be plotted on a graph to examine the actual profile (peak times and off-peak times). The following documents were obtained from the CoCT through CPUT's finance department
    - Billing Months
    - Days
    - Billing month.
    - Days in the billing cycle.
    - Kilowatt-hours.
    - Time-based kilowatt-hours (if billed on this basis).
    - Kilo-VAR-hours.
    - Power factor.

The above information (maintenance records and electricity accounts) will be used as part 4 of the study: ELECTRICITY BILL ANALYSES).

- Different tariff options available from the supply authorities
- Architectural and engineering drawings
- Specification of Control systems, these specifications will be compared against the actual operations (there were no records available).
- Building electrical drawings (there were no records available).

- Operational and maintenance manuals, maintenance records and complaints books should be acquired if available (there were no records available).

Below is the other relevant information that the energy auditor should establish before the energy audit.

- Standards desired by owner/occupants in terms of:
  - Lighting.
  - Temperature.
  - Humidity.
  - Fresh air intake.
  - Ventilation.
- The pattern of usage in the building:
  - Hours occupied and hours of operation of equipment for different areas.
  - Periods when cleaners are busy and the method of cleaning.
  - Energy consciousness of occupants

3.5.2.2 WALKTHROUGH ENERGY AUDIT

The walkthrough was done in two parts namely, walkthrough tour and walkthrough (getting detailed data using the walkthrough energy audit sheet shown in appendix D and E)

The energy audit was conducted at the G-Block of the Catsville residence. The architectural drawing of the building is attached on appendix C.

The energy audit guide includes all necessary equipment needed to be checked during the audit is provided in appendix D.

This building is student accommodation, the students have their own rooms, one student per room and/or in pairs. In the building, the students use the commune kitchen, restrooms and recreational area which they share among themselves. During the tour, it was also established that the students are not allowed to cook in their room but some do.

The building will be audited in two parts namely, the student rooms and other building areas.

Student rooms

- Building envelope
  - Solar radiation through windows
  - Energy transmission through walls, roof, windows and doors.
- Lighting

- Heating, Ventilation and Air Conditioning (HVAC)
- Space heating (Inside the student rooms)
- Water heating
- Cooking
- Other electrical appliances

Other building areas (corridors, ablution, recreation area, staircases, storage rooms, kitchen):

- Lighting
- Motors and Drives
- HVAC
- Other electrical equipment
- Water heating
- Space heating

As the audit was performed, the auditor made some notes on equipment that are potential ECO's. This required a good knowledge of the possible replacement technologies of those equipment seen as possible ECOs

3.5.2.3 Analysis of the data collected (Post Audit) Formulation of energy-saving solutions

Subsequent the energy audit, all the data recorded was carefully analysed, organised and reviewed for completeness and any possible anomalies. Any important missing data required the auditor to revisit the building. The potential ECOs identified during the audit were fully reviewed and the actual equipment analysis or operational changes were conducted.

The analysis involved determining the cost and benefits of the potential ECOs and making a cost-effective judgement of the identified potential ECO. Cost-effective judgement involves a payback period which most companies prefer it to be 2 years at most.

3.5.2.4 Reporting of results (conclusions and recommendations)

After the analysis, the energy audit report must be generated which details final results and recommendations. The length of the report depends on the facility or the building that was audited.

In this document, the results will be discussed in chapter 4 and section 9.4.

3.5.3 DATA LOGGING: INSTRUMENTATION AND MEASUREMENTS (PART 3)

This section discusses how the data collected as outlined in Part 3: Data logging (Instrumentation and Measurements) above in 3.4.1.3 will be analysed. This was important to the study as the actual consumption of the student block can be obtained for analysis and create an energy consumption profile, this offered a much better understanding of how students use electricity.

Due to equipment constraints and the design of the building, the data logging was done for 1 block (G-Block) as shown in figure 3.2 on the next page.

The infeed distribution board at G-block had two separate circuit breakers (for Westside and the Southside of the building), and therefore the measurement was done at the G-Block South.

This gave conclusive results as the building sides (west and south) are the same and the occupants' behaviour is believed to be the same

The metering was performed in two phases, between December 2018 and March 2019 as well as March 2020 and August 2020. This was mainly due to the measuring equipment shortage.

Both meterings were successful, however, there was complication as the authorised personnel from the maintenance department did not have the relevant personal protective equipment (PPE) but arrangements were put in place to make the metering safe for both the personnel and equipment.

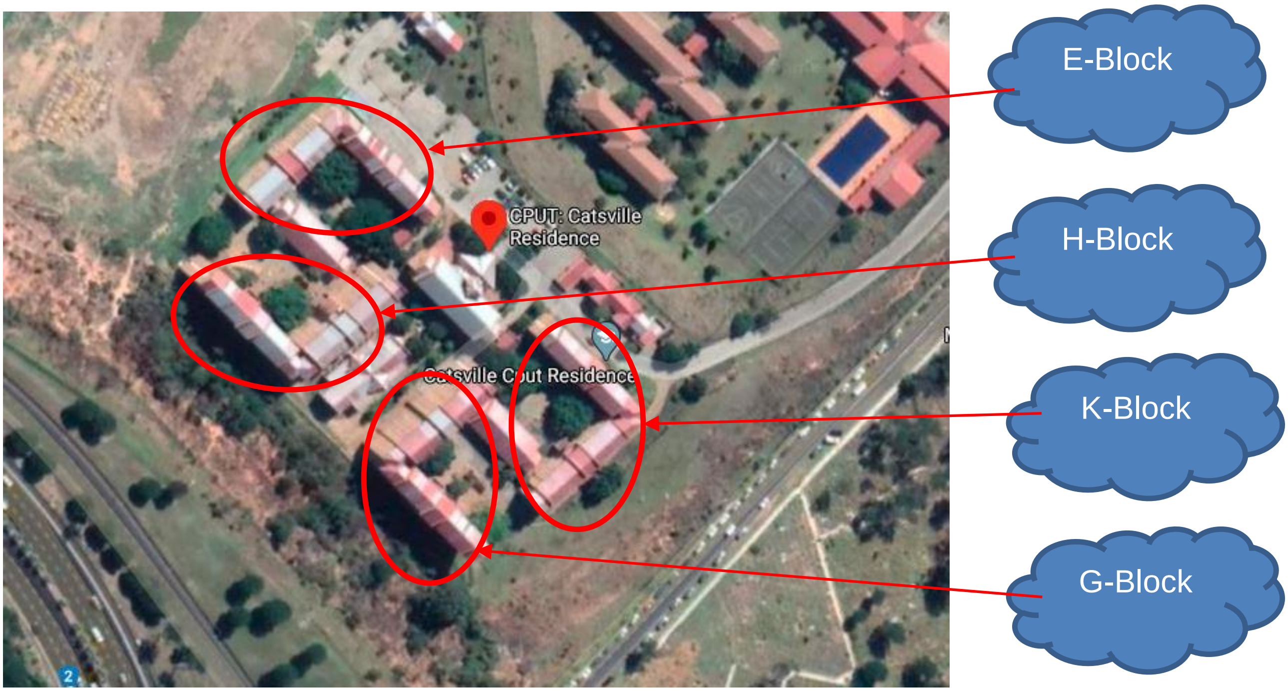

Figure 3.2:Catsville Residence Aerial view (Courtesy of Google.com)

The measuring equipment used (Fluke 1730 power analyser) was set to average the logged parameters (Voltage, Power, Current, Energy etc.) every 1 minute and there were no gaps found on the downloaded data

The data logger could generate data in form of a spreadsheet and Microsoft EXCEL pivot chart was used for the analyses.

The downloaded data will be analysed in chapter 5 to determine the energy consumption profile. The fluke 1730 also offers high-level power quality measurements such as voltage imbalances, phase loading, power factor and harmonics; these aspects of power quality will be presented in Chapter 6. Chapter 6 will present the analyses of these power quality issues and compare the results with the known standards such as IEEE – 519: 1992 and NRS 048 – part 2.

3.5.4 ELECTRICAL BILLS ANALYSES

The electricity bills were obtained from the City of Cape Town through the CPUT's Finance Department. The bills available were for 2 years running from December 2017 to November 2019.

Data was then translated into a Microsoft Excel spreadsheet outlining each month's energy cost, total power consumption, tariff structure, service fees and taxes.

From this, the totals for the year were calculated including daily average consumption, average daily cost and then results were displayed on the line graph to make proper analyses. The energy consumption and the related cost of 2018 and 2019 were compared using statistical programs to make a definite conclusion.

The results are analysed in Chapter 7.

3.5.5 STUDENT QUESTIONNAIRE/SURVEY

The online survey link was sent out to students who reside at the student accommodation with the help of other students who then relayed the link to other students. The residence database was used to send out the link to students who responded in numbers to formulate a conclusive result. According to (DelİCe, 2001), for the population sub-group, at least 5% of the total would yield reasonable results. The analyses of the results are in chapter 8 and the questionnaire questions are available in appendix A.

3.6 DATA ANALYSIS

This is the gigantic section of the research thesis which consists of the collected data, the analysis and presentations of results or findings (Oliver, 2008). Data Analysis depends on the nature and form of the data that has been recorded. Therefore, data can require either qualitative or quantitative analysis, the basic idea of data analysis is to transform raw data into understandable data.

In this chapter, there is no actual data that is analysed but the overview/process on how data will be analysed in this thesis. Data analysis and the results derived from the overview/process discussed in this chapter will be presented in the later chapters as follows:

- Chapter 4: Results Analyses: Energy Audits
- Chapter 5: Results Analyses: Data logging: Consumption pattern models
- Chapter 6: Power Quality
- Chapter 7: Electricity Bill Analyses
- Chapter 8: Student awareness questionnaire/survey

Evaluation of various measures discussed in the next chapters and the collected data will be compared and analysed to indicate the nature of energy consumption or energy efficiency in the built environment at the higher institutions of learning, the Cape Peninsula University of Technology student accommodation in particular.

3.6.1 QUALITATIVE ANALYSIS

This form of data analysis is extracting all points, from raw data, that the researcher considers being relevant to the topic in question. Qualitative data is analysed thematically, thematic analysis can include analysis of words, concepts, literary devices and nonverbal cues.

3.6.2 QUANTITATIVE ANALYSIS

Quantitative analysis is the use of mathematical operations to investigate the properties of data. Quantitative data are analysed statistically. Statistical analysis can be descriptive or inferential.

Descriptive Analysis – It is used to describe and summarise the basic features of data in a study and is used to provide a quantitative description in a manageable and intelligible form. This type of analysis measures the central tendency – mean, mode and median – and the dispersion – standard deviation – is adopted.

Inferential Analysis – To draw the conclusion that extends beyond the immediate data. Raw data from close-ended questions will be analysed using statistical software such as SPSS and resulting calculations will be generated and then interpreted

3.6.3 DATA ANALYSIS IN THIS STUDY

The data, collected at the CPUT's Catsville infeed using the Data-logger will, therefore, be used through statistical programs to determine the electricity usage on the campus, therefore determining the baseline. The analyses will, therefore, provide answers to the research questions.

3.7 CONCLUSION

This chapter outlined the data needed to fulfil the aim and the objectives of the study therefore responding to the problem statement. The thesis will test five parameters in line with the objectives, energy audit, data logging (metering), electrical bills analyses and student questionnaire analyses.

The following chapters (4,5,6,7 and 8) present a series of the results obtained through the methods mentioned in this chapter, the next chapter (chapter 4) present the results from the energy audit.

CHAPTER FOUR

4 ENERGY AUDIT RESULTS

4.1 INTRODUCTION

This chapter presents the data collected during the energy audit at Catsville Residence (G –Block) and the cost associated with the energy-consuming equipment. Photographs were taken of all the energy-consuming equipment and are also presented in this chapter.

This building is a student accommodation and junior students stay in pairs while senior students stay individually. Activities such as cooking and ablution are for every student's usage (sharing) and are not strictly specified to any student.

The study assesses each room and the floor plan of each room will be shown, however, these rooms are identical (in terms of floor area and standard equipment) hence the study will only show one single room and one double room. In addition to this, all floors are identical therefore only one floor will be analysed.

4.2 STUDENT ROOMS

4.2.1 LAYOUT (FLOOR PLAN)

Figure 4.1 below shows the floor plan of a typical single and double room at Catsville.

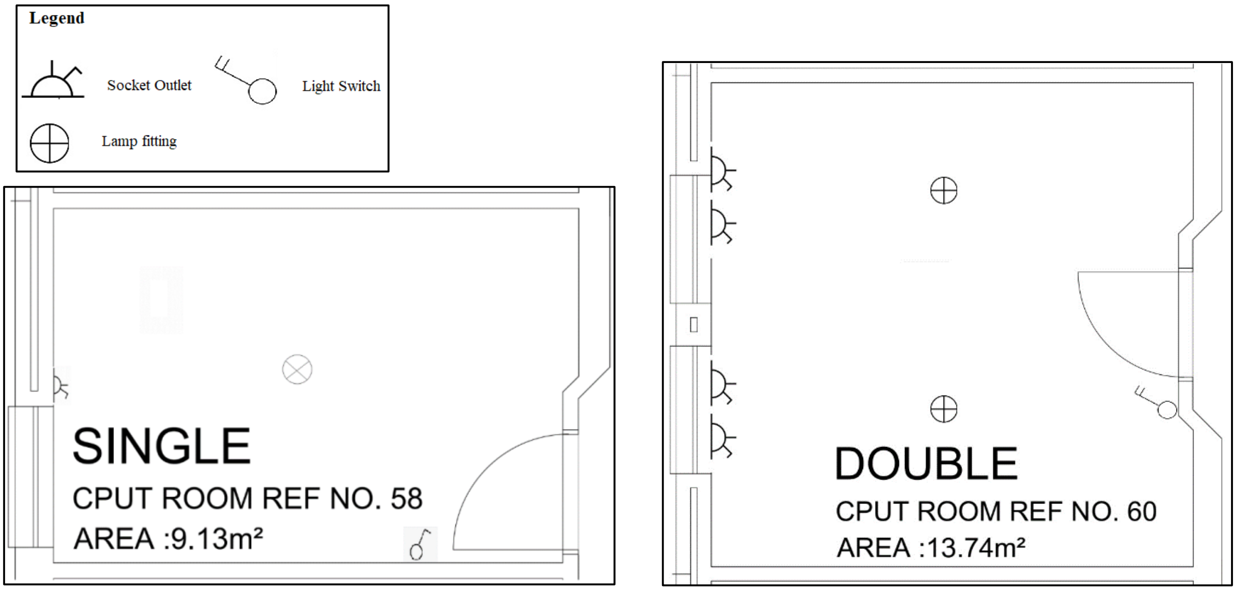

Figure 4.1: Single and Double room layout at Catsville (CPUT, 2019)

4.2.2 LIGHTING

Single rooms are fitted with one lamp fitting and the double rooms are fitted with two lamp fittings (one fitting per student as the room is partitioned into two sections), this can be seen in the floor plan layout in figure 4.1 above. There is inconsistency in the lamp fittings as other lamp fittings can fit two bulbs and others can fit only one. In some rooms where the lamp fitting can fit two bulbs had only one bulb fitted with the other one missing. Figure 4.2 below shows the fittings.

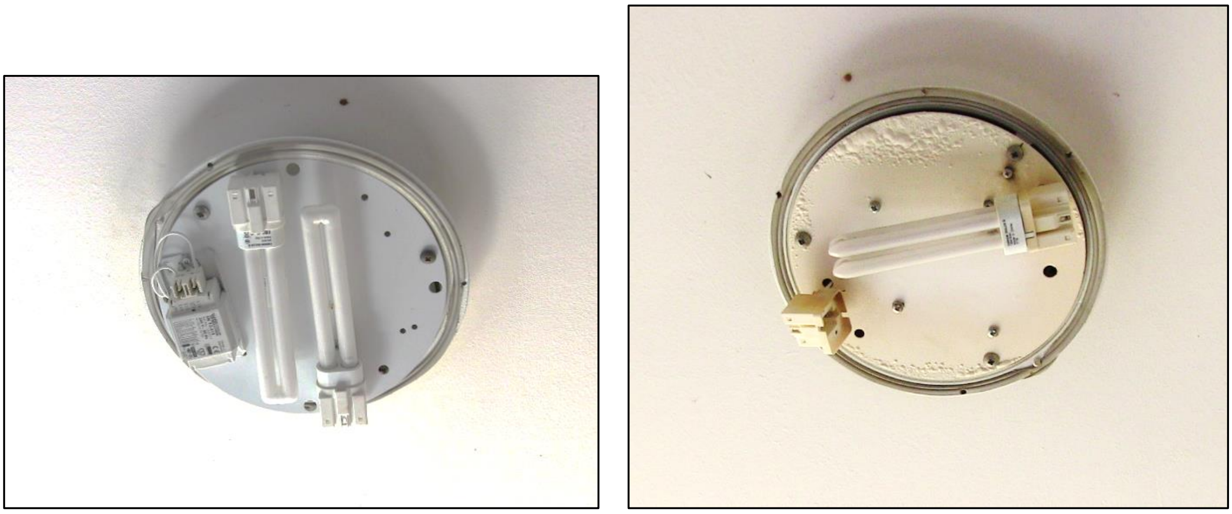

Figure 4.2: Lamp Fittings used in the student rooms (Lokailwe, 2019)

The fitted bulbs range from 9W to 18 W (watts) Compact fluorescent lamps (CFL) manufactured by OSRAM as shown in figure 4.3 below. The difference in the wattage is because of the inconsistencies when replacing the bulbs mainly because the audit did not find any CPUT standard for recommended bulb ratings or types.

Figure 4.3: CFL bulbs fitted in the student rooms (Lokailwe, 2019)

During the audit, occupants were interviewed, and they were happy with the luminance of the bulbs even though some did point out that the luminance is not good enough (or comfortable) for reading or studying.

For these cases, most of the student rooms had study lamps as shown in figure 4.4 on the left. Even though some study lamps were found with no bulbs fitted. The fitting is compatible with incandescent bulbs, halogen bulbs, LED bulbs or CFLs. However, the bulbs fitted are the CFL rated between 9 and 18 Watts.

Figure 4.4: Study lamps

The lighting in each room is manually controlled using a light switch, the audit also found that some students' lights are always on even though they are not inside the room.

4.2.2.1 DISCUSSIONS/OBSERVATIONS ON LIGHTING

Based on the illuminance *(illuminance describes the quantity of luminous flux (luminous flux describes the quantity of light emitted by a light source) falling on a surface)* that was measured, there is enough lighting during the day as the sunlight enters through the windows. At the time of the audit, in the double rooms, the illuminance levels were averaging 212 lx when the light is OFF and 280.3 lx when the lights are ON.

When the lights are OFF, the high lux value is obtained and this is because of the daylight. According to (National Optical Astronomy Observatory, 2009), the indoors illumination level on full daylight is about 10 000 lx and on starlight (night time) it drops to 0.0011 lx which can be considered to be zero. The 10 000 lx obtained is dependent on how much sunlight enters the building through windows as this value can drop to 25 – 50 lx mostly in the middle areas which will require additional lighting to compensate these low levels. Based on this, it is concluded that the difference between the lux when the lights are ON and when the lights are OFF should give the lux levels of the lighting (lamps when ON) at night, in other words:

$$Lux_{night} = DaylightLux_{lights(ON)} - DaylightLux_{lights(OFF)} \quad 4.1$$

The illuminance in the double rooms is averaging 212 lx when the light is OFF and 280.3 lx when the lights are ON, this means the lux level at night due to lighting will be $280.3 - 212 = 68.3lx$

In the single rooms the illuminance was averaging 140 lx when lighting is OFF and 190 lx when lighting is ON, this means the lux level at night due to lighting will be $190 - 140 = 50lx$. The difference in terms of illuminance in the rooms is mainly because double rooms have two lamp fittings and also have two windows when compared to those of the single rooms which only have one lamp fitting and one window. According to (SABS, 2005) the lighting illuminance in the restrooms must be above 100 lx and lux measured in the rooms during the daylight was within the limits. However, the night lux level calculated to be 68.3 lx and 50 lx for both double room and single room respectively, this disqualifies the lighting as they are below the 100 lx minimum.

The rooms are also used as study rooms and the standard requires a minimum luminance of 400 lx for the reading table. Because of this, the study lamps (placed directly on top of the reading table as shown in figure 4.4) are used to improve lighting to meet the requirements. The only concern is that most of the rooms were found without functioning study lamps or there were no lamps fitted due to poor maintenance.

NB.: (SABS, 2005) **is the SOUTH AFRICAN NATIONAL STANDARD: Interior lighting Part 1: Artificial lighting of interiors (SANS 10114-1:2005 Edition 3)**

4.2.3 INSULATION

The windows in the rooms and other areas of the building are fitted with the normal float glass on the aluminium framing. Float glass is a regular fragile glass made from molten glass (BOB's Glass, 2019) and it is commonly found in the residential areas. The walls and ceiling (of the entire building) are made of brick/cement except for the rooms on the sixth floor (top floor) where the ceiling boards are used. The picture below (figure 4.5) shows the lamp fitting mounted on the ceiling.

Figure 4.5: Lamp fitting mounted on the ceiling

4.2.4 SPACE HEATING OR COOLING

According to the students, they mainly rely on natural cooling (opening of windows) during summer even though there is a small portion who have their personal fans.

For space heating, they rely on electric heaters during wintertime. Each student room has been equipped with the wall-mounted panel heater supplied by Econo-Heat as shown in figure 4.6 below.

Figure 4.6: 400W panel heater (wall mounted)

The audit could not determine the material used for designing the heater. According to the information from the panel heater manufacturer, (Foxees heaters, 2020), the heaters nowadays are made of glass, ceramics, pottery, cement, poly-carbonates or plastics. These heaters go through rigorous testing such that they can comply with the SABS as well as I.E.C. 335-2-35, E.M.I & E.M.C. The materials for manufacturing these heaters are of importance because before 1995 they were made of the deadly asbestos, in 1995 Montreal Protocol was introduced to ban the use of asbestos in products all over the world (Foxees heaters, 2020). (Foxees heaters, 2020) claims that their wall-mounted panel heaters are "*made from cellulose fibre cement. It does not contain any asbestos products or any hazardous additives. It is coated with the highest quality non-toxic PVA paint.*"

Some student rooms' panel heaters are either physically damaged or electrical dysfunctional and this has led to other students buying electrically powered bar heaters or even using the electrically powered single/double spiral hotplate stove (shown in figure 4.7 below) for space heating.

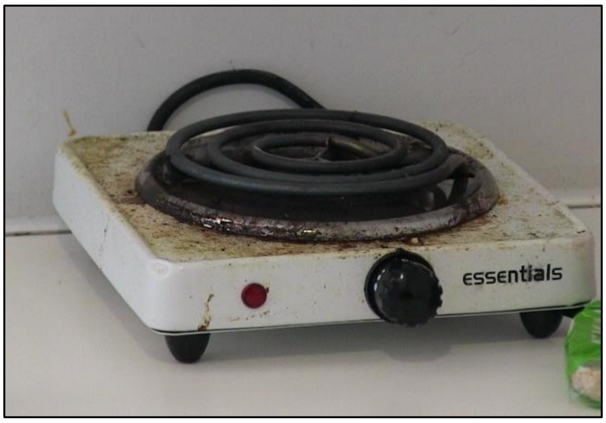

Figure 4.7: Single Spiral Hotplate stove

4.2.5 OTHER APPLIANCES

The students' rooms were found to have their own appliances to meet their basic needs or convenience as shown in table 4.1 below (all these appliances are electricity driven).

Table 4.1: Other appliances found in the student rooms with their power rating

Appliance	Wattage (rating)
Electric kettle	2 kW
Electric Iron	1.8 kW
Bar fridge	260 W
Laptop	65 W
Speakers	50 W
Stove	2 kW

The survey in chapter 4 (section 8.5) reveals in detail the other appliances students own.

4.3 OTHER BUILDING AREAS (CORRIDORS, ABLUTION, RECREATION AREA, STAIRCASES, STORAGE ROOMS, KITCHEN)

4.3.1 CORRIDORS

Lighting – similar bulbs and fittings to those of the student rooms are used. Figure 4.8 below shows the corridor.

Figure 4.8: Corridor with lights ON (left) and Corridor with lights OFF (right)

The illuminance in the corridors during the day when lights are OFF is about 2 lx and 22 lx when lights are ON, this implies that the illuminance at night will be $22-2=20lx$. The low illuminance value when lights are ON is attributed to the fact that most lights are not functioning and students rely on the sunlight, however, at night, they rely on opening their doors to light up the corridor using the light from their rooms as the illuminance is only 20 lx. When the lux measurement is taken from the sections where the lamps are in a working condition, the illuminance was recorded to be 102 lx. Even though 102 lx is within the prescribed minimum luminance of 100 lx according (SABS, 2005), the other parts of the corridors are a concern as they do not conform with the standards, however, this is a maintenance problem. Since the illuminance level is 2 lx when lights are OFF, this means the lighting on the corridors are an essential requirement and must be kept ON at all times.

4.3.2 STAIRCASES

Lighting – The visibility on the staircases is excellent due to the daylight, however, at night the lamps provide good lighting which is above the minimum required of 150 lx by SANS 10114-1:2005. The audit found that some of the lights are not functioning which is another maintenance issue. The stairway is shown in figure 4.9

Figure 4.9: Staircases

4.3.3 KITCHEN

The kitchen is shared by students whose rooms are closer to it. Each floor has two semi-furnished kitchens (only basics). Figure 4.10 below shows the kitchen floor plan layout.

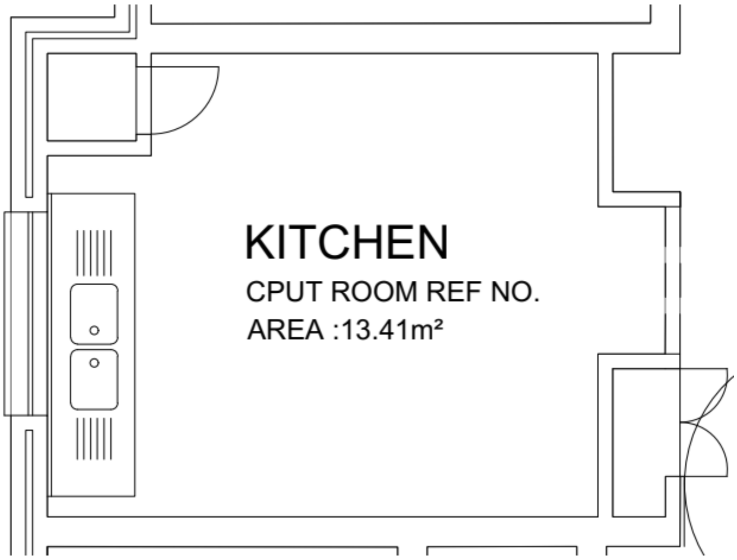

Figure 4.10: Kitchen at Catsville

Lighting

The kitchen uses the tube fluorescent lamps; the fittings could fit two tubes. Each kitchen is equipped with two fittings which are spaced equally to distribute light evenly, at the time of the audit, both fittings were fitted with 2x36 W fluorescent tubes as shown in figure 4.11.

Figure 4.11: Kitchen area showing lamp fittings, sink and stove.

The lux obtained during the day was averaging 529 lx when lights are ON and 420 lx when lights are OFF. The illuminance at night is $529 - 420 = 109 lx$. During daylight when lights are ON, the illuminance level is within the **500 lx** minimum required as stipulated by (SABS, 2005). Based on this, the illuminance of 109 lx obtained at night, as well as 420 lx obtained during the day when lights are OFF, are not conforming with the minimum of 500 lx as required by SANS 10114-1:2005. However, according to the Occupational Health and Safety Act of 1993 (RSA Ministry of ManPower, 1993) (ministry of manpower is now known as the department of labour) which was gazetted in Cape Town on the 2nd July 1993, the minimum illuminance required was 150 lx. When considering this, the illuminance level would have been within the limits. The SANS 10114-1:2005 requirements will supersede the Occupational Health and Safety Act of 1993 since it is recent. (National Optical Astronomy Observatory, 2009) states that in the earlier days, the illuminance levels were not set to be high but the improvement in technology and safety standards have resulted in the high minimum requirements of illuminance levels for normal activities.

Cooking

Each kitchen unit is equipped with two units of four plates electric stove rated at 5.5 kW as shown in figure 4.12 below. The stove is for sharing by the students whose rooms are closer to that particular kitchen. The stoves were not in a good condition as they were either not fully functional, not functional at all or even missing, this has led to students buying their own one/two plate stove to use in their rooms which is a fire risk.

Figure 4.12: Four plate electric stove (left) and the stove is missing (right)

Water heating

Each kitchen is provided with a wall-mounted 7.5-litre hydro boil rated at 1.5 kW (shown in figure 4.13). The hydro boil is for sharing by the students whose rooms are closer to that particular kitchen. The units were not in a good condition as they were either not fully functional or not functional at all, this has led to students buying 1.8 kW kettles to use in their rooms for water heating.

Figure 4.13: Hydro boil in the Catsville kitchen

4.3.4 ABLUTION/RESTROOMS (BATHROOM AND TOILETS)

The restrooms are shared by students whose rooms are closer to it. Every floor has four restrooms each with a floor area of about 27m^2. Each restroom is equipped with washbasins, shower, toilet and bathtub as shown on the floor plan layout in figure 4.14 (next page).

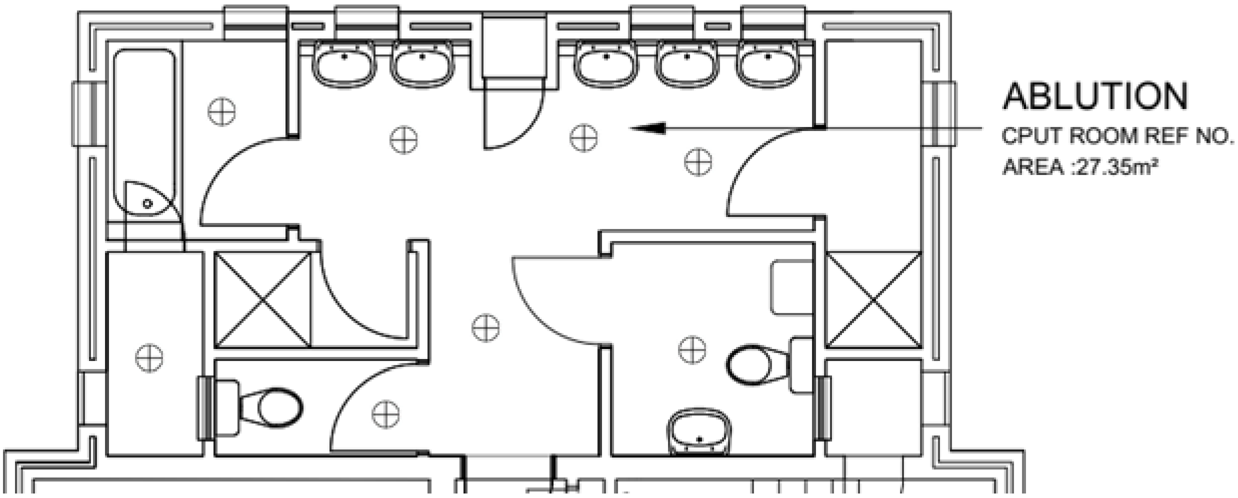

Figure 4.14: Restroom in Catsville

Lighting

Each restroom is equipped with eight lamp fittings; the fittings could fit a maximum of two CFL lamps and were fitted with 9W or 18W CFL lamps. It was noted that some of the lamp fittings had no lamps or the lamps had fused out. Figure 4.15 below shows the lamps fittings in the restrooms.


Figure 4.15: Lamp fittings in the restrooms (Left: ON and Right: OFF)

The illuminance readings obtained during the day were 90.2 lx when the lights were ON and 60 lx when lights were OFF, from this, the illuminance at night was calculated to be $90.2-60=30.2lx$ The SANS 10114-1:2005 recommends that the minimum lux level in the ablution area be at a minimum 200 lx, the lux figures obtained either when lights ON, lights OFF or at night do not meet the requirements.

The second lux measurements were taken with all the lamps fitted and the illuminance level improved to 350 lx when lights ON and 91 lx with lights OFF. From this test, it can be concluded that illuminance in the ablution area conforms with the standards when all the lamps are fully functional.

Water Heating

Each ablution area gets hot water supply from a dedicated 200-litre geyser rated at 4 kW. The heater had no insulation to preserve the hot water and it is constantly powered ON. The geyser is equipped with the manufacture standard thermostat to maintain the water temperature at 70℃. Figure 4.16 below shows the installed geyser.

Figure 4.16: 200-liter 4kW geyser

4.3.5 RECREATION AREA

This is the area (shown in figure 4.17 below) designated for students to use during their free times, either to have quick meetings, watch TV, relax or engage in discussions. Each floor has two recreation areas located next to the kitchen, this offers convenience for students who are busy in the kitchen to use it as a waiting area.

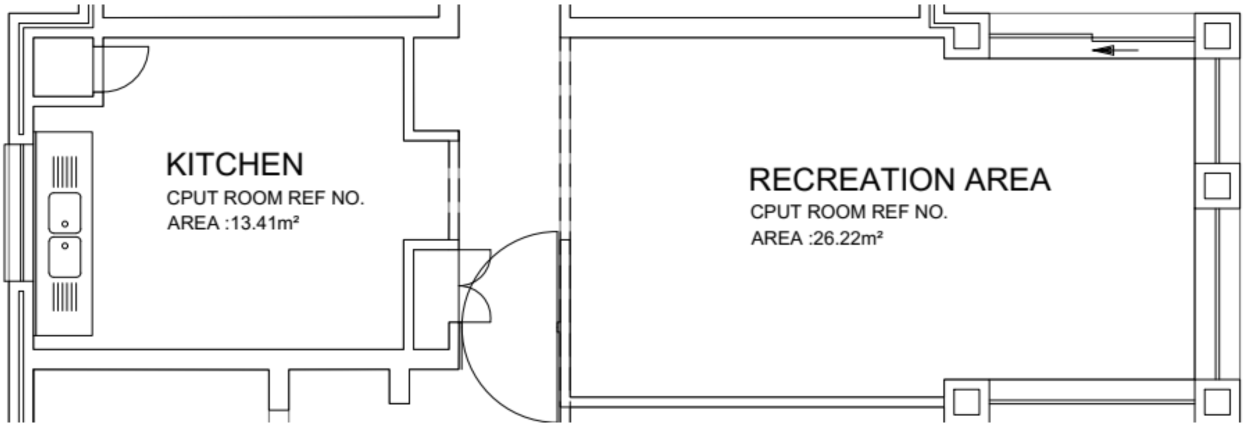

Figure 4.17: Recreation Area

Lighting

The lighting in the recreation areas is similar to that of the student rooms, each recreation room is equipped with four lamp fittings which are spaced equally to distribute light evenly, the fittings can fit two lamps and at the time of the audit, the fittings were fitted with 2x18W CFL lamps. Figure 4.18 below shows the lamps in the recreation area.

Figure 4.18: Lamp fittings in the recreation area

The illuminance readings obtained during the day were 391 lx when the lights were both ON and OFF. The lamps were all not functional hence there was no difference in readings for both ON and OFF, these readings were due to the sunlight. The SANS 10114-1:2005 recommends that the minimum lux level in the recreation area be at a minimum of 200 lx, the lux figures obtained either when lights ON, lights OFF or at night do meet the requirements. Since there were no functional lamps, it can be concluded that the requirements will not be met at night time, but the kitchen area is very close to the recreation area, therefore, the light from the kitchen overlaps and provides a little bit of light in the recreation area.

Other Appliances in The Recreation Area

There were no appliances found, however, there were plugs (as seen in figure 4.19 below) showing that the area used to have a television set which was not available.

Figure 4.19: Socket outlet and TV mounting bracket

4.3.6 ELEVATOR

At the time of the audit, the elevator was not operational, according to the residence manager, the lift has been out of service for a couple of years and the residents rely on stairs. The image below shows the closed elevator.

Figure 4.20: Elevator at Catsville

4.4 Safety and Maintenance of Electrical equipment

Maintenance of electrical equipment (switchboards, circuit breakers, fuses etc.) and systems is crucial as poor maintenance leads to unplanned and lengthy power outages (University of Australia, 2016).

The audit found that some of the electrical boards are not in a good condition as shown in figure 4.21 below. It can be seen that the arc protection shields are missing, in case of a spark or any event this can prove to be problematic. The figure also shows the dirt/dust build-up on the terminals and this is a concern as dust is a major contributor to insulation degradation and dust particles are also a fire risk in case there is a spark generated on the terminals (Kumar & Dave, 2018)

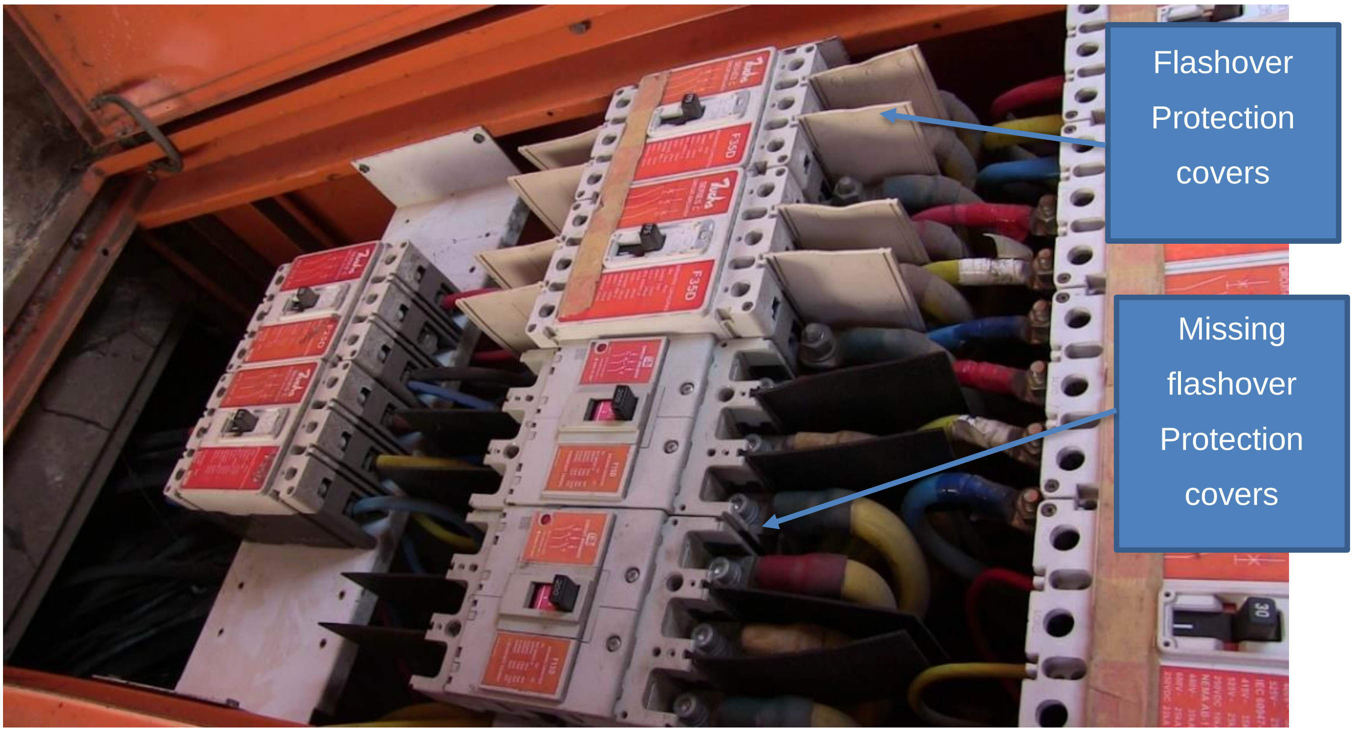

Figure 4.21: Catsville main incomer distribution board

The figures (4.22 to 4.25) below show some of the images of concern which were captured during the audit.

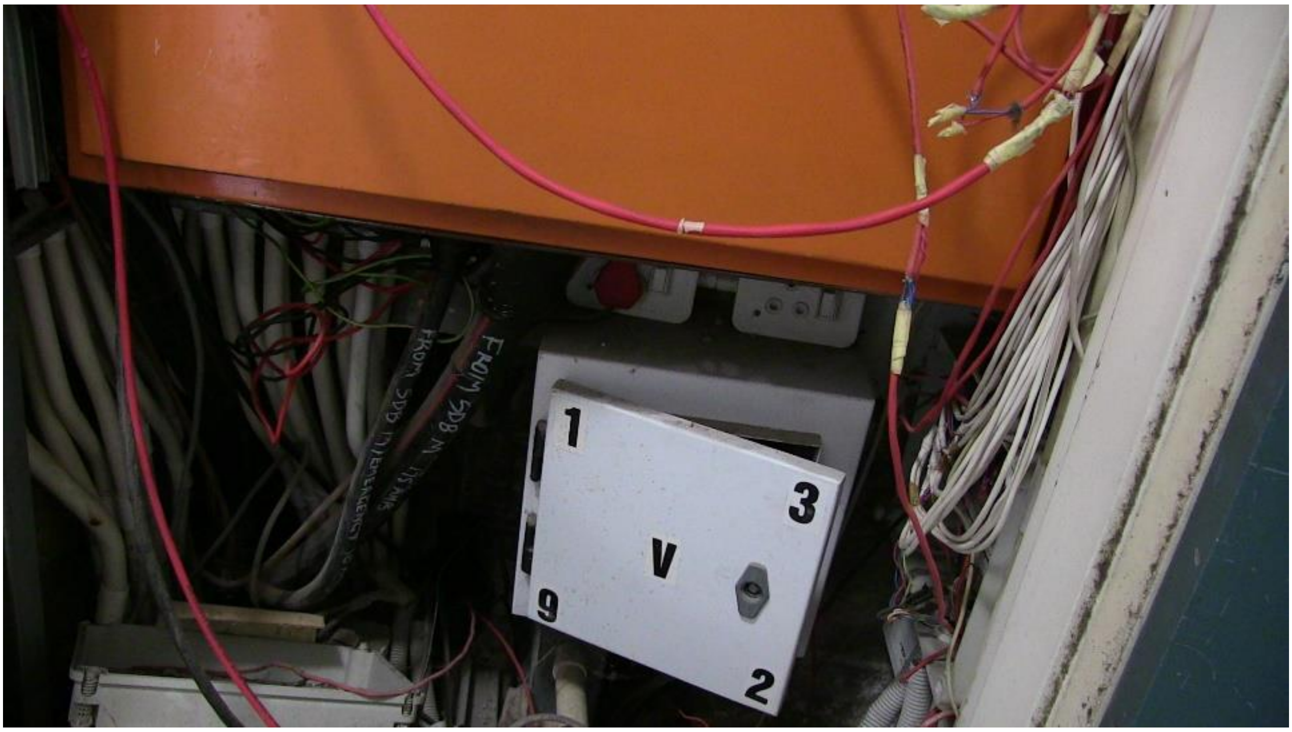

Figure 4.22: Distribution board (G-block) showing dirt participles at the bottom of the DB as well as loose wires

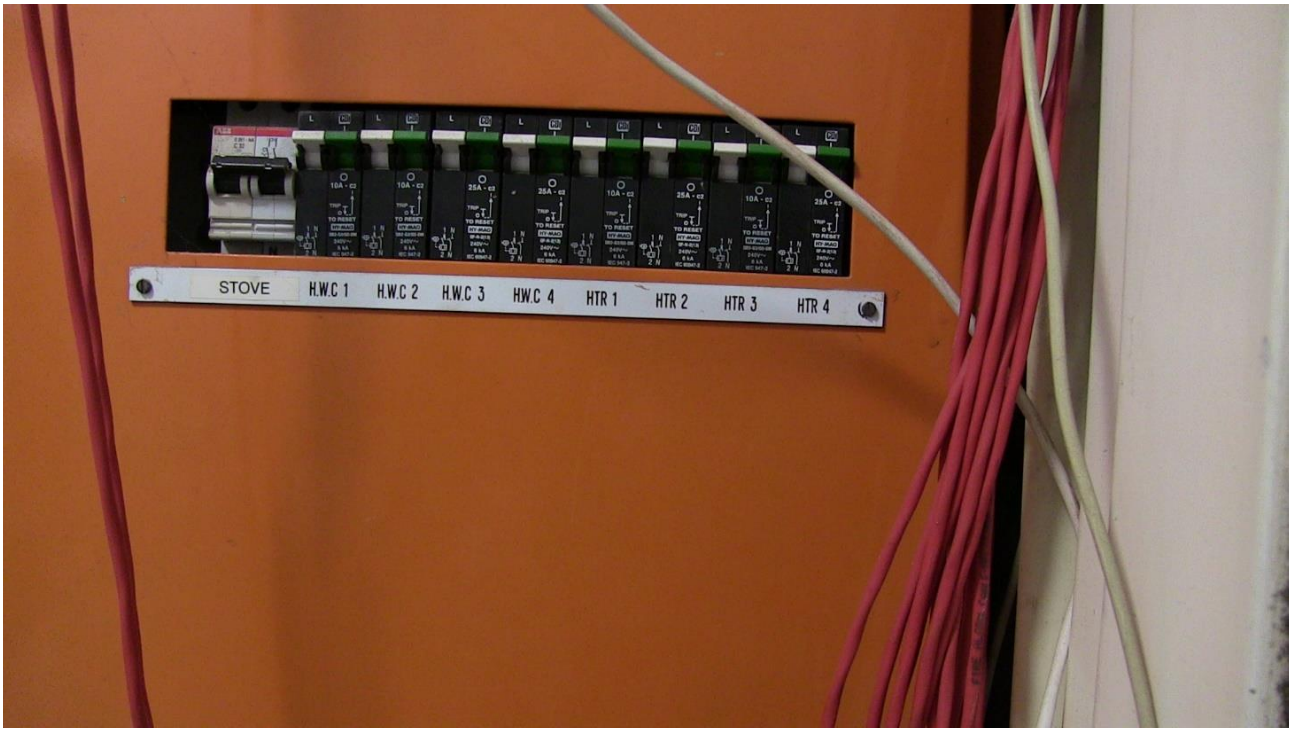

Figure 4.23: Distribution board at G-Block with wires hanging loosely

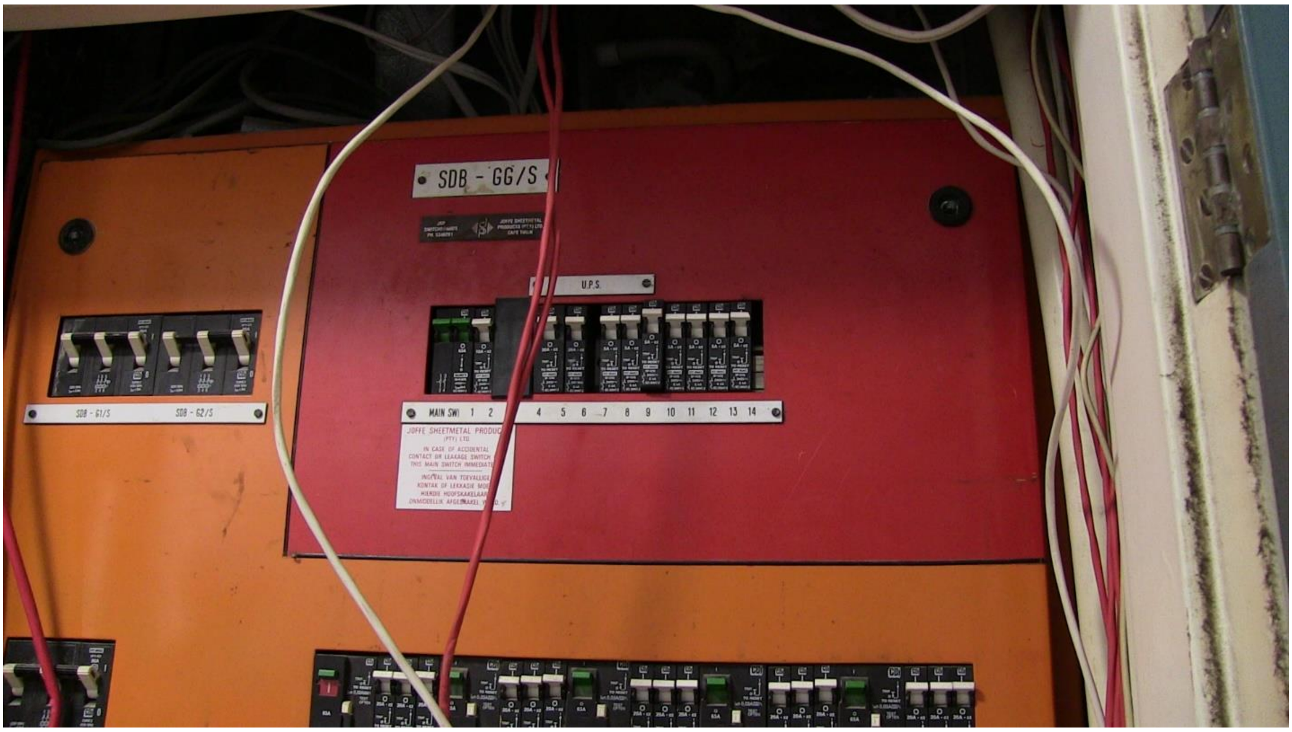

Figure 4.24: Distribution board at G-Block with wires hanging loosely

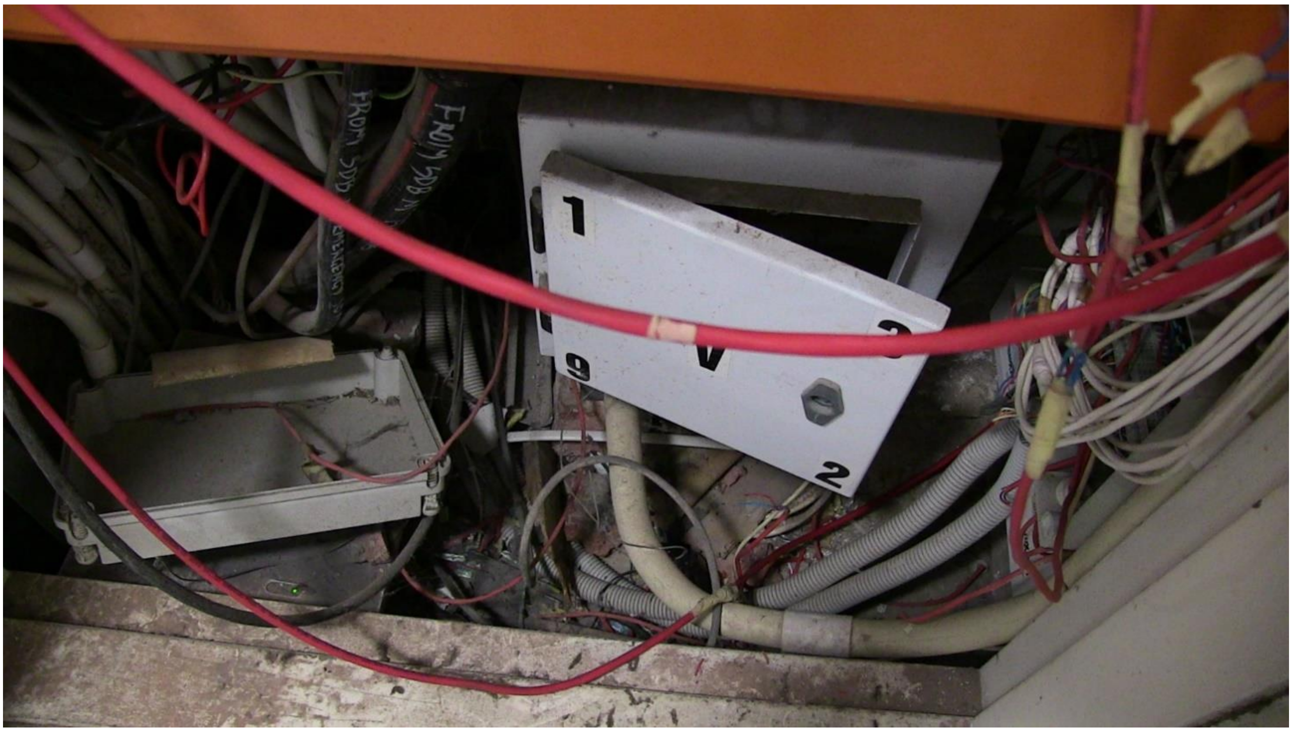

Figure 4.25: Distribution board at G-Block with wires hanging loosely and tangled. Dirt can also be seen

Disasters don't just happen; they are a chain of critical events. "*Like any other major event, they happen due to a combination of factors, of smaller, lesser "mini-events" that existed within the systems and processes. Some of these precursors were known, some were not – but nobody expected them to combine into a costly and potentially deadly event!*"

(Johnson, 2013). (Johnson, 2013) was reporting on a major nuclear event that led to a 62 days plant shutdown at Koeberg during the 2013 Nuclear Seminar.

The quote from Johnson implies that if these electrical boards remain unattended they could brew something undesirable.

4.5 CONCLUSION

This chapter presented the results of the energy audit which was to understand what is consuming electricity at the catsville residence. The appliance on each area was discussed in terms of their operating, power rating as well as their necessity.

CHAPTER FIVE

5 RESULTS – ENERGY CONSUMPTION

5.1 INTRODUCTION

This chapter presents and discusses the energy consumption at the Catsville residence during the periods 01 December 2018 to 31 March 2019 as well as 02 March 2020 to 05 August 2020. The objective is to obtain an average energy consumption (electrical) at the G-block (the layout of the building is shown in the appendices). Specific factors influencing the consumption and the maximum demand patterns are highlighted.

5.2 CATSVILLE RESIDENCE

The electrical energy survey was performed at the G – Block for the period of 3 months (December 2018 to March 2019) and 6 months (March 2020 to August 2020) using the Fluke 1730 power meter. This particular building consists of six floors (ground floor to the fifth floor) with an external area of approximately 890 m^2 and internal area of 775 m^2 per floor making an overall building internal area of 4600 m^2 and external area of 5300 m^2.

As aforementioned, the energy metering was performed on the circuit breaker feeding the G-Block south side. The results are analysed as follows and will be presented in two parts namely: PART 1 (DEC 2018 TO MARCH 2019) and PART 2 (02 MARCH 2020 TO 05 AUGUST 2020)

5.3 PART 1 (DEC 2018 TO MARCH 2019)

5.3.1 AVERAGE ENERGY CONSUMPTION PROFILES

The consumption profiles of the building are displayed graphically to make an appropriate analysis. The December to January period is considered as a recess period according to the CPUT calendar. The period from February to March is accordingly regarded as the in-session period (academic activities in progress). Both periods are presented on different graphs, similarities and differences of all the profiles are discussed. Peak demands and few key profiles with notable features are also discussed.

5.3.2 THE PATTERN FOR THE IN-SESSION AND OUT OF SESSION PERIODS

The average diurnal electricity consumed during the after completion of fourth term recess is analysed in section 5.3.3 for weekdays Monday to Thursday and Weekend Friday to Sunday. The recess period covered on this analysis was from the 07 December 2018 (summer) to 25 January 2019 (summer). The month of January is when the students are busy with registrations and residential applications, it is therefore expected that the consumption will be low between December and January months.

The first term of 2019 began on the 29th of January 2019 (summer) and ended on the 29th March 2019 (autumn). During this term, the consumption is expected to be at its peak and its consumption is analysed in section 5.3.4

5.3.3 AVERAGE CONSUMPTION FOR OUT OF SESSION (DECEMBER TO JANUARY)

The section looks at the consumption pattern during the period mentioned. Energy (kWh), Maximum Apparent Power (kVA), True Power (kW).

5.3.3.1 ENERGY CONSUMPTION (KWH)

The average diurnal electricity (energy) consumed during the recess period is shown in this section for weekdays Monday to Thursday and Weekends, Friday to Sunday. During this period, the university is closed after completion of the fourth term.

- **Weekdays**

The average diurnal consumption (weekdays) for the recess period after the conclusion of term four is presented in figure 5.1 below for the period of the 12 December 2018 (midsummer) to 25 January 2019 (late summer).

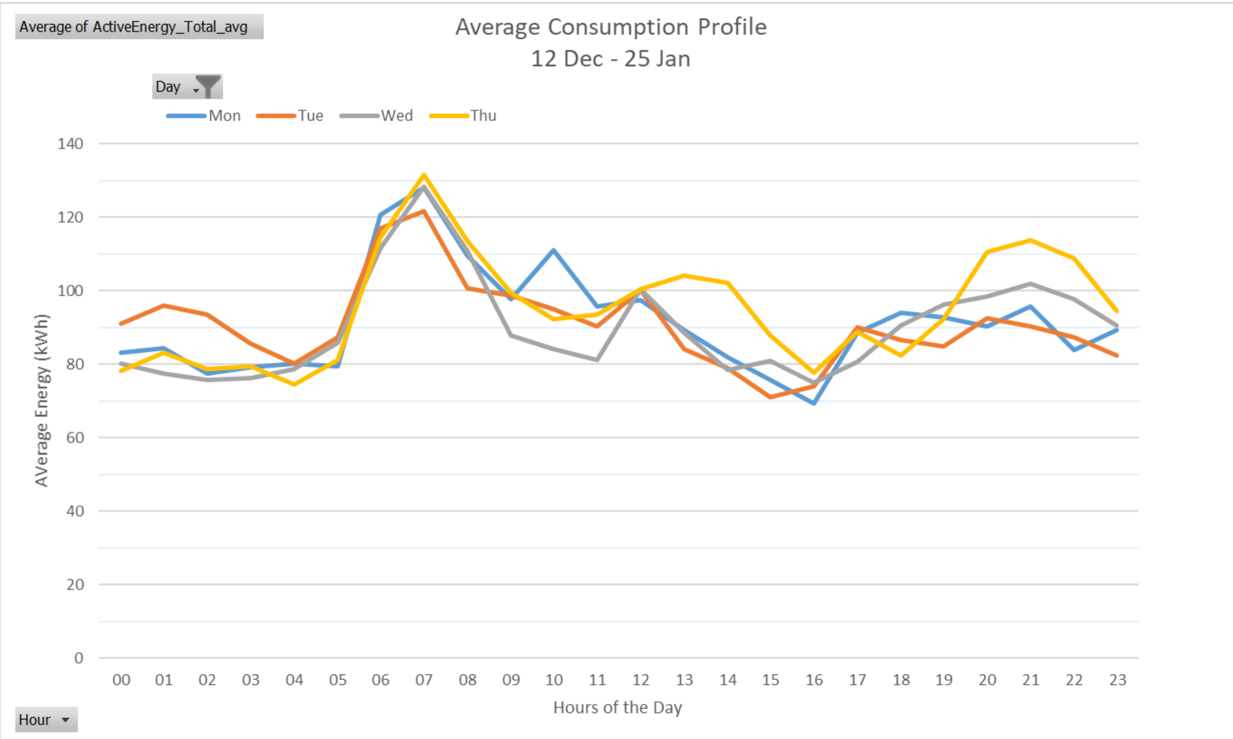

Figure 5.1: Average diurnal consumption profile for the recess period (12 Dec 25 Jan)

Based on the graph as seen in figure 5.1 above, the consumption rises sharply just after 05:00 am for all the weekdays reaching the maximum of just above 130 kWh.

The said peak (high loading) is reached at around 07:00 am and starts to fall within two hours as at 9:00 am the consumption has dropped drastically to just below 100 kWh then at 10:00 am there is a steady decline for five hours as it reaches the lowest peak hitting figures below 80 kWh at 16:00.

However, from 17:00 there is a noticeable rise in consumption reaching around 100 kWh at 21:00 then thereafter the graph normalises to an average of 90 kWh throughout the night until the early hours of the morning and the cycle starts again. This cycle happens consistently for all the weekdays as seen on the graph.

Discussions on Weekdays' consumption patterns

The rise and drop were not expected as this was during the recess period, based on the site visit and interviews, there were students (or tenants) residing in the residence during this period. Most of these tenants were employees hence the busy morning (between 5 am and 8 am). During the day, there is less consumption because few people are using the electricity, however, it was realised that most students (tenants) leave their lights and some appliances powered on hence the usage doesn't reach the zero mark or even close but remains almost consistent at approximately 90 kWh. After 4 pm, the consumption rises as tenants are now back home doing their evening chores. From 9 pm, consumption is back at approximately 90 kWh throughout the night.

- **Weekends**

This section analyses the trends of Friday, Saturday and Sunday

Friday

On this document, Friday is considered as part of the weekend even though it is generally taken as a normal working day, therefore the representation of the consumption of Friday as seen on figure 5.2 on the next page was to be expected as they are closely similar to the weekdays which were analysed in figure 5.1. However, the Friday morning peak is the highest of them all sitting at about 150 kWh.

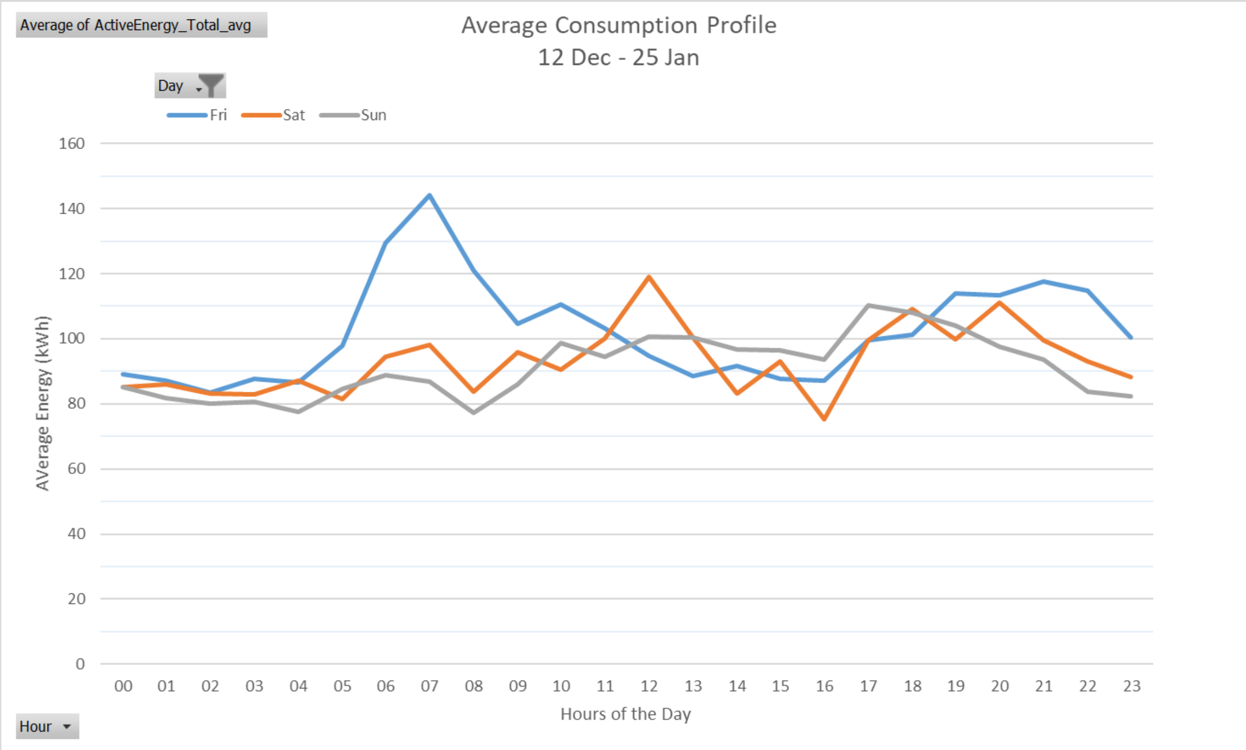

Figure 5.2: Average diurnal consumption profile for the recess period (12 Dec 25 Jan)

Saturday

Saturday's consumption profile is analysed from midnight (the beginning of the day) where it is sitting steadily at figures just above 80 kWh until it starts to climb (just after 05:00 am) to the morning maximum within 2 hours in the similar pattern as the weekdays and Fridays as seen earlier. However, Saturday's morning peak consumption hitting just under the 100kWh mark was noticeably lower (~40 kWh) than the weekdays and Fridays. The consumption drops and rises again throughout the day until it reaches the ultimate peak of about 120 kWh at noon then it falls steadily for 4 hours to about 70 kWh (the lowest peak) at 4:00 pm. The evening consumption starts to show after 4:00 pm and continues to rise steadily until 8:00 pm reaching a peak of 110 kWh then starts to finally drop to just above 80 kWh at the end of the day.

Discussion on Saturday

Saturday's consumption profile is not out of the ordinary, the morning peak is not comparable to the weekdays because only a handful are going to work and most tenants are still in bed and only start their day from 10 am hence the sudden rise in consumption reaching the ultimate peak at noon. Late afternoon into the evening is almost similar to the weekdays, however, most students (tenants) at this time are either doing their evening chores or preparing for late dinners, a night out or even clubbing.

Sunday

The Sunday profile was relatively flat at above 80 kWh from 00:00 to 04:00 am, then before 05:00 am the consumption starts to rise to about 88 kWh at 06:00 am (morning peak) which is 10 kWh and 60 kWh below the Saturday and weekdays morning peak respectively. The morning peak only lasts for about one hour as at 08:00 am the consumption is at its lowest (about 75 kWh). However, at 09:00 am, the consumption steadily climbs for about 7 hours reaching the highest peak of Sunday of 110 kWh at 5:00 pm then declines bit by bit for 6 hours reaching around 80 kWh at 23:00.

Discussions on Sunday

Sunday is normally not a busy day but some people do go to church in the morning then upon returning from the church they start cooking Sunday lunch, preparing for the week ahead or just doing the normal Sunday chores like laundry and ironing. This is the reason for the late afternoon peak which then steadily drops.

5.3.3.2 MAXIMUM DEMAND PROFILE (KVA)

Weekdays

The maximum demand as shown in figure 5.3 were closely aligned with the electricity consumption (seen in the previous section as well as real power consumed (figure 5.4 on the next page). It can, however, be noted that the demand patterns also have rising and falling patterns, this was expected because in most cases peak demands appear at different times and days because of different activities (by the consumer) which are not necessarily related to each other.

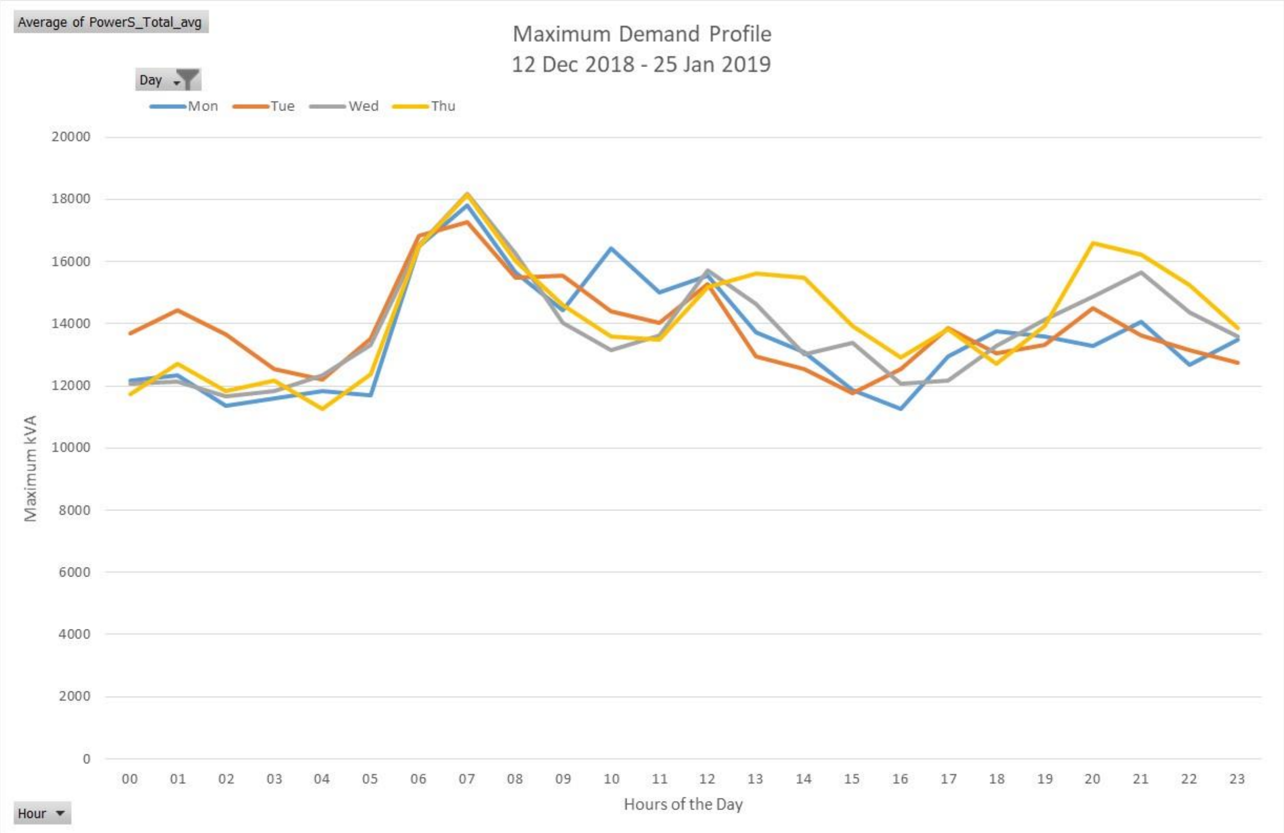

Figure 5.3: Consumed power in VA (Maximum Demand)

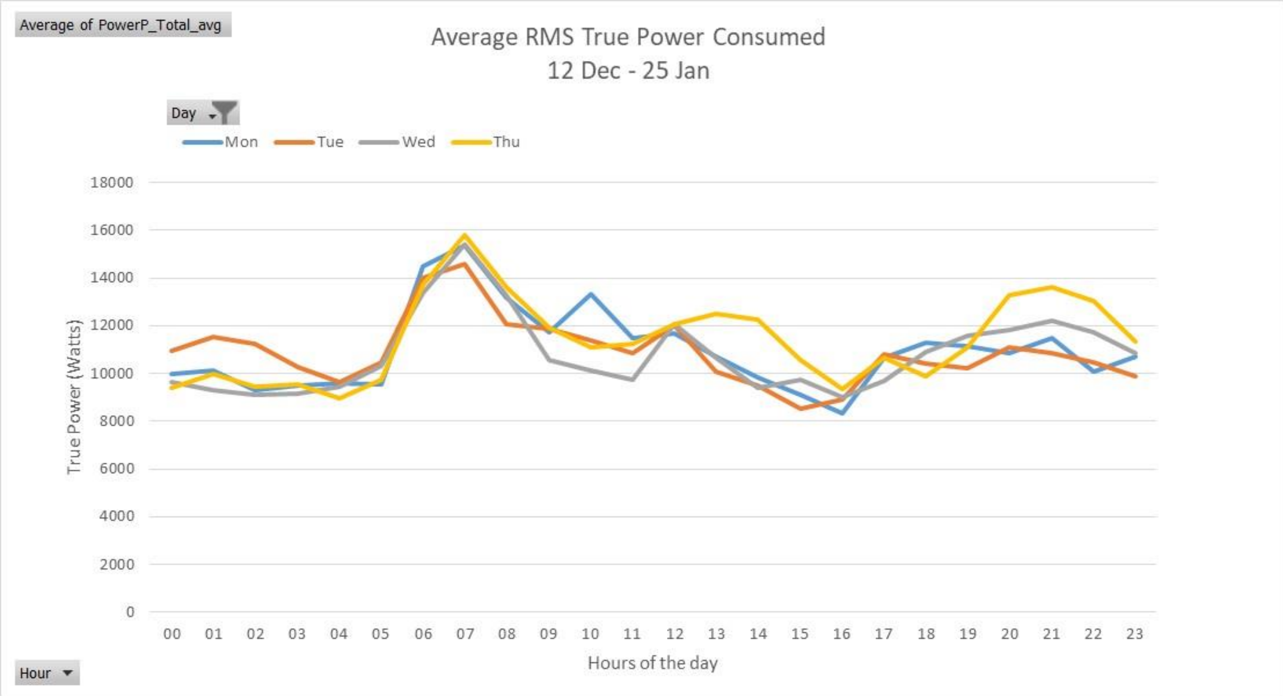

Figure 5.4: Consumed power in Watts

Weekends

The evening load profile for peak demands shows that Friday (as shown in figure 5.5 on the next page) and Thursday are closely matched but different from other weekdays. The morning rise is steeper as compared to the average consumption morning rise even though they begin at the same time, 05:00 am, leading to a shorter rise time of 1.5 hours as the peak is reached just after 06:00 am. The maximum demand of the week peaked in the morning at around 18 kVA (figure 5.3) except for Friday which is at 20 kVA. However, the maximum peak of Saturday (16.5 kVA) is reached at noon while Sunday (17 kVA) is reached at 5:00 pm. These trends in figure 5.5 are similar to that of real power (see figure 5.6 on the next page)

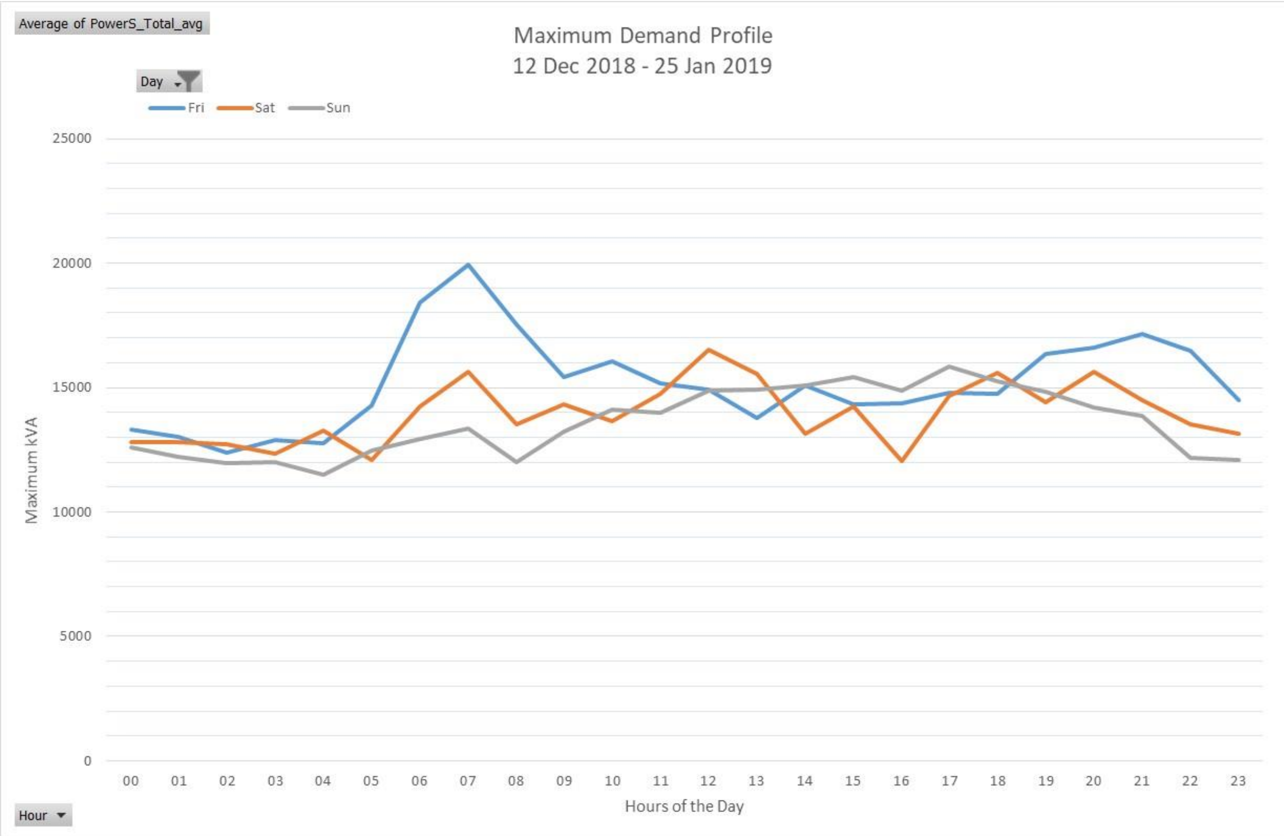

Figure 5.5: Consumed power in VA (Maximum Demand)

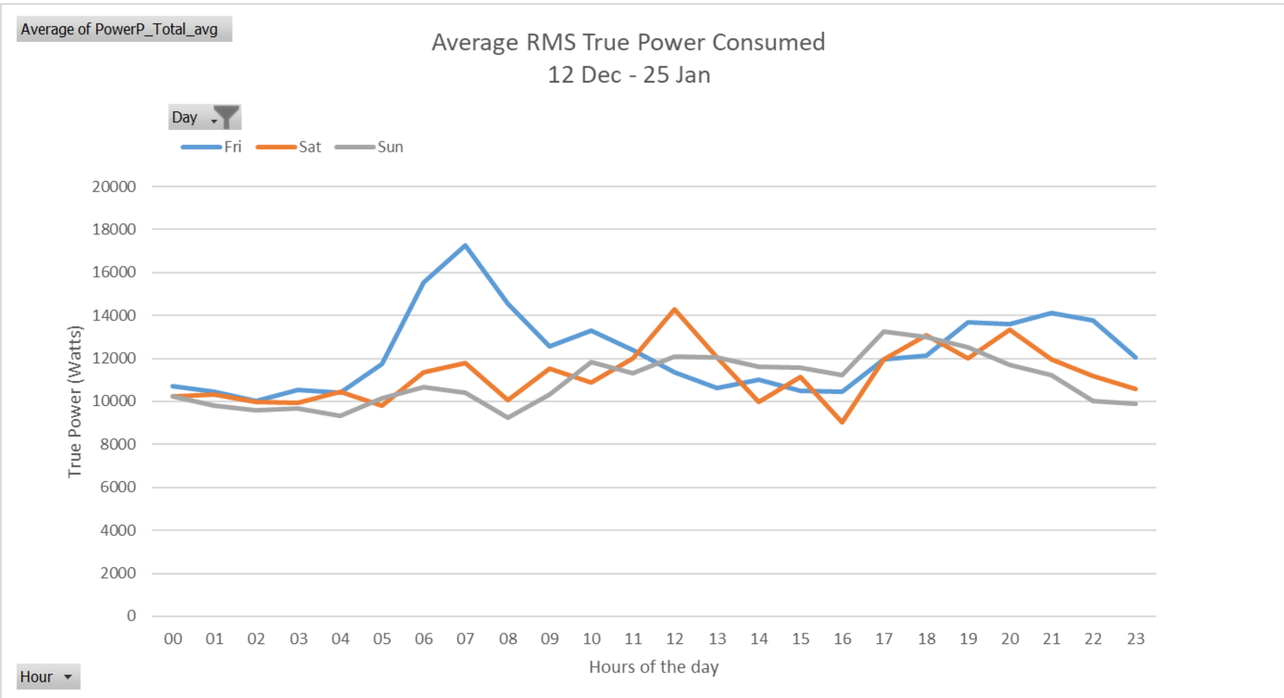

Figure 5.6: Consumed power in Watts

5.3.3.3 CONCLUSION

The graphs of the maximum demands and energy consumption (which is calculated using real power) are almost the same. The reason is that the power factor in the residential buildings is almost at unity and real power and apparent power will be very close.

5.3.4 AVERAGE CONSUMPTION FOR IN-SESSION (JANUARY TO MARCH)

The section looks at the consumption pattern during the period mentioned. Energy (kWh), Maximum Apparent Power (kVA), True Power (kW).

5.3.4.1 ENERGY CONSUMPTION(KWH)

The average diurnal electricity (energy) consumed during the period where the school is in-session is shown in this section for weekdays Monday to Thursday and Weekends, Friday to Sunday. This period, the university is open for the commencement of the first term.

Weekdays

The average diurnal consumption (weekdays) for the in-session period at the beginning of term 1 is presented in figure 5.7 below for the period of the 26 January 2019 (late summer) to 02 March 2019 (early autumn).

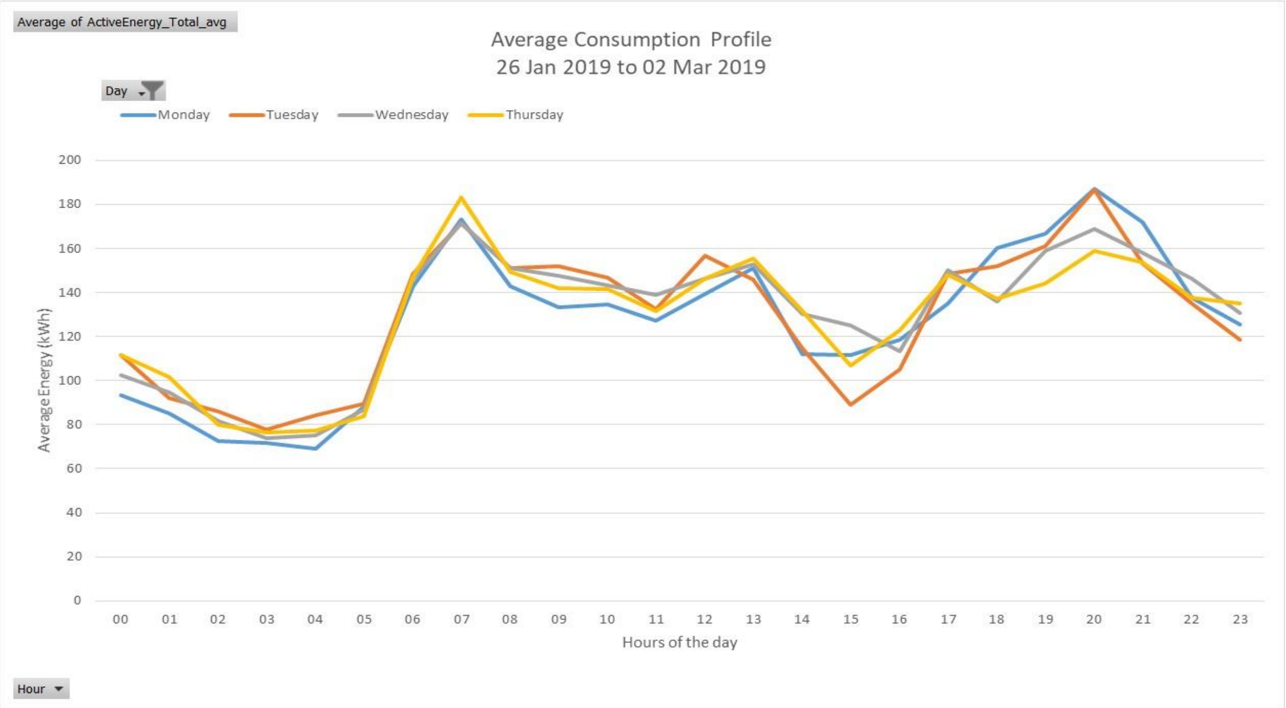

Figure 5.7: Average diurnal consumption profile for the in-session period (26 Jan – 02 Mar 2019) for weekdays

Based on the graph on figure 5.7 (previous page), the patterns are more similar to that of recess period but there is an increase in demand which was expected because the normal activities of the university are in progress and students are back from the December holidays.

From the graph, the consumption is in a steady decline from about 100 kWh at midnight and reaches a minimum of 70 kWh around 04:00 am before it rises steeply from 05:00 am to a maximum of about 180 kWh at around 07:00 am. The consumption starts to fall slowly and averages 140 kWh from 08:30 am to 13:00. After 13:00 there is an unexpected drastic decline from 140 kWh to reach a midday minimum of about 110 kWh at 15:00.

However, after 16:00 there is a noticeable rise in consumption reaching a peak of around 180 kWh at 20:00 then thereafter the graph normalises to an average of 100 kWh throughout the night until the early hours of the morning and the cycle starts again. This cycle happens consistently for all the weekdays as seen on the graph (figure 5.7).

Discussions on Weekdays' consumption patterns

The rise and drop in consumption are expected as this was during the time where university activities were intensively in progress. Most classes start in the morning which explains the busy morning, however, the students do not have a consistent pattern as they attend classes at different times which explains the steady drop from 08:30 am to 13:00.

Even though students attend at different times, normally after lunch most students are on campus for various activities ranging from attending classes, studying or just a catch-up session with other students. This explains the drastic drop in consumption from 13:00 to around 16:00.

The university business day normally ends at 16:00, this explains the rise in consumption just after 16:00 as students will be back at their student accommodation to do their evening chores such as cooking, cleaning, leisure activities or studying. After 20:00 there is less activity as most are now preparing for the next day. it must be noticed that the consumption does not reach a zero mark (or close to it), this is because students have different patterns, those who do not have an early morning for the next day, they will use the night quiet time to do their activities and sleep the next day.

Weekends

This part analysis the trends of the weekend (Friday, Saturday and Sunday) as seen in figure 5.8 below

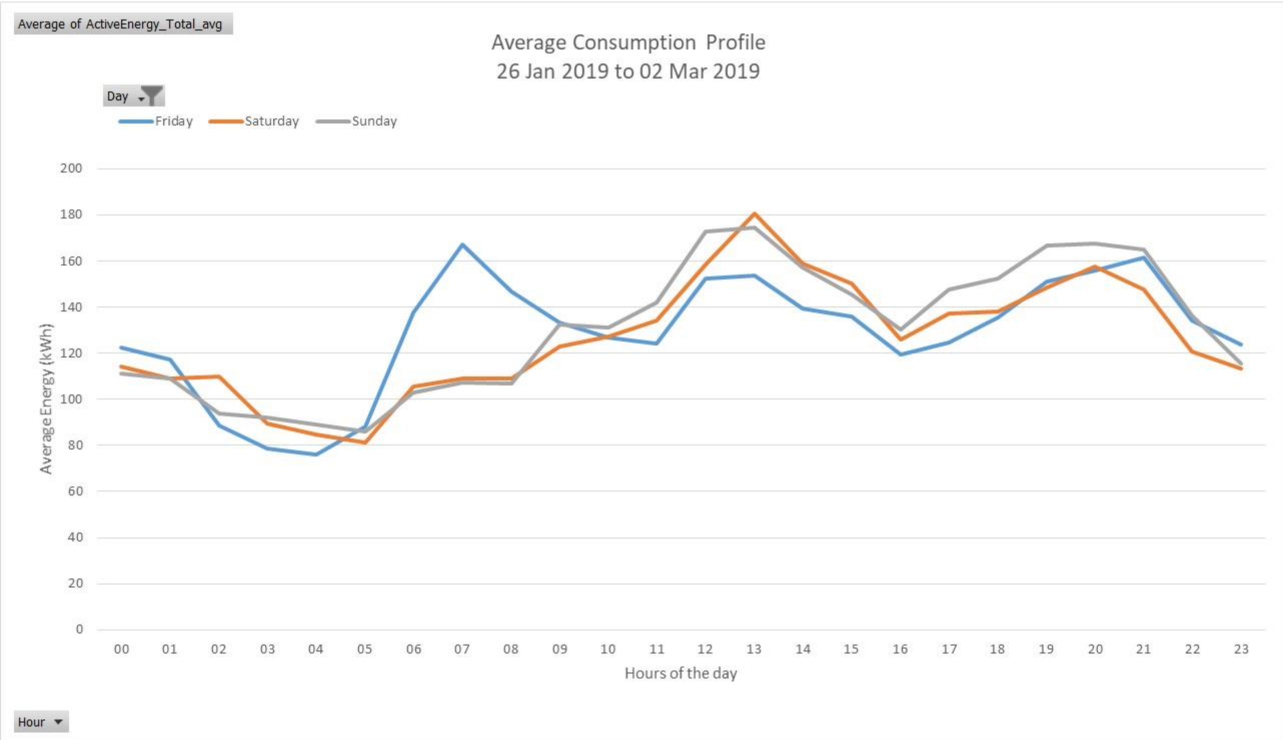

Figure 5.8: Average diurnal consumption profile for the in-session period (26 Jan – 02 Mar 2019) for weekends

- **Fridays**

This document considers Friday as part of the weekend even though it is generally taken as a normal working day, therefore the representation of the consumption of Friday as seen on figure 5.8 above is as expected closely similar to the weekdays which were analysed in figure 5.7.

- **Saturday**

Just like on weekdays, after midnight, the consumption is gradually decreasing from 120 kWh to a minimum about 80 kWh then at 05:00 am, there is a noticeable increase in a linear fashion until the peak of about 180 kWh is reached at 13:00. Just after lunchtime, there is a decrease in consumption in a slightly quicker fashion for about three hours. At 16:00, the afternoon minimum of about 120 kWh is reached and then there is a steady rise as the evening approaches until the evening peak of about 160 kWh attained at 20:00 then there is a steady decrease until midnight and the new cycle starts again.

- **Discussion on Saturday**

Saturday is a day where most people are not due to report for school unless those few individuals who are working or those who have the additional Saturday classes. This explains the slow start to the day which led to a lunchtime peak. Late afternoon into the evening is almost similar to the weekdays, however, most students (tenants) at this time are either doing their evening chores or preparing for the late dinners, a night out or even clubbing.

- **Sunday**

The Sunday profile is relatively similar to that of Saturday.

- **Discussions on Sunday**

Just like Saturday, Sunday is normally a relaxed day, it must be noticed that from 08:00 am to 09:00 am there is a steep increase in consumption, this can be attributed to those who use the facilities as they prepare to go to church. Furthermore, the profile is virtually similar to that of Saturdays.

5.3.4.2 MAXIMUM DEMAND PROFILE (KVA) FOR IN-SESSION PERIOD

Weekdays

The maximum demand pattern shown in figure 5.9 (on the next page) was closely aligned with the electricity pattern consumption (seen in the previous section as well as real power consumed shown on figure 5.10 on the next page). It can, however, be noted that the demand patterns also have rising and falling patterns, this was expected because in most cases peak demands appear at different times and days because of different activities (by the consumer) which are not necessarily related to each other.

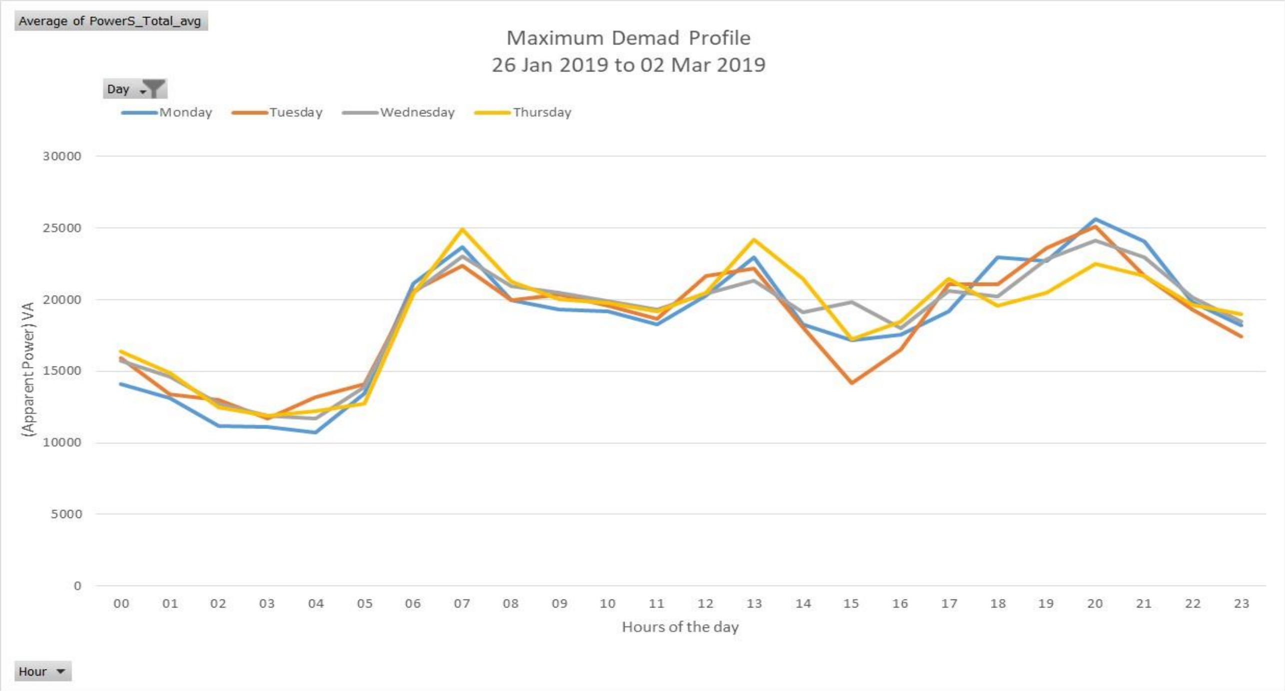

Figure 5.9: Consumed Maximum Demand in VA

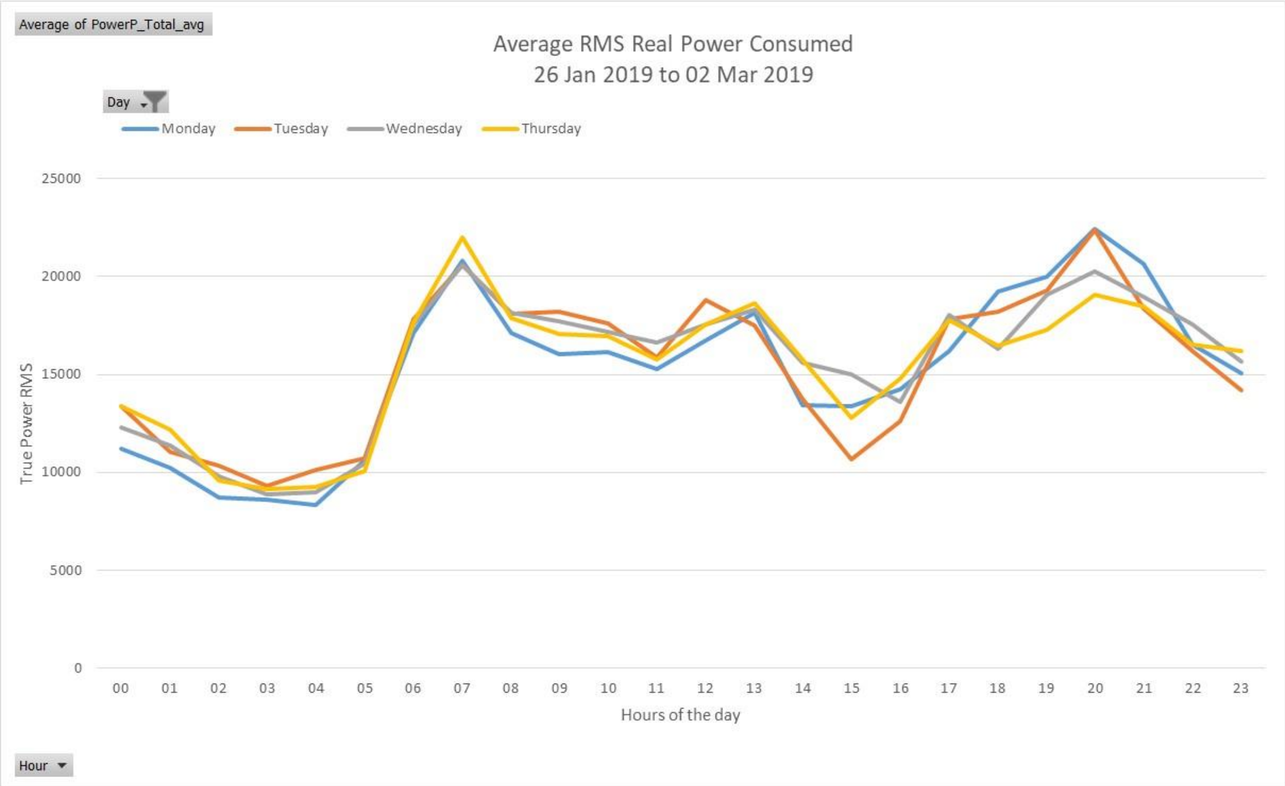

Figure 5.10: Consumed power in Watts

Weekends

The evening load profile for peak demands shows similarities with the consumption profiles as seen in figure 5.11 below. These trends are similar to that of real power (shown in figure 5.12 below)

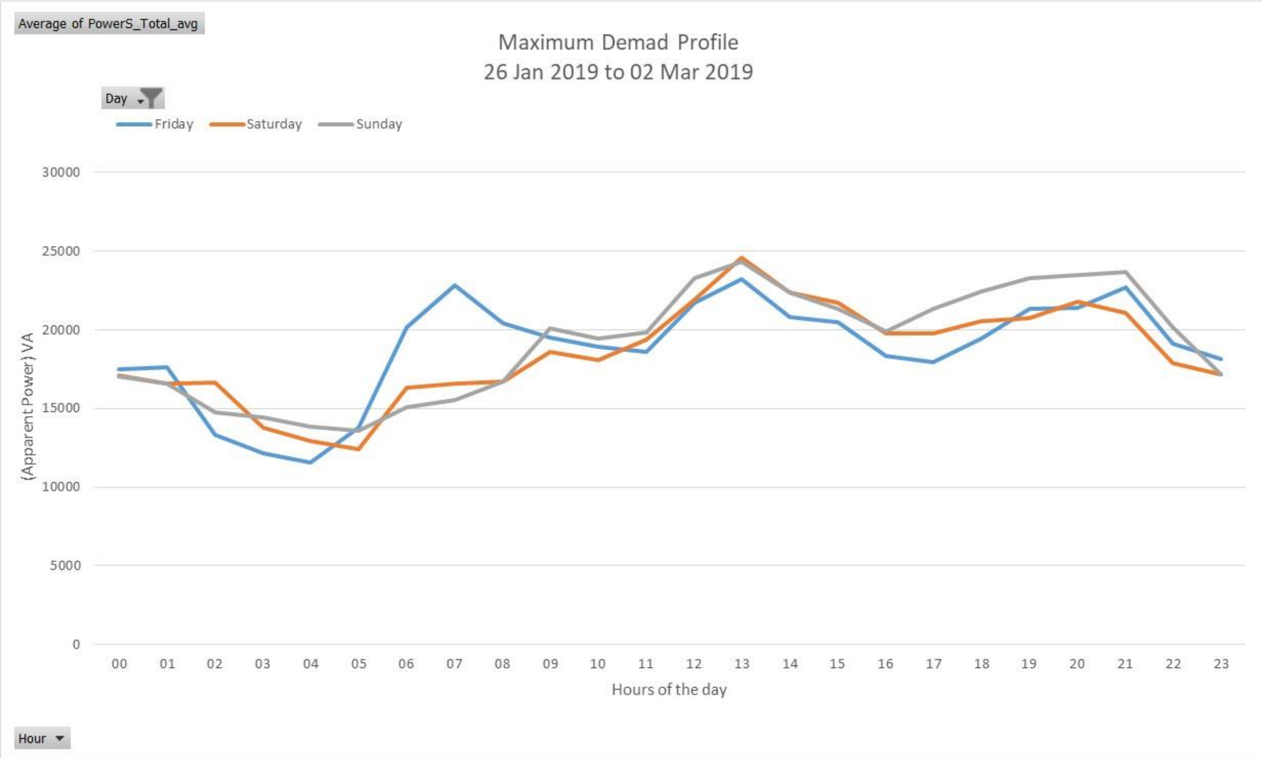

Figure 5.11: Consumed power in VA (Maximum Demand)

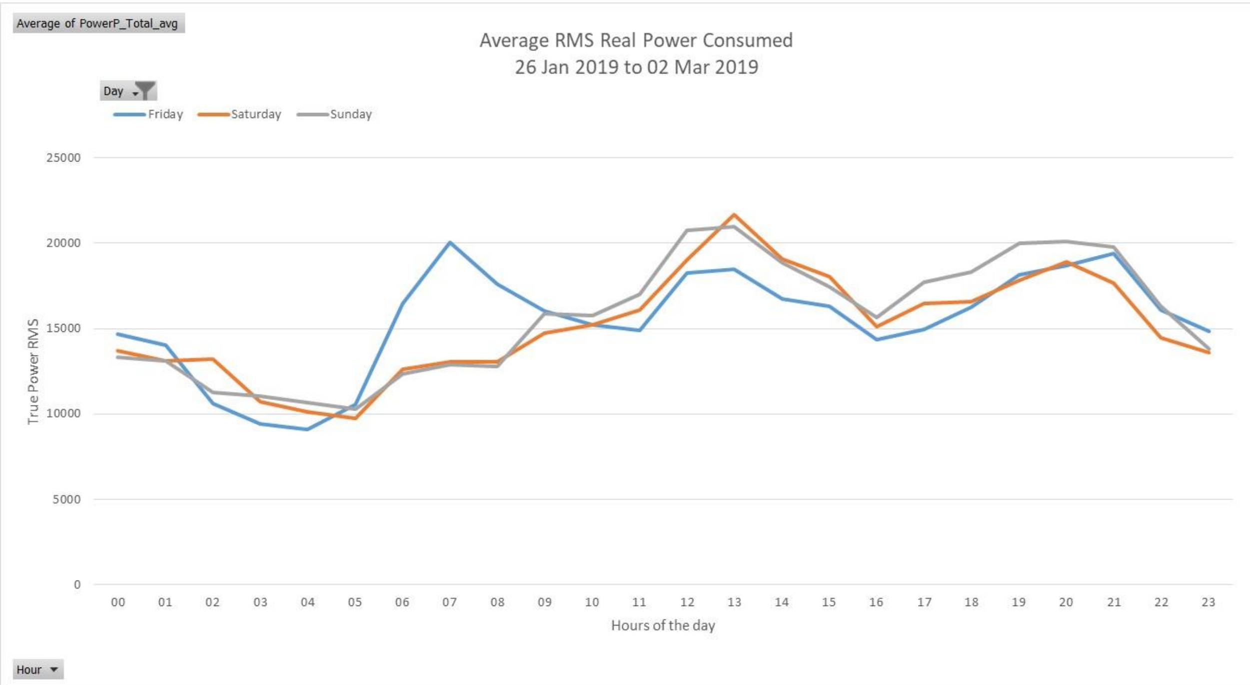

Figure 5.12: Consumed power in Watts

5.3.5 CONCLUSION

The student's accommodation energy consumption patterns seem to be very complicated when compared to patterns of on-campus office area energy consumptions (seen from the study by (Maistry et al., 2012) at the University of Johannesburg). The profile of Monday to Friday is consistent and the peaking points and surges are consistent with the literature. The Saturday and Sunday profiles are rather not as expected as there are many dips and swells which cannot be understood, this, however, cannot be controlled as the analyses are for hundreds of students who do things differently and at different times and the student's behaviour is different to those of individuals at work areas or homes.

During the visit, it was established that the lighting on passages, patios and restrooms remains on at all times, therefore it can be concluded that consumption will never reach figures close to 0 kWh during off-peak hours unless there are changes in the system.

5.4 PART 2(02 MARCH 2020 TO 05 AUGUST 2020)

5.4.1 ENERGY CONSUMPTION PROFILES

The consumption profiles of the building are displayed to make an appropriate analysis since the previous section presented the consumption file graphically, this section will therefore present them in a form of tables showing the total recorded consumption. The data obtained in this section will be separated into three parts namely, before lockdown, during the hard lockdown and during lockdown (when restrictions were relaxed). South Africa embarked on the unprecedented pandemic (COVID-19) preventative method of enforcing hard lockdown which meant that the country will be in a total shutdown (Alvarez et al., 2020). Lockdown is one of the non-pharmaceutical ways of curbing the spread of the coronavirus since it is known to spread through contact and respiratory droplets (Liu Xing & Za Zhi, 2020).

Lockdown is when the government is essentially ordering the people to stay at home and only essential workers or personnel are allowed to move around. The State President, Cyril Ramaphosa, and the cabinet enforced hard lockdown from the 27 of March 2020 for five weeks, this meant students were sent home and residences were virtually empty (Republic of South Africa, 2020a). On the 1st of June, the president ordered that some restrictions will be relaxed to allow the economic activities to commence and movement such as those of educational purposes. For educational purposes, this was limited to only final year students (limited to 33%) who really required to be on Campus (Republic of South Africa, 2020b).

Based on this, the consumption profiles will be compared as follows.

1. Before lockdown – 02 March to 27 March 2020
2. During hard lockdown – 28 March to 31 May 2020
3. During lockdown with relaxed regulations – 01 June to 05 August 2020

All periods are presented on different tables, similarities and differences of all the profiles are discussed. Peak demands and few key profiles with notable features are also discussed. It must be noted that during this period, period 1 and period 3 there was a load-shedding.

5.4.2 CONSUMPTION PATTERNS (02 MARCH 2020 TO 04 AUGUST 2020)

This section looks at the energy consumption pattern during the period mentioned. As aforementioned, the results will be split into 3 sections namely before lockdown (02 March 2020 to 28 March 2020), during the hard lockdown (28 March 2020 to 31 May 2020) and relaxed lockdown (01 June 2020 to 04 August 2020).

5.4.2.1 ENERGY CONSUMPTION (KWH)

The total electricity (energy) consumed during the period under study is shown in this section for before lockdown, during lockdown hard lockdown and lockdown with relaxed restrictions. The provided data was downloaded from the FLUKE 1730 power meter which was measuring the power usage at the G-block south.

Before Lockdown (02 March 2020 to 28 March 2020)

Table 5.1: Total energy consumption before lockdown

ES.026

Active energy, forward	8.551	MWh
Active energy, reverse	0.000	MWh
Total active energy	8.551	MWh
Max. demand	33.663	kW
	15/03/20	19:30:00

Cost of Energy

○ standard ◉ advanced

Total energy cost

R15,049.161$_f$

Topology: 3-ph Wye
Start date: 02/03/20 12:00:00
End date: 28/03/20 01:00:00
Duration: 25d 13h 0m 0s
Demand interval: 10min
Number of demand intervals: 3678
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

Table 5.1 shows the total consumption at the G-block south for a period of 25 days (02 March 2020 to 28 March 2020), this gives the baseline of consumption as this was the period where the students were in the residence and the university was in full operation. It must be noted that the total consumption was 8.551 MWh and costing R15 049.16 based on the current tariff rate of 1.76 R/kWh (provided by the City of Cape Town). This will form the bases of comparison with the other periods as follows. The average daily consumption was calculated to be 342.04 kWh per day.

During hard lockdown (28 March 2020 to 31 May 2020)

Since the before lockdown data (table 5.1) is considered as the baseline, table 5.2 below shows the consumption of electricity for the same period of 25 days after the implementation of hard lockdown (28 March 2020 to 22 April 2020). During this period, only a handful (below 10%, according to the residence management) of students were in the accommodation as most of them were transported home.

Table 5.2: Total Consumption during the lockdown, first 25 days (28 March to 22 April 2020).

ES.026

Active energy, forward	7.462	MWh
Active energy, reverse	0.000	MWh
Total active energy	7.462	MWh
Max. demand	29.112	kW
	31/03/20	20:10:00

Cost of Energy

○ standard ◉ advanced

Total energy cost

R13,133.202$_f$

Topology: 3-ph Wye
Start date: 28/03/20 01:00:00
End date: 22/04/20 14:00:00
Duration: 25d 13h 0m 0s
Demand interval: 10min
Number of demand intervals: 3678
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

Based on the information in table 5.2, the consumption had only dropped by 1.089 MWh (from 8.551 MWh to 7.462 MWh) costing R13 133.20 which is a drop by R 1915.96 from R15 049.16 before lockdown. Based on this, the average daily consumption was calculated to be 298.48 kWh per day.

These results are quite alarming as they are out of the ordinary and were not expected to be like this. With the fact that students were not in the residence, the drop was expected to be more significant. This also confirms the information from the energy audit where it was found that energy is not a concern to students and there were no measures installed to semi-automate the appliances using energy. There is reason enough to believe that the appliances such as lights; geysers were operational even though no one was using them.

Table 5.3 below also shows the profile of the second 25 days (22 April 2020 to 17 May 2020) of hard lockdown, it can also be seen that the consumption was virtually similar to the first 25 days of hard lockdown. This is reason enough to believe that there was little human intervention (because the residence was empty and no one was using the electricity) and only the appliances that were left operational were using electricity constantly. In this case, the average daily usage was 308.36 kWh.

Table 5.3: Total Consumption during lockdown second 25 days (22 April to 17 May 2020)

ES.026

Active energy, forward	7.709	MWh	Cost of Energy	Topology: 3-ph Wye
Active energy, reverse	0.000	MWh	○ standard ◉ advanced	Start date: 22/04/20 01:00:00
Total active energy	7.709	MWh	Total energy cost	End date: 17/05/20 14:00:00
Max. demand	27.923	kW	R13,567.225$_f$	Duration: 25d 13h 0m 0s
	29/04/20	19:00:00		Demand interval: 10min
				Number of demand intervals: 3678
				Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

Table 5.4 below also shows the profile of the full duration of the hard lockdown (28 March 2020 to 31 May 2020). The electricity consumed was 19.848 MWh for a period of 64 days which translates to 304.438 kWh per day. This daily average consumption is very similar to the two periods shown above (table 5.2 and 5.3) as they also average 300 kWh per day.

Table 5.4:Total Consumption during a hard lockdown, full period (22 Mar to 31 May 2020)

ES.026

Active energy, forward	19.848	MWh	Cost of Energy	Topology: 3-ph Wye
Active energy, reverse	0.000	MWh	○ standard ◉ advanced	Start date: 28/03/20 01:00:00
Total active energy	19.848	MWh	Total energy cost	End date: 31/05/20 14:00:00
Max. demand	29.112	kW	R34,932.308$_f$	Duration: 64d 13h 0m 0s
	31/03/20	20:10:00		Demand interval: 10min
				Number of demand intervals: 9294
				Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

During relaxed lockdown (01 June 2020 to 04 August 2020)

During this period, the restrictions were relaxed and 33% of students were allowed back to Campus and respective residences. This section will also look at the first 25 days, second 25 days as well as the full period of relaxed lockdown.

Table 5.5 below shows the total consumption for the first 25 days (01 June 2020 to 26 June 2020) during the relaxed lockdown regulations and restrictions. The consumed energy rose to 8.514 MWh which is similar to the figures of before lockdown (02 March to 28 March) and the bill was R14 984.76. Based on this, the daily consumption was 340.56 kWh per day which is very close to that of before lockdown (342.04 kWh).

Table 5.5: Total Consumption during the relaxed lockdown, first 25 days (01 June to 26 June 2020)

ES.026

Active energy, forward	8.514	MWh
Active energy, reverse	0.000	MWh
Total active energy	8.514	MWh
Max. demand	28.323	kW
	14/06/20	18:40:00

Cost of Energy	
○ standard	◉ advanced
Total energy cost	
R14,984.762$_f$	

Topology: 3-ph Wye
Start date: 01/06/20 01:00:00
End date: 26/06/20 14:00:00
Duration: 25d 13h 0m 0s
Demand interval: 10min
Number of demand intervals: 3678
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

The consumed 8.514 MWh (as shown in table 5.5) was to be expected since the students are now back in the residence.

Table 5.6: Total Consumption during the relaxed lockdown, second 25 days (26 June to 21 July 2020)

ES.026

Active energy, forward	11.152	MWh
Active energy, reverse	0.000	MWh
Total active energy	11.152	MWh
Max. demand	40.138	kW
	12/07/20	20:20:00

Cost of Energy	
○ standard	◉ advanced
Total energy cost	
R19,627.067$_f$	

Topology: 3-ph Wye
Start date: 26/06/20 01:00:00
End date: 21/07/20 14:00:00
Duration: 25d 13h 0m 0s
Demand interval: 10min
Number of demand intervals: 3678
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

In table 5.6 above, the total electricity consumption during the relaxed lockdown, second 25 days (26 June to 21 July 2020) had risen to 11.152 MWh from 8.514 MWh offering a difference of 2.638 MWh as seen on table 5.5. This also resulted in the rise in the bill which was now R19 627.07 from R14 984.76 offering the difference of R4642.31. This was expected as the residence is now accommodated and it was during wintertime and students were now using their space heating equipment more often and most of them were spending much of their time in their rooms as this was in line with one of the lockdown regulations which stated that people must stay indoors as much as possible to avoid the spread of the virus. The average daily was calculated to be 446.08 kWh per day.

To examine the trend, the last 15 days of the observed period (during relaxed lockdown) is also considered as shown in table 5.7 below, as expected the total consumed energy is 6.856 MWh which is less than the first and second 25 days. However, the daily average was 457.07 kWh which shows a slight increase when compared with the second 25 days of the relaxed lockdown as shown in table 5.6 above.

Table 5.7: Total Consumption during the relaxed lockdown, last 15 days (21 July 2020 to 05 August 2020)

ES.026

Active energy, forward	6.856	MWh
Active energy, reverse	0.000	MWh
Total active energy	6.856	MWh
Max. demand	34.668	kW
	21/07/20 20:20:00	

Cost of Energy

○ standard ◉ advanced

Total energy cost

R12,066.659$_f$

Topology: 3-ph Wye
Start date: 21/07/20 01:00:00
End date: 05/08/20 14:10:00
Duration: 15d 13h 10m 0s
Demand interval: 10min
Number of demand intervals: 2239
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

Table 5.8 below also shows the profile of the full duration of the relaxed lockdown (01 June to 04 August 2020). The electricity consumed was 25.694 MWh for a period of 64 days which translates to 401.469 kWh per day. This daily average consumption is slightly below the two periods shown above (table 5.6 and table 5.7) as they average 450 kWh per day.

Table 5.8: Total consumption during the relaxed lockdown, full period (01 June to 04 August 2020)

ES.026

Active energy, forward	25.694	MWh
Active energy, reverse	0.000	MWh
Total active energy	25.694	MWh
Max. demand	40.138	kW
	12/07/20 20:20:00	

Cost of Energy

○ standard ◉ advanced

Total energy cost

R45,222.302$_f$

Topology: 3-ph Wye
Start date: 01/06/20 01:00:00
End date: 04/08/20 14:00:00
Duration: 64d 13h 0m 0s
Demand interval: 10min
Number of demand intervals: 9294
Cost: 1.76R/kWh, fwd; 0R/kWh, rev;...

5.4.3 CONCLUSION

The three compared periods are not out of the ordinary as they concur with the literature. The lockdown period introduced a very interesting aspect of this energy analysis, the data now shows that even when the building is unoccupied, the electricity is still consumed in huge amounts. This is a concern because of the current South African energy crisis which also influences the increase in tariffs which are already skyrocketing.

5.5 CONCLUSION

This chapter presented the energy consumption profiles of two periods. The results are similar for both periods and this clearly shows the consistency in the consumption. Of both the results, the survey concluded that there are visible energy-saving opportunities that are possibly not costly or very low cost.

CHAPTER SIX

6 POWER QUALITY

6.1 INTRODUCTION

Power quality is the measure of how voltage, frequency and waveform of the power supply system conform with the established standards (Bollen, 2010). This section compares the metered data with the NRS 048 Part 2 of 2003 (Voltage Characteristics, Compatibility Levels, Limits and Assessment Methods) and IEEE – 519 of 1992 (harmonics) to establish if there are any power quality issues or not.

Power factor will also be analysed to assess if it (the metered) is in line with the recommended minimum or maximum in the literature.

The systems voltage, current, real power, apparent power, power factor as well as harmonics will be analysed. The trends were metered from 02 March 2020 to 05 August 2020. This was also an interesting period as South Africa was experiencing load shedding. According to (Van Zyl, 2020), load-shedding damages even the best of high quality electrical and electronic equipment, this is not due to the power cut, but when it is restored there is a significant surge in voltage and current which results in the equipment damage.

6.2 VOLTAGE, CURRENT, FREQUENCY AND HARMONICS

Table 6.1 below shows the overview of voltage, current and total harmonic distortion each of these aspects will be compared with the relevant standards (NRS – 048: 2003 and IEEE – 519: 1992) to make better analysis and conclusions. In the observed 156-day period, the average is shown and the max/min represents the highest/lowest recorded at a particular time for each parameter as shown in table 6.1.

Table 6.1: Voltage (V), Current (A), Frequency (Hz), THD (%) overview table

ES.026

Voltage [V]		L1N	L2N	L3N
	Max	242.4 V 09/03/20 11:01:00	243.6 V 09/03/20 11:01:00	244.5 V 09/03/20 11:01:00
	Avg	232.6 V	233.6 V	233.8 V
	Min	0.0000 V 10/03/20 00:04:00	0.0000 V 10/03/20 00:04:00	0.0000 V 10/03/20 00:04:00
Current [A]		L1	L2	L3
	Max	236.2 A 29/03/20 05:41:00	206.0 A 14/07/20 16:21:00	575.6 A 31/03/20 16:47:00
	Avg	25.6 A	24.6 A	22.6 A
	Min	0.0000 A 10/03/20 00:04:00	0.0000 A 10/03/20 00:04:00	0.0000 A 10/03/20 00:04:00
Frequency [Hz]		L1N		
	Max	51.12* Hz 15/03/20 08:12:00		
	Avg	50.00* Hz		
	Min	39.05* Hz 12/07/20 16:01:00		
V THD [%]		L1N	L2N	L3N
	Max	47.6* % 15/03/20 08:12:00	38.6* % 15/03/20 08:12:00	37.0* % 13/03/20 22:51:00
	Avg	1.3* %	1.2* %	1.3* %
	Min	0.37* % 12/05/20 07:31:00	0.36* % 13/04/20 09:49:00	0.40* % 08/05/20 08:17:00
A THD [%]		L1	L2	L3
	Max	78.2* % 13/06/20 14:52:00	44.8* % 13/03/20 01:51:00	104.6* % 12/04/20 04:14:00
	Avg	2.7* %	2.4* %	4.9* %
	Min	0.85* % 27/05/20 13:56:00	0.38* % 11/06/20 19:38:00	0.42* % 15/07/20 09:42:00

Logging Information

Study type:
Energy study

Topology:
3-ph Wye

Start date:
02/03/20 11:51:44

End date:
05/08/20 14:11:00

Duration:
156d 2h 19m 16s

Averaging interval:
1min

Number of averaging intervals:
224780 (224780)

* ... series contained invalid values that have been discarded for the shown result.

6.2.1 VOLTAGES

The voltage was measured from each live wire of the 3 phase to neutral. For Line 1 (known as the red phase and shown as L1N), the maximum recorded was 242.4 V on 09/03/2020 at 11:01:00. Since the standard or declared fixed voltage is 230 V, the standard (NRS 048) recommends that if the declared fixed is less than 500 V the limit is ±10%. In this case, the maximum tolerable is about $230 \times (1+0.10) = 253V$ and the minimum tolerable is about $230 \times (1-0.10) = 207V$

Across all the lines, L1 had a maximum recorded of 242.4 V, L2 had a maximum recorded of 243.6 V, L1 had a maximum recorded of 244.5 V and they all occurred on the 09th of March 2020 at 11:01:00.

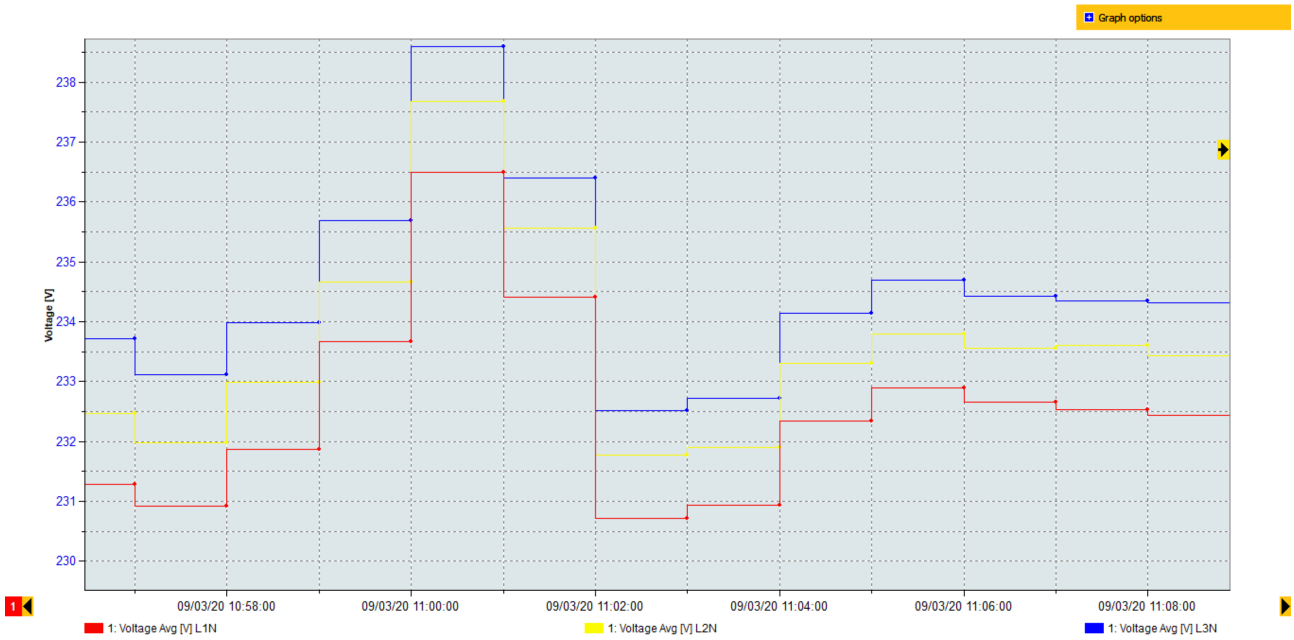

Figure 6.1: Maximum voltages reached on the 09/03/2020 at 11:01:00

Figure 6.1 above shows the voltage spike but they only lasted for one second from 11:00:00 to 11:00:01. Since this did not last for a long time and it is within the limits as prescribed by NRS 048, this should not be a concern.

Based on the information on table 6.1, the minimum reached across all the phases is 0V and they all occurred at 00:04:00 on the 10th of March 2020. Figure 6.2 below shows the voltage events of the 10th of March 2020.

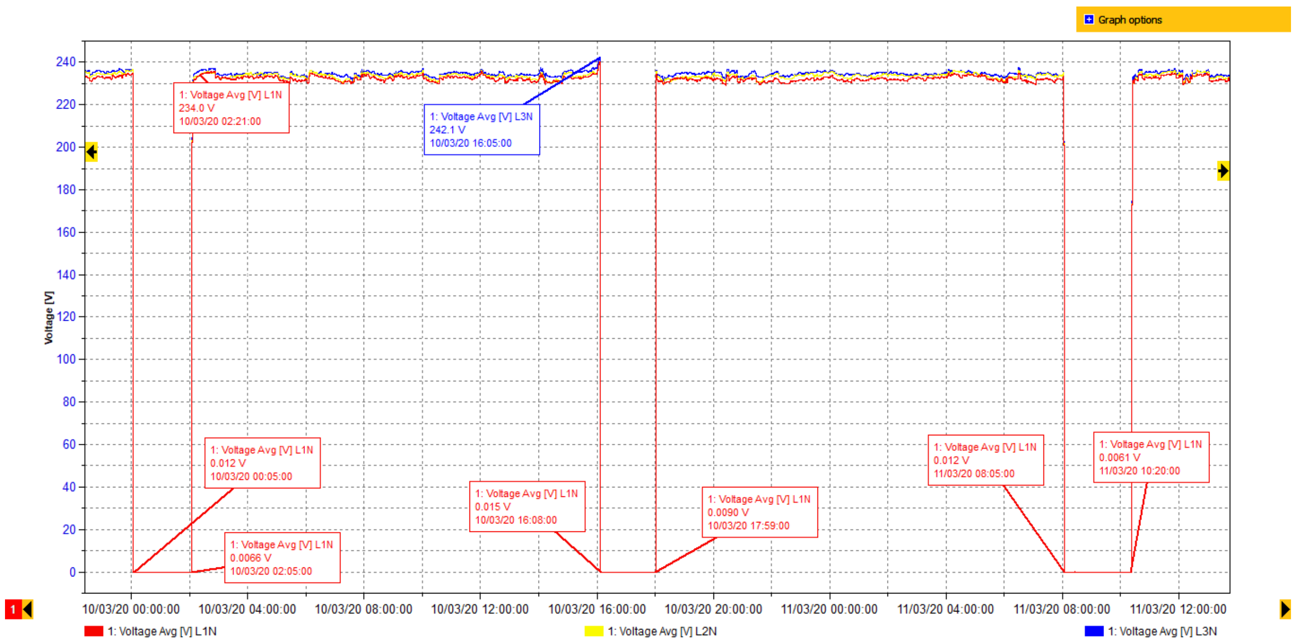

Figure 6.2: Minimum voltages reached on the 10/03/2020

As observed from figure 6.2 above, at 00:00 the voltage dropped to zero and remained at zero for two hours and steeply rose to the normal. The very same event occurred on the same day at 16:00 as well as at 08:00 on the 11th of March. According to Eskom, load shedding normally lasts up to 2 hours before the power is restored. These events can be attributed to load-shedding and they should not be a power quality concern.

6.2.2 CURRENTS

According to table 6.1, the current across all the phases (L1, L2 & L3) is averaging around similar figures as L1 average = 25.6 A, L2 average = 24.6 A and L3 average = 22.6 A. This is acceptable as it shows that the phases are almost balanced and there is no heavy loading on a particular phase, however, if there are any additional loads to be added, the electrician must consider loading L3 as its average is lower than the others.

The fluke 1730 did record a maximum current drawn by each phase during the metering period. L1 recorded a maximum of 236.2 A at 05:41:00 on the 29/03/2020, L2 recorded a maximum of 206.0 A at 16:21:00 on the 14/07/2020 and L3 recorded a maximum of 575.6 A at 16:47:00 on the 31/03/2020. The following figures will analyse what exactly happened during these maximum current values recorded.

Current spike on L1

As seen on figure 6.3 below, the current on L1 was just under 240 A at 05:40:00 for one minute and dropped down to the normal at 05:41:00, the circuit breaker did not trip because it is rated at 250 A. This needs to be looked at as the duration was long and the cabling is not rated for such currents.

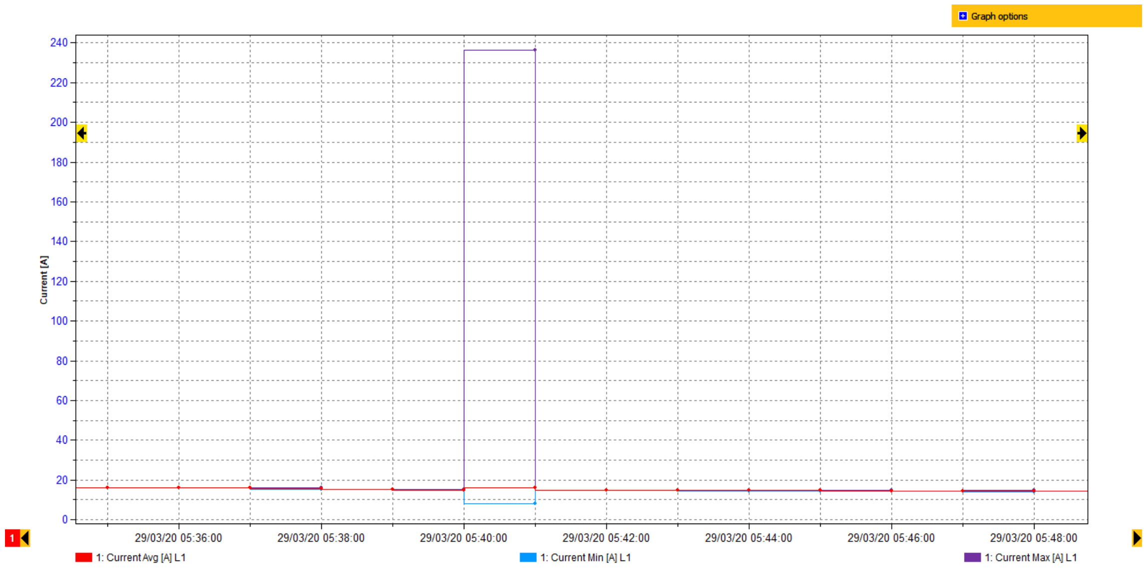

Figure 6.3: Maximum current for L1 on the 29/03/2020

Figure 6.4 below shows the behaviour of other currents when L1 reaches a maximum of 236 A, all seem to be normal. This is the same case for voltage as it remained at the normal limits during the current (L1) spike as seen on figure 6.5 below.

Figure 6.4: Behaviour of all currents on the 29/03/2020

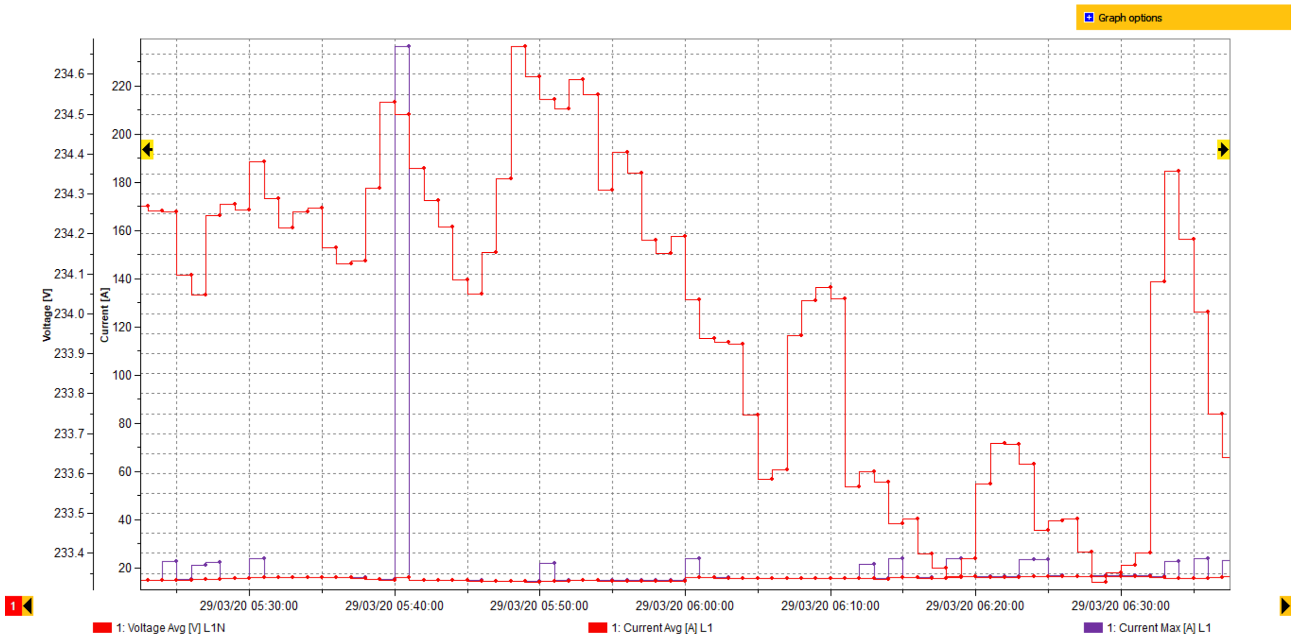

Figure 6.5: The voltage behaviour when L1 reached 232 A

Current spike on L2

Line 2 also experienced the peak current of 206.0 A on the 04/07/2020 at 16:21, this is less than that of line 1 as discussed above. As seen on figure 6.6 below, this is the similar case to that of line 1 (as discussed in the section above), the maximum of 206 A was reached but it only lasted for 1 minute. This still remains a mystery and it should be investigated to determine the occurrence of these spikes to conclude if they are a concern or not.

Figure 6.6: Current spike on L2 on the 14/07/2020

Figure 6.7 below shows the behaviour of other currents when L2 reaches a maximum of 206 A, and all seem to be normal. In terms of voltage as seen on figure 6.8 and 6.9, the voltage before the spike was zero volts, the spike only happens when the voltage starts to rise to 230, this can be attributed to the transients due to switching.

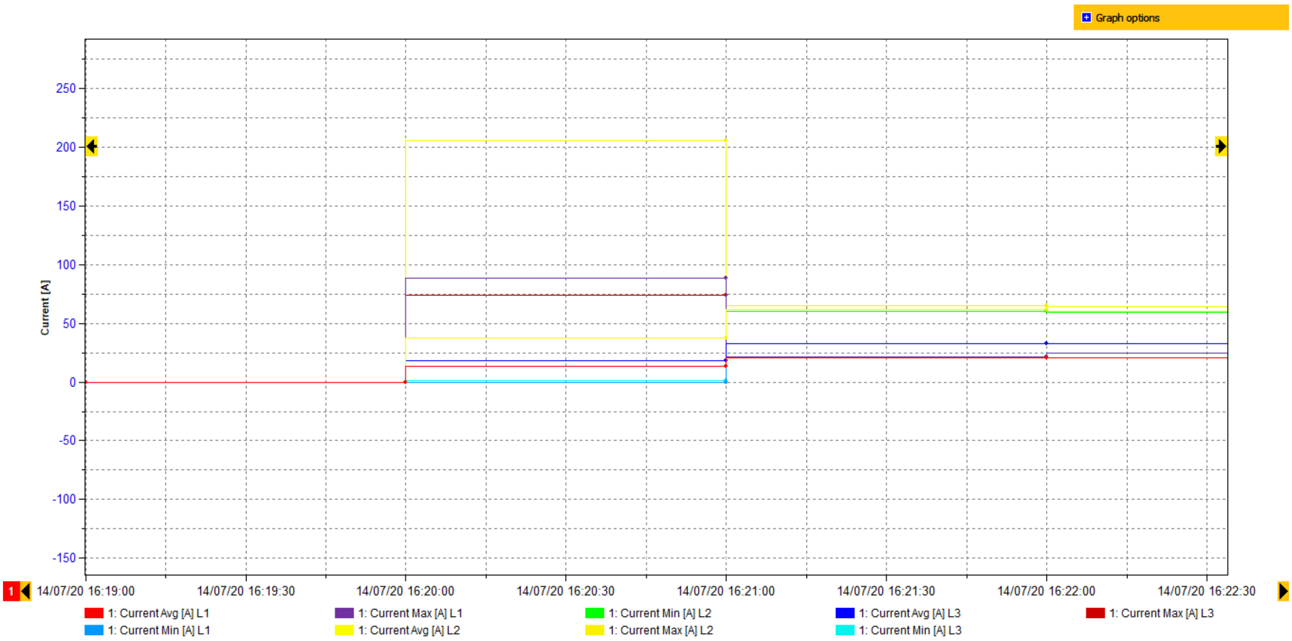

Figure 6.7: The Behaviour of other currents during the spike on L2

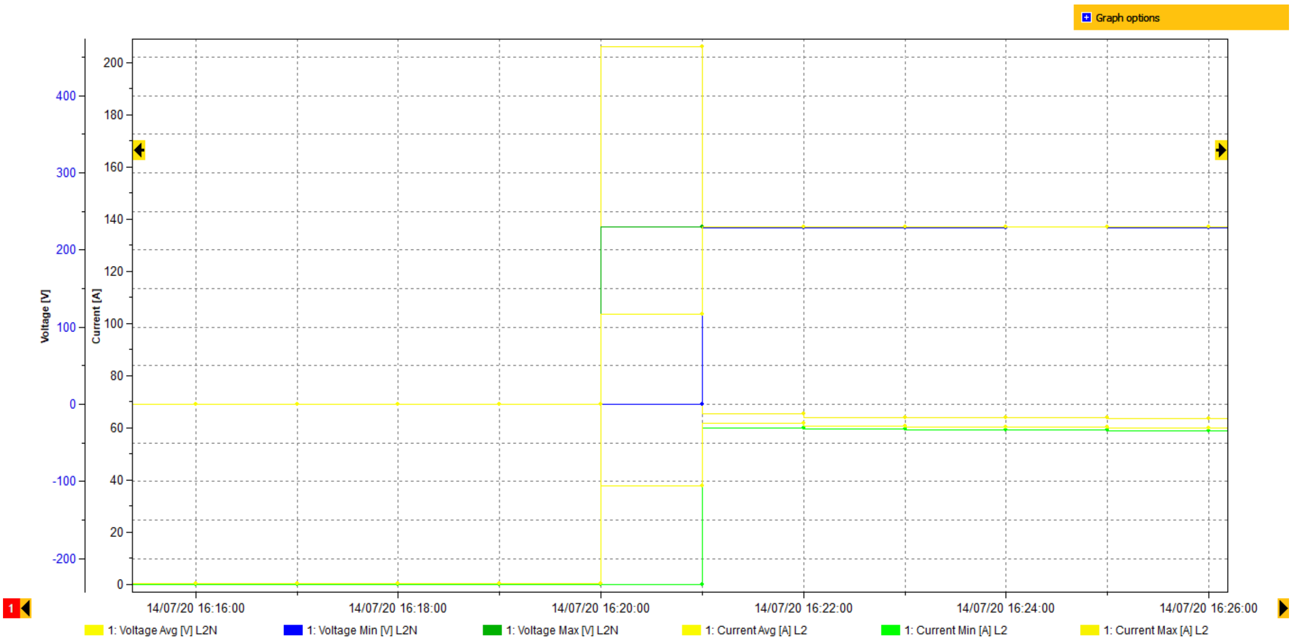

Figure 6.8: Voltage behaviour during the spike on L2

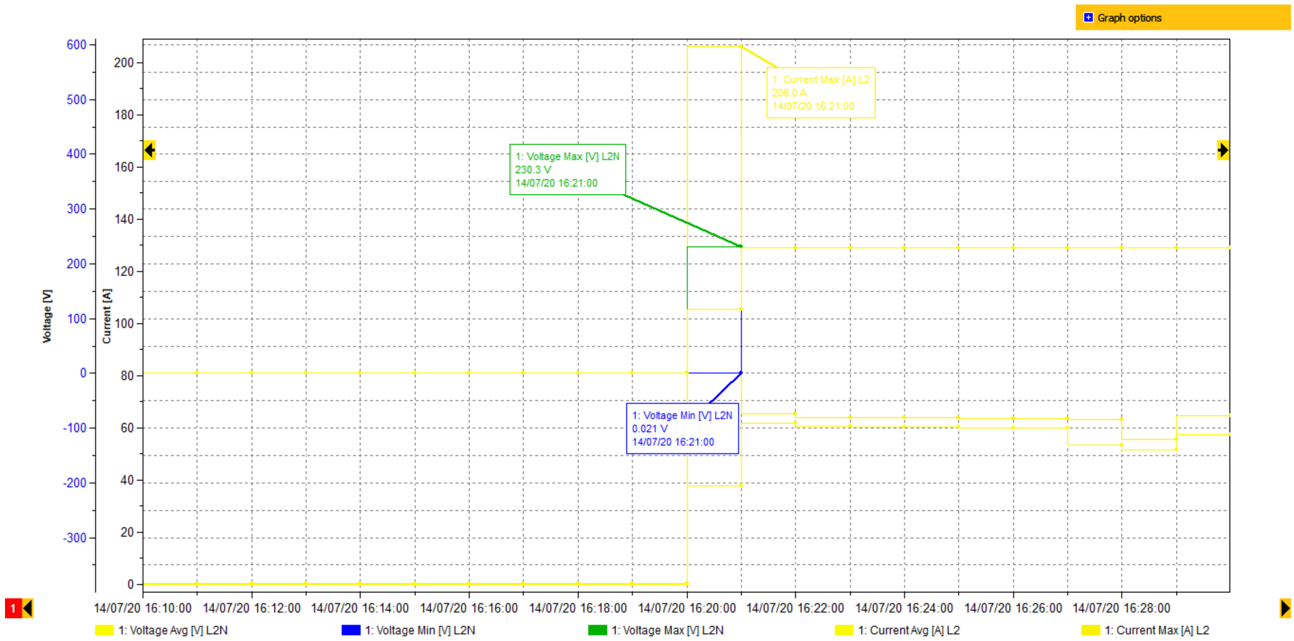

Figure 6.9: Voltage behaviour during L2 current spike

Current spike on L3

On the 31/03/2020 at 16:47:00, current on line 3 reached an all-time maximum of 575.6 A. This is the highest recorded across all the phases during the period of metering. The spike on L3 lasted for one minute as it can be seen in figure 6.10 below. The voltage also dipped from the normal 230 reaching the minimum of 219.9V as seen on figure 6.11 and 6.12 below.

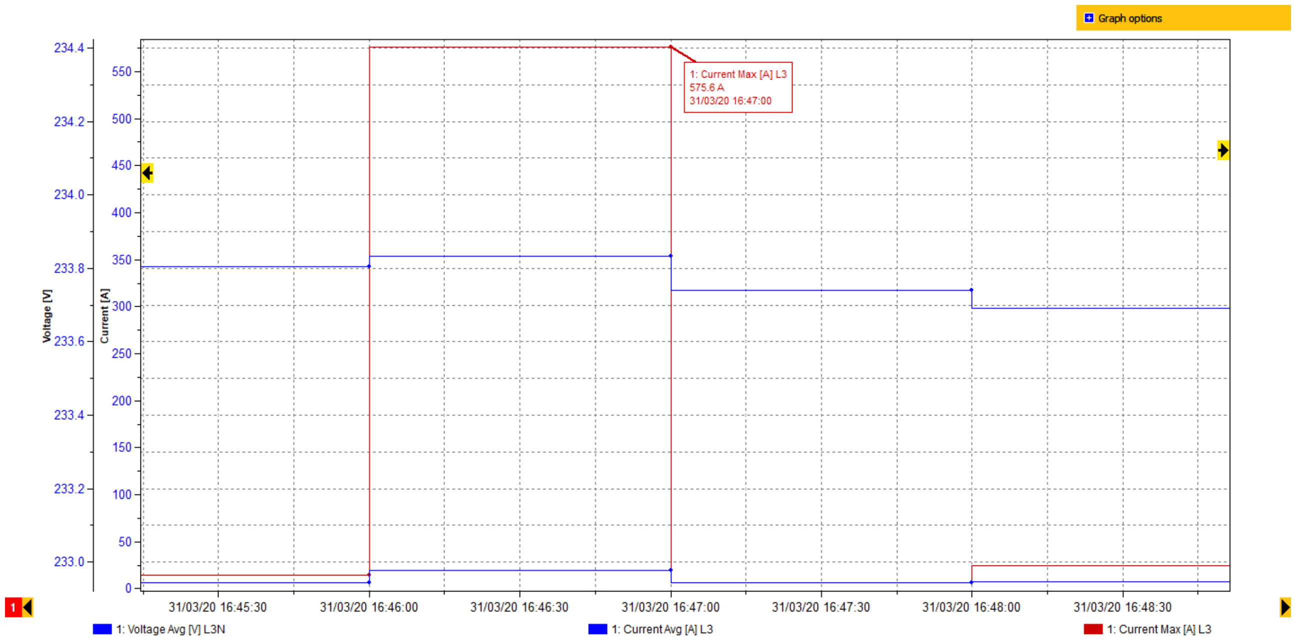

Figure 6.10: Current spike on L3

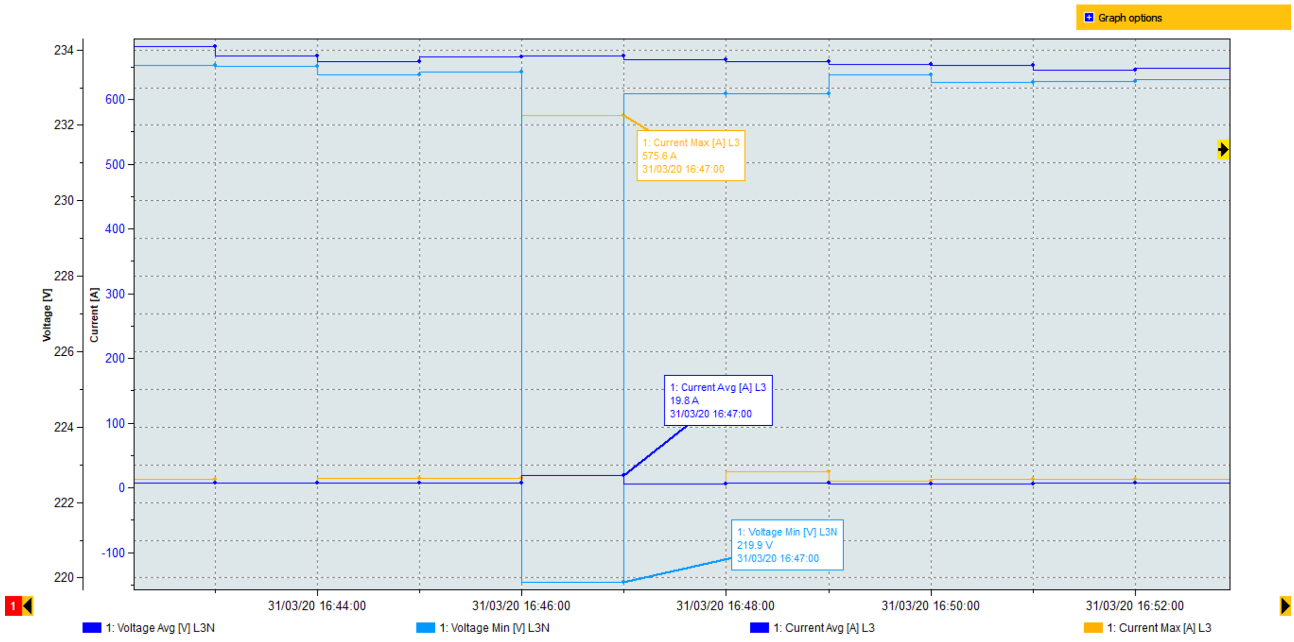

Figure 6.11: Current spike and voltage behaviour on L3 on the 31/03/2020

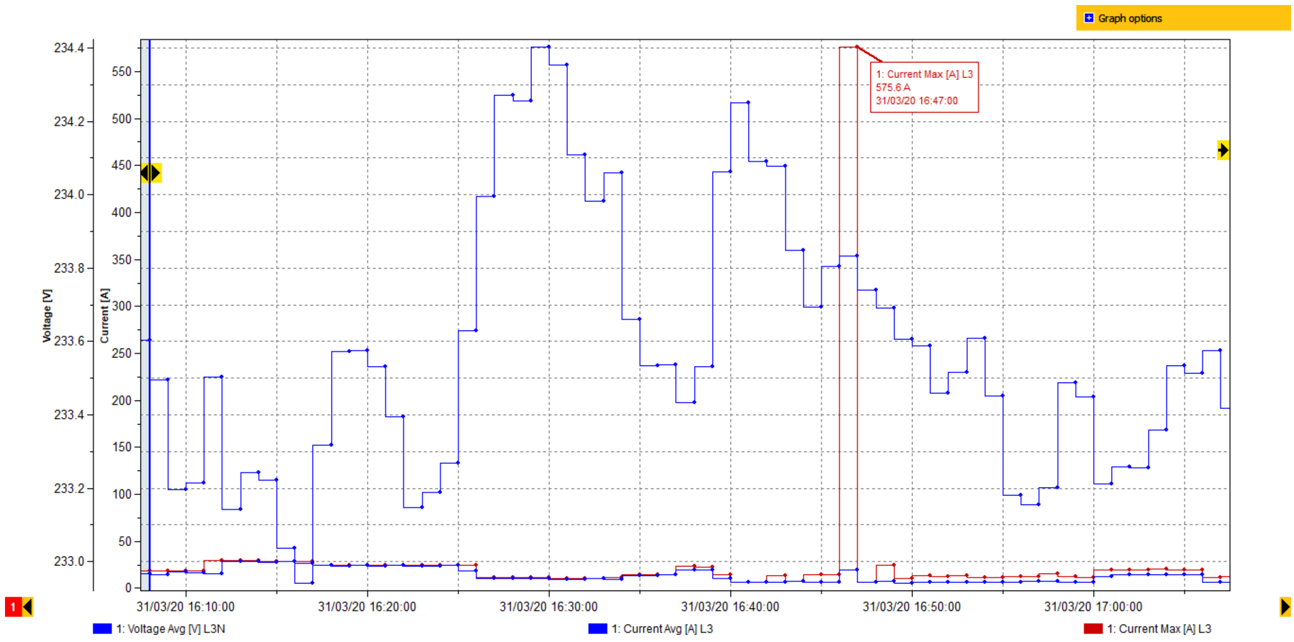

Figure 6.12: Current spike and voltage behaviour on L3 on the 31/03/2020

6.2.3 FREQUENCY

According to NRS 048, standard South Africa's frequency is 50 Hz and the deviation is only allowed for ±2.5% which translates to ±1.25 Hz in other words, 48.75 Hz to 51.25 Hz is the limit. According to the data on table 6.1, the frequency was only measured on line 1 and it averaged 50 Hz there entire metering period. On 15/03/2020 at 08:12:00, the frequency recorded the maximum of 51.12 Hz, this is within the required limit.

Table 6.1 also shows that the frequency recorded a low of 39.05 Hz on the 12/07/2020 at 16:01:00 and this is below the limit as prescribed by NRS 048. Figure 6.13 below shows the frequency trends on the 12/07/2020 and the graph shows that this lasted for about 2 hours (from 16:00 to 18:00) and the same happened with voltage and current (as seen on figure 6.14 below), based on this, this can be attributed with load-shedding.

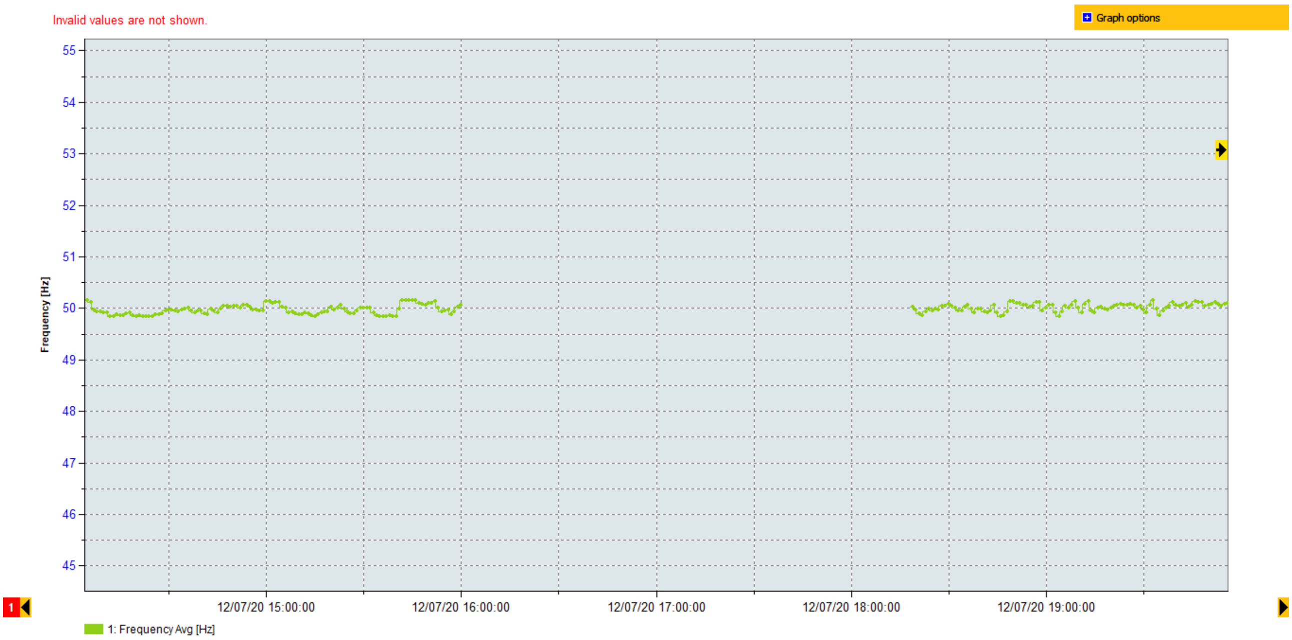

Figure 6.13: Frequency recorded on the 12/07/2020

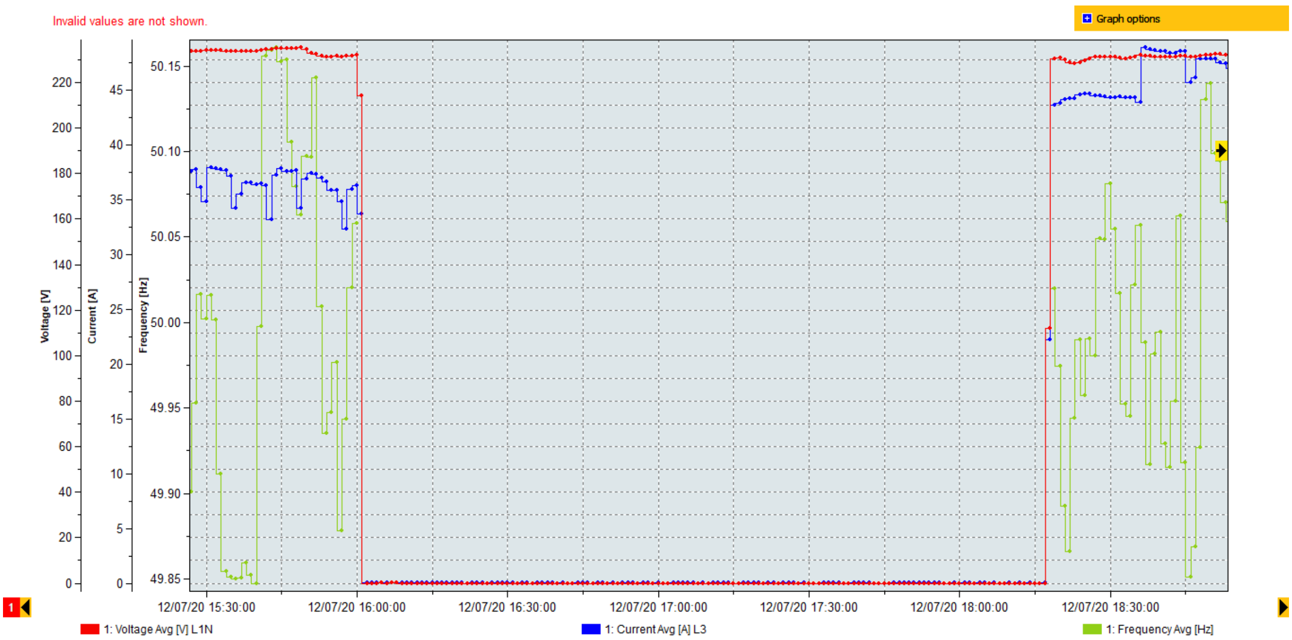

Figure 6.14: Frequency, voltage and current trends recorded on the 12/07/2020 at 16:00

6.2.4 HARMONICS

The standard governing harmonics is the IEEE 519 of 1992, the standard recommends that for general use, voltage Total Harmonic Distortion (V – THD) must not exceed 5.0% and the current Total Harmonic Distortion (I – THD) has a recommended limit of 4.0%.

Table 6.2: Frequency (Hz), Voltage (V), Current (A) and THD overview table

ES.026			
Voltage [V]	**L1N**	**L2N**	**L3N**
Max	242.4 V 09/03/20 11:01:00	243.6 V 09/03/20 11:01:00	244.5 V 09/03/20 11:01:00
Avg	232.6 V	233.6 V	233.8 V
Min	0.0000 V 10/03/20 00:04:00	0.0000 V 10/03/20 00:04:00	0.0000 V 10/03/20 00:04:00
Current [A]	**L1**	**L2**	**L3**
Max	236.2 A 29/03/20 05:41:00	206.0 A 14/07/20 16:21:00	575.6 A 31/03/20 16:47:00
Avg	25.6 A	24.6 A	22.6 A
Min	0.0000 A 10/03/20 00:04:00	0.0000 A 10/03/20 00:04:00	0.0000 A 10/03/20 00:04:00
Frequency [Hz]	**L1N**		
Max	51.12* Hz 15/03/20 08:12:00		
Avg	50.00* Hz		
Min	39.05* Hz 12/07/20 16:01:00		
V THD [%]	**L1N**	**L2N**	**L3N**
Max	47.6* % 15/03/20 08:12:00	38.6* % 15/03/20 08:12:00	37.0* % 13/03/20 22:51:00
Avg	1.3* %	1.2* %	1.3* %
Min	0.37* % 12/05/20 07:31:00	0.36* % 13/04/20 09:49:00	0.40* % 08/05/20 08:17:00
A THD [%]	**L1**	**L2**	**L3**
Max	78.2* % 13/06/20 14:52:00	44.8* % 13/03/20 01:51:00	104.6* % 12/04/20 04:14:00
Avg	2.7* %	2.4* %	4.9* %
Min	0.85* % 27/05/20 13:56:00	0.38* % 11/06/20 19:38:00	0.42* % 15/07/20 09:42:00

Logging Information

Study type:
Energy study

Topology:
3-ph Wye

Start date:
02/03/20 11:51:44

End date:
05/08/20 14:11:00

Duration:
156d 2h 19m 16s

Averaging interval:
1min

Number of averaging intervals:
224780 (224780)

* ... series contained invalid values that have been discarded for the shown result.

6.2.4.1 VOLTAGE – THD

Based on the information on table 6.2, the average voltage total harmonic distortion is within the limits. L1 = 1.3%, L2 = 1.2% and L3 = 1.3%. This is below the minimum recommended

6.2.4.2 CURRENT – THD

Based on the information on table 6.2, the average current total harmonic distortion is within the limits. L1 = 2.7%, L2 = 2.4% and L3 = 4.9%. This is below the minimum recommended

6.3 POWER FACTOR

Table 6.3 below shows the facility's power consumption behaviour for 156 days (from 02/03/2020 to 05/08/2020)

Table 6.3: Power consumption

ES.026				
Active Power [kW]	**L1**	**L2**	**L3**	**Total**
Max	25.880 kW 16/07/20 16:03:00	40.161 kW 14/07/20 16:21:00	22.705 kW 05/04/20 17:40:00	74.776 kW 14/07/20 16:21:00
Avg	5.414 kW	4.508 kW	4.679 kW	14.602 kW
Min	-0.0017 kW 11/03/20 16:13:00	-0.246 kW 13/03/20 06:09:00	-0.086 kW 12/03/20 08:13:00	-0.050 kW 10/03/20 16:07:00
Apparent Power [kVA]	**L1**	**L2**	**L3**	**Total**
Max	26.060 kVA 16/07/20 16:03:00	41.176 kVA 14/07/20 16:21:00	54.650 kVA 31/03/20 16:47:00	133.761 kVA 31/03/20 16:47:00
Avg	5.944 kVA	5.746 kVA	5.289 kVA	18.331 kVA
Min	0.0000 kVA 11/03/20 09:33:00	0.0000 kVA 10/03/20 17:22:00	0.0000 kVA 17/06/20 10:10:00	0.0000 kVA 12/07/20 16:22:00
Non-Active Power [kvar]	**L1**	**L2**	**L3**	**Total**
Max	13.388 kvar 29/03/20 05:41:00	9.626 kvar 12/03/20 18:05:00	54.632 kvar 31/03/20 16:47:00	133.302 kvar 31/03/20 16:47:00
Avg	2.454 kvar	3.563 kvar	2.465 kvar	11.082 kvar
Min	0.0000 kvar 11/03/20 09:55:00	0.0000 kvar 10/03/20 17:22:00	0.0000 kvar 17/06/20 10:10:00	0.0000 kvar 12/07/20 18:19:00
Power Factor [1]	**L1**	**L2**	**L3**	**Total**
Max	1.00* 31/07/20 11:30:00	1.00* 12/07/20 20:13:00	1.00* 13/07/20 16:03:00	0.99* 11/06/20 15:00:00
Avg	0.91	0.78	0.88	0.80
Min	0.81* ind 04/03/20 22:10:00	0.50* ind 10/04/20 21:57:00	0.33* ind 31/03/20 16:47:00	0.48* 30/03/20 09:28:00

As seen from the table 6.3, each phase has a surge in power (true power, reactive power and apparent power), this can be attributed to similar factors that contribute to current and voltage surges as discussed in section 6.2 above. However, the average power consumption across all phases is almost similar which means that the phases are fairly balanced.

In terms of power factor, (Eskom, 2020b) in their fact sheet specifies that the power factor is an integral part of any system as when it is not taken care of, it will lead to facility's inefficiency, increase in operating cost, breakdowns or an increase in the maintenance costs. Eskom recommends that the average power factor in a facility must be below 0.96 lagging as they charge the facilitates an additional charge if the recommendation is not abided to.

The total average power factor as seen in table 6.3 is 0.8 lagging, this is below the recommended by Eskom and it should be looked at.

6.4 CONCLUSION

This chapter assessed the systems power quality in terms of voltage imbalances, current, frequency as well as harmonics. Most of the spikes in the voltages last up to 1 minute, and since they last up to 1 minute, this can be attributed with voltage swells (sudden momentary increase in the RMS voltage) which according to (FLUKE, 2020) normally last up to 1 minute. Most voltage swells are caused by an abrupt reduction in the loading of the circuit which either has a poor/damaged voltage regulator or the voltage regulator is absent. In some cases, the voltage swells can be caused by a damaged or loose neutral connection.

Since there were voltage swells, current also tends to follow the same trend, these spikes in current can lead to damage on sensitive electrical equipment. During the observed period, the current on line 3 had a maximum of over 500 A (for 1 minute), this did not trip the circuit breaker, this is also the cause for concern.

Load-shedding is also another contributor to these voltage and current spikes when the power is restored, equipment such as surge protection devices (SPDs) can be a recommendation because it assists in suppressing the voltage surges.

CHAPTER SEVEN

7 ELECTRICAL BILLS ANALYSES

7.1 INTRODUCTION

The analyses in chapter 5 were interpreting the real-time data of a particular building (G-Block), and this gave an insight in terms of energy usage and the energy consumption profile.

This chapter presents the interpretation of energy consumption at the Catsville residence based on the data collected from the electricity bills provided by the City of Cape Town. The monthly consumption of the entire complex and the bills associated are presented in a tabular format for better analysis.

7.2 ANALYSES OF DATA BASED ON THE MONTHLY ELECTRICAL BILLS

The monthly data for Catsville residence is presented in table 7.4 (on page 120) from December 2017 to November 2019. The data shows how much energy was consumed per month as well as the associated costs.

Table 7.4 (on page 120) presents the summarised data as collated from the bills. It must be noted that there is missing data for particular months and they were then recorded in the following month. The reason for this is that the meter used for billing is monitored manually and at other instances, the CoCT electrician cannot access the metering room because of several reasons such as refused entry to the room, faulty meter, etc. However, when the data was not collected, the CoCT will submit the bill with estimates based on previous consumption rates. Table 7.1 and 7.2 below show the bill for December 2017 and January 2018 where the reading is an estimate based on the consumption of the previous December and January respectively. The total estimated bill was R 243 052.10 + R 151 998.48 = R395 050.58 for both months. CPUT was then billed with this amount as an estimate for December 2017 and January 2018. This includes a standard service charge of R 1 779.18 for December 2017 and R 1 140.50, since this service charge amounts are calculated per day at R 45.62 rate, they are then not considered as estimates, therefore, the estimates will be R 243 052.10 + R 151 998.48 – R 1 779.18 – R 1 140.50 = R 392 130.90

Table 7.1: Bill with estimates for December 2017 (Courtesy of CoCT)

Account details as at 19/12/2017	Account number 121452026
ELECTRICITY (Period 14/11/2017 to 08/12/2017 - 25 Days) (Estimate reading)	
At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815	
Meter no: 694509 / Consumption 186000.000 kWh / Daily average 7440.000 kWh	
* Consumption charge: Commercial (Small Power User - High)	
(97500.000 kWh X R 1.3006)	126808.50
* Service charge	
(25 Days X R 45.6200)	1140.50
* Off peak (50kVA or more)	
(88500.000 kWh X R 1.3006)	115103.10
	243052.10

Table 7.2: Bill with estimates for January 2018 (Courtesy of CoCT)

Account details as at 22/01/2018	Account number 121452026
ELECTRICITY (Period 09/12/2017 to 16/01/2018 - 39 Days) (Estimate reading)	
At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815	
Meter no: 694509 / Consumption 115500.000 kWh / Daily average 2961.538 kWh	
* Consumption charge: Commercial (Small Power User - High)	
(54300.000 kWh X R 1.3006)	70622.58
* Service charge	
(39 Days X R 45.6200)	1779.18
* Off peak (50kVA or more)	
(61200.000 kWh X R 1.3006)	79596.72
	151998.48

Because they are estimates, they were not recorded in Table 7.4 as it only shows the actual readings.

To correct the estimates, the CoCT billing department will wait for the electrician to get access to the meter and then bill the client (CPUT in this case) from the date of the last recorded consumption to the current, this will include the months in arrears. The bill that was issued based on estimates will then be subtracted from the actual, if the CoCT had overbilled the client then the client will be reimbursed and if the CoCT had under billed, the client will have to compensate the difference. Table 7.3 below shows the process.

Table 7.3: Bill for Feb 2018 with actual readings including the missed readings

Account details as at 20/02/2018	Account number 121452026
ELECTRICITY (Period 14/11/2017 to 13/02/2018 - 92 Days) (Actual reading) **At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815** **Meter no: 694509 / Consumption 383700.000 kWh / Daily average 4170.652 kWh**	
* Consumption charge: Commercial (Small Power User - High)	
(195300.000 kWh X R 1.3006)	254007.18
* Off peak (50kVA or more)	
(188400.000 kWh X R 1.3006)	245033.04
* Service charge	
(28 Days X R 45.6200)	1277.36
Reversal of estimated consumption (301500.000 kWh)	392130.90-
	108186.68

As seen in Table 7.3 above, this bill covers 92 days (the equivalent of three months namely Dec 2017, Jan 2018 and Feb 2018). It must be noted that the R 392 130.90 is subtracted from the 92-day bill to give the accurate billing amount since the R 392 130.90 was already paid, the balance will be the difference which is R 108 186.68. The months with no data are marked in red in Table 7.4.

When considering the consumption in Table 7.4, the average consumption per month is about 214 418.18 kWh (214.419 MWh) which translates to a monthly average cost of R 347,840.98 including tax (VAT – Value Added Tax). For the 2-year (2018 and 2019) period under study, the total consumed energy is 4 717 200 kWh (4.717 GWh) which costs R 7,652,501.52 including tax. The bill for 2018 (Dec 2017 to Nov 2018) was R 3,723,586.73 and R 3,928,914.79 for 2019 (December 2018 to November 2019)

According to CoCT electricity bills, the Catsville tariff structure is the Commercial (Small Power User - High). Even though Catsville is a residential place, they are supplied with more than 100A three-phase supply therefore they are billed as commercial customers (The City of Cape Town, 2015).

During the period audited, there were changes in the billing and the affected months were split into two namely before changes and after changes. It must be noted that a bill of a particular month overlaps (e.g.: April bill recorded from mid-March to mid-April) into the other month hence the splitting of a month into two. On the 01st April 2018, there was a change in VAT from 14% to 15% hence the April bill was split into before VAT increase and after VAT increase. The same applies to July 2018 and July 2019, this is the period where the tariff rates are increased hence the bill is split into two parts namely before tariff increase and after tariff increase.

Table 7.4: Summary of energy consumption and cost for Catsville residence complex

	Date	kWh for a month	Average Daily kWh	Unit cost (R/kWh)	Consumption cost	From	To	Period (days)	Service Cost Per day	Service Cost (R)	Total Cost (R)	Total Cost Inc VAT (R)
1	December 2017	Not recorded										
2	January 2018	Not recorded										
3	February 2018	383700	4170.652	1.3006	R 499,040.22	14/11/17	13/02/18	92	R 45.62	R 4,197.04	R 503,237.26	R 573,690.48
4	March 2018	145500	5196.429	1.3006	R 189,237.30	14/02/18	13/03/18	28	R 45.62	R 1,277.36	R 190,514.66	R 217,186.71
5	April 2018	106500	5940.000	1.3006	R 138,513.90	14/03/18	31/03/18	18	R 45.62	R 821.16	R 139,335.06	R 158,841.97
	VAT increase	71700		1.3006	R 93,253.02	01/04/18	12/04/18	12	R 45.62	R 547.44	R 93,800.46	R 107,870.53
6	May 2018	246300	7037.143	1.3006	R 320,337.78	13/04/18	17/05/18	35	R 45.62	R 1,596.70	R 321,934.48	R 370,224.65
7	June 2018	222000	8222.222	1.3006	R 288,733.20	18/05/18	13/06/18	27	R 45.62	R 1,231.74	R 289,964.94	R 333,459.68
8	July 2018	115500	6802.941	1.3006	R 150,219.30	14/06/18	30/06/18	17	R 45.62	R 775.54	R 150,994.84	R 173,644.07
	Tariff increase	115800		1.4065	R 162,872.70	01/07/18	17/07/18	17	R 49.33	R 838.61	R 163,711.31	R 188,268.01
9	August 2018	228600	8164.286	1.4065	R 321,525.90	18/07/18	14/08/18	28	R 49.33	R 1,381.24	R 322,907.14	R 371,343.21
10	September 2018	296400	9561.290	1.4065	R 416,886.60	15/08/18	14/09/18	31	R 49.33	R 1,529.23	R 418,415.83	R 481,178.20
11	October 2018	263400	8231.250	1.4065	R 370,472.10	15/09/18	16/10/18	32	R 49.33	R 1,578.56	R 372,050.66	R 427,858.26
12	November 2018	196800	6560.000	1.4065	R 276,799.20	17/10/18	15/11/18	30	R 49.33	R 1,479.90	R 278,279.10	R 320,020.97
13	December 2018	137700	5100.000	1.4065	R 193,675.05	16/11/18	12/12/18	27	R 49.33	R 1,331.91	R 195,006.96	R 224,258.00
14	January 2019	Not recorded										
15	February 2019	261900	4029.231	1.4065	R 368,362.35	13/12/18	15/02/19	65	R 49.33	R 3,206.45	R 371,568.80	R 427,304.12
16	March 2019	153900	5496.429	1.4065	R 216,460.35	16/02/19	15/03/19	28	R 49.33	R 1,381.24	R 217,841.59	R 250,517.83
17	April 2019	Not recorded										
18	May 2019	413700	6672.581	1.4065	R 581,869.05	16/03/19	16/05/19	62	R 49.33	R 3,058.46	R 584,927.51	R 672,666.64
19	June 2019	234300	8079.310	1.4065	R 329,542.95	17/05/19	14/06/19	29	R 49.33	R 1,430.57	R 330,973.52	R 380,619.55
20	July 2019	102600	6436.364	1.4065	R 144,306.90	15/06/19	30/06/19	16	R 49.33	R 789.28	R 145,096.18	R 166,860.61
	Tariff increase	109800		1.5314	R 168,147.72	01/07/19	17/07/19	17	R 53.71	R 913.07	R 169,060.79	R 194,419.91
21	August 2019	289200	8763.636	1.5314	R 442,880.88	18/07/19	19/08/19	33	R 53.71	R 1,772.43	R 444,653.31	R 511,351.31
22	September 2019	210900	7532.143	1.5314	R 322,972.26	20/08/19	16/09/19	28	R 53.71	R 1,503.88	R 324,476.14	R 373,147.56
23	October 2019	Not recorded										
24	November 2019	411000	6421.875	1.5314	R 629,405.40	17/09/19	19/11/19	64	R 53.71	R 3,437.44	R 632,842.84	R 727,769.27
	Total	4717200			R 6,625,514.13			736		R 36,079.25	R 6,661,593.38	R 7,652,501.52
	Average	214418.18	6758.83		R 301,159.73					R 1,639.97	R 302,799.70	R 347,840.98

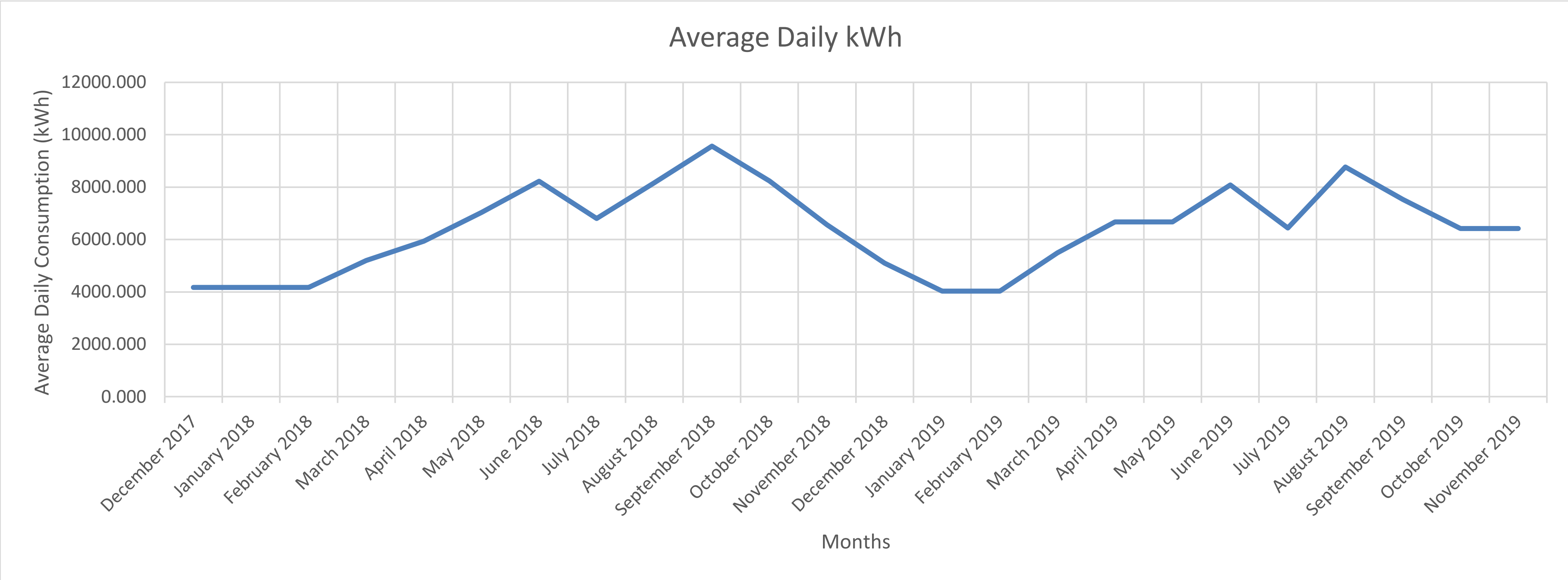

Figure 7.1: Average Daily Consumption for each month

Line charts are commonly used to analyse data and illustrate the trends (Thovhakale, 2011). For this section, line charts will be used to demonstrate the trends of energy consumption and associated costs. Figure 7.1 (on the previous page) indicates the daily average energy consumption for the period from December 2017 to November 2019. The daily average consumption was used to eliminate errors associated with the fact that the energy consumption meters were not read at similar intervals and this resulted in significant variations in the number of days per month. The data used figure 7.1 was obtained by converting monthly consumption into daily average consumption.

According to the graph in figure 7.1, the consumptions averaging around 4000 kWh per day from December 2017 to February 2018 (normally the university is on recess during these months) then there is a steep increase in consumption from march until June reaching over 8000 kWh per day in June, this indicates that the university is back on sessions. Between June and July, there is a sudden dip in the consumption which indicates the mid-year recess where students are now back home. After July 2018 until September 2018, there is a steady increase in consumption indicating the return to normal activities at the university, the winter season has also influenced the consumption rates because of usage of more appliances for space heating. After September 2018, there is a decline in consumption which indicates the springtime where summer is closing in, the decline continues until February 2019 where 4000 kWh is recorded. After February 2019, the cycle then starts again which is virtually similar to the previous year.

7.3 Descriptive Statistics

Table 7.5 shows the descriptive statistics for the data set as provided in table 7.4 for the Catsville complex.

7.3.1 Daily Consumption

2018 (December 2017 to November 2018) show that the average daily consumption ranged from 4 170.65 kWh to 9 561.29 kWh per day at the mean value of 6 988.62 kWh/day, this means the daily consumption for 2018 was averaging 6 988.62 kWh. The figures for 2019 (December 2018 to November 2019) were almost similar to those of 2018, the daily consumption ranged from 4 029.23 kWh to 8 763.64 kWh leading to a mean value of 6 436.36. The 2-year period (December 2017 to November 2019) showed that the daily consumption ranged from 4 029.23 kWh to 9 561.29 kWh with a mean of 6 758.83 kWh.

All the values for each year are closely matched but the mean for 2019 (6 503.51 kWh) is slightly lower than that of 2018 (6 988.62 kWh) by about 485.11 kWh, this could be because the residence was underpopulated or effects of load-shedding (load-shedding means less power is used as the electricity is frequently cut) which was heavily experienced during 2019 as reported by (Laher et al., 2019).

The standard deviation for both 2018 and 2019 was 1 617.26 kWh and 1 491.45 kWh respectively, this showed that the data series was very close to the mean and this shows the stability in the data.

7.3.2 ELECTRICITY DAILY COST

The trends in the daily cost seem to match the trends in daily consumptions.

In 2018, the cost of electricity per day ranged from R 6,235.77 to a maximum of R 15,521.88 which meant that the average (mean) daily cost of electricity was R 10,850.24.

The 2019 figures were ranging from R 6,573.91 to R 15,495.49 with an average of R 10,985.99.

Unlike the energy consumption as seen in 7.3.1 above (where 2019 daily consumption is less than of 2018), the daily energy cost of 2019 is slightly higher than in 2018. The average daily cost of 2019 (R 10,985.99) is marginally higher than 2018 (R 10,850.24) by R135.75.

The slight increase in cost even though the consumption dipped marginally can be attributed with inflation as well as the increase in the Value-Added Tax (VAT) from the 01st of April 2018 as it was announced by the then Minister of Finance, Melusi Gigaba (Gigaba, 2018) when he presented the budget speech before the parliament in February 2018.

The standard deviation for both 2018 and 2019 was R 2,556.95 and R 2,378.41 respectively, this showed that the data series was very close to the mean which shows data stability.

Table 7.5: Descriptive Statistics

	Paremeter	Range	Minimum	Maximum	Mean	Mode	Median	Standard Deviation
2018	**2018**							
	Total Cost per month	R 465,819.95	R 107,870.53	R 573,690.48	R 310,298.89	#N/A	R 326,740.32	R 143,494.03
	Average Daily Cost	R 9,286.11	R 6,235.77	R 15,521.88	R 10,850.24	#N/A	R 10,758.41	R 2,556.95
	Energy Consumption (kWh) per month	312000.00	71700.00	383700.00	199350.00	#N/A	209400.00	91905.24
	Average Daily Consumtion (kWh)	5390.64	4170.65	9561.29	6988.62	#N/A	6920.04	1617.26
2019	**2019**							
	Total Cost per month	R 560,908.66	R 166,860.61	R 727,769.27	R 392,891.48	#N/A	R 376,883.55	R 195,892.00
	Average Daily Cost	R 8,921.58	R 6,573.91	R 15,495.49	R 10,985.99	#N/A	R 11,110.43	R 2,378.41
	Energy Consumption (kWh) per month	311100.00	102600.00	413700.00	232500.00	#N/A	222600.00	113695.03
	Average Daily Consumtion (kWh)	4734.41	4029.23	8763.64	6503.51	#N/A	6436.36	1491.45
					135.75			
2018 &2019	**Both years (2018 & 2019)**							
	Total Cost per month	R 619,898.74	R 107,870.53	R 727,769.27	R 347,840.98	#N/A	R 351,842.17	170303.2823
	Average Daily Cost	R 9,286.11	R 6,235.77	R 15,521.88	R 10,850.24	#N/A	R 10,758.41	2556.950761
	Energy Consumption (kWh) per month	342000.00	71700.00	413700.00	214418.18	#N/A	216450.00	101241.22
	Average Daily Consumtion (kWh)	5532.06	4029.23	9561.29	6758.83	#N/A	6672.58	1535.68

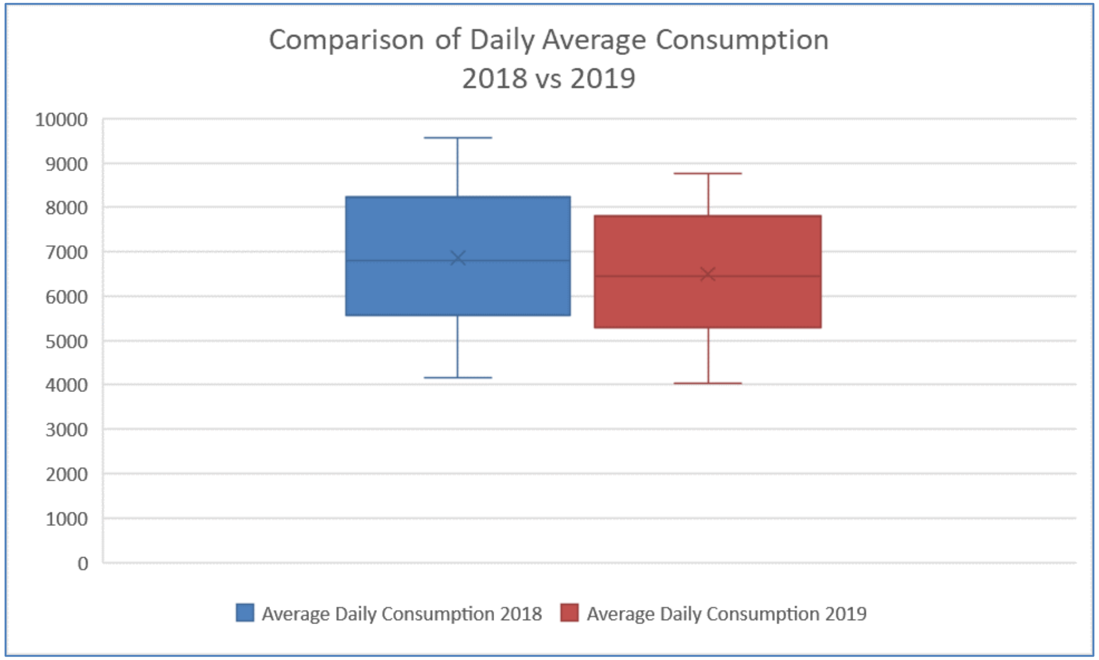

Figure 7.2: Comparison of average daily consumption between 2018 and 2019

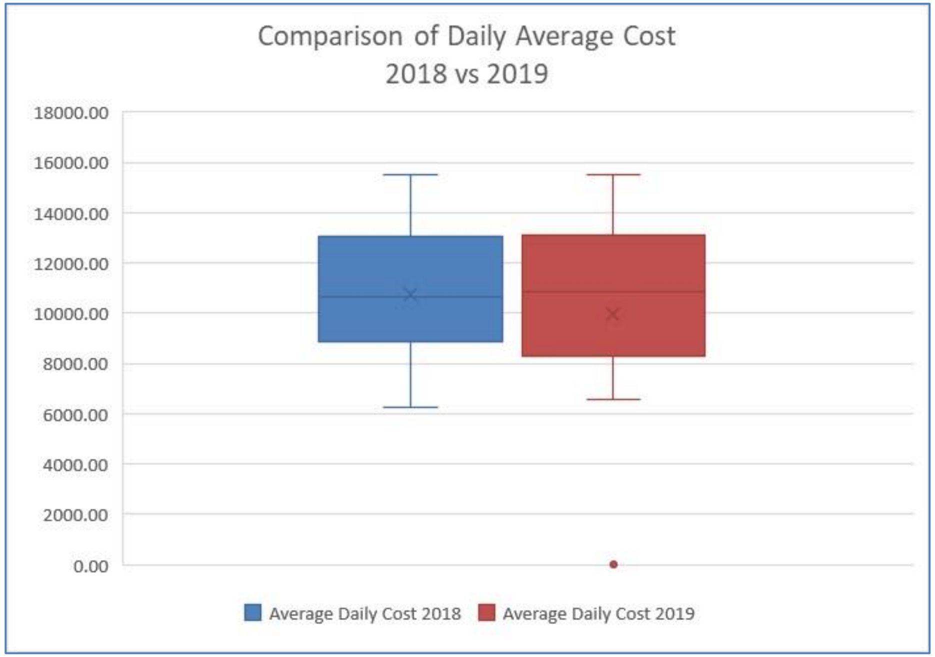

Figure 7.3: Comparison of average daily electricity cost between 2018 and 2019

For a better comparison of the scores (average daily consumption and daily average consumption cost) between 2018 and 2019, figure 7.2 and 7.3 (in the previous page) visually compares the scores of 2018 and 2019 using a box and whisker chart.

Figure 7.2 shows the daily average consumption for both 2018 and 2019, the chart shows that 50% of the data is between 5 600 kWh and 8 200 kWh for 2018. In the case of 2019, the 50th percentile is between 5 200 kWh and 7 900 kWh. The upper (75%) and lower (25%) boundary for 2018 was 9 500 kWh and 4 100 kWh respectively with a mean of 6 900 kWh. The figures for 2019 are slightly lower as the upper boundary is at 8 900 kWh and lower boundary at 4 000 kWh with a mean of 6 500 kWh. The charts clearly show that there was an overall drop in electricity consumption.

In figure 7.3, the average daily consumption cost for both 2018 and 2019 are shown side by side for a better visual comparison. The upper boundary (75% of the data) for both 2018 and 2019 is equal at around R15 500 whereas the lower boundary (25th percentile) is about R9 000 for 2018 and R8 200 for 2019. The mean for both 2018 and 2019 are closely matched at about R10 800 and R11 000 respectively. The chart shows that the cost of electricity increased slightly even though there was a drop in consumption.

7.4 ELECTRICITY COSTS

In 2017/18, the electricity unit cost was R 1.30/kWh and increased to R 1.41/kWh in the 2018/19 year, this was an increase of eleven cents which translates to an 8.5% increase. In the 2019/20 year, the unit was charged R 1.53, based on the 2018/19 rates, the increase was 12^{C} which translates to 8.5% increase which is similar to the previous year. At this rate, this implies that the electricity will cost almost double in 2025 (7 years since 2018), however, these rates cannot be predicted.

Added to this, there is a service cost that is paid to the City of Cape Town, the cost is charged per day at the rate of R 45.62/day in 2017/18 season. Then there was a R3.71 increase in 2018/19 which is equivalent 8.13% increase and the new cost was R49.33/day. The increase in the rate is almost similar to that of the tariffs. The service charge in 2019/20 is now R 53.71 which is an increase about R 4.38 (8.88% increase) and it will also increase (same applies to the tariffs) in July 2020 for the 2020/21 financial year.

7.5 CONCLUSION

This chapter presented the energy bills based on the invoices provided by the CoCT. The results prove that CPUT is paying just under R4 million per annum which can be considered significant. Unless there are any changes effected into the system, in 2025, the bill can be predicted to be over R8 million (double the current bill) based on the 2017/18 bills.

CHAPTER EIGHT

8 STUDENT ENERGY AWARENESS SURVEY

8.1 INTRODUCTION

This chapter identifies the institutional barriers to a successful implementation of energy efficiency interventions at the university residences from the student's perspective. The specific barriers are related to the participant's attitude, knowledge, perception and behaviour of students within the institution's residences. The survey also covers the energy needs or electricity usage by the students in residences for cooking, space heating, water heating with respect to related appliances. Based on the audit results in chapter 4, electricity in the main source of energy in the residences.

Data was collected utilizing electronic online survey which was distributed to over 100 CPUT students who stay in the residence. The survey focussed on the following areas:

- Commitment towards using energy – are the students concerned on how they use electricity?
- Attitude towards energy efficiency – What do student understand about energy efficiency
- Knowledge about electricity costs and savings
- Appliances – which appliances do students use to complete their activities?
- ENCON - any ENCONs noted by students?

The survey questions are provided as part of the appendix in chapter 12 (appendix A).

The following sections will show the survey results.

8.2 COMMITMENT TOWARDS ENERGY EFFICIENCY

The students were asked about their commitment to energy efficiency. The questions such as concern when it comes to using energy in their homes versus using it at the university were asked. This brought an understanding of whether the students do care about the university facilities more than their homes or they are simply not aware. The other questions were surveying if the students do understand or do feel they have a responsibility to save electricity whether at home or school.

The 5-point Likert scale (1 to 5, 1 means strongly disagree and 5 means strongly agree) was used to assess the students on these questions. Table 8.1 below presents the statistically analysed responses.

Table 8.1: Degree of Commitment to Energy Efficiency

Item No.	Description	Mean/ Avg	Mode	Median	Standard Deviation
8.2A	I am concerned about saving electricity at home	4.57	5	5	0.859
8.2B	I am concerned about saving electricity at my residence	4.28	5	5	1.079
8.2C	I feel I have a responsibility to save electricity	4.52	5	5	0.850
8.2D	I want to know more about how to save electricity	4.16	5	5	1.064

Definitions of the terms in table 8.1:

Mode: *the number that appears the most in the series*

Standard Deviation: *The variation from the mean/average*
Median: *The middle number in the series*
The information on table 8.1 above was translated from the responses shown graphically (bar graph) in figure 8.1, 8.2, 8.3 and 8.4 below.

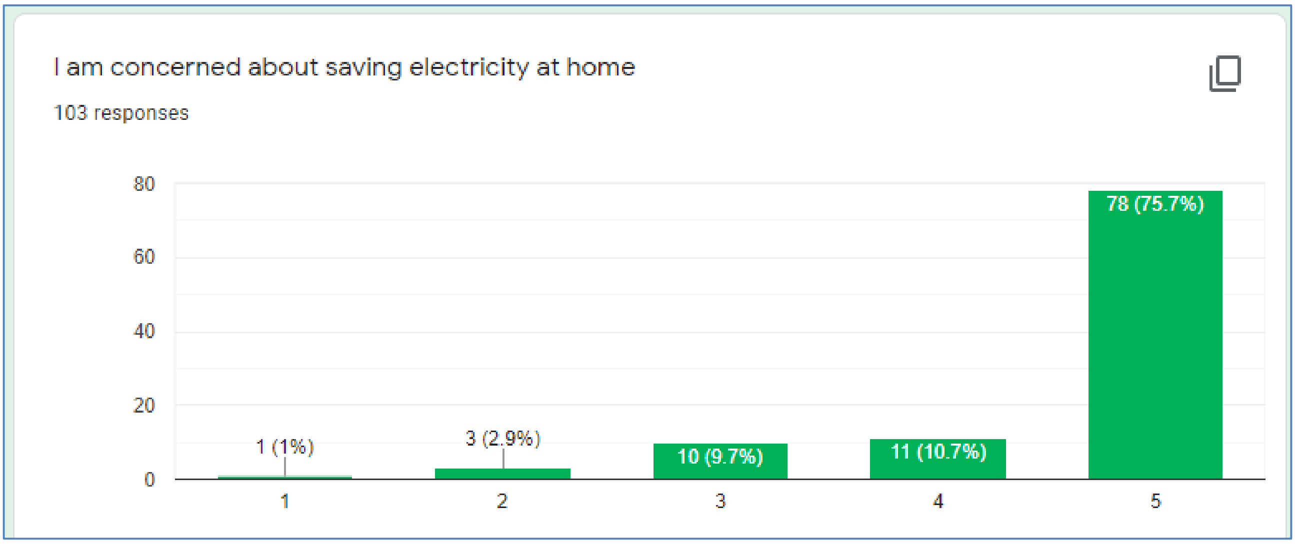

Figure 8.1: Concerns about saving electricity at home

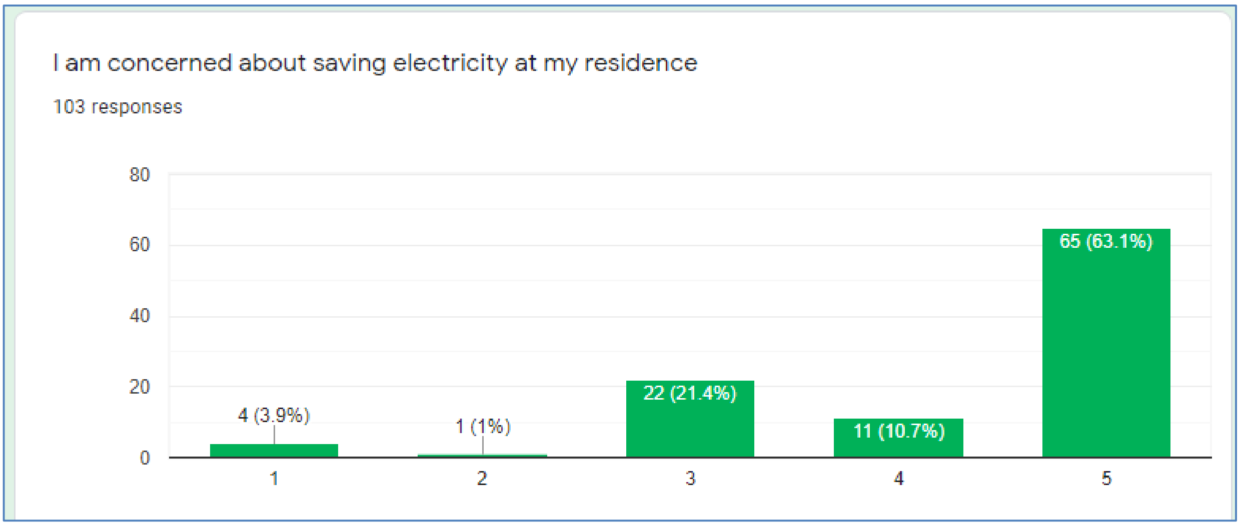

Figure 8.2: Concerns about saving electricity at my residence

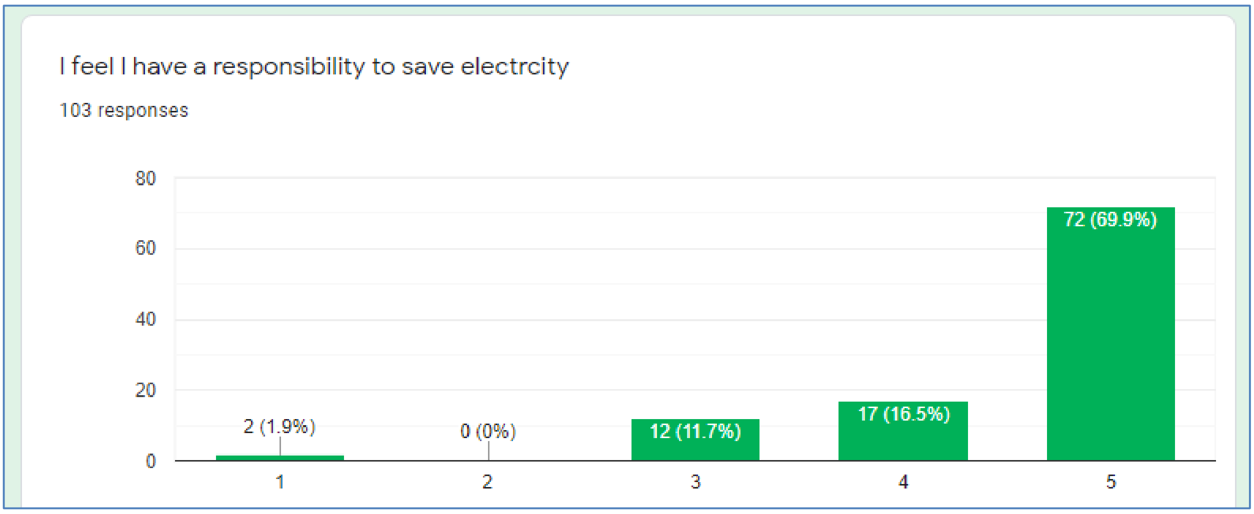

Figure 8.3: Responsibility towards saving electricity

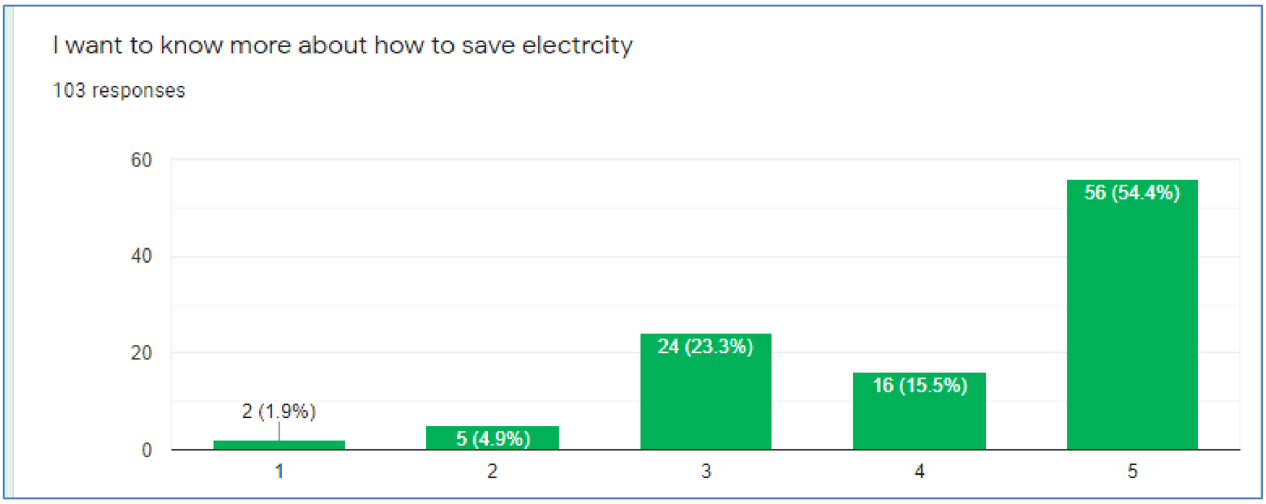

Figure 8.4: Willingness to know more about electricity savings

From the data provided above, At the mean of 4.52 (70% strongly agree and 17% agree), this shows that the students feel they have a responsibility to save electricity in general. However, most students are more concerned about saving electricity in their homes than at their residence. In the case of saving electricity at home, most of the students are (76% at a mean of 4.57) strongly agree that they are a concern, However, 63% (mean of 4.28) feel that they do not see the worth of saving electricity at their residence.

At the mean of 4.16 (54% strongly agree and 16% agree), this shows that some of the students are willing to learn the importance of saving electricity when offered an opportunity, even though this is not the majority but it could assist in closing the gap between saving electricity at home and the residence deficit.

Based on these results, it is believed that the most important thing missing is awareness and lack of education when it comes to energy and usage of energy. The next section discusses the results on the attitude towards energy efficiency

8.3 ATTITUDE TOWARDS ENERGY EFFICIENCY

Table 8.2 below shows the types of questions were asked to students with regards to their attitude towards energy efficiency, as in section 8.2, the students were surveyed through the 5-point Likert scale (1 to 5, 1 means strongly disagree and 5 means strongly agree)

Table 8.2: attitude towards energy efficiency

Item No.	Description	Mean/ Avg	Mode	Median	Standard Deviation
8.3A	Awareness Campaigns will encourage students to use less electricity	4.2	5	5	1.106
8.3B	I think there are opportunities to save electricity at my residence.	3.98	5	4	1.099

The information on table 8.2 above was translated from the responses shown graphically (bar graph) in figure 8.5 and 8.6 on the next page.

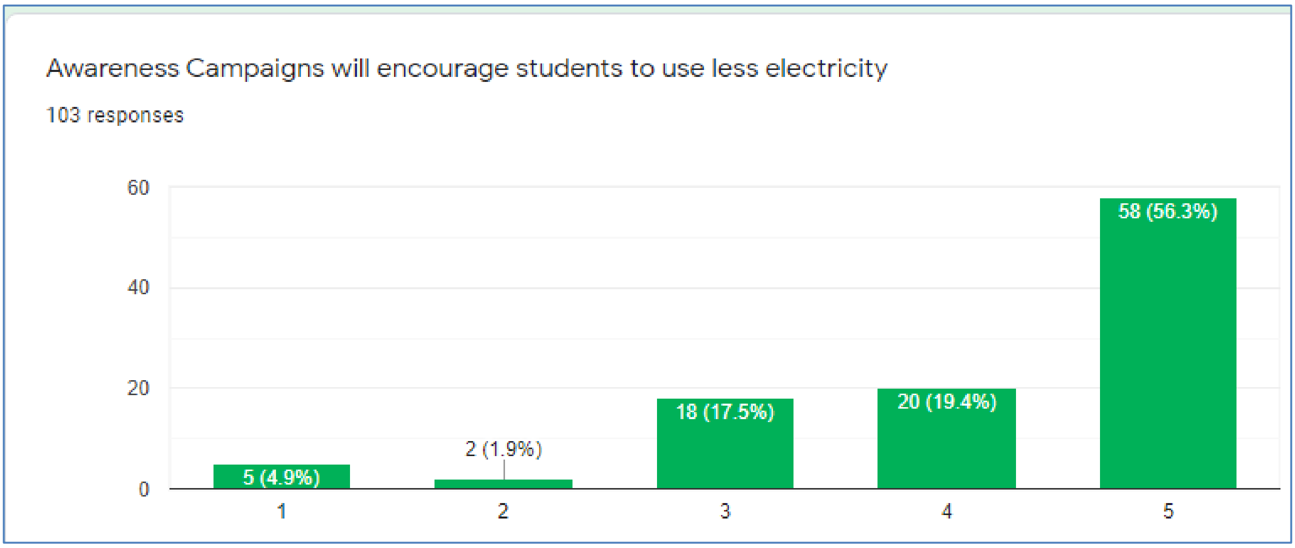

Figure 8.5: Necessities of awareness campaigns

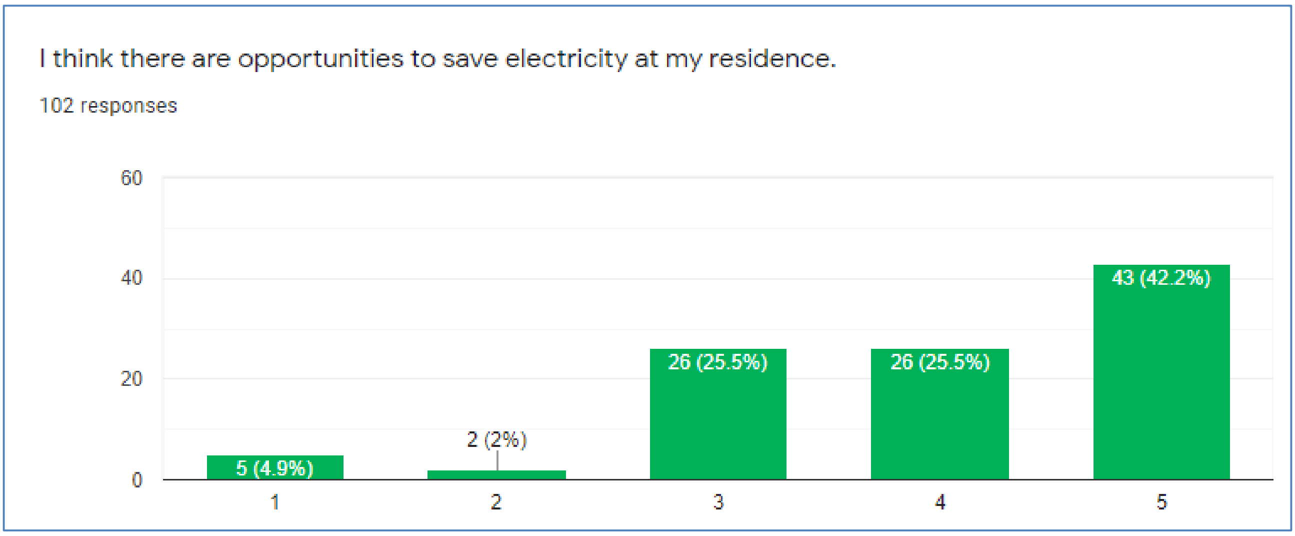

Figure 8.6: Possible energy-saving opportunities

With the mean of 4.2, 56% (more than half) of the respondents (the student) believe that there is a need for awareness campaigns to improve or instil energy efficiency or electricity saving behaviour in the students' minds. This could prove important as only an average of 3.98 believe that there are opportunities to save electricity in their residence, as seen in figure 8.6, 42% strongly agree and 26% agree that there are energy-saving opportunities, to show that there is a need for awareness, 26% are neutral, meaning that they are not sure or they do not know. And there is 7% who disagree completely that there are energy-saving opportunities in their residence, this can be mean either the students do not know what are the energy-saving opportunities or their residence is very energy efficient (which is not the case)

In addition to this, the students were asked about their understanding of the phrase 'energy efficiency'. They were given answers to choose from and the results are shown in figure 8.7 below.

According to (Feng & Wang, 2017), Energy efficiency can be easily defined as using less energy to perform the same task, this can be achieved by reducing energy losses

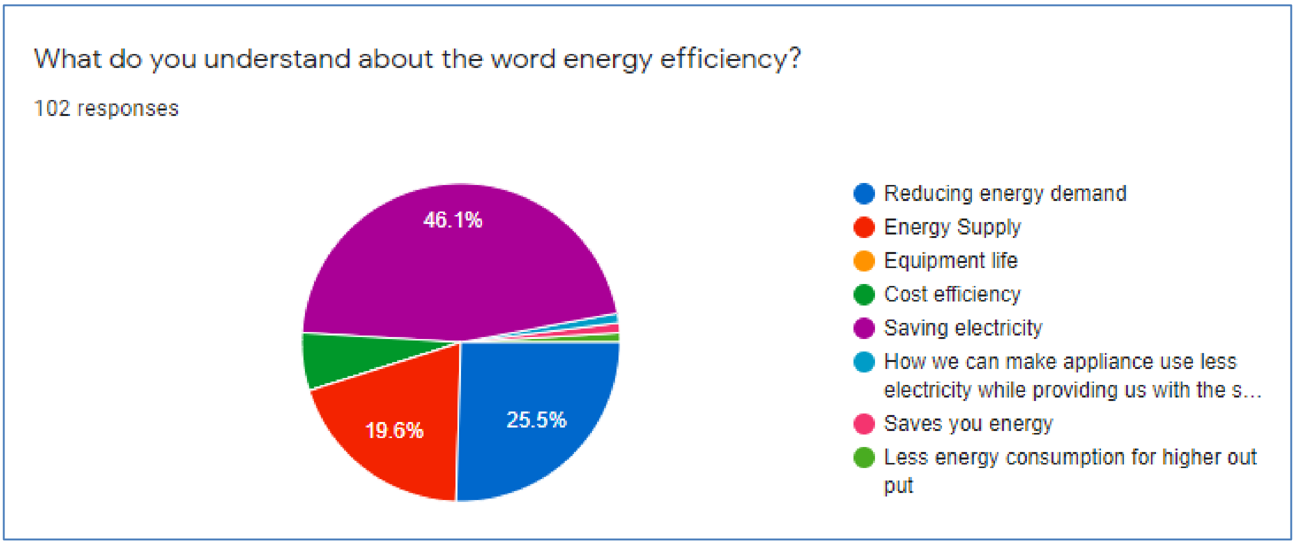

Figure 8.7: Understanding of the term energy efficiency

According to the results in figure 8.7, 46% and 26% of the students (respondents) believe that energy efficiency is saving electricity and reducing energy demand respectively, this shows some sense of understanding of the term. However, some 20% believe that energy efficiency is energy supply, this shows that there is a gap that needs to be closed in terms of teaching the respondents about energy and its aspects.

8.4 KNOWLEDGE ABOUT ELECTRICITY COSTS AND SAVINGS?

Sometimes attitude towards energy efficiency is driven by knowing the cost associated with being energy inefficiency, the next survey looked into understanding if the students do know of the costs of consumption of electricity in their residences. Figure 8.8 below shows the results.

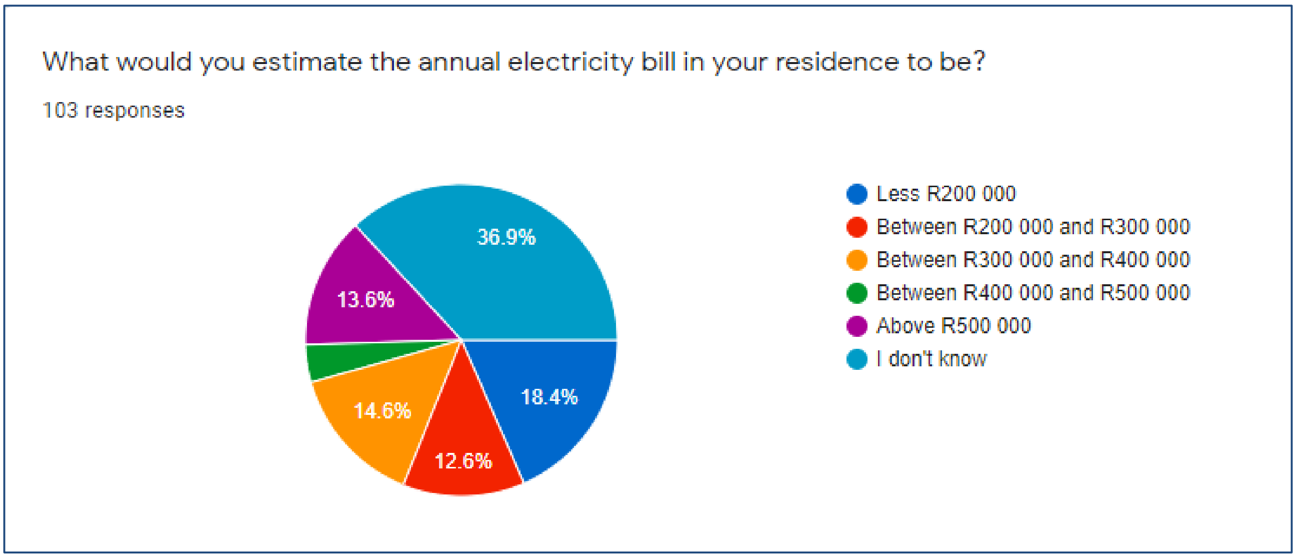

Figure 8.8: Survey on the understanding of the annual cost of electricity

From figure 8.8 above, most of the respondents (37%) have no idea of what is the cost of electricity for their residence. About 18% of the students believe the bill is under R200 000 and only 14% think the bill is above R500 000. The actual annual bill of the residence under study (Catsville) is averaging under R4 million per year as seen in Chapter 7. The lack of knowledge about the bills can be the biggest contributor to a lack of interest in energy efficiency

8.5 APPLIANCES

This part of the survey has established the appliances that the students do have in their rooms, this offers an understanding of what else uses the electricity in the residence except the standard appliances recorded during the energy audit which was discussed in Chapter 4. Figure 8.9 on the next page shows the appliances students have in their rooms

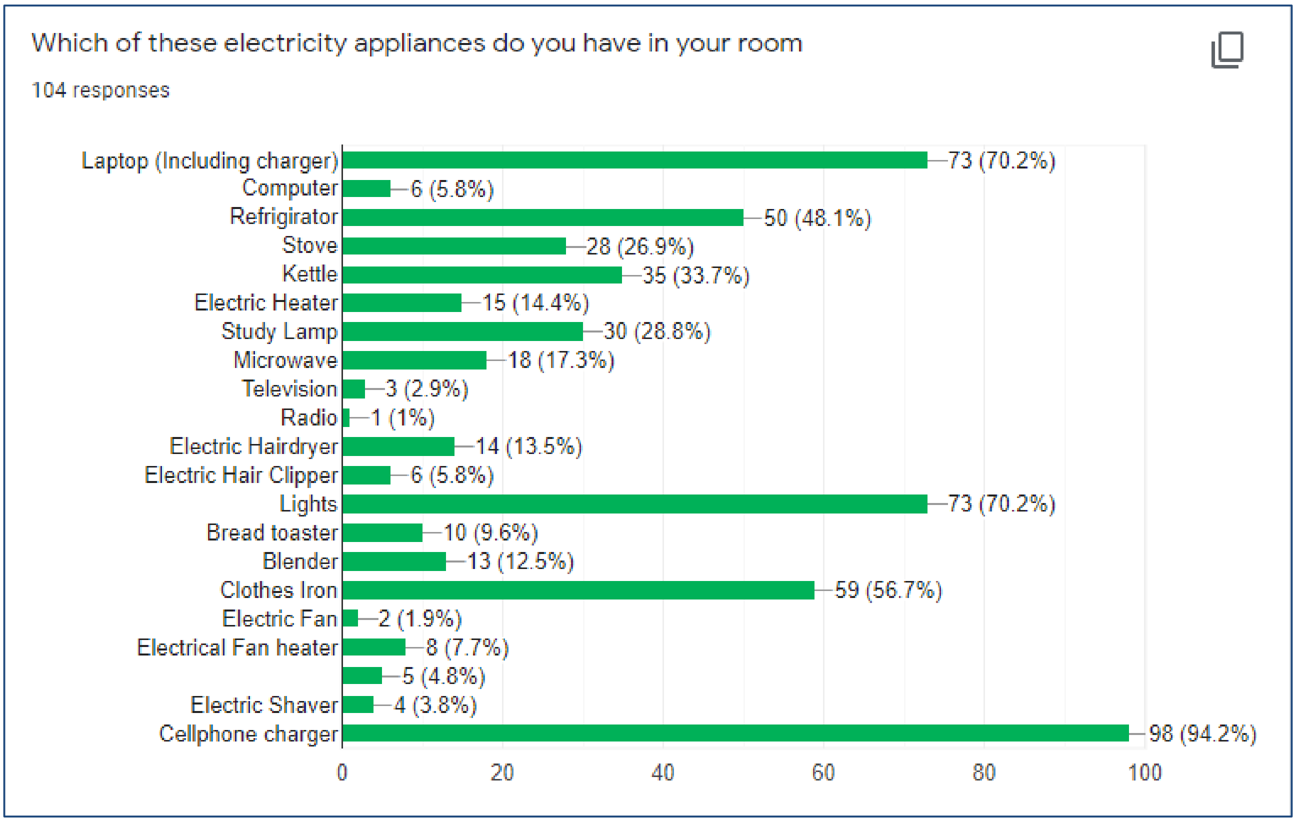

Figure 8.9: Appliances in the student rooms

Figure 8.9 shows that most of the students (94%) do own mobile phones and this is expected as the recent advances in technology could prove. The survey shows that only 70% of the students do have lighting in their rooms, this out of the ordinary as it is expected that each student must have basic lighting in their rooms, however, this can be attributed to poor maintenance in the residences. This also the case with study lamps, only 29% of the students have the study lamps in their room, this is a concern since it is a necessity for students when they are studying or doing school-related activities. 27% and 14% of the students own electric stove and electric heater respectively, this is typically not allowed as it becomes a fire risk if they are operated with less caution, the CPUT residence rules do not allow this type of appliances but as expected, there will be such cases where students own them. Other appliances are deemed a privilege to have as only a handful own them, they can be seen in figure 8.9.

The next questions were looking to establish the usage of these appliances and the results are shown in figure 8.10 on the next page

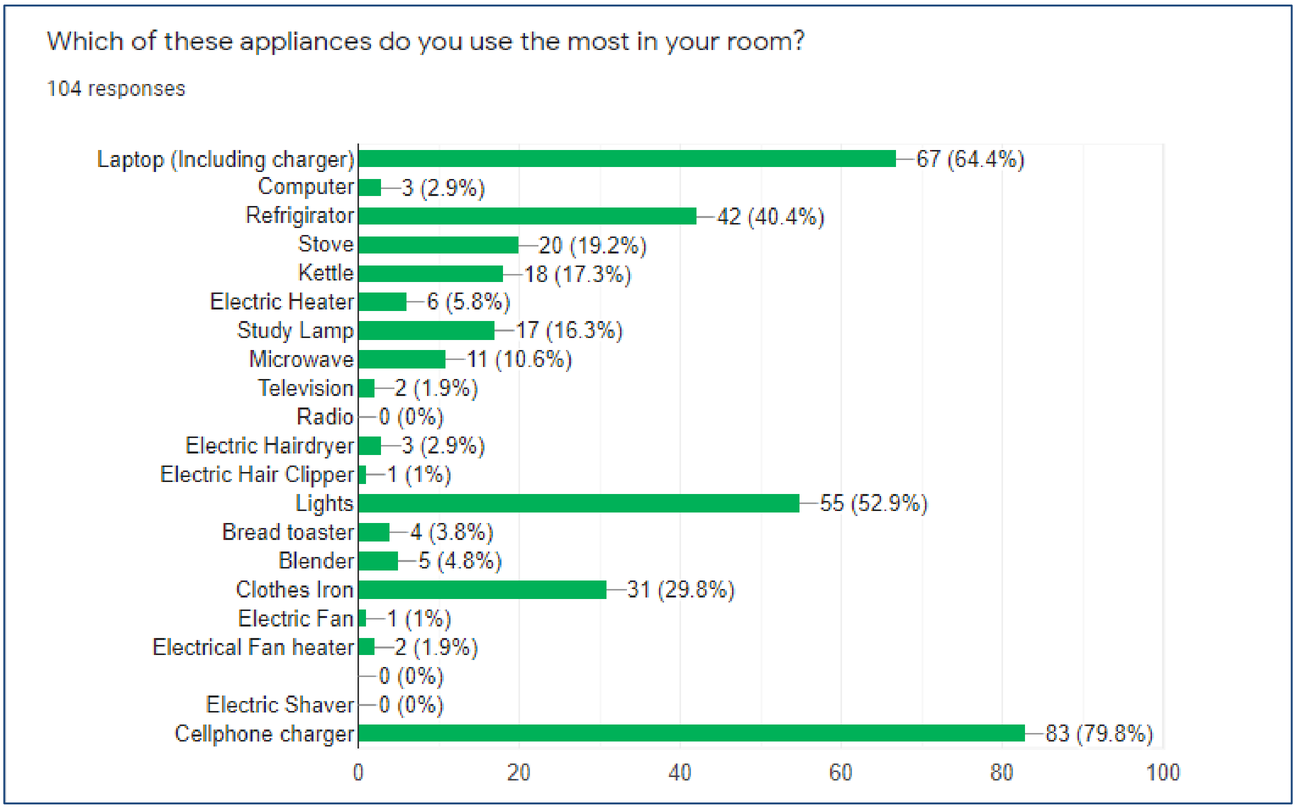

Figure 8.10: Usage of student appliances in their rooms

The results in figure 8.10 are to be expected as the most five used appliances are cell phone charger (80%), laptop charger (64%), lights (53%), refrigerator (41%) and clothes iron (30%). Other devices are not used more often because most students do not own them as seen in figure 8.9 above.

8.6 MAJOR USERS OF ELECTRICITY

The section evaluates the students' knowledge and opinions on which appliances and which activities are the major users of electricity in their residence. Figure 8.11 and 8.12 below shows the results of the survey.

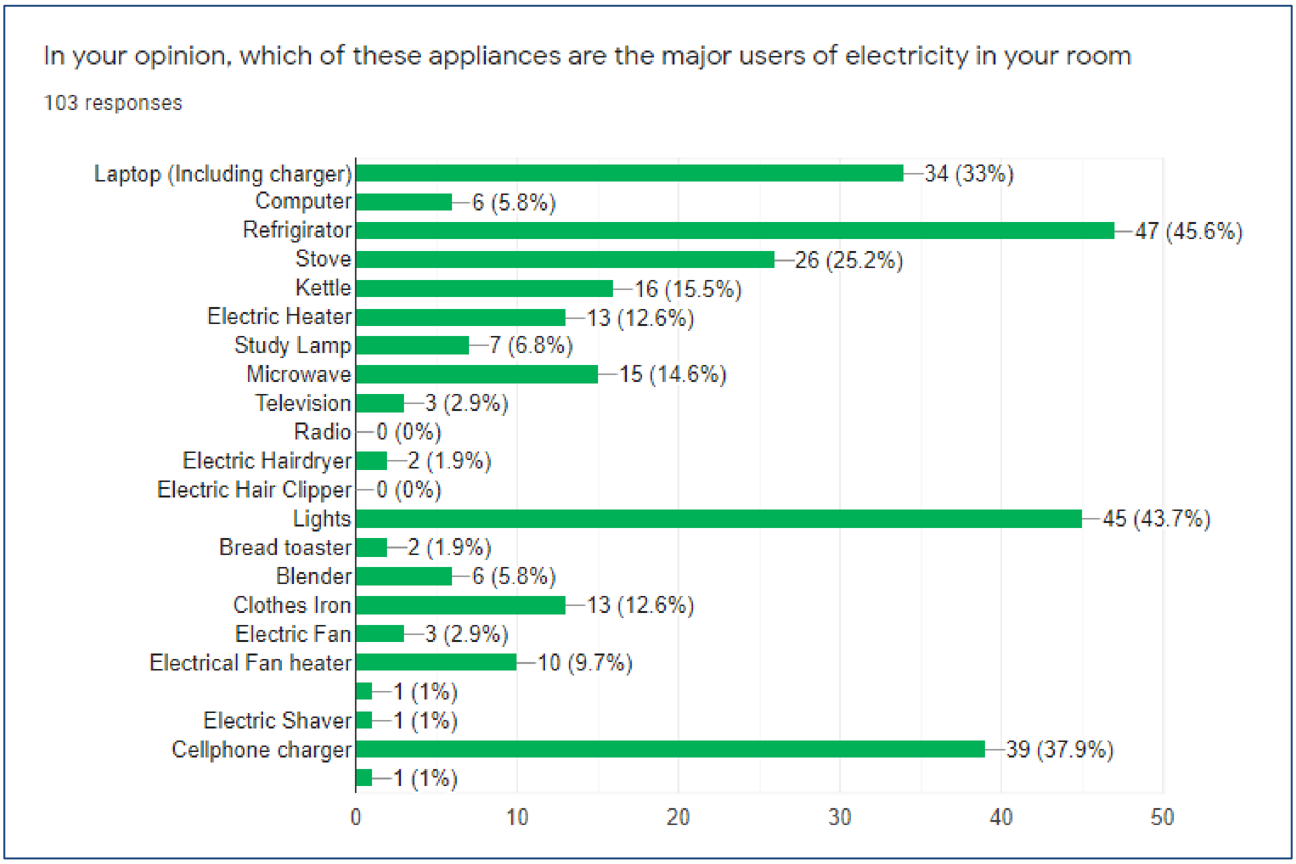

Figure 8.11: Appliances that use more electricity

This question was based on the student's opinion regardless of their expertise on matters related to electricity. According to the responses, the major user of the electricity is the refrigerator (46%) followed by lighting (44%). This is expected as these two appliances are always in operation and this was established during the audit.

Figure 8.12 below shows the survey on student's opinion regarding the activities that use more electricity in their residence. The respondents were given a choice to choose from the most common activities in the residence such as cooking, lighting, bathing, recreational activities such as watching TV, space heating, space cooling and laundry.

Based on the survey results as shown in figure 8.12 on the next page, the respondents believe that cooking is the activity that uses the electricity the most in the residence at 90%. The next most user of electricity according to the survey is bathing/shower with 76% followed by lighting at 60% of the laundry activities at 53%. The results were based on the student's observations and opinions.

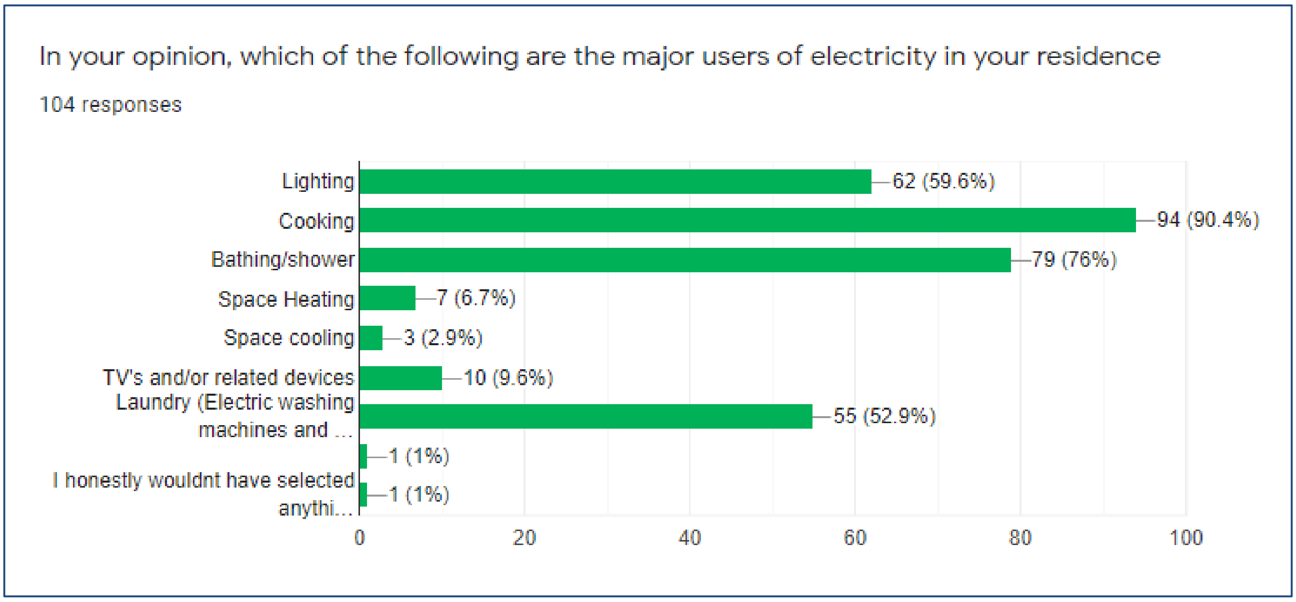

Figure 8.12: Activities which uses more electricity

From this, it shows that cooking is the most frequent activity at the residence and that it is expected in a residential area, this results will provide the energy auditor with an idea which areas to pay more attention to when implementing the energy audit outcome.

8.7 LIGHTING

This section analyses the student's behaviour when it comes to lighting and efficient or inefficient usage of lighting.

8.7.1 LIGHTING IN CORRIDORS/PASSAGES

The first question was assessing the opinions of the respondents (students) on the lighting on the corridors. As shown in figure 8.13 below, the students were questioned in terms of the lighting in the corridors if, in their opinion, the lighting is necessary. Most respondents (56%) are of the opinion that the lights are not necessary during the day and about 39% of them feel that it is dark when the lights are off regardless if it is during the day or night. This can also be corroborated to the data recorded during the energy audit as presented in Chapter 4. Part of the respondent responded that they do not know, this shows a lack of interest or lack of awareness on electricity/energy-related matters.

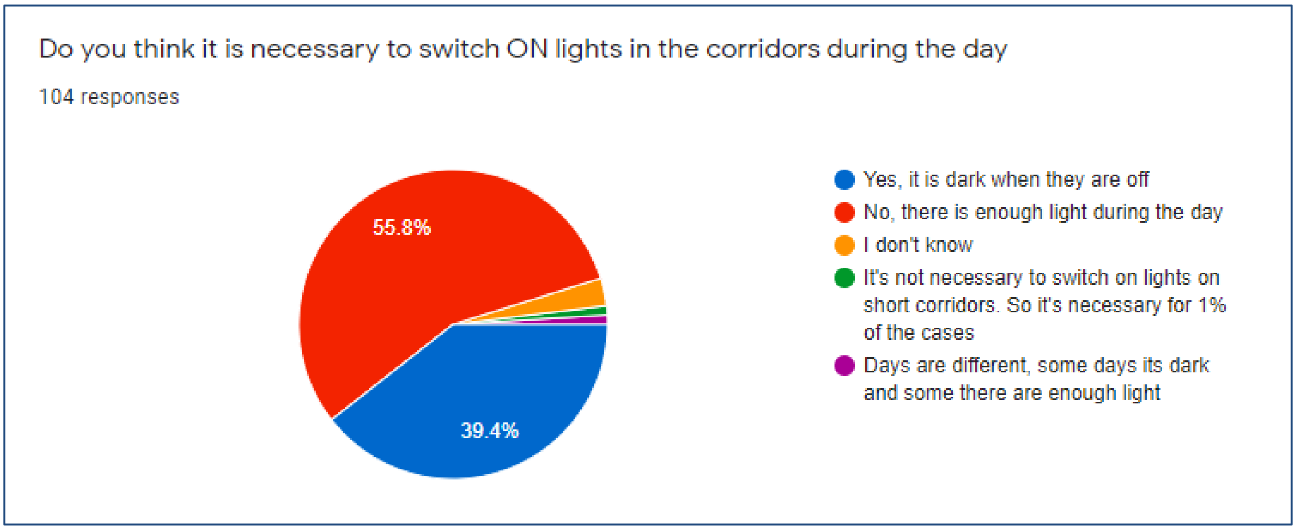

Figure 8.13: Lighting on Corridors

The next question assessed the interventions and the respondents' responses are shown in figure 8.14 below.

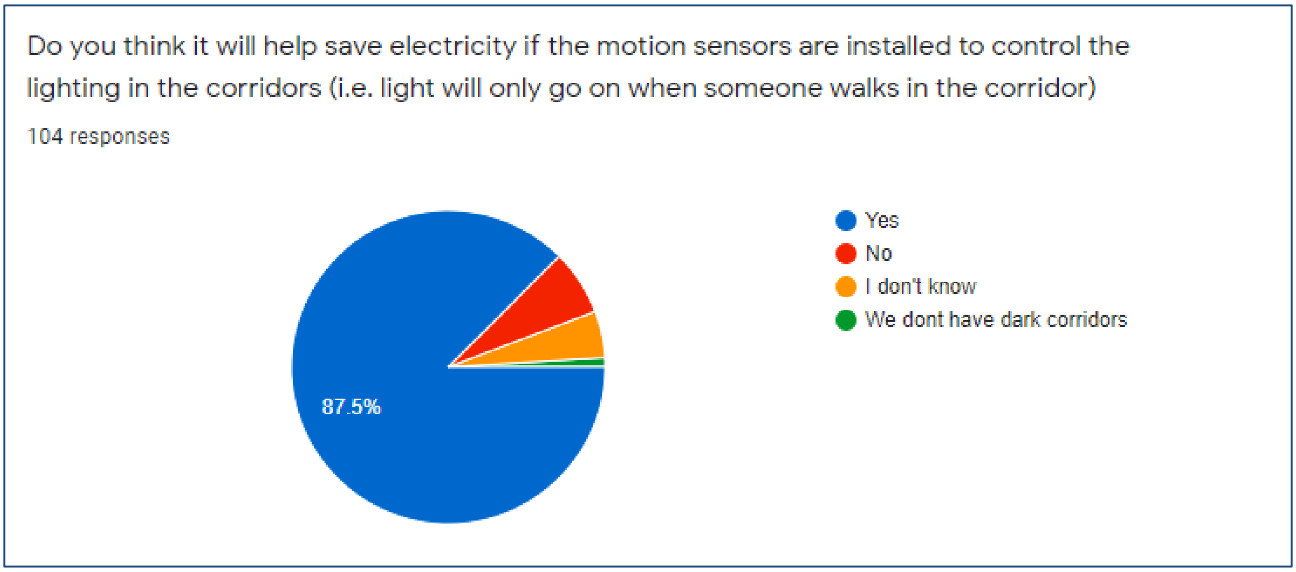

Figure 8.14: Automatic corridors lighting control system

Almost all the students (88%) agreed that the motion sensors are a viable option to only switch on the lights when there is a need. This is a widely used intervention as (Thovhakale, 2011) stated in her study.

8.7.2 LIGHTING IN THE STUDENT ROOMS

This section was assessing student's behaviour in terms of how they use lighting in their rooms.

The first of the set of questions was investigating how often is the lighting used in the rooms, the results are shown in figure 8.15 below. As seen in the figure, most of the students (46%) use the lights for between 5 to 10 hours in a day, however, 40% claim to use the lights only less than 5 hours in a day on average. A handful of students indicated that they never switch off the lighting in their rooms.

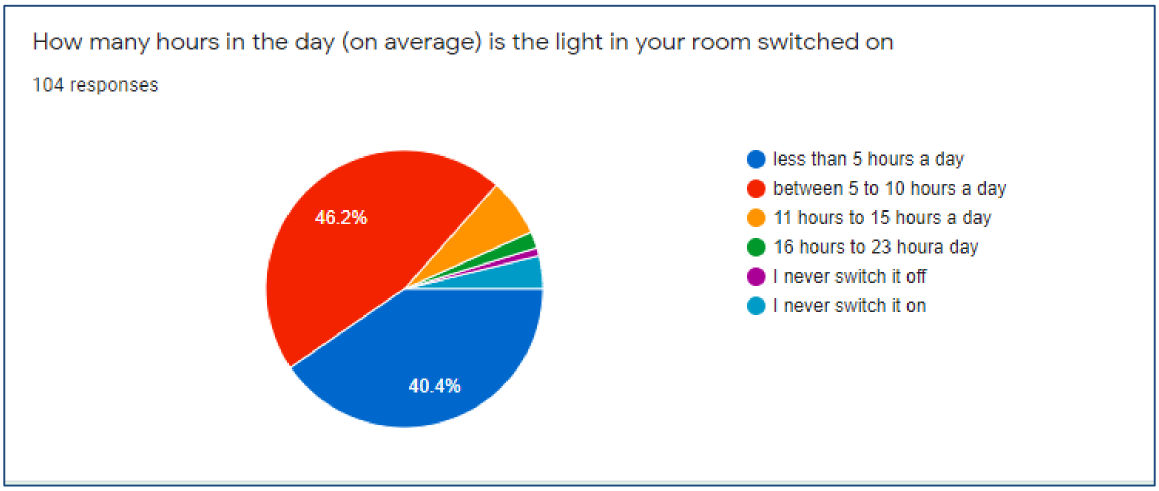

Figure 8.15: Average usage of lighting per day

The next question was assessing how often the students leave the lights ON in their rooms as shown statistically on table 8.3 below. This assessment used the 4-point Likert scale (1 to 4, 1- Never 2- Rarely 3- Sometimes 4- Often).

Table 8.3: Student's behaviour on lighting and plug usage

Item No.	Description	Mean/ Avg	Mode	Median	Standard Deviation
8.7.2A	How often do you switch off the lights when you leave your room?	3.58	4	4	0.634
8.7.2B	How often do you switch off the lights in your room when you necessarily don't require them (during the day or when sleeping)?	3.49	4	4	0.8
8.7.2C	How often do you switch off the unnecessary plugs when you leave your room?	3.84	4	4	1.373

The information on table 8.3 above was translated from the responses shown graphically (bar graph) in figure 8.16, 8.17 and 8.18 on the next page.

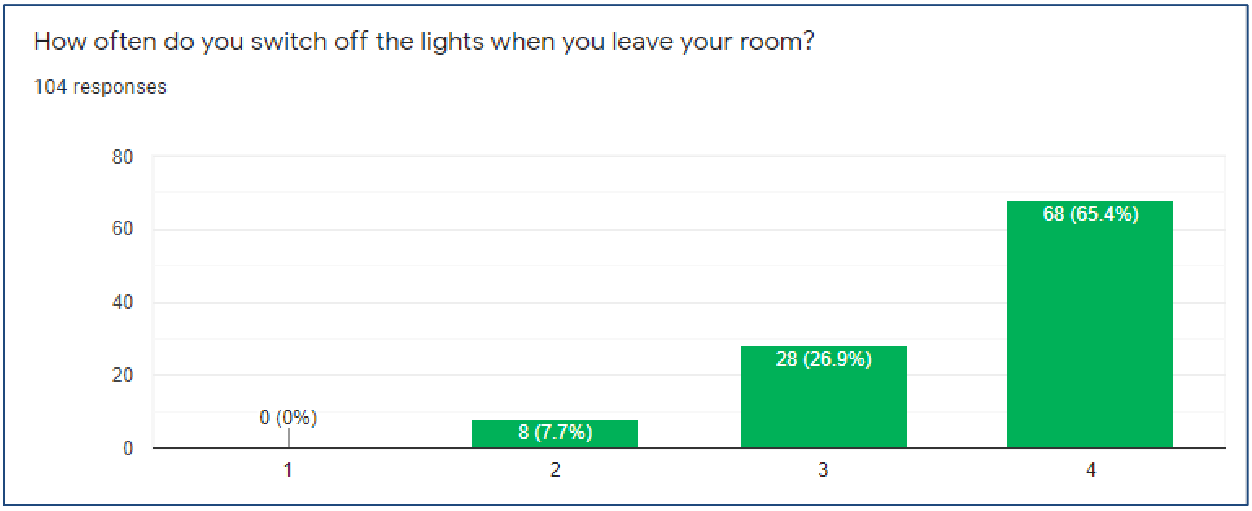

Figure 8.16: How often are lights left on when the student leaves the room

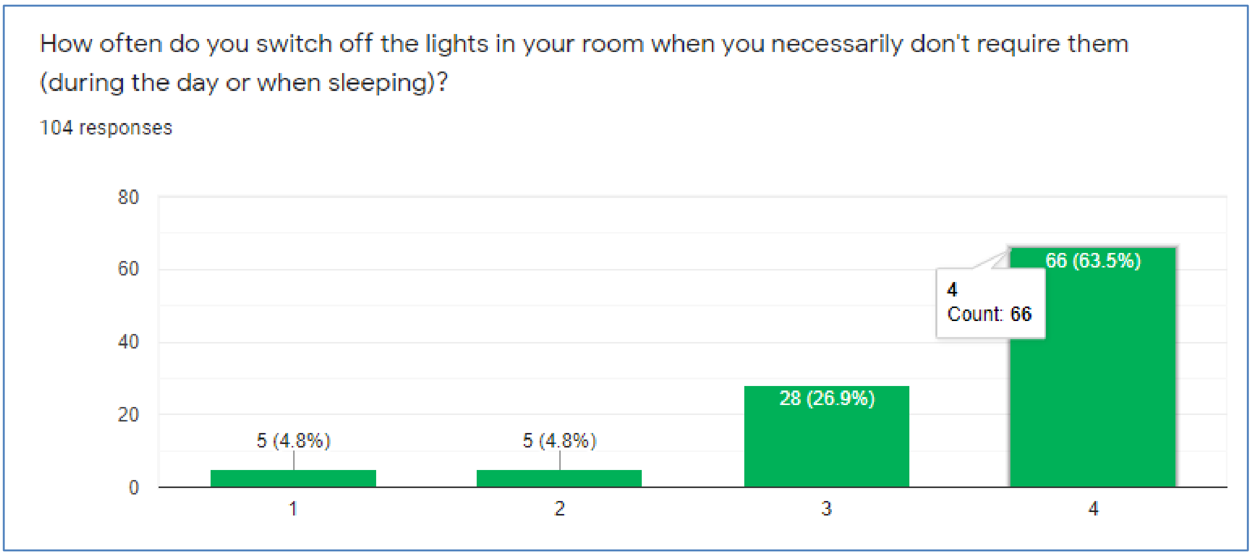

Figure 8.17: How often are lights switched off when not in need

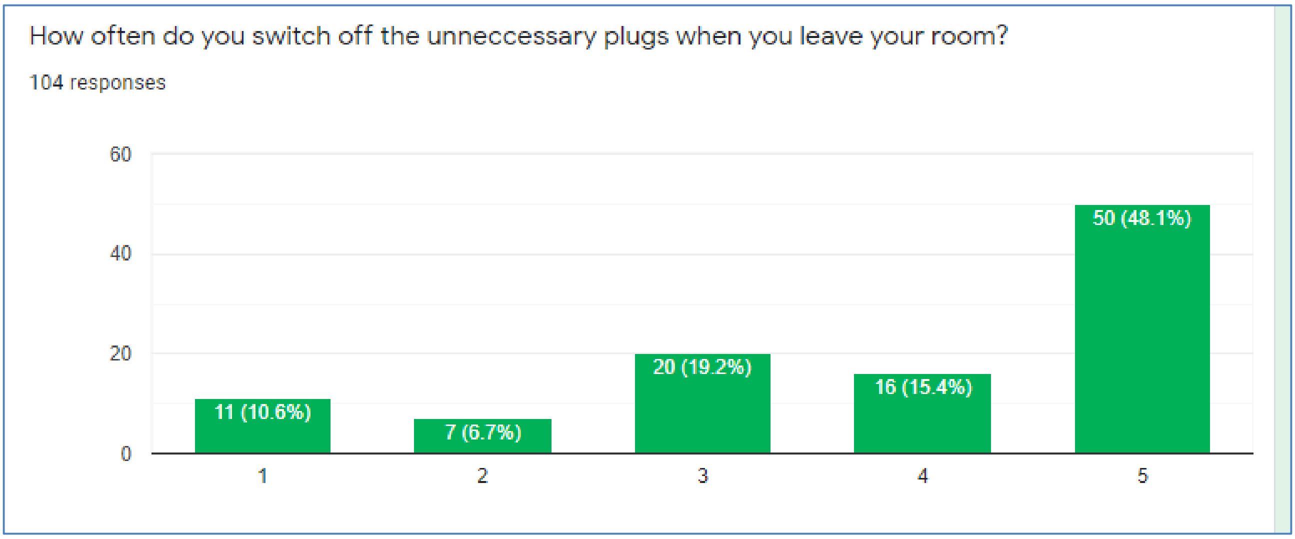

Figure 8.18: How often are unnecessary plugs switched off

From table 8.3, with the mean of 3.58 shows that 66% of the students do switch off their lights more often whereas 15% of the respondents sometimes switch off their lights. The standard deviation of 0.634 shows that the data is very close to the average score of 3.58

These results are almost similar to that of 8.7.2B (on table 8.3) where it shows that 64% (mean of 3.49) of the students switch off the lights when not necessarily needed like during the day or when the occupants are sleeping. The standard deviation of 0.8 shows that the data is very close to the average score of 3.49

In terms of the plug usage, 48% (average of 3.84) of the surveyed samples often switch off the plugs if they are not in use. Only about 15% switch off the plugs when not in need and 11% never switch them off. This can also be seen from the standard deviation of 1.373 that the data is spread out and not necessarily close to the mean value.

Based on the mean score of these activities, it shows that most of the students are energy conscious even though they might not know it as shown in section 8.2 where over 20% of the students did not understand the definition of energy efficiency.

8.8 SPACE HEATING AND COOLING

This section assessed what do students use for space heating during wintertime and space cooling during summertime.

8.8.1 SPACE HEATING

The main source of energy in the residence is electricity. The results as depicted in figure 8.19 on the next page show that 61% of the students rely on natural means of heating, which is by closing windows and doors to preserve heat. Only about 29% of the students use an electrical heater to heat their rooms, this can be attributed to that not all the students have heaters in their rooms as shown in section 8.5 where only 14% of the students reported that they have electric heaters in their rooms

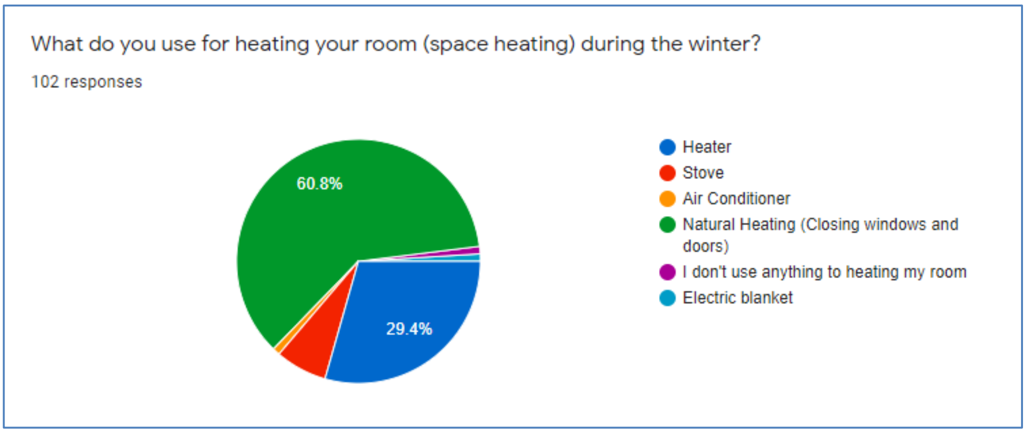

Figure 8.19: Space heating methods used

The respondent where asked how often did they use their electrical heating equipment during wintertime as shown in figure 8.20 below.

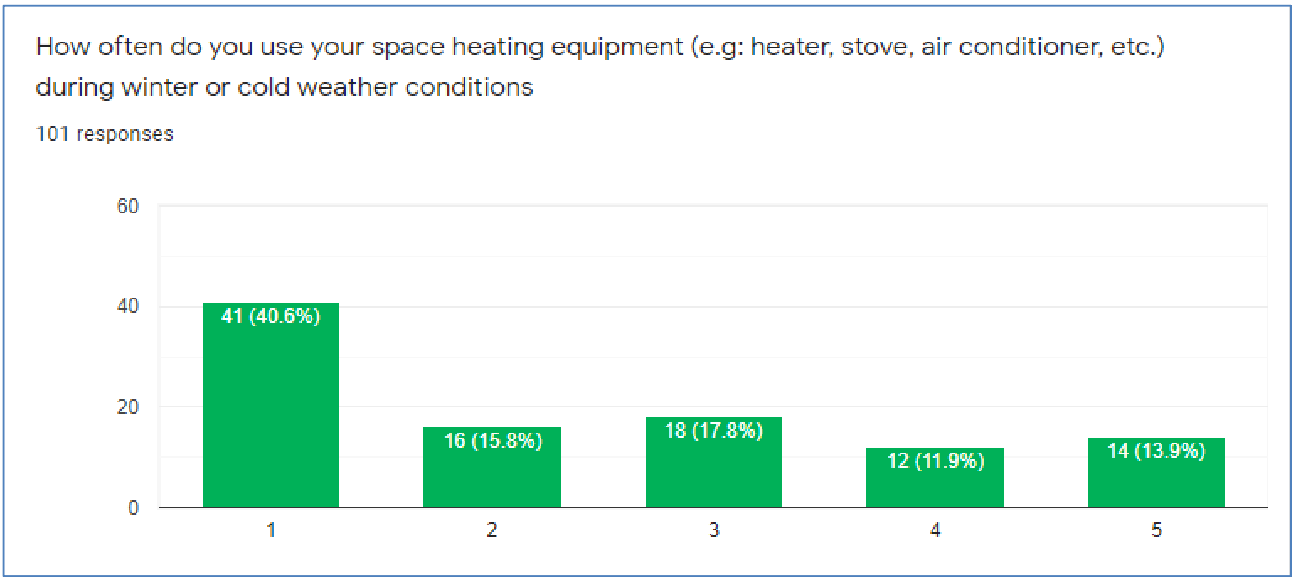

Figure 8.20: Usage of Space Heating Equipment

The results on figure 8.20 had a Mean value of 2.43, Mode of 1, Median of 2 and Standard Deviation of 1.465. Based on the model, the mean is closer to the value 2 which represents a “rarely used” option, this means most of the students rarely use the space heating equipment during winter. As seen in figure about 14% of the sample always use the heating equipment during wintertime, this was expected as only 14% of the student own electric heaters as seen in section 8.5.

8.8.2 SPACE COOLING

The next phase of the questionnaire was on space cooling, this was to determine which equipment students use for space cooling and how often they are used during summertime. The results as seen in figure 8.21 below show that 90% of the students use the natural cooling method which is to open doors and windows, only a handful (7%) use the electric fan for cooling, this was expected to be low as only 2% of the students own the electric fan as shown in section 8.5.

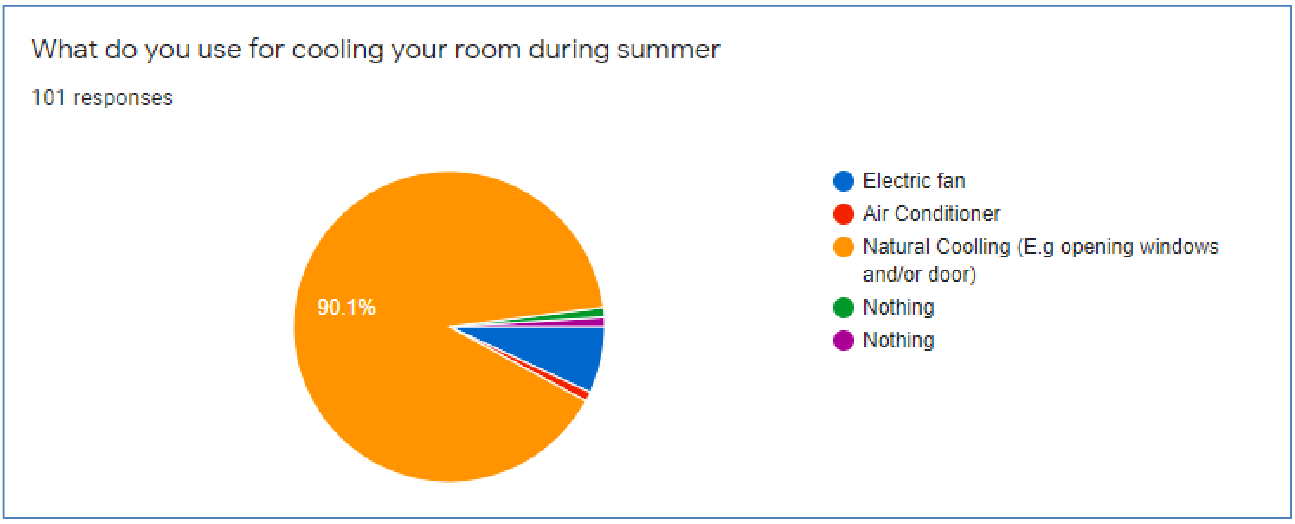

Figure 8.21: Space Cooling Methods used

The respondents were then asked how often did they use their electrical space cooling equipment during summer time as shown in figure 8.22 below.

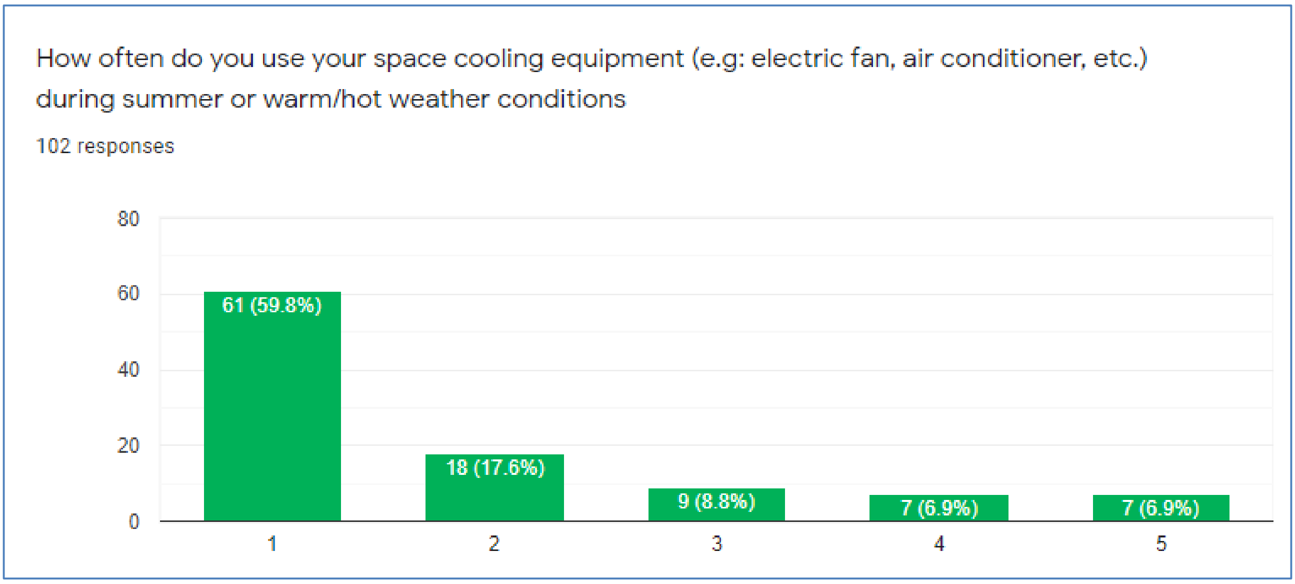

Figure 8.22: Usage of Space Heating Equipment

The results on figure 8.22 had a Mean value of 1.83, Mode of 1, Median of 1 and Standard Deviation of 1.251. Based on the model, the mean is closer to the value 2 which represents a “rarely used” option, this means most of the students rarely use the space cooling equipment during summer. As seen on figure 8.22, about 14% of the sample always use the space cooling equipment during summertime, this was expected as only 2% of the students own electric fans as seen in section 8.5.

8.9 COOKING, WATER HEATING, LAUNDRY AND SHOWERING/BATHING

The next set of questions was looking at other activities happening in the residence such as cooking, water heating, laundry and bathing.

8.9.1 COOKING

As seen in section 8.5, only the electric stove is at the disposal of the students to use and this can also be corroborated with the audit in Chapter 4 where the audit found that the student kitchens are equipped with the electric stove. The survey was assessing how many times students cook.

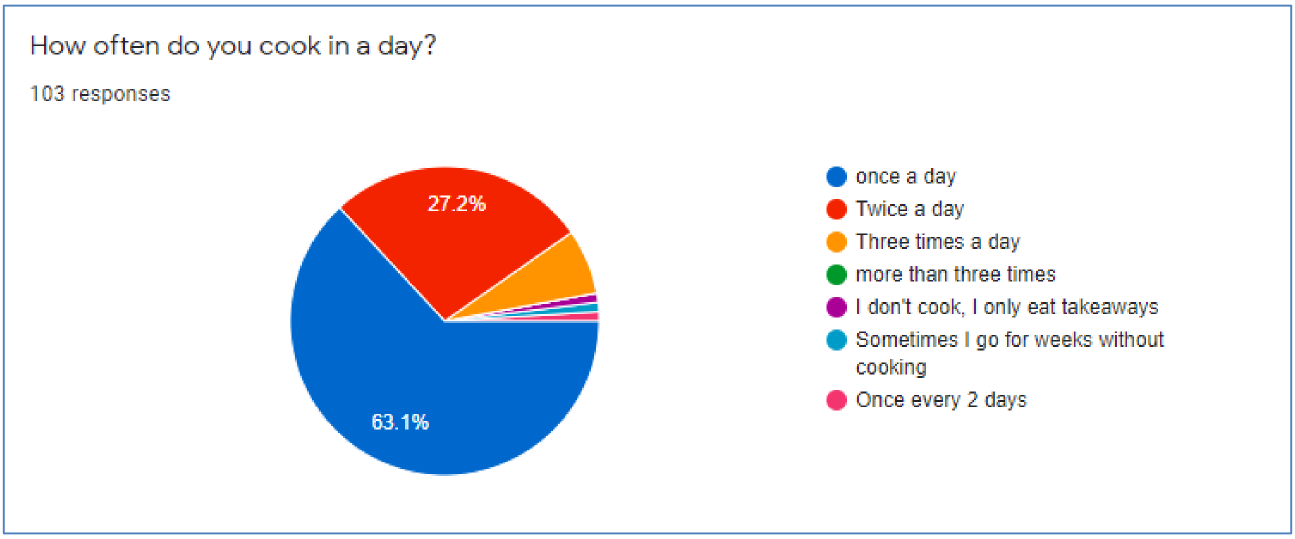

Figure 8.23: Student's daily cooking frequency

As observed in figure 8.23 above, 63% of the surveyed students cook once a day and about 27% cook twice a day.

8.9.2 WATER HEATING

This survey was assessing where students get hot water for any usage. The audit in Chapter 4 showed that the student kitchens are equipped with a hydro-boiler and also supplied with hot water from the geyser. Section 8.5 showed that 34% of the surveyed students do have kettles in their room which they also use for water heating. Figure 8.24 below shows the survey results.

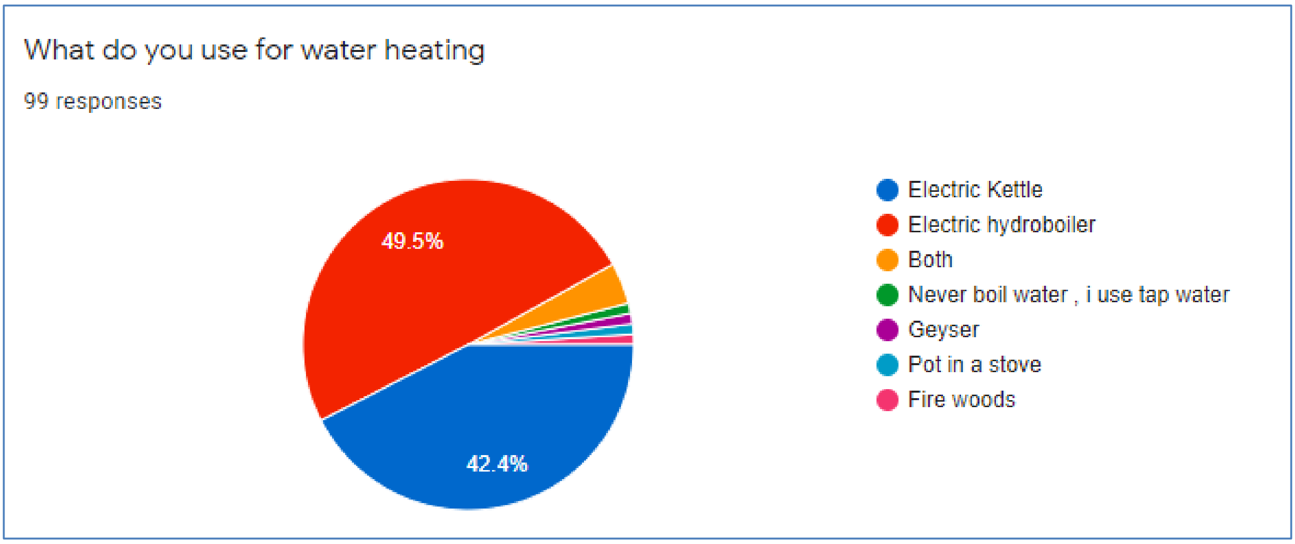

Figure 8.24: Student ways of water heating

Figure 8.24 above shows that 42% of the students use electric kettles for water heating and about 50% use electric hydro-boilers for water heating. Based on the audit in chapter 4, it was established that the residence is equipped with the hydro-boiler in the kitchen, therefore, this explains the high usage in the hydro-boiler. Because of poor maintenance, not all the hydro-boilers are functional and this explains the usage in electric kettles.

8.9.3 LAUNDRY

The residence does offer laundry facilities, these laundry rooms are centralised and are available to all the students who stay at the residence. Based on the visit to the facilities, it was found out that the laundry rooms are equipped with a set of washing machines and tumble dryers. The survey was establishing how often do students use the laundry facilities and the results are presented in figure 8.25 below.

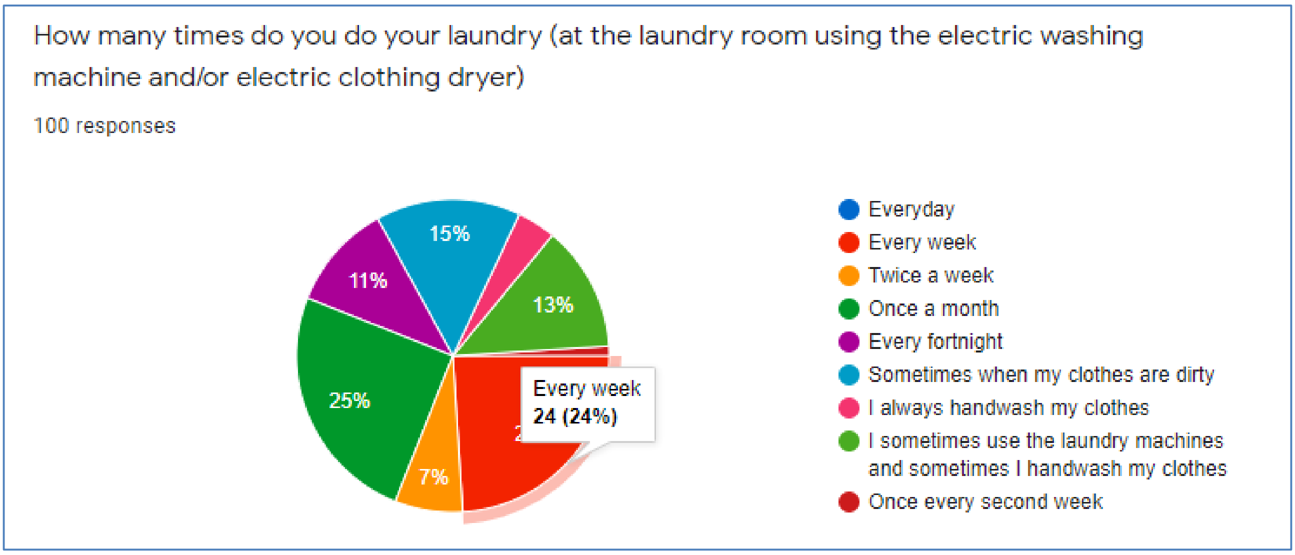

Figure 8.25: Student's laundry facilities usage frequency

The residence students are very diverse and as expected will behave in different ways, this was already established in Chapter 5 where consumption patterns could not be understood at times. As seen on figure 8.25, 25% of the students do their laundry once a month, then 24% stated that they use the facilities every week and 15% only wash their clothes when they are dirty. In terms of those who wash their clothes using both the laundry facilities and hands (handwashing), the surveyed established that only 13% participate in that activity. And finally, about 11% of the students do their laundry every fortnight.

8.9.4 SHOWERING/BATHING

As already established in the energy audit in Chapter 4, the residence is equipped with showers and baths, however, the baths were not working during the audit. The energy audit also found out that the ablution areas (shower, baths and basins) are supplied with hot water from a dedicated 200-litre geyser. This survey was determining how many times students take showers and the results are presented in figure 8.26 below.

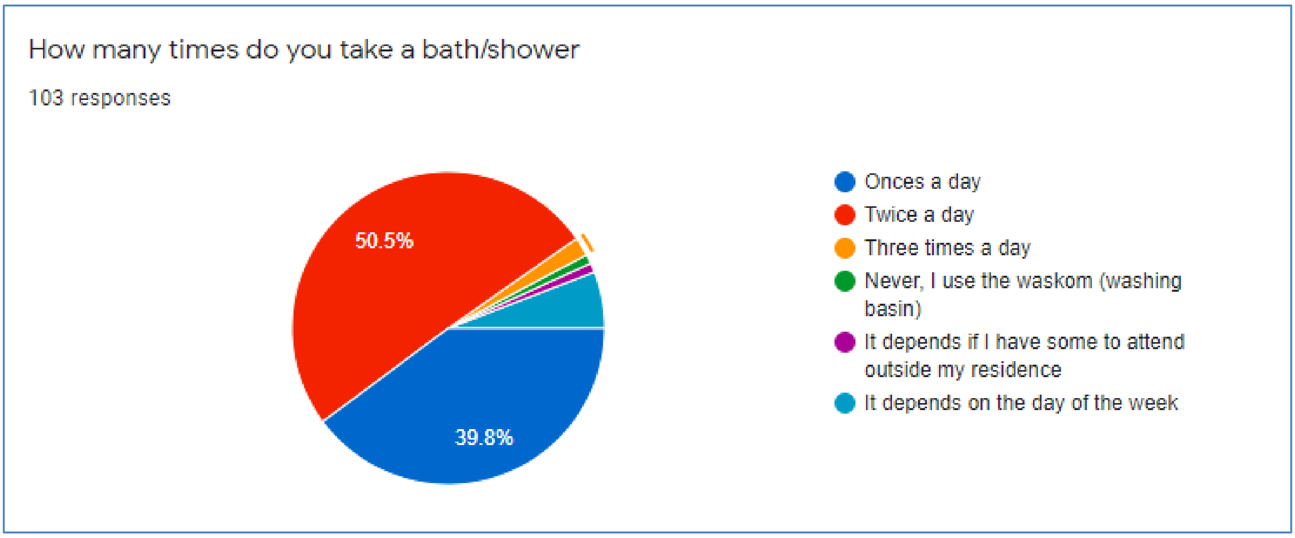

Figure 8.26: Student's showers/bathes usage frequency

About 51% of the surveyed students stated that they use the showering facilities twice a day as shown in figure 8.26 above. Furthermore, about 40% of the surveyed students take a shower once a day

8.10 Conclusion

The survey brought insight into whether the students are energy efficient or they need more training. Even though most of the activities are done unwittingly in an efficient way, there is still a need for students to be schooled about the aspects of energy efficiency.

CHAPTER NINE

9 DISCUSSIONS

9.1 INTRODUCTION

This chapter deals with the depth interpretation and exploration of the results and the findings. The results will be interpreted with respect to the main aim and research question.

The main aim of the research was to establish if energy management strategies can be deployed at the student accommodation to enforce energy efficiency which leads to cost-saving.

9.2 FINANCES AND BILLS

Based on the information from the residence supervisors/manager, Catsville residence can accommodate about 738 students each paying an average of R 34 589.50 per the academic year which translates to residence revenue of about R 25 527 051 annually. As seen in chapter 8, the total annual consumption of electricity is about 2 358 600 kWh which over the study period resulted in a R3 826 250.76 bill including the CoCT statutory service charges. This amount is about 15% of the revenue which excludes other overheads such as water and sanitation. According to (Stats-SA, 2020), the current (2020) inflation rate is 4.6% and the electricity is expected to increase to figures more than the inflation rate. As aforementioned, the increase in the tariffs since 2018 was an average of 8.5% which implies the electricity cost will almost double in 2025 (7 years since 2018), however, these rates cannot be predicted. Based on this, by the year 2025, the annual electricity cost at Catsville is predicted to be just under R8 million.

9.3 ELECTRICITY CONSUMPTION

The consumption patterns during the in-session show that the morning peak hours are between 06:00 am and 09:am (means the students are busy preparing for the day in Campus) and the evening peak is from 16:00 to 21:00 (which means the students are back from Campus and performing the evening chores), however, the off peaks hours (between 09:00 am and 15:00 as well as 21:00 to 06:00) are very close (slightly lower) to the peak which was an indicator that the energy used even though the students are expected to be on Campus or sleeping.

The recess patterns are also very similar to in-session patterns and the average consumption per hour during recess (90 kWh) is almost similar to that of on-session (100 kWh) but slightly lower.

The data recorded during hard-lockdown (as shown in section 5.2), where students were not residing in the residences and the universities were closed, shows that there was significant energy used even though the primary users are not available. This was confirming what section 5.1 and chapter 4 had already revealed.

The recess period at CPUT starts at the beginning of December, and according to the bills in chapter 8, the electricity consumed during the December month (December 2018) 137 000 kWh costing R 224,258.00, the preceding months of September, October and November consumption was 296 400 kWh (R 481,178.20), 263 400 kWh (R 427,858.26) and 196 800 kWh (R 320,020.97) respectively. This shows there was significant usage of electricity even during recess and this was not expected as there were no users in the residences at the time.

From this, it is evident that energy management strategies interventions must be implemented because chapter 5 and chapter 8 prove that there is a use of energy even when there are no occupants.

9.4 Energy Audit (Potential ENCONs)

The energy audit presented what are the users of energy in Catsville more especially in the student blocks and G-block was the focus.

Retrofitting in buildings is key to the energy inefficiency problems and can be applied to new and old buildings, it also raises important issues such as those of environment-friendly technologies which leads to building energy efficiency improvement, therefore, providing efficient lighting system and other energy-efficient equipment (Thovhakale, 2011)

Each student room is fitted with the CFL lamps ranging from 9W to 18W, the fittings are either double fitting or single fitting. It is highly recommended that there should be a standardised fitting across all the student rooms while monitoring if the illuminance levels are conforming with the standards.

Table 9.1: Comparison of different types of lighting

Parameter	Incandescent	Halogen	CFL	LED
Power Usage	60W	43W	13W	8.8W
Light Output Level	700 Lm	750 Lm	850 Lm	800 Lm
Life Span	2000 h	1000 h	10 000 h	15 000 h
Cost	Low	Medium	High	High

From the data in table 9.1 above, the already installed CFL are not entirely inefficient, however, according to (Tsuei et al., 2008) LEDs are more viable in terms of performance as their wattage is less and has a longer lifespan even though a little bit expensive. Considering that the complex has over a 1000 lamps fitted, LED lights could prove to be cost and energy-efficient in terms of its long life span and low wattage.

However, the LED lamps have the main disadvantage, according to the laboratory test performed by (Uddin et al., 2012), LED lamps compromise power quality by injecting the unwanted harmonics into the system which could overload the network unnecessarily.

In the audit analysed in Chapter 4, the lighting in the student rooms is not always switched OFF and this is the case for corridors and ablution areas which explains the constant usage of power even though the students are not in the residence as explained in chapter 5 and 8. According to (Thovhakale, 2011), light motion sensors are one of the cost-effective and energy-efficient semi-automated systems that can be installed. These sensors only activate the lamps when there is motion detected in a particular area.

The water heating is done through the use of a standard geyser with no heat preservation insulation which (Tangwe et al., 2015) states that they are the most inefficient popular and conventional modes of hot water production in South Africa. (Tangwe et al., 2015) suggested that the more energy-efficient Air Source Heat Pump (ASHP) is currently the new trend in the market. The ASHP heats the water to 55℃ which is the minimum threshold temperature to eliminate bacteria, the 55℃ is produced through ambient aero-thermal energy (60 to 70%) and electrical energy (30 to 40%), this could prove very cost-effective as it uses less electric energy (Tangwe et al., 2015).

9.5 Power Quality

9.5.1 Voltages

The voltage imbalances in the system were with the limits, however, the spikes that come with the powering of the circuits or when the power is restored after load-shedding could prove problematic. To combat this, (Schneider Electric, 2020) who are the electrical equipment manufacturer, prescribes the use of Surge Protection Devices (SPD) which are designed to protect the electrical network from over and under voltages.

9.5.2 Currents

Current imbalances do not have any limits but it is advised by literature to maintain the constancy between the phases, this is a bit of a concern as the average current drawn from the Red phase is slightly higher than the other two phases (Yellow and Blue) and Blue phase is lower than the rest. The problem with this case of imbalances in currents as stated by (Hughes, 2008) is that the neutral wire will tend to be loaded as it carries this excess current.

This problem can be solved by trying to load the blue phase should there be any future single-phase installations. Figure 9.1 below shows red phase at 22A, yellow at 10A and blue phase at only 4A, this shows the loading in the system where the red phase is carrying more than twice of the yellow phase and more than five times of the blue phase currents respectively.

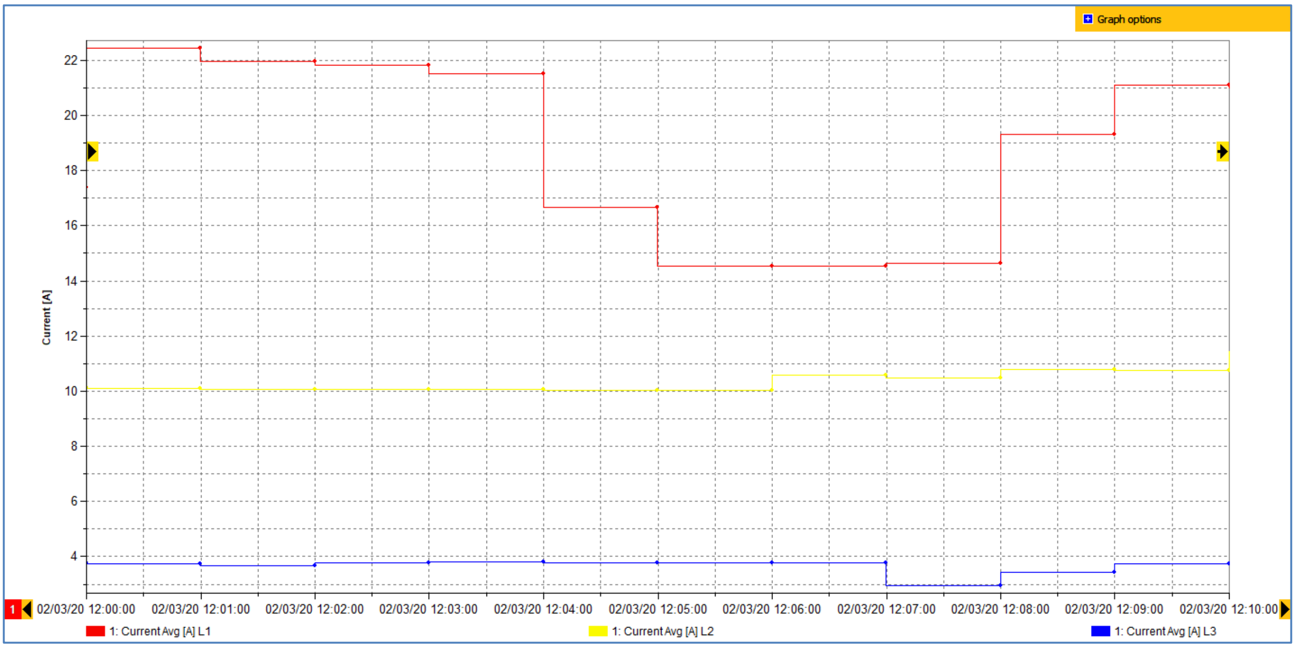

Figure 9.1: Typical Current imbalances

9.5.3 POWER FACTOR

The power factor is averaging at 0.8 lagging which is less than the recommended by (Eskom, 2020b) fact sheet on power factor, this is something to consider as according to Eskom, any consumer who is less than the 0.96 lagging may be subjected to a fine. However, the peak demand (kVA) is charged at the same rate as the normal consumption (kWh) as shown in figure 9.2 below. This can be reduced by embarking on the power factor correction schemes if deemed necessary.

Account details as at 20/12/2018	Account number 121452026
ELECTRICITY (Period 16/11/2018 to 12/12/2018 - 27 Days) (Actual reading) **At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815** **Meter no: 694509 / Consumption 137700.000 kWh / Daily average 5100.000 kWh**	
& Consumption charge: Commercial (Small Power User - High)	
(71700.000 kWh X R 1.4065)	100846.05
& Off peak (50kVA or more)	
(66000.000 kWh X R 1.4065)	92829.00
& Service charge	
(27 Days X R 49.3300)	1331.91
	195006.96

Figure 9.2: Typical CoCT electricity bill

9.5.4 FREQUENCY AND HARMONICS

Frequency and Harmonics were determined to be within the recommended average by the relevant standards.

9.6 STUDENT SURVEY

The student survey indicated that the students have a will to learn the basic energy-saving strategies and overall, they can be energy efficient if the system allows. The survey shows that most students are not clued up in terms of the electricity cost and this could contribute to them being energy inefficient as the survey also showed that the students are only concerned with saving electricity at home than at the residence.

The survey also showed that the students resort to alternative measures that could prove dangerous or risky if the university-provided facilities are not maintained regularly. In the case heating and cooking, if the stoves in the kitchens are not functional, students use their own electric stoves or use the electric bar heater if the supplied wall-mounted heaters are not functional; and this could prove dangerous as they are a fire risk mostly in the confined space like the student rooms. This calls for improvement in maintenance systems and procedures to ensure continuous operation of residence equipment.

9.7 GENERAL

The maintenance in the building as found through the energy audit was a concern. Measures need to be put into place such that the building's electrical systems can be maintained. The main issue with maintenance is the lack of the following:

1. **Maintenance Procedures:** This assists the electrician or contractor in terms of what is required when tackling a certain defect and also gives them guidance in terms of the electrical systems. This also applies to the contractors such that the integrity of the building's electrical systems can be maintained and also the work to be up to standard and offer consistency. Standards can be drafted in the maintenance procedures.
2. **Electrical Drawings:** The energy audit found that the buildings do not have electrical drawing, this makes it difficult for the electricians or contractors to complete their job with no issues. As seen during the metering analysis in terms of power quality in Chapter 6, other phases (mostly Blue phase) are loaded more than the others, having electrical drawing can solve this problem as the electrician/contractor will know which lines are loaded from the drawings and avoid adding more circuits to them.
3. **Planned Maintenance (preventative maintenance):** There is a need for routine maintenance on the systems to keep them in the working condition to avoid failure which in turn it's an inconvenience to the students. If students are inconvenienced will resort to risky and dangerous measures to get the required activities done as seen in chapter 8
4. **Maintenance Records:** During the audit, there were no maintenance records of any equipment, the records assist in keeping track of who was doing what and when such that the next person will know what are the changes into the system.
5. **Housekeeping:** Most electrical boards are not in good condition and are sometimes used as storage rooms, this is a hazard and needs to be corrected. Cleaning of the boards, putting safety signs and keeping the area around them clean and free of anything that isn't supposed to be there is strongly recommended.
6. **Locking:** The electrical systems where sometimes found unlocked, this can be a risk to those who are not electrically inclined, proper locking systems need to be put in place.

CHAPTER TEN

10 Conclusions and Recommendations

10.1 Introduction

This chapter presents the conclusion of the study, the main aim of the study was to determine if the energy management strategies can be applied to the student accommodations to effect energy efficiency therefore reduce costs. This chapter will form a conclusion in terms of whether the principal aim was fulfilled and also if the research questions were all answered. The objectives were set to achieve the aim as shown in table 10.1 below.

10.2 Objectives Achieved

Table 10.1 below establishes if the objectives of the study were all fulfilled and specifies which chapter answers to which objective.

Table 10.1: Objectives

Specific Objectives of the Study	Objective Achieved and Where
1. **Survey literature relating to the built environment energy optimisation focussing on:** a) **Energy consumption** b) **Energy efficiency** c) **Energy Audit** d) **Energy management** e) **Power Quality**	**Yes – Chapter 2** Chapter 2 investigated in depth the related topics to the principal aim of the study through credible sources.
2. **To investigate and analyse the energy consumption at the CPUT buildings (student accommodation) through:** a) **Energy Audit** b) **Data logging (obtaining the consumption profile through metering)**	**Yes – Chapter 4** Chapter 4 presented the results from the energy audit which determined energy-consuming equipment, as part of the audit, the energy metering was performed using a data logger (Fluke 1730 power analyser).

Specific Objectives of the Study	Objective Achieved and Where
3. **To establish a database of the historical energy consumption on CPUT through:** a) **Logged Data analyses** b) **Electricity Bills analyses**	**Yes – Chapter 5 and Chapter 7** From the data logged using the Fluke 1730 power analyser, the consumption profile was established and presented in chapter 5. The utility bills obtained from the municipality we used to perform the analysis of the electricity cost at the student accommodation and they were presented in chapter 7
4. **Investigate major energy users as well as causes of inefficiencies (if any) and therefore quantify their consumption patterns and identify trends where possible through** c) **Energy Audit results analyses** d) **The Student Survey Analyses**	**Yes – Chapter 9 and Chapter 8** Chapter 9 presented the discussions, in-depth analyses and conclusions based on the results from preceding chapters The student behaviour and knowledge regarding matters of energy and energy usage were presented in chapter 8
5. **Investigate the building's power quality and other related electrical issues.**	**Yes – Chapter 6** From the logged data using the Fluke 1730 power analyser, the power quality issues were also analysed to determine if they also contribute to the energy efficiency in the building
6. **Recommend the energy-saving opportunities and also make recommendations on any other energy-related issues identified**	**Yes – Chapter 10** Chapter 10 combined all the results and made the necessary recommendation on what must be done as the next step if the report was to be adopted.

10.3 RESEARCH QUESTIONS ANSWERED

In line with the principal aim, the following questions were asked:

1. **What are the major consumers of energy at student accommodation?**

   Based on the energy audit in chapter 4 and the student survey in chapter 8, the research identified the typical and major consumers of the electricity are activities such as lighting, cooking and bathing/showering.

   The reason these activities are major users of electricity can be attributed to lack of awareness and education to students regarding matters related to energy efficiency or energy savings as analysed in chapter 8.

   The second reason is lack of energy management systems in the buildings (student accommodation in this case), these systems could assist in making the unused equipment to be switched off automatically such as motion sensors for controlling the lighting as discussed in chapter 4, 5 and 7.

2. **Can the implementation of energy management programs at the South African Higher Institutions of learning contribute to minimising energy consumption?**

   The study determined that the buildings are inefficient because of their age, from this it was determined that the energy management strategies will assist in minimising energy consumption. Chapter 4 established that many energy conservation measures can be put in place such as retrofitting of lighting, geysers, showerheads, etc.

3. **Are there any energy conservation measures in place in the South African Higher Institutions of learning?**

   NO, based on the audit, there were no energy conservation measures in place at the audited building. Chapter 5 also revealed, through energy consumption patterns, that electricity is used even though the residence is unoccupied.

4. **How does an increase in the electricity cost impact on the South African Higher Institutions of learning's fiscal?**

   The audited building resulted that the cost of electricity is just under R4 million per annum and this is about 15% of the residence's annual revenue, these prices will increase while the revenue is not increasing because of the recent student uprising and this will affect the operations of the university in a long run

10.4 RECOMMENDATIONS

Specifically, for CPUT, the following components of energy management/energy efficiency are recommended:

1. Use this study as the basis of embarking on the energy efficiency research across the university buildings to establish records that can be used for future research work.
2. Perform a detailed energy audit in the CPUT buildings to determine where energy can be preserved
    a. The audit will ensure the load reduction measures, lighting retrofitting into efficient lighting, installation of motions sensors especially on the student residences and other areas that will be determined by the audit
    b. Install the internal meters that will confirm the bills from the CoCT, this will ensure that the university has its own energy consumption and bills monitoring systems in place
    c. Installation of the SPDs into the system to prevent damage from overvoltage due to load shedding and other factors that contribute to overvoltage.
    d. Thoroughly investigate the power quality issues established in chapter 6 to ensure their reduction if possible and economically feasible.
    e. After the implementation of the energy management systems and strategies, the consumption profiles must be established in conjunction with the electricity bill to make a clear determination of the effectiveness of the strategies.
    f. If the LED lighting technology is deployed in attempts to improve the lighting efficiency, the harmonics analysis must be performed after their installations to ensure that the harmonic levels are still within the prescribed limits.
3. The university to implement the energy policy that will ensure the energy efficiency across all the university buildings
    a. Establish an energy management committee that will oversee mater relate to energy management
4. Improve maintenance across all the buildings by
    a. Developing maintenance procedures, preventative maintenance plan schedules
    b. Acquire more semi-skilled or skilled workers to fast track the maintenance backlogs.
    c. Improve on safety standards

5. Implement the link between the research centres and the facilities management to ensure continuous research on the university's buildings which will assist in making them energy efficient and ensure the advances in technologies in the institution's buildings.
    a. Subsequent to this, a fund must be created that will ensure that all the energy management interventions are self-sustainable
6. Embark on energy efficiency educational campaigns to alert the users (students – this could include staff) on the importance of energy efficiency. According to (Maistry et al., 2012) this will help in the behavioural approach.
    a. Most of the users do not know the cost involved with the electricity, therefore the users need to be taught on this

Based on this study, the following are proposed for future research work:

1. A study on the feasibility of renewable energy (rooftop solar, wind turbines etc.) at the CPUT buildings.
2. An Energy Efficiency study at the CPUT's Main Campuses
3. Study the effects of power cuts (load-shedding) on the electrical systems in the university buildings.
4. The severity of harmonics caused by the usage of LED technology lights in the built environment
5. Study in the effects of Installation of sub-metering to monitor the performance of the building and building sections within the university

10.5 CONCLUSION

This document presented a pilot study that will form the bases for future research work on energy efficiency assessment at the institutions of higher learning (including CPUT) student accommodations.

The presented study mainly focussed on the energy management at the CPUT's student accommodation through a preliminary energy audit, data logging (using a three-phase energy logger supplied by Fluke), electricity bill analysis and occupants(student) survey to fulfil the principal aim which was to establish if the energy management strategies can be applied to the student accommodations to effect the cost and energy efficiency.

Based on the results, the study found the gap and determined that the student accommodations at CPUT need energy management interventions.

The study also shows that the energy efficiency at the residences is not a priority at the moment and this requires the management to act swiftly as this can be seen as the cost-saving opportunity in this time where the country's economy is ailing while energy crises (load-shedding) and global warming are still on the horizon.

The student accommodations are the forgotten users of energy which if not taken care of in the immediate will result in unwanted cost wastage.

THE END

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APPENDICES

12 List of Appendices

12.1 Appendix A: Student Questionnaire

CPUT Residence Student Questionnaire

1. Thank you for participating in the questionnaire
2. This questionnaire is about the use of electricity in your residence
3. You will not be required to enter your personal details
4. Read the questionnaire and select the option that best fits you.
5. There is no wrong or right answer, just be honest.
6. Your answers will remain anonymous
7. Your input is highly valued
8. Your cooperation is greatly appreciated.

* Required

1. Which CPUT residence do you stay at? *

____

2. I am concerned about saving electricity at home

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

3. I am concerned about saving electricity at my residence

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

1 2 3 4 5

Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

4. I feel I have a responsibility to save electricity

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

	1	2	3	4	5	
Strong Disagree	◯	◯	◯	◯	◯	Strong Agree

5. I want to know more about how to save electricity

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

	1	2	3	4	5	
Strong Disagree	◯	◯	◯	◯	◯	Strong Agree

6. Awareness Campaigns will encourage students to use less electricity

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

	1	2	3	4	5	
Strong Disagree	◯	◯	◯	◯	◯	Strong Agree

7. I think there are opportunities to save electricity at my residence.

1- Strongly Disagree 2- Disagree 3- Neutral 4- Agree 5- Strongly Agree

Mark only one oval.

	1	2	3	4	5	

Strong Disagree ⬭ ⬭ ⬭ ⬭ ⬭ Strong Agree

8. What do you understand about the word energy efficiency?

Mark only one oval.

- Reducing energy demand
- Energy Supply
- Equipment life
- Cost efficiency Saving
- electricity Other:
- ______________________

9. What would you estimate the annual electricity bill in your residence to be?

Mark only one oval.

- Less R200 000
- Between R200 000 and R300 000
- Between R300 000 and R400 000 Between R400
- 000 and R500 000
- Above R500 000
- I don't know

10. Which of these electricity appliances do you have in your room

If any of the appliance in your room is not listed, select the "other" option and specify

Check all that apply.

- [ ] Laptop (Including charger)
- [ ] Computer
- [ ] Refrigirator
- [ ] Stove
- [ ] Kettle
- [ ] Electric Heater
- [ ] Study Lamp
- [ ] Microwave
- [ ] Television
- [ ] Radio
- [ ] Electric Hairdryer
- [ ] Electric Hair Clipper
- [ ] Lights
- [ ] Bread toaster
- [ ] Blender
- [ ] Clothes Iron
- [ ] Electric Fan
- [ ] Electrical Fan heater
- [ ] Electric Hair Straightner or Curler
- [ ] Electric Shaver
- [ ] Cellphone charger

Other: [ ] ______________________

11. Which of these appliances do you use the most in your room?

Select the top 7

Check all that apply.

- [ ] Laptop (Including charger)
- [ ] Computer
- [ ] Refrigirator
- [ ] Stove
- [ ] Kettle
- [ ] Electric Heater
- [ ] Study Lamp
- [ ] Microwave
- [ ] Television
- [ ] Radio
- [ ] Electric Hairdryer
- [ ] Electric Hair Clipper
- [ ] Lights
- [ ] Bread toaster
- [ ] Blender
- [ ] Clothes Iron
- [ ] Electric Fan
- [ ] Electrical Fan heater
- [ ] Electric Hair Straightner or Curler
- [ ] Electric Shaver
- [ ] Cellphone charger

Other: [ ] ____________________

12. In your opinion, which of these appliances are the major users of electricity in your room

Select the top 7

Check all that apply.

- ☐ Laptop (Including charger)
- ☐ Computer
- ☐ Refrigirator
- ☐ Stove
- ☐ Kettle
- ☐ Electric Heater
- ☐ Study Lamp
- ☐ Microwave
- ☐ Television
- ☐ Radio
- ☐ Electric Hairdryer
- ☐ Electric Hair Clipper
- ☐ Lights
- ☐ Bread toaster
- ☐ Blender
- ☐ Clothes Iron
- ☐ Electric Fan
- ☐ Electrical Fan heater
- ☐ Electric Hair Straightner or Curler
- ☐ Electric Shaver
- ☐ Cellphone charger

Other: ☐ ______________________________

13. In your opinion, which of the following are the major users of electricity in your residence

Select the top 3

Check all that apply.

- ☐ Lighting
- ☐ Cooking
- ☐ Bathing/shower
- ☐ Space Heating
- ☐ Space cooling
- ☐ TV's and/or related devices
- ☐ Laundry (Electric washing machines and dryers)

Other: ☐ ______________________________

14. Do you think it is necessary to switch ON lights in the corridors during the day

Mark only one oval.

- Yes, it is dark when they are off
- No, there is enough light during the day
- I don't know Other:
-

15. Do you think it will help save electricity if the motion sensors are installed to control the lighting in the corridors (i.e. light will only go on when someone walks in the corridor) *Mark only one oval.*

- Yes
- No
- I don't know
- Other:

16. How many hours in the day (on average) is the light in your room switched on

Mark only one oval.

- less than 5 hours a day between 5 to
- 10 hours a day 11 hours to 15 hours a
- day
- 16 hours to 23 hours a day
- I never switch it off
- I never switch it on

17. How often do you switch off the lights when you leave your room?

1- Never 2- Rarely 3- Sometimes 4- Often*Mark only one oval.*

1 2 3 4

Never	⬭	⬭	⬭	⬭	Often

18. How often do you switch off the lights in your room when you necessarily don't require them (during the day or when sleeping)?

1- Never 2- Rarely 3- Sometimes 4- Often*Mark only one oval.*

	1	2	3	4	
Never	⬭	⬭	⬭	⬭	Often

19. How often do you switch off the unnecessary plugs when you leave your room?

1- Never 2- Rarely 3- Sometimes 4- Often*Mark only one oval.*

	1	2	3	4	5	
Never	⬭	⬭	⬭	⬭	⬭	Often

20. What do you use for heating your room (space heating) during the winter?

Mark only one oval.

- ⬭ Heater
- ⬭ Stove
- ⬭ Air Conditioner
- ⬭ Natural Heating (Closing windows and doors) Other:
- ⬭ ______________________

21. How often do you use your space heating equipment (e.g: heater, stove, air conditioner, etc.) during winter or cold weather conditions

1- Never 2- Rarely 3- Sometimes 4- Often*Mark only one oval.*

	1	2	3	4	5	
Never	⬭	⬭	⬭	⬭	⬭	Often

22. What do you use for cooling your room during summer

Mark only one oval.

- Electric fan
- Air Conditioner
- Natural Cooling (E.g opening windows and/or door) Other:
- ______________________

23. How often do you use your space cooling equipment (e.g: electric fan, air conditioner, etc.) during summer or warm/hot weather conditions

1- Never 2- Rarely 3- Sometimes 4- Often*Mark only one oval.*

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Often

24. How often do you cook in a day?

Mark only one oval. once a day

- Twice a day Three times a
- day more than three times
- I don't cook, I only eat takeaways
- Other:
- ______________________
- 25. What do you use for water heating

Mark only one oval.

- Electric Kettle
- Electric hydro-boiler
- Both
- Other:

26. How many times do you do your laundry (at the laundry room using the electric washing machine and/or electric clothing dryer)

Select 1 option

Mark only one oval.

- Everyday
- Every week
- Twice a week
- Once a month
- Every fortnight
- Sometimes when my clothes are dirty
- I always hand wash my clothes
- I sometimes use the laundry machines and sometimes I hand wash my clothes
- Other:

27. How many times do you take a bath/shower

Mark only one oval.

- Onces a day
- Twice a day
- Three times a day
- Never, I use the waskom (washing basin)
- It depends if I have some to attend outside my residence
- It depends on the day of the week Other:
-

12.2 APPENDIX B : TYPICAL CITY OF CAPE TOWN ELECTRICITY BILL

Page 1 of 2

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

Civic Centre
12 Hertzog Boulevard 8001
PO Box 655 Cape Town 8000
VAT registration number
4500193497

Tax invoice number	180006680067
Customer VAT registration number	
Account number	121452026
Distribution code	
Business partner number	1001033082

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY
PO BOX 1906
BELLVILLE
7535

Computer generated copy tax invoice

Tel: 086 010 3089 - Fax: 086 201 1017
Tel: International calls +27 21 401 4701
E-mail : accounts@capetown.gov.za
Correspondence: Director : Revenue, P O Box 655, Cape Town 8000
Web address:www.capetown.gov.za

Account summary as at 23/04/2018 **Due date 18/05/2018**

At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815

Previous account balance		217186.71
Less payments (07/04/2018)	Thank you	217186.71-
(a)		**0.00**
Latest account - see overleaf		266712.50
Current amount due (b)	**Payable by 18/05/2018**	**266712.50**
	Total (a) + (b)	**266712.50**
Total (a) + (b) above	266712.50	
Total liability	**266712.50**	

THINK WATER
CARE A LITTLE. SAVE A LOT.
www.capetown.gov.za/thinkwater

Current charges totalling R 266712.50 will be debited from your bank account.

Please note:

1. Payment options

(a) Debit orders: Call 0860 103 089 or visit a Customer Service Centre.(b) Internet payments: Visit www.Easypay.co.za or www.payCity.co.za.

(c) Electronic payments (EFT): Select the City of Cape Town as a bank-listed beneficiary on your bank's website. Use only your nine-digit municipal account number as reference

(d) Direct deposit at Nedbank: Please present your account number 121452026 to the bank teller. (e) Cash, debit card, credit card and other: Please present your account to the cashier.

2. Where the City incurs bank costs on any mode of payment, the City will recover such cost on the portion of the amount above R7000.00 per transaction per account number. The City absorbs such costs in respect of a single payment of R7000.00 and below.

3. Interest will be charged on all amounts still outstanding after the due date.

4. You may not withhold payment, even if you have submitted a query to the City concerning this account.

5. Failure to pay could result in;

(a) The City recovering debt overdue on the purchasing of pre-paid electricity,

(b) your water and/or electricity supply being disconnected/restricted. Immediate reconnection of the supply after payment cannot be guaranteed.

A disconnection fee will be charged and your deposit amount might be increased.

Pay points: City of Cape Town cash offices or the vendors below:

NEDBANK, Post Office, SHOPRITE, Pick n Pay, Checkers, EasyPay, WOOLWORTHS, payCity, W, SPAR, PEP

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

Account number	**121452026**
Total due if not paid in cash	266712.50
Amount due if paid in cash	266712.50
Rounded down amount carried forward to next invoice	0.00

>>>>> 915551214520269

Account details as at 23/04/2018	Account number	121452026

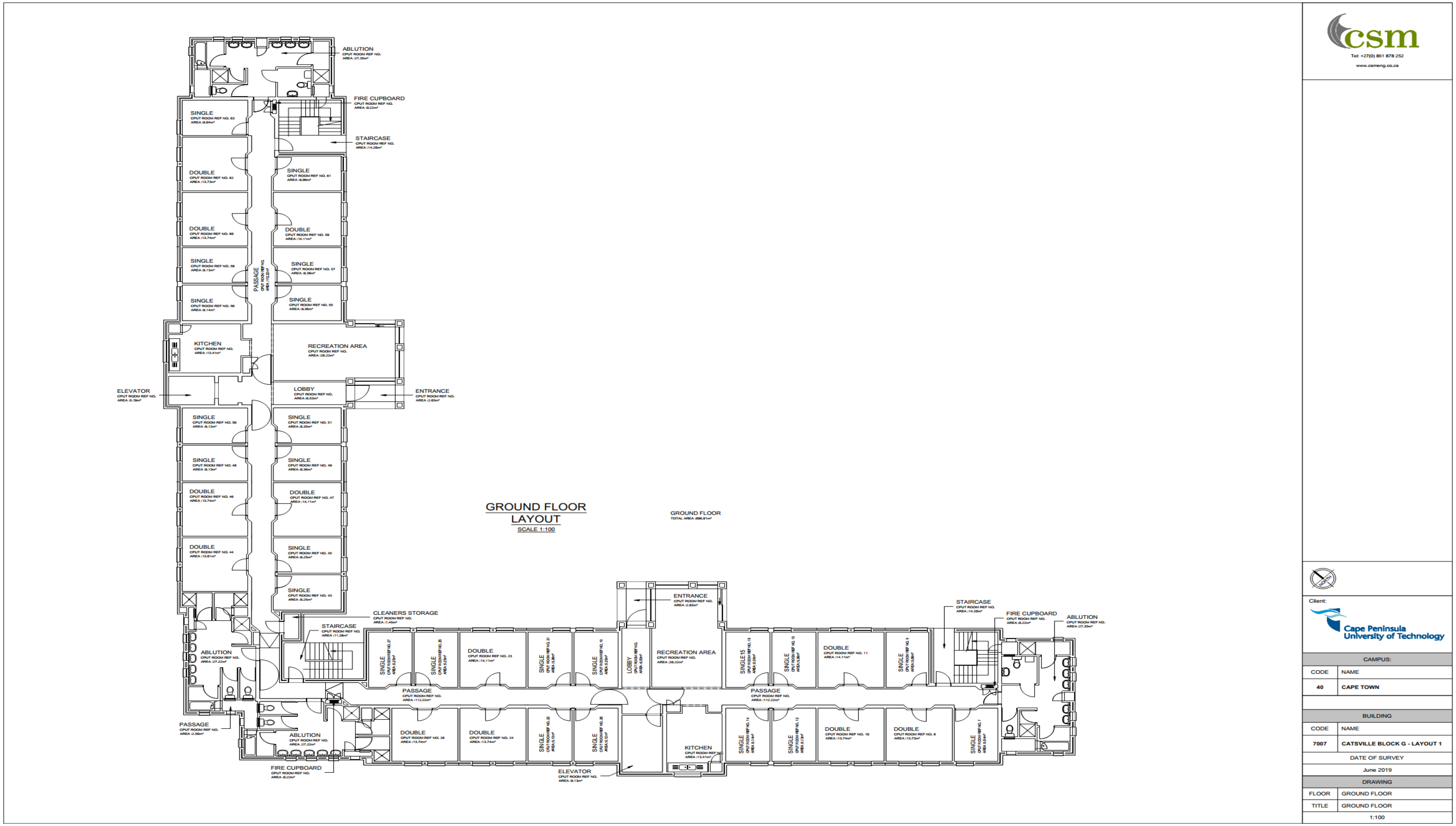
ELECTRICITY (Period 14/03/2018 to 12/04/2018 - 30 Days) (Actual reading)
At CAPE TECH RESIDENCE, 69 BROWNING ROAD, SALT RIVER / Erf 27815
Meter no: 694509 / Consumption 178200.000 kWh / Daily average 5940.000 kWh

* From 14/03/2018 : Consumption charge: Commercial (Small Power User - High)	
(54300.000 kWh X R 1.3006)	70622.58
& From 01/04/2018 : Consumption charge: Commercial (Small Power User - High)	
(36600.000 kWh X R 1.3006)	47601.96
* Off peak (50kVA or more)	
(52200.000 kWh X R 1.3006)	67891.32
& From 01/04/2018 : Off peak (50kVA or more)	
(35100.000 kWh X R 1.3006)	45651.06
* From 14/03/2018 : Service charge	
(18 Days X R 45.6200)	821.16
& From 01/04/2018 : Service charge	
(12 Days X R 45.6200)	547.44
	233135.52

Add 14% VAT on amounts marked with * above	**19506.91**
Add 15% VAT on amounts marked with & above	**14070.07**
Current account: Total due	**266712.50**

Meter details		**Previous reading**		**New reading**		**Units used**
ELECTRICITY 694509	002	73720.000kWh	(Actual)	74023.000kWh	(Actual)	303.000(X300)kW
ELECTRICITY 694509	001	63357.000kWh	(Actual)	63648.000kWh	(Actual)	291.000(X300)kW

12.3 Appendix C: Catville Complex G-Block Ground Floor Layout



12.4 APPENDIX D: BUILDING INFORMATION SHEET

BUILDING INFORMATION						
Building Description: Building Name: Address: Contact Person: Telephone: Date: Completed By:			Year FirstOccupied: Year Refurbished: Number of Floors Underground: Above Ground: Gross Floor Area: Net Floor Area:			
USE OF BUILDING Average Daily Occupation Hours In Use Electrical/Mechanical Weekdays to Saturdays to Sundays to Provision after hours:			Use Offices □ Shops □ Laboratory □ Residence □ Lectures □			
Physical Properties			**Mechanical/Electrical Systems**			
Windows:% of Walls	N/NE %E/SE %		A/C Type	Room Units	□	
	S/SW %W/NW %			Packaged Units	□	
	Can be opened (Y/N)?			Central System VAV	□	
Glass type: Regular □ Double □	Reflect Absorb □			Dual Duct System	□	
Shadow Factor:				Fan Coil Unit	□	
Type of Shading	Overhang above Window	□		Induction Unit	□	
	Fins next to window	□		Other	□	
	Outside Shading	□				
	Blinds Inside	□	Lighting Type:		Fluorescent	□
	Outside Glass Panel	□	Lamps per fitting:		Incandescent	□
	Other	□	Lamp Length:		Other	□
External Wall	Asbestos or Steel	□				
	25 mm Insulation	□				
	50 mm Insulation	□	Total Installed Capacity			
	Concrete	□	Lighting :		Cooling:	
	Brick	□	Transformer:		Heating:	
	25 mm air space	□				
	Other	□	Temperature Required Summer	______ to ______ °C		
External Wall Thickness: mm Colour:			Winter	______ to ______ °C		
Internal Wall	None	□	Temperature Measured Summer	______ to ______ °C		
	Light Weight	□	Winter	______ to ______ °C		
	Partitions	□	Lighting Required		Lux	
	Brick	□	Measured		Lux	
Thermal Mass Of Building	Light □ Medium □ Heavy □		Comments			

Previous Energy Management Activities:

Has Energy Audit Been Completed: When: By Whom:

Were Energy Management Activities Implemented: When: By Whom

Description:

Energy Management System in Use: When

Person Responsible:

12.5 APPENDIX E: WALK THROUGH AUDIT SHEET

WALK THROUGH AUDIT SHEET 1							
Category	**Situation**	**Specific Problem**					**Description/Remarks**
		Leakage	**Isolation**	**Damage**	**Dirt**	**Safety**	
Building Internal Climate							
Air Circulation System							

WALK THROUGH AUDIT SHEET 2							
Category	**Situation**	**Specific Problem**					**Description/Remarks**
		Leakage	**Isolation**	**Damage**	**Dirt**	**Safety**	
Cooling							
Heating and Water							

WALK THROUGH AUDIT SHEET 3 - LIGHTING							
Situation	**Lighting at Working Level (Lux)**		**Specific Problem**				**Description/Remarks**
	Measured	**Required**	**Diffuser Dirty or Discoloured**	**Tubes inoperative**	**Lights on in unoccupied areas**	**Lights on after hours**	