DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

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CASE STUDY OF ENERGY UTILIZATION/MANAGEMENT AT THE NCCRC

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Project report submitted in partial fulfillment for the Degree of Masters of Science in Energy Management at the Department of Mechanical and Manufacturing Engineering, University of Nairobi

DECLARATION

I declare that this work has not been previously submitted, and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the study report has no material previously published or written by another person except where due reference is made in the report itself.

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APPROVAL

The project report has been submitted with our approval as the university supervisors.

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Firstly, I thank God for the provision of good health through the entire period of my study at University of Nairobi.

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ABSTRACT

Energy demand has been escalating mainly because of the growing population and increasing standards of living for many. However, consumers have not used energy efficiently due to either lack of energy management principles or negligence. High consumption or energy wastage has been linked to climate change because of CO_2 emissions. This project report focused on energy assessment and management at the National Climate Change Resource Centre facility to recommend energy-saving measures for significant energy savings and a decrease in environmental impact due to CO_2 emissions. This study further examined sources of energy and established that the facility has a hybrid system composed of KPLC utility, standby generator, PV solar system and biogas digester. It was determined that only two sources of energy are currently utilized: KPLC utility company as a primary source and 50kVA standby generator to take over in case of the primary source outage. From the findings, several energy-saving opportunities were identified that could be implemented. Economic evaluations were done to ensure the implementation of these saving measures is viable to produce the best results. The simple payback period calculations established that this could be achieved at a maximum of 2.5 years, while the potential maximum carbon saved can be expected to be 3.4 tons/year. Finally, the energy-saving opportunities of Ksh 2,501,500.00 investment were recommended that could result in an annual cost saving of Ksh 979,291.00 at the NCCRC facility.

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LIST OF ABBREVIATIONS

KPLC	Kenya Power & Lighting Company Ltd
kVA	kilo Volt Amperes
KSH	Kenya Shillings
NCCRC	National Climate Change Resource Center
GHG	Greenhouse Gases

CHAPTER 1: INTRODUCTION

1.1 National Climate Change Resources Center (NCCRC)

National Climate Change Resources Center (NCCRC) located off Ngong Road, is a government-owned institution in the Ministry of Environment and Natural Resources (MENR). It provides public awareness on climate change and related pertinent issues to different sectors such as agriculture and water resource management. The centre has a specialized library with digital and physical climate change resources, training rooms installed with teleconferencing, webinar facilities and exhibition space to display climate-smart technologies and innovations.

This project report focuses on energy assessment and management at the facility, whereby it establishes the sources of energy used at NCCRC.

1.2 Background Information

One of the inputs for the economic development of every organization is energy. Energy use has recently increased rapidly across the continents due to increase in population and improved living standards. On the other hand, high consumption of energy increases energy bills as well as being detrimental to the environment due to greenhouse gases (GHG) emissions. Some factors affect the energy consumption of buildings: impact of the occupants, energy used by ventilation systems, heat loss from conduction through the building envelope, and occupants attempting to prevent the resulting draft. One of the ways of achieving significant energy saving is to improve the airtightness of the building envelope. Excellent means of reducing energy consumption, however, is to encourage the occupants to save energy. The climate change resulting from GHG emissions has drawn the attention of various agencies and organization to come up with tools to minimize its effects [1]. One of the tools to curb these effects is energy-auditing programmes that have effective energy conservation measures if implemented correctly.

The energy audit is an essential exercise for managing energy consumption. It attempts to balance the total energy inputs with its use, hence serves to identify all the energy streams in a facility [2]. The energy audit is defined as an inspection, survey and analysis of energy flow for energy conservation in industry and suggesting a process to reduce the amount of energy input into the system without negatively affecting the output [3]. Kenya, like any other developing country, has recently adopted energy audit scheme; the Energy Regulatory Commission is mandated to offer certificates of expertise to carry energy assessments in every commercial or residential building.

1.3 Condition of the NCCRC Facility

The observation made in November 2017 showed that the main facility load consists of the lighting system, ICT equipment and air conditioning units. Table 1.1 contains the inventory of the loads at the facility.

The facility has installed four sources of energy: utility grid (KPLC), solar PV systems, biogas digester and 50kVA Cummins generator. The current situation is that the PV system and biogas digester are not utilized. Only KPLC and generator energy sources are in use, but there is negligence on the part of the occupants in most cases. For example, there is a tendency to leave lights on all day, even when there is sufficient natural lighting in most sections of the facility.

Table 1. 1: Total quantities of the loads at the facility

S/No	Type	Qnty (Q)	Rating (W)
1	T8 4ft fluorescent tube	77	58
2	T8 2ft fluorescent tube	128	30
3	B22 CFL	25	13
4	2D CFL	23	16
5	Led bulb	4	9
6	B22 CFL(Security lights)	25	13
7	LG split room AC model USUH1865NW0	6	1880
8	Water dispenser	5	550
9	Water pump	2	550
10	APC 560VA UPS	1	400
11	Computers	39	100
12	Hp laser jet printers	8	35
13	Other printer	1	350
14	Scanner	1	600
15	Television set	1	140
16	APC 15VA UPS	1	9000
17	Refrigerator	2	100

1.4 Problem Statement

NCCRC currently utilizes two energy sources; a primary source from KPLC utility provider and secondary energy from a standby generator. The primary energy source contributes most of the energy used at the facility.

Table 1.1 shows that there was a continuous increase in monthly energy consumption between 2015 and 2018 with the monthly consumption increasing from 414.1kWh in 2015 to 1,273.15kWh in 2018. It is also noted that the energy cost per unit of consumption also increased in the period. Therefore, there is a need to introduce conservation measures to control escalating energy consumption.

Table 1. 2: Energy consumed at NCCRC

Time	Total Units (kWh)	Incurred Cost (Ksh)	Usage per month (kWh)	Cost/Unit (Ksh/kWh)
11/6/2015 to 16/10/2015	1,726.80	32,010	414.10	18.54
26/1/2016 to 12/12/2016	9,786.30	189,000	914.61	19.31
27/1/2017 to 24/11/2017	10,487.50	213,500	1,059.34	20.36
9/1/2018 to 8/3/2018	2,546.30	56,000	1,273.15	21.99

1.5 Justification

Electricity is a significant necessity in institutions and organizations for effective delivery of their functions. Typically, 70% of all energy consumed in a typical office goes to lighting, heating and cooling, and is expected to rise due to additional equipment/appliances [4]. There is a need to consider implementing energy-saving measures by purchasing energy-efficient appliances and improving interior building design.

Some new technologies, such as smart control systems can automatically control the lighting system. The implementation of such techniques is useful in situations where occupants tend to forget to turn off electricity when not required.

1.6 Objectives

1.6.1 The main objective of the study was to carry out an assessment of energy management at NCCRC with a view of recommending measures for significant reduction of energy consumption and cost.

1.6.2 Specific Objectives of the Study

a) Document energy usage at the facility

b) Identify potential energy-saving measures and opportunities at the facility

1.7 Scope

The study focused on energy assessment at the National Climate Change and Recourse Center (NCCRC) premises. It relied on nominal inventory data wattage, historical data obtained from the power utility company KPLC and real-time measurements. The data collected was used to evaluate the energy consumption trend and hence recommend energy-saving measures.

1.8 Hypothesis

The proposed energy conservation measures leading to a full implementation could result in reducing energy wastage. Consequently could reduce greenhouse gases (GHG) emissions leading to cost-saving at the National Climate Change and Resource Center (NCCRC) facility.

CHAPTER 2: LITERATURE REVIEW

2.1 Energy Assessment and Management

The principle of an energy assessment is energy audit in other words, and it merely means a systematic study to identify how energy is used in a building. The energy-saving opportunities are identified at the end of this exercise. On the other hand, energy management is an accurate and effective use of energy to maximize profits and enhance competitive positions [5]. Energy management is a tool used for reducing the cost of energy used by an institution.

Management of energy had not been taken seriously for quite some time until the early 1980s when the United Kingdom developed the first monitoring and targeting program [6]. Since then, energy assessment and management have become mandatory in both commercial and residential buildings. Governments have passed policies that ensure there is a secure supply of energy for better economic growth [7]. Also, climate change has been linked to high-energy usage, thus, strengthening the implementation of energy management policies in every organization or building. Importance of energy management is the adoption of good policies, total commitment and adoption of suitable technologies [8].

2.2 Energy Usage

Energy usage has been increasing due to some factors such as lifestyle standards and economic improvement. Recently, people have been purchasing several electronic gadgets for their household use. Again, there has been an expansion of offices and commercial buildings hence increasing energy consumption daily. Studies also show that 40% of energy is consumed in buildings [9]. Again, about 90% of our time is spent in the office or at home, hence accounting for a large percentage of a country's total energy consumption [10].

2.3 Smart Building Technology

Research carried out by the European Union indicated that smart and sustainable energy strategies that drive the economy would be realized by 2020 [11]. The benefits of these strategies that could contribute to energy efficiency include reduced greenhouse gases, lower energy bills, increased energy security and a deferred need to invest in new infrastructure [12].

It is assumed that energy-saving opportunities target achieving 20% of energy supply from renewable sources that will drastically reduce GHG by 20% [9]. One of the best ways of accomplishing this is to consider the energy mix in buildings by implementing technologies such as PV solar systems and biogas digesters. The study done in Western Australia determined that using 90% renewable energy can reduce GHG up to around 95% [13]. Hence, smart integration of renewable energy sources, for example, biogas and PV solar systems in a building improves overall efficiency and balances the annual energy output [14]. Biogas digesters projects grow the energy mix in an urban setup since they offer a better option to curb increasing energy demand [15].

2.4 History of Energy Assessment

Since the inception of energy management policies, there has been much progress, especially in the developed countries in controlling energy use in both residential and commercial sectors. The world largest economies, for instance, the United States, United Kingdom and China, have encouraged energy efficiency technologies through highly effective building codes [16]. The United States of America energy policy Act 2005, for example, requires that all existing and new state buildings should make sure energy consumption is reduced by 30% in 2015 as compared with previous years. It is necessary that new constructions must achieve efficiencies of 30% or better [16]. Cities such as Los Angeles and San Francisco in California State have made energy efficiency measures compulsory in existing and newly built houses [17]. The United Kingdom began its energy assessments in 1976, whereby their crucial objective was to research on energy saving potential on the buildings and to carry out building renovation [18]. Since that period, there have been achievements in the energy sector by reducing the wastage of energy in many buildings. The People's Republic of China has decentralized energy assessment exercises to its regions, whereby new energy-saving technologies have been used to save 8% to 12 % of energy [18].

The Government of Kenya enacted the Energy Act 2006 intending to improve energy efficiency in government and private institutions. This Act requires every organization to carry out energy assessments, implement plans and measures for energy savings [19]. The process has shown tremendous progress, especially in the government institutions, whereby plenty of sensitization has been carried out.

Kenya Association of Manufacturers (KAM) provides energy and conservation programs that help companies and institutions identify energy wastage, decide and implement saving potential and measures. [20].

2.5 Expectation

This study was able to identify and recommend the energy-saving conservation measures that could benefit the National Climate Change and Resources centre (NCCRC). The recommendations included the best management systems and efficient technologies adoption. The implementation of these technologies would lower energy wastage by at least 15% at the facility.

CHAPTER 3: METHODOLOGY

3.1 Research Procedure

The energy evaluation in this report was based on both descriptive and historical research using past data and real-time measurements. The descriptive analysis involves the collection of data from observation, case study review and survey to answer questions or come up with recommendations [21]. Historical research, on the other hand, involves data collection, verification and synthesized evidence from the past to establish the facts that defend or refute a hypothesis.

The overall research design specified the following:

a) Techniques of data collection

b) Collection of data

c) Data analysis

d) Determining recommendations

3.2 Data collection

Data collection included observation of records and real-time measurements. During the observation walk through survey exercises, both primary and secondary data were collected. The measurements of power consumption were conducted at the main electricity supply point. The data collection was categorized as follows;-

3.2.1 Walk through survey

One-day walk through surveys of the entire NCCRC facility were carried out in November 2017 and February 2018. One of the walk through surveys was done to identify the required equipment for data collection and to assess the current level of operation and practice within the facility. This exercise also identified the major sources of energy and consumers.

The following was observed;-

i. Sources of energy

- At the facility, a solar PV system, and a small biogas digester have been installed to provide alternative energy.
- There are three main sources of energy sources currently utilized at the facility; utility grid (KPLC), 50kVA Cummins generator which had run a total 128hrs 33min by 16th February 2018 and socket tapped PV solar energy utilized by only a few people, although its reliability is not yet fully confirmed.

ii. General loads and facility envelope

- Main facility load comprises the lighting system, ICT equipment and air conditioning units as summarized in Table 1.1.
- There is no air conditioning for most offices and rooms. AC is installed in data centers and server rooms.
- There are only two uninterruptable power supplies (UPS) of 400W and 9kW capacities within the facility to store and provide clean power for use. These are used only in supplying power to sensitive equipment within the facility.
- There is direct heating of most of the offices by high solar radiation at 60% of their daily operational hours.

iii. Behavioral issues of the users

- Natural light is tapped in some section of the offices especially to reduce electrical lighting load. This confirms that very few occupants are aware of energy conservation measures such as switching off lights during the day. There was a tendency to leave lights on all day even when there was sufficient natural light in most sections of the facility.

3.2.2 Documentation and Records

NCCRC facility has a hybrid energy system that is made up of renewable and non-renewable energy. One way of analyzing energy, is reviewing the records kept in the past to track the energy used from all the sources of energy.

The prepaid meter number installed at the site was used to inquire the consumption demand data from the power utility company, (see Appendix 2A). There is no data at the site to check the amount of diesel used on a daily basis within the facility. Again, there are no records as to why other energy sources such as PV solar and biogas digester are not utilized fully at the facility.

3.2.3 Measurements

The real time measurements exercise was done by hiring measuring equipment mentioned in Appendix 3. It was agreed to provide data for both working and non-working days. These real time measurements were to affirm the trends of energy consumption at the facility. Parameters such as dates of collection, minimum, maximum and average values for voltages, currents, kW and kVA were used to provide an insight to determine the consumption characteristics at the facility.

3.3 Tools and Equipment Used for Measurements at NCCRC

Assessment at the facility was also carried out using tools and equipment to record the real time measurements. Table 3.1 presents some of the tools and equipment employed during the exercise (see Appendix 3 for more detail).

Table 3. 1: List of measuring equipment

Equipment	Model	Comments
Power Analyzer	C.A 8333	Measure power quality on single and three phase networks
Clamp Meter	AC/DC Am PROVA-11	Measure current
11-in-1 Environmental Meter	Extech EN150	Measure UV light level
Energy Meter	PEL 103	Measure and log current, harmonics, voltage and power factors

3.4 Assumptions

1. The NCCRC runs 8-10 hours a day and 5 days a week. The working days at the facility was established to be 5 days a week.
2. The security lights are on throughout the night from 6:00 pm to 6:00 am.
3. Consolidated unit cost of grid electrical energy is KSH 19.48 per kWh
4. About 0.2212kgs of GHG is emitted by 1kWh of electrical energy generated.
5. The 24 hour cycle of operation observed during the audit is the typical operation cycle throughout the year.
6. Conversion factor: 1 kWh = 3.6 MJ

The facility is a government institution, where official working hours are 8 hours a day from Monday to Friday and is rarely occupied up to 10 hours a day. The security lights are mandatory to automatically switch on between 6 pm to 6am daily. The cost of 1 kWh was determined from the average value of the historical data refer to (Appedndix 2C). The assumption made for greenhouse gases emission was based on RenSmart standard [22].

CHAPTER 4: DATA COLLECTION AND ANALYSIS

4.1 Introduction

The facility is connected to the national grid and is billed under the CI1 tariff category via a KPLC prepaid meter. The energy audit at the facility considered all energy-consuming loads. The data and information collected were processed by editing and tabulating to make it suitable for analysis. The data were analyzed to compute appropriate performance indices and establish patterns.

4.1.1 NCCRC Energy Appliances Inventory

Table 1.1 in section 1.3 is a summary of the electrical systems and equipment identified within the facility during the survey carried out between November 2017 and March 2018. The computed total power demand was 39.36kW.

The motive of collecting the inventory of appliances, equipment and operations was to gain a detailed insight into energy sources, transmission and uses intending to identify energy conservation opportunities. This calculation assumes that the facility is occupied for eight (8) hours a day and five (5) days a week. Hence, there are approximately 20 working days or 160 hours in a month. Security outdoor lights run for 12 hours and 30 days in a month. The water pumps are in operation for approximately two hours a day on working days.

Since it is a resource institute, some occupants can extend working hours to about ten (10) hours. There are no records concerning this, but the survey at the facility shows that for approximately two days a month, the facility is occupied for up to 10 hours a day. The observation made in June 2018 indicated that the facility was held for long hours only on two days, mainly to summarize daily activities. Therefore, the facility occupation is rarely extended for 10 hours.

The total energy consumed by the facility is therefore estimated from,

$$E_{(kWh/Month)} = \frac{P_W \times T_{(h/day)} \times D_{month}}{1000_{(\frac{W}{kW})}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.....(4.1)$$

Where;-

P_w	-Total power consumed at that moment
$T_{h/day}$	-Working hours in a day
D_{month}	-Working days in a month

Assuming the facility is occupied for 10 hours two days a week, then there are approximately 12 days the facility is occupied for only 8 hours. The total demand for the appliances that are in operation for 8 hours a day is hence **37,935W**. Substituting this into (4.1), energy consumed monthly is;-

$$E_{(kWh/Month)} = \frac{37{,}935W \ \times 8_{(hours/day)} \times 12_{days/month}}{1000_{(\frac{W}{kW})}}$$

or **3,641.76 kWh**

During days that the facility is occupied for 10 hours, approximately 10% of the computed total energy is consumed, depending on the number of occupants present at that moment and there are eight days in a month. Using equation 4.1, the total energy consumed is **303.48kWh.**

The total monthly energy consumed by security is **117kWh**, while water pumps consumed **44kWh** monthly using equation 4.1. Adding the three values of consumption results to **4,106.24 kWh** or **14,782.46 MJ** consumed per month if all the appliances are working as assumed.

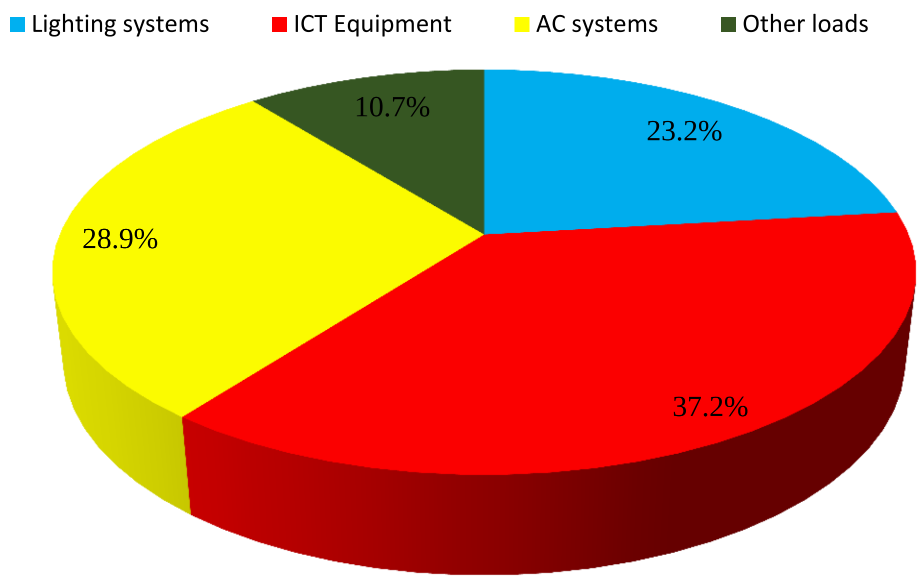

Figure 4. 1: Shared loads at the NCCRC facility

Figure 4.1 shows the shared load demand at the NCCRC facility. The summary indicates that equipment takes a higher percentage of the load than other loads. In this figure the ICT equipment, represent the highest percentage of 37.2% of the total load, while AC systems come second with other loads that include refrigerator, water pumps and water dispensers taking the least at 10.7% of the entire load.

4.1.2 Historical Energy Data Collection

The electrical energy consumption data for the NCCRC facility from 2015 to 2018 was collected from KPLC. The data obtained was for the period the facility has been in operation. Fuel energy data was collected from records for generator fueling over the same period. It is not clear since information only shows that KSH 100,000 is set aside for fuel every month.

The data in Appendix 2C was used to analyze the energy consumption trend between 2015 and 2018. Figure 4.2 is a graphical representation of the table and shows the energy consumption variation for the years 2015 to 2018 as well as the transaction cost for the same period. Monthly energy consumed corresponds to a transaction cost at that period as indicated. The higher the units consumed, the higher the transaction cost, and vice versa. June 2016 recorded 1,703.20kWh which translates to a transaction cost of KSH 35,000.00, while January 2016 recorded 64.70kWh equivalent to a transaction of KSH 1, 000.00. The raw data analyzed is presented in Appendix 2A and Appendix 2B. There were fewer activities, such as testing the installed equipment and completing furnishing activities by the contractor in the facility in 2015. The commissioning of the facility took place during that period. As seen from the figure, the years 2016 and 2017 are the determining years because full data of the respective year are represented.

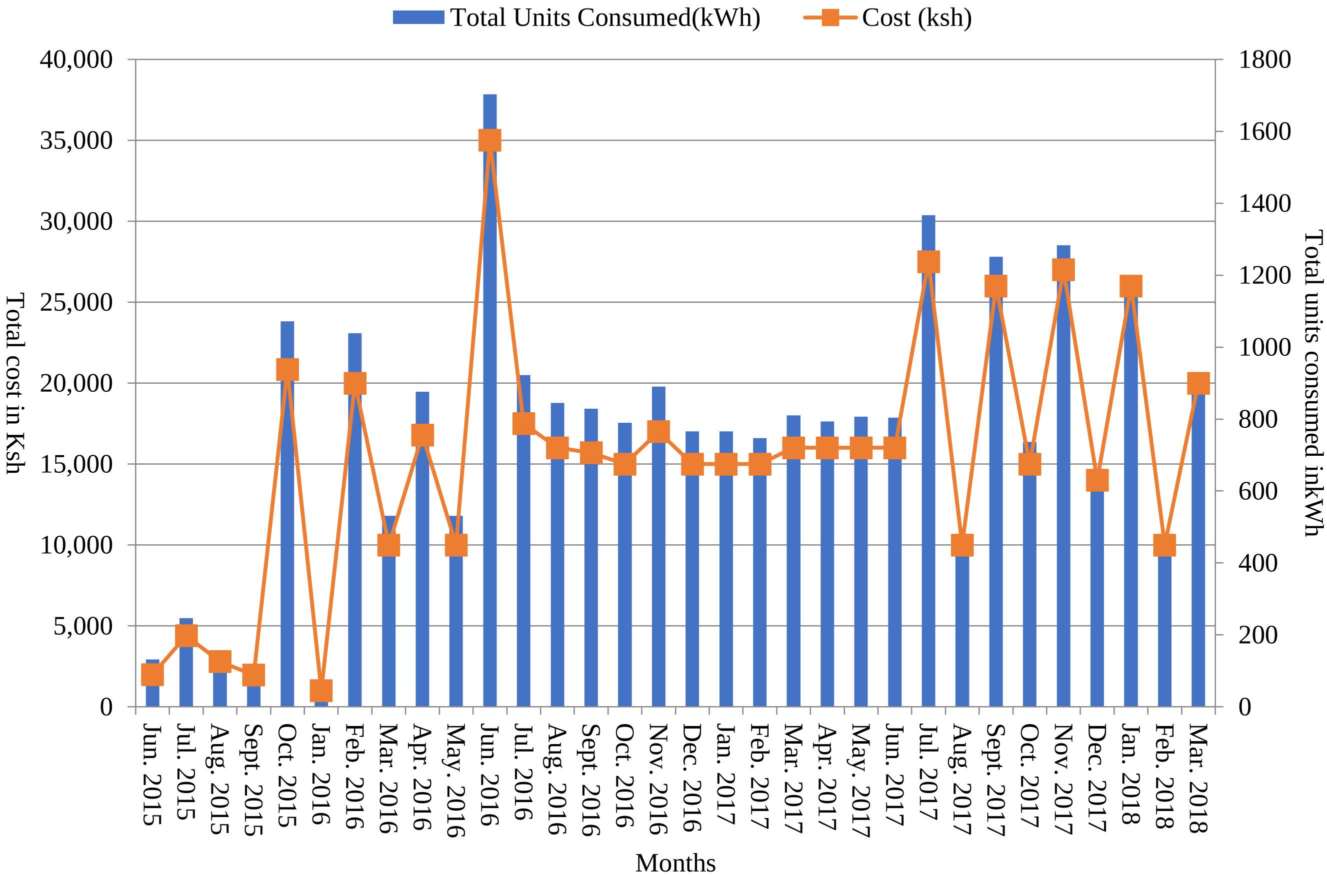

Figure 4. 2: Correlation energy consumption and the cost trends for June 2015 to March 2018

The trend indicates that there was an escalation in energy consumption between March 2017 and March 2018. It shows that June 2016 recorded the highest energy consumption of **1703.2kWh**. This value is within the energy consumption of **4,106.24 kWh** calculated in section 4.1.1. The reason for this could be that the facility was fully occupied, but the other days most people are out for field researches.

The baseline utility energy data for June 2015 to March 2018 shows that kVA demand charges vary depending on the electrical load during operation. The historical data established that NCCRC consumes an average of 844.74kWh per month. The average unit cost of electricity was determined to be KSH 19.48 per unit hence, resulting in a total of KSH 16, 455.54 monthly.

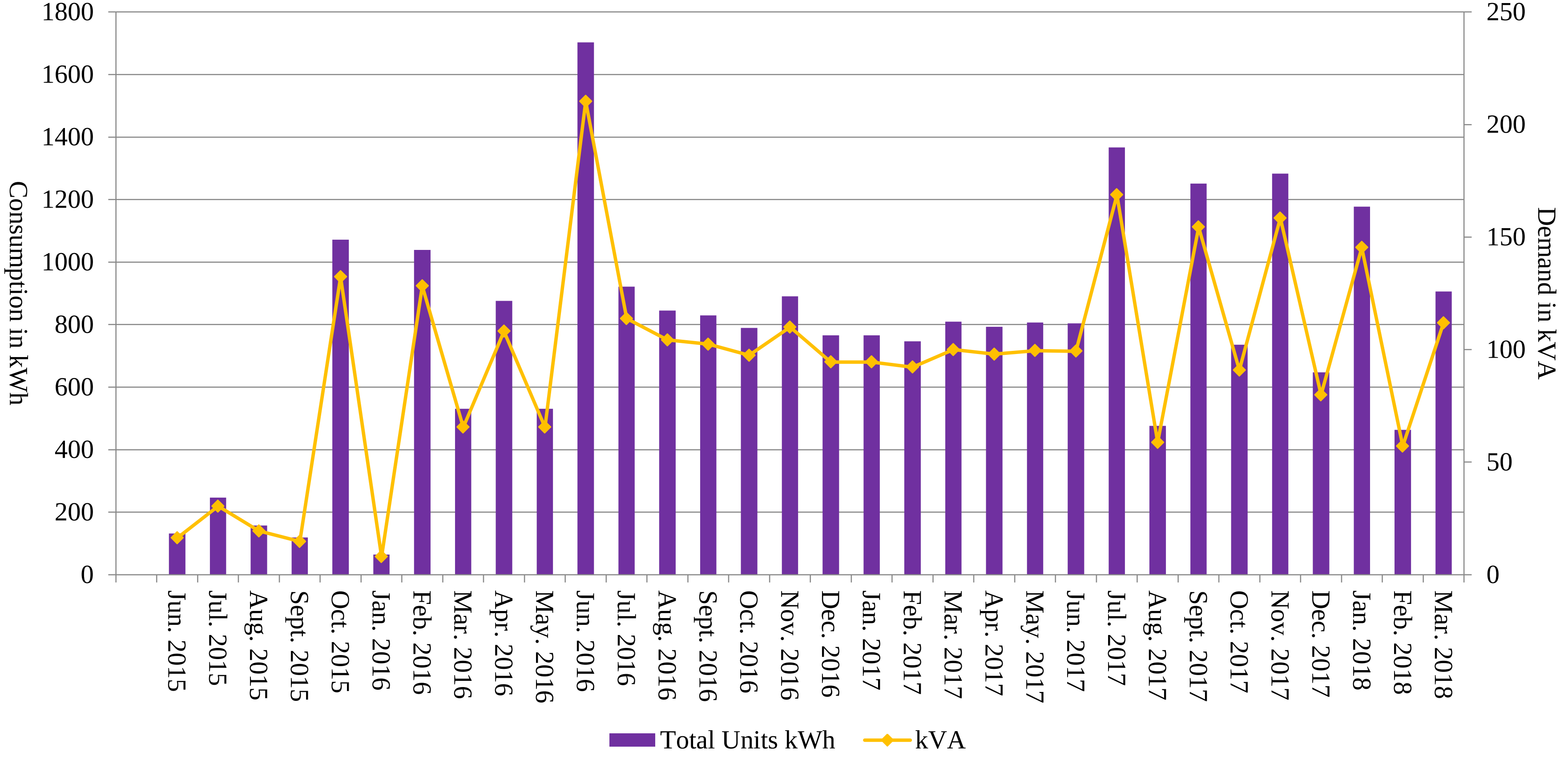

Figure 4. 3: Correlation of electricity consumption and kVA demand for June 2015 to March 2018

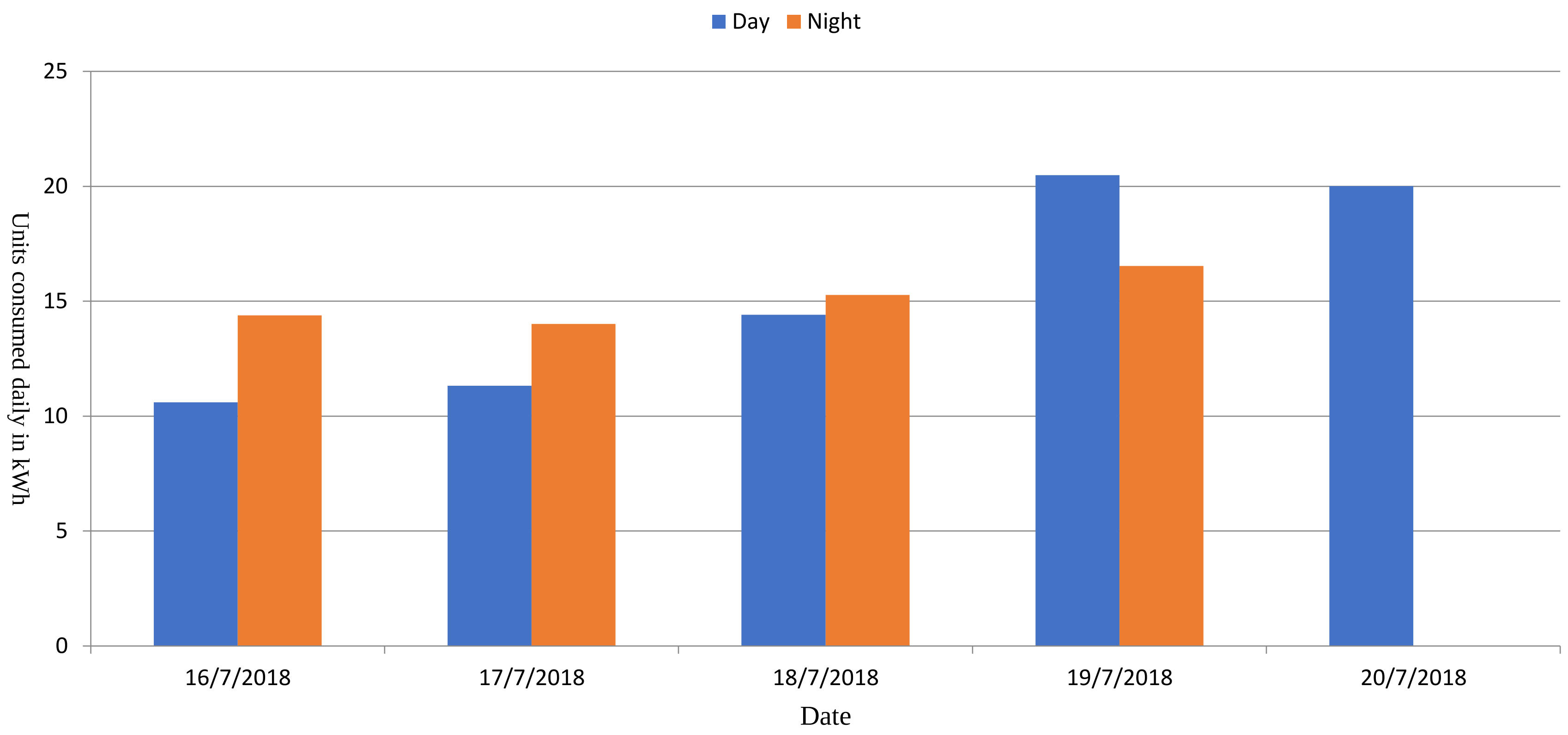

Figure 4. 4: Daily energy consumed between 16-7-2018 to 20-7-2018

The graph in Figure 4.3 shows the trend of maximum kVA demand charge, in correlation with the monthly electricity units. The peak demand was experienced in June 2016, and the least demand experienced in January of 210.27kVA and 7.98kVA respectively. The reasons that could have generated this high demand are: All appliances and lighting systems might have been left on throughout, and many seminars took place during that time. On the other hand, reasons for least demand charge might have been caused by a meager turnout or absence of utility power since the facility is installed with prepaid meter. This was concluded after observing the frequency of the occupants at the facility between November 2017 and February 2018.

Data collected on July 16, 2018, to July 20, 2018(See Appendix 5A), was analyzed and presented in Figure 4.4. Two readings were taken at 8:00 AM and 5:00 PM daily, to give a picture of energy consumed during the day and night. There was high consumption in the night than during the day, and the assumption is that there might be some appliances that were not turned off. Thursday, July 19 and Friday, July 20 recorded high consumptions of 20.49kWh and 20.01kWh respectively, because there was a seminar that took place at the facility. There was a low turnout of the occupants from Monday to Wednesday as compared to other days.

4.2 Real-time Energy Data Measurements

Real-time measurements were done using the equipment mentioned in section 3.4 and Appendix 3. Measurements were done between Thursday, May 24, 2018, and Monday, May 28, 2018, to cover both working days and non-working days at the NCCRC facility. Electrical parameters such as voltage, current, kW and kVA were measured at the switching point. Figures 4.5 to 4.8 are the output measurements from the power data logger used during the assessment in the period under investigation.

Legend	Name	Avg	Min	Min date	Min time	Max	Max date	Max time	Units
---	V12 (VA)	443.509	402.640	28/5/2018	10:01:22.000	468.810	28/5/2018	3:47:47.000	V
---	V23 (VA)	439.229	401.210	28/5/2018	10:01:22.000	458.090	28/5/2018	3:59:28.000	V
---	V31 (VA)	435.023	397.450	28/5/2018	8:39:58.000	457.260	28/5/2018	3:49:20.000	V

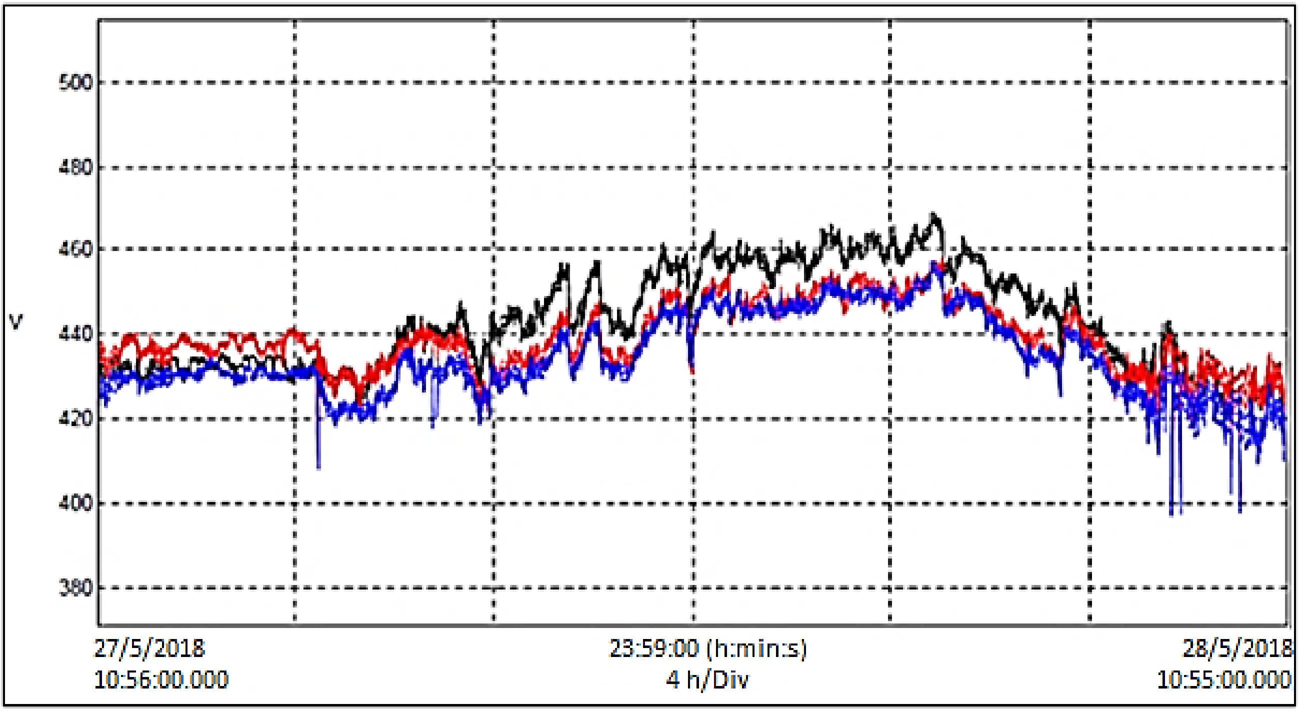

Figure 4. 5: Variations of utility energy supply voltage

Figure 4.5 presents the voltage variation profile for NCCRC facility. The supply voltage was very high in the three lines, i.e. V12, V23, V31 registered high values of 468.8V, 458.1V and 457.3V respectively. The cause of the high voltages recorded might have been transients caused by running the water pump, which under normal circumstances can generate a maximum of 450V. These transients on the supply can cause operational problems and can damage the equipment. Again higher voltages increase power losses, but low values lead to deterioration of operation of machines such as motors. Typically, the energy economic zone for any supply voltage should be about 380V/220V. Allowed voltage variations for 415V is plus or minus 6% [23]. The quality and level of the supplied voltage can vary throughout the day, depending on fluctuations in demand and supply.

In Figure 4.6, the electricity consumption for the lines was logged from 1:17 pm on 24th May 2018 to 9:38 am of 28th May 2018 to determine the characteristic daily energy consumption trend. The measurements activity was studying the power quality and identifying days with no activities that would be important for load scheduling and kVA demand management.

Session Min / Max / Average Values									
Legend	Name	Min	Min date	Min time	Max	Max date	Max time	Avg	Units
---	S (VA)	1.80	24/5/2018	18:01:00.000	16.936	24/5/2018	19:47:00.000	1.718	kVA
---	S1 (VA)	0.349	24/5/2018	17:51:00.000	7.708	24/5/2018	19:47:00.000	0.551	kVA
---	S2 (VA)	0.182	27/5/2018	20:39:00.000	8.200	24/5/2018	19:47:00.000	0.467	kVA
---	S3 (VA)	0.521	24/5/2018	19:25:00.000	2.528	27/5/2018	6:53:00.000	0.700	kVA

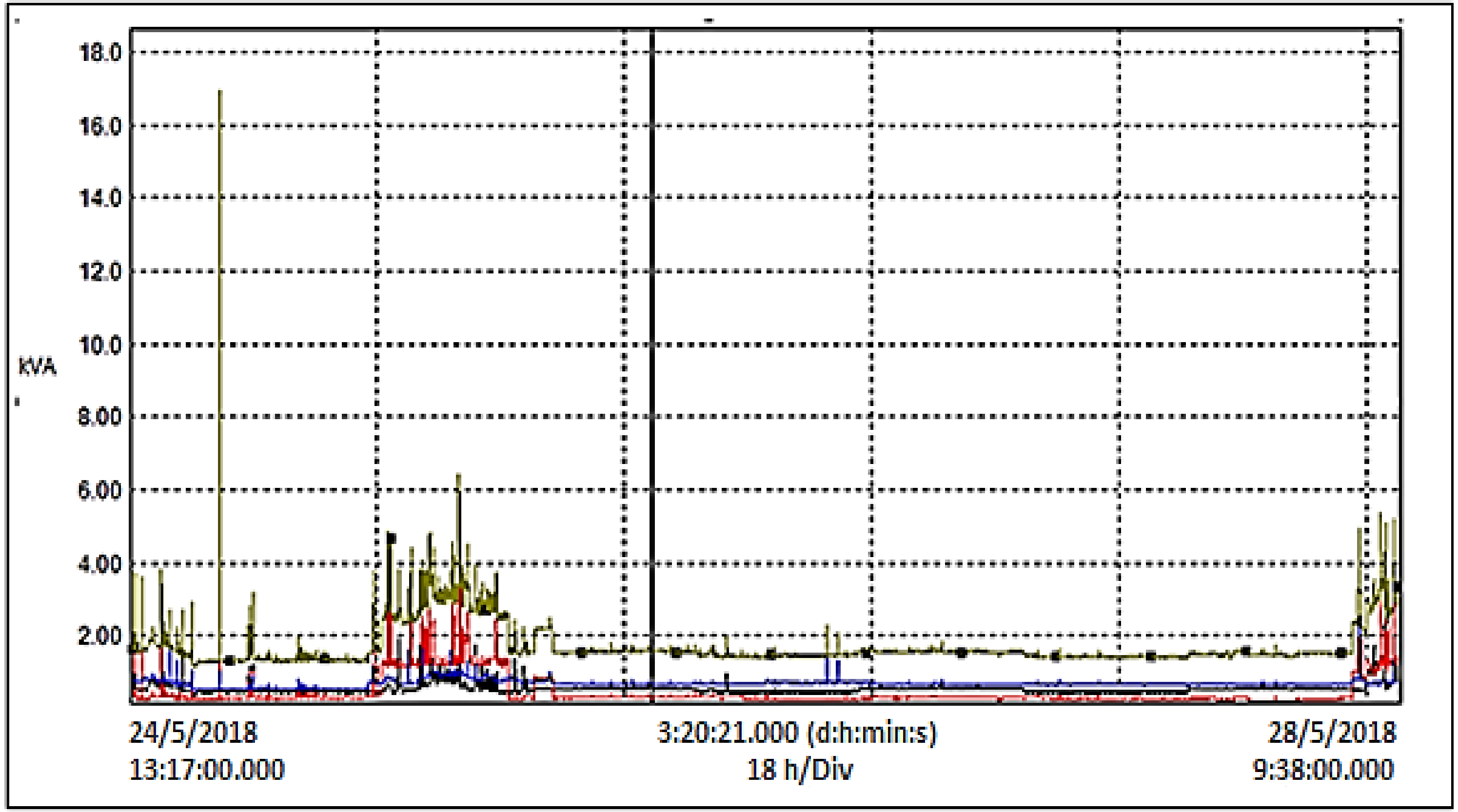

Figure 4. 6:Energy demand load profile for the NCCRC

Figure 4.7 and Figure 4.8 present load-current and load-kW demand, respectively. The measurement was done on May 24, 2018, to May 25, 2018, 6 am to 6 am. Line 1 experienced a higher current of 15.29A at around 8 am during a working day to show there were many activities. The graph shows there were no activities from 6 pm of May 24 to the following day on May 25, since the data logger recorded a constant current of about 1A, indicating that only a few security lights were on at that moment. On the other hand, in Figure 4.8, a maximum power of 3.19kW and 2.996kW for phase line P1 (W) and P2(W) respectively were recorded on May 24, 2018.

	Session Min / Max / Average Values								
Legend	Name	Avg	Min date	Min	Min time	Max	Max date	Max time	Units
---	I1	0.009	24/5/2018	0.000	15:06:07.000	0.220	25/5/2018	5:59:07.000	A
---	I2	7.214	25/5/2018	0.000	1:15:07.000	15.269	24/5/2018	20:59:07.000	A
---	I3	0.763	25/5/2018	0.000	1:15:07.000	6.749	24/5/2018	17:38:07.000	A
---	IN	7.449	25/5/2018	0.000	1:15:07.000	15.722	24/5/2018	20:59:07.00	A

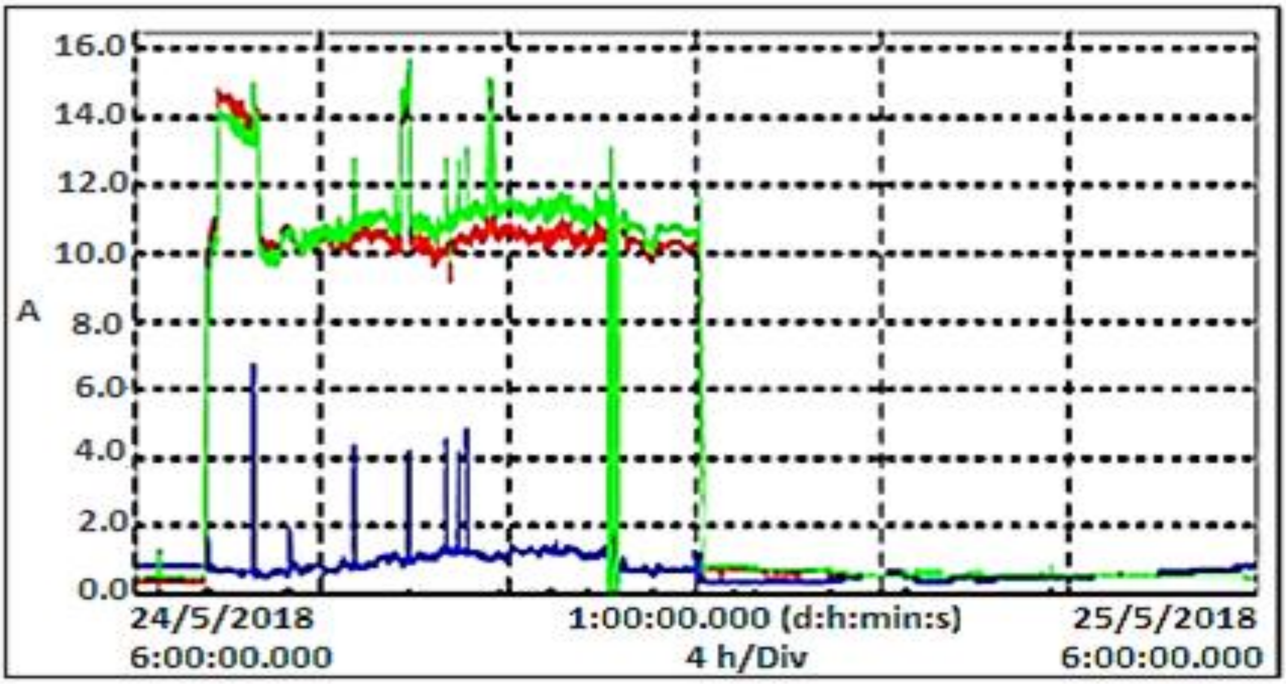

Figure 4. 7: NCCRC real time load-current

Real time measurements show a demand average of 5.9kW (6.56kVA), consumed at the NCCRC facility. Taking an average of nine (9) hours a day and 20days a month, the monthly energy consumed is 1,062kWh equivalent to Ksh20, 687.76 spent in the utility bill every month. Comparing these values with computed historical values as in Table 4.3, the percentage difference is 11%. Both historical and real-time measurements data recorded minimal differences of approximately 3%. The walk through data collected had higher values than the real-time and historical data, this is because it is based on assumptions, hence may not be reliable enough.

Table 4. 1: Comparison of real time and historical information

Sn.	Description	kW-demand	VA-demand	Monthly-kWh	Monthly-Ksh
1	Walk through survey data	39.36	49.2	4,106.24	79,989.53
2	Historical data	4.2	4.69	844.74	16,455.53
3	Real-time measurements	5.9	6.56	1,062	20,687.76

There is still potential to save on kVA and kWh. To save on the electricity bill through demand charge control, the facility must identify all heavy but flexible electrical loads and ensure they are not simultaneously running for longer periods than necessary. In addition, the facility must always make sure that the power factor corrections are operating at their optimum capacity.

	Session Min / Max / Average Values								
Legend	Name	Avg	Min date	Min	Min time	Max	Max date	Max time	Units
---	P (W)	822.236	24/5/2018	-15.000	6:30:00.000	3190.000	24/5/2018	11:52:00.000	W
---	P1 (W)	0.169	24/5/2018	-7.000	14:57:00.000	19.000	24/5/2018	17:06:00.000	W
---	P2 (W)	787.414	24/5/2018	0.000	16:10:00.000	2996.000	24/5/2018	13:36:00.000	W
---	P3 (W)	34.675	25/5/2018	-82.000	4:39:00.000	266.000	24/5/2018	13:05:00.000	W

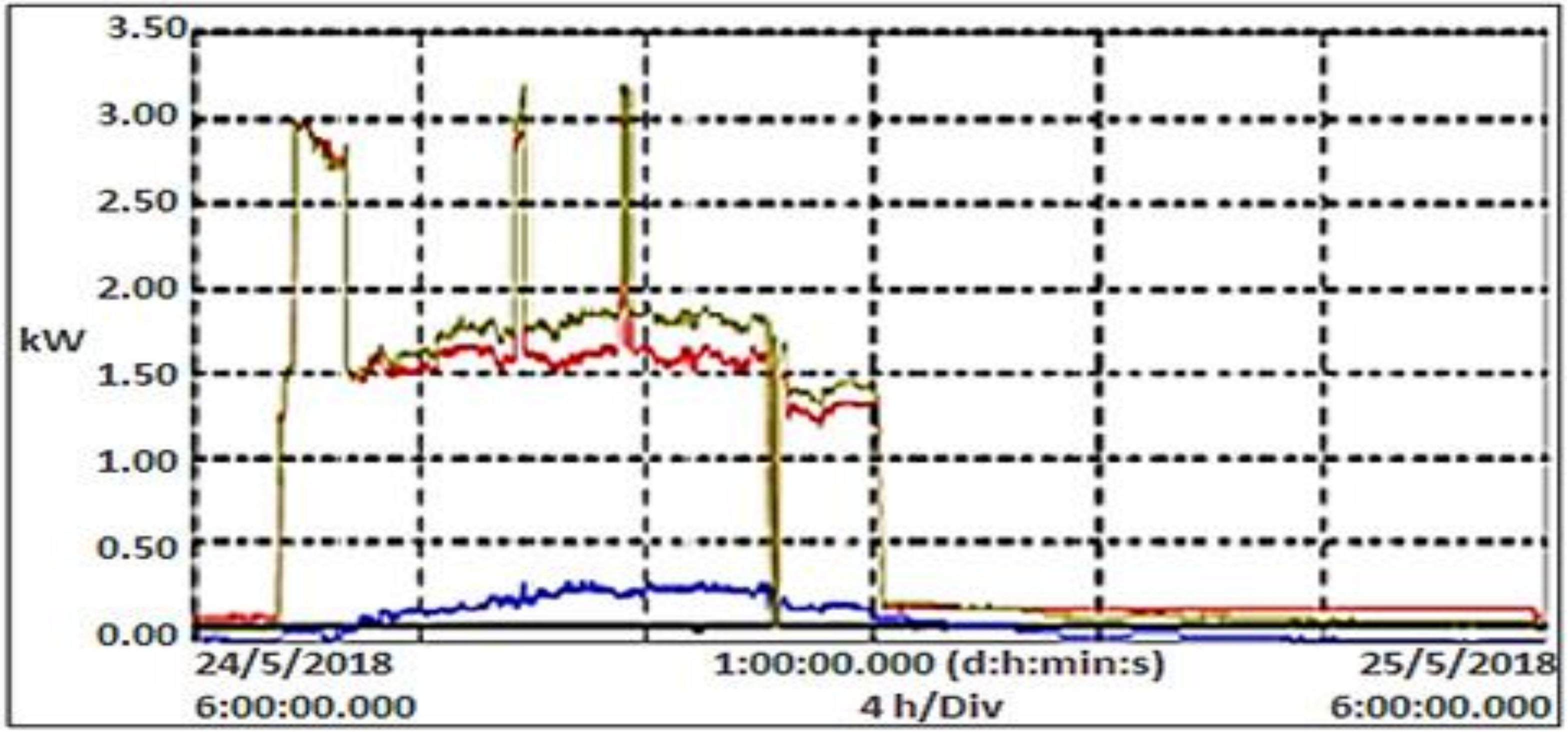

Figure 4. 8:NCCRC real time load-kW demand

4.3 Lux Level Measurements

There are curtains fixed in the windows in most of the offices for privacy and to reduce excess heating and lighting in the offices from bright skies during the working hours. Consequently, the lights are turned on to reduce the darkness in such offices.

The lux levels were found to be within the required standards levels for a normal working office without the lighting (see Appendix 4A and Appendix 4B).

4.4 General Findings on Energy State at the Facility During Audit

The current, kVA and kW parameters were within the normal level, but voltage recorded was very high at some point as indicated in Figures 4.5 to 4.8. Another measurement of voltages was done between July 25, 2018 and July 30, 2018 using a voltmeter and is presented in Appendix 5B.

The NCCRC facility does not have an energy policy; hence, an energy team has not been established to monitor energy usage. Behavioral issues of the occupants might cause energy wastage. Therefore, necessary steps such as retrofitting some lighting fittings, and adopting energy management and control protocol should be implemented. Regular sensitization programs should be conducted on the management of power; this can change the mindset of careless power usage at the facility. Consequently, these helps the company to achieve the following benefits; reduce energy wastage, save fuel and natural resources, save money, and reduce environmental pollution.

4.5 Energy Saving Opportunities for NCCRC

The observations and the measurements done at the facility on power parameters, were reviewed, and analyzed. A number of best practices have been recommended that can see the monthly electricity bill come down. The following are the energy saving opportunities identified for detailed discussion:

i. Retrofit of the existing technology with LED technology
ii. Installation of vacancy sensors to help save energy in unoccupied offices/facilities
iii. Installation of solar film on the windows to replace existing curtains/blinds
iv. Installation of programmable timers for connected loads such as water dispensers
v. Install interactive grid PV solar system of 10kWp
vi. Adoption of good energy management and monitoring protocols in line with ISO50001 and energy management regulation act of 2012
vii. Optimize operation of the existing biogas system already installed at the facility

The amount of energy savings and the payback periods are determined in the following sections. The derating factors used to account for reduce output power rating of the proposed appliances were obtained from manufacturers manuals.

4.5.1 Retrofit of Existing Technology with LED Technology

The study has ranked lighting level as one of the three items of concern in designing a healthy working environment [24]. Low or high level of light affects the workers' productivity. A good lighting system in an office also saves energy and money. Replacing the existing lighting system with LED technology, adds value and enhances performance at the facility.

- 4ft FTL replacing with 18W LED – Ksh 2,700
- 2ft FTL replacing with 9W LED - Ksh 1,800
- B22 CFL replacing with 5W LED - Ksh 1,500

- 2D CFL replacing with 5W LED - Ksh 1,200

Table 4. 2: Economic Lighting analysis

Item	Lamp type	Qty	Existing		Retrofit		Expected Investment (Ksh)
			Rating (W)	Total (kW)	Rating (W)	Saving (kW)	
1	T8 4ft fluorescent tube	77	58	4.47	18	3.08	207,900.00
2	T8 2ft fluorescent	128	30	3.84	9	2.69	230,400.00
3	B 22 CFL	25	13	0.33	5	0.21	37,500.00
4	2D CFL	23	16	0.37	5	0.26	27,500.00
5	B 22 CFL(Security Lights)	25	13	0.33	5	0.21	37,500.00
		278		**9.34**		**6.45**	**540,800.00**

From Table 4.4 the energy savings projected = 6.45kW

Total annual hour is 2,160hrs and derating factor is 35%, hence;-

Annual energy savings	**9,055.8 kWh**
Expected annual cost saving	**KSH 176,406.98**
Expected Investment	**KSH 540,800.00**
Payback Period	**3 Years**
Annual carbon saved	**2 tons/year**

4.5.2 Install Solar Film on Windows

Large windows in the buildings can lead to excessive heat, annoying glare, damaging ultra-violet rays and premature fading [25]. However, solar protective window films can provide a solution to all of these problems, while enhancing view under the following parameters;-

- Reject Ultra-Violet Rays: All types of tinted windows block 99% of harmful UV rays.
- Heat Reduction: Solar film window can reduce the heat transmittance through glass by up to 81%. This will make for a more comfortable environment in the offices.
- Increase Privacy: Tinted window provide privacy from outside, hence brings comfort for the occupants especially on a busy street.

- Glare Reduction: Specifically designed window films can reduce annoying glare by up to 87%. This will provide a softer, and more natural light throughout an office. Reduce Fading: By blocking damaging UV rays and reducing heat and light transmittance through glass, solar film window can reduce the fading of carpets, curtains, and furniture.

To calculate the financial justification for investing in this technology, measurements of windows surfaces were done and tabulated in Table 4.5

Table 4. 3: Surface area of the windows considered

View	Window Type Length (m)	Width (m)	No. of windows	Total Area (m^2)
Front Top	1.77	1.66	18	52.89
Front Ground	1.64	2.00	18	59.04
Rear Ground	1.64	2.00	18	59.04
Rear Top Floor	1.77	1.66	18	52.89
Side Ground	1.64	2.00	2	6.56
Side Top Floor	1.77	1.66	2	5.88
Total				**236.30**

The energy to be saved for this option is wastage energy as a result of using curtains that make the office space dark. The saving projected in this option for the NCCRC facility was calculated using the total window area of $236m^2$ in the NCCRC. Using derating factor of 0.8 x 0.65 and cost per replacing $1m^2$ to be Ksh 1200, hence the analysis;-

Annual energy savings (kWh)	**9,378.89**
Expected annual cost saving (Ksh)	**182,700.83**
Expected Investment (Ksh)	**283,200.00**
Payback Period (years)	**1.5**
Annual carbon saved (tons/year)	**2.1**

4.5.3 Use Programmable Timers

The auxiliary components of electrical systems, lighting and lighting fixtures, water dispenser, office machines and water pumps among other systems should be switched off when not in use to eliminate unnecessary wastage. The timer is an embedded system that can generate an output signal when it reaches a programmed count. The output signal may trigger an interrupt, when it reaches a programmed count using an embedded timer system

Existing situation

The base load for the facility was high and this called for close monitoring of connected loads that are idle or are worth switching off to save energy during off-peak hours. Water dispensers and small UPS serving the computers should be timed to eliminate such wastage.

Summary of financial calculations/implication

From the inventory table in Table 4.1, projected energy savings from water dispensers at NCCRC facility considered was 2.75kW. Annual working hours are 2,160hrs, derating factor of 50% and cost of each timer is Ksh 7,500.00. Hence analysis are;-

Annual energy savings (kWh)	**2, 970.00**
Expected annual cost saving (Ksh)	**57,855.60**
Expected Investment (Ksh)	**37,500.00**
Payback Period (years)	**0.1**
Annual carbon saved (kg/year)	**656.96**

4.5.4 Use Infrared Vacancy Sensors

Infrared vacancy sensors automatically turn lights on when somebody enters a space and off on leaving the space, making them a convenient way to save energy in a home or commercial space.

Existing Situation

There is no automation on indoor lighting circuitry. There are no proper energy management protocols in place to compel or otherwise bind staff to switch off lights and other connected loads whenever they are not in use.

Summary of financial calculations/implication

The number of spaces targeted by this exercise is eleven offices, four corridors, one kitchen and two washrooms; this equals the number of units to be bought at Ksh 35,000.00 each. The total cost of installation is projected at Ksh 10,000.00. The derating factor is 20%, hence the analysis;-

Annual energy savings (kWh)	**13,332.48**
Expected annual cost saving (Ksh)	**259,716.71**
Expected Investment (Ksh)	**640,000.00**
Payback Period (years)	**2.5**
Annual carbon saved (tons/year)	**3**

4.5.6 Install 10kWp Interactive Grid Connected Solar PV System

Photovoltaic systems convert the sun's light into electrical energy. The energy is produced by photovoltaic (PV) cells, which are typically made of silicon. The electricity generated by a system transmitted to an inverter and then into a building [26]. Some systems also have a battery to provide backup electricity.

Existing Situation

There is little exploitation of solar resource at the facility since only about 5kWp roof solar PV system is installed at NCCRC facility. At the time of the audit this was not fully exploited.

The daily solar insolation data is presented in Figure 4.9 for this area.

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	$kWh/m^2/d$	kPa	m/s	°C	°C-d	°C-d
January	18.0	60.0%	68.51	6.54	84.3	3.6	22.9	0	248
February	18.8	56.0%	45.06	6.66	84.3	3.7	23.7	0	246
March	19.4	61.5%	77.46	6.38	84.3	3.7	23.8	0	291
April	19.2	71.0%	130.26	5.32	84.4	3.7	22.9	0	276
May	17.8	73.0%	72.99	4.66	84.5	3.8	22.8	6	242
June	16.3	72.5%	16.81	4.26	84.6	3.9	23.0	51	189
July	15.6	73.0%	12.77	3.75	84.6	3.9	23.0	74	174
August	15.9	70.5%	6.75	4.00	84.6	4.0	24.1	65	183
September	17.3	63.5%	12.38	5.35	84.5	4.1	25.7	21	219
October	18.5	62.5%	18.64	5.63	84.4	3.9	25.3	0	264
November	18.4	70.5%	75.84	5.27	84.4	3.6	22.8	0	252
December	18.1	66.0%	63.17	6.06	84.4	3.4	22.4	0	251
Annual	**17.8**	**66.7%**	**600.64**	**5.32**	**84.4**	**3.8**	**23.5**	**218**	**2,835**
Source	Ground	Ground	NASA	Ground	Ground	NASA	NASA	Ground	Ground
Measured at					m	10	0		

Figure 4. 9: Solar insolation data

Harvesting of renewable energy resources like solar PV has not been fully exploited within the institution despite being abundant at the site. There is also sufficient space especially the car park and rooftop.

<u>Summary of financial calculations/implication</u>

The cost of the solar PV system is costed at Ksh 130.00 per Watt.

From Figure 4.11 the average solar insolation was established at $5.32kWh/m^2/day$

System 10kWp grid connected system for NCCRC. The efficient factor is taken to be 0.8, hence analysis are;-

Annual energy savings (kWh)	**15,534.4**
Expected annual cost saving (Ksh)	**302,610.11**
Expected Investment (Ksh)	**1,000,000.00**
Payback Period (years)	**3.5**
Annual carbon saved (tons/year)	**3.4**

4.5.7 Other Recommendation Outside the Measurement Boundary

I. Adopt good energy management and monitoring protocols within the facility

The protocol involves the use of energy consumption information, in order to control and manage daily consumption. Typically, Monitoring and target setting (M&T) combines statistics and thermodynamics principles. [27]. M&T is use to determine management control protocol for monitoring energy consumption deviation from an established pattern.

Existing Situation

There are no proper energy management and data recording protocols that can be used to verify and cross check energy consumed and other parameters such as daily degree-days.

II. Optimize Operation of the Existing Biogas Plant

The principle behind biogas plant is the degradation process by microorganisms in the anaerobic digester. During this process, microorganism break down biodegradable materials in the absence of oxygen hence, releasing biogas energy.

Existing Situation

There is a human waste to gas bio-digester installed at NCCRC facility to provide gas used in the kitchen for cooking. About $21.67m^3$ of biogas had been generated from the digester and used within the facility since 2015 when the facility was commissioned.

The cleaning of the washrooms is done using stain removal detergents, and other chemicals like scouring powder. These substances contain polycarbonates, silicates, perfumes, polyphosphate and chlorine as bleaching agent. All these chemical components affect the growth of the anaerobic bacteria inside the digester. Therefore, these chemicals should be avoided in order for the facility to fully exploit the energy generation from biogas plant.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main objective of the study was to carry out an assessment of energy usage and management at NCCRC facility with the intention of recommending energy conservation measures. It was able to identify that the facility has installed, a hybrid energy system of KPLC power utility as primary source, standby generator, PV solar system and biogas digester system as secondary sources. During this process, it was found that only the KPLC utility energy and standby generator are utilized, however. There is a need to determine the why PV solar system and biogas digester are not used.

Data was collected using historical, direct observation and real-time measurements. Historical data as baseline data was used to obtain the energy consumption trend between 2015 and 2018. The year 2016 and 2017 were found to be determining years since it had full-recorded data. It concluded that June 2016 recorded the highest value of 1,703.20kWh. The real-time measurements determined the demand average at the facility is 5.9kW. The comparison of the two data collections was found to have a significant difference of 11%. Direct observation during the walk-through survey summarized the inventory data. It was determined that ICT equipment takes the highest load of 37.2%, while other loads contribute 10% of the overall load.

The study was able to identify areas where energy is not utilized efficiently. Examples of such factors are human behavioural issues of neglecting to turn off the power when not in use and appliance technology that needs to be upgraded to an energy-efficient one.

5.2 Recommendations

The study recommends the following measures which can be implemented to significantly bring down energy consumption and cost;-

i. During the survey, it identified that an inefficient lighting system was used in the facility. Hence, it is proposed that NCCRC management take steps to replace all the lighting sources with LED technology as follows;
   - 4ft FTL replacing with 18W LED
   - 2ft FTL replacing with 9W LED
   - B22 CFL replacing with 5W LED
   - 2D CFL replacing with 5W LED

The ratings were chosen based on the existing installation of lights fittings and recommended luminous intensity standards.

ii. It was found the load during the day was minimal, but could be saved further by using film solar tint technology. Replace existing blinds/curtains with thin-film solar tint to help reduce heating, excess lighting and privacy during the day at bright skies. This could encourage the occupants to use natural light during the day and eliminate the use of electricity for lighting at the same time.

iii. Install programmable timers to control water dispensers and isolate appliances such as computers from power when leaving office from 5 pm.

iv. Install vacancy Passive Infrared Sensor to control office and corridor lighting loads whenever there is no one in the office or corridors. The proposed vacancy sensor automatically switches off lighting systems when an office remains vacant for 10 minutes.

v. Install a 10kWp Solar System at NCCRC; frameless solar panels mounted on a constructed car shade in front of the facility. This will improve the existing energy mix at the facility as well as lowering the cost of energy. Solar energy is free energy, even though the initial investment cost for this system is high.

Other recommendations

i. Conduct an electrical inspection and identify all the main lines serving various sections of the facility.

ii. During the audit, it was found there was no monitoring system for determining the utilization of solar energy. The NCCRC should consider installing sub meters to determine the level of solar energy utilization.

iii. Also, the administrative personnel and staff should be fully informed about all energy matters within the facility through training and other awareness forums.

iv. The facility also should optimize the use of the biogas system by preventing water containing cleaning chemicals getting into the digester. This would avoid poisoning of the anaerobic bacteria responsible for gas generation.

v. Carry out more studies on the chemical balance of the digester.

APPENDICES

Appendix 1: National Climate Change Resource Centre Facility

Appendix 2A: Historical KPLC Raw Data

	National Climate Change Resource Centre KPLC Billing Account:14170104930				
DATE	TOTAL UNITS (kWh)	NCCRC TRANSACTION (Ksh)	VAT	SERVICE CHARGE (Ksh)	TRANSACTION TOTAL (Ksh)
11/6/2015	132.1	1246.83	265.79	487.38	2000
3/7/2015	74.1	454.73	133.96	411.31	1000
15/7/2015	45.7	582	119.59	198.41	900
16/7/2015	101.5	1293.25	265.81	440.94	2000
30/7/2015	25.4	323.35	66.44	110.21	500
6/8/2015	44.6	111.45	67.69	320.86	500
13/8/2015	50.6	589.13	133.28	277.59	1000
20/8/2015	4.8	60.45	13.31	26.24	100
21/8/2015	9.5	120.85	26.63	52.52	200
22/8/2015	23.7	302.02	66.61	131.37	500
27/8/2015	7.2	90.64	19.98	39.38	150
29/8/2015	7.2	90.64	19.98	39.38	150
31/8/2015	9.5	120.85	26.63	52.52	200
2/9/2015	8.8	21.85	34.23	193.92	250
4/9/2015	11.5	28.75	13.45	57.8	100
8/9/2015	20.8	51.92	21.46	86.62	160
12/9/2015	10.5	42.21	13.37	44.42	100
15/9/2015	5.5	69.78	14.62	25.6	110
16/9/2015	2.5	31.74	6.63	11.63	50
21/9/2015	2.3	28.57	5.97	10.46	45
22/9/2015	7.5	95.13	19.94	34.93	150
23/9/2015	2.5	31.74	6.63	11.63	50
23/9/2015	5	63.44	13.28	23.28	100
23/9/2015	10	126.83	26.59	46.58	200
24/9/2105	29.9	380.4	79.79	139.81	600
30/9/2105	2.5	31.74	6.63	11.63	50
7/10/2015	22.2	55.48	46.94	242.58	345
15/10/2015	40.2	226.75	66.93	206.32	500
16/10/2015	1009.2	12354.56	2614.28	4683.31	20000
26/1/2016	64.7	311.57	135.04	553.39	1000
1/2/2016	1038.8	12731.55	2659.33	4609.12	20000
30/3/2016	530.8	6254.03	1330.31	2415.66	10000
18/4/2016	73.5	424.27	134.18	441.55	1000
21/4/2016	40.7	518.24	106.31	175.45	800
27/4/2016	762.1	9716.32	1993.52	3290.16	15000
19/5/2016	530.8	6254.03	1330.31	2415.66	10000
7/6/2016	784.8	9492.77	1994.83	3512.4	15000
28/6/2016	918.4	13298.67	2656.74	4044.59	20000

	National Climate Change Resource Centre KPLC Billing Account:14170104930				
DATE	**TOTAL UNITS (kWh)**	**NCCRC TRANSACTION (Ksh)**	**VAT**	**SERVICE CHARGE (Ksh)**	**TRANSACTION TOTAL (Ksh)**
11/7/2016	46.2	115.31	67.8	316.89	500
14/7/2016	28.1	319.35	66.53	114.12	500
15/7/2016	15.5	196.46	39.9	63.64	300
15/7/2016	10.3	131.01	26.59	42.4	200
18/7/2016	51.4	654.8	133.01	212.19	1000
27/7/2016	770.4	9821.39	1995.38	3183.23	15000
23/8/2016	793.3	9602.04	1996.93	3401.03	15000
24/8/2016	25.7	327.44	66.51	106.05	500
31/8/2016	25.7	327.44	66.51	106.05	500
20/9/2016	58.9	237.97	94.45	367.58	700
22/9/2016	770.4	9821.39	1995.38	3183.23	15000
21/10/2016	789.5	9553.02	1997.08	3449.9	15000
22/11/2016	890.7	10843.16	2263.34	3893.5	17000
21/12/2016	765.6	9247.92	1999.7	3752.38	15000
27/1/2017	765.6	9248.32	1999.78	3751.9	15000
23/2/2017	746.9	9009.32	2001.98	3988.7	15000
21/3/2017	809.8	9811.56	2134.08	4054.36	16000
19/4/2017	793.5	9604.06	2135.72	4260.22	16000
19/5/2017	806.6	9771.47	2134.6	4093.93	16000
13/6/2017	804.3	9741.8	2134.7	4123.5	16000
8/7/2017	144.1	1324.47	334.78	840.75	2500
11/7/2017	489.1	6235.86	1333.42	2430.72	10000
28/7/2017	733.7	9353.77	2000.14	3646.09	15000
18/8/2017	475.9	5554.01	1338.18	3107.81	10000
6/9/2017	521.4	6134.75	1471.83	3393.42	11000
21/9/2017	729.8	9303.85	1999.98	3696.17	15000
11/10/2017	736.1	8872.8	2003.06	4124.14	15000
3/11/2017	736.1	8872.8	2003.06	4124.14	15000
24/11/2017	547.4	6978.88	1603.53	3417.59	12000
14/12/2017	647.2	7739.04	1873.16	4387.8	14000
9/1/2018	512.8	6025.45	1472.12	3502.43	11000
26/1/2018	664.6	8472.44	2006.25	4521.31	15000
19/2/2018	462.9	5388.36	1339.3	3272.34	10000
7/3/2018	64.1	304.44	135.42	560.14	1000
8/3/2018	44.4	564.94	133.74	301.32	1000
8/3/2018	797.5	10167.89	2407.75	5424.36	18000

Appendix 2B: Power Consumption Data

NCCRC KPLC Meter No.:14170104930		
Month	**Total Units Consumed(kWh)**	**Total Cost (Ksh)**
Jun. 2015	132.1	2,000
Jul. 2015	246.7	4,400
Aug. 2015	157.1	2,800
Sept. 2015	119.3	1,965
Oct. 2015	1,071.60	20,845
Jan. 2016	64.7	1,000
Feb. 2016	1,038.80	20,000
Mar. 2016	530.8	10,000
Apr. 2016	876.3	16,800
May 16	530.8	10,000
Jun. 2016	1,703.20	35,000
Jul. 2016	921.9	17,500
Aug. 2016	844.7	16,000
Sept. 2016	829.3	15,700
Oct. 2016	789.5	15,000
Nov. 2016	890.7	17,000
Dec. 2016	765.6	15,000
Jan. 2017	765.6	15,000
Feb. 2017	746.9	15,000
Mar. 2017	809.8	16,000
Apr. 2017	793.5	16,000
May 17	806.6	16,000
Jun. 2017	804.3	16,000
Jul. 2017	1,366.90	27,500
Aug. 2017	475.9	10,000
Sept. 2017	1,251.20	26,000
Oct. 2017	736.1	15,000
Nov. 2017	1,283.50	27,000
Dec. 2017	647.20	14,000
Jan. 2018	1,177.40	26,000
Feb. 2018	462.90	10,000
Mar. 2018	906.00	20,000

Appendix 2C: Historical Processed Data

Month	Maximum Demand (kVA)	Total Energy Consumed (kWh)	P.F.	Total Monthly Bill (Ksh)
Jun. 2015	16.30	132.1	0.9	2,000
Jul. 2015	30.45	246.7	0.9	4,400
Aug. 2015	19.39	157.1	0.9	2,800
Sept. 2015	14.72	119.3	0.9	1,965
Oct. 2015	132.29	1,071.6	0.9	20,845
Jan. 2016	7.98	64.7	0.9	1,000
Feb. 2016	128.24	1,038.8	0.9	20,000
Mar. 2016	65.53	530.8	0.9	10,000
Apr. 2016	108.18	876.3	0.9	16,800
May. 16	65.53	530.8	0.9	10,000
Jun. 2016	210.27	1,703.2	0.9	35,000
Jul. 2016	113.81	921.9	0.9	17,500
Aug. 2016	104.28	844.7	0.9	16,000
Sept. 2016	102.38	829.3	0.9	15,700
Oct. 2016	97.46	789.5	0.9	15,000
Nov. 2016	109.96	890.7	0.9	17,000
Dec. 2016	94.51	765.6	0.9	15,000
Jan. 2017	94.51	765.6	0.9	15,000
Feb. 2017	92.20	746.9	0.9	15,000
Mar. 2017	99.97	809.8	0.9	16,000
Apr. 2017	97.96	793.5	0.9	16,000
May. 17	99.58	806.6	0.9	16,000
Jun. 2017	99.29	804.3	0.9	16,000
Jul. 2017	168.75	1,366.9	0.9	27,500
Aug. 2017	58.75	475.9	0.9	10,000
Sept. 2017	154.46	1,251.2	0.9	26,000
Oct. 2017	90.87	736.1	0.9	15,000
Nov. 2017	158.45	1,283.5	0.9	27,000
Dec. 2017	79.90	647.2	0.9	14,000
Jan. 2018	145.35	1,177.4	0.9	26,000
Feb. 2018	57.14	462.9	0.9	10,000
Mar. 2018	111.85	906.0	0.9	20,000

Appendix 2D: Historic Electricity Data for Kenya.

Adopted from Regulus database 2014-2018

	Average electricity cost(Ksh/kWh)					
	DC	SC	CI1		CI2	
Period			Peak	Off-peak	Peak	Off-peak
Jan 2015	20.17	20.56	15.05	15.05	13.60	13.60
Feb 2015	20.29	20.67	15.17	15.17	13.72	13.72
Mar 2015	20.01	20.40	14.89	14.89	13.44	13.44
Apr 2015	19.99	20.37	14.87	14.87	13.41	13.41
May 2015	20.28	20.66	15.16	15.16	13.70	13.70
Jun 2015	20.28	20.66	15.16	15.16	13.70	13.70
Jul 2015	19.72	20.63	15.42	15.42	13.97	13.97
Aug 2015	21.11	22.02	16.81	16.81	15.36	15.36
Sep 2015	20.11	21.02	15.82	15.82	14.37	14.37
Oct 2015	21.05	21.96	16.76	16.76	15.30	15.30
Nov 2015	19.92	20.82	15.62	15.62	14.17	14.17
Dec 2015	19.85	20.75	15.55	15.55	14.10	14.10
Jan 2016	19.68	20.59	15.39	15.39	13.94	13.94
Feb 2016	19.68	20.59	15.39	15.39	13.94	13.94
Mar 2016	19.68	20.59	15.39	15.39	13.94	13.94
Apr 2016	19.68	20.59	15.39	15.39	13.94	13.94
May 2016	19.68	20.59	15.39	15.39	13.94	13.94
Jun 2016	19.68	20.59	15.39	15.39	13.94	13.94
Jul 2016	19.47	20.38	15.18	15.18	13.73	13.73
Aug 2016	19.47	20.38	15.18	15.18	13.72	13.72
Sep 2016	19.47	20.38	15.18	15.18	13.73	13.73
Oct 2016	19.57	20.47	15.27	15.27	13.82	13.82
Nov 2016	19.59	20.50	15.29	15.29	13.84	13.84
Dec 2016	20.18	21.08	15.88	15.88	14.43	14.43
Jan 2017	20.16	21.07	15.87	15.87	14.42	14.42
Feb 2017	20.68	21.59	16.39	16.39	14.94	14.94
Mar 2017	20.31	21.22	16.02	16.02	14.56	14.56
Apr 2017	20.73	21.64	16.43	16.43	14.98	14.98
May 2017	20.39	21.30	16.10	16.10	14.64	14.64
Jun 2017	20.45	21.36	16.15	16.15	14.70	14.70
Jul 2017	20.45	21.35	16.15	16.15	14.70	14.70
Aug 2017	21.95	22.86	17.66	17.66	16.21	16.21
Sep 2017	20.56	21.47	16.26	16.26	14.81	14.81
Oct 2017	20.98	21.89	16.69	16.69	15.24	15.24
Nov 2017	21.92	22.83	17.63	17.63	16.17	16.17
Dec 2017	22.32	23.23	18.03	12.46	16.57	11.73
Jan 2018	22.57	23.48	18.28	12.71	16.83	11.99
Feb 2018	22.57	23.48	18.28	12.71	16.82	11.98
Mar 2018	23.27	24.17	18.97	13.40	17.52	12.68
Apr 2018	23.66	24.57	19.37	13.80	17.92	13.08

Appendix 3: List of Tools and Equipment Used During Audit

PEL 103 Energy Meter

Energy Meter Accuracy	
Voltage range Phase-to-phase RMS Voltages	100V to 1,000V DC ±0.2%Rdg ± 0.4V
Current probe	500mA to 10,000Ams Accuracy ± 1%
Frequency range	40Hz to 69Hz
Harmonics	1 to 50 displayed in percentage 1 to 7 at 400Hz (±655%)

The energy meter is used to measure and logs data such as currents, harmonics, voltages, phase angles and power factors.

C.A 8333 Energy & Power Quality Analyzer

C.A 8333 Energy & Power Quality Analyzer	
Voltage range Voltage ratio	2V to 1,000V AC/DC Up to 500kV
Current probe	1A to 1,300A AC/DC
Frequency range	40Hz to 69Hz
Harmonics	Yes, orders 0 to 50 per phase

The energy & power quality analyzer is a three-phase equipment used to measure and carry out diagnostics and power quality work on single or three phase networks. It can determine harmonic problems originating from source or load.

Extech EN150: 11-in-1 Environmental Meter with UV

Environmental Meter with UV	
m/s (res) Basic Accuracy	0.4 to 20(0.1) ±3% FS
Temperature Basic Accuracy	32 to 122ºF ±2.5ºF
UV Level	2 to 20mW/cm^2
Heat index	0 to 100ºC

Environmental Meter is used for measuring UV light level from natural sunlight.

True RMS AC/DC Watt Clamp-on meter

RMS AC/DC Watt Clamp-on meter	
AC Power Accuracy	40kW to 240kW ±(1.5%+3d @50/60Hz)
DC Power Accuracy	40kW to 240kW ±(1.5%+3d)
Current Accuracy	400A ±(1.5%+3d)
Voltage Accuracy	600V ±(1.5%+3d) @50/60Hz
Frequency range Accuracy	0.01 to 100Hz ±(0.8%+2d)

A clamp meter is used for measuring voltages, currents and resistance

Appendix 4A: Lux Level Mapping and Relative Humidity Measurements Results

Location	Lux Level		Other Parameters		Time
	Lamps On	Lamp Off	RH%	Temp (^{0}C)	Measured
Meeting Room1	537	514	53.5	27.2	12:01
Office 1	385	233	50.8	27.1	12:05
Office 2	954	555	51.3	26.8	12:08
Kitchen	627	495	49.4	27.3	12:20
Meeting Room 2	227	109	50.4	27.3	12:21
Amphitheatre	242	145	50.7	27.5	12:23
Server Room	610	465	51.5	27.1	12:31
National Project Manager Office	563	431	48.7	28.6	12:47
Project Office	277	241	49	28.9	12:51
Online Library	350	291	47.8	29.1	1:01
Library	1058	511	47.8	29.3	1:08

Appendix 4B: Required Lux Level Standards

ROOM TYPE	LIGHT LEVEL (FOOT CANDLES)	LIGHT LEVEL (LUX)	IECC 2015 LIGHTING POWER DENSITY (WATTS PER SF)
Classroom - General	30-50 FC	300-500 lux	1.24
Conference Room	30-50 FC	300-500 lux	1.23
Corridor	5-10 FC	50-100 lux	0.66
Kitchen / Food Prep	30-75 FC	300-750 lux	1.21
Laboratory (Classroom)	50-75 FC	500-750 lux	1.43
Laboratory (Professional)	75-120 FC	750-1200 lux	1.81
Library - Reading / Studying	30-50 FC	300-500 lux	1.06
Lobby - Office/General	20-30 FC	200-300 lux	0.90
Lounge / Breakroom	10-30 FC	100-300 lux	0.73
Mechanical / Electrical Room	20-50 FC	200-500 lux	0.95
Office - Open	30-50 FC	300-500 lux	0.98
Office-Private/Closed	30-50 FC	300-500 lux	1.11
Parking - Interior	5-10 FC	50-100 lux	0.19
Restroom / Toilet	10-30 FC	100-300 lux	0.98
Stairway	5-10 FC	50-100 lux	0.69
Storage Room - General	5-20 FC	50-200 lux	0.63

Appendix 5A: Data Collected Between 16-7- 2018 and 20-7- 2018

Item	Date	Consumption in kWh	
		Day	Night
1	16/7/2018	10.60	14.38
2	17/7/2018	11.32	14.01
3	18/7/2018	14.41	15.27
4	19/7/2018	20.49	16.54
5	20/7/2018	20.01	-

Appendix 5B: Voltages Measurements Between 25-7-2018 and 30-7-208

	Voltages in V	
Date	Morning	Afternoon
25/7/2018	BY-439 BR-436 RY-435	BY-437 BR-434 RY-435
26/7/2018	BY-441 BR-435 RY-435	BY-435 BR-430 RY-429
27/7/2018	BY-440 BR-437 RY-437	BY-438 BR-437 RY-435
30/7/2018	BY-430 BR-428 RY-428	BY-432 BR-433 RY-432

Note. BY-Blue Yellow lines, BR – Blue Red Lines, RY – Red Yellow lines

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