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MAKERERE UNIVERSITY BUSINESS SCHOOL

ASSESSMENT OF ENERGY DEMAND SIDE MANAGEMENT IN HIGHER INSTITUTIONS OF LEARNING LECTURE ROOMS: A CASE OF MUBS

By

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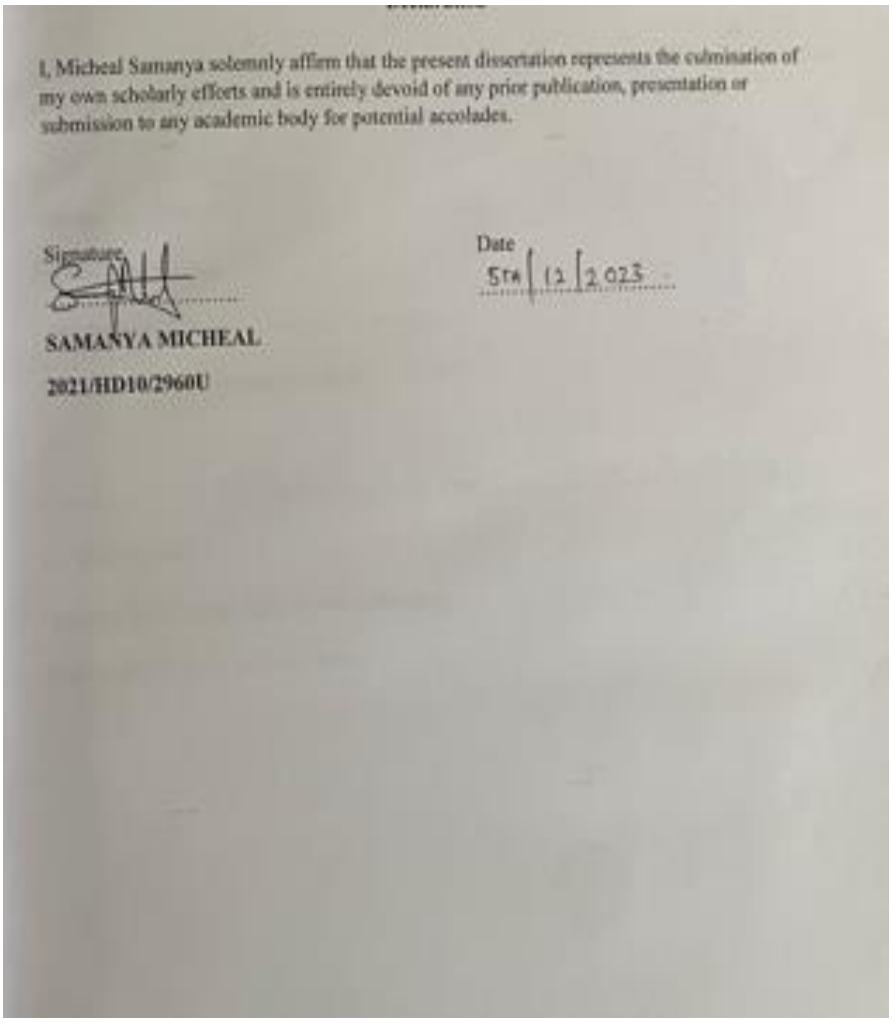
REG. NO: 2021/HD10/202960U

A DISSERTATION SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER'S DEGREE OF ENERGY ECONOMICS AND GOVERNANCE OF MAKERERE UNIVERSITY.

SEPTEMBER, 2023.

PLAN A

Declaration



I, Micheal Samanya solemnly affirm that the present dissertation represents the culmination of my own scholarly efforts and is entirely devoid of any prior publication, presentation or submission to any academic body for potential accolades.

Signature .....

Date 5th | 12 | 2023

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2021/HD10/2960U

Approval

This is to certify that this dissertation has been prepared with our guidance as University supervisors and it is ready for submission.

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Dedication

I wholeheartedly dedicate this dissertation to my invaluable mentors, Dr. Nicholas Mukisa and Dr. Ruth Atuhaire, whose unwavering guidance shaped this endeavor. To my cherished family, dearest friends, fellow course mates, and my ever-supportive parents, I extend my profound gratitude for the unwavering moral sustenance throughout my educational odyssey.

Acknowledgement

With profound gratitude, I extend my heartfelt thanks to the Almighty God for granting me the strength to persevere through myriad challenges and successfully complete this program. I wish to express my sincerest appreciation to my esteemed supervisors, whose unwavering dedication, expert guidance, considerable time, and constant support have been instrumental in shaping this research journey.

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Acronyms

MUBS	Makerere University Business School
IEA	International Energy Agency
kWh	Kilowatt-hours ($10^3\ watt-hours$)
TWh	Terawatt-hour ($10^{12}\ watt-hours$)
MW	Mega Watt
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
COP21	21st Conference Of Parties
GW	Gigawatt
DSM	Demand Side Management
IDSM	Integrated Demand Side Management
DR	Demand Response
EMS	Energy Management System
EE	Energy Efficiency
FERC	Federal Energy Regulatory Commission
DLC	Direct Load Control
TOU	Time-of-use
CPP	Critical Peak Pricing
RTP	Real-time Pricing
IBR	Inclining Block Rate
PAR	Peak-to-Average Ratio
SME	Small and Medium-Sized businesses
EEC1	Energy Efficiency Commitment 1
EEC2	Energy Efficiency Commitment 2
CFL	Compact Fluorescent Lamp
Gtoe/year	Gigaton of oil equivalent per year
CO2	Carbon dioxide
GtCO2	Gigatons of Carbon dioxide
HEI	Higher Education Institutions

Abstract

Global interest in Energy Demand Side Management (DSM) is growing, particularly in industrial and domestic sectors. However, there is a lack of attention in existing literature regarding DSM practices in higher education institutions, especially in developing countries. This study explores DSM in higher education lecture rooms, examining energy consumption, costs, emissions, and optimization strategies.

The analysis of energy consumption patterns in lecture rooms at higher education institutions reveals significant variations throughout the day, emphasizing the need for tailored DSM strategies. Morning sessions consume 2,564 kWh, afternoon sessions 3,467 kWh, and evening sessions peak at 4,095 kWh. Evening sessions stand out as the highest energy consumers due to reduced natural daylight, underscoring the urgency of DSM measures. These variations in energy consumption highlight the importance of adjusting energy use to match actual demand, rather than following static lighting schedules.

Key optimization strategies include dynamic lighting control, automated schedules, energy-efficient technologies like LEDs, maintenance of faulty lights, and occupancy-based lighting. These strategies align with the Unified Theory of Acceptance and Use of Technology (UTAUT), emphasizing factors influencing DSM adoption. Integrating these practices can lead to substantial reductions in energy consumption, further reinforced by figures indicating the potential for energy optimization during all sessions.

The study results revealed that for 76.58% of the study time, the Lights were kept ON and only switched OFF 23.42% of the study time in the month of March. The study quantified energy costs incurred by keeping lights ON during daytime, demonstrating that keeping lights ON in the selected lecture rooms during the morning, afternoon and evening sessions amounted to about UGX 591,504.24, UGX 797,538.89 and UGX 968,310.83, respectively, in the Month of March. These cost variations emphasize the need for DSM to manage demand and reduce expenses. Additionally, the embedded greenhouse gas emissions attributed to keeping lights ON were assessed to underscore the environmental impact. Keeping lights ON in the morning, afternoon and evening sessions accounted for about 189.23 kgCO2eq, 255.14 gCO2eq and 309.77 kgCO2eq emissions, respectively, in the e month of March. Embracing DSM strategies could contribute to a reduction in the carbon footprint in educational institutions' lecture rooms, aligning with global environmental goals. The study also reveals that energy consumption persists during weekends and holidays, with an actual energy consumption of 504.9 kWh. These figures highlight untapped opportunities for energy conservation during non-academic periods, further underscoring the need for efficient resource allocation.

In summary, this study emphasized the dynamic nature of energy consumption in higher education lecture rooms and underscores the significance of DSM strategies in optimizing energy usage. The integration of figures, including frequency, cost, and greenhouse gas emissions, reinforces the importance of DSM in minimizing energy wastage, reducing operational expenses, and contributing to environmental sustainability. Policy recommendations include incentivizing energy-efficient practices, integrating renewables, and fostering collaboration among institutions. Future research avenues involve a comprehensive consumption analysis, longitudinal studies, and advanced technology exploration to further enhance energy management in higher institutions of learning.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The building sector (including services and households) is anticipated to remain the main contributor to global electricity demand by 2040, according to the 2019 World Energy Outlook reported by the International Energy Agency (IEA). Sanchez-Escobar et al. (2021) report that households alone are anticipated to increase electricity consumption by 60%, especially in developing nations. The projected trend is linked to the potential increment in the buildings' demand for electricity by utilising more household appliances, electric vehicles and air conditioners, worsening the risk of increased carbon dioxide emissions. In addition, Härkönen et al. (2022) assert that the rapidly growing exploitation of renewable energy sources, such as solar and wind, raises concerns regarding how to strike a balance between consumption and production in the electric grid, especially with the growing share of non-adjustable generation.

Further, according to Bakare et al. (2023), governments, especially in the developing world regions such as sub-Saharan Africa, are finding it challenging to handle power problems, such as controlling efficiency, dependability, security and power losses amidst the sharp growth in global energy consumption. To address the critical need for energy security and sustainable development worldwide, demand-side management (DSM) has emerged as a crucial approach (Kamalakannan et al., 2018). Although demand-side energy management (DSM) minimises energy acquisition costs and the penalties associated with managing the appliance schedules and monitoring constant energy use, it has been less adopted in developing nations like Uganda (Aalami et al., 2019). However, the slow or failure to adopt advanced energy management techniques like the DSM has resulted in high peak loads, higher carbon emissions and increased levels of power demand, leading to regular power shade-offs.

In sub-Saharan Africa, institutional buildings such as offices consume more energy than households due to their higher access and application of modern electrical appliances, such as routers, conditioners, industrial machines, and other production equipment that rely on power (Ambole et al., 2021). Uganda is experiencing rapid economic growth, population expansion, and urbanisation, which has led to a sharp rise in energy demand (Omolo, 2019). Although Uganda is

endowed with abundant renewable energy resources, energy security, affordability, and accessibility are pressing concerns that demand immediate attention (Omolo, 2019; UBOS, 2021).

Government institutions, such as ministries, agencies and higher learning institutions, such as public universities, still incur exorbitant electricity bills from ineffective energy management strategies. For instance, while Makerere University spent over Ugandan Shillings (UGX.) 300 million monthly in power bills in 2021, UMEME disconnected Kyambogo University over UGX. 67.3 million, as reported by Daily Monitor (2021a; 2021b). The disconnection of Kyambogo University from the power grid left several departments in blackout as the few, like the administration block, relied on a diesel generator with its undesired effects, such as pollution of the environment. Moreover, an energy audit conducted by the Energy Efficiency and Conservation Program (EECP) of Uganda in 2021 identified Kyambogo University and Makerere University Business School (MUBS), an affiliate of Makerere University, among the top energy-consuming higher education institutions in the country partly due to large population of students and staff, as well as power consuming infrastructure compared to other institutions.

The 2019 Energy Policy report attributes energy conservation issues to a lack of awareness among 'energy end-users regarding energy efficiency practices and possibilities, thus hindering investments in demand-side management measures. Other cited causes of conservation inefficiencies include the absence of skilled and specialised personnel in energy management and the lack of incentives, such as reluctance to finance efficient practices and modern technologies (MEMD, 2021). However, the government of Uganda, through its Energy Policy report of 2019, advocates for efficiency in energy usage among institutions and households by advocating for energy conservation measures, such as the adoption of modern technologies, increased awareness and behavioural changes (MEMD, 2021). More so, through the Electricity Regulatory Authority (ERA), the government has set different tariffs to cater to different categories of electricity consumers, such as households, commercial and industry (ERA, 2021). Nevertheless, despite the differences in the tariffs, training and mass sensitisation by the government through the Ministry of Energy and Mineral Development (MEMD) and ERA institutions, particularly universities mainly Makerere University and Kyambogo University, still incur huge electricity bills, further increasing the burden on the taxpayer.

Although numerous empirical studies have been conducted to understand energy demand management at the national and international levels, they do not directly address the specific context of energy demand-side management in the mentioned universities in Uganda. For instance, while the study by Evuti et al. (2020) conducted an energy audit at the University of Abuja in Nigeria, a similar study has not been conducted in the context of energy demand-side management in higher institutions of learning in Uganda. Therefore, this leaves a research gap in understanding the energy consumption patterns, efficiency measures, and demand-side management practices, specifically in the Ugandan universities. Besides, an investigation by Okoboi and Mawejje (2016) focused on examining the trends and medium-term path of electricity peak demand in Uganda at a national level. Some scholars do not provide specific empirical findings on electricity demand patterns and behaviours within the academic settings of universities. This makes it challenging for higher learning institutions to develop effective demand-side management strategies tailored to unique needs.

Demand-side management (DSM) is vital for regulating electricity and gas consumption, benefiting consumers and utilities by managing load demands (Potter et al., 2018). However, insufficient DSM policies, especially in higher learning institutions, raise concerns. Absence of effective DSM programs adversely affects sectors like manufacturing, reducing profits and increasing electricity costs, driving peak loads up by nearly 38% (Javid et al., 2018). Fluctuations in renewable sources and traditional appliances disrupt power grid management (Javaid et al., 2018). This gap is critical in universities where power demand surges across residential, industrial, and campus buildings. Lack of awareness or effective implementation hinders cost reduction, revenue generation, and renewable adoption (Owusu & Asumadu-Sarkodie, 2016). Research is urgently needed to identify utility-integrated DSM strategies, considering customer roles (Potter et al., 2018; Corbett et al., 2018). Focus on smart devices in communities and homes is crucial (Gazafroudi et al., 2019). Universities can educate students about energy-saving, aiding sustainability. This study targets DSM challenges in higher education, aiming to guide energy-efficient policies and methods (Potter et al., 2018). The goal is a sustainable future for universities and the community.

Further, the existing studies provide sketchy information on how Uganda heavily relies on hydropower for electricity generation and faces challenges due to this overdependence. Although

Bongomin and Nziu (2022) and Fashina et al. (2019) point to the existence of energy systems that can diversify electricity generation, the researchers do not reveal specific information on the level of development and utilisation of these alternative energy systems in the context of the universities under consideration and the entire higher institutions of learning. In addition, despite Gołębiowska et al. (2020) exploring the impact of social norms on electricity consumption decisions, the study does not focus on the context of higher learning institutions in Uganda. Therefore, this leaves a huge research gap in understanding the influence of social norms on energy consumption behaviour among students, staff, and faculty at universities. To address the existing empirical research gaps, this study was considered the Lecture rooms of the different faculties in Makerere University Business School to assess the energy demand-side management practices. This study involved energy surveys and data analysis to understand the specific opportunities and challenges in promoting efficient energy consumption in the higher institutions in Uganda.

1.2 Problem statement

Demand-side management (DSM) is vital for regulating electricity and gas consumption, benefiting consumers and utilities by managing load demands (Potter et al., 2018). However, insufficient DSM policies, especially in higher learning institutions, raise concerns (Javid et al., 2018). Absence of effective DSM programs adversely affects sectors like manufacturing, reducing profits and increasing electricity costs, driving peak loads up by nearly 38% (Corbett et al., 2018; Javid et al., 2018). Fluctuations in renewable sources and traditional appliances disrupt power grid management (Javaid et al., 2018). This gap is critical in universities where power demand surges across residential, industrial, and campus buildings. Lack of awareness or effective implementation hinders cost reduction, revenue generation, and renewable adoption (Owusu & Asumadu-Sarkodie, 2016). Research is urgently needed to identify utility-integrated DSM strategies, considering customer roles (Potter et al., 2018; Corbett et al., 2018). Focus on smart devices in communities and homes is crucial and universities can educate students about energy-saving, thus, aiding sustainability (Gazafroudi et al., 2019).

The absence of effective energy DSM practices in higher learning institutions, particularly Makerere University (and MUBS) and Kyambogo in Uganda, has resulted in high monthly electricity bills and disconnections by the service provider (Joseph, 2021). For instance, in 2021, Makerere University spent over UGX. 300 million monthly on power bills, and Kyambogo University was disconnected due to unpaid bills of UGX. 67.3 million (Daily Monitor, 2021a;

2021b). Furthermore, EECP's energy audit clustered these universities among the country's top energy-consuming higher education institutions, partly due to inefficient energy management practices (EECP, 2021).

Despite the government's intervention through its policies advocating for energy efficiency and conservation, the challenge of high electricity bills among these institutions remains persistent (MEMD, 2021). Moreover, the existing studies such as Bongomin and Nziu (2022), Fashina et al. (2019), and Okoboi and Mawejje (2016) do not directly address the specific context of energy demand-side management in Higher Institutions of Learning, creating knowledge gaps in understanding these institutions' energy efficiency measures, demand-side management practices and energy consumption patterns. Therefore, to address these knowledge gaps, this study conducted energy surveys and data analysis to identify opportunities and develop effective demand-side management strategies tailored to Institutions of Higher Learning Lecture rooms' unique needs.

1.3 Purpose of the study

The main aim of this study was to examine the appropriateness of energy demand side management in Higher Institutions of Learning Lecture rooms.

1.4 Research objectives

i. To determine the daily electricity consumption units due to daytime lighting in the Lecture rooms.
ii. To determine the daily electricity costs incurred due to daytime lighting in the Lecture rooms.
iii. To investigate the greenhouse gas emissions due to daytime lighting in the Lecture room.
iv. To propose energy management measures Institutions of Higher Learning Lecture rooms can undertake to minimise energy wastage.

1.5 Research Questions

1. How many units of electricity are consumed daily due to lighting of the Lecture rooms during daytime?
2. What are the daily costs incurred to light the Lecture rooms during daytime?
3. What environmental consequences are associated with lighting the Lecture rooms during daytime?

4. What are the best DSM strategies that Higher Institutions of Learning in Uganda can adopt to minimise electricity wastage?

1.6 Scope of study

1.6.1 Content scope

This study aimed at exploring the feasible Energy Demand Side Management (DSM) strategies for reducing electricity costs in higher education institutions without compromising educational services. Practical approaches were identified and evaluated through literature review and case studies. The research assessed the energy consumption patterns, conducted financial analyses, and considered the institutional contexts to propose tailored DSM solutions. Additionally, emphasis was placed on behaviour change and awareness campaigns to foster a culture of energy conservation within the institutional community.

1.6.2 Geographical scope

This study focused on 27 out of the 35 existing Lecture rooms of the seven faculties at Makerere University Business School's main campus, Nakawa, to examine the behavioural patterns of both students and staff towards energy conservation. Acknowledging that the students across this Higher Institution of Learning originate from more or less similar communities and often share residences, it was assumed that students carry the same energy behavioural patterns to other institutions of learning. Likewise, several university staff, particularly teaching staff, work in more than one institution of learning; thus, using MUBS as a focal Institution of Higher Learning would depict more or less a similar pattern as for the other Institutions. Worth noting, the shortage of comprehensive DSM assessments and tailored energy management strategies in these institutions creates a scholarly gap in the understanding of energy demand management in the context of higher education (Otim et al., 2020).

1.6.3 Time scope

All study activities were executed within seven months, from February to August 2023. The tasks included proposal writing and approval, data collection and analysis, and report writing and submission.

1.7 Significance of the study

i. The study findings could guide the management of Institutions of Higher Learning, particularly MUBS in designing and implementing policies to minimise energy wastage. The study provides information on electricity consumption incurred daily due to lighting

the Lecture rooms. Therefore, by understanding the number of units consumed or the costs incurred daily, the management of these institutions can make informed decisions regarding the appropriate policies to manage their monthly electricity bills.

ii. By assessing the environmental impact of lighting the lecture rooms, the research determined how much greenhouse gas emissions threaten the natural environment. Hence, the study findings could guide the policymakers, Higher Institutions of Learning management, their staff members and students on the appropriate environmental strategies.

iii. Lastly, this study provided valuable insights into different factors influencing energy DSM among Institutions of Higher Learning. Therefore, the information gathered could be used to manage Uganda's energy sector for consultancy and scholarly purposes.

1.8 Conceptual framework

Figure 1 shows the conceptual framework for the proposed study.

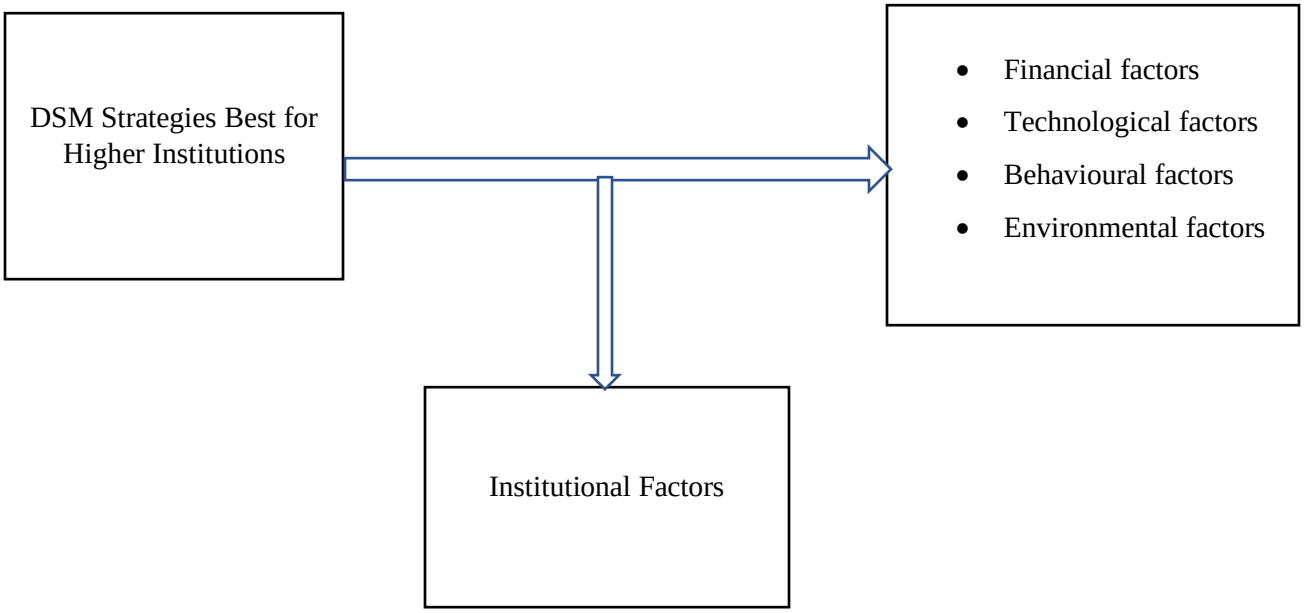


Figure 1: Study Conceptual Framework

Source: Author

The conceptual framework comprises four main components: Institutional Factors, Technological Factors, Behavioral Factors, and Environmental Factors, which were used to evaluate the effectiveness of Energy Demand Side Management (DSM) initiatives in Higher Institutions of Learning.

Institutional Factors: This component includes institutional culture, leadership, and policies that can influence the adoption and implementation of DSM initiatives in higher learning institutions. For example, the level of commitment from top management in implementing DSM initiatives, the availability of funding for DSM projects, and the existence of policies and regulations that support DSM initiatives.

Technological Factors: This component includes the technological solutions used to implement DSM initiatives, such as energy-efficient lighting, heating and cooling systems, renewable energy systems, and energy management systems. The effectiveness of these technologies was assessed based on their energy savings potential, cost-effectiveness, and ease of implementation.

Behavioural Factors: This component includes the behaviour of the various stakeholders in the higher institution of learning, such as students, faculty, staff, and administrators. These

stakeholders' behaviour can significantly influence DSM initiatives' success or failure. For example, the willingness of stakeholders to participate in energy-saving campaigns, adopt energy-efficient practices, and follow energy-saving guidelines.

Environmental Factors: This component includes the impact of DSM initiatives on the environment, such as reduction in greenhouse gas emissions, energy consumption, and carbon footprint. The environmental impact of DSM initiatives was evaluated based on the reduction in energy consumption and greenhouse gas emissions achieved.

By evaluating these four components, the study assessed the effectiveness of DSM initiatives in higher institutions of learning and identify the key factors that contribute to their success or failure.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Review

The Unified Theory of Acceptance and Use of Technology (UTAUT)

The study was anchored on the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT is a theoretical framework that explains how institutions and individuals adopt and use technology (Hewavitharana et al., 2021; Ayaz & Yanartaş, 2020). According to Hewavitharana et al. (2021), the theory identifies key factors influencing technology adoption and usage, including effort, performance, facilitating conditions, and social influence. These factors collectively contribute to an individual's or institution's intention to use a technology, which in turn influences their actual usage behaviour. In addition, the theory introduces moderating variables, such as gender, institutional factors, and age, which can impact the relationships between the explained and explanatory variables.

In this study, UTAUT provides a valuable lens to understand how financial, technological, behavioural, and environmental factors collectively shape the adoption of DSM strategies in higher institutions' lecture rooms. For example, the concept of "Facilitating Conditions" highlights the importance of available resources and support, which in this study relates to the financial resources that Higher Learning Institutions allocate for implementing energy-efficient technologies and practices. The study by Evuti et al. (2020) revealed how highly perceived financial facilitation leads to a positive attitude towards DSM among Institutions of learning in Nigeria. This is because institutions are likelier to adopt strategies that align with their budgetary considerations (Evuti et al., 2020).

Besides, the theory links technological factors to *"Performance Expectancy"* and "Effort Expectancy", which can be applied to the technological aspects of DSM. For instance, study findings by Ye et al. (2023), Yaïci et al. (2021), and Mela et al. (2018) resonate with "Performance Expectancy" in their arguments that institutions perceive that the technologies associated with DSM, such as smart meters and other automated energy control systems are efficient in curbing energy consumption and relatively easy to use, they are more inclined to adopt such strategies.

Furthermore, UTAUT's *"Behavioral Intention"* and *"Actual Use"* constructs provide suitable grounds to explain behavioural factors that influence institutions' intentions to engage in DSM

practices. The theory proposed that if the perceived behavioural intention is high, driven by positive attitudes, norms, and perceived behavioural control, the likelihood of adopting new technology, DSM strategies in this case, increases (Tamilarasu et al., 2021; Whittle et al., 2020). In addition, the relationship between institutions' intentions to engage in DSM practices and the environmental factors can be better explained by UTAUT's *"Performance Expectancy."* Helmers et al. (2021) assert that if organisations, such as higher institutions or universities, perceive DSM practices to substantially impact energy consumption and minimise carbon footprint, they tend to develop positive attitudes and intentions towards adopting strategies.

Lastly, the UTAUT framework provides a lens through which institutional factors can be observed as a mediating variable, facilitating the explained and explanatory variables. For instance, institutional support, resources, and policies can enhance or hinder the adoption of DSM strategies among organisations, higher institutions of learning in particular (Tamilarasu et al., 2021), which aligned with UTAUT's emphasis on the impact of facilitating conditions on technology adoption.

2.2 Empirical Review

2.2.1 Impact of Financial Factors on DSM Strategies

Financial development facilitates economic growth and industrialisation, leading to increased energy consumption. The study by Ma and Fu (2020) analysed data from 77 countries from 1990 through 2015 to examine the relationship between financial development and energy consumption. It revealed a positive relationship between financial development and energy consumption (Ma & Fu, 2020). This implies that countries with more developed financial systems tend to have higher energy consumption levels. Similarly, various demand-side policies, including energy efficiency programs, demand response initiatives, and behaviour change energy consumption campaigns (Warren, 2019). Further, Warren (2019) and Hoicka et al. (2021) highlight several mechanisms that can contribute to the success of demand-side policies, including cost-effectiveness, consumer engagement, technological advancements, and supportive institutional arrangements, of which the majority of these factors have financial implications on the energy consumers.

Although Ma and Fu (2020) and Warren (2019) acknowledge financial factors as the leading influencing energy demand variable, Panda et al. (2022) cite various aspects of residential DSM, including modelling techniques, optimisation algorithms, and potential future directions for research and implementation as the major influencers. Optimisation techniques in residential

DSM, including mathematical programming, evolutionary algorithms, and machine learning approaches, significantly influence the achievement of optimal energy management and cost savings (Panda et al., 2022).

On the other hand, Usman et al. (2022) and Bakare et al. (2023) discuss a wide range of DSM strategies, including time-of-use pricing, demand response programs, energy efficiency programs, and load management techniques. Lack of incentives, behavioural challenges, and technological limitations are the major barriers to adopting DSM strategies (Usman et al., 2022).

2.2.2 Influence of technological factors on energy DSM strategies

The studies by Bakare et al. (2023); Nasir et al. (2021); and Hussain et al. (2021) highlight the importance of technological solutions and methodologies for Energy Demand Side Management (DSM). These studies collectively emphasise the need for advancements in smart appliances, home energy management systems, and advanced metering infrastructure to enable effective DSM strategies. In addition, Bakare et al. (2023) and Nasir et al. (2021) suggest that integrating energy storage systems, electric vehicles, and renewable energy sources can significantly enhance grid reliability and flexibility. This integration allows for better energy demand and supply management, reducing peak demand and promoting energy efficiency. Advanced metering infrastructure and smart meters, as emphasised by Hussain et al. (2021), play a crucial role in enabling efficient DSM at the household level.

Nasir et al. (2021) further present alternative methodologies and techniques, such as optimisation algorithms, machine learning, and data analytics, which can optimise DSM strategies and improve their effectiveness. These advanced techniques allow for more accurate forecasting, demand response, and load balancing, leading to better energy management and cost savings.

On the other hand, Elio et al. (2021) provide an in-depth overview of various energy storage technologies suitable for DSM in industrial operations. By analysing the benefits and drawbacks of technologies like batteries, flywheels, compressed air energy storage, and thermal energy storage, Elio et al. highlights the importance of selecting the most appropriate energy storage solution based on specific industrial requirements. Furthermore, Dahiru et al. (2023) and Elio et al. (2021) emphasise the need to comprehensively examine energy storage technologies to identify the most suitable solutions for DSM in industrial operations. This highlights the importance of

considering cost-effectiveness, scalability, environmental impact, and operational requirements when implementing DSM strategies.

In conclusion, the mentioned studies provide valuable insights into technological solutions, methodologies, and the integration of renewable energy sources and energy storage systems for effective Energy Demand Side Management. These findings contribute to developing more efficient and sustainable DSM strategies for residential and industrial settings.

2.2.3 Behavioral factors and energy DSM strategies

Energy consumption within the residential sector is influenced by various factors, including consumer behaviour, social norms, and appliance choices (William et al., 2023). It is important to raise awareness, provide education, and engage stakeholders to promote energy-saving behaviours (Khan, 2019; William et al., 2023). Understanding energy consumption's cultural, social, and behavioural components is crucial for successful Demand Response (DR) programs, which aim to change energy consumption patterns based on power supply and demand (Shekari et al., 2021).

In addition, Traditional DR approaches often overlook human behaviour's significance in driving energy consumption patterns (Pratt & Erickson, 2020). By understanding and leveraging human behaviour, such as cognitive biases and social conventions, DR programs can effectively encourage customers to adopt energy-saving behaviours and participate in demand response activities (Schrammel et al., 2023; Silva et al., 2022; Pratt & Erickson, 2020).

Furthermore, Sloot et al. (2023) argue that behavioural science plays a vital role in understanding consumer participation in DR initiatives. Psychological elements, such as attitudes, beliefs, and preferences, influence customers' willingness to engage in demand response activities (Sloot et al., 2023; Lemon & Verhoef, 2016). It is essential to develop individualised and targeted approaches to engage consumers in demand response activities, taking into account their unique characteristics and preferences (Sloot et al., 2023; Lemon & Verhoef, 2016).

2.2.4 Institutional factors and energy DSM strategies

Energy management is important in educational institutions due to the substantial energy consumption associated with activities like heating, lighting, air conditioning (HVAC) systems, and ventilation (Tamilarasu et al., 2021). It is crucial to incorporate user comfort into demand-side management (DSM) strategies to ensure the acceptance and effectiveness of energy-saving measures. This highlights the need to consider the preferences and satisfaction of users when implementing energy-saving initiatives in educational institutions.

The success of DSM initiatives in educational institutions is significantly influenced by various factors, as highlighted by Usman et al. (2022). Legislative frameworks have a significant impact on the adoption and effectiveness of DSM initiatives. Policies, incentives, and laws that encourage educational institutions to actively participate in energy-saving measures can be effective. (Dahiru et al., 2023; Usman et al., 2022). Additionally, Usman et al. (2022), Panda et al. (2022), and Bakare et al. (2023) argue that another major issue is the availability of infrastructure and resources. DSM methods, such as investing in energy-efficient technologies and infrastructure renovations, can be adopted and implemented more easily by educational institutions with adequate infrastructure and resources.

2.2.5 Environmental factors and energy DSM strategies

DSM has the potential to cut energy consumption, increase energy efficiency, reduce peak load, and improve grid resilience. These advantages help to ensure environmental sustainability, financial savings, and energy security (Usman et al., 2022; Sylvia et al., 2013; Dahiru et al., 2023). In addition, Weather conditions have a considerable impact on energy demand. Weather-sensitive demand response programs can successfully regulate energy usage during extreme weather events by anticipating demand changes and adjusting pricing or incentives based on weather forecasts (Gurriarian et al., 2023; Burillo, 2018).

The increasing use of renewable energy sources such as solar and wind needs adaptable DSM techniques. DSM is critical in balancing energy supply and demand, optimising renewable energy consumption, and decreasing dependency on traditional backup power sources (Panda et al., 2022).

2.3 Summary of the Literature and Gaps/ Limitations in the Existing Studies

In the domain of financial factors and their influence on DSM strategies, a shared understanding emerges regarding the positive correlation between financial development and increased energy consumption (Ma & Fu, 2020). This observation underscores the potential role of financial systems in shaping demand-side policies. However, a discernible gap becomes evident in the literature: a lack of thorough investigation into specific financial barriers that might hinder the effective adoption of these policies. Additionally, while scholars acknowledge the link between financial development and energy consumption, there remains a distinct lack of granularity in delineating the precise mechanisms through which financial systems influence the success of demand-side policies, underscoring a significant knowledge gap (Ma & Fu, 2020).

Turning to technological factors and their impact on energy DSM strategies, researchers converge on the importance of technological solutions such as smart appliances and integrating energy storage systems to enhance DSM effectiveness (Bakare et al., 2023; Nasir et al., 2021). Nonetheless, divergent viewpoints arise when considering the focus on residential versus industrial contexts. While some studies prioritise the residential domain, others emphasise industrial applications of DSM. This divergence reveals a conspicuous gap in the lack of holistic evaluation of energy storage solutions tailored to specific contexts. This gap hampers the seamless implementation of DSM strategies across varied sectors and impedes the potential for holistic efficiency improvements.

The impact of behavioural factors on energy DSM strategies garners consensus around the pivotal role of consumer behaviour and the imperative of awareness-raising initiatives (William et al., 2023). However, an unmistakable gap emerges regarding integrating behavioural insights into Demand Response (DR) programs. While some researchers acknowledge the importance of leveraging human behaviour to promote energy-saving practices, the broader infusion of cognitive biases and social conventions into DR initiatives remains relatively underdeveloped. This gap underscores an unexplored opportunity to harness behavioural science's full potential to enhance DSM strategies' effectiveness.

To conclude, the exploration of financial, technological, behavioural, and institutional factors within the context of energy DSM strategies reveals both convergent viewpoints and areas of divergence among researchers. These divergent perspectives underscore notable literature gaps,

including the need for in-depth examinations of financial barriers, contextually tailored evaluations of energy storage solutions, and a more comprehensive integration of behavioural insights into DR programs. Addressing these gaps could substantially advance the understanding and implementation of effective DSM strategies across diverse contexts, thereby contributing to more sustainable and efficient energy consumption practices.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

The utilized delivery techniques for this study are discussed in this chapter. It elucidates the different methods and procedures that were used to collect and evaluate the data, as well as the population and sample methodologies applied for this project. The chapter specifically covers the research design, methodology, study population, sampling process, data collecting, procedure, research instruments, data analysis, validity and reliability, research ethics, and data analysis.

3.2 Research design

A quantitative approach entails precise measurements, mathematical, numerical, or statistical analysis of the data gathered through questionnaires, polls, and surveys, or the use of computing methods to alter the previously collected statistical data (Saunders et al., 2009). The research employed a quantitative assessment of the DSM strategies on energy consumption. From this, the research suggested the best DSM technique that Institutions of Higher Learning can use to enhance energy efficiency and management.

3.3 Study Population

A study population is a broad category from which conclusive evidence must be drawn (Banerjee & Chaudhury, 2010). According to Babbie (2011), the population has characteristics in common from which the researcher hopes to derive conclusions. The study population consisted of 35 Lecture rooms shared by seven faculties, out of which 27 were used as study units in this research, as shown in **Table 1**. The Lecture rooms for blocks highlighted in blue color in **Table 1** were not considered in this study.

Table 1: Study blocks and rooms at MUBS

Blocks	Room	Blocks	Room	Blocks	Room	Blocks	Room
Block 2	Rm1	Block 7	Rm1	Short Tower	Level1	Digital Laboratory	Rm1
Block 3	Rm1		Rm2		Level2	Former Minister's Block	Rm1
	Rm2	Block 8	Rm1		Level3		Rm2
	Rm3	Block 11	Rm1	ADB	Lecture theatre1	Former Library	Upper
Block 4	Rm1		Rm2		Lecture theatre2		Lower
	Rm2	Walusansa	Rm1	Kamya House II	Room1		
	Rm3	Former GRC	Rm1	Block G	Upper		
	Rm4	Block 12	Rm1		Lower		
Block 5	Rm1		Rm2	New Building	Upper		
	Rm2	WTO	Rm1		Lower		

Source: Author

3.4 Sample size determination

Sampling refers to a technique in which a subset of people (sample size) or social phenomena are chosen from a broader universe (population) to which they belong in order to be studied (Kothari, 2004). A sample is a representative subset of the population (Johnson & Christensen, 2012).

It has been stressed that sampling is a key tactic for accurately describing the characteristics of a population under study (Ngulube, 2010). This study focused on six blocks randomly selected to study their electricity usage during and after classroom time.

3.5 Data Collection Method

In a mixed-methods design, data is gathered using complementary data collection techniques that independently enlist quantitative and qualitative data sequentially or concurrently (Halcomb et al., 2009). In this study, data was collected using a catalogue designed to capture all the necessary

information about electricity usage that will facilitate the effective study of the DSM in different Lecture rooms of Higher Institutions. Data collection was based on an observatory approach where the researcher routinely visited the different lecture rooms to record whether the lights are ON or OFF and whether there are lectures or not during the data collection period. Figures 2 and 3 show some of the energy management observations made while collecting data. Additional figures are given in the Appendix 2.



Figure 2: New Building Upper taken on 19/03/2023, at 9:03A*M*
Source: Author's phone camera observational empirical data



Figure 3: Digital Laboratory taken on 13/03/2023 at 3:06PM.
Source: Author's phone camera observational empirical data

3.6 Study definitions

Demand Side Management: Demand-side management is a "*set of technologies, actions and programs on the demand-side of energy meters, as implemented by governments, utilities, third parties or consumers, to manage or decrease energy consumption through energy efficiency, energy conservation, demand response or on-site generation and storage, in order to reduce total energy system expenditures or to contribute to the achievement of policy objectives, such as emissions reduction, balancing supply and demand or reducing consumer energy bills"* (Warren, 2018).

Literature broadly categorizes DSM into two classifications (Albadi et al., 2007).

(i) Demand Response

(ii) Energy Efficiency

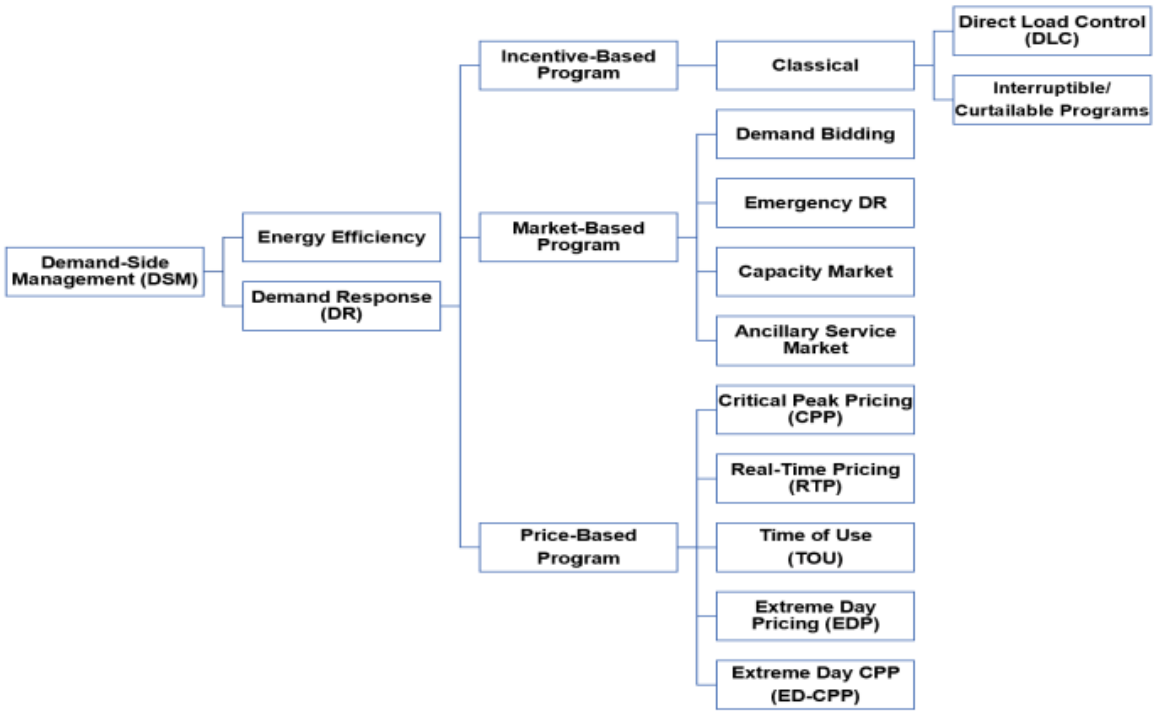


Figure 4: Classification of the Demand Side Management (Albadi et al., 2007).

Demand Response

Demand Response as ‘‘*changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized*” according to the Federal Energy Regulatory Commission (FERC).

Demand response (DR) describes the variations in load consumption by end-user side consumers from their typical usage patterns in response to the change in unit tariffs over time or based on incentivized programs offered to reduce the load consumption during times of high tariffs in the electricity wholesale market or during situations where the grid stability is unstable (Lee et al., 2013). When demand is low, or the spinning reserve capacity is at a minimum, DR is largely concerned with making short-term adjustments during the day's important peak pricing/usage periods (Panda et al., 2022).

Demand Response programs can be categorized into three categories according to the party utilizing the DR program, as illustrated below:

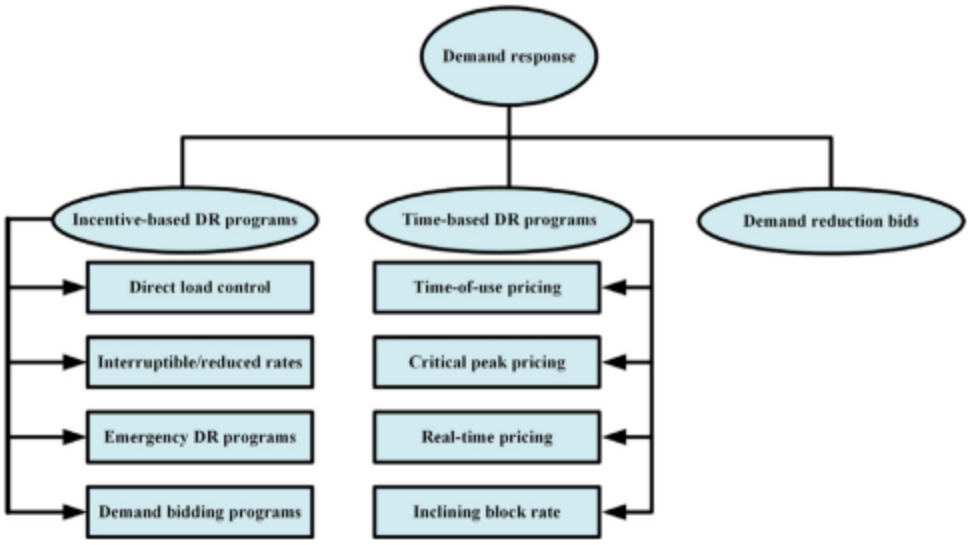


Figure 5: Demand Response Programs based on the initiating party (Panda et al., 2022).

(i) Incentive-Based Programs

In this program, consumers that make up the participating mass in the proposal of voluntary basis demand reduction bids or mandatory orders are delivered a mixture of DR signals that have been notified by the utility or the DR management service provider (aggregator). Based on information signals received from the system operators, a number of resources can be integrated under the self-dispatch program, which can be directly controlled, or loads that can be disrupted or demand can be lowered (Brooks et al., 2010).

The following are some of the strategies under this category.

Direct Load Control (DLC)

Under this program, select customers or devices are registered so that the utility can remotely regulate them and turn them off or change their operating cycle as needed (often during peak load times or events) (Zhang et al., 2016; Cui et al., 2015; Shad et al., 2015). The customers who are the participants of this program are paid in the form of an incentive to induce them to go in for this program.

Interruptible/ reduced rates

Some customers can choose specific pricing plans that may have an impact on other customers in the event of a curtailment, but they benefit from limited load shelters. Reserve capacity may typically be sent out in these circumstances for crucial tasks without upsetting the general consumer base, generating more revenue (Panda et al., 2022).

Emergency DR programs

In this scheme, some customers can manually reduce their loads on their own initiative to give the utility more control in emergencies. The consumers who participate voluntarily receive incentives as a reward (Lee et al., 2013).

Demand bidding programs

In this scheme, consumers can gain from cost savings through their willingness to reduce certain consumption at a specified bid tariff during peak periods or crisis scenarios (Saebi et al., 2010). This program is often available to large users (more than 1 MW), while for small users, participation in the bidding process requires third-party representation (Panda et al., 2022).

(ii) Time-based DR Programs

These are also known as price-based DR programs, which enable the provision of various tariff rates to consumers at various times (Yang et al., 2014).

According to the information available on this tariff, consumers will consume less electricity during periods of high prices, which eventually results in a fair reduction of the load demands during the peak periods of the day (Zhou et al., 2019: Celebi & Fuller, 2012: Yang et al., 2012).

In this approach, rather than reducing load by directly controlling appliances, consumers dynamically alter their load usage profile patterns in response to changes in tariff rates (Panda et al., 2022).

The following are some of the time-based tariff assignment methods used.

Time-of-use (TOU) Pricing

In this pricing method, different tariffs are applied at various times throughout the day, and tariff rates are gradually altered based on a number of time blocks. A single day is typically divided into three blocks: the on-peak, mid-peak, and off-peak periods (Datchanamoorthy et al., 2011).

The utility operators maintain the tariff at higher levels during on-peak times, leading to high unit purchase prices for electricity during these peak times. For the purpose of balancing the overall load consumption pattern, this encourages users to reduce their load usage during peak hours and move these loads to either mid-peak or off-peak durations (Panda et al., 2022).

Critical Peak Pricing (CPP)

The majority of the time, this method is used when the load utilization exceeds 20 kW, and there is a smart metering capability that logs the load usage every fifteen minutes. This time period is identified as a critical moment when significant load utilization is concentrated there (Herter, 2007). The TOU peak tariff is switched out for the CPP tariff during the crucial period. Consumers are expected to shift their load usage to times outside of crucial periods in order to balance out the load demand (Panda et al., 2022).

Real-time Pricing (RTP)

This approach is also known as a dynamic pricing approach since it predetermines different rates for certain time intervals (often every 15 minutes) based on hourly-ahead or day-ahead tariffs and consumption trends (Allcott, 2009). RTP is regarded as one of the most effective and financially viable time-based pricing approaches (Edward & Policy, 2005). An excellent illustration of RTP implementation is the hourly-based RTP used in Illinois, USA (Panda et al., 2022).

Inclining Block Rate (IBR)

This technique makes use of various blocks of tariff structures, often a two-level tariff structure (low and high pricing block). The consumer must pay the higher tariff on a per-kWh basis who consumes more electricity (Borenstein, 2008). After exceeding a particular limit, increasing electricity use will cause the customer to be moved to a higher tariff block, acting as a kind of penalty-based pricing. IBR offers incentives to customers in exchange for them spreading out their

usage throughout different hours of the day to avoid paying higher rates, which gradually lowers the grid system's peak-to-average (PAR) ratio. Since the 1980s, this tariff technique has been successfully and widely applied in numerous power distribution businesses. Pacific Gas and Electric, San Diego gas providers, and Southern California Edison are just a few examples (Borenstein, 2008).

(iii). Demand reduction bids

Demand reduction bids between the utility and operator are used by participating consumers to transact (Mohagheghi et al., 2010). The bids typically include the demand price and any available demand reduction capacity. This tactic persuades large-scale users to reduce their loads at a price they feel comfortable changing their usage habits or accepting the amount of load that can be reduced within the announced/bid price (Han & Piette, 2008).

Energy Efficiency

These changes mainly concentrate on reducing the load profile at the device level through energy efficiency enhancement strategies, hence permanently improving load consumption. As opposed to focusing on an event-driven method for load reduction, here energy efficiency refers to the outcomes produced by giving more output power for each unit of power that is given as an input to the appliance, leading to a reduction in consumption at all times (Chowdhury et al., 2018: Tronchin et al., 2018). Energy efficiency strongly emphasises convincing consumers to use efficient items to reduce demand (Behrangrad, 2015; Palensky et al., 2011 & Albadi et al., 2008). There are sixty-three million small and medium-sized businesses (SMEs), of which the majority lack energy efficiency because of outdated, inefficient technologies (Usman et al., 2022).

3.7 Data Analysis and Presentation

The data collected was analyzed using statistical software (Microsoft Excel) where the study assessed the effect of DSM strategies on the consumption of energy.

A List of equations used in the data analysis was categorized depending on the following:

i. Frequency of usage of the lights

Let X represent the number of lights being switched on at the time of data collection

Let X' represent the number of lights being switched off at the time of data collection

Let F represent the number of functional lights at the time of data collection

Let F' represent the number of lights being faulty at the time of data collection

Let Y represent lectures being ongoing at the time of data collection

Let Y' represent lectures not being ongoing at the time of data collection

Let L represent the total number of lights in the lecture rooms under study

Let N represent the total number of data points

To get the frequency of lights being on, this can be utilized:

$$Frequency\ of\ Lights\ ON = \frac{Number\ of\ times\ \ Lights\ are\ ON}{Number\ of\ data\ points}$$

$$F(X) = \frac{n(X)}{n(N)} \quad (1)$$

To compute the frequency of lights being off;

$$Frequency\ of\ Lights\ being\ OFF = \frac{Number\ of\ times\ Lights\ are\ OFF}{Number\ of\ Data\ points}$$

$$F(X') = \frac{n(X')}{n(N)} \quad (2)$$

The Frequency of Functional Lights is computed as:

$$Frequency\ of\ Functional\ Lights = \frac{Number\ of\ Functional\ Lights}{Total\ Number\ of\ Lights}$$

$$F(F) = \frac{n(X \cap F)}{n(L)} \quad (3)$$

The frequency of Faulty lights is given as:

$$Frequency\ of\ Faulty\ Lights = \frac{Number\ of\ Faulty\ Lights}{Total\ Number\ of\ Lights}$$

$$F(F') = \frac{n(X \cap F')}{n(L)} \quad (4)$$

The frequency of lectures being ongoing is given as follows:

$$Frequency\ of\ Lectures\ being\ ongoing = \frac{Number\ of\ times\ are\ ongoing}{number\ of\ Data\ points}$$

$$F(Y) = \frac{n(Y)}{n(N)} \quad (5)$$

The frequency of lectures not being ongoing can be computed as follows:

$$Frequency\ of\ Lectures\ not\ ongoing = \frac{number\ of\ times\ lectures\ were\ not\ ongoing}{number\ of\ Data\ points}$$

$$F(Y') = \frac{n(Y')}{n(N)} \quad (6)$$

How often are lights ON when lectures are ongoing?

$$Frequency\ of\ lights\ ON\ and\ Lectures\ ON \frac{=\ the\ number\ of\ times\ Lectures\ are\ Ongoing\ and\ Lights}{are\ on\ a\ number\ of\ Data\ points.}$$

$$F(X \cap Y) = \frac{n(X \cap Y)}{n(N)} \quad (7)$$

How often are lights OFF when lectures are ongoing?

$$Frequency\ of\ lights\ OFF\ and\ Lectures\ ON = \frac{number\ of\ times\ Lectures\ are\ Ongoing\ and\ Lights\ being\ OFF}{Number\ of\ Data\ points.}$$

$$F(X' \cap Y) = \frac{n(X' \cap Y)}{n(N)} \quad (8)$$

How often are lights ON when there are no lectures?

$$Frequency\ of\ lights\ ON\ and\ Lectures\ OFF = \frac{number\ of\ there\ are\ no\ lectures\ and\ Lights\ being\ ON}{Number\ of\ Data\ points.}$$

$$F(X \cap Y') = \frac{n(X \cap Y')}{n(N)} \quad (9)$$

How long were the lights on during the day?

That question was answered based on the assumptions the researcher made while conducting the research. The researcher visited these lecture rooms in three periods that can be categorized as follows in Table 2.

Table 2: A table of the disaggregation of the different study session periods in hours

S/N	Sessions	Observation time	Period (hours)
I	7:00 AM-10:00 AM	9:00 AM	3
II	10:00 AM-2:00 PM	11:00 AM	4
III	2:00 PM-7:00 PM	3:00 PM	5

Source: Author

Remark: If the lights were found on, then they were expected to stay on for the entire session, and if the lights were found off, then they were expected to stay off the entire session.

ii. Energy consumption

$$Energy\ Consumption = Power\ (W) \times time(h) \quad (10)$$

The power rating of each of the fluorescent lights used in the Lecture rooms at MUBS is 36W.

Energy Consumption per session

Let S_I represent the morning session, S_{II} represent the afternoon session, and S_{III} represent the evening session.

Energy consumed was categorized as expected energy consumed, the actual energy consumed, energy consumed due to faulty lights and the unconsumed energy due to faulty lights.

Expected energy consumed per session

$$E_{E,S_I} = L_{T,n} \times L_W \times S_I \times M_d \quad (11)$$

Where, E_{E,S_I} is the expected energy consumed during the morning session

$L_{T,n}$ is the total number of lights in each study unit

S_I is the morning session duration

L_W is the Wattage of the fluorescent tubes

M_d is the period of the study

Note, it is only the session time that changes for the afternoon and evening sessions to get their respective expected energy consumed.

For the afternoon;

$$E_{E,S_{II}} = L_{T,n} \times L_W \times S_{II} \times M_d \quad (12)$$

S_{II} is the afternoon session duration

For the evening session.

$$E_{E,S_{III}} = L_{T,n} \times L_W \times S_{III} \times M_d \quad (13)$$

S_{III} is the evening session duration

Actual energy consumed per session

For the morning session

$$E_{A,\,S_I} = F_l \times L_W \times S_I \quad (14)$$

$E_{A,\,S_I}$ is the Actual energy consumed during the morning session

F_l is the number of functional lights

S_I is the morning session duration

For the afternoon session

$$E_{A,S_{II}} = F_l \times L_W \times S_{II} \quad (15)$$

S_{II} is the afternoon session duration

$$E_{A,S_{III}} = F_l \times L_W \times S_{III} \quad (16)$$

S_{III} is the evening session duration

Ratio (Share) of Actual energy consumed to Expected Energy consumed per session

For the morning session

$$S_{E\ S_I} = \frac{E_{A,S_I}}{E_{E,S_I}} \tag{17}$$

For the afternoon session

$$S_{E\ S_{II}} = \frac{E_{A,S_{II}}}{E_{E,S_{II}}} \tag{18}$$

For the evening session

$$S_{E\ S_{III}} = \frac{E_{A,S_{III}}}{E_{E,S_{III}}} \tag{19}$$

For the evening session

$$S_{E\ SIII} = \frac{E_{A,SIII}}{E_{E,SIII}} \tag{20}$$

Energy not consumed due to faulty lights (energy saved by faulty lights)

$$E_{F,S_I} = F_f \times L_w \times S_I \tag{21}$$

E_{F,S_I} is the energy that is not consumed due to the faulty lights during the morning session

F_f is the number of faulty lights

L_W is the Wattage of the fluorescent tubes

S_I is the morning session duration

For the afternoon session

$$E_{F,S_{II}} = F_f \times L_w \times S_{II} \tag{22}$$

S_{II} is the afternoon session duration

$$E_{F,S_{III}} = F_f \times L_w \times S_{III} \tag{23}$$

S_{III} is the evening session duration

Proportion of energy due to faulty lights per session

$$S_{E_{U_{fI}}} = \frac{E_{F,S_I}}{E_{S,S_I}} \quad (24$$

$S_{E_{U_{fI}}}$ is the proportion of unconsumed energy due to faulty lights during the morning session

E_{F,S_I} is the energy not consumed by faulty lights during the morning session

E_{S,S_I} is the energy that should be consumed during the morning session

$$E_{F,S_I} + E_{A,S_I} = E_{S,S_I} \quad (25)$$

For the afternoon session

$$S_{E_{U_{fII}}} = \frac{E_{F,S_{II}}}{E_{S,S_{II}}} \quad (26)$$

$S_{E_{U_{fII}}}$ is the proportion of unconsumed energy due to faulty lights during the afternoon session

$E_{F,S_{II}}$ is the energy that is not consumed due to faulty lights during the afternoon session

$E_{S,S_{II}}$ is the energy that should be consumed during the afternoon session

$$E_{F,S_{II}} + E_{A,S_{II}} = E_{S,S_{II}} \quad (27)$$

For the evening session

$$S_{E_{U_{fIIi}}} = \frac{E_{F,S_{III}}}{E_{S,S_{III}}} \quad (28)$$

$S_{E_{U_{fIII}}}$ is the proportion of unconsumed energy due to faulty lights during the evening session

$E_{F,S_{III}}$ is the energy that is not consumed due to faulty lights during the evening session

$E_{S,S_{III}}$ is the energy that should be consumed during the evening session

$$E_{F,S_{III}} + E_{A,S_{III}} = E_{S,S_{III}} \quad (29)$$

Cost of Energy

The total energy cost of the university on lighting can be computed as follows:

$$Energy\ Cost = Energy\ consumption \times Days\ per\ month \times Energy\ cost\ per\ \frac{kWh}{1000} \quad (30)$$

Cost of Expected energy

In the morning session

$$C_{E,S_I} = E_{E,S_I} \times P_{TOU} \quad (31)$$

Where, $C_{E,\,S_I}$ is the cost of expected energy during the morning session

E_{E,S_I}, is the expected energy during the morning session

P_{TOU} is the time of use tariff price

For the afternoon session

$$C_{E,S_{II}} = E_{E,S_{II}} \times P_{TOU} \quad (32)$$

For the evening session

$$C_{E,S_{III}} = E_{E,S_{III}} \times P_{TOU} \quad (33)$$

Cost of Actual energy

$$C_{A,S_I} = E_{A,S_I} \times P_{TOU} \quad (34)$$

Where $C_{A,\,S_I}$ is the cost of actual energy during the morning session

E_{A,S_I} is the actual energy during the morning session

P_{TOU} is the time of use tariff price

For the afternoon session

$$C_{A,S_{II}} = E_{A,S_{II}} \times P_{TOU} \quad (35)$$

For the evening session

$$C_{A,S_{III}} = E_{A,S_{III}} \times P_{TOU} \quad (36)$$

Cost of Energy saved when lights are switched ON per session

$$C_{E_F,S_t} = E_{F,S_t} \times P_{TOU} \quad (37)$$

C_{E_F,S_I} is the cost of energy saved due to faulty lights during the day

E_{F,S_t} is the energy that is not consumed (saved) due to faulty lights during the day

P_{TOU} is the time of use tariff price

In this research, saving was defined as a situation where, on a given day, lights were ON for at least one session. Thus, a day where the lights were OFF for all the sessions is described as an expected situation.

iii. Green House Gas (GHG) emissions

Expected GHG emissions per session

$$GHG_{E,S_I} = E_{E,S_I} \times G_{ef} \quad (38)$$

Where, $GHG_{E\ S_I}$ is the expected GHG emissions during the morning session

E_{E,S_I} is the expected energy consumed during the morning session

G_{ef} is the grid emission factor of the fluorescent tubes

For the afternoon session

$$GHG_{E,S_{II}} = E_{E,S_{II}} \times G_{ef} \quad (39)$$

For the evening session

$$GHG_{E,S_{III}} = E_{E,S_{III}} \times G_{ef} \quad (40)$$

Actual GHG emissions per session

Morning session

$$GHG_{A,S_I} = E_{A,S_I} \times G_{ef} \quad (41)$$

Where, $GHG_{E\ S_I}$ is the actual GHG emissions during the morning session

$E_{A,\ S_I}$ is the actual energy consumed during the morning session

G_{ef} is the grid emission factor of the fluorescent tubes

For the afternoon session

$$GHG_{A,S_{II}} = E_{A,S_I} \times G_{ef} \quad (42)$$

For the evening session

$$GHG_{A,S_{III}} = E_{A,S_{III}} \times G_{ef} \quad (43)$$

GHG emissions saved/ avoided during the study

$$GHG_{Sa,S_I} = E_{F,S_t} \times G_{ef} \quad (44)$$

Where, GHG_{Sa,S_I} is the GHG emissions avoided during the study

E_{F,S_t} is the energy not consumed (saved) by faulty lights during the day

G_{ef} is the grid emission factor of the fluorescent tubes

The results of the analyses provided substantial grounds to propose better energy-saving methods to take on as Institutions of Higher Learning.

3.8 Validity and Reliability of the Research Instruments

While validity represents the degree of accuracy and precision assessed by the researcher from all the data in the study, reliability refers to the consistency of ratings (Bryman, 2008). To verify the validity and reliability of the data obtained, the supervisors did a pre-test the research instruments for item suitability.

CHAPTER FOUR

4.0 PRESENTATION, ANALYSIS AND INTERPRETATION OF RESULTS

4.1 Introduction

In this pivotal chapter, the study transitions from theoretical exploration to empirical revelation, presenting the culmination of the assessment of Energy Demand Side Management (DSM) within lecture rooms of higher learning institutions. This chapter encompasses the presentation, interpretation, and analysis of the obtained results aligned with the study's predefined objectives. These objectives encompass:

i. To determine the daily electricity consumption units due to daytime lighting in the Lecture rooms.
ii. To determine the daily electricity costs incurred due to daytime lighting of the Lecture rooms.
iii. To investigate the Green House Gas emissions due to daytime lighting of the Lecture rooms.
iv. To propose energy management measures Institutions of Higher Learning Lecture rooms can undertake to minimize energy wastage.

4.2 Descriptive statistics

Descriptive statistics have been meticulously computed to analyze the frequencies of various operational states within the lecture rooms at Institutions of Higher Learning. These states include Lights ON, Lights OFF, Functional Lights, as well as Faulty or Malfunction Lights. Additionally, the frequencies of ongoing lectures, instances where lectures are not being held, and specific combinations such as Lights ON with Lectures On, Lights ON with Lectures OFF, and Lights OFF during Lectures have all been examined. This comprehensive analysis is imperative, as these combined factors significantly influence the efficacy of energy Demand Side Management (DSM) strategies within lecture rooms at academic institutions.

4.2.1 Status of Lecture room illumination

By integrating Equation 1 and Equation 2 with the empirical data acquired from the lecture rooms, the outcomes are unveiled through Figure 4. This visualization effectively portrays the frequency distribution of Lights ON and Lights OFF instances, painting a comprehensive picture of the energy consumption patterns within the lecture rooms. The insights offered by Figure 6 underscore these equations' critical role in discerning and addressing the intricate interplay between lighting utilization and energy efficiency.

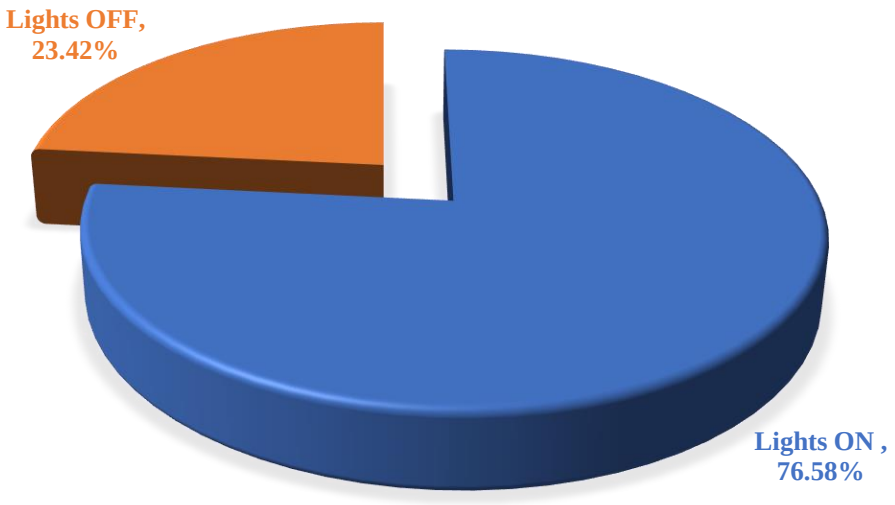


Figure 6: Frequency of the Lights ON/ Lights OFF in the Lecture rooms.
Source: Author's own computation using observational empirical data

The analysis of the collected data reveals significant insights into the energy consumption patterns within lecture rooms in higher institutions of learning. The results indicate that lights were ON for

approximately 76.58% of the entire data collection period, while they were OFF for the remaining 23.42% of the time. This stark contrast highlights a potential area for improvement through the implementation of Energy Demand Side Management (DSM) strategies.

The prominent finding that lights were ON for the majority of the data collection period underscores the necessity for a more efficient approach to energy consumption. The presence of instances when lights remained ON even when not essential, suggests a clear opportunity for energy conservation.

In this analysis, we delve into the status of lights within different study blocks of the institution, shedding light on the percentage of lights left on. This breakdown provides valuable insights into energy consumption patterns, highlighting areas where energy management measures can be strategically implemented to minimize wastage and promote sustainability as shown in Figure 7.

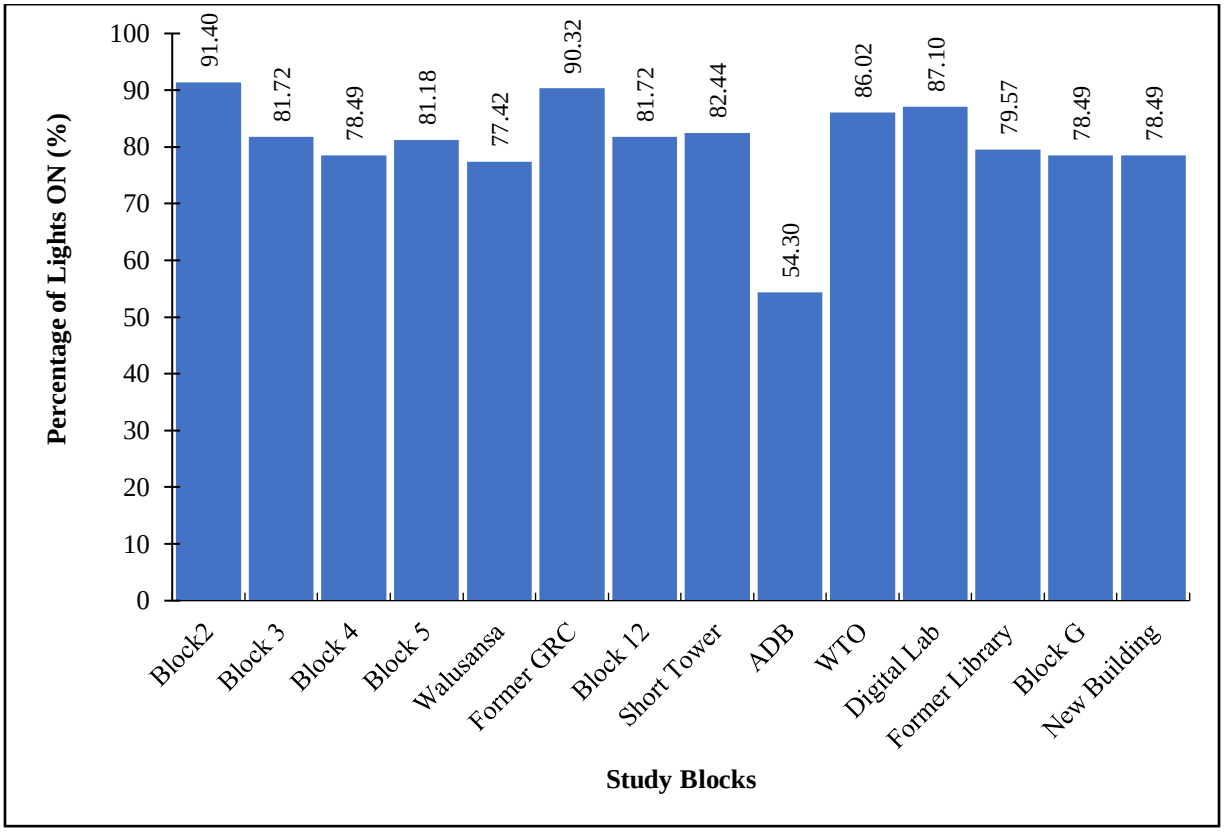


Figure 7: A bar graph of the frequency of Lights ON during the study time
Source: Author's own computation using observational empirical data

The data presented illustrates the percentage of lights that are switched on in various study blocks within the institution. These percentages offer valuable insights into the energy consumption patterns in different areas of the campus.

Notably, block 2 stands out with the highest percentage of lights switched on, at 91.40%. This may indicate a need for more effective energy management strategies in this specific block, such as implementing automated lighting controls or raising awareness among occupants about the importance of turning off lights when not in use.

Other blocks, such as Block 3, Block 4, and Block 5, maintain relatively high percentages of lights being on, ranging from 78.49% to 81.72%. While these percentages are not as high as Block 2, they still signify opportunities for energy optimization. Implementing occupancy sensors and scheduling systems in these areas could help reduce energy wastage.

The ADB block, on the other hand, has a notably lower percentage of lights on, at 54.30%. This may be due to reduced activity or occupancy in this block during the observed period. It's essential to consider the specific function and usage patterns of each block when interpreting these percentages.

Overall, these figures emphasize the importance of targeted energy management efforts tailored to the unique characteristics of each study block. By identifying areas with consistently high energy consumption, institutions can prioritize the implementation of energy-saving measures to reduce unnecessary energy usage, lower operational costs, and contribute to sustainability goals.

The duration of lights being on in lecture rooms during various study sessions reveals significant energy consumption patterns as illustrated in Figure 8.

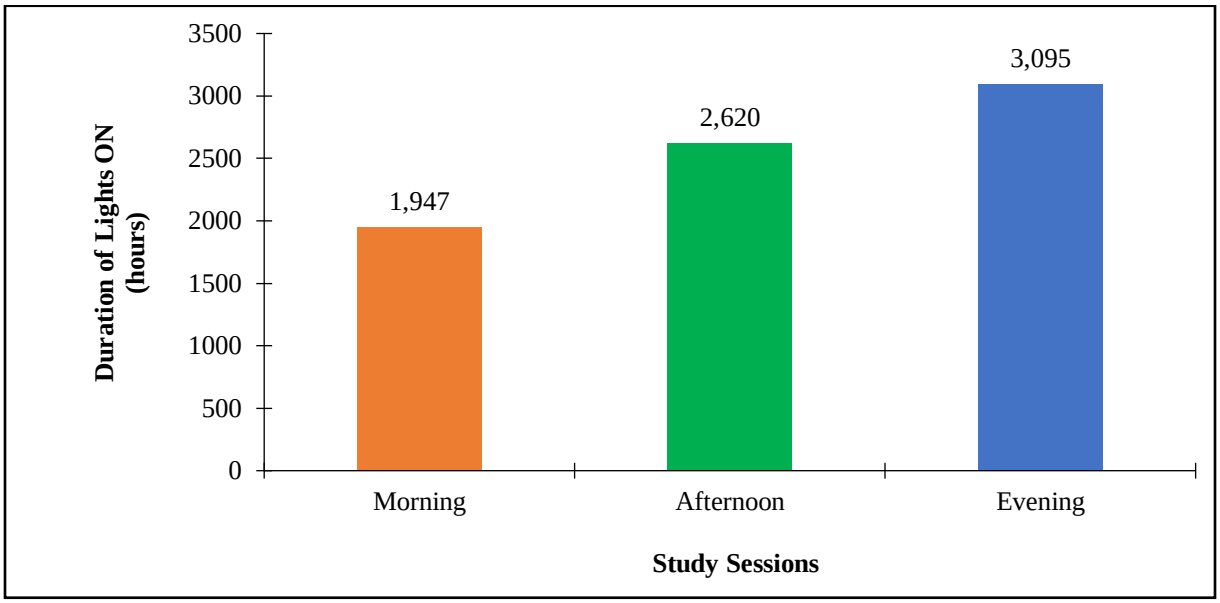


Figure 8: A line graph of durations of Lights ON during different study sessions
Source: Author's own computation using observational empirical data

The data on the duration of lights being on in lecture rooms during different study sessions highlights substantial variations in energy consumption throughout the day. Notably, the evening sessions recorded the highest duration of lights being on, totaling 3,095 hours. This prolonged usage during the evening can be attributed to the decreasing availability of natural daylight, necessitating a heavier reliance on artificial lighting to maintain adequate illumination levels.

Conversely, the morning sessions had the shortest duration of lights being on, totaling 1,947 hours. This could be due to the presence of natural daylight during morning hours, reducing the need for artificial lighting. The afternoon sessions fell in between, with a total duration of 2,620 hours.

These findings emphasize the dynamic nature of energy needs in lecture rooms and the importance of implementing energy management measures that align with these patterns. Strategies such as intelligent lighting controls, efficient lighting technologies, and occupancy-based systems can help optimize energy usage, reduce costs, and contribute to sustainability by ensuring lights are on only when necessary.

4.2.2 Ratio of Functional to Faulty Lights

Leveraging the power of Equation 3 and Equation 4 in conjunction with the empirical data meticulously gathered from lecture rooms in Institutions of Higher Learning, a revealing portrait of functional and faulty lights (worth noting there are 434 lights in total) materializes in Figure 9.

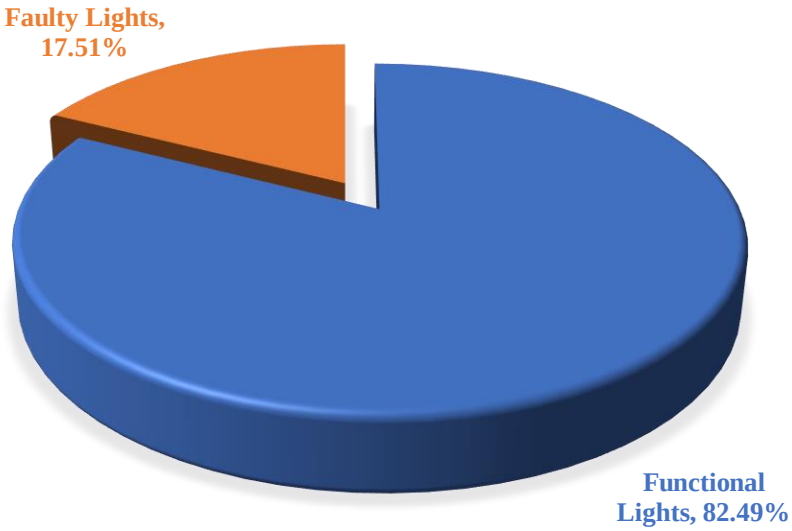


Figure 9: Ratio of Functional to Faulty Lights during the time of study
Source: Author's own computation using observational empirical data

The data reveals that a significant portion of the lights, approximately 82.49%, are functional, while the remaining 17.51% are faulty. This finding emphasizes the urgent need for action from the Estates department to address the non-functional lights.

The high percentage of functional lights is a positive indicator of the institution's initial efforts in maintaining the lighting infrastructure. However, the presence of a considerable proportion of faulty lights cannot be overlooked. These faulty lights contribute to unnecessary energy wastage, impacting both operational costs and overall energy efficiency. Moreover, the dysfunctional lights can lead to suboptimal learning environments, affecting the quality of education for students. The Estates department's role in maintaining the lighting system is crucial to achieving effective energy demand side management. The identified faulty lights must be promptly repaired or replaced to ensure a balanced and efficient energy consumption pattern. This action aligns with the broader objective of energy conservation, cost reduction, and sustainable practices.

Table 3: A summary of the status of Lights of the different Lectures

Buildings	Rooms	Functional Lights	Faulty Lights
Block 2	Rm 1	4	4
Block 3 Rm1	Rm1	6	0
	Rm2	3	3
	Rm3	9	6
Block 4 Rm3	Rm1	8	7
	Rm2	10	7
	Rm3	6	7
	Rm4	4	1
Block 5	Rm1	11	1
	Rm2	6	0
Walusansa	Rm1	4	5
Former GRC	Rm1	15	3
Block 12	Rm1	11	1
	Rm2	10	2
Short Tower	Level 1	62	4
	Level 2	40	0
	Level 3	26	10
ADB	Lecture Theatre1	20	0
	Lecture Theatre 2	20	0
WTO	Rm1	14	0
Digital Lab	Rm1	23	1
Former Library	Upper	11	1
	Lower	1	11
Block G	Upper	1	1
	Lower	4	1
New Building	Upper	14	0
	Lower	15	0

Source: Author's own computation using observational empirical data

Table 3 presents a comprehensive overview of the lighting conditions in different lecture rooms across various buildings within the campus. The table outlines the number of functional lights and the count of faulty lights for each specific room, offering insights into the state of lighting fixtures throughout the premises. Notable observations include Block 2, Room 1, where all lights are reported as faulty, emphasizing the need for urgent attention. In contrast, Block 3, Room 1, exhibits excellent lighting status with all 6 lights functional and no faults. Across Block 4, Room 3, and Room 4, the number of functional and faulty lights is close, implying potential room for

improvement. Differing trends continue, with variations observed in the Short Tower across different levels and a lack of reported faults in Lecture Theatre 1 and 2 of the ADB building. Overall, the data underscores the significance of addressing faulty lights promptly to ensure adequate illumination and energy-efficient operations within lecture rooms across the campus.

From Table 3, we can summarize the percentages of the faulty lights in each study block as illustrated in Figure 10.

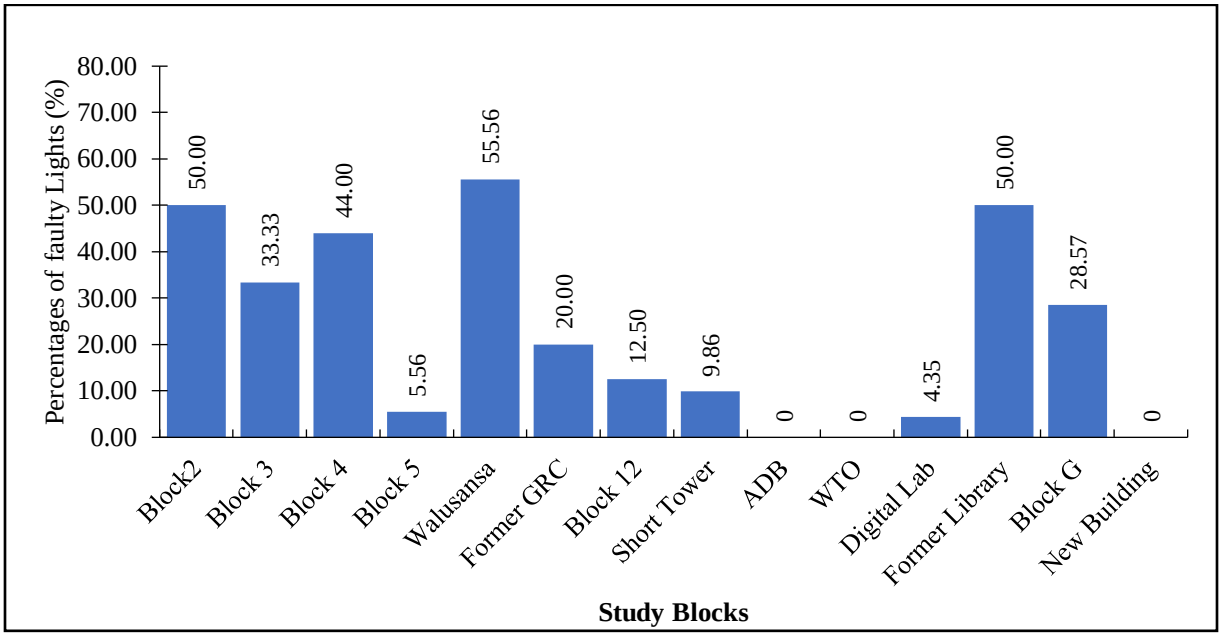


Figure 10: A summary of the percentages of Faulty Lights per study blocks
Source: Author's own computation using observational empirical data

The data on the percentage of faulty lights in various study blocks within the institution reveals disparities in the maintenance and functionality of lighting systems across different locations. Block 5 and ADB demonstrate notably low percentages of faulty lights, at 5.56% and 0% respectively, suggesting efficient maintenance and upkeep in these areas. Conversely, Block 2 and Walusansa show higher percentages, at 50%, indicating a significant portion of lighting fixtures requiring attention and repair.

Former GRC and Former Library also have relatively high percentages of faulty lights, at 20% and 50% respectively. In contrast, Short Tower and Block 12 exhibit lower percentages, at 9.86% and 12.50% respectively. These variations underscore the need for consistent maintenance practices and highlight areas where improvements can be made.

Additionally, the data emphasizes the importance of regular inspections and prompt repairs to reduce energy wastage and enhance overall energy efficiency. Addressing faulty lights not only contributes to energy savings but also ensures a conducive and well-lit environment for educational activities. Institutions should consider implementing proactive maintenance strategies and allocating resources efficiently to maintain lighting systems effectively across all study blocks.

4.2.3 Status of Lecture studies

Employing the computational prowess of Equation 5 and Equation 6 in tandem with the meticulously collected empirical data from lecture rooms, a clear visualization emerges in the form of Figure 11.

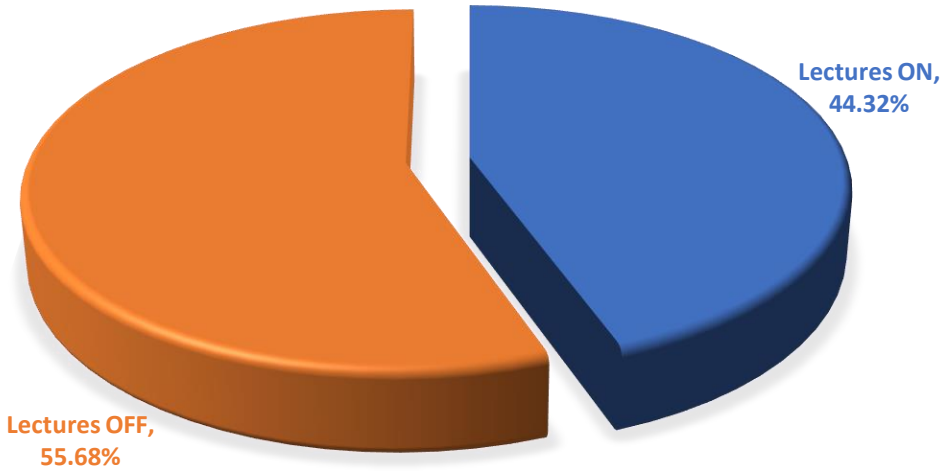


Figure 11: Frequency of Lectures ON/Lectures OFF during the time of study
Source: Author's own computation using observational empirical data

The data shows that lectures were ongoing for 44.32% of the entire data collection period, with lectures not taking place for approximately 55.68% of the time. This finding raises attention to the potential impact of external factors, such as weather conditions and public holidays, on lecture attendance and, subsequently, on energy consumption. The notable decrease in lecture activity, attributed to factors like rainy weather in the month of March and the occurrence of various public holidays, sheds light on the complexity of energy demand side management. External factors that influence lecture attendance directly impact the energy needs of the lecture rooms. On days with reduced attendance due to weather or holidays, energy consumption is naturally expected to be

lower, as fewer resources are required to power the rooms. This insight carries implications for planning and resource allocation within institutions of higher learning.

From the data gathered, we could also notice the following trends of Lectures being ongoing within the different blocks as shown in Figure 12.

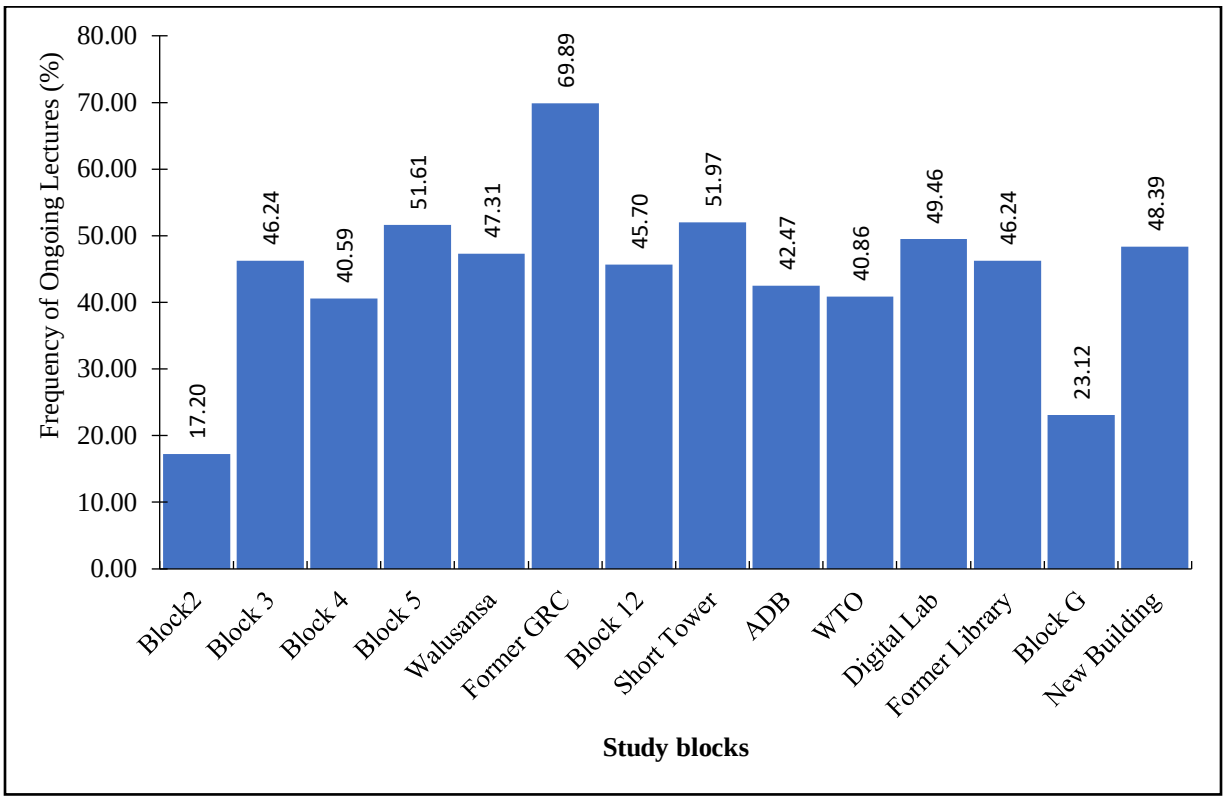


Figure 12: Frequency of Lectures being ongoing during the study time
Source: Author's own computation using observational empirical data

The data on the percentages of lectures conducted in various study blocks within the institution provides insights into the utilization of these spaces for academic activities. Former GRC stands out with the highest percentage of lectures conducted, at 69.89%, indicating that this block is a significant hub for educational purposes. This is followed by Block 5, which has 51.61% of lectures conducted, highlighting its importance as an academic space.

Other study blocks, such as Walusansa, Block 3, and Short Tower, also have relatively high percentages of lectures conducted, ranging from 46.24% to 51.97%. Conversely, Block G has the lowest percentage of lectures conducted, at 23.12%, suggesting that it may be underutilized for academic purposes.

These variations in the percentages of lectures conducted across study blocks underscore the need for efficient space allocation and utilization. Institutions should consider optimizing the use of spaces based on demand and academic scheduling to ensure that resources are allocated effectively. Additionally, understanding the patterns of space utilization can help in making informed decisions regarding maintenance, energy management, and overall facility planning.

4.2.4 Status of Lectures and illumination of the Lecture rooms

Harnessing the computational precision of Equations 7, 8, and 9 in conjunction with meticulously collected data from lecture rooms, a comprehensive depiction comes to fruition in the form of Figure 13.

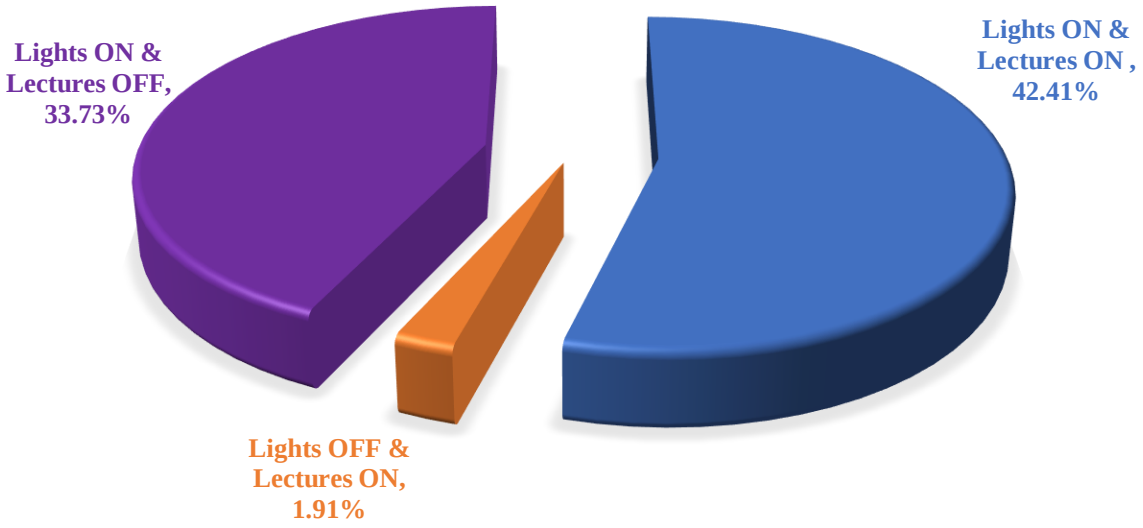


Figure 13: Frequencies of Lights ON & Lectures On, Lights On & Lectures OFF, and Lights ON and Lectures OFF
Source: Author's own computation using observational empirical data

The data analysis provides a clear and alarming picture of energy management inefficiencies within lecture rooms in higher institutions of learning. The results highlight the need for a comprehensive reassessment of energy consumption practices to address wastage and promote sustainability.

Firstly, the finding that lights were ON during 33.73% of the data collection period while lectures were not ongoing signifies a significant concern. This reveals a blatant misuse of energy, as lights were needlessly kept ON when no active educational activity occurred. This situation directly contributes to energy wastage and increased operational costs.

Furthermore, there were instances (1.9% of the time) when lectures were not ongoing, yet lights were switched ON, underscores the lack of awareness or operational oversight. This reinforces the need for stricter control measures and automated systems that can intelligently manage lighting based on room occupancy and lecture schedules.

The data also unveils a concerning pattern where lights were switched ON during 42.41% of the times when lectures were ongoing. This figure becomes even more alarming when considering that lectures were actually ongoing only 44.34% of the time. This implies that the lights were ON nearly 95.64% of the time they could have been potentially switched OFF, indicating a substantial overuse of energy resources.

This evidence underscores the need for immediate and comprehensive energy management interventions. Strategies such as implementing occupancy sensors, timers, and automated lighting systems can be highly effective in addressing these issues. Additionally, raising awareness among faculty, students, and staff about responsible energy consumption can contribute to a cultural shift towards energy efficiency.

Table 4: Frequencies of Lights ON & Lectures On, Lights On & Lectures OFF, and Lights ON and Lectures OFF for the different blocks

Study Blocks	Lights ON & Lectures ON (%)	Lights OFF & Lectures ON (%)	Lights ON & Lectures OFF (%)
Block2	17.20	0	74.19
Block 3	44.80	1.43	36.92
Block 4	37.37	3.23	41.13
Block 5	51.61	0	29.57
Walusansa	46.24	1.08	31.18
Former GRC	69.89	0	20.43
Block 12	44.62	1.08	37.10
Short Tower	51.97	0	30.47
ADB	41.94	0.54	6.45
WTO	38.71	2.15	47.31
Digital Lab	47.31	2.15	39.78
Former Library	45.70	0.54	33.87
Block G	11.83	11.29	27.42
New Building	47.31	6.07	31.18

Source: Author's own computation using observational empirical data

For visualization, the data in Table 4 is illustrated in Figure 14.

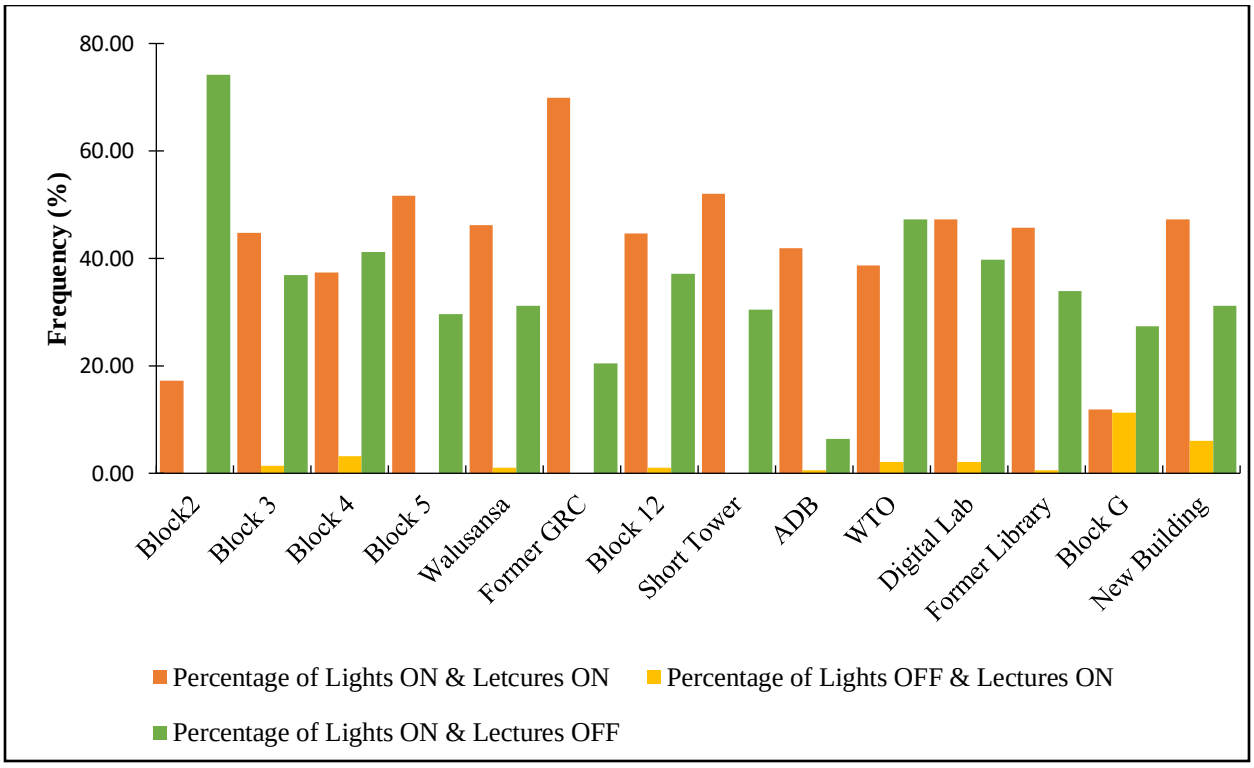


Figure 14: A bar graph to represent the frequencies of Lights ON & Lectures On, Lights On & Lectures OFF, and Lights ON and Lectures OFF of the different blocks
Source: Author's own computation using observational empirical data

The data can be analyzed by dividing it into three categories based on the status of lights in relation to lectures in various study blocks.

The first category, represented by the percentage of lights on while lectures are ongoing, showcases the extent to which lights are utilized during lectures. Former GRC has the highest percentage in this category, with a staggering 69.89% of lights being on while lectures are in session. This implies that lights are frequently left on, even when they are not needed, leading to potential energy wastage. Addressing this issue through stricter lighting management practices could result in significant energy savings.

In the second category, we observe the percentage of lights being off while lectures are ongoing. Block G stands out here, with 11.83% of lights on but 11.29% of lights off while lectures are in progress, resulting in 27.42% of lectures occurring in darkened rooms. This indicates a discrepancy between the scheduling of lectures and the availability of lighting resources. Improving coordination between lecture scheduling and lighting control could enhance the learning environment and reduce energy inefficiencies.

The last category involves the percentage of lights on while lectures are not ongoing. Several study blocks, including Block 3, Block 4, and Block 12, have notable percentages in this category, ranging from 37.37% to 44.80%. These figures suggest that lights are often left on when they are not needed for lectures, leading to unnecessary energy consumption during non-lecture hours. Implementing more efficient lighting control systems to automatically turn off lights when not in use could help conserve energy and reduce operational costs.

In conclusion, the data highlights discrepancies in the utilization of lighting resources during lectures and non-lecture hours across different study blocks. It emphasizes the importance of optimizing lighting management practices to minimize energy wastage, enhance the learning environment, and achieve sustainability goals within the institution

4.3 Energy consumption units due to daytime lighting in Lecture rooms

4.3.1 Expected Energy and Actual Energy consumed

Below is a tabulated representation of the results obtained by integrating equations 10 to 20 and incorporating the collected data related to lecture rooms. The table presents the expected energy, actual energy, and their corresponding ratios as part of the assessment of energy demand side management in lecture rooms within higher education institutions.

Table 5: Results of the Expected Energy, Actual Energy and the Ratio of Expected Energy to Actual Energy

Study Sessions	**Expected Energy (kWh)**	**Actual Energy (kWh)**
Morning (Session I)	39,231.864	941.436
Afternoon (Session II)	52,309.152	1,269.36
Evening (Session III)	65,386.44	1,541.16

Source: Author's own computation using observational empirical data

Upon examining these figures, several observations can be made:

Energy Consumption Variation

The variation in energy consumption across different sessions within the lecture rooms underscores the dynamic nature of energy needs throughout the day. This variation points to the importance of tailoring energy consumption to match actual demand rather than following a static, uniform lighting schedule. Such fluctuations present an opportunity for DSM strategies to play a crucial role in optimizing energy usage.

Evening Session Dominance

The evening session's dominance in energy consumption highlights a critical challenge. As natural daylight decreases during evening hours, there is a significant rise in the demand for artificial lighting to ensure adequate illumination levels. This reliance on artificial lighting, particularly during darker hours, accentuates the urgency of implementing DSM measures to manage this heightened energy demand. By employing strategies that intelligently adjust lighting based on occupancy and daylight availability, institutions can effectively minimize the energy needed for illumination.

Afternoon Session

The higher energy consumption during the afternoon session compared to the morning session can be attributed to a combination of factors, including the extended availability of daylight during the morning hours and varying occupancy patterns. This discrepancy accentuates the need for flexible lighting solutions that can adapt to changing daylight conditions and room occupancy. DSM strategies incorporating occupancy sensors and automated lighting controls can ensure that lighting is optimized based on actual room usage, helping curtail unnecessary energy consumption.

Energy Optimization Potential

The data's revelation of potential energy optimization during all three sessions underlines the significant room for improvement. Implementing DSM techniques holds promise for achieving these optimizations. Adjusting lighting levels based on the actual presence of occupants, integrating energy-efficient lighting technologies such as LEDs, and deploying automated lighting controls can collectively lead to a substantial reduction in energy consumption. Such measures

align with the overarching goals of DSM by efficiently managing energy usage and promoting sustainability.

In summary, the dynamics of energy consumption variations, the dominance of energy consumption during evening hours, the disparities between afternoon and morning energy usage, and the evident potential for optimization all spotlight the necessity for Energy Demand Side Management in Institutions of Higher Learning Lecture rooms. By adopting intelligent lighting solutions, integrating energy-efficient technologies, and promoting a culture of responsible energy consumption, educational institutions can reduce costs and contribute to a more sustainable future. The implementation of DSM strategies can effectively bridge the gap between energy supply and demand, leading to more efficient and environmentally conscious energy usage in lecture room environments.

From Table 6, the ratio of Expected Energy to Actual energy can be plotted in Figure 15

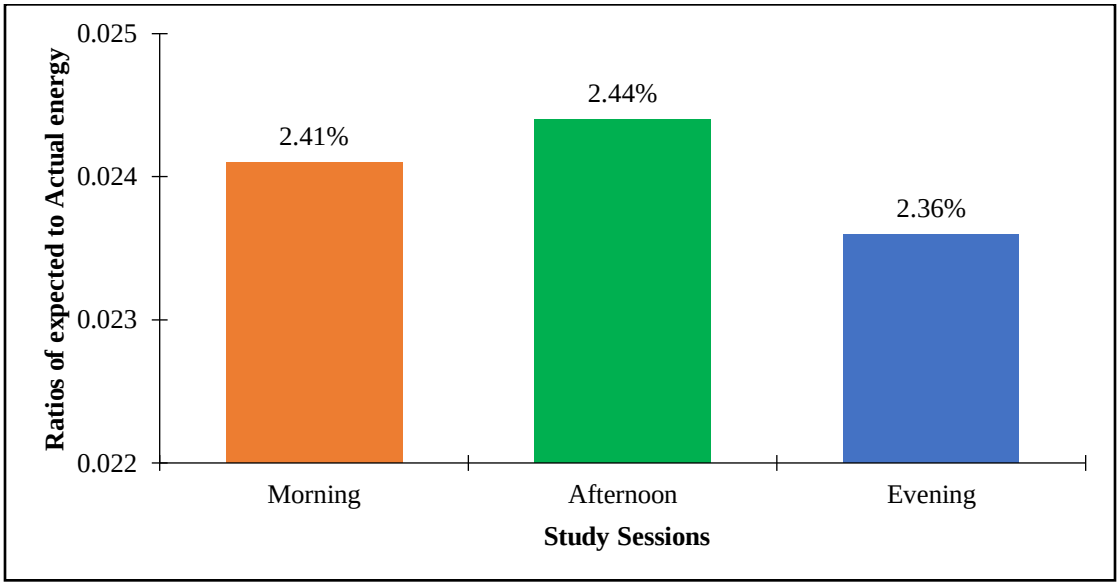


Figure 15: A line plot of the Ratios of Expected Energy to Actual energy
Source: Author's own computation using observational empirical data

The slight variations in these ratios between morning, afternoon, and evening sessions may reflect differences in occupancy patterns, natural daylight availability, or specific lighting controls during these times. For instance, lower energy consumption in the morning could be attributed to the availability of natural daylight, which reduces the need for artificial lighting.

In addition, the Actual energy consumed on Weekends and public holidays throughout the Month of March, 2023 in the Lecture rooms was evaluated as 504.9kWh based on the collected data. This unveils a rather startling revelation. The persistence of considerable energy usage during non-academic periods raises a red flag about the energy management practices within these spaces. The fact that substantial energy consumption persists even when academic duties are not taking place paints a concerning picture of wastage and inefficiency. These energy levels are alarmingly high given the absence of typical academic activities.

This situation underscores the urgency of implementing targeted energy management strategies to curtail this unnecessary consumption during idle times. It brings to the forefront the need for stricter controls over lighting and electrical equipment usage during weekends and holidays. This scenario prompts a reevaluation of the overall energy infrastructure within the lecture rooms and highlights the untapped potential for energy conservation measures during off-peak periods. Addressing this issue requires a holistic approach, including the installation of automated systems that can intelligently adjust lighting and equipment usage based on occupancy and time of day. By recognizing the significance of these energy levels in the absence of academic duties, institutions can take proactive steps to mitigate wasteful energy consumption, thereby aligning with sustainability goals and responsible energy usage practices.

4.3.2 Energy saved due to the faulty Lights

By applying Equations 21 to 29 to the dataset collected from lecture rooms during the month of March 2023, the ensuing data showcases the energy savings attributable to malfunctioning lights during individual sessions, alongside the proportion of energy savings directly linked to these faulty lights. The results are illustrated in Figure 16.

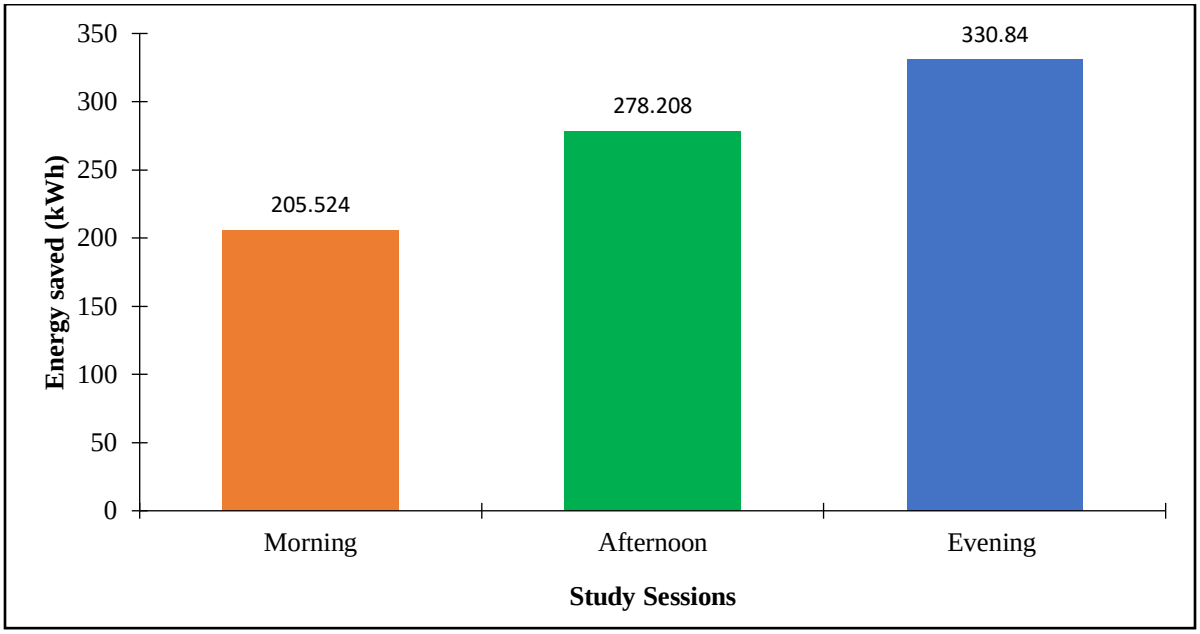


Figure 16: Energy saved by faulty Lights in different sessions
Source: Author's own computation using observational empirical data

The results of the study on energy savings due to faulty lights in higher institutions of learning lecture rooms reveal valuable insights for energy demand side management. The data indicates that faulty lights result in substantial energy savings, with the highest savings occurring during the evening, followed by the afternoon and morning hours. These findings are further reinforced by the data on the duration of time lights were ON during different study sessions. The highest duration of time lights were ON was observed during the evening session, totaling 3,095 hours, followed by the afternoon session with 2,620 hours, and the morning session with 1,947 hours. This data not only confirms the higher energy consumption during evening sessions but also highlights the need for proactive energy management strategies, particularly during times when natural daylight is lower.

4.3.3 Proportion of energy saved due to faulty Lights

Figure 17 should the proportion of energy that was saved due to having faulty Lights in some of the rooms.

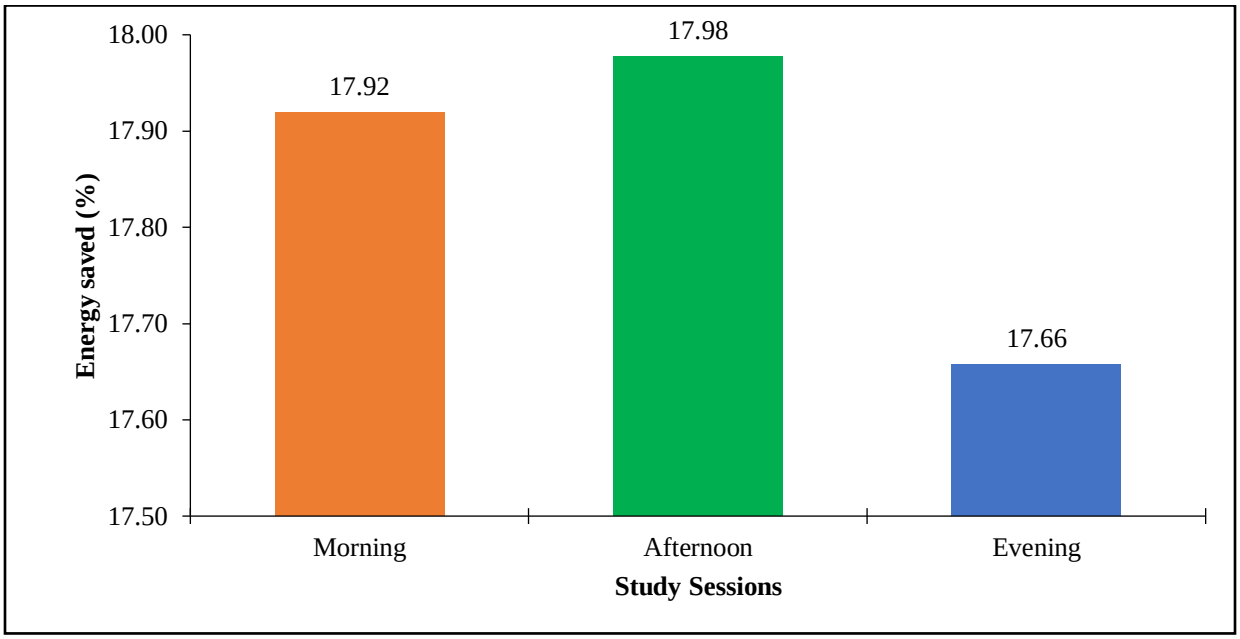


Figure 17: Results of Energy saved due to faulty lights as a fraction of Lights being ON
Source: Author's own computation using observational empirical data

The study on energy savings in higher education lecture rooms due to faulty lights highlights significant opportunities for energy efficiency. Faulty lights result in substantial energy savings, with the highest proportion saved during evening sessions (17.66%), followed by afternoon (17.98%) and morning sessions (17.92%). These findings underscore the potential for optimizing lighting systems to conserve energy and reduce costs, supported by data showing longer light durations during evening sessions. Proactive energy management measures, including maintenance and energy-efficient technology upgrades, are crucial, especially during periods with reduced natural daylight, to enhance sustainability and reduce greenhouse gas emissions in educational institutions. Addressing faulty lights is a simple yet effective way to optimize energy usage and reduce wastage, ensuring that energy is used only where and when needed. In addition, the data strongly underscores the role of DSM strategies in achieving energy efficiency. By actively identifying and addressing inefficiencies like faulty lights, institutions can better manage their energy consumption, leading to reduced costs and a smaller environmental footprint.

4.4 Energy daily costs incurred due to daytime lighting of Lecture rooms

By employing equations 30 to 37 in conjunction with the comprehensive dataset gathered from lecture rooms within Institutions of Higher Learning, the ensuing outcomes regarding both the energy expenses attributed to illuminating lecture rooms across various sessions throughout the day in March 2023, quantified in Ugandan shillings.

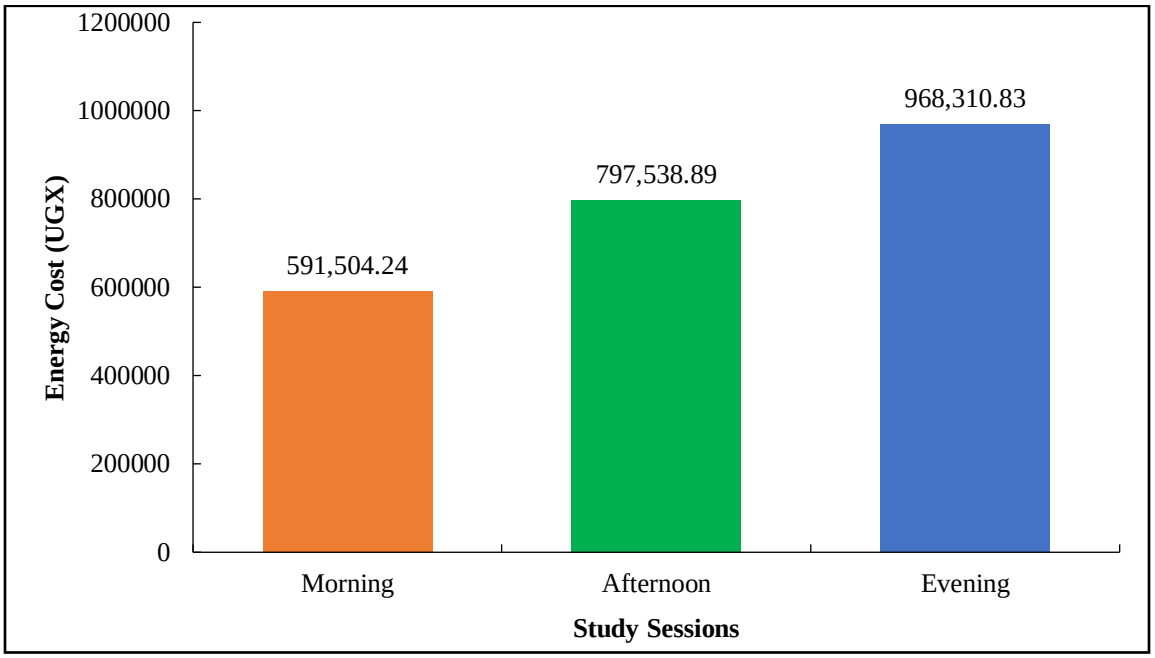


Figure 18: Results of the Energy cost of Lighting the Lecture rooms in the Month of March 2023.
Source: Author's own computation using observational empirical data

The provided energy costs due to lighting in different sessions of the day for the month of March 2023 in Ugandan shillings highlight significant implications for Energy Demand Side Management (DSM) strategies in Institutions of Higher Learning Lecture rooms.

The data reveals a clear variation in energy costs across different sessions. The evening session incurs the highest energy cost, followed by the afternoon and morning sessions. This cost variation underscores the importance of optimizing energy consumption to avoid unnecessary expenses. The higher energy costs during peak hours, such as the evening session, underscore the need for DSM strategies that can effectively manage energy demand during periods of high usage. Implementing strategies such as load shedding, dynamic pricing, and energy-efficient technologies can contribute to reducing energy costs during these expensive hours.

In addition, the elevated energy costs during the evening session might indicate that peak demand charges are applied during this period. Proper DSM implementation can help institutions avoid peak demand charges by reducing energy consumption during high-demand times, thus leading to substantial cost savings. The significant energy costs highlight the financial impact of inefficient energy consumption practices. Adopting DSM strategies can help institutions allocate resources more effectively, redirecting funds from unnecessary energy expenses toward educational and operational priorities. Moreover, the data reinforces the importance of energy-efficient lighting technologies. Energy-efficient lighting, such as LEDs, could significantly reduce energy consumption and subsequently lower energy costs without compromising the quality of lighting within lecture rooms. The total energy costs for all sessions in the month of March can be substantial. Institutions can potentially achieve notable cost savings over time by optimising energy consumption through DSM practices.

In conclusion, the energy costs associated with different sessions in the month of March underscore the critical role of DSM in managing energy demand and costs within Institutions of Higher Learning Lecture rooms. The variability in costs throughout the day emphasizes the need for strategies that optimize energy consumption, reduce peak demand charges, and enhance energy efficiency. By implementing effective DSM measures, institutions can achieve significant cost reductions, promote sustainability, and allocate resources more efficiently toward their core educational missions.

4.5 Green House Gas emissions due to daytime lighting of Lecture room

Utilizing Equations 38 to 44 in conjunction with the dataset collected from lecture rooms within Higher Institutions of Learning, the resulting Greenhouse Gas emissions linked to the illumination of these lecture rooms during the specified sessions are quantified and expressed in kilograms of CO2 equivalent per kilowatt-hour. The grid emission factor for Uganda of 201 gCO2eq/kWh (Mukisa et al. 2021). These emissions are comprehensively presented in Figure 19 for clear elucidation.

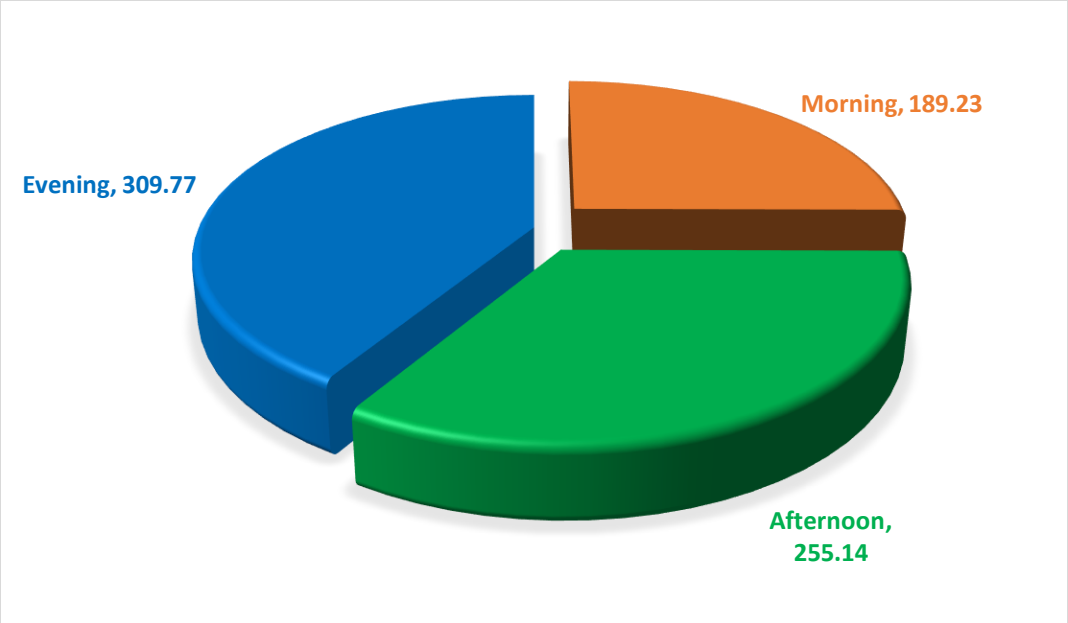


Figure 19: Results of the Green House Gas emissions in kgCO2eq due to the illumination of Lecture rooms in the Month of March 2023.
Source: Author's own computation using observational empirical data

The provided data on Greenhouse Gas (GHG) emissions due to lighting in lecture rooms during different sessions of the day for the month of March 2023, expressed in kgCO2eq highlights the environmental implications and the importance of Energy Demand Side Management (DSM) in Institutions of Higher Learning Lecture rooms.

The data reveals a clear variation in GHG emissions across different sessions. The evening session has the highest GHG emissions, followed by the afternoon and morning sessions. This variation underscores the need to optimize energy consumption during peak hours to reduce environmental impact. Higher GHG emissions during peak hours, such as the evening session, indicate that energy consumption during these times contributes significantly to carbon emissions. Implementing DSM strategies to manage energy demand during peak hours can directly contribute to reducing carbon emissions.

The data underscores the role of energy-efficient lighting technologies in reducing GHG emissions. Energy-efficient lighting options, such as LEDs, consume less energy and result in lower emissions per unit of energy consumed. Implementing DSM strategies that focus on energy conservation, load shedding, and efficient lighting can substantially reduce the institution's carbon

footprint. This aligns with global efforts to mitigate climate change and reduce overall environmental impact.

By optimizing energy consumption and reducing GHG emissions, institutions contribute to environmental sustainability and potentially lower costs associated with carbon taxes or emission-related charges. The cumulative impact of GHG emissions over the course of a month can be significant. By adopting DSM practices, institutions can proactively reduce their contribution to climate change and demonstrate their commitment to environmental responsibility.

In conclusion, the GHG emissions associated with different sessions in the month of March underscore the crucial role of DSM in minimizing the environmental impact of energy consumption within Institutions of Higher Learning Lecture rooms. The variability in emissions throughout the day emphasizes the need for strategies that optimize energy consumption, reduce peak emissions, and promote energy-efficient technologies. By implementing effective DSM measures, institutions can contribute to a greener future, align with sustainability goals, and foster a culture of responsible energy usage.

4.6 Proposed energy management measures Institutions of Higher Learning Lecture rooms can undertake to minimize energy wastage.

This recommendation emerged subsequent to the comprehensive exposition and deliberation on the findings stemming from the economic, social, and environmental evaluations. The identification of the most viable Demand Side Management (DSM) strategies is rooted in the outcomes derived from the pursuit of objectives (i), (ii), and (iii). These outcomes pave the way for formulating the most practical and tenable approach to implementing DSM within Institutions of Higher Learning.

The analysis of the provided data and its corresponding interpretive insights yield a spectrum of pragmatic Energy Demand Side Management (DSM) strategies, offering avenues for institutions of higher learning to ameliorate energy wastage within lecture rooms. These strategies, informed by empirical evidence, hold the potential to not only abate energy consumption but also foster a sustainable energy consumption paradigm.

Dynamic Lighting Control emerges as a prudent approach in the quest for energy conservation. Encompassing the integration of intelligent lighting systems equipped with occupancy and daylight sensors, this strategy engenders an adaptive luminance environment. The sensors facilitate

the activation of lights solely in the presence of occupants and the modulation of illumination levels in response to ambient natural light levels. Such responsive luminosity management circumvents the superfluous use of lighting during periods of low occupancy and ample natural light, consequently mitigating energy waste.

Automated Lighting Schedules, underpinned by programmable lighting control systems, constitute a methodological intervention aimed at curbing unnecessary energy expenditure. This approach, harmonized with the temporal parameters of lecture sessions and occupancy patterns, orchestrates the activation and deactivation of lighting systems with precision. By extinguishing lighting fixtures during periods of inactivity, this practice upholds the principle of energy thriftiness.

Energy-Efficient Lighting Technologies, particularly the transition to Light Emitting Diode (LED) bulbs, imparts tangible dividends in energy conservation. The intrinsic attributes of LEDs, including superior energy efficiency and extended operational lifespans, contribute synergistically to energy parsimony and concomitant curtailment of maintenance costs.

From the further analysis of the 36W fluorescent tube, the following assumptions can be made:

Table 6: Assumptions on the market prices of both LED and Fluorescent tubes

Variables	**Value**	**Unit**
LED Wattage	20	Watts
LED Single Unit cost	30,000	UGX
Existing Light Wattage	36	Watts
Existing Light Unit Cost	10,000	UGX
Number of lamps (LFL)	434	Lamps
Running time per day	12	Hours
Operational days per year	365	Days
Cost of energy /kWh	682.3	UGX

From Table 6, the following computations can be made:

Table 7: Cost of replacing existing Lights with LED Lights

Calculations	**Existing system**	**LED**
Electrical cost		
Electrical Load of lamps	15,624	8,680
Running time per year (hours)	4,380	4,380
Energy consumed per year (kWh)	68,433.12	38,018.4
Energy demand saving (kWh)	0	30,414.72
Total cost of energy per year (UGX)	46,691,917.78	25,939,954.32
Saving per year (UGX)	0	20,751,963.46
Capital Requirements		
Purchase requirement cost	4,340,000	13,020,000
Installation cost per unit (UGX)	2,000	1,000
Installation cost (UGX)	868,000	434,000
Total capital investment requirement (UGX)	5,208,000	13,454,000
Net investment requirement (UGX)	0	20,751,963.46
Total operating costs per year (UGX)	**51,899,917.78**	**39,393,954.32**
Total savings first year	**0**	**20,751,963.46**

Source: Author's own computation using observational empirical data

From the above, we can generate a plot to visualize the computations.

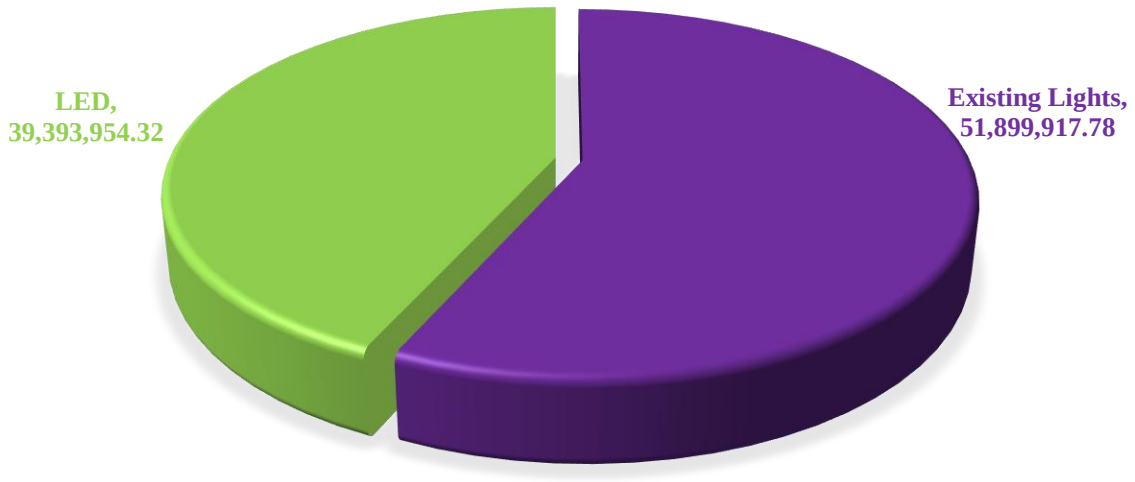


Figure 20: A comparison of the total operating costs of the existing Lights and LED Lights
Source: Author's own computation using observational empirical data

From the above, it is evident that the operating costs of existing lights is way much higher than that of the LED lights. In addition, the variations in the energy consumed by the two sets of lights can be illustrated in Figure 21.

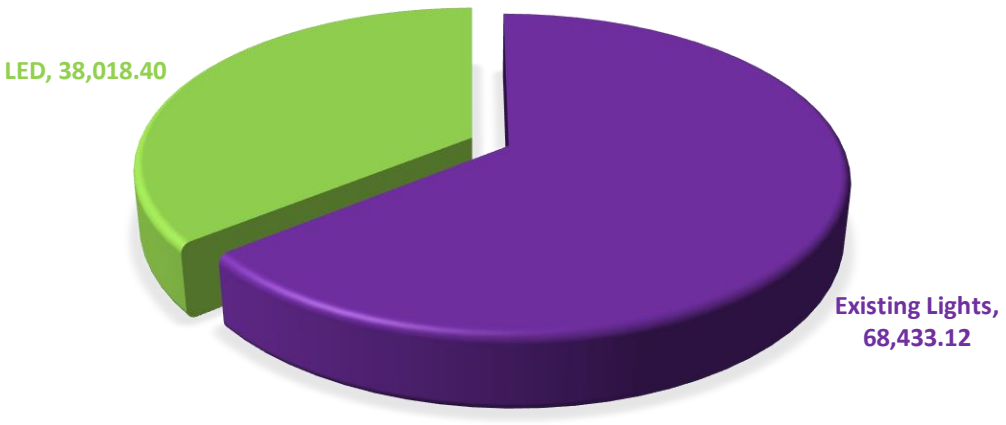


Figure 21: A variation of the energy consumptions between Existing Lights and LED Lights in kWh throughout the year
Source: Author's own computation using observational empirical data

These calculations demonstrate the financial and energy-saving benefits of switching from the existing lighting system to LED. The LED system significantly reduces energy consumption, leading to substantial cost savings over time. While there is an initial capital investment requirement for the LED system, the savings in energy costs make up for this investment in the first year and continue to provide cost benefits in subsequent years.

Occupancy-based lighting, predicated on the deployment of occupancy sensors and responsive controls, furnishes a compelling mechanism to mitigate energy profligacy. By engendering a lighting paradigm that solely corresponds to occupied spaces, this strategy effectively nullifies energy wastage in areas devoid of human presence, such as unoccupied lecture rooms and corridors.

Enforcing fines for leaving lights on in unoccupied rooms serves as a direct and tangible incentive for individuals to be more mindful of their energy consumption habits. This approach creates an immediate consequence for energy wastage, encouraging students, faculty, and staff to actively participate in the energy-saving endeavor. Fines provide a visible deterrent against leaving lights on unnecessarily, promoting a culture of responsibility and accountability for energy usage within

the academic community. Furthermore, the introduction of fines can serve as a catalyst for behavioral change. As individuals become more conscious of the financial implications associated with energy wastage, they are likely to adopt more energy-efficient practices. This behavioral shift can extend beyond just turning off lights; it can lead to a broader understanding of energy conservation and inspire individuals to adopt other sustainable habits in their daily routines.

By adopting this comprehensive repertoire of DSM strategies, institutions of higher learning can effectuate a holistic transformation toward energy-efficient lecture room environments. These strategies, validated by data-driven insights accentuating energy consumption variations, optimization prospects, and financial ramifications, underscore their critical role in institutionalizing sustainability and curtailing operational costs.

CHAPTER FIVE

5.0 DISCUSSION OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this chapter, the findings presented in chapter four are discussed, conclusions drawn, and recommendations suggested based on the study's objectives and research questions. It further discusses the limitations of the study and the proposition of areas for further research. The journey included literature review, theoretical analysis, methodology, and empirical results to comprehensively understand energy management in these educational spaces. The study bridges the gap between theory and practice, presenting findings that shed light on the efficacy of Energy DSM strategies within higher education lecture rooms. This chapter serves as a conduit for informed decision-making and further exploration in the domain of energy efficiency within lecture rooms, emphasizing the potential for sustainable practices. The study strives to illuminate the interplay between theory and real-world application through rigorous analysis, offering insights that can reshape energy consumption practices in higher education institutions. The outcomes detailed in this chapter underscore the potential for transformation and sustainable practices in the context of lecture room energy management.

5.2 Discussion of results

The discussion of the results was rooted in the study's objectives and subsequent findings, as follows:

5.2.1 The Energy consumption due to daytime lighting in Lecture rooms

In the energy demand side management (DSM) realm within higher education lecture rooms, the interplay between the study's findings and the existing literature showcases both areas of agreement and divergence. The study's observations on energy consumption variations across sessions resonate with the literature's recognition of the dynamic nature of energy needs (Warren, 2019). This consensus underscores the significance of adapting energy usage to actual demand, thereby highlighting the potential of DSM strategies to optimize energy utilization (Usman et al., 2022). Similarly, the study's identification of evening session dominance in energy consumption aligns with literature discussing the challenge of increased demand for artificial lighting during darker hours (Bakare et al., 2023). This common ground underscores the urgency for DSM measures to address this demand surge, effectively bridging the gap between energy supply and demand (Sylvia et al., 2013). Furthermore, the study's revelation of afternoon session energy

disparity is in harmony with the literature's emphasis on varying occupancy patterns and daylight availability affecting energy consumption (Hussain et al., 2021). This correspondence reinforces the necessity for flexible lighting solutions and DSM techniques to curtail unnecessary energy usage (Pratt & Erickson, 2020). Additionally, the study's emphasis on energy savings due to faulty lights is aligned with the literature's recognition of operational inefficiencies' impact on consumption (William et al., 2023), yet the study does not extensively explore financial facets as the literature does.

5.3 Energy daily costs incurred due to daytime lighting of Lecture rooms

The findings concerning energy costs due to lighting across different sessions in Ugandan shillings present key implications for Energy Demand Side Management (DSM) in Institutions of Higher Learning Lecture rooms. The variation in energy costs throughout the day highlights the importance of optimizing energy consumption to avoid unnecessary expenses (Usman et al., 2022). Notably, the higher costs during peak hours, like the evening session, underscore the necessity for effective DSM strategies that manage energy demand during periods of heightened usage (Sylvia et al., 2013). Strategies such as load shedding and energy-efficient technologies can mitigate costs during these high-demand hours, ultimately reducing expenses (Bakare et al., 2023).

Additionally, the study acknowledges the potential application of peak demand charges during the evening session, emphasizing the significance of DSM to circumvent these charges and achieve substantial cost savings (Ma & Fu, 2020). The study's recognition of the financial impact of inefficient energy consumption aligns with the literature highlighting the relevance of financial development and demand-side policies (Warren, 2019). Furthermore, the study's emphasis on energy-efficient lighting technologies resonates with literature discussing the adoption of energy-efficient strategies to reduce costs without compromising quality (Panda et al., 2022).

Conclusively, the data on energy costs in different sessions aligns with the literature's focus on DSM's financial, technological, behavioural, institutional, and environmental dimensions. The study's emphasis on session-based energy cost variations underscores the need for strategies to optimize energy consumption and reduce peak demand charges, aligning with literature discussing cost-effective measures (Usman et al., 2022). Ultimately, the findings underscore DSM's critical role in managing energy demand and costs within Institutions of Higher Learning Lecture rooms, and they echo the literature's stance on the multifaceted nature of DSM strategies (Dahiru et al.,

2023). By adopting effective DSM practices, institutions can significantly reduce costs, foster sustainability, and allocate resources more judiciously, which is in line with the literature's emphasis on effective energy management practices (Tamilarasu et al., 2021).

5.4 Green House Gas emissions due to daytime lighting of Lecture room

The data provided on Greenhouse Gas (GHG) emissions resulting from lighting in lecture rooms during different sessions of the day for March 2023 underscores the environmental significance of Energy Demand Side Management (DSM) within Institutions of Higher Learning Lecture rooms. The clear variation in GHG emissions across sessions highlights the need to optimize energy consumption during peak hours to mitigate the environmental impact, aligning with the literature's emphasis on energy conservation and efficiency (Usman et al., 2022; Sylvia et al., 2013). Notably, the highest emissions during peak hours, particularly in the evening session, emphasize the contribution of energy consumption to carbon emissions and the direct role of DSM strategies in reducing these emissions (Bakare et al., 2023).

The study's recognition of energy-efficient lighting technologies' potential to reduce GHG emissions aligns with the literature's discussion on the adoption of such technologies to lower emissions per unit of energy consumed (Panda et al., 2022). The connection drawn between DSM strategies, energy conservation, load shedding, and efficient lighting underscores the study's alignment with global efforts to mitigate climate change and environmental impact (Nasir et al., 2021). Moreover, the mention of lower costs associated with carbon taxes or emission-related charges aligns with the literature's acknowledgement of the financial implications of energy consumption and emissions (Warren, 2019).

The study's emphasis on the cumulative impact of GHG emissions and the potential role of DSM practices in reducing an institution's contribution to climate change resonates with the literature's overarching focus on environmental sustainability and carbon footprint reduction (Dahiru et al., 2023). The study's conclusion aligns with the literature's call for strategies to optimize energy consumption, reduce peak emissions, and foster responsible energy usage to achieve a greener future (Tamilarasu et al., 2021). Incorporating the Unified Theory of Acceptance and Use of Technology (UTAUT) provides a theoretical lens that aligns with the study's emphasis on financial, technological, behavioural, and environmental factors shaping DSM adoption (Hewavitharana et al., 2021). The empirical review further solidifies the study's findings, with

literature consistently discussing the impact of financial, technological, behavioural, institutional, and environmental factors on DSM strategies (Ma & Fu, 2020; Nasir et al., 2021; Sloot et al., 2023; Usman et al., 2022). The literature emphasizes the multifaceted nature of DSM solutions and the importance of tailored approaches in achieving energy efficiency and sustainability goals (Elio et al., 2021).

In conclusion, the study's analysis of GHG emissions during different sessions aligns well with the literature's emphasis on the multifaceted dimensions of DSM and their impact on environmental sustainability. The study's emphasis on DSM strategies, energy-efficient technologies, and environmental responsibility resonates with the literature's focus on the need for effective measures to reduce emissions, mitigate climate change, and promote responsible energy management in various settings.

5.5 Recommendations

Policy Recommendations

In light of the extensive research analysis, literature review, and study results, several policy recommendations emerge to enhance energy efficiency and sustainability within higher education institutions' lecture rooms.

Firstly, the implementation of mandatory energy efficiency standards is crucial. Enforcing regulations that stipulate the adoption of energy-efficient lighting technologies, occupancy sensors, and daylight harvesting systems would establish a foundation for effective energy conservation practices.

Secondly, the integration of renewable energy sources should be incentivized. By offering grants, subsidies, or tax incentives, institutions can encourage the installation of solar panels on campus buildings, reducing reliance on conventional energy sources and decreasing greenhouse gas emissions.

Lastly, fostering a culture of education, collaboration, and behaviour change is paramount. This can be achieved through curriculum integration, collaborative research initiatives, and widespread awareness campaigns. Empowering students, faculty, and staff with the knowledge and tools to embrace energy-efficient practices can catalyze a collective effort toward a more sustainable future.

By adopting these recommendations, institutions can proactively address energy consumption challenges, reduce costs, and contribute to broader environmental goals. The synergy of mandatory standards, renewable energy integration, and transformative educational initiatives can pave the way for enhanced energy management within lecture rooms and beyond.

Practical Recommendations to Institutions of Higher Learning

To begin, a strategic approach involves retrofitting existing lighting systems with advanced technologies. Incorporating occupancy sensors and daylight sensors can intelligently regulate lighting levels based on room occupancy and natural light availability. This targeted control minimizes unnecessary energy consumption, fostering a more efficient energy use pattern. Conducting regular energy audits of lecture rooms is paramount. These audits help identify energy inefficiencies and provide insights into areas that require improvement. By quantifying energy consumption patterns, institutions can establish a baseline for energy-saving initiatives and track progress over time.

Transitioning to energy-efficient LED lighting is a tangible step towards sustainability. LED bulbs consume significantly less energy and have longer lifespans, reducing both electricity consumption and maintenance costs. Alongside this, the implementation of automated lighting controls is recommended. Utilizing programmable lighting systems aligned with lecture schedules can ensure lights are activated only when needed. This can curb energy wastage during unoccupied periods. A proactive approach to maintenance, including prompt repair of faulty lights, contributes to energy savings. Regular inspections can detect malfunctioning fixtures, preventing unnecessary energy use and associated costs.

Moreover, occupancy-based lighting controls offer promising benefits. Integrating sensors that detect room occupancy and adjust lighting accordingly can lead to substantial energy reduction in unoccupied areas. Task lighting solutions, which direct light to specific areas rather than uniformly illuminating entire rooms, effectively balance illumination and energy conservation. As part of a comprehensive strategy, institutions can conduct energy awareness campaigns to engage students, faculty, and staff in responsible energy use practices. Encouraging habits such as switching off lights when leaving rooms contribute to collective energy savings.

During peak hours, load-shedding strategies can be employed. Implementing protocols that temporarily reduce non-essential lighting or reschedule activities to off-peak times can alleviate

peak energy demand. The integration of renewable energy sources, like solar panels on campus buildings, offers a dual advantage. It offsets energy consumption from the grid and contributes to reduced carbon emissions. Furthermore, data monitoring and analysis play a vital role in DSM. Deploying energy monitoring systems enables institutions to identify trends, evaluate the effectiveness of measures, and refine strategies accordingly.

Engaging students through involvement in energy-saving initiatives can drive sustainability across the campus. Encouraging them to develop and implement energy-efficient projects can yield innovative solutions while fostering a culture of environmental responsibility. Faculty training on efficient classroom lighting management is also crucial. Equipping instructors with knowledge about lighting controls and energy-conscious practices enables them to lead by example. Additionally, instituting incentive programs that acknowledge individuals or departments for consistent energy-saving behaviour can stimulate engagement and commitment.

A collaborative approach involving facilities management, environmental clubs, and academic departments ensures a holistic implementation of DSM practices. By working together, institutions can pool resources, expertise, and perspectives to create a campus-wide culture of energy efficiency. These practical recommendations collectively contribute to minimizing energy wastage, reducing operational costs, and advancing sustainability goals within higher education institutions.

5.6 Limitations of the study

Despite the valuable insights gained from this study, several limitations should be acknowledged. Firstly, the study's scope was limited to a specific subset of higher education institutions, potentially impacting the generalizability of the findings. The selected institutions may have unique energy consumption patterns, infrastructure, and cultural factors that differ from other institutions, limiting the study's applicability on a broader scale. Future research could benefit from a more diverse and representative sample of institutions to ensure a comprehensive understanding of energy consumption behaviours.

Another limitation is the reliance on collected data from a single month (March 2023) to draw conclusions about energy consumption and associated factors. Energy consumption patterns can exhibit seasonal variations due to factors like weather, academic schedules, and special events, which may not be fully captured within this short timeframe. A longer data collection period could

provide a more accurate representation of energy consumption trends throughout different seasons and academic periods.

Additionally, the study primarily focused on energy consumption related to lighting in lecture rooms, which is just one aspect of energy usage within higher education institutions. Other factors, such as heating, cooling, and electronics, contribute to the overall energy footprint of these institutions. The study's limited focus on lighting may not provide a complete picture of energy management strategies required for comprehensive sustainability efforts. Future studies could consider a broader examination of energy consumption sources to provide a more holistic view.

Furthermore, the study did not extensively delve into qualitative aspects such as the attitudes, perceptions, and behaviours of students, faculty, and staff members towards energy conservation. Qualitative insights could offer a deeper understanding of the social and cultural dynamics that influence energy consumption practices and the adoption of energy-saving measures. Incorporating qualitative research methods, such as interviews or surveys, could enhance the study's depth and provide a well-rounded perspective.

5.7 Areas of further research

The current study has shed light on critical aspects of energy consumption and Energy Demand Side Management (DSM) practices within a specific subset of higher education institutions. However, there are several avenues for further research that could expand and deepen our understanding of this topic**.**

Comprehensive Energy Footprint

Extend the research to encompass a broader examination of energy consumption patterns beyond lighting, encompassing heating, cooling, electronic devices, and other energy-consuming activities within higher education institutions. Analyzing the entire energy footprint can provide a more holistic perspective on potential energy-saving strategies.

Longitudinal Analysis

Conduct a longitudinal study that spans multiple academic years to capture seasonal variations in energy consumption and DSM practices. This longer timeframe could reveal patterns and trends that short-term studies may overlook.

Qualitative Explorations

Incorporate qualitative research methods such as interviews, focus groups, or surveys to gain insights into the attitudes, perceptions, and behaviours of students, faculty, and staff regarding energy conservation. Qualitative data can help identify barriers, motivations, and potential strategies for encouraging energy-saving practices.

Technological Advancements

Investigate emerging technologies, such as smart grid systems, advanced energy management systems, and AI-driven energy optimization tools, and assess their potential for enhancing DSM strategies and reducing energy consumption.

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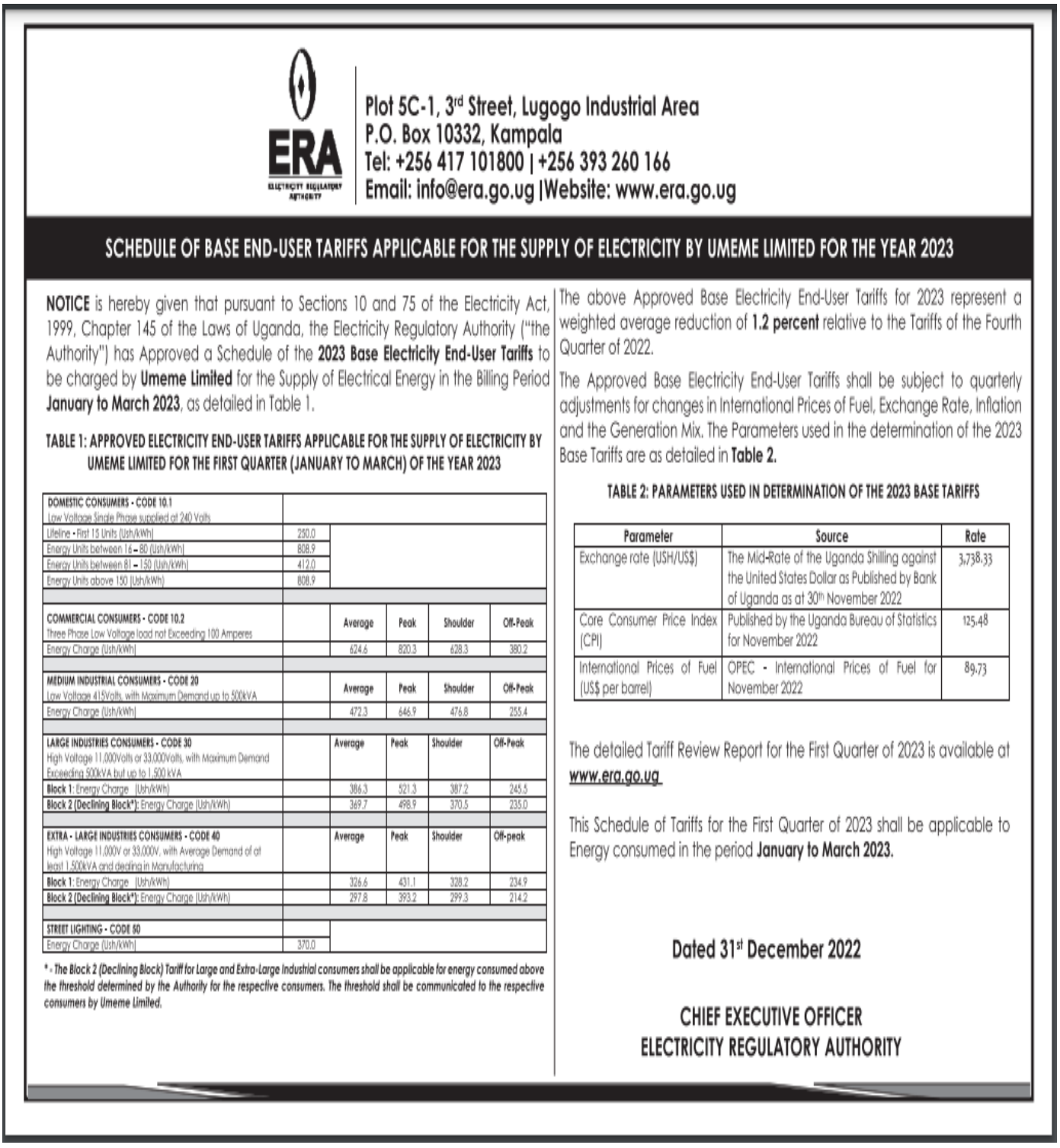
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Appendix 1



ERA
ELECTRICITY REGULATORY AUTHORITY

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P.O. Box 10332, Kampala
Tel: +256 417 101800 | +256 393 260 166
Email: info@era.go.ug |Website: www.era.go.ug

SCHEDULE OF BASE END-USER TARIFFS APPLICABLE FOR THE SUPPLY OF ELECTRICITY BY UMEME LIMITED FOR THE YEAR 2023

NOTICE is hereby given that pursuant to Sections 10 and 75 of the Electricity Act, 1999, Chapter 145 of the Laws of Uganda, the Electricity Regulatory Authority ("the Authority") has Approved a Schedule of the **2023 Base Electricity End-User Tariffs** to be charged by **Umeme Limited** for the Supply of Electrical Energy in the Billing Period **January to March 2023**, as detailed in Table 1.

TABLE 1: APPROVED ELECTRICITY END-USER TARIFFS APPLICABLE FOR THE SUPPLY OF ELECTRICITY BY UMEME LIMITED FOR THE FIRST QUARTER (JANUARY TO MARCH) OF THE YEAR 2023

DOMESTIC CONSUMERS - CODE 10.1 Low Voltage Single Phase supplied at 240 Volts					
Lifeline - First 15 Units (Ush/kWh)	250.0				
Energy Units between 16 – 80 (Ush/kWh)	808.9				
Energy Units between 81 – 150 (Ush/kWh)	412.0				
Energy Units above 150 (Ush/kWh)	808.9				
COMMERCIAL CONSUMERS - CODE 10.2 Three Phase Low Voltage load not Exceeding 100 Amperes		Average	Peak	Shoulder	Off-Peak
Energy Charge (Ush/kWh)		624.6	820.3	628.3	380.2
MEDIUM INDUSTRIAL CONSUMERS - CODE 20 Low Voltage 415Volts, with Maximum Demand up to 500kVA		Average	Peak	Shoulder	Off-Peak
Energy Charge (Ush/kWh)		472.3	646.9	476.8	255.4
LARGE INDUSTRIES CONSUMERS - CODE 30 High Voltage 11,000Volts or 33,000Volts, with Maximum Demand Exceeding 500kVA but up to 1,500 kVA		Average	Peak	Shoulder	Off-Peak
Block 1: Energy Charge (Ush/kWh)		386.3	521.3	387.2	245.5
Block 2 (Declining Block*): Energy Charge (Ush/kWh)		369.7	498.9	370.5	235.0
EXTRA - LARGE INDUSTRIES CONSUMERS - CODE 40 High Voltage 11,000V or 33,000V, with Average Demand of at least 1,500kVA and dealing in Manufacturing		Average	Peak	Shoulder	Off-peak
Block 1: Energy Charge (Ush/kWh)		326.6	431.1	328.2	234.9
Block 2 (Declining Block*): Energy Charge (Ush/kWh)		297.8	393.2	299.3	214.2
STREET LIGHTING - CODE 50					
Energy Charge (Ush/kWh)	370.0				

** - The Block 2 (Declining Block) Tariff for Large and Extra-Large Industrial consumers shall be applicable for energy consumed above the threshold determined by the Authority for the respective consumers. The threshold shall be communicated to the respective consumers by Umeme Limited.*

The above Approved Base Electricity End-User Tariffs for 2023 represent a weighted average reduction of **1.2 percent** relative to the Tariffs of the Fourth Quarter of 2022.

The Approved Base Electricity End-User Tariffs shall be subject to quarterly adjustments for changes in International Prices of Fuel, Exchange Rate, Inflation and the Generation Mix. The Parameters used in the determination of the 2023 Base Tariffs are as detailed in **Table 2.**

TABLE 2: PARAMETERS USED IN DETERMINATION OF THE 2023 BASE TARIFFS

Parameter	Source	Rate
Exchange rate (USH/US$)	The Mid-Rate of the Uganda Shilling against the United States Dollar as Published by Bank of Uganda as at 30th November 2022	3,738.33
Core Consumer Price Index (CPI)	Published by the Uganda Bureau of Statistics for November 2022	125.48
International Prices of Fuel (US$ per barrel)	OPEC - International Prices of Fuel for November 2022	89.73

The detailed Tariff Review Report for the First Quarter of 2023 is available at ***www.era.go.ug***

This Schedule of Tariffs for the First Quarter of 2023 shall be applicable to Energy consumed in the period **January to March 2023.**

Dated 31st December 2022

CHIEF EXECUTIVE OFFICER
ELECTRICITY REGULATORY AUTHORITY

Figure 22:Schedule of bases end-user tariffs applicable for the supply of electricity by UMEME for the 2023.

Appendix 2

This appendix represents the state of different Lecture rooms during the time of the study.



Figure 23: Former Minister's Block taken on 1/03/2023, at 9:03Am.

Source: Author's phone camera observational empirical data



Figure 24: Block 3 upper taken on 28/03/2023 at 11:04Am.

Source: Author's phone camera observational empirical data

Appendix 3

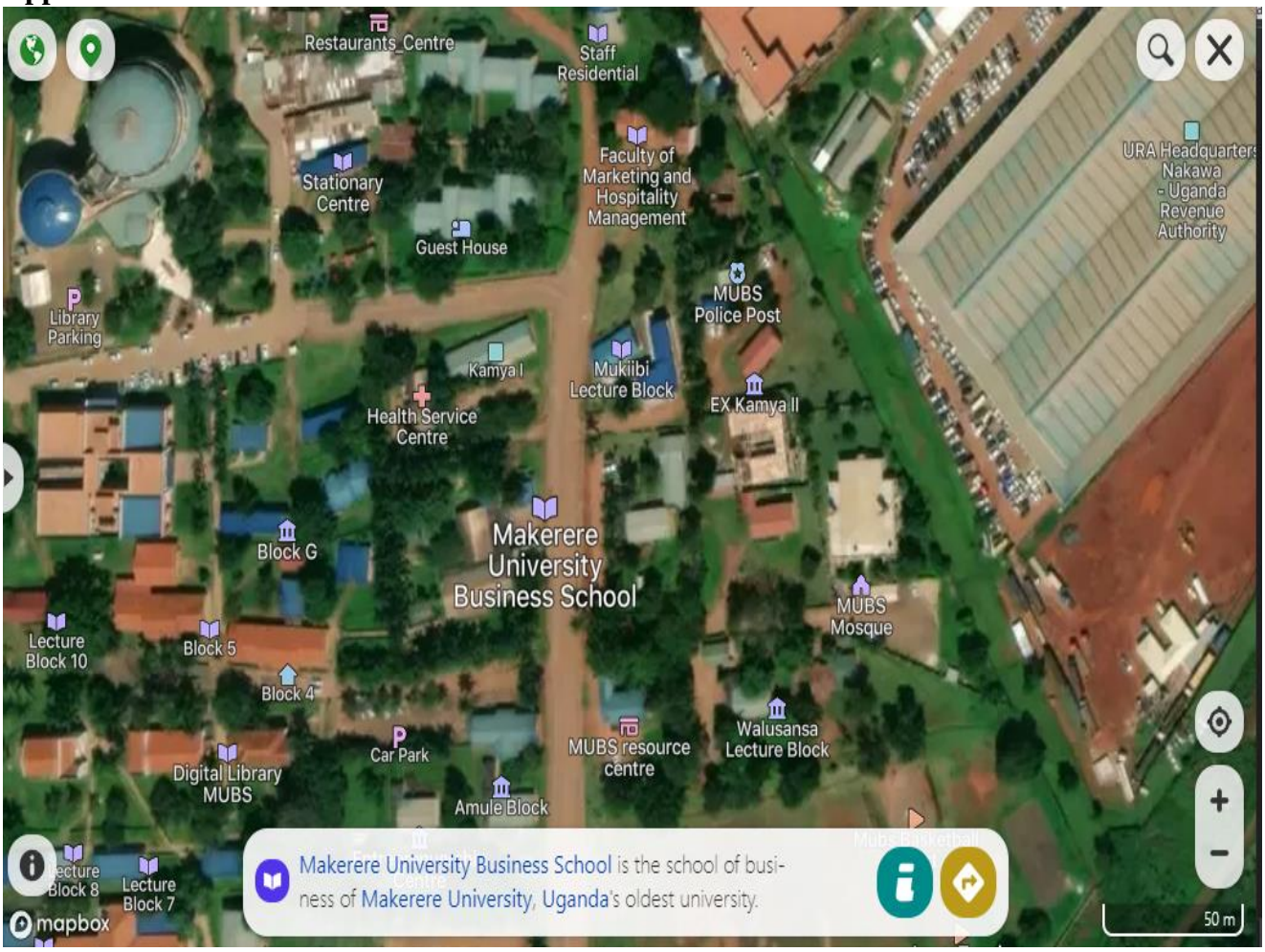


Figure 25: A satellite overview of Makerere University Business School