Potential of Energy Efficiency and Conservation Measures in Residential Buildings in Ghana (Case Study of Student Hostel)

Sufyan Yakubu[1,2,*], Anuware Sadat Abdulai[2], Mathias Maclar[2], Francis Atta Kuranchie[2], Talib Paskwali Beshir Latio[1], Nyagong Santino David Ladu[3]

[1]Pan African University, Institute of Water and Energy Sciences, University of Tlemcen, Algeria

[2]University of Energy and Natural Resources, Sunyani, Ghana

[3]Rumbek University of Science and Technology, South Sudan

Research Article

Open Access &

Peer-Reviewed Article

DOI: 10.14302/issn.2642-3146.jec-24-4935

Corresponding author:

Sufyan Yakubu, Pan African University, Institute of Water and Energy Sciences, University of Tlemcen, Algeria, University of Energy and Natural Resources, Sunyani, Ghana

Keywords:

Energy efficiency and Conservation, Energy audit, University of Energy and Natural Resources, Energy management program, Residential Energy consumption, Ghana

Received: January 23, 2024

Accepted: March 12, 2024

Published: March 18, 2024

Academic Editor:

Loai Aljerf, Department of Life Sciences, Faculty of Dentistry, University of Damascus

Citation:

Sufyan Yakubu, Anuware Sadat Abdulai, Mathias Maclar, Francis Atta Kuranchie, Talib Paskwali Beshir Latio, et.al(2024) Potential of Energy Efficiency and Conservation Measures in Residential Buildings in Ghana (Case Study of Student Hostel). Journal of Energy Conservation– 1 (4): 23-41. https://doi.org/10.14302/issn.2642-3146.jec-24-4935

Abstract

Promoting responsible energy usage in student hostels and residential buildings plays a crucial role in ensuring sustainable development. By implementing cost-efficient strategies for managing and conserving energy, both students and homeowners can not only reap economic and social benefits but also mitigate the adverse environmental effects associated with energy consumption. Unfortunately, student hostels and residential buildings in developing countries like Ghana are falling behind in the adoption of energy efficiency and management practices, thereby missing out on valuable implementation opportunities. This study investigates the potential for energy efficiency and conservation measures in student hostels, specifically the GETFUND hostel of the University of Energy and Natural Resources in Ghana. The hostel's monthly energy consumption is approximately 64,929.458kWh, which translates to $5,667.20. The objectives of the study include analysing the current electricity consumption pattern, identifying energy misuse, and recommending measures to save energy, as well as calculating the financial benefits of implementing energy management practices. The methodology employed is an energy audit approach. The results of this study can contribute to overall energy conservation efforts in Ghana and may be applied to other university residence halls in sub-Saharan African countries with similar climatic and energy-use characteristics. In a broader sense, the primary objective of this study is to enhance the energy efficiency of the GETFUND hostel and minimize energy wastage, resulting in substantial financial savings.

Introduction

Over the years, global warming has become a major concern on both national and international fronts, leading to various efforts being directed towards addressing this challenge. One approach to combating this issue is the implementation of energy efficiency and conservation measures, which are both easy and cost-effective. By adopting this approach, the combustion of carbon compounds at power generation stations will be greatly reduced, consequently mitigating the emission of greenhouse gases. These gases are the primary drivers of global warming. Energy efficiency and conservation measures are being explored to achieve sustainability, economic growth, development, climate protection, and resource protection, including through proper energy management systems. Buildings are responsible for approximately 30% of the total global final energy demand and contribute to one-third of energy-related emissions [1]. The promotion of energy efficiency and conservation not only contributes to emissions reduction but also stimulates economic growth and fosters development [2].

Due to factors such as industrialization, population growth, and economic expansion, the global demand for energy continues to increase in both developed and developing economies. Energy consumption in Ghana is estimated to be increasing by 10% annually due to the demand from a growing population and inefficient energy use [3]. The government should take the lead in promoting efficient energy use at the national level by implementing energy efficiency legislation and devoting budgets to encourage energy efficiency programs and raise awareness[2]. The energy commission in Ghana has launched several energy efficiency initiatives, such as distributing six million compact fluorescent lamps, a capacitor installation program, and a refrigerating efficiency and market transformation project [5]. Despite these efforts, more intense public education and awareness in energy management programs is needed to achieve a sustainable energy industry.

Energy conservation and energy efficiency are two important ways of reducing energy consumption patterns. Energy-efficient practices lead to energy conservation, and conserving energy leads to effective energy use, hence ensuring energy efficiency. The two terms are often used interchangeably.

Research shows that Ghana's population is increasing annually, which in turn increases energy demands. However, Ghana's energy data is not encouraging due to its instability. Hydro power was the main source of energy in the country until thermal power was introduced due to electricity shortages and load shedding [2]. Despite having one of the highest rates of electricity accessibility in Sub-Saharan Africa, with 86% of the population having access in 2020[4], [5], energy efficiency in Ghana remains poor in both domestic and commercial usage. Improper appliance usage in households, government and private offices, and enterprises leads to wastage of energy [4].

The energy crisis has raised many concerns, including the overlooked issue of energy management programs as an option to stabilize and sustain the energy sector through efficient energy use. This project aims to make available to the public measures that can be taken in residential buildings to ensure efficient and conservative energy use, reducing monthly energy bills and reducing pressure on the country's energy supply, thus ensuring sustainability of the sector.

In recent years, advancement in technology and equipment has greatly impacted on global energy consumption both positively and negatively. The advancement has seen to lots of improvements in the efficiency of various energy consuming equipment's, but due to technological improvements in other sectors of life, high rating equipment to facilitate work and comfort also consumes lots of energy. Studies have advanced in this area with respect to energy efficiency and conservation and its effect by technology advancement. [6] presented an analysis of technical parameters on the use of gas and electricity for Dutch homes while also considering demographic characteristics of the residents. The findings indicated that systemic habitation features predominantly influence residential gas consumption, while electricity consumption is more closely associated with household composition, particularly factors such as income and family structure. The neutral network method of estimating energy consumption is more accurate than engineering models in predicting energy consumption in homes [7].

The stability of residential energy consumption is greatly affected by climate and weather changes. Thermal comfort is one major area that rule the sector of energy consumption with respect to climate changes in residential buildings. Seasonal changes come with different consumption patterns as different activities need to be taken care of. In a study conducted by [8], a method was developed to identify and assign weights to indicators used for evaluating the energy efficiency of residential buildings in China. The assessment of energy efficiency indicators was carried out for both summer and winter seasons. The study employed a questionnaire survey and employed the group analytic hierarchy process to determine the relative importance of the identified indicators. The findings suggest that different climate zones require distinct indicators.

The occupants of buildings play an important role in the energy consumption of the building, in fact, they determine the appliances that need to be "ON" and for how long. As such, a building's efficiency level is so dependent on resident's behaviour, which is characterized by their knowledge in the concept of energy efficiency and conservation. Informing the public, homes, and individuals on energy appliance selection is critical in assisting in making the best decision when acquiring an electrical appliance, which will result in economic and environmental benefits [9]. In a separate study conducted by [10], a systematic procedure was employed to investigate the influence of occupant behaviour on building energy consumption. The results demonstrated that this method improved the assessment of building energy-saving potential by addressing occupant behaviour. Furthermore, it provided comprehensive insights into the various aspects of building energy end-use patterns associated with occupant behaviour. Furthermore, a research study conducted by [11] aimed to recommend a range of efficient and economically viable energy conservation techniques. These techniques were proposed to reduce the overall energy consumption of typical residential buildings in Jordan. The researchers utilized DesignBuilder software to assess and analyse the impact of these recommended measures. The findings demonstrated that the implementation of these measures resulted in a considerable decrease in yearly electricity usage. Furthermore, the implementation of the retrofit program yielded significant reductions in both peak demand and carbon emissions. In the initial stage of the program, which required minimal costs, a total of 1955 GWh of electricity was saved annually, along with a reduction of 489 MW in peak demand and a decrease of 1321 kilotons of CO_2 emissions on an annual basis. The installation of an automated temperature control system, insulation of the building's roof, and improved lighting have been determined to be the most efficient energy-saving techniques. The most important plan for public buildings in Egypt that Ingy El-Darwish and Mohamed Gomaa examined by [12]. A Kuwaiti residential structure could benefit from an energy-efficient renovation effort, according to a study by Moncef Krarti. The program's goal was to reduce Kuwait's high energy usage over the course of three stages. The outcomes of the simulation demonstrated that significant economic and environmental gains are possible [13]. [14] proposed an energy retrofitting program for Oman's fleet of buildings. The scheme reduced peak demand by 214 MW and yearly power usage by 957 GWh A similar retrofit study by [15] for Saudi Arabian saved 62,839 GWH of power annually. Also, [16] conducted a thorough analysis of Ghana's public and commercial offices' energy efficiency. They focused their investigation on how much electricity air conditioners use. The results showed that Ghana uses air conditioners at an energy consumption of between 3000 and 5400 kWh annually depending on their brand and cooling capacity. Low energy efficiency rating of air conditioners of a major contributing factor to their high electricity consumption. The studies concluded that 480MW of power generation will be required by 2030 if the nation continues its path of using low-energy efficient rating air conditioners. Study [17] investigated potential opportunities for cost-saving in public tertiary institutions by exploring energy efficiency approaches and the adoption of solar energy. The research aimed to identify strategies that could effectively reduce energy costs in these institutions.

Numerous studies have been conducted on the topics of energy efficiency and conservation in various types of buildings, including residential, public, and commercial structures. However, most studies have suggested an economically efficient approach of retrofitting as a measure to significantly reduce energy wastage and decrease the levels of CO_2. Although there is an increasing awareness of energy efficiency and conservation measures in residential and commercial buildings in Ghana, there is no study focusing on the potential of these measures in student hostels. This study gap needs to be addressed as students' hostels play a significant part in energy consumption in the country and a better understanding of their energy-saving potential can contribute to overall energy conservation efforts in Ghana.

It is possible to learn important lessons from the UENR case study that may be applied to other university residence halls not just in Ghana but also in other sub-Saharan African countries with comparable climatic and energy-use characteristics. The methodology employed in this study is an energy audit approach.

To accomplish the aforementioned goal, the following objectives were taken into account:

- Conduct a study on the current electricity consumption pattern in the GETFUND hostel of the UENR in Ghana.
- Identify instances of energy misuse and recommend potential measures to save energy.
- Determine the economic advantages of adopting energy management practices.

The aim of this study is to make the GETFUND hostel more energy efficient. It is undeniable that hostels of various institutions consume a significant amount of energy, and it is also undeniable that we squander a significant portion of it. The hostel's monthly energy consumption is roughly 64,929.458kWh, which equates to $5667.20. This sum is enormous, and it naturally draws our attention when we consider that a significant amount of energy is being spent, implying that a significant number of financial resources is being wasted.

The paper is structured into five sections. The introduction, presented in Section 1, provides an overview of the study. Section 2 offers a comprehensive description of the study area. The materials and methods employed in the research are outlined in Section 3. The findings of the study are presented and analysed in Section 4. Finally, Section 5 concludes the paper and provides recommendations based on the study's findings.

Description of facility

Feature	**Description**
Location	Campus-based hostel, located close to the lecture halls
Building	Four-story building
Residential rooms	173 rooms

Additional spaces	Management offices, recreational spaces, study rooms, supermarket, hair salon, printing press, store rooms, kitchens, television rooms, and a radio station
Student population	670 students (majority are first-year students; 483 males and 185 females)
Energy source	Electricity
Monthly energy consumption	64,929.458 kWh
Financial impact	Significant financial resources being wasted
Electricity billing	Free electricity for occupants, not directly billed to them

Materials and methods

The research used an energy audit technique, which enables us to better understand how energy is utilized in a building and identifies potential energy wasting areas as well as areas for improvement. The various process are as follows:

1. Preparation/ Pre-audit phase: This involves collecting data on the hostel facility, including its physical characteristics, energy consumption history, and any existing energy management systems or programs.
2. Physical Inspection: it involves a walk-through audit of the hostel facilities, observing the students' behaviors and consumption patterns to obtain a clear understanding of the energy consumption pattern.
3. Data Collection: Data was collected by physically counting lighting and electrical items, as well as determining the average usage time, number of rooms, and number of students in each room. Structured questionnaires were administered to a sample of students to obtain information regarding their awareness of energy conservation, energy consumption patterns, and energy-saving practices. The hostel population was divided into two main strata: male and female. The questionnaires were administered using a combination of simple random sampling and stratified sampling techniques. A total of 80 rooms were included in the study, which accounted for more than 45% of the entire hostel population.
4. Data Analysis: Microsoft excel was used to analysed the data. Based on the end-use, the connected loads were classified into different categories (e.g., lighting, refrigeration, cooling, cooking, heating, and others) and estimate the electricity usage using load reducing factors such as diversity factor and duty cycle.

Results and Discussion

Data Analysis and Results

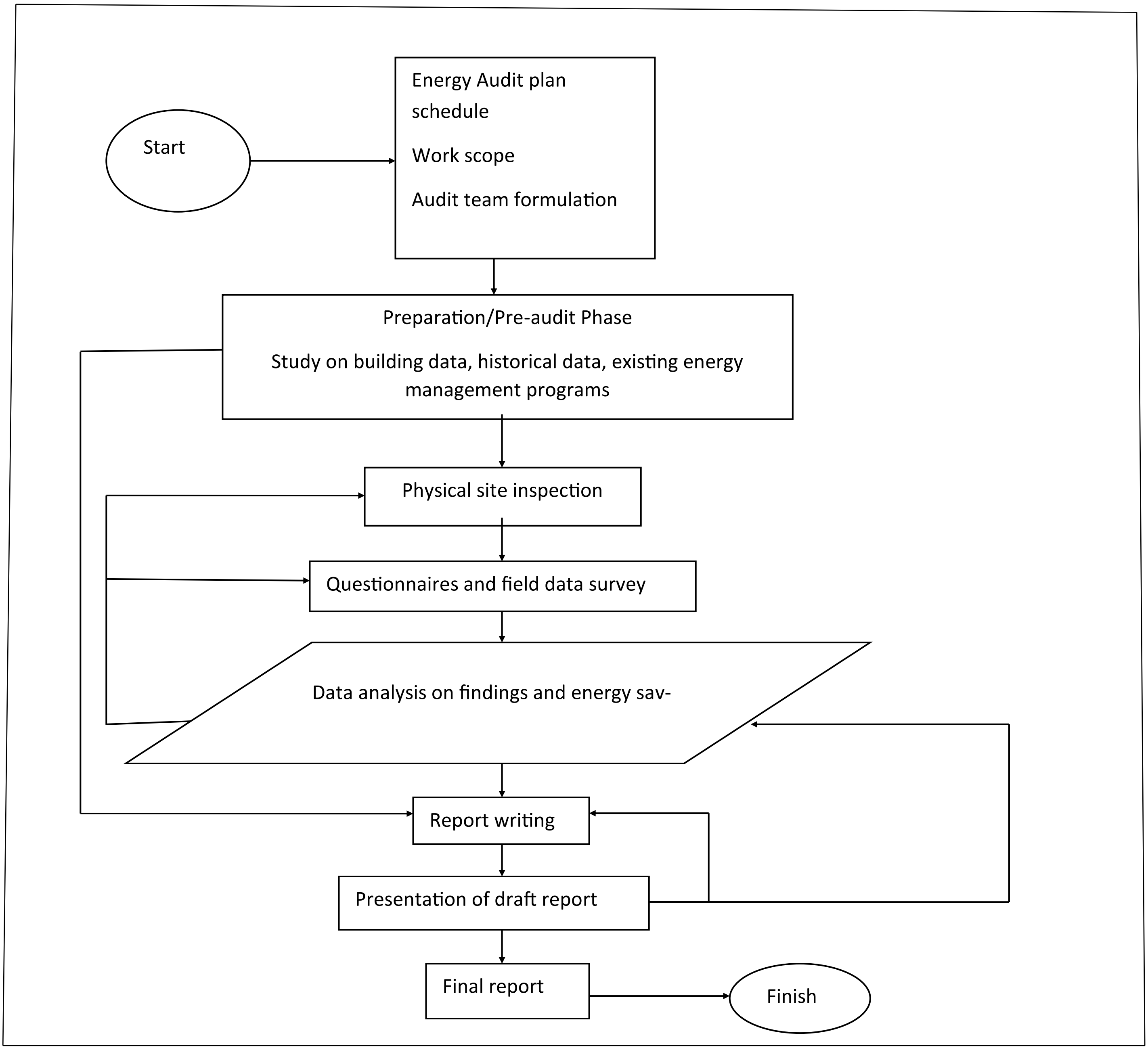

Table 1. Hostel energy audit for lighting

Load description	QTY	Av. Watt.	Hours/day	kWh/day	Days/week	kWh/month	kWh/ year
fluorescent tube(4 ft)	256	36	14	129.024	7	3,913.73	46,964.7 4
fluorescent tube(2 ft)	340	18	14	85.68	7	2,598.96	31,187.5 2
CFL bulb	510	18	14	128.52	7	3,898.44	46,781.2 8
SUBTOTAL	**1106**			**343.224**		**10,411.13**	**124,933.**

Table 2. Hostel Energy Audit for Male Block

Load description	QTY	Av. Watt.	Hours/day	kWh / day	Days/week	kWh/month	kWh/ year
Rice cooker	200	700	1.5	210	7	6,370	76,440
Electrical hot plate	122	2250	1.5	411.75	7	12,489.75	149,877
Microwave	6	1000	0.5	3	7	91	1,092
Blender	15	3500	0.25	13.125	4	227.5	2,730
Electrical kettle	76	2000	0.25	38	7	1,152.67	13,832
Electric iron	122	1000	0.5	61	7	1,850.33	22,204
Refrigerator	61	150	12	109.8	7	3330.6	39967.2
electric fan	33	60	16	31.68	7	960.96	11,531.52
Laptop	363	45	8	130.68	7	3,963.96	47,567.52
Television	13	60	4	3.12	7	94.64	1,135.68
Phone	484	3	3	4.356	7	132.132	1,585.58
SUBTOTAL				**1016.511**		**30663.54**	**367962.5**

Table 3. Hostel Energy Audit for Female Block

Load description	QTY	Av. Watt (W)	hours/day	kWh/ Day	days/week	kWh / Month	kWh/yr.
rice cooker	94	700	1.5	98.7	7	2,993.90	35,926.80
electrical hot plate	94	2250	1.5	317.25	7	9,623.25	115,479
Microwave	15	1000	0.5	7.5	7	227.5	2,730
Blender	30	3500	0.25	26.25	4	455	5,460
electrical kettle	30	2000	0.25	15	7	455	5,460
electric iron	102	1000	0.5	51	7	1,547	18,564
Refrigerator	47	150	12	84.6	7	2566.2	30794.4
electric fan	24	60	16	23.04	7	698.88	8,386.56
Laptop	142	45	8	51.12	7	1,550.64	18,607.68
Television	12	60	4	2.88	7	87.36	1,048.32
Phone	188	3	3	1.692	7	51.324	615.888
SUBTOTAL				**679.032**		**20256.1**	**243073**

Table 4. Hostel Energy Audit for Management Offices

Load description	QTY	Av. Watt. (W)	hours/ day	kWh/ day	Days/ week	kWh/ month	kWh/ year
Refrigerator	3	150	12	5.4	7	163.8	1965.6
electric fans	6	75	12	5.4	7	163.8	1965.6
air conditioner	4	3000	5	60	5	1300	15600
laptop/desktop	5	100	10	5	5	108.33	1300
Television	1	60	15	0.9	7	27.3	327.6
SUBTOTAL				**76.7**		**1763.233**	**21158.**

Table 5. Hostel energy audit for commercial activities

Load descrip-	QTY	Av. watt.	hours/day	kWh/day	Days/week	kWh/month	kWh/year
Refrigerator	5	200	12	12	7	364	4368
electric fan	6	75	15	6.75	6	175.5	2,106
laptop/desktop	12	100	20	24	6	624	7,488
Television	5	60	12	3.6	6	93.6	1,123.20
Photocopier	2	750	12	18	6	468	5,616
Printer	2	20	10	0.4	6	10.4	124.8
hair dryer	5	100	10	5	6	130	1,560
SUBTOTAL				**69.75**		**1865.5**	**22386**

Overview of Current Energy Cost

Cost of Energy = Energy (kWh)* 0.08728235 USD/kWh … …. (1)

Table 6. Residential tariff rates from Public Utilities Regulatory Commission (PURC)[18]

Residential End User Tariff (EUT)/kWh	Charge Per Kilo-watt hour (Ghp/kWh)	Charge Per Kilo-watt hour (USD/kWh)
0 – 50	32.6060	0.030169789
51 – 300	65.4161	0.060528429
301 – 600	84.8974	0.078554152
600+	94.3304	0.08728235

Table 7. Load Categorization with Monthly Energy Cost

Load Categorization	kWh/Month	Energy Cost (USD)
Lighting	10411.13	908.71
Refrigeration	6424.6	560.75
Cooling	3299.14	287.96
Cooking	32129.4	2,804.33
Heating	5453.5	475.99
Others	7211.688	629.45
TOTAL	**64929.458**	**5,667.20**

Table 8. Energy consumption(kWh) by each block in terms of load category

Block	Lighting	Refrigeration	Cooling	Cooking	Heating	Others	Total
Male	------------	3330	960.96	19087.25	3094	4190.732	**30663.542**
Female	------------	2566.2	698.88	13072.15	2229.5	1689.326	**20256.05**
Management offices	------------	163.8	1463.8			135.63	**1763.23**
Commercial activities	------------	364	175.5		130	1196	**1865.5**
Total	**10411.125**	**6424.6**	**3299.14**	**32159.4**	**5453.5**	**7211.688**	**64959.45**

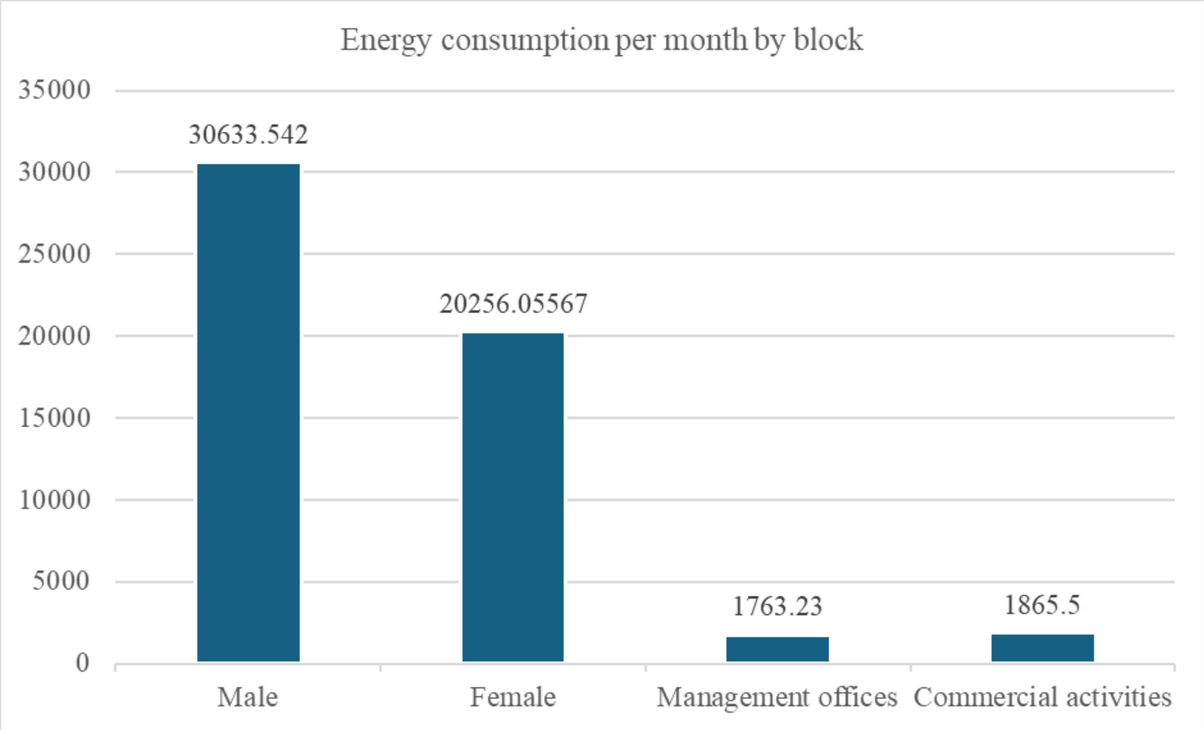

Figure 1. Electricity consumption (kWh) per month by block

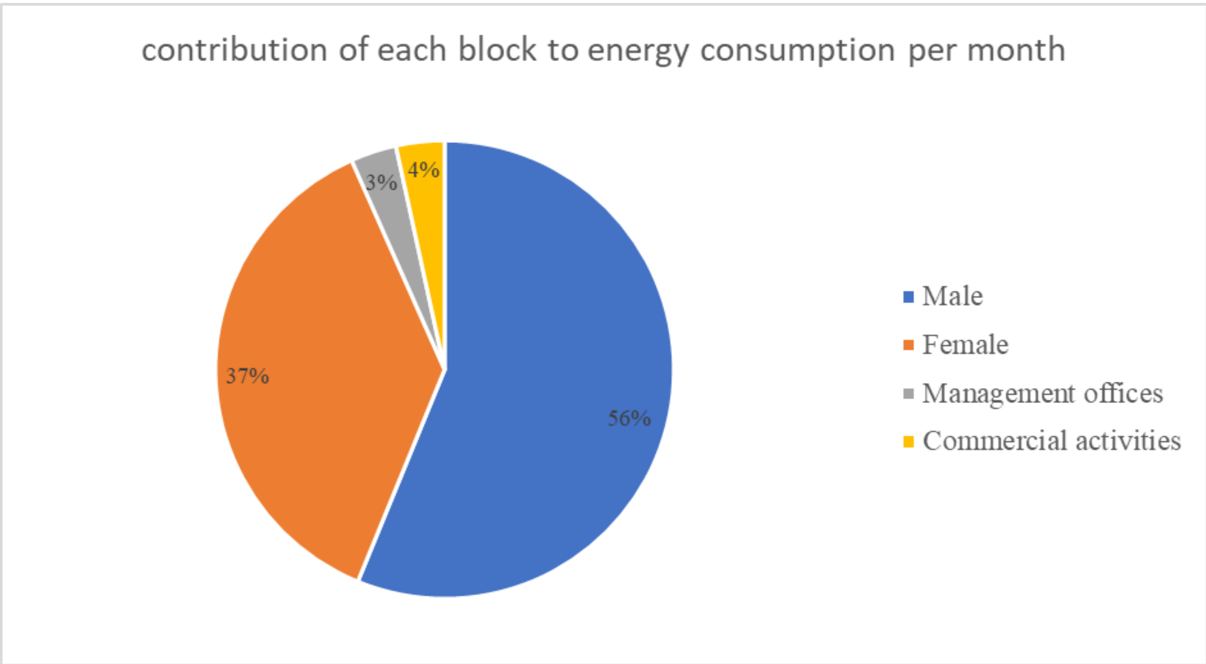

Figure 2. Percentage contribution of each block to energy consumption per month

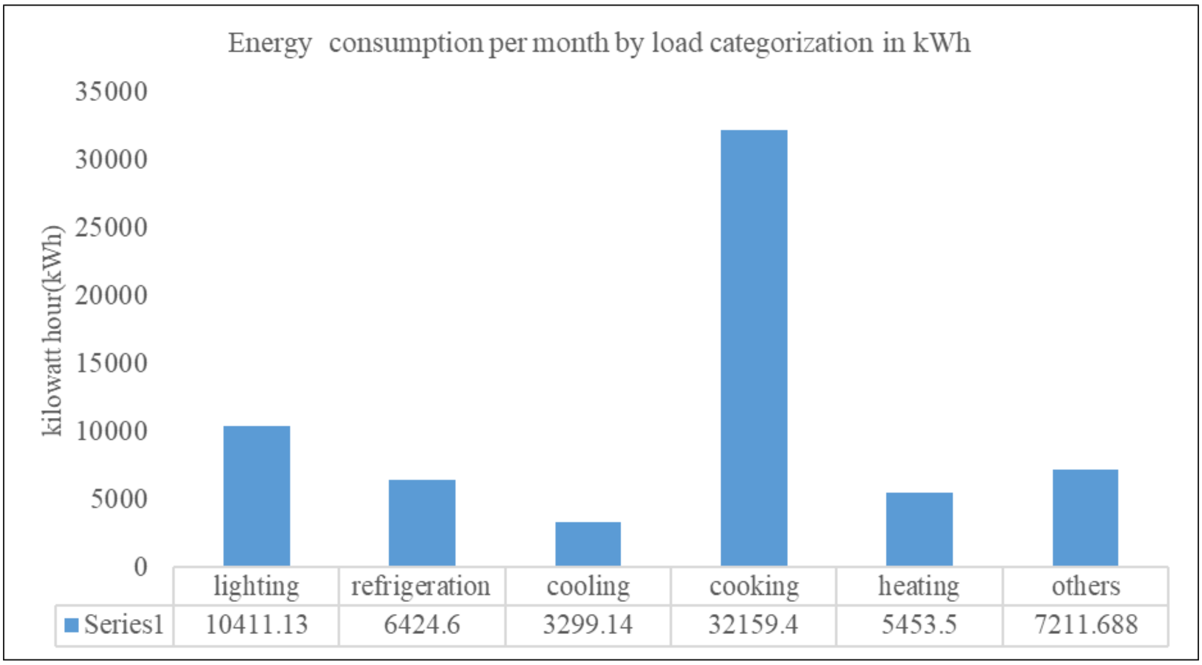

Figure 3. Electricity consumption(kWh) per month by load categorization

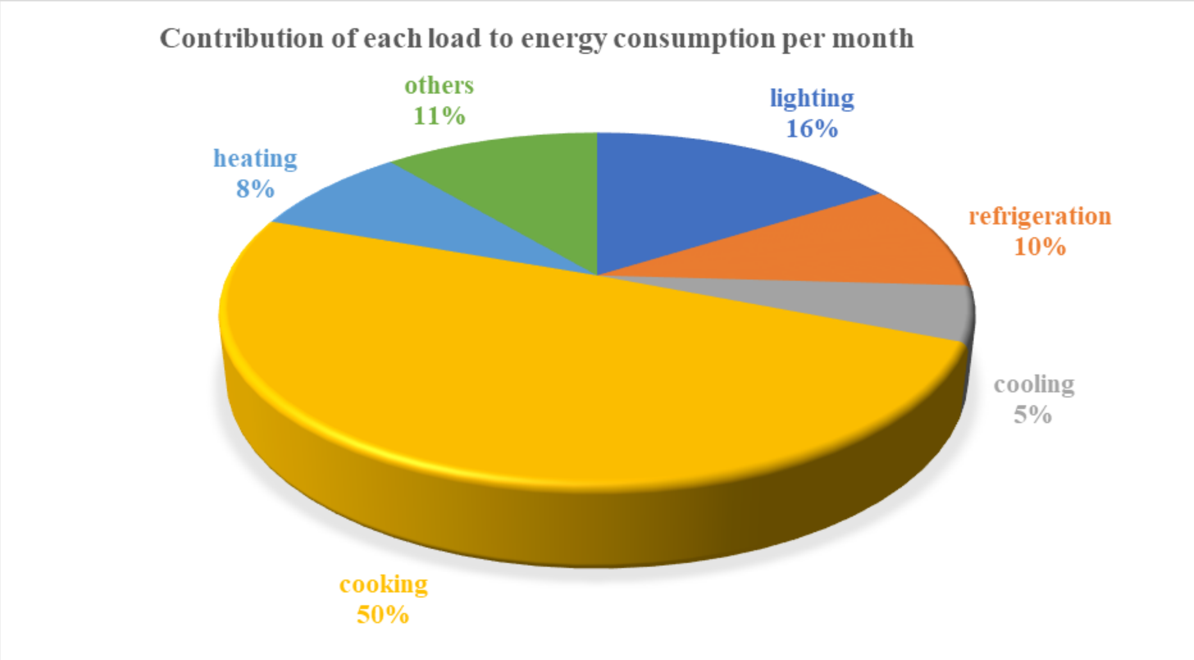

Figure 4. Percentage contribution of each load to energy consumption per month

Discussion

The data presented in figures 1 and 2 of the study indicate that a substantial proportion of the electricity consumed in the hostel is credited to the male and female hostel blocks. These two blocks constitute the majority of the residents in the hostel, and collectively they account for 93% of the total electricity used in the building. The remaining 7% of electricity consumption is attributed to the management offices and the commercial activities within the hostel building, which accounts for 3% and 4% respectively. Further analysis of the data reveals that out of the 93% of electricity consumed by the two blocks, the male block contributes about 56%, while the female block accounts for 37% of the total electricity usage. This information indicates that addressing energy efficiency and conservation measures within the male and female blocks would be a significant step towards reducing overall electricity consumption in the hostel.

The study analysed the energy consumption of the student hostel and found that there were significant differences in electricity usage among different categories of loads. Results from figures 3 and 4 show that cooking is the biggest energy consumer, accounting for 50% of the total electricity consumed by the hostel on a monthly basis. This finding confirms that the male and female blocks, who are the only contributors to cooking, are the major consumers of energy in the hostel. Lighting is also a major contributor to electricity consumption, representing about 16% of the total energy used. Refrigeration, heating, cooling, and other categories of loads also contribute to electricity consumption, with refrigeration accounting for 10%, heating for 8%, cooling for 5%, and others contributing about 11% of the consumed electricity in a month.

The various categories, their consumption and contributions to the electricity bills are further discussed in details below.

Lighting

The audit team observed that the hostel management has installed mostly Compact Fluorescent Lamps (CFLs) and fluorescent bulbs, which are energy-efficient types of bulbs. However, during the walk-through audit and based on the responses from the administered questionnaires, the audit team observed that external light bulbs were often left switched on during the day. Additionally, it was noted that students frequently left the light bulbs in their rooms illuminated even when they were away attending lectures. The questionnaire results revealed that 69% of the respondents agreed that light bulbs were occasionally left on during the day, a finding that was corroborated by the audit team's daily visits.

By turning off the lights in rooms when not in use and turning on external light bulbs only at night, the average daily 'ON' hours of light bulbs can be reduced to 9.5 hours from 14 hours, which results in a 32% reduction in energy spent on lighting is equivalent to 3,331.56kWh or $290.79 in cost savings. This reduction in energy consumption will lead to a decrease in electricity bills for the hostel. Additionally, to make the lighting system of the hostel more efficient, the hostel management can consider replacing the CFLs and fluorescent bulbs with LED bulbs. LED bulbs are highly efficient, have a longer lifespan, emit little heat, do not contain toxic materials like mercury dust found in fluorescent bulbs, and are more versatile. This could result in even greater energy savings and cost reductions for the hostel over the long term.

When considering power consumption, energy efficiency, energy costs, and average lifespan, replacing current CFL bulbs with LEDs will cut lighting electricity consumption in half, resulting in close to 50% monthly savings. The 18W CFLs will be replaced by 8W LEDs, and the 36W fluorescent will be replaced by 26W LEDs, which are slightly more expensive than CFLs. LED bulbs cost between $1.2 and $1.5.

Possible savings if the bulbs were to be replaced by LED bulbs

18W CFLs to 8W LEDs and 36W Fluorescent to 26W LED.

10W saved by replacing each 18W CFL bulb and 36W fluorescent bulbs,

Total number of bulbs = 1,106 bulbs

Total wattage saved = 10 * 1,106 = 11,060W = 11.06KW

Total energy saved daily = 11.06 * 14 = 154.84KWh per day.

Percentage saved = 154.84/343.224 = 45.11%

This 45.11% in savings corresponds to 4,627.747kWh savings per month, which is equivalent to $403.92 savings per month.

Possible savings in replacing with LED and reducing operational (ON) hours =

4,627.747kWh +1,850.68kWh=6,478.429kWh

(6,478.429/10,411.06) * 100 = 62.22%

If bulbs were to be replaced with LEDs and the bulb operational hours also reduced, this corresponds to 62.22% savings in lighting.

Payback period for bulbs replacement

Bulk purchase of LED bulbs = $1.2 each

Number on demand = 1,106 pieces

Cost of bulbs = $1,327.2

Additional cost = $604.21

Total cost = $1,931.41

Payback period = total cost of replacement/monthly savings = 1,931.41/403.92 = 4.78 months, which is approximately 5 months.

Cooking

The cooking category in the hostel consists of rice cookers, electrical hot plates, and blenders, and it is identified as the activity that consumes the highest amount of electricity. According to Figure 4, it contributes to around 50% of the total electricity usage in the hostel. Figure 6 provides a breakdown of the contributions of each cooking appliance to the overall electricity consumption in cooking activities alone. The results depicted in Figure 6 reveal that electrical hot plates alone consume approximately 69% of the electricity utilized for cooking, resulting in a monthly consumption of 22,113 kWh and a corresponding cost of $1930.07.

The hot plates used in the hostel exhibit the highest percentage of energy consumption compared to other appliances. Specifically, rice cookers contribute to 29% of the energy used for cooking, while blenders only account for 2%. During a walk-through inspection of the hostel, it was observed that many students utilize inefficient hot plates instead of efficient ones. These inefficient hot plates have high-power ratings and lack proper regulation, operating with a duty cycle of one, meaning they continue to draw current even when the heating element is already red-hot. As a result, a significant amount of electrical energy is wasted, and there is a risk of damage to cables and socket outlets. By transitioning to efficient hot plates with lower power ratings and improved duty cycles, energy consumption could be significantly reduced. Efficient hot plates are equipped with regulators for temperature and duty cycle control. If the regulated hot plates were the primary ones used in the hostel, the high efficiency they offer could lead to energy savings of over 50%. Currently, the majority of hot plates in use are inefficient, with power ratings exceeding 2,000W, representing approximately 90% of all hot plates in the hostel.

Possible savings from the use of efficient electrical hot plates:

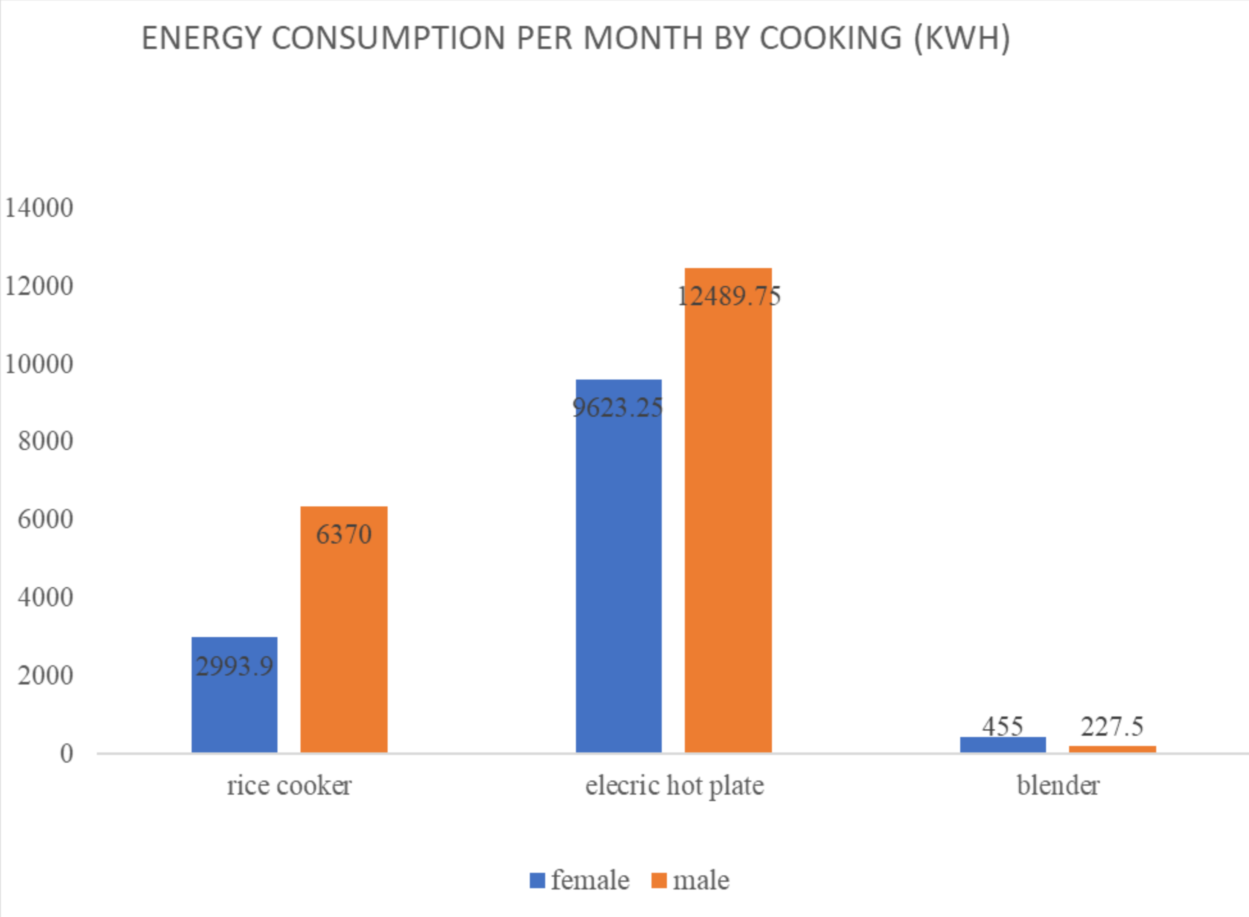

Figure 5. Energy consumption(kWh) per month by the various appliances that makes up the cooking category

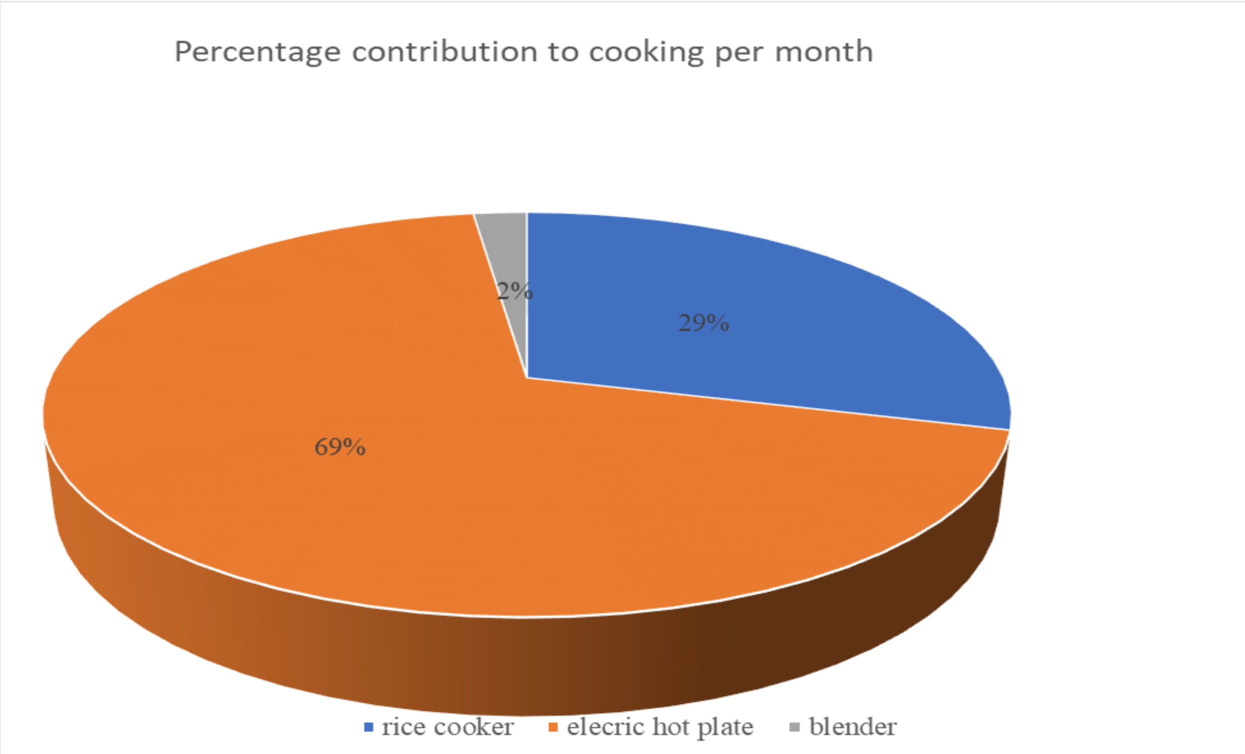

Figure 6. Percentage contribution of the various cooking loads

Average Power ratings of inefficient hot plates: 2,250W = 2.25KW

Average power ratings of efficient (regulated) hot plates: 1000W = 1KW

Replacing the inefficient hot plates with the efficient regulated hot plates implies a 1250W or 1.25kW savings per each used hot plate.

As such, (1.25/2.25) * 100 = 55.56% energy savings from the hot plates.

Amount of energy used by hot plates monthly = 22,113KWh

55.56% of 22,113kWh = **12,285.98kWh**

That is **$1072.35** savings monthly.

Refrigeration

As shown in figure 4, this accounts for 10% of the monthly electricity consumption. The hostel has a total of 116 refrigerators, with 61 in the male rooms (as indicated in table 2), 47 in the female rooms (as indicated in table 3), 3 in the management offices, and 5 in other areas (as indicated in tables 4 and 5, respectively). Options for saving energy primarily depend on the habits and behaviours of the users. Therefore, residents' behaviour towards the use of such appliances should be a priority, ensuring that they have some basic knowledge concerning the use of such things. Some of these include:

1. Location: During our visits, we noticed that residents placed their refrigerators near areas where they engage in cooking. These are typically warm places that increase the compressor work and, therefore, increase energy consumption. They should be informed to place them in well-ventilated areas to enhance air flow and improve efficiency.
2. To save energy, it is important to develop good habits such as tightly closing refrigerator doors after use. This helps maintain the desired temperature and prevents energy loss. Additionally, switching off the refrigerator when it is empty can contribute to further energy savings.
3. Unnecessary opening of the refrigerator also increases energy consumption.

Heating

As shown in figure 4, this category accounts for 8% of the electricity consumed in the hostel monthly. The heating category consists of irons, heating kettles, hair dryers, and microwaves. Most appliances in this category operate for a short period of time, and with their high input power ratings, they do not work for a long time, hence they do not consume lots of energy over the operating time. Ironing, which is part of this category, was a major contributor to the consumption of the category. Each room has at least two irons, and in most rooms, only one is used by all four members in the room.

To save energy from ironing, residents should practice ironing in bulk. This means they can always iron as many clothes as they will be using over the week and do it together instead of doing it individually on a daily basis. This reduces the consumption of ironing as they always surge to heat up initially anytime, they are plugged in, drawing huge amounts of power in the process of starting up. So, if they were to practice bulk ironing, they would not be using much power for surge, and most of the irons also have good duty cycles, hence they will operate for longer periods without consuming throughout the whole time of operation. However, from our daily visits, we realized that students mostly iron when they are about to leave for lectures, so they put the iron 'on' for what they want to wear at that moment. Doing this individually increases consumption.

Cooling

The category comprising air conditioning and fans accounts for 5% of the monthly electricity consumption in the hostel, as shown in figure 4. Only a few areas in the building have air conditioning units installed and operational, most of which have high ratings with good duty cycles, making them relatively efficient. However, the temperature settings are frequently adjusted, causing the air conditioners to work harder to cooperate with the new settings. Consequently, they record very low duty cycles, which reduces their efficiency and leads to an increase in consumption. To operate efficiently, the temperatures should be kept relatively stable and not set too high from the ambient temperature, which helps the air conditioners work within a certain range over a more extended period. This ensures good duty cycles, which will increase efficiency and reduce consumption.

Fans, which are also part of this category, make up a significant part of the cooling consumption due to their numbers. During our audits, we observed that some residents leave their fans on for extended periods, even when they are not present. They justify their actions by saying that they want to cool the room before returning. However, it should be noted that the longer the fan operates, the more heat energy it produces. This heat will then have to be battled by the same fan, reducing its efficiency and increasing consumption. Therefore, residents should turn off their fans when leaving their rooms. Additionally, natural ventilation should also be used to support the cooling of the rooms, as the hostel is located in a forest zone with tall trees. The rooms have spacious windows and an open balcony to support natural ventilation, which will reduce the operation hours of the cooling equipment and hence reduce consumption.

Other

This category encompasses all other appliances not included in the previous categories, such as computers (laptops and desktops), phones, photocopiers, printers, televisions, and others. As shown in figure 4, this category accounts for 11% of the monthly energy consumption in the building. The high consumption in this category is largely due to misconceptions about the operation of some appliances and the poor behavioural habits of the residents when using them.

During the audit, it became evident that most residents do not unplug their laptops and phones from the chargers or remove the chargers from the sockets when the batteries are fully charged. This means that these appliances continue to draw current from the source unnecessarily, using more energy than needed and increasing consumption. Many residents mistakenly believe that leaving the chargers plugged in has no effect when the batteries are fully charged, but this is not the case.

To save energy, desktops, printers, and photocopiers should be put on energy saver or standby modes when not in use, or turned off if they will not be used for extended periods. This will reduce energy consumption and minimize wastage.

Potential Savings from The Audit

Savings from reducing operational (ON) time of lighting = **32%** = **3,331.56kWh** and amount to **$290.79** per month.

Savings from lighting with retrofitting = **45.11%,** making **4,627.747kWh**, which is equivalent to **$403.92** savings per month.

Savings from lighting by retrofitting and reducing "ON" time = **62.22%** which is equivalent to **6,478.429kWh** and amount to **$565.45**

Savings from cooking = **55.56%** = **12,285.9828kWh**, that is **$1072.35** savings monthly

Total savings (reducing "ON" time + cooking) = **15,617.543KWh** = **$1363.14**

Total savings (with retrofits + cooking) = **16,913.7298kWh** = **$1476.27**

Total savings (reducing "ON" time + cooking + retrofitting) = **18,764.4118kWh** = **$1637.80**

In comparison to the monthly electricity bill of **$5,667.20**, the total savings amount to a significant **29%** reduction in the hostel's monthly electrical energy costs.

Summary of Savings

The table 9 below shows a summary of potential recommendation measures and estimated monthly and energy savings from our audit hotspots (lighting and cooking).

Table 9. Summary of recommended measures and their estimated monthly energy and cost savings

No.	Recommended Measure	Estimated monthly energy savings	Estimated monthly cost savings	Estimated implementation cost	Payback period
1	Observing proper use of lighting system to reduce operational hours.	3,331.56kWh	$290.79	-----	------
2	Replacing CFLs and Fluorescent bulbs with low wattage LEDs.	4,627.75kWh	$403.92	$1,931.41	5 months
	Replacing with LED and reducing "ON" time	6,478.43kWh	$565.45		
3	Replacing in efficient electrical hot plates with efficient hot plates	12,285.98kWh	$1,072.35	-----	------
Total savings for replacing with LEDs + reducing "ON" time + cooking savings		**18,764.41kWh**	**$1,637.8**	**$1,931.41**	**1.2 Months**

Recommendations and Conclusion

Recommendations

After investigating the potential of energy efficiency and conservation measures in residential buildings in Ghana, with a focus on a student hostel as a case study, the following recommendations are proposed:

1. Increase awareness: Create awareness about energy-saving habits and their benefits through various mediums such as the hostel notice board, the student representative council (SRC), and the

university's FM radio station.

2. Upgrade lighting: Replace current CFL bulbs with more energy-efficient LED bulbs in the long-term plan of the hostel to increase savings and reduce energy costs.
3. Regulate appliance usage: Include a list of inefficient appliances, such as unregulated electric hot plates, in the hostel's rules and regulations, which should be given to students before they are admitted into the hostel.
4. Automate external lighting: Utilize light sensing devices to automate the control of external lighting, ensuring that they turn off during the day and on at night.
5. Establish an energy audit committee: Set up an energy audit committee consisting of representatives from each hostel block, including porters or security personnel, to enforce energy-saving practices within the hostel.
6. Implement decentralized metering: Decentralize the hostel's metering system to enable effective monitoring of consumption patterns for each building block.
7. Integrate energy-saving measures in architectural designs: Incorporate energy-saving measures in future architectural designs for the university to minimize the need for interior lighting during the day and reduce overall energy demand.
8. Extend energy audits: Conduct electrical energy audits for other parts of the institution to identify areas of waste and potential savings.
9. Promote gas cooking and safety: Encourage the use of gas cooking appliances in the hostel's communal kitchen or designated cooking areas to promote energy efficiency. However, it is important to prioritize safety by implementing proper safety measures. This includes ensuring professional installation of gas lines, regular maintenance, and providing safety education to students on proper usage, handling of gas cylinders, and detecting gas leaks. It is also important to have adequate ventilation in the cooking areas to remove any potentially harmful gases. By promoting gas cooking with safety considerations, the hostel can reduce reliance on electricity for cooking and improve overall energy consumption efficiency.

These recommendations collectively aim to promote energy efficiency and conservation practices in the student hostel and other residential buildings in Ghana. By implementing these measures, energy consumption, costs, and environmental impact can be reduced, contributing to a more sustainable living environment.

Conclusion

In conclusion, an electrical energy audit was conducted on the UENR GETFUND hostel to evaluate its energy consumption patterns. The study analysed various energy load categories, including lighting, cooking, refrigeration, heating, cooling, and others. The findings indicated significant energy wastage in the cooking and lighting categories.

Based on the results, recommendations have been proposed to mitigate energy consumption and improve energy efficiency. These recommendations target all six load categories and aim to maximize energy savings. The study revealed a potential energy savings of 29%, which translates to a monthly cost reduction of $1637.80. This emphasizes the importance of implementing these recommendations to minimize energy waste and decrease the financial burden associated with energy consumption.

This present study is in line with [19] where top energy-consuming loads in the hostels were electric cooking elements followed by lighting and as observed in both cases, the high consumption of electrical energy was attributed to the use of unregulated hot plates and poor user habits. The paper also estimated the electricity bill based on the connected load and highlighted possible energy-saving options. By implementing these options, a 38% reduction in electricity bills could be achieved. Findings from this present study can collaborated by [20] which include demonstrating the potential for energy development plans in institutions and recommending approaches to enhance energy efficiency. They found that energy consumption in student hostels can be reduced by 15-37% through adequate energy-saving measures.

The study recognizes a limitation in addressing the practical challenges of implementing energy efficiency and conservation measures in student hostels and residential buildings. Factors such as financial constraints, lack of awareness, technical expertise, regulatory constraints, and behavioural/ cultural factors can hinder the successful adoption of these measures. Further research is needed to better understand and overcome these challenges to ensure the effective and sustainable implementation of energy efficiency practices.

Conflict of Interest statement

The authors declare that they have no conflicts of interest.

Funding Statement

There is no funding received for the project**.**

References

1. "Buildings – Analysis - IEA." Accessed: Feb. 03, 2023. [Online]. Available: https://www.iea.org/reports/buildings
2. Renewable Energy & Energy Efficiency Partnership, "Energy efficiency technologies and benefits," *Int. Energy Agency*, no. April, pp. 1–29, 2012.
3. S. Gyam, F. A. Diawuo, E. N. Kumi, and F. Sika, "The energy e ffi ciency situation in Ghana," vol. 82, no. June 2017, pp. 1415–1423, 2018, doi: 10.1016/j.rser.2017.05.007.
4. "Access to electricity (% of population) - Sub-Saharan Africa | Data." Accessed: Jan. 15, 2023. [Online]. Available: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZG
5. W. EA, IRENA, UNSD, World Bank, "Tracking SDG 7: The Energy Progress Report," *Iea*, pp. 158–177, 2022, [Online]. Available: https://trackingsdg7.esmap.org/data/files/download-documents/2021_tracking_sdg7_chapter_6_outlook_for_sdg7.pdf
6. D. Brounen, N. Kok, and J. M. Quigley, "Residential energy use and conservation: Economics and demographics," *Eur. Econ. Rev.*, vol. 56, no. 5, pp. 931–945, 2012, doi: 10.1016/j.euroecorev.2012.02.007.
7. M. Aydinalp, V. Ismet Ugursal, and A. S. Fung, "Modeling of the appliance, lighting, and space-cooling energy consumptions in the residential sector using neural networks," *Appl. Energy*, vol. 71, no. 2, pp. 87–110, 2002, doi: 10.1016/S0306-2619(01)00049-6.
8. Y. Yang, B. Li, and R. Yao, "A method of identifying and weighting indicators of energy

efficiency assessment in Chinese residential buildings," *Energy Policy*, vol. 38, no. 12, pp. 7687–7697, 2010, doi: 10.1016/j.enpol.2010.08.018.

9. P. Gyberg and J. Palm, "Influencing households' energy behaviour-how is this done and on what premises?," *Energy Policy*, vol. 37, no. 7, pp. 2807–2813, 2009, doi: 10.1016/j.enpol.2009.03.043.
10. Z. Yu, B. C. M. Fung, F. Haghighat, H. Yoshino, and E. Morofsky, "A systematic procedure to study the influence of occupant behavior on building energy consumption," *Energy Build.*, vol. 43, no. 6, pp. 1409–1417, 2011, doi: 10.1016/j.enbuild.2011.02.002.
11. K. Bataineh and A. Alrabee, "Improving the energy efficiency of the residential buildings in Jordan," *Buildings*, vol. 8, no. 7, pp. 1–16, 2018, doi: 10.3390/buildings8070085.
12. I. El-Darwish and M. Gomaa, "Retrofitting strategy for building envelopes to achieve energy efficiency," *Alexandria Eng. J.*, vol. 56, no. 4, pp. 579–589, 2017, doi: 10.1016/j.aej.2017.05.011.
13. M. Krarti, "Evaluation of large scale building energy efficiency retrofit program in Kuwait," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 1069–1080, 2015, doi: 10.1016/j.rser.2015.05.063.
14. M. Krarti, "Evaluation of Energy E ffi ciency Potential for the," *Energies*, 2019.
15. M. Krarti, K. Dubey, and N. Howarth, "Evaluation of building energy efficiency investment options for the Kingdom of Saudi Arabia," *Energy*, vol. 134, pp. 595–610, 2017, doi: 10.1016/j.energy.2017.05.084.
16. R. Opoku, I. Adjei, and A. Agyarko, "Energy ef fi ciency and cost saving opportunities in public and commercial buildings in developing countries e The case of air-conditioners in Ghana," vol. 230, pp. 0–7, 2019, doi: 10.1016/j.jclepro.2019.05.067.
17. R. Opoku, E. A. Adjei, D. K. Ahadzie, and K. A. Agyarko, "Energy efficiency, solar energy and cost saving opportunities in public tertiary institutions in developing countries: The case of KNUST, Ghana," *Alexandria Eng. J.*, vol. 59, no. 1, pp. 417–428, 2020, doi: 10.1016/j.aej.2020.01.011.
18. "Tariff Category VRA BGC (GHp / kWh) Composite BGC (VRA and IPPs) Effective 1 st January 2021 Tariff Category TSC 1 * (GHp / kWh) Effective 1 st January 2021 Tariff Category (GHp / kWh) (GHp / kWh) (GHp / kWh) Effective 1 st January 2021 Tariff," vol. 1997, no. December 2020, 2021.
19. C. Paper, T. Minna, T. Minna, and T. Minna, "Investigation of Electrical Energy Use Efficiency of Students ' Hostel in Gidan-Kwano Campus of Federal university of Technology Minna," no. April 2016, pp. 116–124, 2013.
20. A. C. Study and A. B. U. Zaria, "Energy Auditing And Management," vol. 2, no. 7, pp. 1807–1813, 2015, [Online]. Available: https://www.academia.edu/105209801/Energy_Auditing_And_Management_A_Case_Study_of_Student_Hostel?ri_id=36078