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Assessing the Potential for Energy Savings at Kwara State Polytechnic, Ilorin: Strategies for Sustainable Growth

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ABSTRACT **Original research paper**

This study assesses the potential for energy savings at Kwara State Polytechnic, Ilorin, as part of efforts to enhance sustainable energy management in public tertiary institutions. Data from a comprehensive audit of administrative, residential, and commercial sections revealed an annual energy consumption of 578,447 kWh and an Energy Use Intensity (EUI) of 20 kWh/m²/yr. Lighting and office gadgets accounted for 96% of total electricity use, while HVAC systems contributed 4%. Through retrofitting, metering, and photovoltaic (PV) system integration, the institution could achieve up to 25% annual energy savings. The findings establish a baseline for benchmarking and provide a replicable model for sustainable campus energy management in Nigeria.

Keywords: Energy Audit, Energy Efficiency, Renewable Energy, Sustainability, Institutional Energy Management.

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1. Introduction

Energy demand in tertiary institutions in Nigeria continues to rise due to increased academic, administrative, and laboratory activities. Public polytechnics are particularly challenged by unstable grid supply, limited renewable integration, and inefficient energy use [3]. According to the International Energy Agency (IEA), educational buildings account for approximately 15% of public sector energy consumption globally [4]. In Nigeria, the Energy Commission of Nigeria (ECN) reported that institutional energy inefficiencies result in annual wastage exceeding 20% of total consumption [5]. Kwara State Polytechnic, Ilorin, typifies these challenges, facing unmetered consumption and high dependence on the national grid. This paper aims to assess energy-saving potential and propose strategies that align with sustainable growth objectives and global best practices. The novelty of this study lies in integrating energy audit results with sustainability planning for institutional management.

Energy utilization at Kwara State Polytechnic is influenced by the diversity of its facilities, ranging from administrative buildings and classrooms to residential apartments and commercial units. Each of these categories exhibits distinct load characteristics, operational schedules, and occupancy behavior that collectively determine the overall institutional demand pattern [3]. The audit revealed that most buildings depend solely on grid electricity, with limited integration of solar photovoltaic (PV) systems or alternative energy sources. This dependency has exposed the institution to frequent disruptions, voltage fluctuations, and high operational costs, especially during peak production hours or examinations when electrical demand surges [4].

The administrative buildings, which host the Rector's office, Academic departments, and ICT facilities, were identified as the highest energy-consuming units, contributing over 60% of total consumption. This dominance stems from the continuous operation of lighting systems, office equipment, and air conditioning units, often left running beyond working hours [5]. The residential blocks for staff and students, though accounting for 25% of total energy use, also show inefficiencies arising from old wiring systems, lack of sub-metering, and inconsistent appliance control [6]. The commercial areas including laboratories, workshops, and cafeterias represent 15% of the energy profile, with significant potential for demand side management and efficiency retrofits [7].

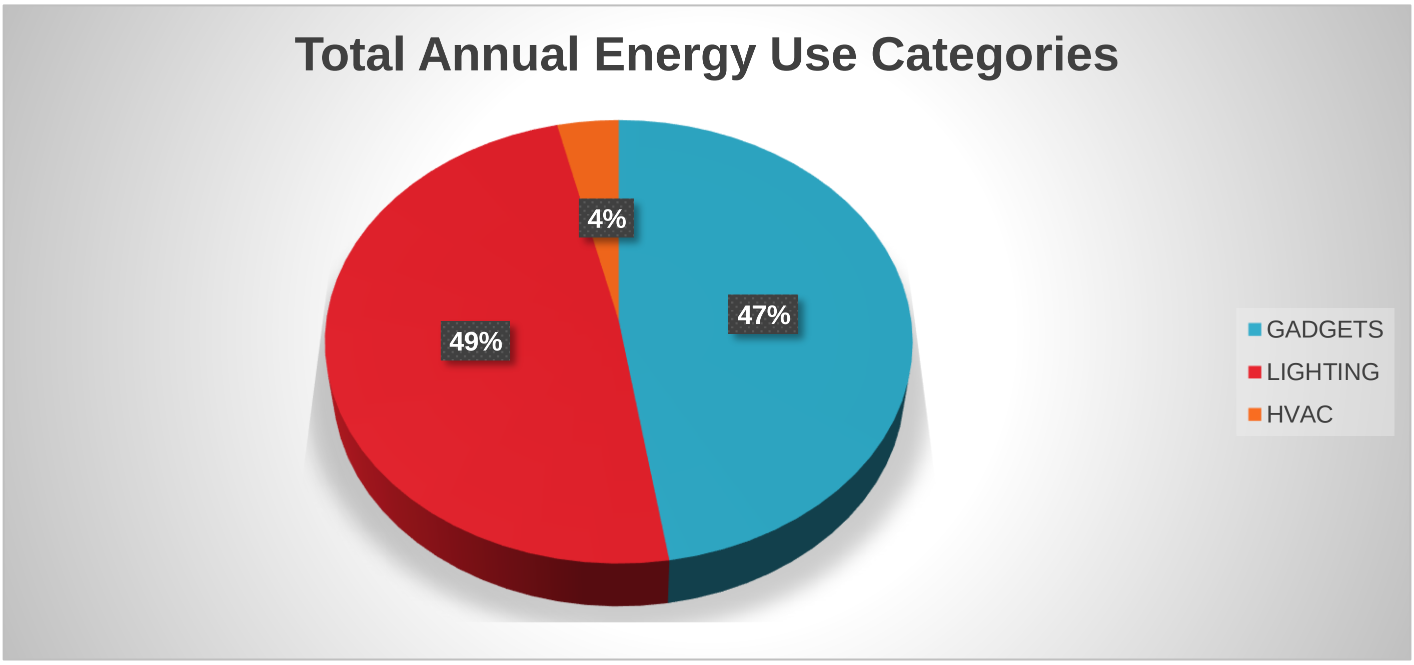

Figure 1.1: Annual Energy Consumption at Main Campus

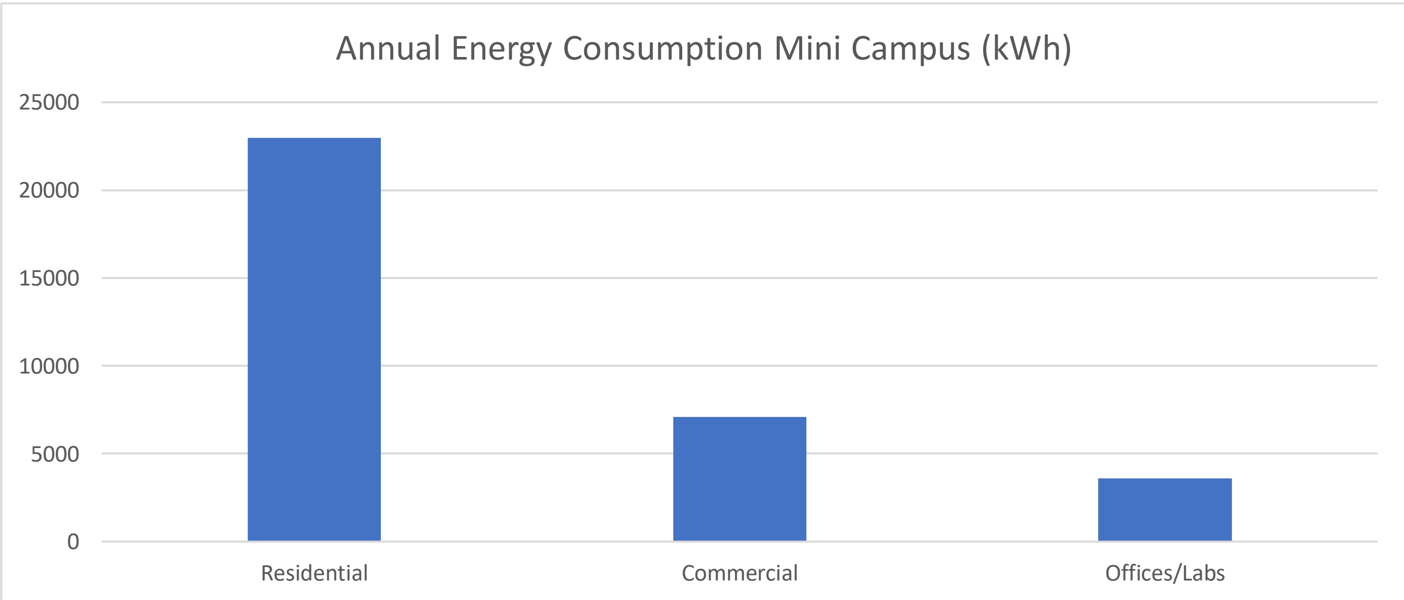

Figure 1: Annual Energy Consumption at Mini Campus

A notable observation from the audit is the absence of functional sub-meters in some administrative and residential sections. Without metering granularity, it becomes difficult to assign accountability or track consumption trends across units [8]. This aligns with findings from the Energy Commission of Nigeria [9], which reported that less than 40% of public tertiary institutions in Nigeria have building level metering. Consequently, energy wastage often goes unnoticed, while budgeting for electricity bills remains generalized rather than performance based. The absence of a data-driven monitoring system further complicates predictive maintenance and load forecasting.

In HVAC systems, energy inefficiency is primarily associated with the use of outdated, non-inverter air conditioners. Most units operate at fixed speeds and lack thermostatic control, resulting in excessive energy draw during partial load conditions [12]. Previous research has shown that inverter-based cooling systems can achieve up to 30% reduction in annual energy consumption under tropical climatic conditions [13]. The cooling demand peaks during the dry season in the polytechnic, from February to May, when ambient temperatures often exceed 35°C. Enhancing envelope insulation, reflective roofing, and natural ventilation could mitigate such loads by reducing indoor temperature rise [14].

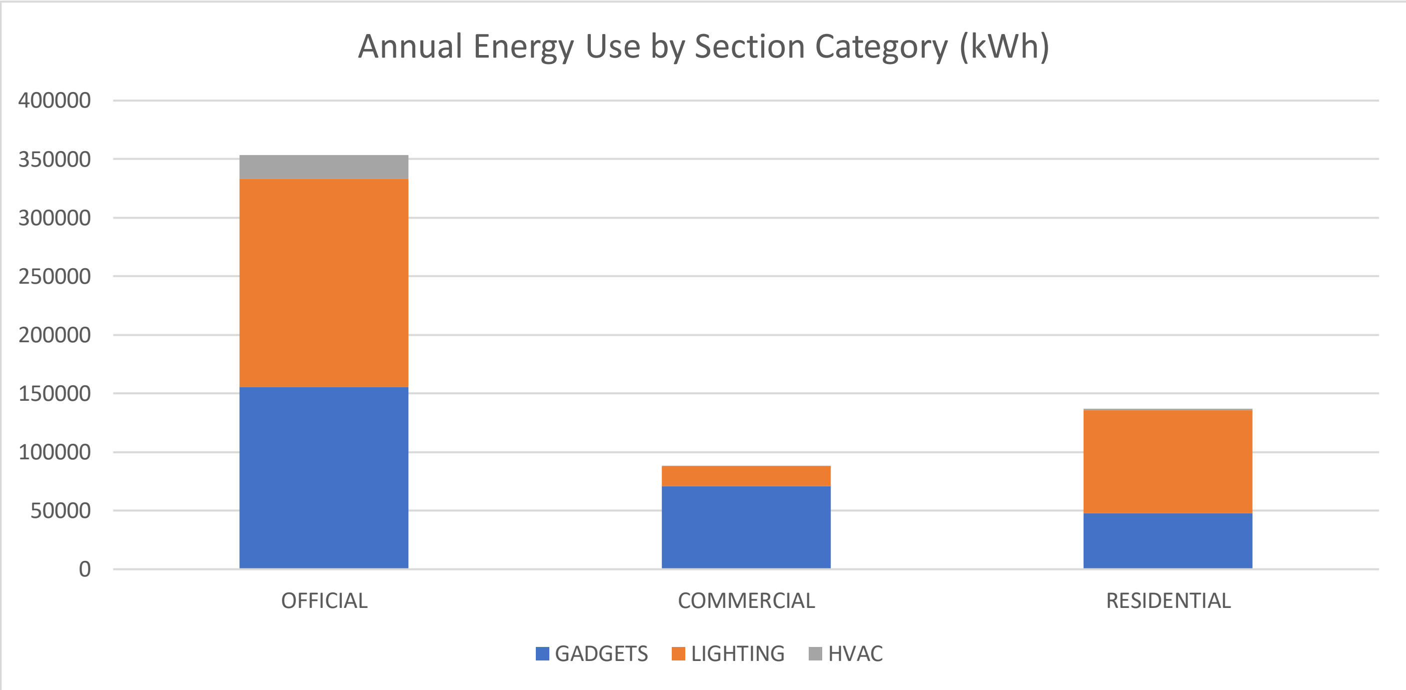

Figure 2: Annual Energy Use by Sections

The building envelope assessment within the audit showed that many structures possess moderate insulation and window-to-wall ratios between 10% and 22%. However, issues such as worn-out window seals, cracked louvers, and poor ceiling insulation contribute to thermal leakage and higher cooling loads [15]. Interventions like reflective paint coatings, solar control films, and roof insulation panels can significantly improve thermal comfort and energy efficiency. In similar case studies in tropical institutions, envelope retrofits have yielded up to 12% total energy reduction [16].

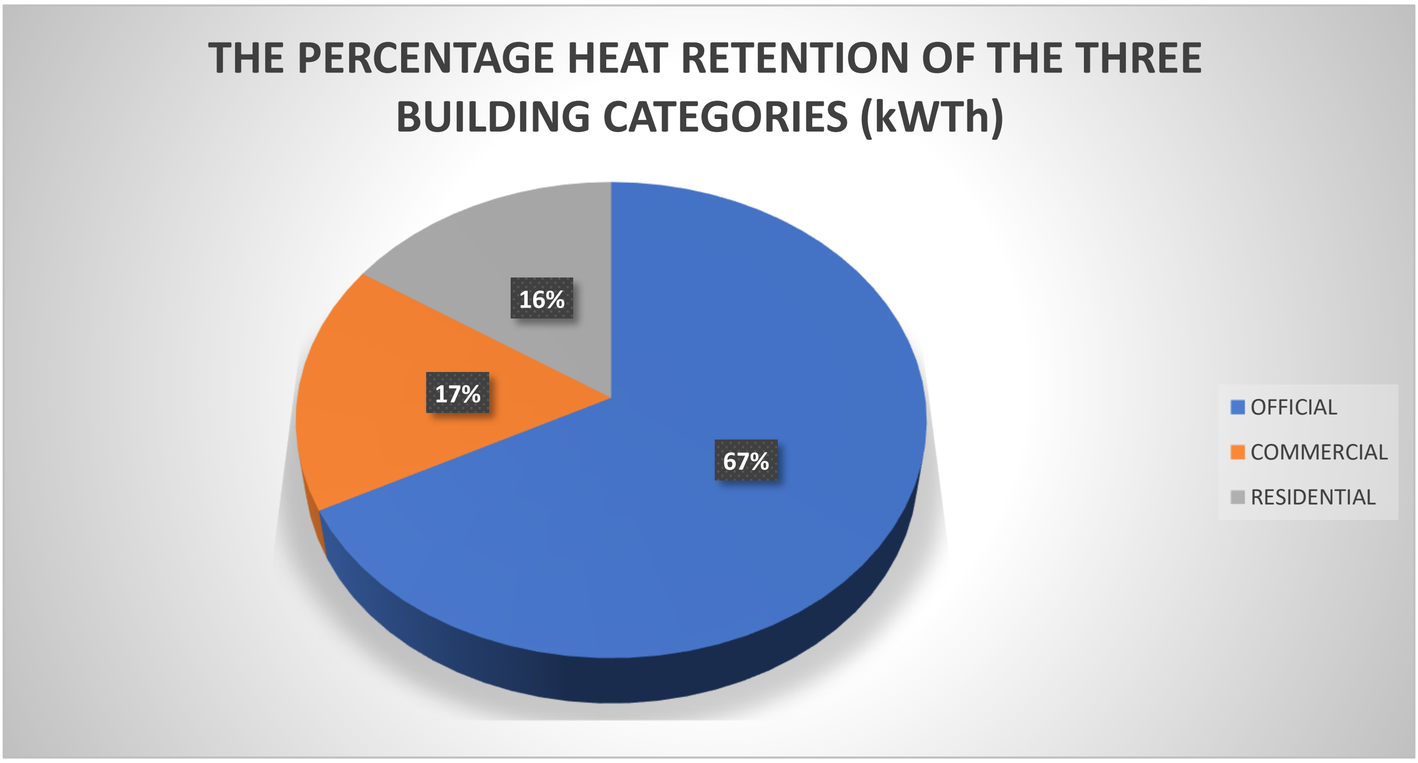

Figure 3: Heat Retention Capability of the Sections

From a behavioral standpoint, energy misuse due to human habits remains a major challenge. The audit observed that lights and computers are often left on after hours, particularly in offices and ICT laboratories [17]. Field observations indicated that standby power accounted for approximately 7% of total daily consumption a pattern consistent with findings by Bello et al. [18], who studied behavioral energy waste in Nigerian polytechnics. Sensitization campaigns and institutional energy policies, such as "switch-off when not in use," are therefore essential components of sustainable management.

Another critical challenge identified is the absence of a structured Energy Management Unit (EMU). Currently, energy related issues are handled by the Works and Maintenance Department without dedicated personnel or continuous data analysis [3]. Establishing an EMU would enable real-time monitoring, fault detection, and benchmarking against national and international standards. Such institutional frameworks are consistent with ISO 50001 Energy Management Systems [15], which recommend data-driven energy performance improvement cycles.

The introduction of renewable energy, especially solar photovoltaic systems, presents a viable path toward energy diversification and resilience. The geographic location of the Polytechnic in Ilorin (latitude 8.5°N, longitude 4.55°E) provides average solar irradiation of 5.2 kWh/m²/day, making PV deployment technically and economically feasible [16]. The audit revealed an existing 10 kW solar powered installation at the Institute of Technology, 5kW at the Institute of Environmental studies, 20kW in total in the administrative block, which operates independently to power laboratory and office loads. Scaling this initiative to other departments, units and Institutes could supply up to 25% of total energy needs while reducing greenhouse gas (GHG) emissions by approximately 50 tonnes of CO_2 annually [17].

In economic terms, implementing comprehensive retrofitting including LED replacement, inverter ACs, and PV integration could reduce annual consumption from 578,447 kWh to approximately 430,000 kWh. This represents a potential cost saving of ₦7.4 million annually, assuming current tariff rates. With an estimated total investment of ₦25–30 million, the simple payback period is projected at 8 years, aligning with international benchmarks for institutional retrofits [18]. Such economic viability enhances the case for immediate policy intervention and phased implementation through public-private partnerships or internally generated revenue allocations.

Finally, institutionalizing energy management aligns with broader energy efficiency roadmap in Nigeria and Sustainable Development Goal (SDG) 7; Affordable and Clean Energy. Public tertiary institutions play an important role as demonstration centers for sustainable technologies and behavioral transformation. Hence, improving energy efficiency at Kwara State Polytechnic not only enhances operational sustainability but also contributes to national decarbonization targets [9]. This study thus underscores the urgent need for data-driven, technology-integrated, and behaviorally informed approaches to energy management across public educational institutions in West Africa.

2. Literature Review

Energy audits have evolved into integral tools for evaluating institutional energy performance. Earlier studies focused on lighting and HVAC loads, while recent approaches incorporate energy modeling and digital monitoring systems [6]. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) classifies audits into Level 1 (walk-through), Level 2 (energy survey and analysis), and Level 3 (detailed analysis of capital-intensive projects) [7]. Akinyele et al. [8] emphasized that Nigerian tertiary institutions could reduce energy use by 25–40% through retrofitting and behavioral change. Similarly, Okafor and Eze [9] observed that lighting upgrades yield the highest savings in educational facilities. International benchmarks such as the ASHRAE and UNEP guidelines set the EUI for tropical institutions at 15–25 kWh/m²/yr [10]. Given that Kwara State Polytechnic records an EUI of 20 kWh/m²/yr, there exists significant potential for operational and behavioral efficiency improvements.

Previous studies have demonstrated that institutional energy inefficiencies are typically driven by outdated electrical infrastructure, poor maintenance culture, and lack of behavioral discipline among occupants [6]. In the context of Nigerian public tertiary institutions, the Energy Commission of Nigeria (ECN) emphasized that lighting and equipment loads represent more than 75% of total electricity consumption in administrative and classroom buildings [7]. This is consistent with the findings at Kwara State Polytechnic, where lighting and gadgets accounted for 96% of total energy consumption. The dominance of these end-use categories underscores the need for a comprehensive approach that blends technology retrofitting, operational control, and user education [8].

Lighting efficiency remains one of the most cost-effective energy-saving measures in tropical institutions. Studies by Okafor and Eze [9] and Akinyele et al. [10] reveal that replacing fluorescent lamps with LED luminaires could yield between 40–60% energy savings depending on occupancy duration and daylight availability. The lighting audit of the Polytechnic indicated that while LED adoption has commenced in some blocks, about 70% of existing luminaires remain fluorescent, with several faulty ballasts still drawing standby current. This phenomenon of "phantom load" was also reported by Udo and Ajayi [14], who observed that malfunctioning fittings can consume up to 30% of rated power even when not fully operational. Therefore, upgrading to efficient LED systems and introducing occupancy sensors are dual solutions to minimize wastage.

Another critical area highlighted in literature is the energy performance of HVAC systems, which, though smaller in proportion compared to lighting, often contribute significantly to peak demand [11]. The use of fixed-speed, non-inverter air conditioners is widespread across Nigerian campuses, leading to high start-up currents and energy spikes. ASHRAE [7] recommends inverter-based units with energy efficiency ratios (EER) above 3.5 for institutions, capable of reducing annual cooling energy by 20–30%. Moreover, envelope integrated cooling strategies such as reflective roofs and ventilated facades can further stabilize indoor thermal conditions [12]. At Kwara State Polytechnic, the audit recorded mean room temperatures of 31°C during midday, indicating substantial opportunities for passive cooling interventions [13].

The literature also emphasizes the importance of behavioral and policy-driven interventions. According to Bello et al. [17], user awareness and institutional energy policies are as crucial as technological retrofits. Behavioral energy waste, such as leaving appliances and lighting on after office hours, can constitute 5–10% of daily consumption in academic environments. In the case of Kwara State Polytechnic, the audit observed several instances of unregulated device usage in ICT centers and administrative offices, reaffirming the necessity of behavioral change campaigns. Institutions that have introduced “switch-off” campaigns and incentive-based monitoring programs have reported notable savings with minimal capital input [18].

Furthermore, research has highlighted the role of data analytics and digital monitoring in sustaining efficiency gains. ISO 50001 [15] and CIBSE Guide F [9] recommend continuous energy performance tracking using sub-meters and smart energy dashboards. Real-time monitoring not only improves accountability but also enables early fault detection and load forecasting. While Kwara State Polytechnic currently lacks such systems, the establishment of an Energy Research and Monitoring Unit (ERMU) could fill this gap by combining technical data analysis with policy implementation.

Conclusively, renewable integration has become a central component of institutional energy efficiency frameworks worldwide. The International Renewable Energy Agency (IRENA) [16] and UNEP [2] advocate hybrid approaches combining grid supply with solar PV and energy storage for resilience and cost reduction. Given the average solar irradiation of the polytechnic which is 5.2 kWh/m²/day, deploying photovoltaic systems across rooftops and open spaces could yield up to 25% energy substitution, as modeled in the renewable simulation of the audit. Comparable case studies across West Africa have shown payback periods of 6–9 years for campus PV installations under similar conditions [10].

3. Methodology

The study followed ASHRAE Level 1 and 2 audit procedures, focusing on the administrative, residential, and commercial zones of Kwara State Polytechnic. Measurements were conducted using digital power analyzers, lux meters, and temperature sensors. Electricity consumption data were obtained from metering points (MP1–MP4) and billing records between January and December 2024. Energy Use Intensity (EUI) was computed as the ratio of total annual energy consumption (kWh) to the total floor area (m²). Data were analyzed using Microsoft Excel and RETScreen Expert software to estimate savings potentials and greenhouse gas (GHG) reductions [11]. Ethical clearance was obtained from the Energy Management Committee of the institution, and all field measurements complied with safety standards [12].

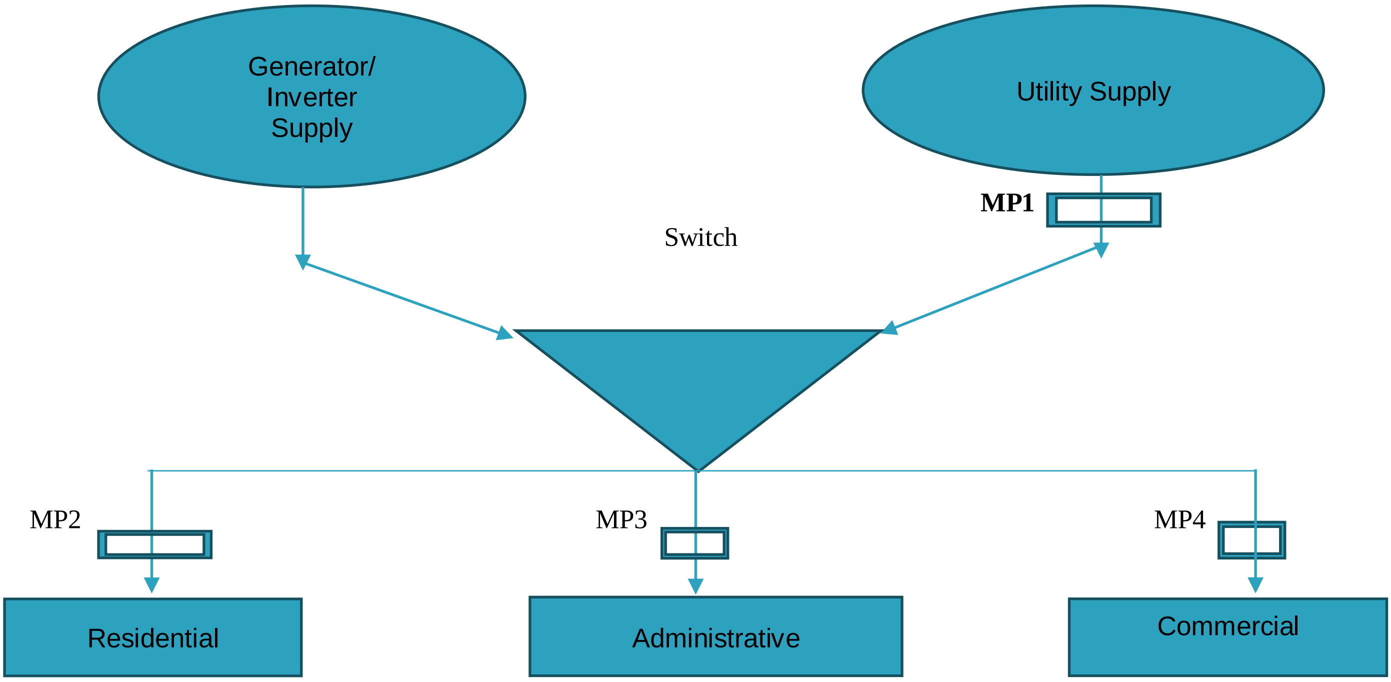

Figure 4: Single line diagram showing measurement points

The audit process for this study followed a structured multi-phase approach involving pre-audit planning, field data acquisition, analytical modeling, and validation**.** During the pre-audit phase**,** background information such as building layouts, occupancy schedules, and connected load inventories was obtained from the Works and Maintenance Department. Each floor area of the building was measured to allow for accurate computation of Energy Use Intensity (EUI) in kWh/m² per annum [7]. The classification of energy zones into *administrative*, *residential,* and *commercial* categories was based on functional use and load characteristics, enabling comparative analysis across similar end-use profiles.

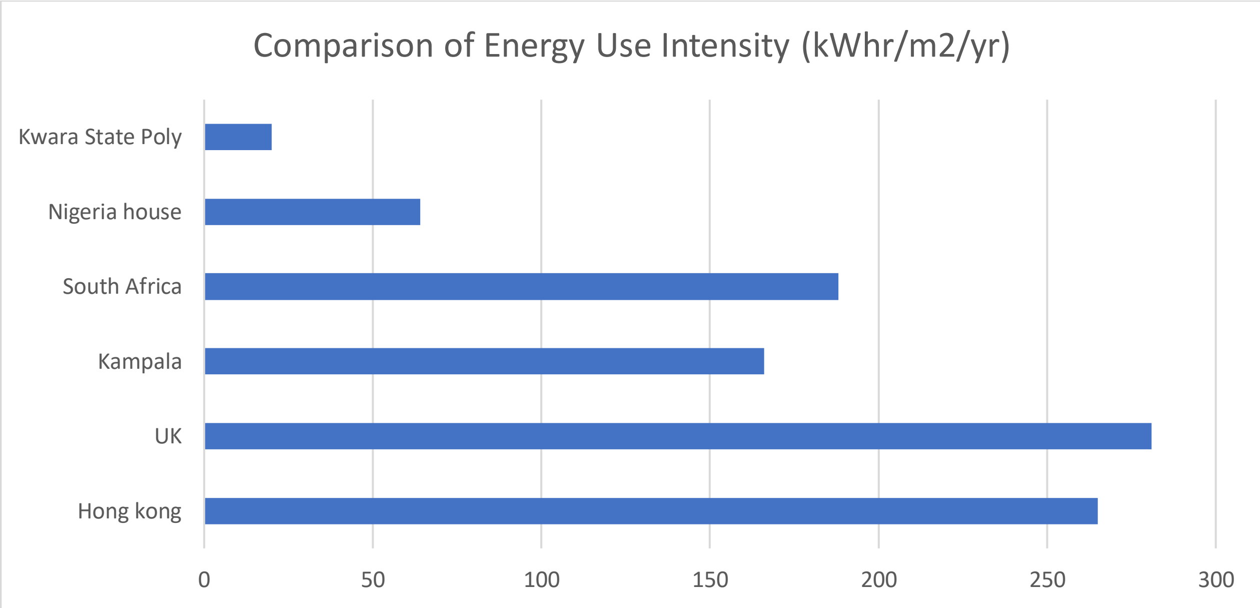

Figure 5: EUI of the Main Campus

(Nelson Isaiah Mukwaya) Source: http://iieng.org/images/proceedings_pdf/E0514065.pdf

Field measurements were conducted over a twelve month period to account for seasonal variations in energy use. Portable digital power analyzers and clamp meters were deployed at four metering points (MP1–MP4) representing the major distribution feeders [8]. Parameters recorded included voltage, current, apparent power, power factor, and cumulative energy (kWh). Lighting levels were evaluated using lux meters positioned one meter above the working plane, in accordance with CIBSE Guide F recommendations [9]. Thermal comfort data such as ambient temperature and relative humidity were captured using digital thermohygrometers to support HVAC load assessment [10]

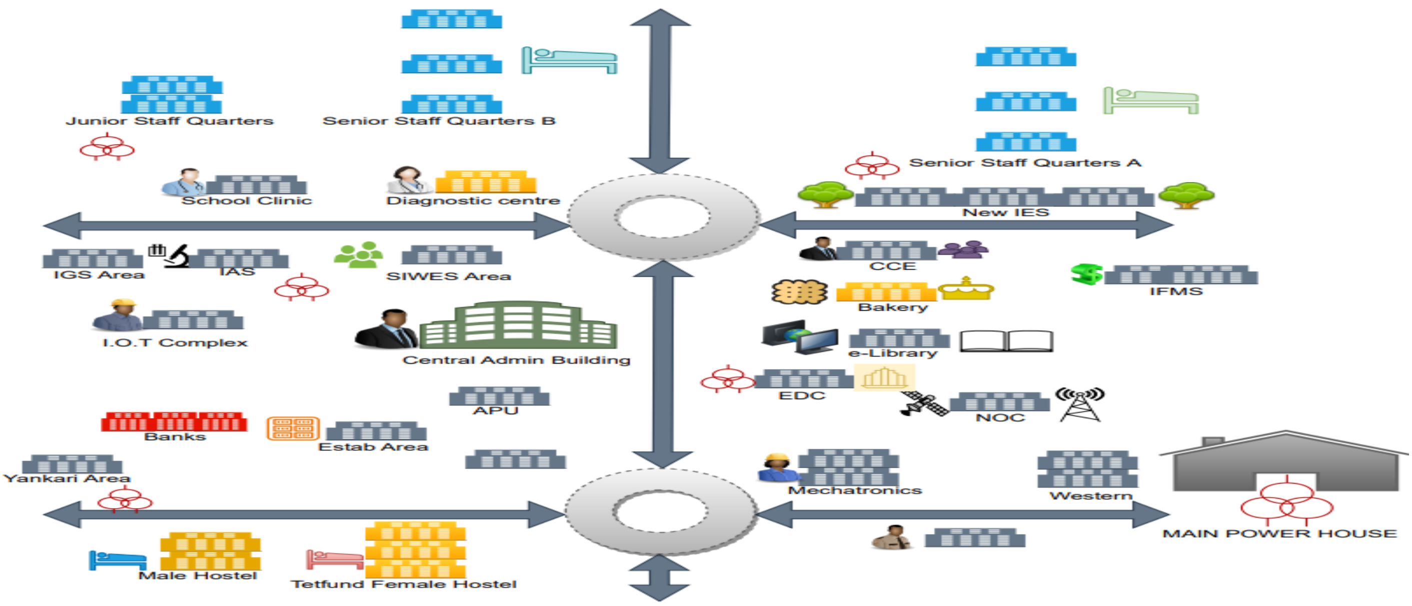

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Figure 6: Schematic diagram of buildings in Main Campus

To ensure reliability, each instrument was calibrated before deployment, and spot measurements were repeated at three-hour intervals during working days. The measured data were supplemented by electricity bills obtained from the utility provider and the Finance Unit of the Polytechnic, allowing reconciliation between field data and official billing records

[11]. Data inconsistencies greater than 5% were investigated through cross-checking of meter readings and equipment nameplates.

The **EUI** for each building category was determined using:

$$EUI = \frac{Eannual}{Afloor}$$ ASHRAE, ***ANSI/ASHRAE Standard 105-2021***

where Eannual is the annual energy consumption (kWh) and Afloor is the conditioned floor area (m²). This index provided a normalized benchmark for comparing the energy performance of the Polytechnic with international standards [14]. In addition, the building envelope was evaluated using a qualitative checklist covering wall orientation, shading, window-to-wall ratio, and roof insulation type. Photographs and infrared thermographic scans were used to identify thermal leaks and excessive solar gain zones [15]. The methodology also incorporated stakeholder interviews with facility managers, departmental heads, and technical staff to capture behavioral and operational practices influencing energy use [16].

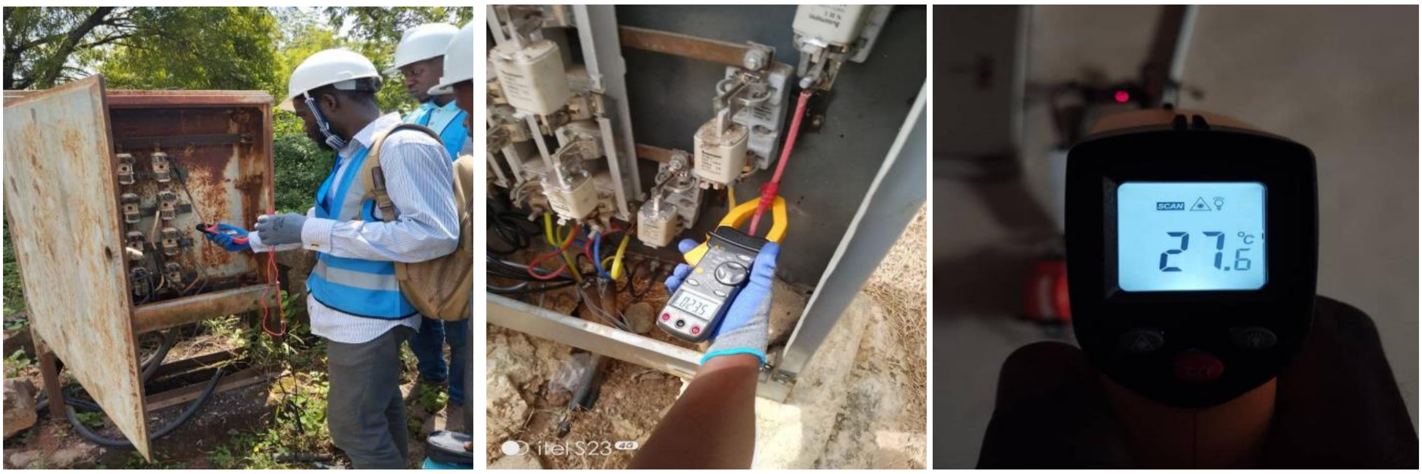

Figure 7: Feeder pillar load and temperature measurement process during field energy assessment.

Ethical and safety considerations were observed throughout the process. All measurements adhered to the Nigerian Society of Engineers (NSE) Field Safety Code [12], ensuring personnel used appropriate protective equipment when handling live electrical components. Ethical approval was granted by the Energy Management Committee of the institution, emphasizing confidentiality of consumption data and responsible dissemination of findings.

4. Results and Discussion

The total energy consumption of the Polytechnic in 2024 was 578,447 kWh, distributed across administrative (60%), residential (25%), and commercial (15%) sections. The computed EUI of 20 kWh/m²/yr falls within moderate efficiency range but above international best practices for educational institutions [13]. Lighting accounted for 49% of total energy use, followed by office gadgets (47%) and HVAC systems (4%). At an average tariff of ₦50.11/kWh, the annual electricity expenditure of the institution amounted to ₦28.9 million. Simulation results indicate that replacing all remaining fluorescent lamps with 150 W AKT LEDs (saving 50 W per unit) could save 25% of lighting energy. Installing occupancy sensors and daylight controls could achieve an additional 10% reduction [14]. For HVAC systems, adopting inverter-type air conditioners can reduce energy consumption by 15–20%. Envelope assessment revealed average window-to-wall ratios of 10–22%, indicating moderate daylight access but weak insulation performance. Improving roof reflectivity and sealing leaks could lower cooling loads by 5–10%. Behavioral patterns, such as leaving computers and lighting on after hours, contributed to 7% avoidable consumption.

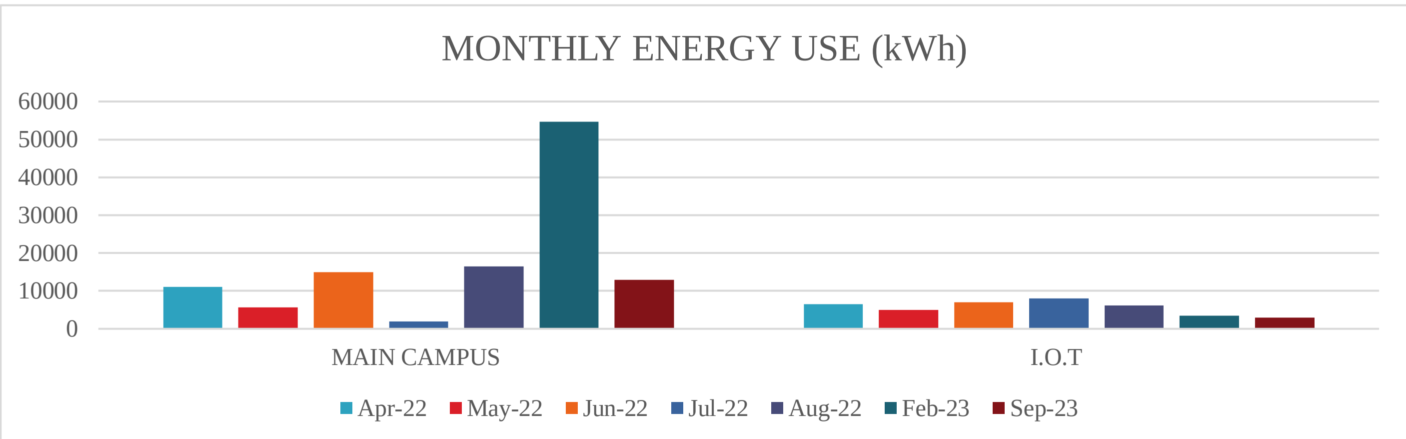

Figure 8: Monthly Energy Consumption at Main Campus and Mini Campus

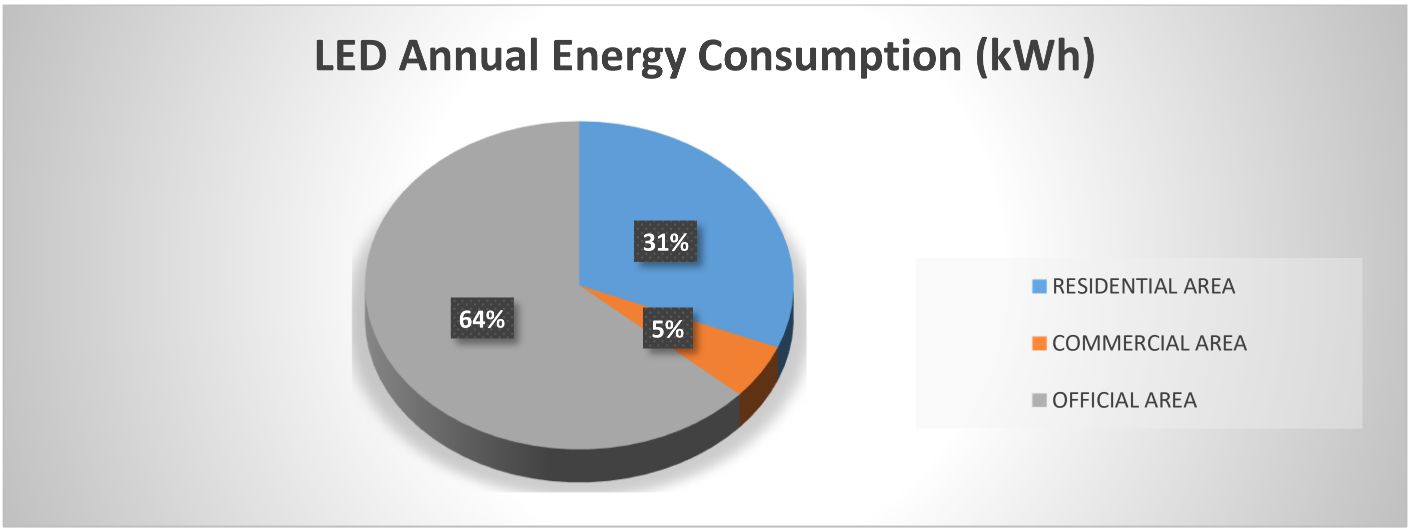

Figure 9: Annual Energy Consumption by Non LEDs S

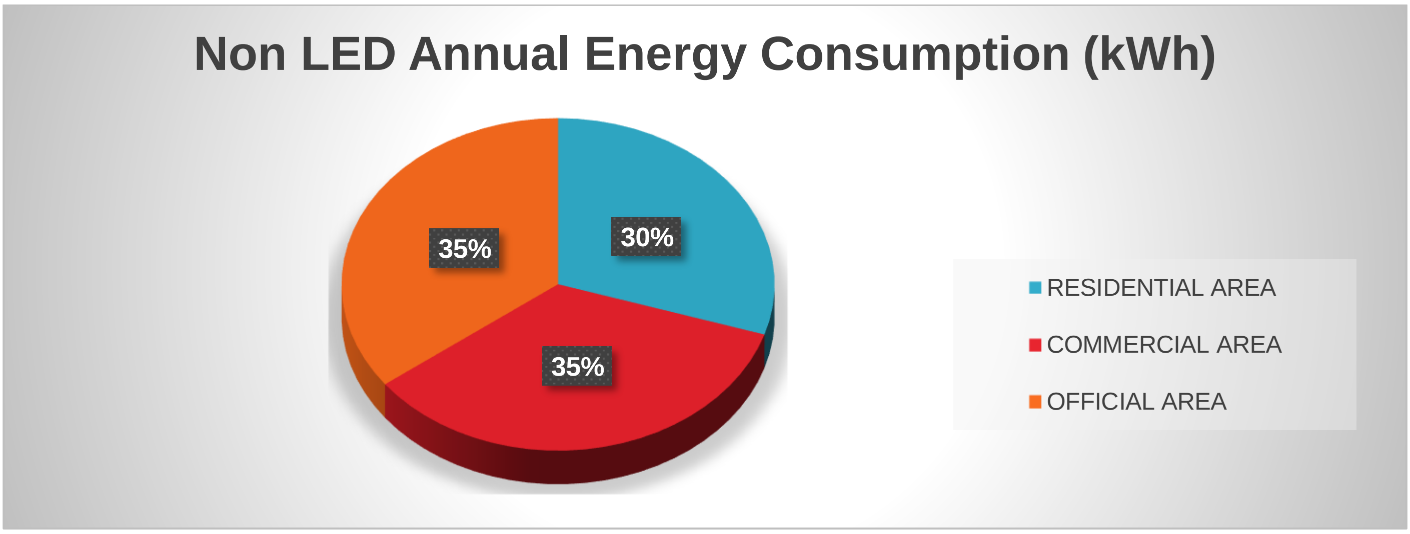

Figure 10: Annual Energy Consumption by LEDs

The Mini Campus integrates staff offices, commercial units, and residential buildings, each exhibiting distinct energy use characteristics. The staff offices, which have only recently become operational, recorded relatively low levels of energy consumption, a trend largely attributable to the limited use of electrical appliances, with energy demand primarily driven by point lighting and a few cooling fans during the monitoring period. Commercial activities on the campus were centred around cafés and small business centres providing services such as typing and printing. These facilities relied on conventional office and service equipment including laptops, photocopiers, printers, lighting fixtures, and electric cooking appliances. However, operational activity remained minimal, as only four commercial outlets were functional at the time of assessment, a situation influenced by the academic vacation and the recent relocation of part-time programmes to the Mini Campus. The Staff Quarters comprises sixteen residential buildings, of which approximately six were found to be in a dilapidated state, while the remaining ten appeared to be fully occupied. This variation in occupancy and structural condition contributes to uneven residential energy demand patterns across the Mini Campus.

Table 4.1: I.O.T Mini Campus Load

	Total Load (kW)	Daily Energy (kWh)	M Monthly Energy (kWh)	Annual Energy (kWh)	Total Cost (N)
Residential	9.58	76.64	1916	22992	1,336,065
Commercial	3.70	29.60	592	7104	412,813
Ofices/Labs	3.00	15.00	300	3600	209196
Total	16.28	121.24	2808	33696	1,958,075

The window-to-wall ratio (WWR) is a measure of the proportion of an exterior of the building that is occupied by windows. It is calculated by;

$$\frac{\text{Total window area}}{\text{Total wall area.}}$$ **Halil Zafer Alibaba (2016)**

Diagnostic Center (18.851%), IOT (22.92%), Tetfund Female Hostel (17.094%) and SIWES Office (16.65%); These buildings have a higher percentage of window area, suggesting a focus on maximising natural light potentially for better visibility, energy efficiency, or aesthetic reasons. These are closer to the recommended 20% of the Nigeria Building Energy Efficiency Codes (NBEEC).

Having a low WWR (Between 10% and 15%), New IES (10.018%), NOC (10.018%), E-library (13.158%), School Clinic (14.056%), Administrative Block (10.096%) and Yankari Area (13.435%); These buildings strike a balance between natural light and structural integrity. They likely aim for a good amount of daylight while considering other factors like insulation and energy conservation.

Having a low WWR (Below 10%), Senior Staff Quarters A (9.057%), Senior Staff Quarters B (3.229%), Mechatronics (3.211%), EDC (4.295%), IBAS (1.039%), ESTAB (6.957%), APU (5.431%), Bakery (0.0774%), CCE (3.063%), IGS Area (7.198%), Male Hostel (12.155%), Junior Staff Quarters (10.045%) and Western Area (7.983%); These buildings have a lower percentage of window area, which may indicate a design prioritising privacy, energy efficiency, or structural considerations over maximising natural light.

Special Consideration is given to IFMS Area (31.712%). This area has a notably high WWR, potentially indicating a design emphasising openness, transparency, or a connection with the surrounding environment. Carbon monoxide readings around various areas within and outside the campus buildings were measured between 28 and 35 ppm. The lowest is around the Estab Unit, Tetfund female hostels, and the Junior Staff Quarters. Something that seems familiar to these areas is plants that absorb CO_2 and make the air cleaner. Carbon monoxide readings around various areas within and outside the campus buildings were measured between 28 and 35 ppm. The lowest is around the Estab Unit, Tetfund female hostels, and the Junior Staff Quarters. Something that seems familiar to these areas is plants that absorb CO_2 and make the air cleaner.

Out of the 274,752kWh of Energy estimated to be used by gadgets and other equipment in the Polytechnic, machines and other gadgets in the Diagnostic centre, Computers in the NOC and other gadgets in the SIWES office and new IES area account for more than half of the total annual energy consumption of gadgets. This is understandable from the functions of the diagnostic centre and the NOC. Other areas captured have very few computer gadgets and other devices.

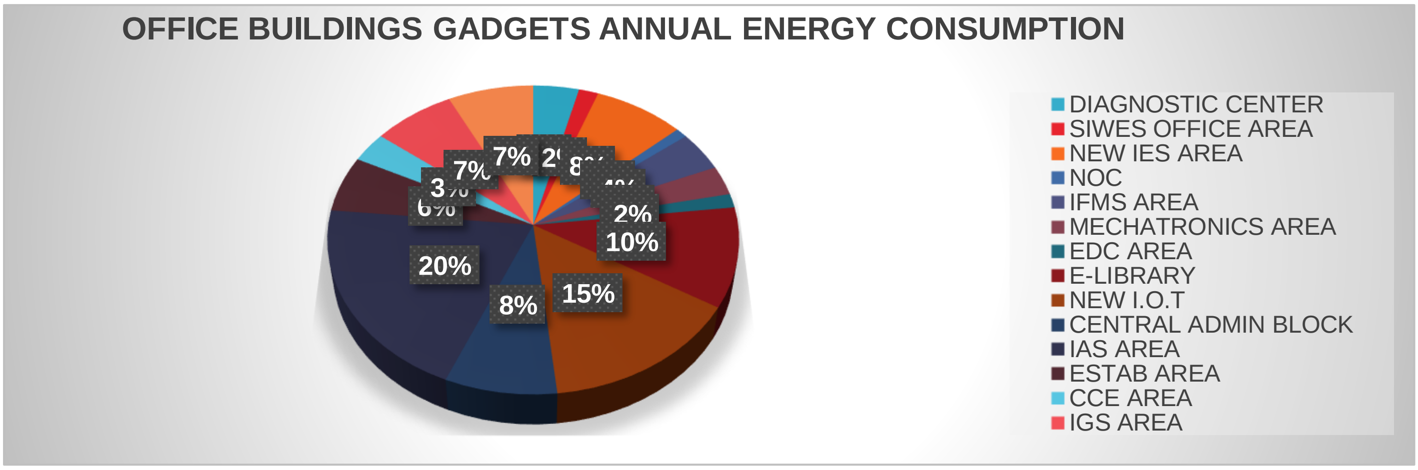

Figure 11: Official Units' Annual Energy Consumption by Gadgets

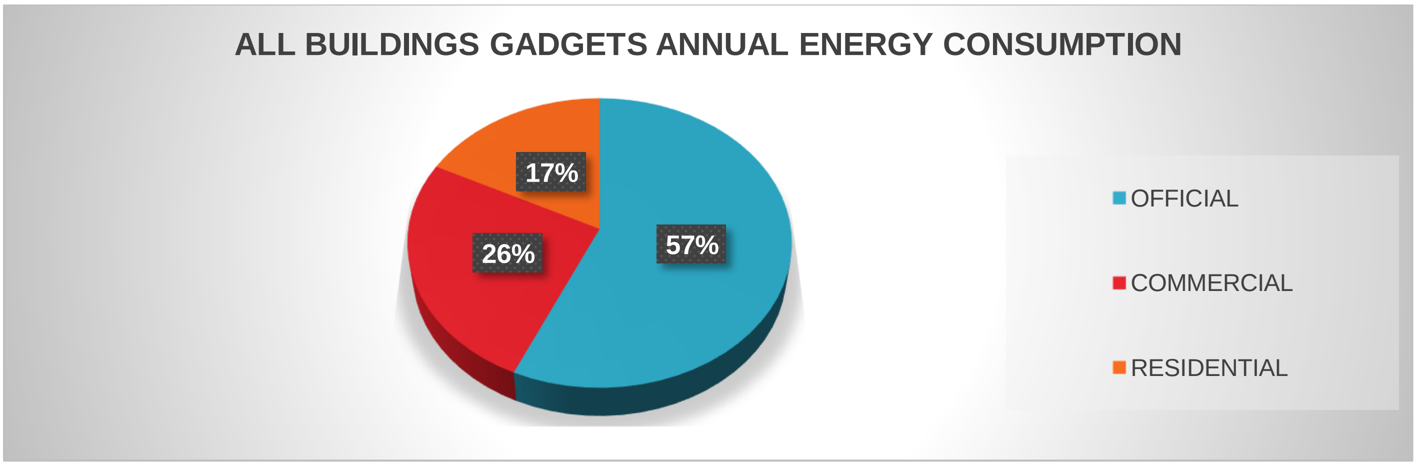

Figure 12: The Commercial Units' Annual Energy Consumption by Gadget

In the areas designated as commercial areas, the Yankari, Western and Tetfund female hostel triad accounts for over 90% of the energy used by gadgets and other equipment. The male hostel and Bakery do not have much of this facility.

5. Energy Efficiency strategies for sustainable growth

The audit findings informed a comprehensive framework for energy management at Kwara State Polytechnic. The proposed strategies include:

i. Installation of sub-meters in major facilities for real-time monitoring [15].

ii. Retrofitting all lighting systems with LED technology, estimated to yield a 25% reduction in total energy consumption.

iii. Expansion of the solar PV capacity to contribute at least 25% of the total energy mix [16].

iv. Implementation of load balancing to minimize voltage fluctuations and improve transformer efficiency [19].

v. Capacity building and awareness programs targeting staff and students to promote behavioral efficiency [17].

vi. Establishment of an Energy Research and Monitoring Unit (ERMU) responsible for periodic audits and policy implementation.

vii. Economic evaluation indicates that the LED retrofit investment (₦23.4 million) could yield annual savings of ₦2.9 million, with a simple payback period of 8 years.

6. Conclusion

This study demonstrated that Kwara State Polytechnic can achieve up to 25% reduction in annual electricity consumption through targeted retrofits, behavioral modifications, and renewable energy integration. The EUI benchmark of the institution of 20 kWh/m²/yr provides a performance baseline for future audits and inter-institutional comparisons. This study contributes a data-driven framework for benchmarking energy performance in Nigerian polytechnic. Institutionalizing periodic audits, implementing energy management systems, and promoting renewable adoption will drive long-term efficiency and resilience [18]. Future studies should explore dynamic modeling of seasonal loads and hybrid PV–battery systems to enhance reliability and sustainability.

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