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ASSESSMENT OF ENERGY CONSUMPTION PERFORMANCE OF SELECTED COMMERCIAL BUILDINGS IN KADUNA METROPOLIS

ISAH, Ibrahim[1]*, ABDULSALAM, Dalhatu[1], MUHAMMAD Shehu[1], AYENI Olugbenga[1]

[1]Department of Building, Ahmadu Bello University, Zaria

Correspondence: iisah@abu.edu.ng

ABSTRACT

The building sector accounts for approximately 40% of global energy consumption and nearly 30% of greenhouse gas emissions. Commercial buildings have shown high levels of energy use. Implementing energy-efficient practices can lower energy bills, improve occupant comfort, and reduce carbon emissions. However, there are limited empirical studies on the actual energy consumption of Nigerian commercial buildings. Most research focuses on residential buildings or theoretical savings estimates, leaving a gap in understanding the real operating conditions of commercial buildings. A quantitative research method was used, involving a field survey with a structured checklist to collect data on building features, energy use, and appliance performance. The data were analyzed using descriptive and inferential statistics. The results indicate that the Energy Use Intensities (EUIs) of the malls (153, 271, 354, and 157 kWh/m²/year) all significantly exceed the global best-practice benchmark of 130 kWh/m²/year, with some more than doubling it. Disaggregated end-use analysis showed that cooling loads accounted for an average of 55% of annual energy consumption, followed by appliances (26%) and lighting (19%). Despite differences in building size and operation, no statistically significant variation in consumption patterns was observed (p=0.316), suggesting widespread inefficiencies. These results highlight that BEEC provisions alone are insufficient without strict enforcement and monitoring. Targeted interventions, such as horizontal shading, roof insulation, inverter-based HVAC systems, and efficient lighting, along with stronger compliance mechanisms, are necessary to achieve substantial reductions in energy use.

KEYWORDS: *Benchmarking, Commercial Buildings, Energy Consumption Performance, Energy Efficiency*

INTRODUCTION

Energy crisis and global warming have been significant issues faced by both developed and developing countries since the 1970s. The building industry alone accounts for about 40% of total energy consumption and 30% of greenhouse gas (GHG) emissions (Boyd *et al.*, 2018). The reliance on fossil fuel-based energy has produced adverse environmental impacts such as ozone layer depletion, global warming, and climate change (Owusu & Asumadu-Sarkodie, 2016). With the continuous development of human society, global energy demand and consumption continue to rise, making energy conservation a strategic priority of national development policies (Zou *et al.*, 2018). Buildings, as essential part of energy use, have consequently become the focus of global attention for over three decades.

In response, many governments have introduced mandatory building energy efficiency codes and performance targets. For example, the United States enacted the 2007 Energy Independence and Security Act (EISA), which requires specific federal buildings to eliminate fossil emissions by 2030 (Briller, 2013), while the United Kingdom mandates that new buildings achieve a Building Energy Rating (BER) below prescribed thresholds (Menezes *et al.*, 2012). China also enforces energy control at the national, regional, and building levels (Zou *et al.*, 2018). In Nigeria, the Federal Ministry of Power, Works and Housing introduced the Nigerian Building Energy Efficiency Code (NBEEC) in 2017 to regulate design practices, reduce operational energy consumption, and mitigate carbon emissions (FMPWH, 2017).

Commercial buildings are becoming subject of attention recently. Globally, they account for approximately 12% of final energy use, with significant shares of electricity demand driven by HVAC, lighting, and plug loads in spaces with extended operating hours and high occupant densities (Rafsanjani *et al.*, 2015; Manic *et al.*, 2016). When compared to residential buildings, commercial buildings typically record nearly five times higher energy intensities, mainly due to longer operating times, inefficient appliances, and occupant indifference toward energy charges (Bhatt *et al.*, 2005; Sadrzadehrafiei *et al. 2012*). In rapidly urbanising cities globally, commercial buildings, including shopping malls, offices, and retail centres, continue to exhibit highly variable energy performance due to inconsistent construction quality, system maintenance, tenancy patterns, and limited adoption of advanced energy management technologies (Zhou *et al.*, 2012; Cox *et al.*, 2013).

Understanding the energy consumption performance of commercial buildings in Kaduna, one of Nigeria's largest commercial cities, is essential for three main reasons. First, conducting energy audits can reveal opportunities for cost-effective savings through measures such as lighting retrofits, HVAC system upgrades, and improved operational practices. Empirical studies indicate that lighting and HVAC systems together account for 60–80% of energy loads in malls and commercial buildings, representing significant opportunities for savings (Zhou *et al.*, 2012; Azar & Menassa, 2014).

Second, commercial buildings hold potential for demand-side management and grid services. HVAC systems can provide frequency reserves without compromising occupant comfort when supported by effective control strategies (Vrettos et al., 2015). Finally, Occupant behaviour and organizational practices significantly impact actual energy consumption, often more so than the variations predicted by design models. Research shows that implementing targeted management interventions can lead to measurable reductions in commercial energy use, thereby complementing technological retrofits (Azar & Menassa, 2012; Almeida *et al.*, 2020).

Despite the opportunities available, empirical studies assessing the actual energy consumption of Nigerian commercial buildings remain limited. Most research focuses on residential buildings or theoretical savings estimates, leaving a gap in understanding the operational realities within commercial buildings. Addressing this gap is essential for guiding benchmarking, setting retrofit priorities, and supporting broader goals of urban sustainability and climate resilience in Nigeria. Therefore, this study evaluates the energy consumption of selected commercial buildings in Kaduna metropolis, comparing actual usage against the Building Energy Efficiency Code (BEEC) and international standards, while also identifying the key factors that drive differences in consumption.

LITERATURE REVIEW

Building Energy Audit

Building energy audit involves investigating and detailed analysis of the energy entering and leaving a building (Harris, 2012). The purpose of an energy audit is to understand where and how energy is used in a specific structure and to identify and prioritise the areas where improvements can be made, either for that building or future designs (Harris, 2012; Ingle, Moezzi, Lutzenhiser & Diamond, 2014).

Numerous energy audit procedures have been developed by energy and building services' professional bodies, including the International Energy Agency (IEA, 2016), the Chartered Institution of Building Services Engineers (CIBSE) (2008) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE, 2011). A common energy audit procedure for commercial buildings can be classified into three levels: walk-through analysis, energy survey analysis and detailed analysis of capital-intensive modifications. A preliminary energy use analysis is a prerequisite for any audit. Rajagopalan (2019) insist that an energy audit is essential to understand where and how energy is used in buildings and, consequently, to identify those areas where improvements can be made. Ideally, energy audits take a whole-building approach by examining the building envelope, building systems, operations and energy consumption, especially the electricity usage.

Building Energy Benchmarks

The lack of reliable data for residential and non-residential buildings makes it hard to set local benchmarks in Nigeria. The recent development of energy efficiency regulations in South Africa provide a useful case study for Nigeria. While setting simple performance targets in kWh/m²/year is attractive to legislators, in reality, it is very difficult to enforce such targets since the responsibility for excessive energy use can be blamed on many factors such as the original design, the construction quality, inefficient equipment installed, inefficient operation and maintenance, etc. Benchmarks developed in South Africa, where non-residential building construction is similar to that in Nigeria and where energy consumption is primarily in the form of electricity, therefore offer a practical and contextually relevant reference point that can guide the development of Nigeria's own energy performance benchmarks and regulatory framework.

In addition to South Africa, benchmarks from Malaysia, CIBSE, and ASHRAE are also referenced to provide a broader international context and facilitate comparison of energy performance standards across regions with varying climatic and operational conditions, as shown in Table 1.

Table 1: Building energy benchmarks

S/No	Benchmark	Best Practice kWh/m²/yr	Good Practice kWh/m²/yr	Typical Existing kWh/m²/yr	Poorly Performing Spaces kWh/m²/yr
1	Nigeria	< 130	130-209	210-320	> 320
2	South Africa	< 130	130-209	210-320	> 320
3	Malaysia	≤ 135	136-179	180-250	>250
4	CIBSE	≤ 122	-	195	> 195
5	ASHRAE	≤ 58	-	130	> 130

The South African building regulation SANS 10400-XA, introduced in 2011, sets a target that the energy consumption of an office building in a subtropical coastal climate should not exceed 190 kWh/m²/year. In Malaysia, the recommended Energy Use Intensity (EUI) standard for commercial buildings is 135 kWh/m²/year, serving as the baseline for achieving energy efficiency in buildings (Moghimi *et al.,* 2014). According to CIBSE (2012), the recommended benchmarks for commercial establishments are 122 kWh/m²/year for best practice and 195 kWh/m²/year for typical practice. Similarly, the ASHRAE 90.1 standard sets thresholds of 58 kWh/m²/year and 130 kWh/m²/year for best and typical practice, respectively (AIA California, 2021).

Building Energy Consumption Performance

Over the years, different methods have been developed to estimate building energy use and performance. It had evolved from simple survey approaches like monitoring, metering, simple walkthrough/ detailed energy audits to more complex engineering methods such as simulation modeling, computational energy analysis, life-cycle energy assessment, and benchmarking using standardized Energy Use Intensity (EUI) frameworks (Cole, 1998; Krarti, 2012). Building energy audit is the first step in the energy analysis of buildings. Audit reveals type, cost, what, where and how energy is used towards identifying saving opportunities. However, auditing buildings that are not metered individually is an arduous task. In this light, calculation methods using mathematical models/formulas are equally an acceptable alternative means used in several studies in the absence of energy bills (Batagarawa, Hamza & Dudek, 2011; Rosenberg, 2014; Mu'azu, 2015). Moreover, the calculation method had the advantage of disaggregating energy into end-uses like Heating, ventilation and air-conditioning (HVAC), lighting, equipment and building services as encapsulated in extant literature. Building services in this respect refers to any other energy-consuming appliances apart from air-conditioning, for example, lift pumping machines that ensure optimal functioning of the buildings (CIBSE 2012).

Meanwhile, according to Poel, Van - Cruchten and Balaras, (2007), energy consumption indicators are necessary for a successful evaluation of the energy performance of buildings. The globally acceptable performance indicators are Energy Use Index or Intensity (EUI), Energy Cost Index (ECI) and Carbon Emission Index (CEI) but the most widely used among them is Energy Use Index or intensity [EUI]. This approach had been explored in different parts of the world for office and other building types (Perez-Lombard *et al.,* 2008; Saidur & Masjuki, 2008). These indicators are expressed as follows:

EUI is the summation of total energy use per unit floor area per year.

Hence; EUI (KWh/m^2/yr) =

$$\frac{\text{Total annual energy consumption}}{\text{The total floor area of the building}}$$

……………………………equation 1

It can be seen from equation (1) that the floor area normalises the total annual energy consumption. According to Batagarawa, Hamza and Dudek (2011), total or aggregated end-use electricity consumption is normalised with thermal comfort parameters, such as gross floor area for places such as commercial areas, occupants in locations such as hostels and hotels, and cooling degree days, where there is diverse energy consumption variation within a season, to account for variations in those parameters. In this work, electricity consumption is normalised by gross floor area to give the Energy use indicator/index (EUI), also called a normalised performance index (NPI).

The use of gross floor area for normalization is widely adopted because it provides a consistent and easily measurable parameter that reflects the functional size of a building. It enables meaningful comparison of energy performance across buildings of varying scales and uses, independent of their absolute energy consumption. Moreover, unlike parameters such as occupancy or operational hours, floor area remains relatively constant over time, making it a stable basis for deriving the Energy Use Intensity (EUI) or Normalized Performance Index

METHODOLOGY

This study adopted a quantitative research design using a case study approach to assess the energy consumption performance of selected commercial buildings in Kaduna metropolis. Case studies were considered appropriate given the limited empirical research on building energy efficiency in Nigeria and the need for in-depth exploration of current practices. A structured checklist was developed. The checklist was piloted for validity, and data collection combined walkthrough audits, on-site measurements, electricity bills, and interviews with facility managers.

Purposive sampling was employed to select four purpose-built shopping malls (SM1–SM4) that satisfied explicit criteria. These included accessibility to functional spaces, classification under KAEDCO's "Band A" tariff (ensuring ≥20 hours/day electricity supply), and availability of verifiable metered energy bills. Additional criteria were that the buildings must have been constructed or retrofitted within the past decade, use similar building materials, and be purpose-built as shopping malls within Kaduna metropolis. This selection ensured consistency in envelope characteristics while enabling analysis of actual energy consumption patterns in modern commercial facilities.

Primary data were collected using two instruments. First, a structured checklist captured general building details (location, floor area, orientation, supply sources) as shown in Table 2, and energy audits of appliances. The inventory of appliances, their ratings, and operational hours were recorded to estimate disaggregated consumption for cooling, lighting, and plug loads. Second, an interview schedule was used to gather some information from the facility manager. The interview schedule refers to a structured set of questions prepared in advance to guide discussions with the facility managers, with questions such as "What are the average daily and weekly operating hours of the mall?". The facility managers provided complementary data on daily operating hours, electricity supply sources (grid, generator, or solar), and monthly electricity bills. Six months of postpaid bills, from February to July 2021, were retrieved and used to compute annual consumption. This was justified by evidence that seasonal variation in Nigerian cooling loads is relatively small, typically below 15% (Okoronkwo *et al.,* 2018).

Table 2: Building data

Description	Building Orientation	Sources of Power Supply	Operating hours/days	Operating days/week	Cooling Degree Days per Annum (days)	Floor Area (m^2)
SM1	North	Grid & Gen	14.5	7	246	589
SM2	West	Grid & Gen	15	7	246	268
SM3	North	Grid, Gen & Solar	13	7	246	172
SM4	East	Grid & Gen	13	7	246	302

Data analysis involved both descriptive and inferential statistics. Descriptive analysis computed Energy Use Intensity (EUI, kWh/m²/yr) for each mall by dividing annual consumption by total floor area. Estimated consumption was calculated using appliance ratings, quantities, and operating hours. The Results were presented in tables and charts to determine the consumption patterns relative to global benchmarks. Inferential analysis employed two-way ANOVA to test for significant variation in energy consumption across the four malls, with statistical significance determined at $p < 0.05$.

RESULTS AND DISCUSSION

Actual Energy Consumption Performanc

In this study, the total energy consumption was derived through the electricity bills from meters and the alternate supply from each shopping mall. Although the total annual consumption from the grid supply was collected from electricity bills, the alternate supply source was computed based on the average number of daily hours of usage. The trend in energy usage from February to July is shown in Figure 1 and the total annual consumption in kWh/yr/m^2 is presented in Table 3.

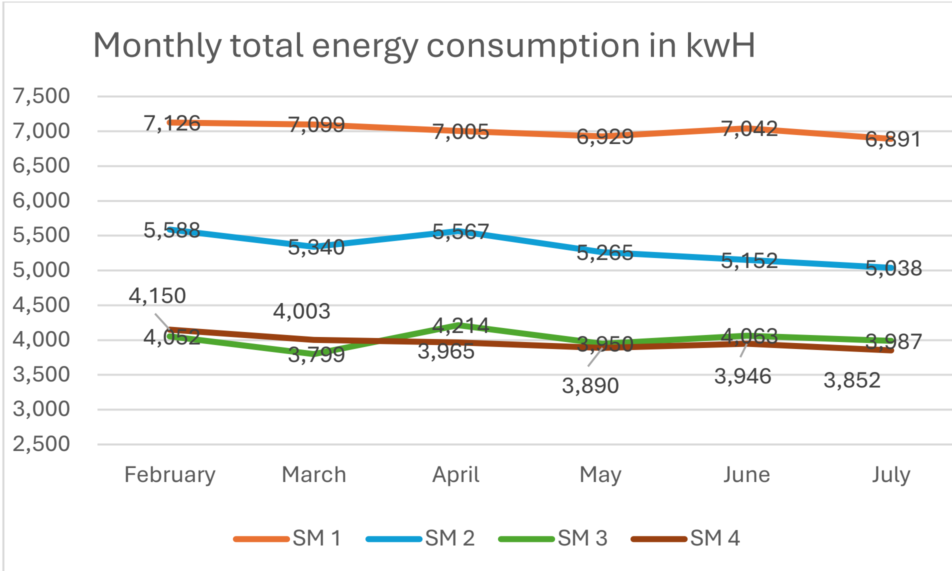

Figure 1: Monthly total energy consumption in kwh

From Figure 1, SM1, SM2, and SM4 all consume much higher energy in February, while SM3 consumes higher energy in April. Although all four buildings are located within the same climatic region, variations in their peak energy consumption periods are attributed to differences in building orientation, occupancy patterns, and operational schedules. SM1, SM2, and SM4 likely experience higher loads in February due to consistent occupancy or increased equipment use during that period. In contrast, SM3's peak in April may result from changes in operational intensity, such as increased equipment use or occupancy later in the dry season. This indicates that even under similar climatic conditions, building-specific design and usage factors can significantly influence monthly energy consumption patterns

A similar research was conducted by Moghimi *et al.,* (2014) In large-scale hospitals in Malaysia, electricity usage is similar throughout the year, with minimal seasonal variation in cooling demand, while reaching a peak in February and March.

Table 3: Actual energy consumption

Description	Annual National Grid Electricity Consumption (kWh/yr)	Annual Back-up Electricity Consumption (kWh/yr)	Total Annual Consumption (kWh/yr)	Total Annual Consumption per Area (kWh/yr/m^2)
SM 1	62,128	21,794	83,922	153.29
SM 2	46,732	16,540	63,272	270.77
SM 3	35,502	12,529	48,031	354.43
SM 4	35,366	11,803	47,169	156.88

From the result in Table 3, the shopping malls have an annual energy consumption from grid supply of 62,128 kWh, 46,732 kWh, 35,502 kWh and 35,366 kWh for SM 1, SM 2, SM 3 and SM 4, respectively. Based on the computation, electricity from backup sources for SM 1, SM 2, SM 3 and SM 4, are 21,039 kWh, 15,705 kWh, 12,217 kWh and 11,798 kWh, respectively. The sum of electricity consumption from the main and backup supplies yielded the total annual energy consumption. SM 1, SM 2, SM 3 and SM 4 have a total consumption of 83,166.8 kWh, 62,819 kWh, 47,719 kWh, and 47,164 kWh, respectively.

The results indicate that SM1 and SM2 are significantly more energy-intensive than SM3 and SM4, suggesting possible differences in building size, occupancy density, equipment load, or/and operational hours. The relatively high contribution of backup power (about 25–30% of total use) across all malls highlights a strong reliance on generators, which not only increase operational costs but also lower energy efficiency and increase carbon emissions.

Comparison of energy consumption performance with benchmarks

Energy consumption performance indicators are paramount for the successful evaluation of the energy performance of buildings. The most recognised indicator is the Energy Use Index or Intensity (EUI). The indicators are expressed in KWh/m^2/yr. The EUI of the shopping malls were compared to other global benchmarks presented in Table 4.

Table 4: Comparison of energy consumption performance with benchmarks

Shopping Mall	Annual Energy Consumption in kWh/m²/yr										
	Obtained	**Benchmarks**									
		Nigeria			**Malaysia**			**CIBSE**		**ASHRAE**	
		BP	**GP**	**TP**	**BP**	**GP**	**TP**	**BP**	**TP**	**BP**	**TP**
SM 1	153	< 130	130 - 209	210 - 320	≤ 135	136 - 179	180 - 250	≤ 122	195	≤ 58	130
SM 2	271	< 130	130 - 209	210 - 320	≤ 135	136 - 179	180 - 250	≤ 122	195	≤ 58	130
SM 3	354	< 130	130 - 209	210 - 320	≤ 135	136 - 179	180 - 250	≤ 122	195	≤ 58	130
SM 4	157	< 130	130 - 209	210 - 320	≤ 135	136 - 179	180 - 250	≤ 122	195	≤ 58	130

Key: BP = Best Practice; GP = Good Practice; TP = Typical Practice

The results in Table 4 show that SM1, SM2, SM3, and SM4 have EUI of 153, 271, 354, and 157 kWh/m^2/yr, respectively. From the results, none of the SMs met the minimum benchmark for any global best practice. Only SM 1 and SM 4 fall under the category "good practice" for Nigeria, South Africa, Malaysia, and CIBSE benchmarks, with EUI of 153 and 157 kWh/m^2/yr. SM 2 with an EUI of 271 kWh/m2/yr met only the Nigeria and South Africa "typical practice" benchmark, while SM 4 did not fall under any global benchmark category.

From the result, SM 1 has exceeded the minimum benchmarks of Nigeria and South Africa of 130 kWh/m^2/yr by 18.41%, while SM 2, SM 3, and SM 4 have exceeded the benchmark by 108.90%, 178.12%, and 20.21%, respectively. This implies that SMs that accumulate low EUI are likely to experienced more energy savings. For instance, SM 2 and SM 3 can save up to 108% and 178% if the buildings comply with provisions of the code. Therefore, the greater the compliance to the BEEC, the lower the EUI and the more tendency to achieve the best practices targets set by the benchmarks.

Several scholars have conducted similar studies where commercial buildings consumed higher than the expected benchmark. For instance, Aziz *et al.* (2012) conducted studies on a commercial building in Shah Alam, Malaysia. The building under study consumed 183.25 kWh/m^2 per year based on the air-conditioned area of 119,561 m^2. The building, therefore, is regarded to be about 40% higher than the recommended 135 kWh/m^2/year. Another study of energy audits on commercial buildings in Malaysia revealed that most buildings had EUI in the range of 200 to 250 kWh/m^2/year (Aziz *et al.,* 2012). Abu Bakar *et al.,* (2015) investigated the EUI of residential and non-residential buildings using case studies. The result revealed that the EUI for residential buildings was between 150 and 400 kWh/m^2/yr (primary) and the range of EUI was between 250 and 550 kWh/m^2/yr (primary) for commercial buildings. Adebisi *et al.,* (2019) studied the energy performance of administrative buildings in tertiary institutions in Niger State, Nigeria. In their study, the EUI for the administrative buildings is averaged 181.34 kWh/m^2/yr, which is also above the global best practice. This higher EUI for commercial buildings can be attributed to many reasons. Longer operating hours in shopping malls require more operating energy due to high occupant intensity, large electrical load usage, and more energy are needed to maintain comfort conditions inside the building.

Disaggregated primary energy consumption

The disaggregated primary energy consumption otherwise known as the energy consumption by end-uses was derived from the energy audit carried out during the survey. According to the results in Table 3, energy consumption by end-uses is categorised into lighting, ventilation and air conditioning, and appliances(such as refrigerators, Printers, etc.). Each category is audited based on the nature of the appliance and hours of operation. The energy consumption by end-use shown in Table 5 includes the sum of supply from the national grid and alternative sources of energy (e.g., diesel generators, solar).

Table 5: Energy consumption by end-use

Category	Lighting (kWh/m^2 /yr)	VAC (kWh/m^2 /yr)	Appliance (kWh/m^2 /yr)
SM 1	25	88	41
SM 2	39	175	57
SM 3	81	174	102
SM 4	32	77	48
Average Total	**44**	**129**	**62**

The SM 1 outcomes of the energy consumption by end-use from Table 5 revealed that lighting, VAC, and appliances accounted for 25 kWh/m^2/yr, 88 kWh/m^2/yr and 41 kWh/m^2/yr of the annual energy use. In contrast, 39 kWh/m^2/yr, 175 kWh/m^2/yr and 57 kWh/m^2 /yr respectively were the annual energy consumption by end-use for SM 2. As for SM 3, the end-use disaggregation was 81 kWh/m^2 /yr,174 kWh/m^2/yr and 102 kWh/m^2 /yr while the end-use consumption for SM4 are 32 kWh/m^2/yr, 77 kWh/m^2/yr and 48 kWh/m^2/yr. The cumulative percentage average of energy consumed by the shopping malls revealed that lighting, VAC and appliances account for 19%, 55% and 26% of the annual energy consumption by end-use, respectively, as shown in Figure 2

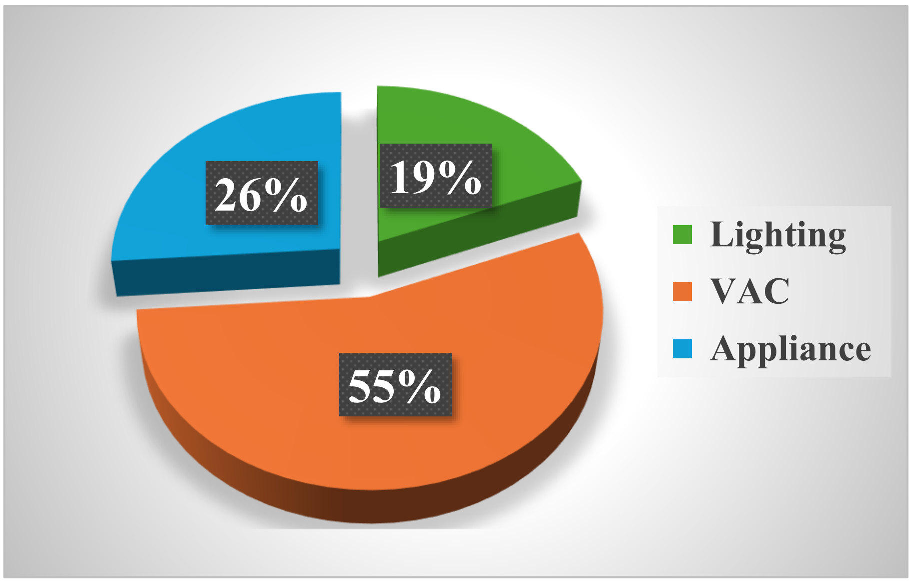

Figure 2: Energy consumption by end-use

Generally, the results in Figure 2 indicate that cooling load accounted for 55% of the energy consumed by shopping malls. This result equally buttresses the dominance of cooling loads as the highest energy consumption by end-use as investigated by earlier studies on commercial buildings.

In their research, Moghimi *et al.,* (2014) investigated the end-use energy in large scale hospitals. Air conditioning accounts for the largest share of energy consumption at around 62%, followed by lighting at roughly 22% and other equipment at nearly 16%. Aziz *et al.,* (2012) results show that the energy consumed for cooling represents 58% while equipment and lighting consume around 48% of the total energy consumption. Another similar study by Pusat Tenaga in 2003 reveals that energy consumption is typically 62% air conditioning, 20% appliance, and 18% lighting. Similar studies conducted in Nigeria also show higher cooling load energy consumption. Adebisi *et al.,* (2019) found that VAC consumes up to 46% while lighting and appliance consume about 10% and 44% energy by end-use, respectively. Unarguably, cooling loads have consumed a significant amount of energy by end-use. The higher energy consumption may be attributed to wasteful usage patterns, as users often have little control over the cooling system or are indifferent to energy costs, compounded by the use of faulty or inefficient systems that fail to adjust to varying cooling demands. In contrast, the adoption of inverter air conditioners (ACs) offers a more efficient alternative, as they automatically regulate energy supply based on real-time demand, thereby optimizing consumption in commercial spaces.

Statistical Variation in Energy Consumption

A two-way ANOVA was conducted to examine the extent of variation in energy consumption across the shopping malls. This analysis was necessary because the descriptive results alone could not determine whether the observed differences in energy usage were statistically significant. For instance, the findings showed that the shopping malls exceeded the 130 kWh/m²/year threshold by 18% in SM1, while SM2, SM3, and SM4 exceeded the benchmark by 108.90%, 178.12%, and 20.21%, respectively. Therefore, to verify whether these variations were statistically significant, the data were subjected to inferential statistical analysis using a Two-Way Analysis of Variance (ANOVA), which was deemed appropriate based on the nature of the variables involved. The ANOVA results are presented in Table 6.

Table 6: ANOVA result

ANOVA					
Annual Energy consumption by End-use					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9962.000	3	3320.667	1.385	.316
Within Groups	19186.667	8	2398.333		
Total	29148.667	11			

As shown in Table 6, the variation in energy consumption by end-use across the shopping malls is not statistically significant, with a p-value of 0.316 ($p > 0.05$). This indicates that despite differences in floor area and the number of installed equipment, the overall energy consumption patterns remain similar among the malls. The result suggests that energy use behaviors and operational practices are largely uniform, reflecting comparable levels of efficiency or inefficiency across the facilities. This uniformity may imply that common design standards, management practices, or user habits dominate energy performance. Therefore, this indicates the need for targeted energy efficiency interventions and behavioral change programs that can effectively address these general patterns across similar commercial buildings.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study assessed the energy consumption performance of four selected shopping malls in Kaduna metropolis. The findings reveal that the Energy Use Intensities (EUIs) of the malls (153, 271, 354, and 157 kWh/m²/yr) significantly exceeded the global best-practice benchmark of 130 kWh/m²/yr, with some malls surpassing this threshold by over 100%. Comparative analysis with benchmarks from Nigeria, South Africa, Malaysia, CIBSE, and ASHRAE further confirmed that none of the malls achieved best-practice performance, and only two (SM1 and SM4) fell within the "good practice" category for some regional standards. This suggests that the energy efficiency gap in commercial buildings is not only a function of design flaws but also of poor enforcement and inadequate operational practices.

The disaggregation of energy use highlighted that cooling loads dominate overall consumption, averaging 55% of total annual use, followed by appliances (26%) and lighting (19%). This aligns with studies in similar climatic contexts, where cooling demand is the primary driver of high consumption. The results also indicate that even with variations in floor area, equipment numbers, and operating hours, energy consumption patterns across the malls did not differ statistically ($p = 0.316$), reinforcing the observation that common inefficiencies, rather than building-specific differences, drive overall poor performance.

Recommendations

The implications of these findings are twofold. First, they confirm that without strict enforcement and continuous monitoring, BEEC provisions alone cannot guarantee meaningful reductions in energy use. Second, it highlights the need for targeted interventions, such as the provision of energy-efficient appliances through retrofitting. Beyond technical measures, policy reforms should prioritise strengthening compliance mechanisms, including permit-stage checks, construction-phase verification, and post-occupancy audits.

REFERENCES

Abu Bakar, N. N., Hassan, M. Y., Abdullah, H., Rahman, H. A., Abdullah, M. P., Hussin, F., & Bandi, M. (2015). Energy efficiency index as an indicator for measuring building energy performance: A review. *Renewable and Sustainable Energy Reviews*, *44*, 1–11. https://doi.org/10.1016/j.rser.2014.12.018

Adebisi, G. O., Olagunju, R. E., Akande, O. K., & Akanmu, W. P. (2019). Energy Performance of Selected Administrative Buildings in Tertiary Education Institutions in Niger State , Nigeria. *Environmental Technology & Science Journal*, *10*(1), 16–27.

AIA California. (2021). *Energy Use Intensity*. AIA California Website. https://doi.org/10.1007/978-3-319-95864-4_300072

Almeida, L., Tam, V., Le, K., & She, Y. (2020). Effects of occupant behaviour on energy performance in buildings: a green and non-green building comparison. *Engineering, Construction and Architectural Management*, 27, 1939-1962. https://doi.org/10.1108/ecam-11-2019-0653

ASHRAE. (2011). *Procedures for commercial building energy audits, 2nd edn. ASHRAE, Atlanta*. https://www.google.com/search?q=ASHRAE+%282011%29+Procedures+for+commercial+building+energy+audits

Azar, E., & Menassa, C. (2012). Agent-Based Modeling of Occupants and Their Impact on Energy Use in Commercial Buildings. *J. Comput. Civ. Eng.*, 26, 506-518. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000158

Azar, E., & Menassa, C. (2014). Framework to Evaluate Energy-Saving Potential from Occupancy Interventions in Typical Commercial Buildings in the United States. *J. Comput. Civ. Eng.*, 28, 63-78. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000318

Aziz, M. B. A., Zain, Z. M., Baki, S. R. M. S., Hadi, R. A., Mara, U. T., & Alam, S. (2012). *Air-Conditioning Energy Consumption of an Education Building and it ' s Building Energy Index : A Case Study in Engineering Complex , UiTM Shah Alam , Selangor*. *Icsgrc*, 175–180.

Batagarawa, A., Hamza, N., & Dudek, S. (2011). Batagarawa, A., Hamza, N. and Dudek, S.J., 2011. Disaggregating primary electricity consumption for office buildings in Nigeria. In Proceedings of Building Simulation 2011: 12th Conference of International Building (Vol. 1416). *In Proceedings of Building Simulation 2011: 12th Conference of International Building*, *1416*, 14–16. http://www.ibpsa.org/proceedings/BS2011/P_1379.pdf

Bhatt, M. S., Rajkumar, N., Jothibasu, S., Sudirkumar, R., Pandian, G., Nair, K. R. C., EIA, EIA: Energy Usage Summary, EIA: Use of Energy Explained, & Reference, A. E. O. (2005). Commercial and Residential Building Energy Labeling. *U.S. Energy Information Administration*, *64*(1), 30–34. https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php

Boyd, P., Schweber, L., Zou, P. X. W., Xu, X., Sanjayan, J., Wang, J., Gerrish, T., Ruikar, K., Cook, M., Johnson, M., Phillip, M., Shrubsole, C., Hamilton, I. G., Zimmermann, N., Papachristos, G., Broyd, T., Burman, E., Mumovic, D., Zhu, Y., … Kimpian, J. (2018). A Review of Operating Performance in Green Buildings: Energy Use, Indoor

Environmental Quality and Occupant Satisfaction. *Energy and Buildings*, *183*(1), 500–514. https://doi.org/10.1016/j.enbuild.2018.11.017

Briller, D. L. (2013). Adapting to a New Reality—Strategies for Building Energy Design in a Changing Climate. *Strategic Planning for Energy and the Environment*, *32*(4), 14–64. https://doi.org/10.1080/10485236.2013.10677560

CIBSE. (2012). Energy efficiency in buildings: CIBSE Guide F. In *Energy Efficiency Research* (3rd ed.). The Lavenham Press Ltd.

Cole, R. J. (1998). Emerging trends in building environmental assessment methods. *Building Research & Information*, *26*(1), 3–16.

Cox, M., Brown, M. A., & Sun, X. (2013). Energy benchmarking of commercial buildings: a low-cost pathway toward urban sustainability. *Environmental Research Letters*, 8. https://doi.org/10.1088/1748-9326/8/3/035018

FMPWH. (2017). Development of the Nigerian Building Energy Efficiency Code (BEEC) Technical Study. In *Federal Ministry of Power, Works and Housing* (Issue April).

Harris, D. J. (2012). A Guide to Energy Management in Buildings. In *A Guide to Energy Management in Buildings* (1st ed.). Spon Press. https://doi.org/10.4324/9781315651576

IEA. (2016). Final Report Annex 53. Total energy use in buildings Analysis and evaluation methods. *International Energy Agency Programme on Energy in Buildings and Communities*, *June*, 132.

Ingle, A., Moezzi, M., Lutzenhiser, L., & Diamond, R. (2014). Better home energy audit modelling: incorporating inhabitant behaviours. *Building Research & Information*, *42*(4), 409–421. https://doi.org/10.1080/09613218.2014.890776

Krarti, M. (. (2012). *Energy audit of building systems: an engineering approach*. CRC PRESS LCC.

Manic, M., Wijayasekara, D., Amarasinghe, K., & Rodriguez-andina, J. (2016). Building Energy Management Systems: The Age of Intelligent and Adaptive Buildings. *IEEE Industrial Electronics Magazine*, 10, 25-39. https://doi.org/10.1109/MIE.2015.2513749.

Menezes, A. C., Cripps, A., Bouchlaghem, D., & Buswell, R. (2012). Predicted vs. Actual Energy Performance of Non-domestic Buildings: Using Post-Occupancy Evaluation Data to Reduce the Performance Gap. *Applied Energy*, *97*, 355–364. https://doi.org/10.1016/j.apenergy.2011.11.075

Moghimi, S., Azizpour, F., Mat, S., Lim, C. H., Salleh, E., & Sopian, K. (2014). Building energy index and end-use energy analysis in large-scale hospitals-case study in Malaysia. *Energy Efficiency*, *7*(2), 243–256. https://doi.org/10.1007/s12053-013-9221-y

Mu'azu, A. I. (2015). *Sustainable Design Strategy: Assessment of impact of Design Variables on Energy Consumption of Office Buildings in Abuja, Nigeria*. University of

Portsmouth, U.K.

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of Renewable Energy Sources, Sustainability Issues and Climate Change Mitigation. In *Cogent Engineering* (Vol. 3, Issue 1). Cogent OA. https://doi.org/10.1080/23311916.2016.1167990

Perez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy Consumption information. *Energy and Buildings*, *40*(3), 394–398.

Poel, B., Van Cruchten, G., & Balaras, C. A. (2007). Energy Performance Assessment of Existing Dwellings. *Energy and Buildings*, *39*(4), 393–403.

Rafsanjani, H. N., Ahn, C., & Alahmad, M. (2015). A Review of Approaches for Sensing, Understanding, and Improving Occupancy-Related Energy-Use Behaviors in Commercial Buildings. *Energies*, 8, 10996-11029. https://doi.org/10.3390/EN81010996

Rajagopalan, P. (2019). Energy Performance in the Australian Built Environment. In *Energy Performance in the Australian Built Environment, Green Energy and Technology*. Springer Singapore. http://link.springer.com/10.1007/978-981-10-7880-4

Rosenberg, E. (2014). Calculation method for electricity end-use for residential lighting. *Energy*, *66*(C), 295–304.

Saidur, R., & Masjuki, H. (2008). Energy and Associated Emission Analysis in Office Buildings. *International Journal of Mechanical and Materials Engineering*, *3*(1), 90–96.

Zhou, C., Zhu, W., & Jiang, Y. (2012). Research and discussion on energy consumption indicators of different items of large-scale public buildings in Shanghai. *International Journal of Low-carbon Technologies*, 7, 226-233. https://doi.org/10.1093/IJLCT/CTS034

Zou, P. X. W., Xu, X., Sanjayan, J., & Wang, J. (2018). Review of 10 years research on building energy performance gap: Life-cycle and stakeholder perspectives. *Energy and Buildings*, *178*, 165–181. https://doi.org/10.1016/j.enbuild.2018.08.040

Sadrzadehrafiei, S., Sopian, K., Mat, S., Lim, C., Hashim, H. S., & Zaharim, A. (2012). Enhancing energy efficiency of office buildings in a tropical climate, Malaysia. International journal of energy and environment, 6(2), 209-216.

Okoronkwo, C. A., Nwaigwe, K. N., Ogueke, N. V., Anyanwu, E. E., & Okwu, M. (2018). Effects Of Seasonal Weather Variations on the Measured Performance of A Nocturnal Cooling System in Owerri, Nigeria.