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ELECTRICITY USE FOR HOTEL FACILITIES IN KEBBI STATE, NIGERIA

Aminu Bn Musa[1], Amina Batagarawa[2]

Department of Architectural Technology, Waziri Umaru Federal Polytechnic, Birnin Kebbi, Nigeria[1]
Baze University, Abuja, Nigeria[2]

Emails: elamin199@gmail.com[1] aminab_@hotmail.com[2]

Abstract

The world is shifting to using renewable energy sources, largely to mitigate climate change. In addition, the uncertainty in the global oil and gas sector is pushing Nigeria's policy to diversify into other sectors like tourism and recreation to develop the economy. Some non-oil producing states in Nigeria especially, are looking at the hotel industry as a viable diversification option. However, this sector requires energy as the backbone of its operations and these facilities are located in energy-poor states where the most prevalent mode of backup power supply is by using diesel generators. To plan a shift to a cleaner energy supply, it is important to have accurate information on the energy consumption patterns of these tourism facilities. This research aims to evaluate electricity consumption and supply patterns in hotels in a non-oil-producing state in northern Nigeria. The methodology involves conducting energy audits in three selected facilities, which are classified as small, medium, and large in Kebbi state. Analyses on demand versus supply, energy disaggregation, and energy use intensity were conducted. The results show that none of the facilities has a renewable electric energy supply. All three hotels have their energy demand higher than the energy supplied with a 5% energy supply deficit in the case of the large and medium facilities, and up to 23% deficit for the small facility. The consumption is disaggregated into HVAC loads, plug loads, water supply loads and lighting loads with each factor having an average percentage of energy consumption of 58%, 18%, 18% and 6% respectively which is met solely with electricity. An annual Energy Use Intensity of 145.21kWh/m2, 380.19kWh/m2 and 232.40kWh/m2 is calculated for the small, medium and large facilities respectively, with an average value of 166kWh/m2. The results show a clear indication of the need for an energy efficiency intervention to match supply to demand.

Keywords: Climate Change, Electricity, Energy audit, Energy Use, Hospitality Facilities

INTRODUCTION

The move against global warming redirects new developments, changes and improvements in different fields of human endeavour, to mitigate Greenhouse Gas (GHG) emissions or adapt to its effects (United Nations, 2019). One of the major areas experiencing rigorous changes is the energy sector. The drivers of change in the energy sector include an effort to lessen the overdependence on fossil fuel and coal used for energy generation. Many countries have set targets and streamlined policies that would eventually ease the shift to renewable energy by 2030 (International Energy Agency, 2020). About 88% of Nigeria's income is generated from exporting crude oil (Africa Check, 2018). However, despite Nigeria's abundant oil and gas resources, electricity generation hovers around 4000MW (USAID, 2021) and an average power supply of only 9 hours daily. This is grossly inadequate and especially challenging for the non-oil producing states in the country who aim to diversify their economies.

Birnin Kebbi is the capital city of Kebbi state. Like most state capitals in Nigeria, it enjoys the privilege of being the seat of the state government. The state borders Sokoto, Zamfara and Niger states. On the international level, it borders Niger Republic and Benin Republic to its North and West respectively. This makes it a centre of trade at both national and international levels. Kebbi state is internationally recognised as the location for three renowned festivals: the Argungu International Fishing Festival, Uhola Agric Festival Zuru and Yauri Rigata Agricultural Show. As a result of these, Birnin Kebbi witnesses a constant influx of visitors throughout the year leading to the need to invest in the provision of accommodation facilities within and around the metropolis.

Tourism has been identified as a potential source of Internally Generated Revenue (IGR), especially for the non-oil-producing states in Nigeria (Ajani & Kalu, 2017; Oyedepo, 2012). However, hospitality facilities require a steady power supply to operate (Ibrahim, 2010). This further challenges the diversification of the hospitality sector and hinders investments across the value chain due to the enormous cost involved in operating or maintaining facilities.

Utilizing renewable power sources is identified as a potential solution to the energy poverty problem in Nigeria generally and in northern Nigeria particularly (Agaptus, Segun, & Oluwaseun, 2019). This option, however, relies on adequate and accurate information on the energy consumption pattern of a facility (Abisha, et. al., 2018). From a global perspective, HVAC and Transportation are the major consumers of energy, with a demand estimate of over 80% as shown in (REN21, 2019; US Department of Energy, 2015; Shoubi et al., 2014). This is a cause for concern and likely a potential focus for stakeholders

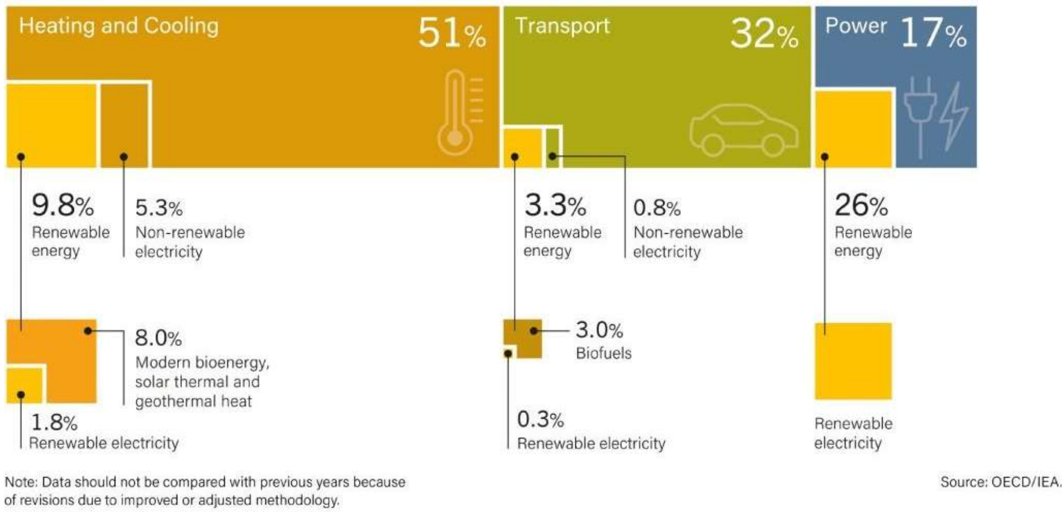

Figure 1: Power consumption breakdown according to sector

Source: REN21 (2019)

in the building industry to catalyse new ideas that would substantially reduce energy demand in buildings, particularly HVAC loads, through design, materials and construction techniques in all phases of the building life cycle (Yuksek & Karadayi, 2017). According to the European Commission, non-residential buildings are 40% more energy intensive as they consume up to 250kWh/m2 of energy against 180kWh/m2 for residential buildings (European Commission, 2019; Shehu et al., 2019).

To plan a shift to a cleaner energy supply in non-residential buildings such as those in the tourism sector, it is important to have accurate information on the energy consumption patterns of these facilities. This research aims to evaluate electricity consumption and supply patterns in hotels in Kebbi state, Nigeria. The objectives are to:

i. Estimate annual electricity supply.
ii. Estimating annual electricity demand.
iii. Disaggregating end-uses.
iv. Estimating Energy Use Intensities.

LITERATURE REVIEW

Hotel buildings consume large amounts of energy to provide the best service possible for guests (Shehu et al., 2019; Farrou, Kolokotroni, & Santamouris, 2012; Xydis, Koroneous, & Polyzakis, 2009). The energy used in running hotels is largely from fossil fuels, which not only exacerbates climate change but also reduces profits due to high energy costs (Oluseyi & Babatunde, 2016).

From the available data on energy consumption of hotels in North America, Europe, and Asia between the years 1990 to 2000 (Abisha et al., 2018) an average of 401kWh/m2 of energy is consumed in the United States per year, out of which about 41% is electricity. In Canada, the average annual energy consumption of between 612 kWh/m2 and 689 kWh/m2 is consumed over the same period, out of which electricity accounts for about 29%. In Europe, hotel energy consumption accounts for 1% of the total (39,000,000,000 kWh), 50% of which is electricity (Bohdanovicz & Martinac, 2007). In Singapore, a study conducted in 1993 on the energy consumption of hotel buildings indicates that an annual average of 468 kWh/m2, is consumed annually. A later study in the same location of 29 hotels conducted between 2005 and 2006 reported an annual electricity consumption of 361 kWh/m2 per annum. In Hong Kong, a two-year research conducted between 1995 and 1997 indicates that consumption of energy in hotels in that location ranges between 406 kWh/m2 and 564 kWh/m2 per annum.

Studies conducted in Nigeria show similar results. In 2015, six hotels were audited in northern Nigeria. It was estimated that an average of 303 kWh/m2 is consumed annually (Musa, Batagarawa, & Mohammed, 2015). In the southeastern part of Nigeria, an assessment conducted in 2019 estimated a higher annual consumption of 403 kWh/m2 (Sam-Amobi, Ekechukwu, & Chukwuali, 2019). These results indicate that electricity is the main form of energy used to power these hotels.

All the aforementioned Energy Intensity Use values were determined using Energy Auditing processes. It is widely considered to be the best form of energy data collection and analysis model because it involves physical interactions and inspection (Mahdy, 2018; Abisha, et. al, 2018; Moncef, 2021; Tomaskova, et. al., 2023; Pradhan & Panda, 2022; Stavset & Kauko, 2015; Nnaemeka & Samson, 2015). Literature shows that shifting to sustainable energy is capital intensive and requires a longer payback period. As such, there is a need to devise means of disaggregating energy use into easily targeted potential areas of energy saving particularly for decision makers and stakeholders (Shehu, et. al., 2019).

MATERIALS AND METHODS

The Study Area

The study area for this research is Birnin Kebbi, a city in northern Nigeria, which is prone to severe weather conditions due to its proximity to the desert and increasing agricultural and industrial activities (Blessing et al., 2012). A joint study conducted by the Climate Research Analysis Group, University of Cape Town, South Africa, and the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria (2011) predicted a warmer climate in the hot-dry region of Nigeria, with a projected temperature increase of 0.04°C per year from now till 2050.

Indicators of a changing climate in the region include an increase in severe weather conditions, massive loss of vegetative ecosystems, and the presence of dunes that were not visible a few decades ago. This changing climate has significant implications for the region's energy consumption and sustainability, particularly in the hospitality industry. To conduct energy audits and assess the energy efficiency of hotels in Birnin Kebbi, three hotel facilities within the metropolis were selected using purposive sampling based on the hotel grouping by Kebbi State Hotels and Tourism Board. The hotels were categorized as large, medium, and small based on the number of rooms, with the large category having more than 50 rooms, the medium category having 30-50 rooms, and the small category having 10-29 rooms.

The selected hotels were Saffar Guest Inn and Conference Centre (large category, 65 rooms), Gesse Hotel (medium category, 44 rooms), and Kakale Crown Guest Inn (small category, 14 rooms). The energy audits were conducted based on this hotel classification.

Data Acquisition

The following data is collected during the energy audit:

i. One-year electricity bills
ii. Diesel consumption data from fuel log book
iii. A log of average daily power outages from the grid
iv. A log of average monthly patronage from the guest register
v. The gross floor area of the facility
vi. The floor area of the conditioned space
vii. The energy rating of all electrical devices used in a facility

The Energy Commission of Nigeria (ECN) is the foremost research institute in Nigeria. The energy audit model adopted is based on the ECN energy audit format (ECN, 2017). However, while comparing its adequacy with other standard models, it was observed that this model lacks formulae to estimate demand and supply. Therefore, this study adapted the ECN model by adding a demand and supply section. Another addition was required to account for power supply inadequacy in Nigeria. Within the data collection process, there was a notable difference between the demand and supply. The model was further adapted to accommodate this inconsistency as shown in the result section.

In light of the power inadequacy experienced in Nigeria, a methodology (Batagarawa, 2013), is presented to account for this inadequacy. However, it is updated to include water supply in the disaggregated energy demand end.

Figure **2** shows how data is analysed to obtain annual energy supply and disaggregated energy demand for the hotels audited.

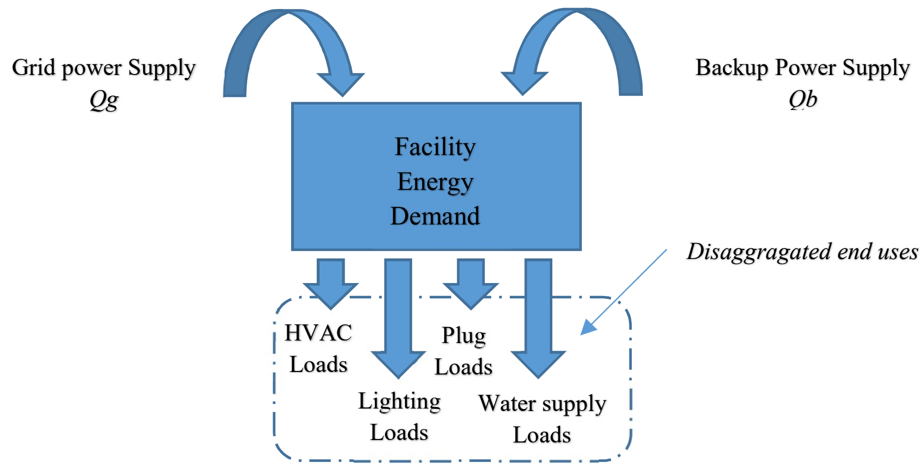

Figure 2: Estimated electricity supply and aggregate demand

Source: adapted from Batagarawa (2013)

Estimating and Contrasting Demand and Supply

To estimate the annual electricity supply:

To estimate the electricity supply, the following set of equations are formulated:

Energy supply is calculated to include grid and backup power supply and thus presented as:

$Qt = Qg + Qb$ Equation 1 source: (Batagarawa, 2013)

Where Qt = total power supply (grid and backup); Qg = power supply from the grid and Qb is power supplied from backup, in this case Generators (Diesel and Petrol types)

Qg is recorded from monthly bills provided by Power Distribution Companies

Qb is estimated by using the manufacturer's specification for fuel consumption obtained from the backup generator manual.

$Qb = pb*ph$ Equation 2, Source: (Batagarawa, 2013)

Where pb is the Generating Power Capacity eg 200kva generator in the big hotel and ph is power outage duration from the grid in hours.

To estimate the average electricity demand.

To estimate the electricity demand, there is a need to disaggregate end uses for the electricity demand, using the following set of equations:

1. Hl1 + Hl2 + Hl3 ……… Hln Equation 3 (Batagarawa, 2013)

Where Hl= HVAC device rating for each type recorded in the audit

2. Ll1 + Ll2 + Ll3 ………… Lln Equation 4 (Batagarawa, 2013)

Where Ll = Lighting fixture rating for each type recorded in the audit

3. Pl1 + Pl2 + Pl3 ………… Pln Equation 5 (Batagarawa, 2013)

Where Pl = Plug appliances rating for each type recorded in the audit

4. Wl1 + Wl2 + Wl3 ….......... Wln Equation 6 (Batagarawa, 2013)

Where Wl = Water pump / Water heater ratings for each type recorded in the audit

The total demand is the sum of the different end-uses, formulated as:

Qd = Hl+Ll+Pl+Wl Equation 7 (Batagarawa, 2013)

Where Qd is the facility's total electricity demand

To estimate the average Electricity Use Intensity

To estimate Energy Use Intensity:

EUI = Qt/A Equation 9 (Batagarawa, 2013)

Where Qt = total power supply (grid and backup) A = facility-conditioned floor area in m2

To contrast between demand and supply

Ideally, there should be little variance between demand and supply. The bigger the variance, the more discomfort experienced by the hotel users in the form of thermal discomfort, lack of hot water and even basic lighting.

Td= Qt – Qd Equation 8 (Batagarawa, 2013)

Where Td is the difference between demand and supply

RESULTS

This section analyses the data collected from the energy audits in the three hotels to achieve the objectives of the study:

1. Estimating annual electricity supply
2. Estimating annual electricity demand
    a. Disaggregating end-uses
    b. Estimating Energy Use Intensities

Estimating annual electricity supply

In all the facilities, electricity is supplied from both grid and backup generators. Daily power supply within the study area is 18 hours generally, thus, 6 hours of backup is required to supplement the power outage period. This rationing approach is embraced by several state and local governments in Nigeria, depending on the available power from the central utility.

The backup generators used in the case of large and medium facilities can accommodate the total electricity demand of the respective facilities, whereas, in the case of the small hotel, a backup generator is used to power only lighting fixtures and fans.

The monthly backup for consumption for large, medium and small hotels are 26645kWh, 21900kWh and 2149kWh respectively as shown in Table 1. These are estimated by using the manufacturer's specification for fuel consumption obtained from the backup generator manual.

Table 1: Electricity supply across the three hotels from monthly bill (grid) logs

FACILITY	DAILY AVERAGE POWER SUPPLY (H)		MONTHLY AVERAGE CONSUMPTION (KWH)		ANNUAL AVERAGE CONSUMPTION (KWH)	GPC
	Grid	Backup	Grid	Backup	Total	
Large Hotel	18	6	12415	26645	618,715	220kva and 70kva
Medium Hotel	18	6	4653	21900	262,800	150kva
Small Hotel	18	6	2192	2149	52,089	Two 3.5kva

Source: Fieldwork (2022)

Table 1 shows total electricity supply data collected from the three hotels is 618,715kW, 262,800kWh and 52,089kWh respectively. The small facility pays a fixed monthly electricity bill throughout the year. This makes the electricity data from the small hotel appear uniform throughout the year. Additionally, the study explored the variance between annual electricity demand and supply in each of the three hotels (Table 2). It was observed that there is a shortfall of 5 - 6% in the large and medium hotels respectively, while in the case of the small hotel, the shortfall is up to 32%. For the large and medium this shortfall can be attributed duration of time to power the generator and engage load which is estimated to be between 5 to10 minutes depending on the circumstance while in the small hotel, only lights bulbs and fans are powered by backup generators, this contributed to the large shortfall between the demand and supply.

Table 2: Shows the demand and supply variance

Facility	Electricity Demand (kWh)	Electricity Supply (kWh)	Variance (kWh)	Percentage Variance (%)
Large Hotel	520910.02	468715	52195.02	5
Medium Hotel	361054.6	318633	42421.56	6
Small Hotel	74799.54	26311	48488.34	32

Source: Fieldwork (2022)

Estimating annual electricity demand

Data collected from the three hotels indicates that the end-uses can be disaggregated into HVAC, lighting, plug and water supply loads as discussed in the previous sub-sections. The study looked at electricity demand by calculating all the power consumption of the appliances using Equations 2 to 5. The results of the analyses indicate that there is potential for energy saving across all the disaggregated end-uses as the current devices installed in the facilities are old or do not comply with energy efficiency guidelines. The disaggregated end-uses for all three hotels are shown in Figure 3 with HVAC consuming the largest share at 58%, water heating and plug loads a similar share at 18% and lights 6%.

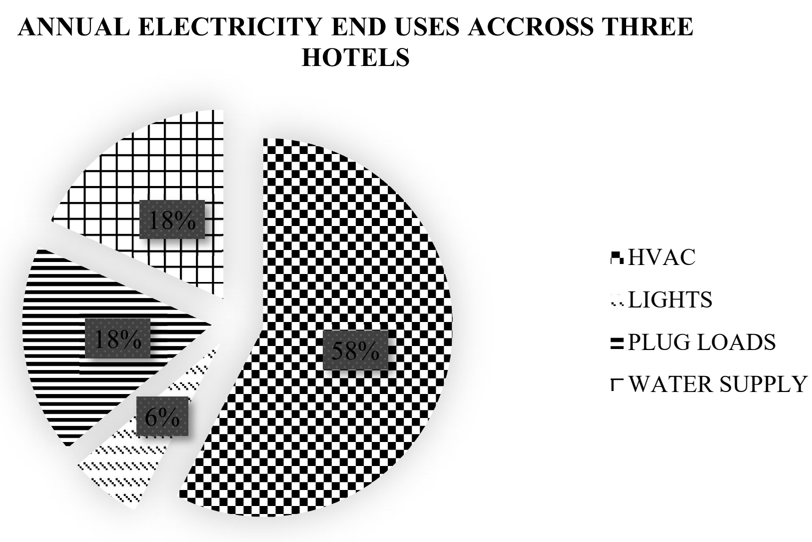

Figure 3 Disaggregated end-uses for three hotels

Electricity Demand: HVAC loads

Tables 3, 4 and 5 show the electricity demand for HVAC in the large, medium and small hotels respectively. The demand ranges from 282,247 kWh/annum for the large hotel, to 114,625 kWh/annum for the medium hotel and 78,227 kWh / annum for the small hotel. The average hours of operation is 12 hours/day.

Table 3: average annual HVAC loads, large hotel

S/n	Item	Location	Qty	Power Rating (w)	Av. Operation (h)	Consumption/ day (kWh)	Total consumption/ annum (kWh)
1	1.5 hp split unit LG Air conditioner	Rooms, offices	83	1100	8	730.4	266,596
2	Standing Fan	Rooms/office	67	80	8	42.88	15651.20
	Total						282,247.2

Source: Fieldwork (2022)

Table 4: Average annual HVAC loads, Medium hotel

S/n	Item	Location	Qty	Power Rating (w)	Av. Operation (h)	Consumption/ day (kWh)	Total consumption/ annum (kWh)
1	1.5 hp window unit LG Air conditioner	Rooms/offices	47	1100	6	310.2	113,223
2	Ceiling Fan	Rooms/office	4	80	12	3.84	1402
	Total						114,625

Source: Fieldwork (2022)

Table 5: Electricity demand for HVAC in a small hotel

S/n	Item	Location	Qty	Power Rating (w)	Av. Operation (h)	Consumption / day (kWh)	Total consumption/ annum (kWh)
1	1.5 hp window unit LG Air conditioner	Rooms/ offices	15	1100	12	198	72,270
2	Ceiling Fan	Rooms/office	17	80	12	16.32	5,956.8
	Total						78,226.8

Source: Fieldwork (2022)

Electricity Demand: Lighting Loads

Lighting loads exhibit a pattern similar to the HVAC loads. The large hotel has the highest lighting loads at 41,063W, followed by the medium hotel at 16,425W and lastly, the small hotel at 5,256W.

Table shows the electricity demand for the lighting appliances across the three hotels. The average hours of operation are 12h / day.

Table 6: Lighting loads demand across the three hotels

Facility	5W (no)	15W (no)	25W (no)	100W (no)	Av. Daily Optn Hrs (h)	Total Ann av. (kWh)
Large Hotel	-	341	20	10	12	41.10
Medium Hotel	4	132	18	6	12	16.43
Small Hotel	-	32	16	-	12	5.30

Source: Fieldwork (2022)

Electricity Demand: Plug loads

The pattern for plug loads differs significantly across the hotels. However, all three hotels have three basic pluggable appliances like a bedside fridge, freezer and TV set as shown in Table 7.

Table 7: Plug loads distribution across the three hotels

Facility	Bedside fridge (Qty/W)	Freezer (Qty/W)	TV set 32" (Qty/W)	Washing machine (Qty/W)	Pressing Iron (Qty/W)	Desktop computer (Qty/W)	Treadmil l (Qty/W)	Av. Daily Optn Hrs (h)	Total An. average (kWh)
Large Hotel	65/120	2/140	70/65	2/2200	1/2000	6/365	4/55	8.11	125.2
Medium Hotel	44/120	1/140	46/65	-	-	-	-	8.11	49.00
Small Hotel	16/120	1/140	16/70	-	-	-	-	8.11	11.00

Source: Fieldwork (2022)

Electricity Demand: Water Supply

The source of water for each of the facilities is from a sunk borehole pumped to an overhead tank and reticulated to respective points. None of the facilities has central water heating; Large and medium use individual water heaters. The small hotel uses a hot water on demand approach. Table below highlights the electricity demand required for the water supply across the three cases studied.

Table 8: Electricity demand for both cold and hot water supply across the three case studies

Facility	Water heater

	Submersible pump (rating/h)	(Qty/W)	Electric kettle/Jug (Qty/W)	Av. Daily Opration Hrs (h)	Total Annual average (kWh)
Large Hotel	2 hp	65/2200	49/2000	4	109.30
Medium Hotel	1.5 hp	44/2200	-	2	72.30
Small Hotel	1 hp	-	2/2000w	1	3.62

Source: Fieldwork (2022)

Estimating Energy Use Intensity

Table 9 presents the Energy Use Intensity (EUI) for the three hotels, representing the energy consumption per square meter of conditioned space. This was calculated by assessing each end-use according to the hotel's conditioned floor area, as outlined in equation 8.

Table 9: Energy Use Intensity unit (EUI) for HVAC accross the three hotels.

Facility	Annual HVAC Load (kWh)	Floor Area (M^2)	Energy Intensity Unit (kWh/M^2)
Large Hotel	282,247	3573	79
Medium Hotel	114,625	1020	112.4
Small Hotel	78,226	483	162

Source: Fieldwork (2022)

Tables 10 and 11 offer a detailed break breakdown of the hotel's Energy Use Intensity (EUI) for lighting and plug loads respectively.

Table 10: Energy Use Intensity unit (EUI) for Lighting across the three hotels

Facility	Annual Lighting Load (kWh)	Floor Area (m^2)	Energy Use Intensity (kWh/m^2)
Large Hotel	41,062.50	3573	11.50
Medium hotel	16,425.00	1020	16.10
Small Hotel	5,256.00	483	10.90

Source: Fieldwork (2022)

Table 11: Energy Use Intensity unit (EUI) for plug loads across the three hotels

Facility	Annual Lighting Load (kWh)	Floor Area (m^2)	Energy Use Intensity (kWh/m^2)
Large Hotel	125,149.52	3573	35.03
Medium Hotel	48,768.80	1020	47.81
Small Hotel	10,953.65	483	22.68

Source: Fieldwork (2022)

In the case of water supply, Table 12 shows Energy Use Intensity per floor area is as thus:

Table 12: EUI, for water supply (hot and cold supply)

Facility	Annual water supply (kWh)	Floor Area (m^2)	Energy Use Intensity (kWh/m^2)
Large Hotel	109.30	3573	0.031
Medium Hotel	72.30	1020	0.071
Small Hotel	3.62	483	0.008

Source: Fieldwork (2022)

According to the European Commission, non-residential buildings consume up to 250kWh/m^2. The Energy Use Intensity estimated for the large, medium and small hotels is 131.2 kWh/m^2, 312.4 kWh/m^2 and 54.5 kWh/m^2, with an average of 166 kWh/m^2 as indicated in Table 13.

Table 13: Estimated Energy Use Intensity across the cases studied

Facility	Grid Power supply (kWh)	Backup Power supply (kWh)	Annual Average (kWh)	Total floor area (m^2)	EIU (kWh/m^2)
Large Hotel	148975	319740	468715	3573	131.2
Medium Hotel	55833	262800	318633	1020	312.4
Small Hotel	20004	6307	26311	483	54.5
				Hotels avg.	**166**

Source: Fieldwork (2022)

DISCUSSION

The study's findings on energy consumption patterns in hotels in Kebbi State, Nigeria, reveal a significant reliance on diesel generators to bridge the energy supply gap. The primary drivers of energy demand are HVAC loads, followed by plug loads, water supply, and lighting. This indicates the need for energy efficiency interventions to align supply with demand and reduce the sector's carbon footprint.

The results indicate substantial potential for energy savings, particularly in HVAC systems, which consume up to 58% of electricity. Furthermore, the current devices installed in across all the cases studied are outdated and not energy-efficient, presenting an opportunity for upgrade and replacement with more efficient alternatives. Moreover, the study reveals that none of the facilities utilize renewable energy technologies, despite the abundance of natural resources in the region. This stresses the need for a shift towards sustainable energy solutions.

Similarly, the Energy Use Intensity (EUI) calculated for different hotel sizes, reveals lower values compared to other countries but highlights the variance between demand and supply. This emphasizes the importance of energy efficiency for comfort and sustainability in the hospitality sector. Overall, the study's findings present the significance of energy efficiency and the potential benefits of renewable energy adoption in hotel facilities, paving the way for a more sustainable future.

CONCLUSION / RECOMMENDATION

In conclusion, this study highlights the importance of understanding energy consumption patterns in hotels in Kebbi State, Nigeria. The findings reveal significant potential for energy savings, particularly in HVAC systems. To address the energy efficiency gap, it is recommended that hotel facilities implement energy-efficient devices and explore renewable energy technologies. Additionally, energy management strategies should be developed to address the variance between energy demand and supply. Furthermore, policy initiatives should be encouraged to promote energy efficiency and sustainability in the hospitality sector. Finally, further research on guest behaviour and energy demand during outage periods is suggested to optimize energy efficiency interventions.

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