

Assessment of energy consumption and carbon footprint from the hotel sector within Lagos, Nigeria

P.O. Oluseyi, O.M. Babatunde*, O.A. Babatunde

Department of Electrical/Electronics Engineering, University of Lagos, Nigeria



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ABSTRACT

Nigeria has one of the lowest electricity consumption per capita in Africa and this is because the power grid capacity has not been able to meet the ever increasing demand for electricity. To remain in business, several business enterprises rely on captive generation of electricity; thus, the hospitality industry is not left out of this experience. Primarily, this study evaluates the energy consumption trend in the Nigerian hotel industry. The energy utilization is modeled in order to appraise its influence on the emission level of the diesel generators, which is the major source of electricity supply in Nigeria. The linear regression method is employed for the characterization of the energy utilization index. Also, correlation analysis is employed to investigate the interdependence of carbon footprint and normalized energy consumption. Results show a significant correlation between energy consumption per unit guest room and the carbon dioxide emission level. This work develops a carbon footprint protocol for the hotel industry in Nigeria by recommending that the annual energy consumption per unit guestroom should be kept at a value not more than 40.278 MW h/guestroom while the annual energy consumption per unit equivalent guest room should be less than 62.861 MW h/equivalent guestroom.

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1. Introduction

The critical role that energy plays in virtually all human activities is widely acknowledged. It constitutes a relatively modest share of Gross Domestic Product (GDP) in most countries [1]. Without a reliable and affordable source of energy, governments, institutions and individuals would find it difficult to realize their social and economic aspirations. Planners, especially those in the developed countries have long recognized the importance of energy as a veritable resource for improving human welfare and driving industrial growth [2]. According to Frey and LaBay, energy consumption in most homes could be reduced by 60% through the use of various conservation methods and investment in new energy efficient products [3]. This is also applicable in commercial buildings.

Energy cost is a vital component of a commercial building operation. With energy efficiency practices and technologies, energy cost can be significantly reduced in buildings without necessarily reducing the comfort of the building occupants. This is achieved by initiating energy assessment and audit of building, accompanied

by the implementation of cost effective energy efficiency measures [4].

Energy efficiency is described as the improvement in practices and products that allow more to be done with less energy. It reduces the energy necessary to provide energy services like lighting, cooling, heating, cooking etc., without compromising the quality of the services, thereby leading to the conservation of available energy resources. Energy efficiency measures are cheaper, cleaner and faster to install than any other energy option [5].

Energy efficiency measures have the prospect of promoting economic development and saving personal income. It is more so important in Nigeria where huge disparity exists between energy demand and supply, a situation that has forced Nigerians to seek for alternatives such as the use of captive generating sets as replacement to dependence on the utility grid for electricity supply. This alternative generation is often at a high cost.

Moreover, energy efficiency plays a pivotal role in the mitigation of climate change. A large part of the greenhouse gases (GHG) emitted into the atmosphere come from energy generation [6]. GHG emissions otherwise known as carbon footprint can be reduced by two processes, namely: implementation of energy efficiency measures [7] and/or production of power by renewable energy supply (RES) initiatives such as passive and active solar, wind, hydro-power, bio fuels, etc. [8].

* Corresponding author.

E-mail addresses: olubayobabatunde@gmail.com, olubayobabatunde2012@gmail.com (O.M. Babatunde).

Hotels are found in many countries to be among the most energy-demanding building categories [9,10]. Substantial amount of energy is consumed in providing comfort and services to guests, many of whom are familiar with, and ready to pay for exclusive amenities, treatment and entertainment [11]. The energy utilization and its attendant waste generation vary substantially among different types of hotels, and is affected by hotel size, class/category, the number of rooms, customer profile (guests visiting for business/on vacation), location (rural/remote or urban), climate zone, as well as by the types of services/activities and amenities provided to guests [12]. A hotel can be seen as an architectural combination of three separate zones, serving specifically different purposes namely: the guest room area (i.e., bedrooms, bathrooms/showers, toilets), the public area (these are reception halls, restaurants, lobby, bars, meeting rooms, swimming pool, sauna, etc. which are spaces with high thermal losses and high internal loads), and the service area (kitchens, offices, store rooms, laundry, staff facilities, machine rooms and other technical sections which are energy intensive areas requiring advanced heating, ventilation and air conditioning (HVAC)). The energy flows in these three areas are usually different in trend and intensity [12].

Since hotel buildings consume a bulk of energy, it is expedient for energy audit to be carried out in such buildings so as to make sure energy is utilized efficiently. There are several factors contributing to the quantum energy consumption rate in hotels, some of which include the design and the use of the building, the construction type, poor maintenance culture, prolonged use of inefficient (e.g., incandescent) lamps, continuous air conditioning, heating of large common spaces etc. Energy wastage could be reduced by incorporating energy efficient practices and technologies.

Hotel business is fast becoming a profitable and huge investment in Nigeria especially in a place like Lagos which is located in south-west Nigeria. This is primarily due to the presence of seaports and an international airport in this coastal megacity. Also, Lagos is a major center of commerce as well as hospitality.

It is noteworthy to state that the hotel industry in Nigeria started before the independence in 1960 in Lagos. Immediately after the independence, the hotel industry expanded due to the socio-economic development and industrial revolution in the country. In the mid-1970s, the oil boom in Nigeria made the country attractive to many tourists from all over the world, thereby increasing the patronage of the industry [13]. In a survey conducted in 1981, the tourism industry accounted for 0.3% of total exports and it is expected to grow up to 4.5% by the year 2020 [14]. Therefore tourism alongside with the need for hospitality has led to the growth of the hotel industry in Nigeria. This has necessitated the need for standard hotels especially in major commercial centers such as Lagos.

Lagos, a former capital of Nigeria, is a strategic location as an entry to the country through major sea ports and has benefited immensely from the boom of tourism and hospitality industries. There are global hotel brands in the city; they are concentrated on the mainland near the international airport and on the island, close to the sea ports.

2. Literature review

The evaluation of a building's energy performance is essential to ascertain the efficiency of energy use as well as the benchmarking of carbon dioxide (CO₂) emitted in such buildings. This process involves the determination of the most significant factors which influence energy consumption and the CO₂ emitted. Hotel building energy performance evaluation was carried out by formulating a normalized model of total energy consumption in

27 Hainan hotels [15]. The potential independent factors were organized into five categories namely: climate, age, construction, occupancy, and energy end-use factors. From the results obtained, electricity percentage, number of guestrooms and number of equivalent guestrooms were the major factors influencing the total energy efficiency of the hotels in the area under consideration. The energy use intensity in these hotels stood at 125.27 kW h/m²/year. Xina et al. reported the energy consumption quota of 19 hotels with detailed energy consumption information and 54 hotels with general energy consumption data [16]. By applying correlation analysis, energy consumption per unit area was identified as the most significant factor in representing energy consumption. The average energy use intensity was found to range from 69.23 to 96.75 kW h/m². Mak et al. carried out a survey of energy consumed by chillers in 11 hotels in Shanghai [17]. The study was able to develop a power consumption model for chillers as well as specify a practical method of reducing power consumption by the chillers. The parameters investigated include air-conditioned floor area, guest floor area, gross floor area, number of employees, room occupancy, food cover, outdoor air temperature, window velocity, service type and relative humidity. Regression analysis gave the number of staff and outdoor temperature as the significant and statistical bases for the elucidation of electricity consumption of chillers in the hotels. The mean annual electricity usage of chillers was found to be 15–33 kW h/m².

Xuchao et al. was able to establish a regression-based benchmarking model for energy consumption and greenhouse gas emission in Singapore's hotel industry [18]. They considered the difference in functional and operational features of the energy performance of hotels. It was discovered that a hotel's carbon intensity ranking is sensitive to the normalizing denominator chosen. The Energy Use Index (EUI) of 16 hotels in Hong Kong was presented by Deng and Burnett [19]. These energy use indices were observed to vary significantly from one hotel to another. The average EUI based on unit floor area stood at 564 kW h/m². Priyadarsini et al. presented a research on energy performance of Singapore's hotel buildings [20]. Energy consumption information and other significant data were gathered from 29 quality hotels through a national survey. The average annual EUI in these hotels was 427 kW h/m². Also, results revealed that three-star hotels differed from high class establishments in energy use.

Filimonau et al. [21] developed a Life Cycle Assessment (LCA) methodology intended to find application for environmental evaluation of hotel accommodation facilities, and their contribution to global carbon footprint. To validate LCA in the tourism sector, a fundamental derivative-Life Cycle Energy Analysis (LCEA) was applied to two 3-star hotels in Poole, Dorset (UK) to compute their carbon footprint. The average EUI for the hotels under consideration stood at 213 kW h/m²/year. Results show that the evaluated hotels consumed less energy with low carbon emission.

A technique of developing energy benchmarks for hotels in Greece based on operational energy use in terms of electricity and oil was presented by Farrou et al. [22]. This was targeted at categorization of such hotels. The scheme of categorization identified clusters of hotels utilizing the k-means algorithm controlled with the silhouette plot after the normalization of the operational energy data to correct for size, operation (seasonal or annual) as well as climatic conditions. Energy use varied significantly between and within clusters indicating its fuzzy nature rather than a distinct value benchmarks for this type of building.

Moreover, an assessment of energy efficiency was carried out in 32 five-star hotels in the Antalya Region of Turkey [23]. Data envelopment analysis was used in evaluating the energy usage performance in the 32 five-star hotel buildings. Results show that eight hotels were energy efficient while twenty-four hotels were inefficient. EUI for the hotels was 388.8 kW h/m²/year. Rossello-Batle

Table 1
Average EUI (kW h/m²/year) for hotels worldwide.

Location (year data was published)	Average EUI (kW h/m ² /year)	Source
Hong Kong (2000)	564	[19]
Cyprus (2001)	272.6	[26]
Greece (2001)	107.52	[26]
Italy (2001)	364.4	[26]
Portugal (2001)	269.5	[26]
New Zealand (2001)	158.6	[26]
Hong Kong (2001)	406	[27]
Hong Kong (2002)	564	[28]
Hong Kong (2002)	342.02	[29]
Hong Kong (2003)	542	[30]
Vietnam (2005)	115.75	[31]
Turkey (2006)	388.8	[23]
Europe (2007) {Hilton hotels}	364.3	[10]
{Scandic hotels}	285.0	
Singapore (2009, 2010)	427	[20,18]
Balearic Islands {Spain} (2010)	147.45	[24]
UK (2011)	213	[21]
Greece (2012)	182	[22]
Taiwan (2012)	211.925	[32]
Hainan Province {China} (2013)	131.81	[15]
South Korea (2014)	346.22	[33]
Taiwan (2014)	269	[34]

et al. [24] evaluated the energy uses, CO₂ emissions and waste materials generated over a life cycle of 50 years in the Balearic Islands (Spain) hotel sector. The stages in the building process were divided to construction phase, operation phase, reforms phase and demolition phase. Results indicate that the operating phase of the building which accounted for between 70% and 80% of the total energy use had the greatest effect and consequently, was the main cause of CO₂ emissions. Bohdanowicz and Martinac [10], in their study presented the resource utilization in 184 Hilton International and Scandic hotels in Europe. Using a multiple variable regression analysis, energy and water use in hotels, in the absence of climate data, was dependent on hotel standard, total hotel floor area, number of guest-nights sold as well as number of food covers sold. The outcome of the study proposed that optimising the performance of upscale hotels individually might be more reasonable than benchmarking an entire class of hotels as a group.

Becken et al. [25] explored the differences in energy consumption in the accommodation industry. Comparison was carried out between the hotel, bed and breakfast, motel, backpacker, and campground accommodation categories. The impact of business size as it relates to consumption was also considered. Benchmarks were proposed for each category for total annual energy use and energy intensities. The results show that hotels consumed bulk of the energy both in terms of total annual usage and use per visitor-night, making up 67% of the total energy use in New Zealand's accommodation sector. Table 1 shows the average EUI (kW h/m²) of hotels in some countries.

Indiscriminate energy consumption in buildings increases the level of GHG emissions, which is a major cause of global warming. To maintain stability between energy and sustainable environment, it is recommended that performance evaluation of such buildings be carried out and analyzed [35]. About 75.96 million metric tons of carbon dioxide was emitted by Nigeria in the year 2011, thus ranking 46th in world carbon dioxide emission list [36]. This is partly due to the inefficient use of energy in large energy-consuming buildings. Apart from this, many of such building use standalone fossil fuel powered generators.

Hotels are ranked among the high energy consuming buildings in the world [18,35]. By implication, they release more GHG to the atmosphere as compared to other building types. Research in this area has of recent been receiving attention. Xuchao et al. considered relevant issues related to energy and environment in Singapore's

hotel industry [18]. CO₂ emissions from the selected hotels were calculated with reference to the standard procedure for corporate GHG emission accounting. Results showed that the hotels' carbon intensity ranking was sensitive to the normalizing denominator chosen. In line with this, Tsai et al. [37] reported a survey carried on the CO₂ emissions from four types of hotels in Taiwan. Results revealed that the average CO₂ emissions of international tourist hotels, standard tourist hotels, general hotels, and homestay facilities were 28.9, 19.2, 12.5, and 6.3 kg-CO₂/person-night respectively. Furthermore, it was established that increasing stays at hotels with low CO₂ emissions, accommodating more guests together per room and efficient energy use, instead of reducing the total number of guests, could efficiently trim down hotel CO₂ emissions. Lai investigated the carbon footprints of three typical hotels in Hong Kong. Results of the analysis showed that the hotels' emissions had a strong positive correlation with outdoor air temperature rather than occupancy rate.

In a bid to reduce the negative impact of GHG emissions in 1997, the Kyoto protocol – a United Nations agenda on Climate Change – was adopted in a city called Kyoto, Japan. The aim was to reduce the level of GHG emissions worldwide through education and awareness. Nigeria, the most populous nation in Africa is yet to take adequate measures in determining as well as reducing the CO₂ emissions caused by energy usage in the sectors of the economy, hotel industry inclusive. Consequently, this research is designed to study the EUI of hotels in Lagos, Nigeria as well as analyze their carbon footprints. In order to achieve this, 28 hotels with star ratings ranging from 2- to 5-star, and with considerably high patronage were considered. In Nigeria, most hotels run on diesel generators because of the gross inadequate and unreliable power supply through the national grid. The use of these diesel generators results in immense environmental pollution. To introduce some innovative approaches to the paper, the amount of carbon dioxide emitted from the hotels was estimated and their correlation with the normalized energy consumption analyzed in order to benchmark the reasonable level of CO₂ emission in relation to the normalized energy consumption.

3. Methodology

Access to data on energy consumption in the hotel sector in Nigeria is limited, and in many cases non-existent. This is because there is no central databank where hotel energy consumptions are periodically documented. In several instances, hotel facility managers have not carried out energy audit of their facilities. As a result, most of the data used for this research were gathered from primary sources. These data were collected through several visits to the hotels. Most of the time, there was a round-the-clock observation and collection of the energy consumption pattern in these hotels.

Moreover, most hotels are not rated. In this research, the sampled hotels (seven in each star category) were carefully chosen. They were chosen based on their geographical locations as well as their energy utilization. They are located in the commercial and industrial centers of Lagos. These hotels experience a large turnout of tourists, investors and educationists. Most of the hotels are located close to the airport, on the island and in the tertiary institutions. This is thus indicative of most patronized star rated hotels in Lagos.

3.1. Description of data samples

A questionnaire was designed to collect the required data which included electricity consumption, total floor area, occupancy rate, number of guestrooms and the number of employees. Meanwhile,

there were difficulties in gathering data on gas consumption of some hotels due to lack of accurate records at the time of the audit. For the purpose of final analysis, the electricity consumption, alongside a factor representing the other sources of energy was used. Regression techniques were used to identify the determinants of the energy use intensities.

3.2. Correlation analysis between energy consumption and other variables

Although many variables may influence the total hotel energy use, the following variables were considered in the study viz:

- Floor area.
- Year of construction.
- Number of guestrooms.
- Number of equivalent guest rooms (guest-nights sold).
- Number of employees.

The correlation analysis basically identified the most significant factors which were used to normalize the energy consumption [16]. Correlation analysis is often used to investigate the relationship between two sets of variables based on the data obtained by observations or experiments [38]. Correlation coefficient is introduced to express the degree of correlation by numerical value. It is a measure of the strength of the linear relationship between two variables, which is usually expressed as r [39]. The range of correlation coefficient is $|r| \leq 1$; the closer $|r|$ is to 1, the stronger the correlation is. Generally, in the case of $r=0$, there's no correlation; while $|r| < 0.3$ means there is weak correlation; if $0.3 < |r| < 0.5$, it exhibits a low correlation; $0.5 < |r| < 0.8$, significant correlation; $0.8 < |r| < 1$, shows a high correlation; $|r| = 1$, perfect correlation [40]. With the knowledge of the correlation analysis results, an appropriate normalized EUI was obtained.

3.3. Evaluation of CO₂ emissions in the sampled hotels

CO₂ emission from a hotel can be calculated using Eq. (1).

$$\text{Annual CO}_2 \text{ emission} = \text{EU} \times \text{CEC} \quad (1)$$

where EU represents the amount of electricity used by the hotel in kilowatt hours (kW h) while CEC is the CO₂ emission coefficient of the electricity used.

Due to the poor supply of electricity from the national grid, virtually all hotels in Nigeria generate their own power through the use of diesel generators. These diesel generators run for almost 24 h per day. For the purpose of this study, diesel generator was used as the only source of electricity in the hotel sector. The metric ton of CO₂ generated by the various hotels was determined using Eq. (2).

$$\text{Metric tons of CO}_2 \text{ per year} = \text{AEC} \times \text{FC} \times \text{E} \times \text{CF} \quad (2)$$

where AEC represents the annual energy consumption (kWh), FC is the fuel consumption of the generator used (in g/kWh) which was gotten from the specification sheet of the generator [41], E is the CO₂ emission of diesel which is 22.37 lbs CO₂/gallon [42], CF is the conversion factor from lbs to metric tons [43].

3.4. Correlation analysis between CO₂ emission and normalized energy consumption

Correlation analysis was carried out between CO₂ emitted from the hotels and normalized energy consumption. This was analyzed in order to identify a value reflecting a reasonable level of CO₂ emission in relation to the normalized energy consumption. Statistical

Table 2
Summary statistics of the hotels.

Variables	Minimum	Maximum	Mean	Std. deviation
Total floor area (m ²)	1020.00	64464.00	20321.61	18892.75
Age (year)	1	72	15.25	19.66
Number of guest rooms	10	654	166.64	177.82
Occupancy rate (%)	40.00	100.00	72.61	15.57
Number of equivalent guest rooms ^a	10.00	412.75	115.81	115.65
Number of employees	8	1475	288.29	374.51

^a The number of equivalent guestrooms is the product of the number of guestrooms and occupancy rate.

methods such as mean, median, percentile and mode were used to ascertain the normalized energy consumption quota.

4. Results and discussions

4.1. Hotel characteristics

The sampled hotels were heterogeneous. Table 2 summarizes the general characteristics of the hotels. The hotels varied from a storey to 23-storey buildings. Depending on the star rating, the facilities in the hotels include guestrooms, suites, presidential suite, conference halls, restaurants, bars, gymnasium, spa, health/fitness center, swimming pool, lobby lounge, ballrooms and business centers. Hotels located on the island are constructed such that guests have the lovely view of the Atlantic Ocean.

4.2. Correlation analysis between energy consumption and other variables

To analyze the relationship between energy consumption in the hotels and the influencing variables, the details of the twenty eight 2-, 3-, 4- and 5-star sample hotels were collected. The detailed information is displayed in Table 3. On the basis of this, Table 4 exhibits the correlation between energy consumption and variables such as total floor area, age, number of guest rooms, occupancy rate, number of equivalent guest rooms and number of employees respectively. The result reflects that total floor area, number of guest rooms, number of equivalent guest rooms and number of employees have significant correlation with the energy consumption, while age and occupancy rate have weak correlation.

The value of R^2 in relation to the total floor area is 0.588 which is lower than findings from some studies where R^2 was 0.77 [25], 0.71 and 0.76 [10]. However, it agrees in little degree with some findings (0.48–0.76) [44]. The R^2 of 0.588 indicates that total floor area can explain 58.8% of the variation of energy use in the hotels. The R^2 of 0.575 in relation to the number of employees means that workers' density alone is able to explain 57.5% of the variation of energy consumption. Superficially, it means that more hotel employees increase the energy demand in hotels. A less obvious but more important reason is that the number of employees actually reflects the level of business activities in a hotel. The hotels with more patronage (not only hotel room guests) and providing more services usually need to consume more energy. At the meantime, they also need more workers to support the guest activities [20]. Additional parameters that can be considered to influence energy consumption include conference center capacities, space air-conditioning installations and other requirements of conference rooms, actual number of conference participants, type, dimensions and water volume flows at pool/spa facilities, size and water-intensity of landscaped lawns, number of daily guests using recreational and health facilities [10].

Due to the significant correlation between energy consumption and total floor area, number of guest rooms, number of equivalent guest rooms and number of employees; energy consumption was

Table 3

Detailed information of 28 two, three, four and five star luxury hotels.

Serial number	Annual energy consumption (MWh)	Star rating	Total floor area (m ²)	Age (year)	Number of guest rooms	Occupancy rate (%)	Number of equivalent guest rooms ^a	Number of employees
1	831.12	2	1822.99	15	20	80.00	16.00	36
2	3217.27	2	5346.02	36	74	50.00	37.00	150
3	2800.78	2	18032.00	16	70	80.00	56.00	100
4	5167.74	4	10197.07	2	65	40.00	26.00	130
5	4580.83	3	12200.08	6	74	85.00	62.90	130
6	8040.81	4	60000.00	5	92	100.00	92.00	160
7	22092.13	5	55196.00	6	64	75.00	48.00	300
8	26400.26	5	40907.04	37	654	56.53	369.71	1475
9	11038.90	5	33864.00	29	332	85.00	282.20	526
10	1709.07	4	8670.00	4	85	65.10	55.34	75
11	1196.99	4	3672.00	3	36	82.90	29.84	35
12	4613.99	5	23868.00	4	234	75.30	176.20	562
13	6940.70	5	35904.00	1	352	75.00	264.00	650
14	12520.86	5	64464.00	54	635	65.00	412.75	1345
15	8777.92	4	26928.00	3	264	90.00	237.60	310
16	828.15	3	4284.00	64	42	60.20	25.28	50
17	288.43	2	6324.00	11	62	70.00	43.40	85
18	558.25	2	20460.00	4	120	82.00	98.40	163
19	46.52	2	1020.00	11	10	100.00	10.00	8
20	3923.86	3	18212.00	3	199	75.00	149.25	87
21	9210.17	4	28392.00	72	277	70.00	193.90	362
22	107.00	2	2104.00	3	23	85.00	19.55	25
23	884.69	3	4500.00	15	44	80.00	35.20	79
24	1407.47	3	6405.00	4	70	40.10	28.07	120
25	4721.46	4	12567.00	5	142	50.00	71.00	105
26	9287.13	5	48042.00	5	471	60.30	284.01	764
27	847.87	3	4200.00	5	43	80.00	34.40	55
28	3723.97	3	11424.00	4	112	75.60	84.67	185

^a The number of equivalent guestrooms is the product of the number of guestrooms and occupancy rate.**Table 4**

Correlations between energy consumption and the variables.

		Total floor area	Age	Number of guest rooms	Occupancy rate	Number of equivalent guest rooms	Number of employees
Annual energy consumption	Pearson Correlation	0.767 [*]	0.261	0.694 [*]	−0.129	0.662 [*]	0.758 [*]
	Sig. (2-tailed)	0	0.18	0	0.513	0	0
	N	28	28	28	28	28	28
	R ²	0.588	0.068	0.482	0.017	0.438	0.575

^{*} Correlation is significant at the 0.01 level (2-tailed).**Table 5**

Statistical overview of the energy use indexes in the hotels investigated.

Statistics	Energy consumption per unit area (kW h/m ² /year)	Energy consumption per unit guestroom (MW h/room/year)	Energy consumption per unit equivalent guestroom (MW h/room/year)	Energy consumption per unit employee (MW h/employee/year)
Minimum	27.285	4.652	4.652	3.393
Maximum	645.372	345.190	460.253	73.640
Mean	265.949	41.281	60.054	22.980
Std. deviation	159.317	62.874	86.974	16.542

normalized by these variables. Thus, the energy use indexes are energy consumption per unit area, energy consumption per unit guestroom, energy consumption per unit equivalent guestroom and energy consumption per unit employee. Table 5 shows the statistical overview of the energy use indexes. Moreover, Fig. 1 shows the EUIs (kW h/m²/year) of hotels in Nigeria and other countries in ascending order. This reveals that the Energy consumption per unit area of hotels in Nigeria is below average when compared to the values obtained in other countries.

From Table 6, further analysis reveals that there is a significant correlation (at 0.05 level) between energy consumption per unit guestroom and the total floor area.

4.3. CO₂ emissions

Table 7 shows the annual metric tons of CO₂ emissions from the 28 sample hotels. In order to find the energy use indexes responsible for the CO₂ emissions, correlation analysis was carried out and the result is displayed in Table 8. Results show that the energy consumption per unit guestroom and energy consumption per unit equivalent guestroom have significant correlations with CO₂ emission.

Statistical options for benchmarking annual energy consumption per unit guestroom and annual energy consumption per unit equivalent guestroom are shown in Table 9. From Figs. 2 and 3, mean is a suitable benchmark for energy consumption per unit equivalent guestroom but it cannot be used for energy con-

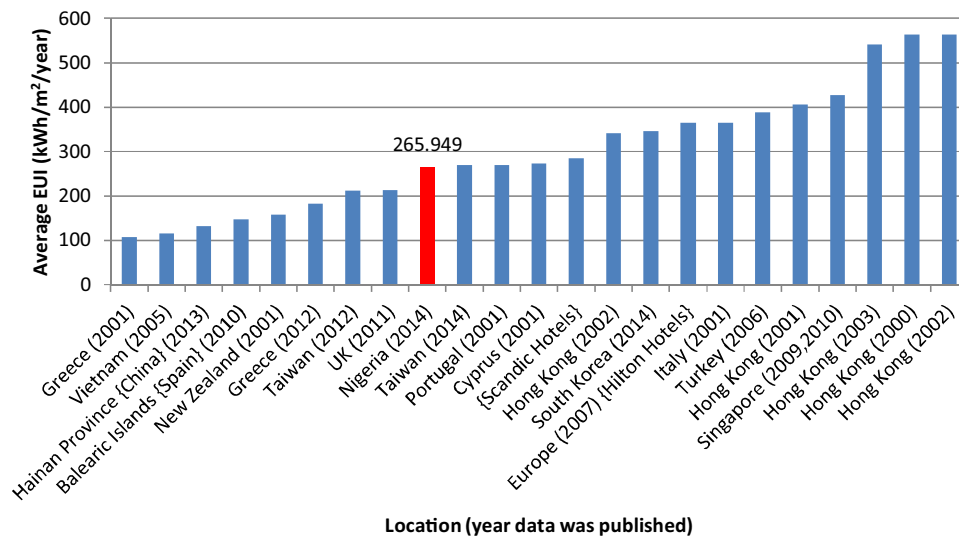


Fig. 1. Graph showing how the Energy Use Index (kWh/m²/year) of hotels in Nigeria compares to other countries.

Table 6

Correlations between the energy use indexes and the variables.

		Total floor area	Age	Number of guest rooms	Occupancy rate	Number of equivalent guestrooms	Number of employees
Energy consumption per unit area	Pearson correlation	−0.069	−0.039	0.046	0.04	−0.051	−0.016
	Sig. (2-tailed)	0.729	0.845	0.815	0.838	0.797	0.936
	N	28	28	28	28	28	28
Energy consumption per unit guestroom	Pearson correlation	0.418*	−0.094	0.122	0.007	−0.123	0.002
	Sig. (2-tailed)	0.027	0.635	0.536	0.973	0.532	0.994
	N	28	28	28	28	28	28
Energy consumption per unit equivalent guestroom	Pearson correlation	0.352	−0.084	0.117	−0.178	−0.143	0.01
	Sig. (2-tailed)	0.066	0.672	0.554	0.365	0.466	0.961
	N	28	28	28	28	28	28
Energy consumption per unit employee	Pearson correlation	0.296	−0.154	0.175	−0.001	−0.163	−0.178
	Sig. (2-tailed)	0.126	0.434	0.372	0.994	0.408	0.366
	N	28	28	28	28	28	28

* Correlation is significant at the 0.05 level (2-tailed).

Table 7

Metric tons of CO₂ emissions of the 28 sample hotels per year.

S/N	Metric tons of CO ₂ emissions per year	S/N	Metric tons of CO ₂ emissions per year	S/N	Metric tons of CO ₂ emissions per year	S/N	Metric tons of CO ₂ emissions per year
1	58189.19	8	55718702.48	15	17813574.30	22	257312.91
2	6496359.37	9	22401920.43	16	1781452.81	23	61939.78
3	5655376.57	10	3260221.86	17	8779.93	24	2684889.72
4	10592085.56	11	2514145.01	18	1161213.43	25	10060627.40
5	9389122.38	12	9831627.13	19	117063.32	26	18846945.55
6	17296774.22	13	14789450.00	20	8042560.35	27	59361.90
7	46626238.47	14	26425727.36	21	18690765.88	28	7632854.76

Table 8

Correlations between CO₂ emission and the energy use indexes.

		Energy consumption per unit area	Energy consumption per unit guestroom	Energy consumption per unit equivalent guestroom	Energy consumption per unit employee
CO ₂ emission	Pearson Correlation	0.09	0.561**	0.549**	0.394*
	Sig. (2-tailed)	0.65	0.002	0.002	0.038
	N	28	28	28	28

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

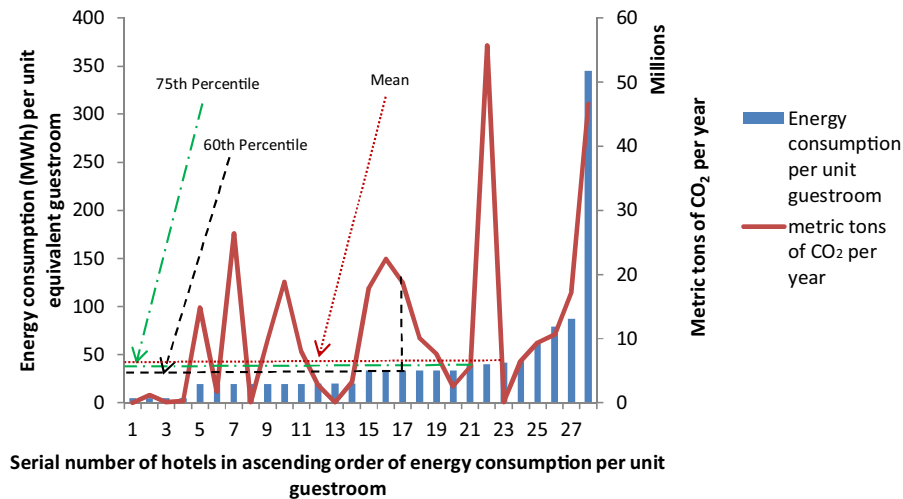
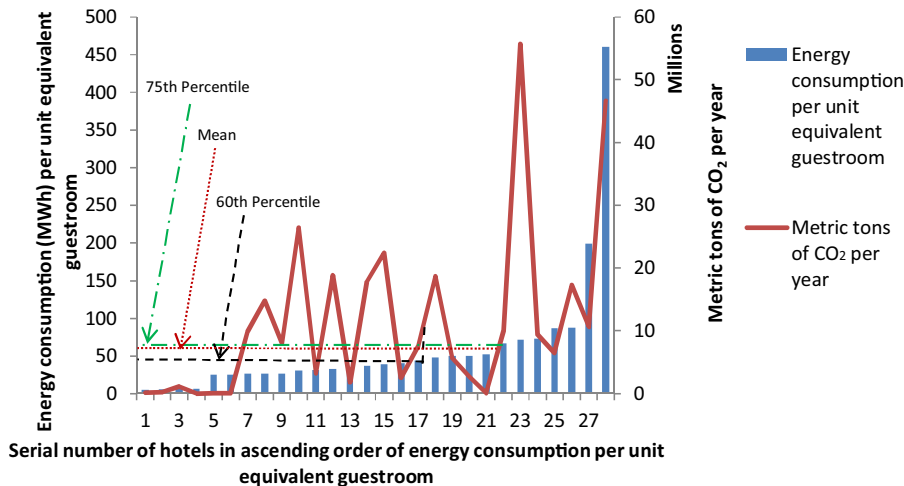
sumption per unit guestroom because of the high CO₂ emission associated with its value. 75th percentile, rather than 60th percentile, is a better benchmark for maximum normalized energy consumption because increase in energy consumption per unit gue-

stroom and energy consumption per unit equivalent guestroom after the 60th percentile still present opportunities for lower CO₂ emission. However, increase of normalized energy consumption after the 75th percentile will lead to extreme CO₂ emission.

Table 9

Options for benchmarking normalized energy consumption quota of the 28 sample hotels using statistical methods.

Statistical analysis	Energy consumption per unit guestroom (MW h/room/year)	Energy consumption per unit equivalent guestroom (MW h/room/year)
Mean	41.281	60.054
Median	26.678	38.031
Mode	4.652	4.652 ^a
60th percentile	33.250	45.388
75th percentile	40.278	62.861

^a Multiple modes exist. The smallest value is shown.**Fig. 2.** Energy consumption per unit guestroom and the corresponding CO₂ emissions.**Fig. 3.** Energy consumption per unit equivalent guestroom and the corresponding CO₂ emissions.

Therefore, annual energy consumption per unit guestroom should not exceed 40.278 MW h/guestroom while the annual energy consumption per unit equivalent guestroom should not exceed 62.861 MW h/equivalent guestroom in order to prevent excessive CO₂ emission into the atmosphere.

5. Conclusion

The activities of the hotel industry in Nigeria has shown a high emission of carbon-dioxide gas. This gas is the primary greenhouse gas contributing to recent climate change. Therefore, there is an urgent need to mitigate the carbon footprint in Nigeria's hotel industry and other commercial buildings. This work has suggested, through systematic approach, that CO₂ gas emissions from hotels

could be curtailed to bearable value through the collaboration of government and the hospitality industry (through legislation and investment respectively) in emission reduction projects, just as it is done in the case of gas flaring in the nation's oil fields.

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