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Research Article

Energy Consumption Pattern and Performance Indices of Federal Medical Center, Jalingo, Nigeria

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Abstract: Energy audit in buildings is an effective energy management tool that seeks to identify all the energy end-users within the buildings under investigation, estimate how much energy is used by each end-user, and determine the amount of energy used in relation to the budgeted or designed values which leads to significant energy and cost saving in addition to direct benefits such as extending equipment life, reducing maintenance costs, increasing comfort, safety and productivity, all leading to enhanced profit and improved efficiency. This study carried out a walk through energy audit for electricity energy consumption from two sources, electricity from the national grid and diesel generators at the Federal Medical Centre Jalingo, Taraba State Nigeria, and covers a period of 10 years (2008-2017). The hospital has a total floor area of 163,823 square meters with a total bed capacity of 425 beds. It is located between latitude 8.8932° N and longitude 11.3590° E. Jalingo climate is typically hot and cool with distinct wet and dry seasons. The mean annual temperature is about 27.9 ℃, mean monthly ranges of maximum temperature range between 25.9 ℃ in December/January and over 36.7 ℃ in the hottest months (April/May). A study of energy consumption, with special consideration on the operation of the air conditioning systems, lighting, electrical equipment and medical equipment was carried out. The consumption pattern showed distinct seasonal variation indicating peak electricity demand during the hot humid summer months from April to August resulting in significant air conditioning requirements. 52.21% of electricity consumed was contributed by the burning of automotive gas oil (AGO) in the diesel power generator showing a greater contribution over that of electricity from the national grid of 47.79% and this is the general trend in most buildings/facilities in Nigeria. 40.44% of electricity was consumed by air conditioners due to high or significant air conditioner requirements, office equipment with 23.49% consumption rate, while medical machine and equipment, and lighting with 28.83% and 7.24%, respectively. The building yearly energy performance index determined for the whole hospital, operating theatres, outpatient department, and inpatient department was 229.726 kWh/m^2/year, 412.349 kWh/m^2/year, 160.790 kWh/m^2/year, and 181.313 kWh/m^2/year respectively. If all the proposed Energy Conservation Measures (ECMs) were implemented, it would give a total of 20.58% energy saving of the annual energy consumption.

***Keywords*:** energy audit, consumption pattern, performance index, energy carriers, end users, hospital

1. Introduction

Hospitals are institutions for the care of the sick and injured and are usually occupied 24 hours per day, all year round. They usually consist of large buildings, and control of their internal temperature is necessary. A high level of

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heat is normally generated internally by sources such as people, medical equipment, computers and electronics, etc. In developing countries like Nigeria where the electricity supply is inadequate, hospitals require stand by generators to ensure a continuous supply of power and in case of emergencies. When considering energy-efficiency in hospitals, it is important to keep in mind that it is not the end user of energy alone, but also the need for efficient building design by incorporating sustainable building materials, optimizing the building orientation for natural ventilation and lighting and efficient insulation to control the indoor climate, which is one of the principal requirements. The indoor climate requirements are determined by the hospital activities in the building. Once these are established, it is necessary to provide the required climate, ideally in the most economical way.

The annual consumption of electricity has been increasing very rapidly over the last three decades. It increased from 1,273 MW in 1970 to 9,575 MW in 2012. This might be attributed to several factors which may include growth in population, technological advancements leading to increased usage of electronic devices, industrial expansion and economic development among others [1]. In a study conducted by the presidential advisory committee on a 15 year power development plan, the electricity demand projection for 10% annual growth of the Gross Domestic Products was given as about 16,000 MW, 30,000 MW and 192,000 MW for the years 2010, 2015 and 2030, respectively. The achievement of the above projected generation capacity will ensure that per capita electricity consumption would be about 5,026 kWh, which is as per the current consumption level in most industrializing countries [1]. The same study also suggested an electricity generation mix of nuclear (2%), hydro (7%), renewable (10%), Coal (11%) and natural gas (70%) in the long term.

In Nigeria, a lot of energy is wasted because households, public and private offices, as well as industries, use more energy than is actually necessary to fulfill their needs. One of the reasons is that they use outdated and inefficient equipment and production processes. Unwholesome practices also lead to energy wastage. In Nigeria the need for energy is exceeding its supply. In view of these circumstances, primary energy conservation, rationalization, and efficient use are immediate needs. Getting all the possible energy from the fuel into the working fluid is the goal of efficient equipment operations. This leads to higher productivity and saves not only money but also influences the safety and life of the equipment and reduces pollution [2]. Steps taken to minimize energy consumption, or to use it more effectively, are steps in the right direction to preserve the global environment.

The following literature review provides a brief overview of some research works and their findings in the field of energy audit. The review provides insight into the trends in energy audit practice and emphasizes the importance of implementing energy efficient measures to reduce operational costs.

Mohamad et al. [3] examined the electricity load apportioning for a hospital building in Selangor, Malaysia through a detailed energy audit. From the energy audit, several Energy Efficiency Initiatives (EEI) were identified in reducing the energy usage in the hospital: room temperature control, efficient lighting system, efficient unit for Air-Conditioning Split Unit (ACSU) and Variable Speed Drive (VSD) installation. The EEIs are expected to produce a total electricity saving of 1,250,692 kWh/year, equivalent to a cost saving of RM 421,706/year and a total emission reduction of 869 tonnes of CO_2 per year.

Rabiu [4] studied the effective energy utilization in Katsina state secretarial complex building, and presented the result that the annual electricity use per unit gross floor area is 85.8 kWh/m^2 with a mean of 37.38 kWh/m^2. The percentage consumption of the three end users, namely ventilation and air conditioning, electrical equipment and lighting were found to be 58.12%, 23.71% and 18.17%, respectively.

Abubakar [5] studied the amount of energy consumed in the Federal College of Education Katsina over a four-year period (2006-2009) and identified areas where energy is wasted and subsequently recommended energy saving measures. The result indicated that air conditioning has the highest rate of 41.2% followed by electrical equipment and lighting with a percentage consumption of 32.22% and 26.50% respectively. Also, the consumption of energy carriers was AGO 58.80% and National Grid 41.20% with yearly saving measures of 35% if implemented.

Mohammed et al. [6] carried out a study on strategies for reducing energy consumption in a student cafeteria of King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, indicated that the result found through various conservation measures with a combined design saving of 27.40% heating, ventilation and air-conditioning (HVAC) system saving 10.6%, implementation of standards saving about 16.7%, lighting 5.6%, equipment 2.6%, and insulation 2.5% and glazing 1.4%.

Tukur [7] carried out a study on the amount of energy consumed in General Hospital Katsina over a period of four years (2009-2012), presented a result that air conditioning has the highest rate of consumption of 38.50%, followed by lightning, then electrical equipment with a percentage of 32.22% and 29.25% respectively. Also, the energy consumption from energy carriers AGO is with the highest percentage of 65% while the National grid has 35% with proposed annual saving measures of 35% if implemented.

Umar et al. [8] carried out research that the amount of energy consumed in Gumel General Hospital, in which the monthly electricity data was gathered and analyzed. Results showed an average electricity consumption of 1,445,448 kWh with an average energy use index of 216.97 kWh/patient/year was obtained. Analysis was performed on the data to identify Energy Conservation Measures (ECMs), which resulted in 37% savings in annual energy consumption.

Nwanya et al. [9] in their studies presented results of energy performance indices for hospital buildings in Nigeria. Results of the analysis show that an average hospital in Nigeria, depending on its category, uses energy as follows: rural 66.93 kwh/day, urban 343.23 kWh/day, specialist hospital 459.872 kWh/day and teaching hospital 1,944.394 kWh/day. Lighting is shown as a critical energy function and accounts for as much as 15%, 36%, 40.5% and 69.5% of daily energy use in rural, urban, Specialist and Teaching Hospitals, respectively. A productivity based energy performance indicator for each hospital category was out to be 3.346 kWh/bed space/day, 2.367 kWh/bed space/day, 4.548 kWh/bed space/day and 19.443 kWh/bed space/day, respectively for typical rural, urban, specialist and teaching hospitals. The respective building index values for the categories of the hospital are as follows: rural 0.13 kWh/m^2/day, urban 0.077 kWh/m^2/day, specialist 0.088 kWh/m^2/day and teaching 0.277 kWh/m^2/day respectively.

Modu et al. [10] in their studies "Energy auditing and management A case study of students hostel, A.B.U Zaria, Nigeria". The presented result of retrofitting which accounted that lighting energy consumption per year before retrofitting was 58% equivalent to 47,888 kWh/yr was reduced to (40%) 19,165 kWh/yr after retrofitting, which resulted in energy saving of 28,722.6 kWh/yr. If implemented properly with an efficient energy saving which will reduce their utility saving by 60%.

UMAR A. [11] in his studies, electrical consumption pattern of Murtala Mohammed Specialist Hospital Kano, from 2012 to 2015, indicated that the energy consumption pattern of the energy carriers showed distinct seasonal variations, indicating peak electricity demand during the hot, humid summer months from April to August resulting in high cooling or significant air conditioning requirement. The overall percentage contribution of the energy carriers was 32.09% and 67.91% from National Grid and AGO respectively of the years under study. The annual energy demand by end-users indicated that air conditioners have the highest percentage consumption of 47.03% followed by office equipment medical machines equipment and lighting with 19.91%, 18.28% and 14.78% respectively. The energy performance index in terms of building energy intensity (BEI) use and energy use index (EUI) for the whole hospital 58.11 kwh/m^2/yr is 23.64% higher than the building code standard value of 47 kWh/m^2/yr for hospital. If all the proposed energy conservation measures were implemented it will give a total of 19.58% savings of the annual energy consumption.

1.1 *Need for this study*

Federal medical center, in Jalingo metropolis, the capital of Taraba state in Nigeria located between latitude 8.8932° N and longitude 11.3590° E. The hospital has a total floor area of 163,823 square meters with a total bed capacity of 425 beds. The city experiences a tropical savanna climate characterized by distinct wet and dry seasons. The mean annual temperature is about 27.9 ℃, mean monthly temperature ranges between 25.9 ℃ in December/January and over 36.7 ℃ in the hottest months (April/May). The wet season starts properly in May and ends in October. November to February is the dry cool season with harmatan haze. Between October to February sunrise is at a few minutes after six in the morning and sunset is a few minutes after six in the evening.

The aim of this work is to conduct an energy audit of the Federal Medical Center, Jalingo from its record of fuel expenditure and its electricity bills for a period of 10 years (2008-2017). The research covers a period of 10 years (2008-2017) and a study of energy consumption, with special consideration on the operation of Air Conditioning systems, lighting, electrical equipment and medical equipment.

2. Methods

Methodology adopted in carrying out this study includes the following:

a. Review of past literature relevant to the current study.

b. Data collection:

i. Monthly consumption figures of the two energy carriers (national grid and diesel generators) for the period of ten years (2008-2017) for the hospital.

ii. Ten years maximum and minimum daily temperatures for Jalingo.

iii. Information on the services installation for the hospital was obtained through a walk-through audit.

c. Data analysis:

i. Monthly consumption average of the two energy carriers (national grid and diesel generators).

ii. Cooling degree day figures.

iii. Consumption pattern of energy end users.

iv. Energy used index.

2.1 *Data collection*

The data collected which covered a period of 10 years (2008 to 2017) was extracted from Power Holding Company of Nigeria (PHCN)/Yola Electricity Distribution Company (YEDC) files of the hospital's registry and maintenance service departments. Tables 1, 2 and 3 present monthly electricity consumption from the National Grid (kWh), monthly diesel consumption in equivalent (kWh) and the estimation of daily energy consumption per equipment for the hospital respectively.

Table 1. Monthly electricity consumption from the national grid (kWh)

Month	Consumption (kwh)									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	10,500	40,082	9,000	9,082	38,700	41,460	56,744	47,560	53,300	38,870
February	40,256	55,740	15,256	57,741	78,139	43,100	51,230	36,062	55,120	58,130
March	42,680	56,320	20,689	55,345	70,487	43,110	61,820	42,250	60,230	71,487
April	75,464	47,111	75,564	41,111	69,253	35,622	75,770	67,842	72,680	75,250
May	80,985	48,260	60,987	47,269	70,897	46,644	61,820	71,550	70,420	79,890
June	103,240	65,921	81,340	65,978	95,325	47,840	57,035	77,100	119,140	90,325
July	103,305	80,100	85,304	84,900	99,600	42,200	47,426	83,248	71,000	95,600
August	80,750	87,560	80,750	88,564	99,854	42,520	61,085	75,000	82,800	91,100
September	87,965	73,489	77,968	80,489	100,500	56,652	42,620	71,710	82,730	96,400
October	75,630	74,965	75,635	89,965	89,700	61,970	55,330	57,910	77,880	65,900
November	49,600	81,539	49,600	92,539	82,900	58,830	65,300	88,528	74,800	49,700
December	40,000	81,539	42,000	80,231	83,598	52,050	61,680	69,570	75,000	68,782
Total	790,375	792,626	674,093	793,214	978,953	571,998	697,860	788,330	895,100	881,434

Source: Maintenance service department of the hospital

Table 2. Monthly diesel consumption in equivalent (kWh)

Month	Diesel Consumption (kWh)									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
January	49,526	50,384	39,020.8	28,836.8	34,411.2	49,987.72	47,704	69,466	60,032	35,376
February	56,065	63,462.4	45,238.4	52,635.2	45,024	77,409.12	68,608	54,565	52,528	42,344
March	61,425	65,928	82,758.4	86,188.8	58,852.8	107,543	100,779	77,134	95,408	68,608
April	74,504	78,792	95,836.8	10,710.5	61,532.8	163,566	108,808	60,032	95,622	104,520
May	75,254.4	86,832	64,427.2	80,292.8	63,355.2	109,880	106,986	86,832	117,384	116,848
June	81,150.4	92,192	70,323.2	56,387.2	64,748.8	77,441.28	106,128	75,040	58,017	86,832
July	86,853.44	99,374.4	85,674	89,190.4	61,318.4	48,486.56	117,706	74,932	101,840	104,198
August	98,677.6	99,696	96,426.4	77,827.2	93,692.8	114,918.4	122,744	100,875	98,946	114,704
September	89,565.6	76,112	67,964.8	55,958.4	48,132.8	63,655.36	90,691	69,680	77,891	104,949
October	63,569.6	66,464	52,742.4	67,107.2	96,158.4	67,000	79,328	54,452	71,824	74,933
November	52,849.6	55,208	52,172.8	53,278.4	84,795.2	45,560	70,752	43,137	57,888	64,106
December	35,054.4	73,968	34,947.2	42,451.2	42,890.2	23,048	63,248	61,211	36,984	45,024
Total	824,495	908,413	787,532	700,864	754,913	818,475	1,083,482	827,356	924,364	962,442

Table 3. Estimation of daily energy consumption per equipment for the hospital

S/N	Equipment Function	Quantity of Equipment (Q)	Power Rating/watts (P)	Operating hours/day (t)	F = Q × P × t/1,000 (kWh/day)
1	Incandescent bulb	454	67	15	456.27
2	Compact fluorescent lamp	1,010	50	13.5	656.5
3	Fluorescent tube	1	43	8	0.344
4	AC (1 hp)	84	746	24	1,450.232
5	AC (2 hp)	27	1,492	24	966.816
6	AC (2 hp)	2	1,492	12	35.808
7	AC (2 hp)	201	1,492	8	2,399.136
8	Stabilizer 5,000 W	11	5,000	12	660
9	Stabilizer 3,000 W	1	3,000	8	24
10	Stabilizer 2,000 W	9	2,000	24	432
11	Stabilizer 2,000 W	9	2,000	8	144
12	Stabilizer 1,000 W	33	1,000	15	495
13	Ceiling fan	401	85	8	272.68
14	Ceiling fan	196	85	24	399.84
15	Standing fan	14	65	24	21.84
16	Standing fan	20	65	8	10.4
17	Industrial fan	6	100	8	4.8
18	Extractor fan	2	150	8	2.4
19	Photocopy machine	8	1,200	3	28.8
20	Computer scanner	1	280	4	1.12
21	Fax machine	1	1,100	2	2.2
22	Computer pointer	68	300	4	81.6
23	Laptop computer	8	65	6	3.12
24	Desk top computer	68	50	8	27.2
25	Table top computer	1	250	8	2

Table 3. (cont.)

S/N	Equipment Function	Quantity of Equipment (Q)	Power Rating/watts (P)	Operating hours/day (t)	F = Q × P × t/1,000 (kWh/day)
26	H170 refrigeration	7	900	24	151.2
27	Satellites decoder	33	75	8	19.8
28	CCTV	1	60	8	0.48
29	TV	13	79	8	8.216
30	TV	30	120	8	28.8
31	Photocopy machine	1	660	3	1.98
32	Bore hole booster	1	746	6	4.476
33	Receipt printer	23	144	8	26.496
34	Blood bank fridge	4	2,000	24	192
35	Deep freezer	1	1,500	24	36
36	Water bath	2	1,000	8	16
37	Centrifuge	8	100	8	6.4
38	Steam sterilizer	1	3,000	6	18
39	Bucket autoclave	1	2,000	3	6
40	Microscope	11	100	5	5.5
41	Rotary shaker	1	50	1	0.05
42	Ultra sound scanner	7	150	5	5.25
43	Thermal printer	2	5.25	6	0.063
44	Trolley ultra sound	1	320	5	1.6
45	Medical oxygen plant	1	415	6	2.49
46	Electric oven	8	3,500	6	168
47	Incubator	6	1,000	24	144
48	Selectra	2	200	3	1.2
49	Electrolyte analyzer	2	165	4	1.32
50	Water distiller	1	1,000	8	8
51	Spectrophotometer	5	50	6	1.5
52	Auto hematology analyzer	3	400	6	7.2
53	Flame photo meter	1	225	4	0.9
54	Automated difference cell	1	220	3	0.66
55	Electro photolysis machine	1	720	6	4.32
56	Humalyzer primus	1	800	8	6.4
57	Cy flow counter	2	35	0.5	0.035
58	Gene pert	1	220	2	0.44
59	Suction machine	50	450	24	540
60	Electric delivery bed	4	230	4	3.68
61	Sphygmomanometer	53	5	3	0.795
62	Infant warmer	7	1,500	24	252
63	Baby incubator	5	1,500	24	180
64	Oxygen concentrator	4	450	6	10.8
65	Phototherapy lamp	2	120	24	5.76
66	Vacuum extractor	1	150	3	0.45
67	Angle pose lamp	17	200	8	27.2
68	ECG machine	5	35	4	0.7
69	X ray viewer	7	20	3	0.42
70	Dental x ray machine	2	2,000	6	24
71	Trimming machine	2	800	3	4.8
72	Polishing machine	1	50	3	0.15
73	Model trimmer	1	800	4	3.2
74	Compressor	2	790	3	4.74
75	Dental chair	2	200	8	3.2
76	Autoclave machine	14	2,000	4	112
77	Vibrating machine	1	50	2	0.1

Table 3. (cont.)

S/N	Equipment Function	Quantity of Equipment (Q)	Power Rating/watts (P)	Operating hours/day (t)	F = Q × P × t /1,000 (kWh/day)
78	Dental circuit	1	235	6	1.41
79	Curing bath	1	110	6	0.66
80	Slit lamp	3	80	4	0.96
81	Vectra refractor	1	100	5	0.5
82	Operating microscope	2	600	6	7.2
83	Direct optical microscope	1	100	3	0.3
84	Tonometer	1	10	6	0.06
85	Flame hectare	1	2,000	6	12
86	Grooving machine	1	380	4	1.52
87	Eagling machine	1	150	3	0.45
88	Hot ear oven	1	200	4	0.8
89	Refractometer	1	100	6	0.6
90	Jensometer	1	800	4	3.2
91	Lensometer	2	15	2	0.06
92	Micro drive	1	1.5	4	0.006
93	Lens maker	1	40	6	0.24
94	12 body freezer	2	2,238	24	107.424
95	Nebulizer	2	192	3	1.152
96	Maxxagling machine	1	4,000	3	12
97	Infra-red radiator	2	230	4	1.84
98	Treadmill machine	2	220	6	2.64
99	Treadmill	2	120.5	4	0.964
100	Tens	1	5	3	0.015
101	IRR standing	2	24	2	0.096
102	Industrial steam sterilizer	1	4,500	6	27
103	Operating lamp	3	450	8	10.8
104	Anesthetic machine	3	150	8	3.6
105	Patient monitor	2	90	6	1.08
106	Hot air oven	1	225	4	0.9
107	Resustaire	1	220	6	1.32
108	Diagnostic set	5	3.5	3	0.0525
109	Static x ray machine	4	50,000	6	1,200
110	Mobile x ray machine	4	21,000	3	252
111	Chest x ray machine	2	4,800	3	28.8
112	Dryer	1	360	3	1.08
113	Auto firm processor	1	300	8	2.4
-	total	-	-	-	12,087.20

Where F in the table is the energy demand per equipment per day

Table 4. Average annual statistic of total number of patients, (inpatients, outpatients and surgical patients)

S/N	Department/Section	Annual average number of patients
1	Surgical patients	26,110
2	Inpatient	120,000
3	Outpatient	720,000
4	Total patients	866,110

Sources: Record office of the hospital

Table 5. Floor area (m^2) of the hospital facilities

Hospital section/facility	Floor area (m^2)
Operating theaters	882.22
Outpatient department	461.55
Inpatient department	3,692.61
Theater	882.22
Hospital floor area	19,204.78

Source: Generated at the maintenance department of the hospital

Table 6. Monthly summary of generator working hours and AGO consumed

S/no	Month	Average working hour (hrs)	Average AGO consumed	Average power delivered (kWh)
1	January	69.40	4,335.3	46,474.42
2	February	83.31	5,224.1	5,578.95
3	Match	120.15	7,505.8	80,462.18
4	April	127.51	7,965.7	85,392.30
5	May	135.60	8,471	90,809.12
6	June	114.72	7,166.6	76,825.95
7	July	129.85	8,111.7	86,957.42
8	August	152.09	9,501	101,850.72
9	September	111.10	6,940.3	74,400.02
10	October	103.57	6,469.9	69,357.33
11	November	86.56	5,407.7	57,970.54
12	December	68.51	4,280.1	45,882.67

Table 7. Average monthly Cooling Day Degree (CDD) for the years under study

Month	2008 CDD	2009 CDD	2010 CDD	2011 CDD	2012 CDD	2013 CDD	2014 CDD	2015 CDD	1016 CDD	2017 CDD	Average CDD
January	9.40	7.53	8.90	7.28	11.05	9.750	8.98	7.15	7.15	7.15	8.43
February	13.25	8.55	8.55	8.60	7.65	10.40	8.75	7.93	8.03	7.93	8.96
March	14.75	10.70	11.00	9.20	11.60	13.25	10.30	12.60	9.20	12.60	11.52
April	15.50	15.00	13.90	14.90	11.75	16.25	14.05	14.00	14.75	13.60	14.37
May	11.85	10.55	13.50	9.85	10.70	12.10	13.50	14.20	9.90	14.20	12.035
June	10.50	10.45	12.15	10.35	10.50	10.50	11.80	11.35	9.60	11.40	10.86
July	8.83	8.95	10.25	8.50	10.05	9.75	9.55	8.85	8.55	8.90	9.22
August	12.25	7.60	8.95	7.20	9.65	8.25	8.90	7.35	7.55	7.50	8.52
September	9.25	9.60	9.50	9.60	9.30	8.50	9.55	8.65	9.05	8.95	9.20
October	9.25	11.20	8.30	10.85	10.00	8.75	8.45	7.80	11.20	7.80	9.36
November	9.25	8.28	8.50	8.65	9.50	8.40	9.28	9.65	8.53	9.95	9.00
December	8.00	7.38	8.35	7.55	8.28	6.60	8.50	8.45	7.55	8.25	7.89

Tables 4, 5, 6 and 7 presents the Average Annual Statistic of total number of patients, Floor Area of the hospital facilities in m^2, Monthly Summary of Generator Working Hours and AGO Consumed, and the Average monthly Cooling Day Degree (CDD) for the years under study respectively.

2.2 *Data analysis*

From the data collected, the following procedural steps were used in the analysis and presented in the required forms:

• Energy types and cost (electricity and fuel) and end-users (lighting, office equipment, air-conditioners, medical equipment) were identified and collated.

• The energy consumption (kWh) per year for each type of end user was determined.

• The percentage breakdown of total energy consumption was calculated.

• The energy performance indices (EUI and BEI) (kWh/bed space and kWh/m^2) per year was determined to establish energy utilization pattern and performance.

• kWh and cost were computed for the energy carriers.

• Specific changes called Energy Conservation Measures (ECMs) are identified and evaluated to determine their benefits and their cost effectiveness. These ECMs are assessed in terms of their costs and benefits, and an economic comparison is made to rank the various ECMs. Finally, an Energy Action Plan is created where certain ECM's are selected for implementation, and the actual process of saving energy and money begins.

• Tables and figures were prepared to show the results of each of the analyses.

3. Results

3.1 *Consumptions pattern of energy carriers*

Figures 1 to 5 present the monthly electricity (kWh) consumption pattern and annual electricity consumption pattern, (from combined source, national gridel and AGO), and for Grid-electricity and AGO respectively.

Figure 1 presents electricity consumed from both energy sources under consideration, i.e. electricity from the national grid and generator. This is a sum of the energy supplied by the two sources monthly for the years under consideration. The 11th bar in the figure shows the average monthly consumption for the 10 years. It can be observed from the figure that energy is consumed most in the month of August and least in the month of January when the average monthly consumption for the years under study is considered.

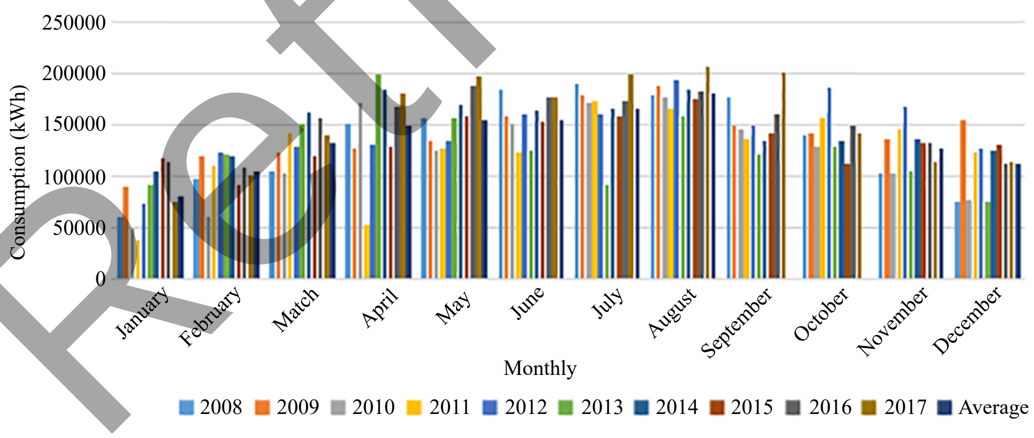

Figure 1. Monthly electricity energy consumption pattern (from combined source, national grid and AGO) (2008-2017)

The monthly electricity consumption from the national grid is presented in Figure 2. This figure shows the amount of energy consumed by the national grid every month for the years under consideration. The figure shows that the monthly highest energy consumed in all the years is that of the month of June 2016, this was due to relatively stable supply by the electricity distribution company which minimizes the use of AGO for electricity generation.

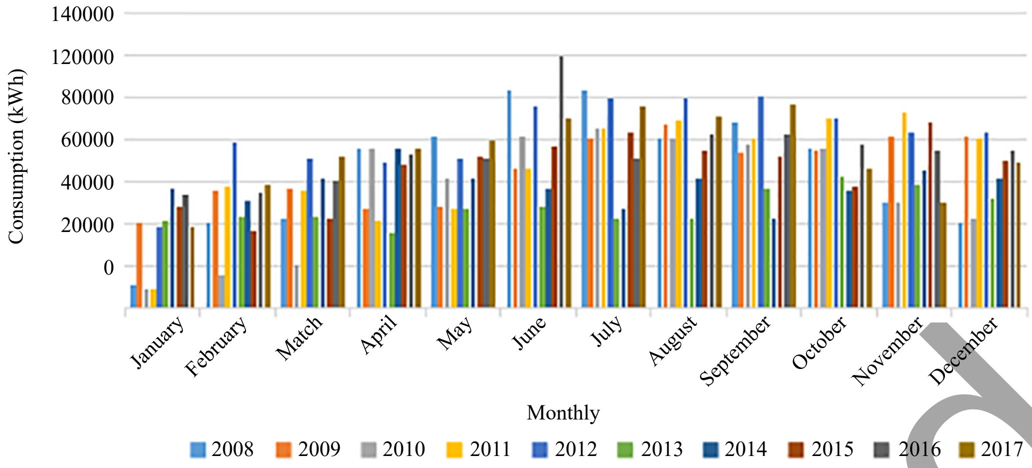

Figure 2. Monthly electricity energy (from national grid) consumption pattern (2008-2017)

The AGO contribution to the overall monthly energy consumption for the years under study is presented in Figure 3, the highest AGO contribution was in the month of April 2013 and can be attributed to low supply from the distribution company coupled with the high energy demand due to prevailing activities in the hospital.

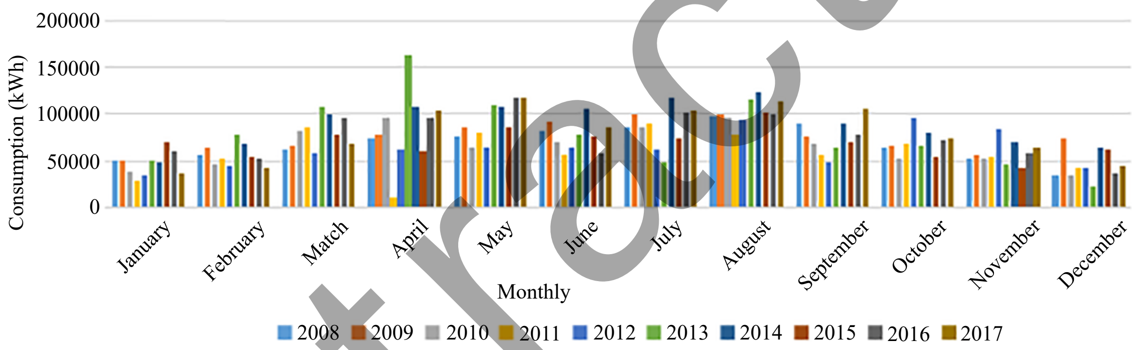

Figure 3. Monthly AGO consumption pattern (2008-2017)

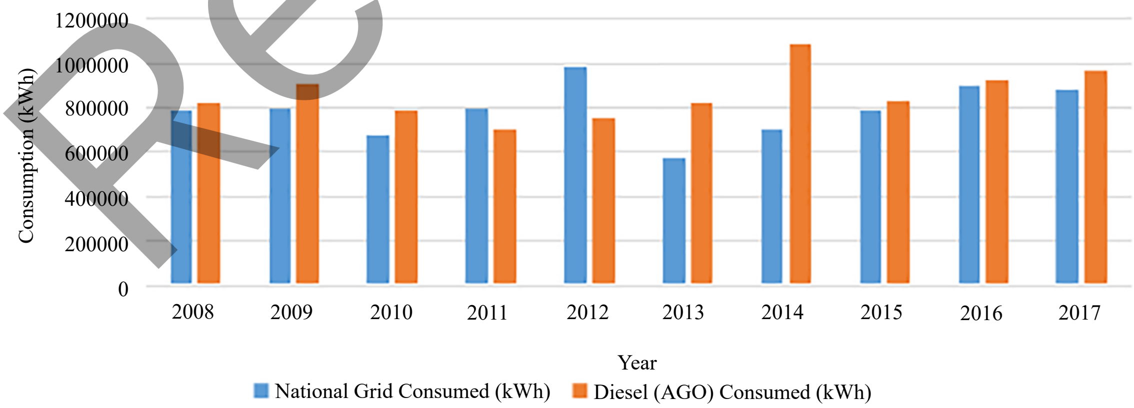

Figure 4. Energy consumed by energy carriers (national grid and AGO)

The annual contributions to the energy supplied by each of the two sources are shown in Figure 4. The use of AGO in the facility is necessitated by the inability of the national grid to meet the timely energy needs of the hospital and in some cases the supply and demand are out of phase. This coupled with other factors such as low voltage electricity supply, and incomplete phases for multiphase machines among other issues makes reliance on AGO inevitable. It can be observed from the figure that AGO contributed more in all the years under study except for the year 2011.

The total annual electrical energy consumption from the combined sources is presented in Figure 5(a), the highest consumption was experienced in the year 2017 while the least in the year 2013. A significant decrease in energy consumption was observed in the years 2010, 2011 and 2013 which might be due disruption of activities in the hospital resulting from industrial disharmony between the federal government and some relevant unions such as the Nigerian Medical Association (NMA), and the National Association of Resident Doctors (NARD). For the years remaining years, energy consumption was observed to increase annually.

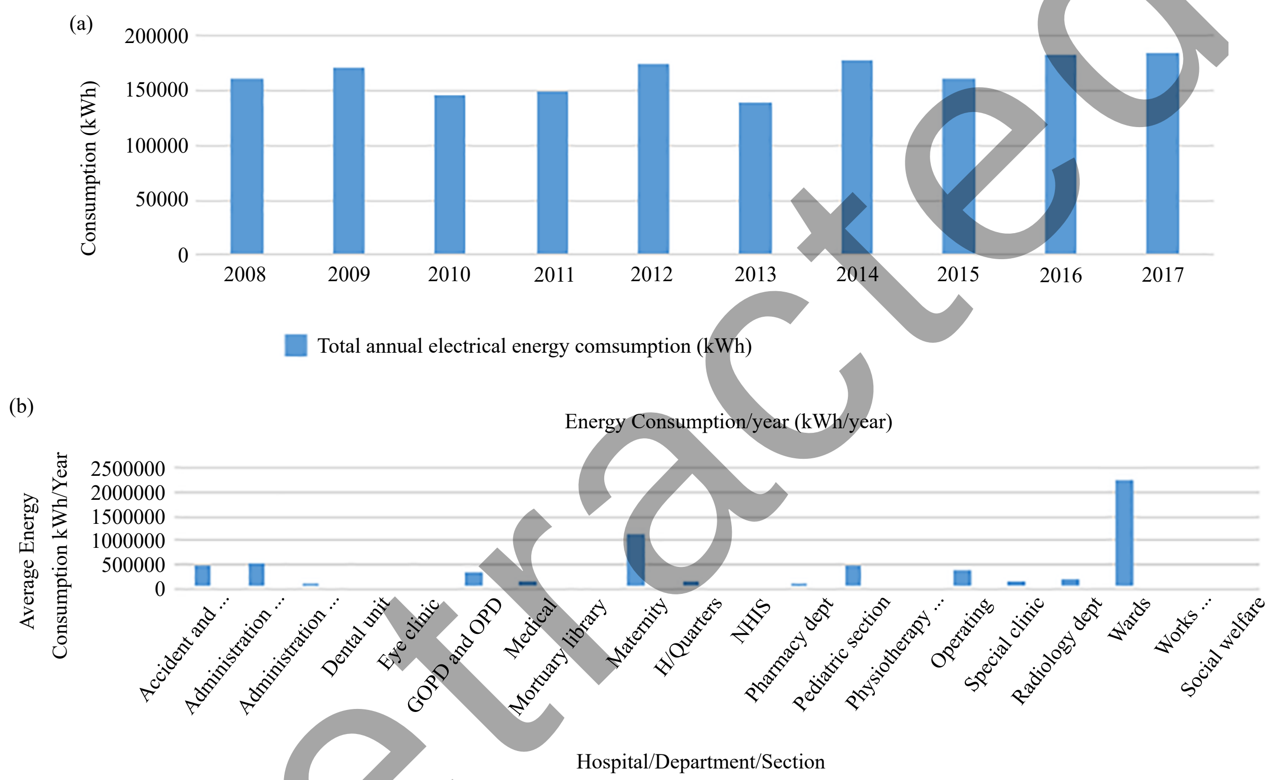

Figure 5. (a) Total annual electrical energy consumption (national grid and AGO); (b) Energy consumed by hospital department/section (2008-2017)

The hospital building is composed of several sections or departments each with a unique activity that takes place. The energy consumed by each unit or section depends largely on the nature of activities, the kind of equipment being used and the working hours. Medical wards record the highest energy consumption as depicted in Figure 5(b) followed by maternity unit, this is because these units are operated 24 hours daily.

3.1.1 *Percentage contribution of energy carriers*

The overall percentage contribution of energy carriers for the period of (2008-2017) for each source is presented in Table 8.

Table 8. Percentage contribution of energy carriers

Percentage consumption by national grid (%) (2008-2017)	Percentage consumption by AGO (%) (2008-2018)	Overall percentage electricity consumption (2008-2017)
47.79	52.21	100

3.2 *Consumptions pattern of energy end users*

Figure 6 presents daily and annual energy consumed by end users and the percentage contribution of each end user.

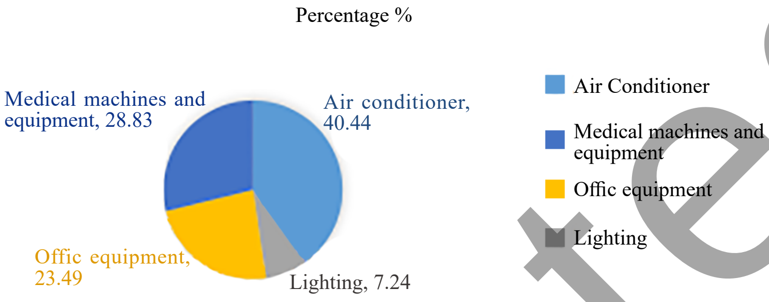

Figure 6. Energy consumption pattern of end-user (2008-2017)

3.3 *Evaluation of energy performance indices*

Tables 9 and 10 present the annual energy demand of the hospital's buildings operating theatres, outpatient department, and inpatient department in terms of building energy use index and productivity based energy use index.

Table 9. Energy consumed and BEI

S/N	Facility	Floor area (m^2)	Energy consumed per day (kWh/day)	BEI (kWh/m^2/day)	BEI (kWh/m^2/year)
1	Whole hospital	19,204.78	12,087.20	0.629	229.726
2	Operating theater	887.22	1,002.312	1.130	412.349
3	Outpatient department	461.55	203.322	0.441	160.790
4	In patient department	3,692.61	1,834.292	0.497	181.313

Table 10. Energy consumed and EUI

S/N	Facility	Number of patient/bed	Energy consumed per day (kWh/day)	EUI (kWh/patient or bed space/year)
1	Whole hospital	866,110	12,087.20	5.0938
2	Operating theater	26,110	1,002.312	14.016
3	Outpatient department	720,000	203.322	0.103
4	Inpatient department	120,000	1,834.292	5.579

3.4 *Evaluation of energy conservation measures*

Table 11 presents the energy saved, cost of saving and the payback period in terms of major investment/retrofitting and schedule of lighting and equipment.

Table 11. Cost of energy savings and payback period for retrofits

Retrofit	Energy saved (kWh)	Cost of saving (N)	Payback period (years)
Lighting	287,074.48	6,674,481.66	1.1270
Air conditioners	620,821.20	14,434,092.90	1.5178

4. Discussion of results

4.1 *Energy carriers*

The consumption pattern showed distinct seasonal variation, indicating peak electricity demand during the hot, humid summer months from April to August resulting in significant air-conditioning requirements. Monthly electrical consumption data were gathered and analyzed and the result is presented in Table 12. The average annual consumption and demand of electricity of the hospital are 1,645,631.9 kWh and 4,411,828 kWh respectively. And overall percentage contribution of the energy carriers was 47.79% and 52.21% from the National Grid and AGO generator respectively, showing that the hospital depended more on the energy from the diesel which is similar to [7]. This trend is seen in most hospitals in Nigeria.

Table 12. Present the result of average monthly electrical energy consumption cost (2008-2017)

Months	Consumption (kWh)	Cost (N)	BEI (kWh/m^2)	EUI (kWh/bed) space
January	80,735.36	1,866,531.18	0.7958	2.7616
February	174,160.32	2,355,428.000	1.7168	5.9573
March	279,294.23	3,051,393.10	2.7531	9.5534
April	338,557.76	2,650,793.70	3.3374	11.5806
May	252,284.00	3,545,273.67	2.4869	8.6295
June	231,729.12	3,519,015.94	2.2843	7.9264
July	165,006.56	3,610,453.83	1.6266	5.6441
August	2,095,006.56	3,346,979.20	2.0661	7.1694
September	119,587.36	3,238,645.25	1.1755	4.0906
October	128,252.00	3,522,116.69	1.2643	4.3869
November	118,668.00	3,218,196.06	1.1698	4.0591
December	85,168.32	2,701,437.08	0.8396	2.9132
Total	2,183,041.43	36,626,264.71	21.5162	74.6721

4.2 *Energy end users*

Figure 6 presents the result of daily and annual energy demand by end-users which indicated that air conditioning has the highest percentage consumption of 40.44% due to high cooling or significant air conditioning requirements, followed by office equipment, medical machine and equipment and lighting with 23.49%, 28.83% and 7.24% respectively. This trend is similar to what is obtained in [7] and [12].

4.3 *Energy performance indices*

Tables 9 and 10 present the result of energy performance indices in terms of building energy indices (BEI) and a productivity based energy performance indicator for the hospital. The building energy indices found were for hospital buildings, operating theatres, outpatient departments and inpatient department of the hospital as 229.726 kWh/m^2/year, 412.349 kWh/m^2/year, 160.790 kWh/m^2/year and 181.313 kWh/m^2/year, respectively. The productivity based energy performance indicators based on the above were 5.50938 kWh/m^2/year and 14.016 kWh/patient/year, 0.103 kWh/patient/year and 5.579 kWh/bed space/year, respectively. That trend of BEI and EUI is similar to what is obtained in [11], [13] and [8] for hospital energy consumption respectively.

4.4 *Energy conservation measures*

Based on the evaluation/analysis of the energy consumption pattern of the hospital, several energy conservation measures (ECMs) were analyzed and these were categorized into three groups no cost, low cost and major cost investment measures.

4.4.1 *No cost measures*

These are measures that can be implemented through operational and behavioral without the need for system or building alteration and therefore do not require extra cost for their implementation [14]. For the hospital, the following measures were identified for implementation. That is applying a schedule of equipment, set point temperature, Infiltration and schedule of lighting will provide a saving of 31.10% of the total annual energy consumed by lighting alone and a 2.33% saving of the total annual energy consumed in the hospital which amount to a cost saving value of ₦ 2,385,484.88 annually.

4.4.2 *Low cost measures*

These are measures that can be implemented for building alterations or modifications through low cost investment. An example through energy efficient lamps retrofitting in the hospital which will provide a saving of 86.82% of the total energy consumed by lighting alone and saving of 6.49% of the total annual energy consumed in the hospital which amounts to a saving of ₦ 14,187,789.26 annually, if implemented.

4.4.3 *Major investment measures*

These measures require major financial investment for their implantation. They can be implemented through system renovation or retrofitting to the office building/hospital's ward or for new similar projects.

4.4.4 *ECM: Replacement of 1.492 kW (2 hp) with 746 Watt (hp) AC systems*

In this energy conservation measure, changing the AC system to 746 watts reduces the amount of electricity consumed by 746 watts for each unit. Table 11 presented a result of an estimation of an annual saving of 34.68% of energy use by air conditioning systems alone and provided a saving of 14.02% of the total annual energy consumed in the hospital, which amounted to a cost-saving value of N 14,434,092.90 annually with a payback period of 1.5178 years if implemented

5. Conclusion and recommendations

5.1 *Conclusion*

The electricity energy consumption pattern of Federal Medical Centre, Jalingo building was investigated and the following conclusions were drawn.

i. The consumption pattern showed distinct seasonal variation indicating peak electricity demand during the hot humid summer months from April to August resulting in significant air conditioning requirements.

52.21% of electricity consumed was contributed by the burning of AGO in the diesel power generator showing a greater contribution over that of the National grid of 47.79% and this is the general trend in most buildings/facilities in Nigeria.

40.44% of electricity was consumed by air conditioners due to high or significant air conditioner requirements, office equipment with 23.49% consumption rate, while medical machine and equipment and lighting with 28.83% and 7.24%, respectively.

ii. The building energy performance index determined for the whole hospital, operating theatres, outpatient department and inpatient department was 229.726 kWh/m^2/year, 412.349 kWh/m^2/year, 160.790 kWh/m^2/year and 181.313 kWh/m^2/year respectively.

The productivity performance index determined for the whole hospital, operating theatres, outpatient department, and inpatient department was 5.510 kWh/pat/year, 14.016 kWh/pat/year, 0.103 kWh/pat/year and 5.579 kWh/pat/year respectively.

iii. If all the proposed ECMs were implemented, it would give a total of 20.58% energy saving of the annual energy consumption. And a proposed 14.01% of energy saving by air conditioners of the total annual energy consumed in the hospital through retrofitting. While 6.06% and 2.33% energy saving through retrofitting and schedule of lighting of the total annual energy consumed by the hospital, was proposed.

5.2 *Recommendations*

Based on the conclusions of this research work, the following recommendations are made for the existing building in Federal Medical Centre, Jalingo as well as for similar future projects.

i. The 2 hp air conditioners to be replaced by 1 hp air conditioners. Also, the air conditioners should be switched off during the early morning hours (6 am-9 am).

ii. It is recommended that light emitting diode of 3 W, 6 W, 12 W and 30 W be used in place of 5 W, 26 W, 40 W, 46 W, 60 W, 85 W, 105 W and 400 W respectively.

iii. It is recommended that the schedule of lighting based on an automated lighting system and equipment should be installed so that they are turned off during unoccupied and low occupancy hours and also the security light should be switched off during the day.

iv. Medical machines and equipment should be considered in the conservation measures analysis in the future study due to advanced technology on current medical machines and equipment with lower energy consumption rates.

v. It is recommended that in a further study exergy analysis should be conducted in the hospital energy audits.

vi. Renewable energy such as solar energy for lighting purposes should be installed in the hospital.

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Conflict of interest

The authors declare no competing financial interest.

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