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Research Paper

Energy Audit of Al-Qalam University, Katsina State Nigeria: A Simulation Approach

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Abstract— Energy audit is an effective method used to check the energy usage and wastage in buildings. This study presents the energy audit of Al-Qalam University Katsina. The audit was conducted to investigate the energy consumption pattern of the energy carries; energy end users; the energy used indices and the energy conservation measures in the university buildings. The Data was obtained for a period (2015-2017). Energy model system eQUEST (Quick Energy Simulation Tool) was used to analyze the energy consumption of the end users. It was finally found that the maximum electricity was demanded during the summer session (i.e., April to September) due to high Air condition requirement. After simulation with eQUEST, the results obtained shows that the total annual energy consumption by the end users were 96587kWh space cooling, 18657kWh ventilation fan, 40001kWh miscellaneous equipment and 55433kWh area lighting, having a total sum of 210678kWh, representing air-conditioning (space cooling) 47%, ventilation fan 10%, miscellaneous equipment 17% and area lighting 26%. The average Energy Used Index (average annual electricity use per student) shows to be 240.56kWh/Student/Annum while the average Building Energy Intensity (BEI) was 149.32kWh/m^2/Annum.

Keywords— Air Conditioning, Energy Audit, Energy Conservation, End Users, Lighting

1. Introduction

Energy demand is always increasing due to high maternity rate globally. Number of students admitted into university is also increasing yearly, this causes large consumption of energy in the universities. Audit of energy consumption in a building will serve as a way of mitigating or reducing environmental hazard (Green House Emission) and also improve energy saving awareness to the users.

Energy consumption is expected to increase by up to 27% and greenhouse gas emissions have to be reduced by 40% by 2030. These are some of the goals for fossil-fuel-based economy to a more efficient low-carbon economy in 2050 [1, 2].

Electricity is the most energy source used in university especially in developing countries like Nigeria [3]. The universities cannot afford to pay for the electricity bills and buying fuel. These have profound effects not only on academic activities but also on the social and economic activities in the system [4].

Moreover, energy usage for operating academic and administrative activities in the university most be improve in order to have smooth operational system to the university since its population (Students, Staff and others doing businesses in the university) is always increasing.

The energy consumption by end users (lighting, space cooling and heating, electronics devices) are the major consumptions in the universities. Energy audit of the university buildings will lead to reduce energy consumption, operating costs, lesser lighting fixture replacements and reduction in accumulated heat generated by them, thereby leading to parts of the drive towards mitigating greenhouse gas emissions and making buildings more environmentally friendly.

University energy potential studies is an energy auditing process that provides an opinion of the availability of energy efficiency resources on the university and allows the development of cost and savings strategies. A university energy potential study provides many of the same benefits as standard energy studies, such as an understanding of how efficient the campus is in energy utilization and a plan for energy reduction strategies [5].

The building sector is the largest energy consumer among other energy using sectors (transport and industry) [6]. Buildings can either be residential, commercial and institution buildings which takes more than 30% of the primary global energy demand. The energy demand in the building sector has been increasing by 3.5% globally by which urban buildings consumed higher levels as compared to rural buildings [6].

For Saudi Arabia, a building takes the lion's share which could exceed 70% of the total electrical energy use in the country [7]. A Study of buildings in Saudi Arabia showed a high consumption of energy due to lack of thermal insulation, absence of other energy efficiency measures and load management strategies [8]. Studies indicated in a supermarket (954m^2 air conditioning flow area), located in eastern province of the Saudi Arabian country, 38% of the energy used annually is by air conditioning; 42% is used in appliances and remaining 20% is used for lighting. It was found that 20% of available municipal electrical energy is used in commercial and office buildings in South Africa [9]. More than 60% of delivered energy in Europe and the United States can be associated with buildings to condition the indoor environment [6].

In an energy audit of building in Riyadh of Saudi Arabia done by Al-Homoud [10], the result of the study shows that 50%, 19% and 40% annual energy can be saved on large, medium and small office buildings respectively for Riyadh buildings. And that of Jeddah buildings were 8%, 12% and 24% for large, medium and small offices respectively for hot-humid.

In another energy auditing done in commercial buildings of USA. The energy consumption by end users are as follows: lighting 25%, space cooling 13%, space heating 12%, electronics 7%, water heating 6%, refrigeration 4%, computers 4%, cooking 2% and others 22%. And lighting 12%, space, cooling 13%, space heating 26% electronics 8%, water heating 13%, refrigeration 7%, cooking 5% water heating 6%, computers and other 1% for residential buildings [11].

Lack of adequate electricity supply from the natural grid is a daily problem in Nigeria. Al-Qalam University Katsina is not an exception; the university suffers immensely from power interruption. Staff and students require electricity for lighting, fans, air conditioners and operation of laboratory equipment for knowledge and research purposes. As a result of these problems, the university is spending a lot of money in buying diesel (AGO) for use in generators in order to keep up with its energy demand. Also, absence of effective electricity metering systems in the university, as several offices, laboratories and residential buildings in the campuses are not metered, leading to high tendency to waste energy and over-estimated billing. Apart from the use of inefficient appliances and poor consumer behaviors, the university does not have programmes and policies to promote energy efficiency best practices and conservation. Hence based on the above problems there is need for the university management to audit its utilization and cost effectively manages it.

2. Materials and Method

2.1 Materials

The following materials were used in this study:

i. Electricity bills file: The monthly consumption figures of Electricity in kWh for a period of 3 years (2015-2017) were extracted from KEDCO Electricity Consumption files.
ii. AGO consumption file: The monthly consumption figures of AGO in litres for a period of 3 years (2015-2017) were extracted from AGO (Diesel) Consumption files.
iii. Records of student's population.
eQUEST 3-6.5 version Energy Simulation Software: The detailed interface may be used to create a building from scratch or to edit a building created by the wizard or imported from an existing BDL input file.

2.2 Methods

2.2.1 Energy Consumption Pattern for Energy Carriers

The monthly consumption data of two energy carriers (Electrical & AGO) for a period of 3 years (2015-2017) were obtained from KEDCO and Diesel Consumption files from (DPP & M) Directorate of Physical Planning and Maintenance of the University.

2.2.2 Energy Consumption Pattern for Energy End Users

a. Data Collection

The data collected include: General building information, floor area (m^2), Envelope Construction Materials, CAD (Computer Aided Design) drawings, HVAC systems, Electrical Equipment load (W/m^2), Lighting Loads (W/m^2), Peak Occupancy (m^2/person), Occupancy, Lights and Equipment Schedules and Thermostat Schedules.

b. Data Analysis/Simulation

eQUEST was used to evaluate the performance of 641.5m^2 university building. From the data collected, the basic steps for creating the Schematic Design energy model and running the simulation are:

i. Open eQUEST and enter relevant data into the SD Wizard.
ii. Navigate sequentially through the SD Wizard screens and input relevant data then click finish.
iii. Simulate the building.
iv. Review the output results.
v. Make changes and simulate again if necessary (Energy Design Resources).

This procedure is explained more using figure 1 below where relevant inputs inserted into the model.

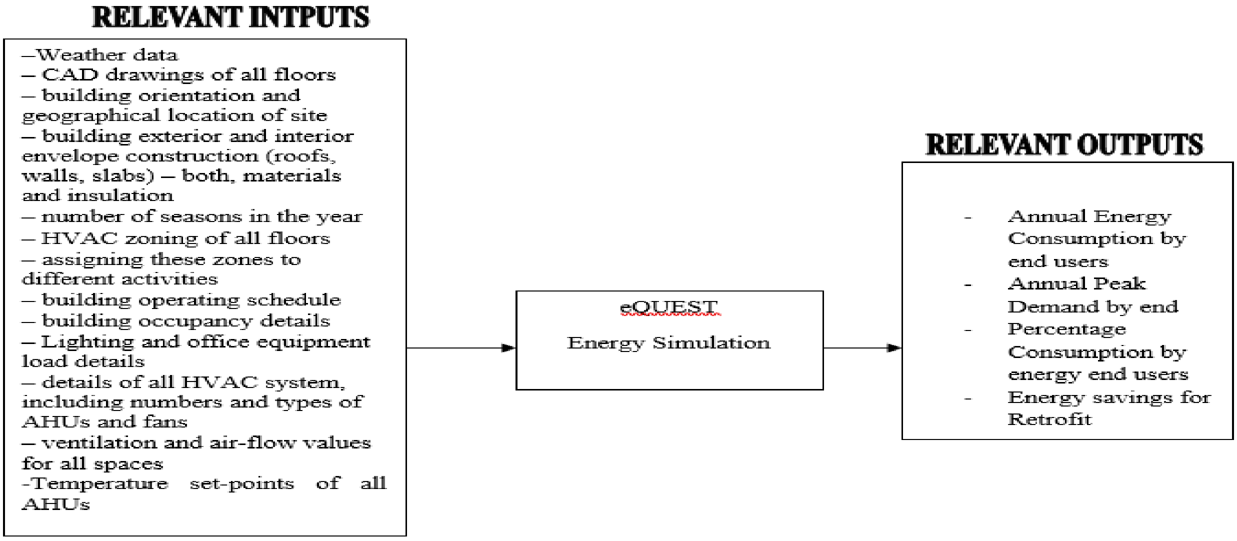

Figure 1: Modelling and Snapshot (input and output variables) of eQUEST energy modelling and simulation.

2.2.3 Evaluation of Energy Performance Indices

The Building Energy Intensity (BEI) or energy use intensity with unit of (kWh/m^2/yr) is the average energy consumption in unit area per year and with regard to the university buildings. The Energy Used Index (EUI) is a productivity index in kWh/student/year. These indices are tools for tracking the performance of the energy consumption.

a. Building Energy Intensity (BEI)

Sample calculation of building Energy Intensity for the year 2015 is given using equation 1.

Building Energy Intensity for 2015:

$$BEI = \frac{total\ \ annual\ energy\ consumption\ (kWh)}{Gross\ floor\ area\ (m^2)} \qquad (1)$$

$$BEI = \frac{764768.8}{6283.1} = 121.7\ \mathrm{kWh}/m^2/\mathrm{year}$$

The remaining (BEI) for 2016 and 2017 were computed and tabulated in table A-1 Appendix.

b. Energy Used Index (EUI)

The energy used index for the year 2015 is given using equation 2.

Energy used index

$$EUI = \frac{Total\ kWh\ of\ energy\ consumption}{Total\ population\ of\ students} \qquad (2)$$

$$EUI = \frac{764768.8}{2702} = 283.04\ \mathrm{kWh/student/year}$$

The remaining (EUI) for 2016 and 2017 were computed and tabulated in Table A-2 Appendix C.

2.2.4 Energy Efficiency Measures (EEMs)

Energy Efficiency Measures (EEMs) was carried out by identifying specific modifications to the baseline model according to the EEMs identified in either the walk-through analysis or on-site building assessment stages. After saving each modification as a separate model, the simulation was then done to quantify a potential energy savings compared to the baseline model.

College of Natural and Applied Sciences (Offices/lecture Hall), Muhammad Sanusi II Information Communication Technology Centre and Female Hostel Block B are the three-case study for the EEMs. The EEMs identified were analysed using the EEMs Wizard in eQUEST for systematic assessment of building energy performance in the selected buildings.

***EEM-01.* Insulated Roof:** Over-deck polystyrene insulation has been provided. R-21 batt insulation is added to the base line R-18 roof insulation i.e., total upgrade to R-39.

***EEM-02.* High Performance Window Glass Type:** Double Guardian Glass type category replaced with Double Low-E films Glass type. This reduces the solar heat gain through the glass and the ultraviolent value (transmittance).

***EEM-03.* Highly efficient Lightning:** The building's lighting power density can be improved by removing some lights in areas of high lighting power density percentage reduction or retrofitting from a regular efficient lightning to a higher efficient lighting system for energy conservation.

***EEM-04.* Thermostat Management:** Space cooling and electrical loads can be reduced by raising the cooling temperature set points during the day to 27ºC. Cooling rate of Air Conditioner is constant, equipment fitted in AC called thermostat has a temperature sensor that controls the room temperature. An air conditioner continuous working until the temperature is equal to the room temperature then the thermostat cut off the compressor but the fan continues to work. While the temperature rises, the thermostat signals the compressor to start. Therefore, it is recommended to adjust the temperature set point a few degrees to conserves energy.

***EEM-05. Highly Efficient* Equipment power density:** Improving the building's equipment power density (plug loads) in W/m^2 which generate heat inside the building; can reduce the energy consumption in the buildings by reduction in plug loads.

Analysis of Energy Efficiency Measures (EEMs)
The formulae used in computation of energy saved, percentage savings and payback period are:

a. Annual kWh energy saved = E_{ES}

b.
$$E_{ES} = E_{CB} - E_{CE} \quad (3)$$

Where: E_{CB} = Annual energy consumed by base model (kWh); E_{CE} = Annual energy consumed by EEMs model (kWh).

c. Percentage Savings (P_S)
$$P_S = \frac{E_{ES}}{E_{CB}} \times 100\% \quad (4)$$

d. Simple Payback
$$Payback = \frac{Cost\ of\ Energy\ Efficient\ Product}{Annual\ Energy\ Savings} \quad (5)$$

Annual Cost Savings
The quickest way to calculate savings is to insert the watt or kilowatt difference between the two products.
$$Annual\ Electricity\ Savings = \frac{T_D \times 365 \times Watts\ Saved \times U_R}{1000} \quad (6)$$

Where: T_D = Product hourly operation/day and U_R = Tariff rate (₦).

Sample calculation for Highly Efficient Equipment Power Density (Muhammad Sunusi II ICT). It was found that laptop computers consume approximately 28watts/hour while the desktop computers including monitor consume approximately 130watts/hour. Retrofitting desktop computers with Laptops computers saves energy.

Using equations (3–6) and simulation results:
E_{CB} = 492.05kWh; E_{CE} = 354.5 kWh; E_{ES} = 137.55kWh and P_S = 38.8 %.
If 1kWh = ₦27.37 (KEDCO) and the energy efficient product (Lap-top computer) costs = ₦63, 000 and the product works 9hrs/day.
$$Annual\ Electricity\ Savings = \frac{9 \times 365 \times 137.55 \times ₦27.37}{1000} = ₦12367.2$$
$$Payback = \frac{₦63{,}000}{₦12367.2} = 5.1 years$$

If you are replacing 100 of these desktops with highly efficient lap-top computers the cost is the same (there is no economy of scale), the payback is still 5.1 years. The remaining payback periods for the EEMs were calculated and tabulated in Table 6.

3. Results and Discussion

3.1 Results

3.1.1 Energy End use
Tables 1 and 2 and figure 2 present the results of the Annual Energy Consumption by end users, Annual Peak Demand by end users and the Percentage Consumption of the end users respectively.

Table 1: Annual Energy Consumption by End user

S/N	Building Name	Space Cooling (kWh)	Vent. Fan (kWh)	Misc. Equipment (plug loads) (kWh)	Area lightning (kWh)	Total (kWh)
1	Aminu Alhassan Dantata Senate Building	15184	4613	12041	23523	55362
2	College of Education	5283	1456	997	2020	9757
3	College of Social & Management Studies (Office/Lecture Hall)	4737	655	574	1844	7810
4	College of Social & Management Studies (Admin Block/Lecture Hall)	4755	617	1909	1485	8766
5	Department of Accounting/Economics	6814	1530	1985	1544	11873
6	Department of Sociology	5096	661	1464	1288	8510
7	College of Humanities (Admin) Block	5613	624	1684	1458	9379
8	Department of English/Literary Studies	6512	1459	1661	1416	11094
9	College of Natural/Applied Science (Offices/Lecture Hall)	4876	570	1464	1288	8199
10	Department of Physics (Lecture Hall)	6137	760	1727	520	10145
11	Muhammad Sanusi II Information/Communication Technology Centre	26064	3700	10091	9350	49205
12	College of Mathematics/Computer Science	5516	704	1661	1461	9343
13	Block A (Female Hostel)	-	613	1506	3716	5835
14	Block B (Female Hostel)	-	695	1237	4520	6452
	Total	96587	18657	40001	55433	**210,678kWh**

Table 2: Annual Peak Demand by End user

S/N	Building Name	Space Cooling (kW)	Vent. Fan (kW)	Misc. Equipment (plug loads) (kW)	Area lightning (kW)	Total (kW)
1	Aminu Alhassan Dantata Senate Building	13362	2005	4006	9242	28615
2	College of Education	16143	2242	2155	4975	25516

3	College of Social & Management Studies (Office/Lecture Hall)	26909	2624	1969	6331	37832
4	College of Social & Management Studies (Admin Block/Lecture Hall)	31939	2951	6419	6229	47538
5	Department of Accounting/Economics	32960	3816	6676	6478	49929
6	Department of Sociology	27432	2484	5658	5491	41066
7	College of Humanities (Admin) Block	30856	2344	6419	6229	45849
8	Department of English/Literary Studies	29581	2821	6419	6229	45050
9	College of Natural/Applied Science (Offices/Lecture Hall)	26967	2141	5659	5491	40259
10	Department of Physics (Lecture Hall)	32927	2857	6676	6476	48938
11	Muhammad Sanusi II Information/Communication Technology Centre	15659	1635	4101	4180	25575
12	College of Mathematics/Computer Science	29304	2646	6419	6229	44598
13	Block A (Female Hostel)	-	1847	4158	9286	15291
14	Block B (Female Hostel)	-	1847	3356	9329	14532
	Total	314039	34260	70090	92195	**510,584kW**

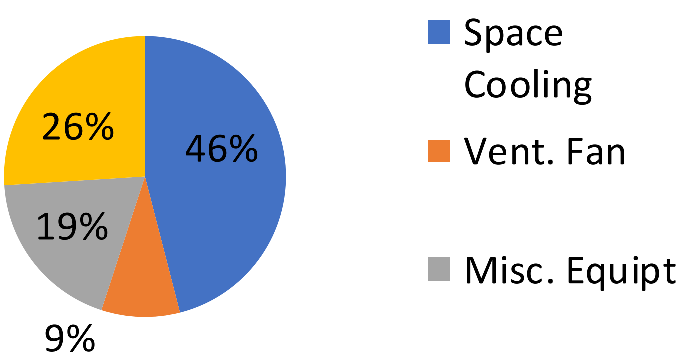

Figure 2: Percentage Consumption of the end users

Miscellaneous equipment: Any device that is plugged into a building's electrical system like computers, printer's data servers etc.

3.1.2 Energy Performance Indices

Tables 3 and 4 present the annual Energy demand results of the university buildings, in terms of building energy used intensity and energy use index.

3.1.3 Energy Efficiency

The results of energy consumption analysis in Muhammadu Sunusi II ICT centre, College of Natural and Applied sciences and Female Hostel Block B are presented in Figure 3, 4 and 5, respectively while Table 5 summaries the savings for the retrofits achieved by combined effect of energy efficiency measures under study.

Table 3: Building Energy Intensity for Al-Qalam University Katsina

Year/Session	Gross Floor Area (m^2)	Electricity consumption (kWh/Annum)	Building Energy Intensity (kWh/m^2/Annum)
2015	6283.1	764768.80	121.72
2016		900923.00	143.39
2017		1148593.00	182.81

Table 4: Energy use index for Al-Qalam University Katsina

Year/Session	Number of Students	Electricity consumption (kWh/Annum)	Energy use index (kWh/student/Annum)
2015	2702	764768.80	283.04
2016	3952	900923.00	227.97
2017	5452	1148593.00	210.67

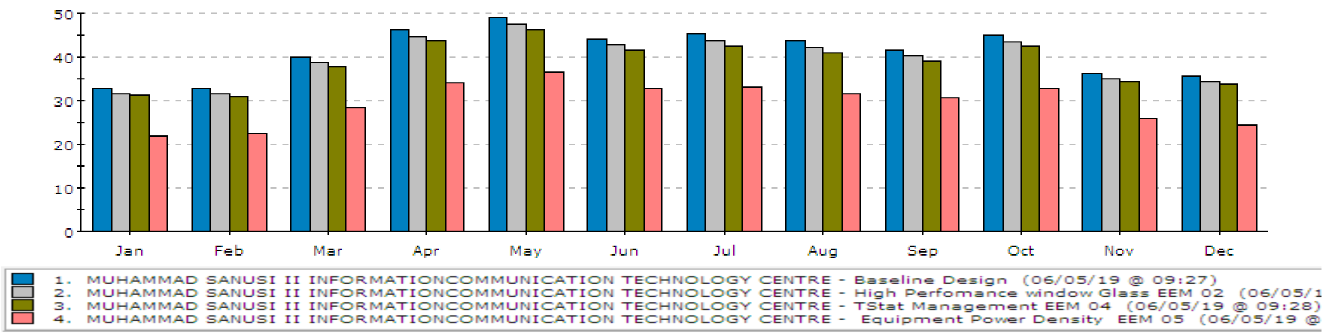

Figure 3: Monthly Total Energy Consumption of EEMs in Muhammadu Sunusi II ICT Building

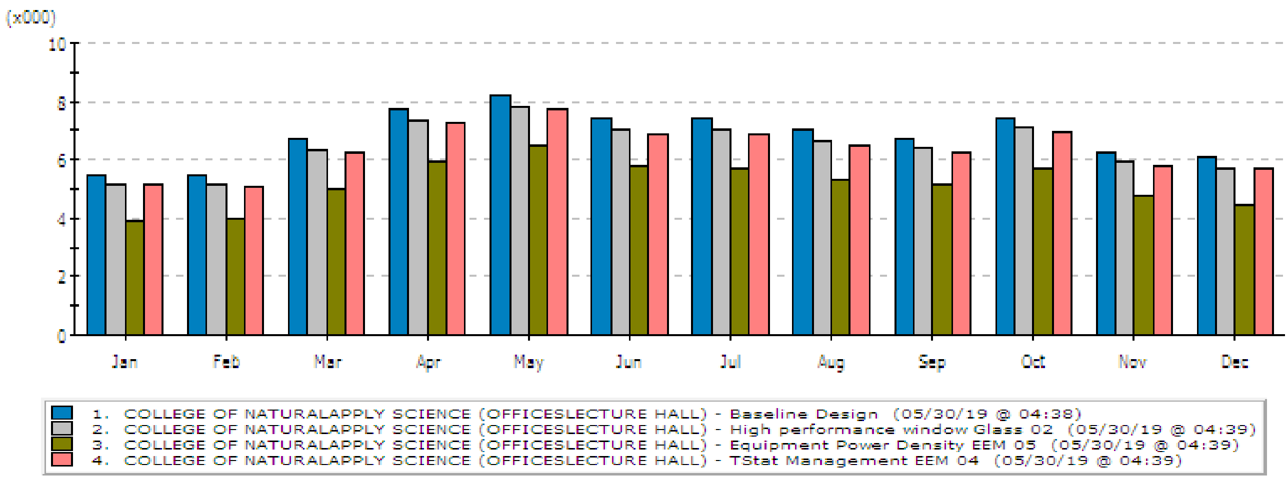

Figure 4: Monthly Total Energy Consumption of EEMs in College of Natural & Applied Sciences

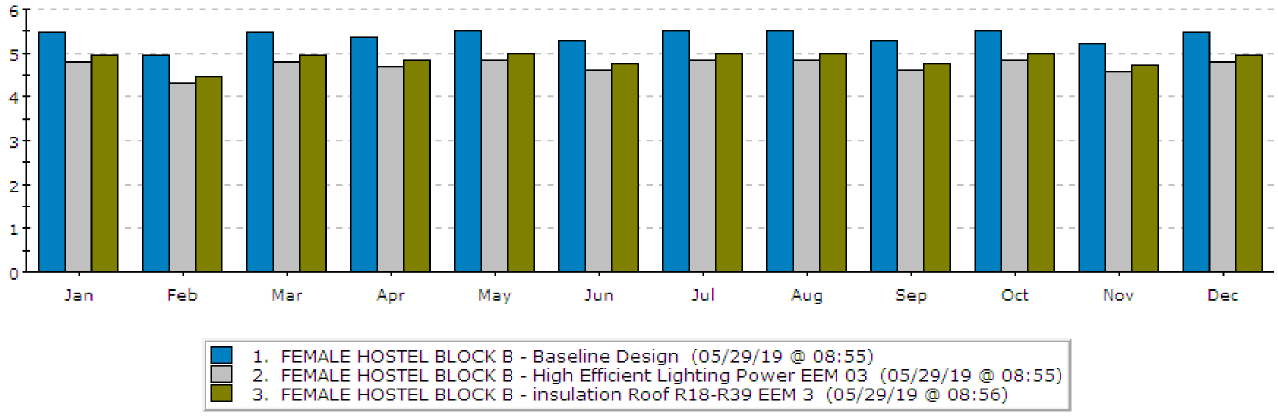

Figure 5: Monthly Total Energy Consumption of EEMs in Female Hostel Block B

Table 5: Energy Savings for the Retrofits

FEMALE HOSTEL BLOCK B			
Base case EEMs	Energy Consumption (kWh)	Energy Savings (kWh)	% savings over Base Case
Baseline Design	64.52	NA	NA
Highly Efficient Lighting Power EEM 03	56.47	8.05	14.26
Insulation Roof EEM 01	58.39	6.13	10.50
COLLEGE OF NATURAL/APPLIED SCIENCES			
Baseline Design	81.99	NA	NA
High Performance window Glass EEM 02A	77.63	4.36	5.62
Equipment Power Density EEM 05A	62.18	19.81	31.86
TStat Management EEMs 04A	76.35	5.64	7.39
MUHAMMAD SUNUSI II ICT CENTRE			
Baseline Design	492.05	NA	NA
High Performance window Glass EEM 02B	476.42	15.63	3.28
TStat Management EEM 04B	465.34	26.71	5.74
Equipment Power Density EEM 05B	354.50	137.55	38.8
	Total	223.88	117.45

Table 6: EEMs categorized on Investment Measures and Pay Back Period

Level of Measure	EEMs	Savings (%)	Pay Back Period Years
Low Investment	TSat Management EMM 04A	7.39	-
	TSat Management EMM 04B	5.74	-
Medium Investment	Highly Efficient Lighting Power EEM 03	14.26	1.4
	Equipment Power Density EEM 05A	31.86	5.3
	Equipment Power Density EEM 05B	38.80	5.1
	Insulation Roof EEM 01	10.50	0.8

Major Investment	High Performance window Glass EEM 02A	5.62	9.0
	High Performance window Glass EEM 02B	3.28	2.5
Total		**117.45**	**24.1**

3.2 Discussion of the Results

3.2.1 Energy End Users

From Table 1, the total annual energy consumption for the buildings indicated that space cooling has the highest consumption of 96587 kWh followed by area lighting, miscellaneous equipment and then ventilation fan with 55433 kWh, 40001 kWh and 18657 kWh respectively. Also, Table 2 shows the total peak demand by end users for the buildings followed the same trend with space cooling having the highest consumption of 314039 kW followed by area lighting, miscellaneous equipment and then ventilation fan with 34260 kW, 70090 kW and 92195 kW respectively. And the percentage contribution showed space cooling has the highest percentage of 46% followed by area lighting, miscellaneous equipment and then ventilation fan with 26%, 19% and 9% respectively. There was no result for space cooling in the university dormitories due to absence of air-conditioning facilities in the buildings. This result is agreed with the results of the studies done by [12-14].

3.2.2 Energy Performance Indices

Table 3 and 4 presented the result of energy performance index in term of building energy intensity (BEI) and energy used index (EUI) for the university. The average building energy intensity 149.31 kWh/m^2/Annum was for the whole university buildings considering the gross area. And the average energy used index was found to be 240.56 kWh/student/Annum. Generally, a low EUI shows better energy performance and its concord to [15]. However, certain property types will always use more energy than others. For example, an elementary school uses relative energy compared to a hospital. The standard SI unit source EUI for Colleges/University is about 569.7 kWh/m^2 (www.energystar.gov/SourceEnergy). For more information about national energy use intensities see the reference: U.S National Energy Use Intensity designed to help in comparing buildings energy use to the national median energy use of similar properties.

3.2.3 Energy Efficiency Measures (EEMs)

The results for energy savings for retrofit for the three selected buildings has been tabulated in Tables 5, and 6 above respectively which shows that an overall energy savings of 223.88 kWh, which was 117.45% over the base cases has been achieved by combined effect of energy efficiency measures in terms of building envelop, HVAC systems and lighting systems under study. The maximum savings has been achieved through equipment power density EEM 05B 38.8% out of total savings obtained in this facility of 117.45%. It has been also noticed that least savings of 3.28% has been found by applying high performance window glass EEM 02B which is a medium investment EEM. The overall savings of 117.45% has shown good results by combined performance of all energy efficiency measures together [15]. The payback period for the various EEM investigated which has been in the range from 0.8 to 9.0 years from Table 6. The TStat Management EEMs 04 is a low investment measure that does not involve retrofitting as a result it doesn't have payback period.

4. Conclusions and Recommendations

4.1 Conclusions

The energy consumption pattern of Al-Qalam University Katsina buildings were investigated and the following conclusions were made:

i. The university buildings were modelled and simulated using eQUEST-3.65 to analyse the building energy consumption pattern. The results of the analysis show that the total annual energy consumption for the buildings for space cooling was 96587kWh while ventilation fan, miscellaneous equipment and area lighting 18657kWh, 40001kWh and 55433kWh, respectively. Also, the total annual peak demand by end users for the buildings followed the same trend with Space cooling consumption of 314039kW while ventilation fan, miscellaneous equipment and area lighting 34264kW, 70090kW and 92195kW respectively. And the percentage contribution showed Space cooling 46%, Area lighting, Miscellaneous equipment and then Ventilation fan with 26%, 19% and 9% respectively.
ii. The building energy performance index for the university buildings average values for three years (2015-2017) were, 149.31 kWh/m^2/Annum and 240.56 kWh/student/Annum respectively.
iii. The university buildings were simulated by using eQUEST-3.65 to explore potential energy savings with implementation of EEMs with regards to building envelop parameters, HVAC systems design and lighting system in the university buildings were studied. The retrofit simulation results of the three selected buildings have shown that Equipment Power Density EEM 05B has given maximum savings of 38.8%. The results also show minimum savings of 3.28 % achieved high Performance window Glass EEM 02B among all the EEMs.

4.2 Recommendations

The following recommendations were made for the existing buildings in Al-Qalam University Katsina as well as for similar future project:

a. The Energy Management Units in the university system should be created to educate students and staff on energy efficiency for better management practice.

b. A comparison study of energy consumption in buildings from an effective metering system (energy from the grid) in kWh and a computer modelling and simulation tool consumption in kWh.

Conflict of Interest

Authors declare that no any conflict of interest.

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No funding source exists during the research study.

Authors' Contributions

Nafi'u Muhammad Saleh: Brought the Idea and Planned the method.

Jamilu Ya'u Muhammad and Anas Bala: Conducted the literature review and found the research gap.

Nafi'u Muhammad Saleh and Anas Bala: Collected the data from the University.

Mukhtar Isa: Examined the architectural structures of the building and suggested the suitable buildings for the study.

Jamilu Ya'u Muhammad and Kadawa Ibrahim Ali: Analyzed the data and Wrote the manuscript.

Joseph Samuel Enaberakhan: Re-examined the spelling and grammar of the article.

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Appendix: Energy Performance Indices

Table A-1: Building Energy Intensity for Al-Qalam University Katsina

Year/Session	Gross Floor Area (m^2)	Electricity consumption (kWh/Annum)	Building Energy Intensity (kWh/m^2/Annum)
2015	6283.1	764768.80	121.72
2016		900923.00	143.39
2017		1148593.00	182.81

Table A-2: Energy use index for Al-Qalam University Katsina

Year/Session	Number of Students	Electricity consumption (kWh/Annum)	Energy use index (kWh/student/Annum)
2015	2702	764768.80	283.04
2016	3952	900923.00	227.97
2017	5452	1148593.00	210.67

AUTHORS PROFILE

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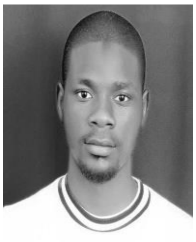

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