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ENERGY CONSUMPTION PATTERNS AND CONSERVATION OPPORTUNITIES IN NIGERIAN UNIVERSITIES: CASE STUDY OF AN ENERGY AUDIT OF BENUE STATE UNIVERSITY, MAKURDI

AONDONA ISAAC TERWASE[1], AONDOSOO IJIR[2], TERKUMA CALEB LUMU[3], ORSEER ACHIMBA[4], AONDONA ISRAEL NYITYO[5], MSUGHTER JOSEPH GUUSU[6], CALVIN AZO BARAKUR[7], TSAVNANDE LAZARUS SHIAONDO[8], SHAGBAOR HYCENT AMOOL[9], ORANDEREN MATTHEW MZOUGH[10], BARNABAS IKYO[11]

[1]MSc Medical and Radiation Physics, Center for Food Technology and Research (CEFTER), Benue State University Makurdi, Email: aondonatwas@gmail.com
[2]Principal Engineer, Center for Food Technology and Research (CEFTER), Benue State University Makurdi, Email: aijir@bsum.edu.ng
[3]B.Eng Electrical/Electronics Engineering, Joseph Sarwuan Tarka University, Makurdi, Email: lumuncaleb@gmail.com
[4]Center for Food Technology and Research (CEFTER), Benue State University Makurdi, Email: aorseer@gmail.com
[5]BSc Industrial Physics, Joseph Sarwuan Tarka University, Makurdi, Email: nyityoaondonaisrael@gmail.com
[6]B.Eng Mechanical Engineering, Joseph Sarwuan Tarka University, Makurdi, Email: guusumjoseph@gmail.com
[7]MSc Electrical Engineering, Saint Petersburg Electrotechnical University Russia Department -Photonics, Email: calvinazo.engr@gmail.com
[8]Center for Food Technology and Research (CEFTER), Benue State University Makurdi, Email: tsavnande.lazarus@cefterbsu.edu.ng
[9]MSc Global Sustainability Engineering, Heriot Watt University, UK, Email: sa2274@hw.ac.uk
[10]B.Sc Geophysics, University of Calabar, Nigeria. Email: oramath70@gmail.com
[11]Professor, Center for Food Technology and Research (CEFTER), Benue State University Makurdi, Email: ikyo12@yahoo.com

Corresponding Author: Terkuma Caleb Lumun

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ABSTRACT

This study conducts a comprehensive energy audit of Benue State University (BSU), Makurdi, Nigeria, to evaluate the university's energy consumption patterns and identify opportunities for energy efficiency improvements. The audit assesses electricity usage cutting across; lighting, heating, cooling, and equipment efficiency across the university's facilities. Key findings reveal a total energy demand of 4794 kW, with the breakdown as follows: lighting accounted for 7% (335.58 kW), ventilation for 52% (2493.88 kW), automatic voltage regulators for 4% (191.76 kW), and plug loads for 37% (1772.78 kW). A significant observation was the labor market's contribution of 497.25 kW, approximately 28% of the total plug load. In 2021, the university spent ₦52,279,149 ($33,214.20; exchange rate of ₦1574: 1$) on 168,306 liters of diesel and 23,328 liters of petrol for generators, and electricity costs amounted to ₦150,653,304.71 ($95,713.66). A notable spike in electricity consumption was observed in September 2021, at 3289.68% higher than average. The audit identifies high-energy-consuming appliances, evaluates energy management opportunities, and explores new technologies for energy efficiency. Key recommendations include transitioning to LED lighting, optimizing plug load management, and considering alternative energy sources like solar power. Implementing these measures could save up to 18% of the university's total energy demand and significantly reduce operational costs. The findings highlight significant potential for savings through the adoption of efficient appliances and regular maintenance, as well as the importance of accurate repair cost tracking for diesel and petrol generators to support cost reduction strategies. By *implementing the recommendations, the university aims to enhance energy efficiency, reduce operational costs, and promote sustainable practices, setting a benchmark for other institutions.*

KEYWORDS*: Energy Audit, Energy Efficiency, Electricity Consumption, Load Demand, Renewable Energy*

1. INTRODUCTION

Benue State University, located in Makurdi, Benue State, Nigeria, is a prominent institution of higher learning dedicated to academic excellence and research (Nyiyongu & Tionsha, 2020). As universities expand and modernize, their energy consumption increases, leading to higher operational costs and environmental impacts (Ogbu & Okoro, 2019). This necessitates a comprehensive evaluation of energy usage to identify inefficiencies, propose improvements, and promote sustainable practices (Abdul & Mohammed, 2021).

An energy audit is therefore a critical tool for assessing how energy is used within an institution. It involves a systematic examination of energy flows and consumption patterns, aiming to reduce energy waste and optimize usage (Tunde & Chukwuma, 2018). By conducting an energy audit, Benue State University can identify areas of excessive energy consumption, recommend energy- saving measures, and potentially reduce costs while contributing to environmental sustainability (Eze & Nwankwo, 2020).

This study focuses on performing an energy audit of Benue State University to provide a clear understanding of its energy consumption. The audit will analyze various components, including electricity usage, lighting, heating, cooling, and equipment efficiency (Bello & Lawal, 2017). Specifically, the objectives of this study are to assess the energy demand of electrical appliances across the university to provide a detailed understanding of consumption patterns and identify high-energy consumers; evaluate the university's energy consumption patterns to identify Energy Management Opportunities (EMOs), including analyzing load profiles and forecasting demands to enhance energy efficiency and reduce costs; investigate and evaluate new technologies that can enhance energy efficiency and production, aiming to explore innovative solutions that align with sustainable energy practices; and measure and evaluate the carbon dioxide equivalent (kgCO2) emissions from fuel usage within the university, addressing the need for a comprehensive environmental impact assessment of energy consumption.

The goal is to develop practical recommendations for energy conservation, thereby supporting the university's mission of fostering a sustainable campus environment (Yusuf & Ogundipe, 2019). Through this audit, Benue State University can set a benchmark for other institutions in Nigeria and beyond, showcasing the importance and benefits of energy efficiency in educational establishments (Adamu & Ibrahim, 2021).

2.0. LITERATURE REVIEW ENERGY AUDITS IN UNIVERSITIES

An energy audit for a university, which typically has a significant load of 4794 kW, involves assessing energy consumption patterns, identifying inefficiencies, and proposing energy-saving measures. Various universities, including Aligarh Muslim University, University of Jos, Teuku Umar University, and Karpagam University, have conducted energy audits aimed at optimizing energy management. These audits analyzed major loads, such as lighting and fans, and recommended efficient replacements like LED bulbs and BLDC fans (Khan et al., 2021). Additionally, these audits focused on determining electrical energy consumption, load profiles, and forecasting demands to enhance energy efficiency and reduce costs (Gwaivangmin, 2021; Saputra, 2018; Balachander & Amudha, 2015). Tools like GridVis software and industrial power analyzers have been utilized to identify areas with the highest potential for energy savings and to implement strategies to optimize energy performance within university facilities (Leiva et al., 2018).

IMPORTANCE OF ENERGY AUDITS

Energy audits are crucial for conserving power consumption. They involve analyzing energy flows in buildings or organizations to identify inefficiencies and opportunities for energy savings. Conducting energy audits allows individuals to determine the efficiency levels of their energy consumption, identify significant energy users, and implement strategies to reduce wastage and save energy (Sinuraya et al., 2022). Various methods, such as calculating energy consumption intensity, utilizing alternative energy sources, and controlling home appliances through smart applications, are employed to enhance energy efficiency and reduce power consumption (Darshan et al., 2022). Energy audits not only help in reducing energy costs but also contribute to sustainable development by promoting the efficient use of limited energy resources.

TECHNOLOGICAL ADVANCEMENTS IN ENERGY EFFICIENCY

The integration of Internet of Things (IoT) technologies has been leveraged to automate appliance control, focusing on high-energy consumers like air conditioners and lights (Chaoudhry et al., 2023). Furthermore, interdisciplinary collaboration plays a crucial role in addressing technical challenges and advancing sustainable energy solutions (Dolge et al., 2023). The integration of Artificial Intelligence (AI) tools in energy systems holds immense potential to enhance efficiency, reliability, and sustainability by optimizing generation, distribution, and consumption (Stecyk & Miciuła, 2023).

3.0 METHODOLOGY

3.1 FACILITY DESCRIPTION

Benue State University, Makurdi is a tertiary education institution, established in 1992 by the Government of Benue State, Nigeria.

The University is located on longitude 7.728517188568424, latitude 8.555919197222266 as obtained on Google Map, presented below in figure1

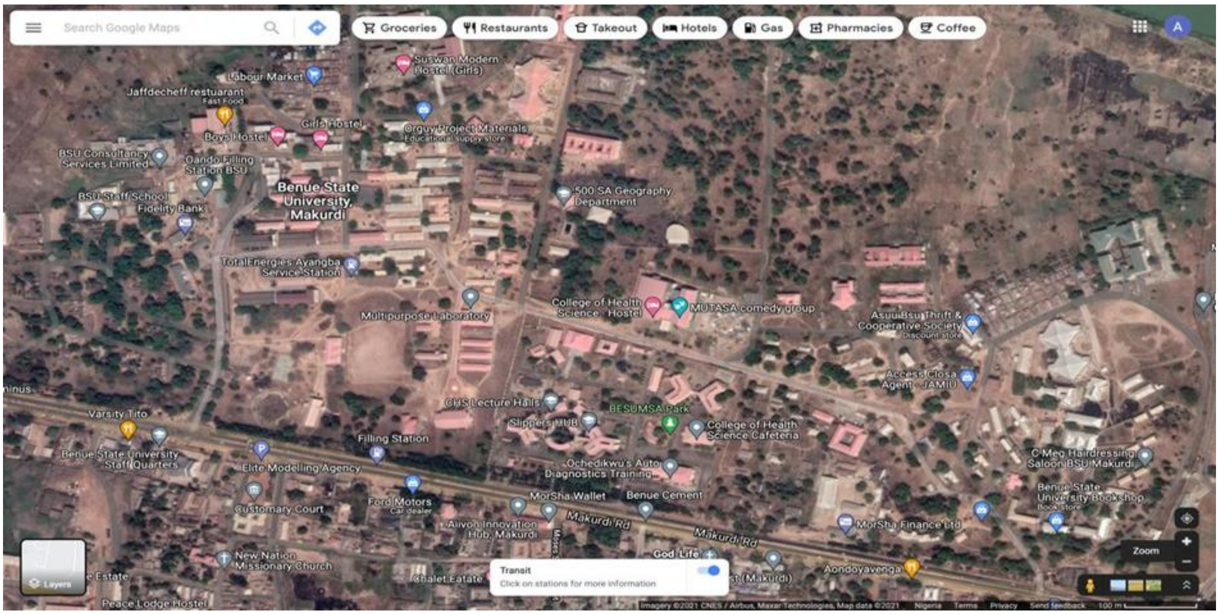


Figure 1: Aerial View of Benue State University Makurdi Source: Formulated by Researcher (2025)

The University has two (2) Campuses namely the West Wing Campus and the East Wing Campus. In between the campuses is the Benue State University College of Health Sciences. At both campuses, it is common to find a mix of offices, lecture halls, residential apartments, student hostels and market (popularly referred to as the Labor Market). All the building infrastructures of the University are built with concrete blocks with either louvre windows, sliding windows, casement windows or a combination of the mentioned. It is unsurprising that, the very old building infrastructure inherited by the University before its establishment in 1992 use louvre windows while latter buildings are fitted with sliding and casement windows.

3.2 METHODS OF DATA COLLECTION

The Load Assessment and Energy Audit exercise deployed the use of questionnaires designed by the energy audit team in addition to on-site survey of all the buildings of the University to collate data on energy demand, energy inputs, utility bills and estimated number of weekly occupants per unit.

The campus's electrical network is divided into two main segments: one further subdivided into 28 units and the other which is the College of Health Sciences. Data collected treated the college of Health sciences as a different entity from the rest of the other 28 units of the university community.

The exercise segmented the loads into; lighting (indoor, security and corridor lights), ventilation (fans, air-conditioners and standing fans), plug loads and Automatic Voltage Regulators.

3.2.1 MATHEMATICAL EQUATIONS USED

Below is a list of mathematical equations used in the electrical audit of Benue State University

1. Power Consumption of Appliances

$$P = \frac{E}{t} \quad (1)$$

Where:

P = Power consumption (kW), E = Energy consumed (kWh), t = Time duration (hours)

2. Energy Cost Calculation

$$C = E \times R \quad (2)$$

Where:

C = Total energy cost (₦), E = Total energy consumption (kWh), R = Rate per unit of energy (₦/kWh)

3. Total Energy Consumption (E)

$$E = \sum_{i=1}^{n} P_i \times H_i \times Q_i \quad (3)$$

Where:

E = Total energy consumption (kWh), Pi = Power rating of appliance i (kW),

Hi = Usage hours per day for appliance i, Qi = Quantity of appliance I, n = Number of different appliances

4. Annual Energy Consumption

$$E_{annual} = P \times H \times D \times Q \quad (4)$$

Where:

E_{annual} = Annual energy consumption (kWh/year), P = Power rating of the appliance (kW)

H = Usage hours per day, D = Number of days in a year (usually 365),

Q = Quantity of the appliance

5. Energy Savings from Replacing Inefficient Appliances

$$S = E_{old} - E_{new} \quad (5)$$

Where:

S = Energy savings (kWh), E_{old} = Energy consumption of the old appliance (kWh)
E_{new} = Energy consumption of the new appliance (kWh)

6. Carbon Emissions Calculation

$$CO_2 = E \times EF \quad (6)$$

Where:

CO_2 = = Carbon dioxide emissions (kgCO_2), E = Total energy consumption (kWh)
EF = Emission factor (kgCO_2/kWh)

7. Energy Efficiency Improvement

$$\eta = \frac{E_{saved}}{E_{total}} \times 100 \quad (7)$$

Where:

η = Energy efficiency improvement (%), E_{saved} = Energy saved (kWh)
E_{total} = Total energy consumption before improvement (kWh)

3.3. Equipment Inventory

The project focused on the following category of loads in use;

i. Lighting fixtures
ii. Ventilation (air-conditioners and fans) fixtures
iii. Plug Loads
iv. Automatic Voltage Regulators

3.3.1. LIGHTING

Lighting fixtures found at Benue State University and the College of Health Sciences are Light- emitting diode (LED), Compact fluorescent lamp (CFL), Fluorescent lamp and Incandescent light bulb.

The exercise considered lighting fixtures to be indoor lighting, security, and corridor lighting for comprehensive analysis of energy demand and proposal of Energy Conservation Measures (EMOs).

3.3.2. VENTILATION

In this report, the fixtures of ventilation are air-conditioners (1hp, 1.5hp and 2hp), ceiling fans, standing fans and others. “Others” refer to air-conditioners with a capacity of 3hp. The East and West Wing Campuses of the University installed 2,226.15 kW of ventilation fixtures. The quantity of ceiling fans is prominent amongst ventilation fixtures although the 1.5hp air- conditioner with 915.68 kW has the highest energy demand.

3.3.3. AUTOMATIC VOLTAGE REGULATORS

Automatic Voltage Regulators popularly referred to as stabilizers are used to control voltage fluctuation at the Benue State University and the College of Health Sciences. These voltage fluctuations can damage appliances, and end prematurely their normal useful life.

These Voltage stabilizers also consume power and the amount of power they consume varies. The cheapest models with poor efficiencies are the most problematic.

Most of the stabilizers installed are 95-98% efficient and consuming 2-5% of the maximum load. Also, Uninterrupted Power Supply (UPS) appliances data was collated during the Energy Audit and Load Assessment exercise. For the exercise, the UPS was assumed to be like the Automatic Voltage Regulator in consuming 2-5% of its maximum load.

3.3.4. PLUG LOADS

This project considered all electrical loads excluding Lighting fixtures, Air-conditioners, Ceiling and Standing fans as plug loads. Plug loads installed in all units had striking similarity. The common plug loads found in the University and College of Health Sciences are Desktop computers, Laptops, Printers, Photocopiers, Fridges, Kettles, Televisions, and Decoders.

Although varying brands were installed per plug load, a common wattage was selected for similar plug loads of the University and the College of Health Sciences. For uncommon plug loads installed mainly in the laboratories and workshops, respective wattage of the various electrical appliance was obtained from their labels.

Desktop (60W), Laptop (15W), Printer (90W), Photocopier (1,200W), Fridge (70W), Kettle (1,500W), Television (50W), Decoder (23W)

4.0. RESULTS AND DISCUSSION

This section presents the energy demand of the individual inventory fixtures in the university, a total energy demand and an overall analysis of the energy consumption.

4.1. LIGHTING FIXTURES

This section presents results of data collected from lighting fixtures. The results are further divided into the East and West wings of the university and the College of health Sciences respectively.

4.1.1 EAST AND WEST WINGS OF THE UNIVERSITY

Total Electrical Demand of all installed lighting fixtures was found to be 218.9 kW for the East and West Wing Campuses of the University. The composition of the installed lighting fixtures was 7,210 (54%) LEDs, 573 (4%)

Fluorescent lamps, 5,224 (40%) CFLs and 237 (2%) Incandescent light bulbs. Figure 2 presents a graphical composition of installed lighting fixtures at the east and west wings of the university.

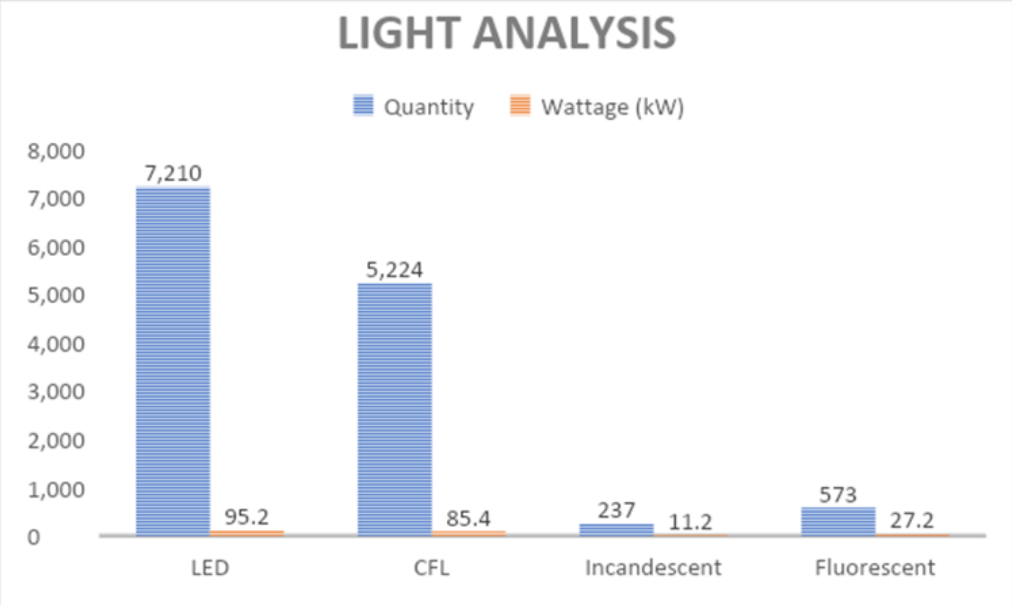


Figure 2: Light Analysis of the East and West Wings of the University Source: Formulated by Researcher (2025)

4.1.2. COLLEGE OF HEALTH SCIENCES

At the College of Health Sciences, Fluorescents made the bulk in quantity of lighting fixtures, and it also had the highest energy demand of 103.5 kW. In total, the College had an installed energy demand of 105.4 kW inclusive of both security and corridor lighting.

Table 1 below presents the total quantity and power consumption of various lighting fixtures.

Table 1: Total Quantity and Power Consumption of Lighting Fixtures

S/ No	Fixture	Quantity	Wattage (kW)
1	LED	30	0.2
2	Fluorescent	3,092	103.5
3	CFL	14	0.1
4	Incadescent	33	1.6
	Total		105.4

Source: Formulated by Researcher (2025)

From the data table presented above, the following analysis have been made;

i. Energy Efficiency: LED bulbs are the most energy-efficient among the fixtures listed, with a low power rating of 10W each. However, they make up a small portion of the total lighting fixtures.
ii. High Energy Consumption: Incandescent bulbs, although less in quantity than fluorescent tubes, have a high power consumption of 60W each, contributing significantly to the total power consumption.

4.2. VENTILATION FIXTURES

A total of 2208kW of power was found to be the load demand due to ventilation in the university, with the east and west wings of the university contributing 2226.15kW and the college of health sciences contributing 281.7kW to the total ventilation load demand. The breakdown is presented below.

4.2.1. EAST AND WEST WINGS OF THE UNIVERSITY

Table 2 below presents the energy demand due to ventilation at the East and West wings of the University.

Table 2: Energy demand Due to Ventilation

S/No	Fixture	Quantity	Wattage (kW)
1	1 hp	215	160.39
2	1.5 hp	819	915.68
3	2 hp	255	380.26
4	Others	132	503.22
5	C/Fan	3,284	246.30
6	S/Fan	369	20.30
			2,226.15

Key
C/Fan: Ceiling fan
S/fan: Standing fan

Source: Formulated by Researcher (2025)

4.2.2. COLLEGE OF HEALTH SCIENCES

At the College of Health Sciences, a similar scenario was obtained with ceiling fan having the highest quantities of installed ventilation fixtures while the 1.5hp air-conditioner had the highest energy demand. Break down is shown in figure 3.

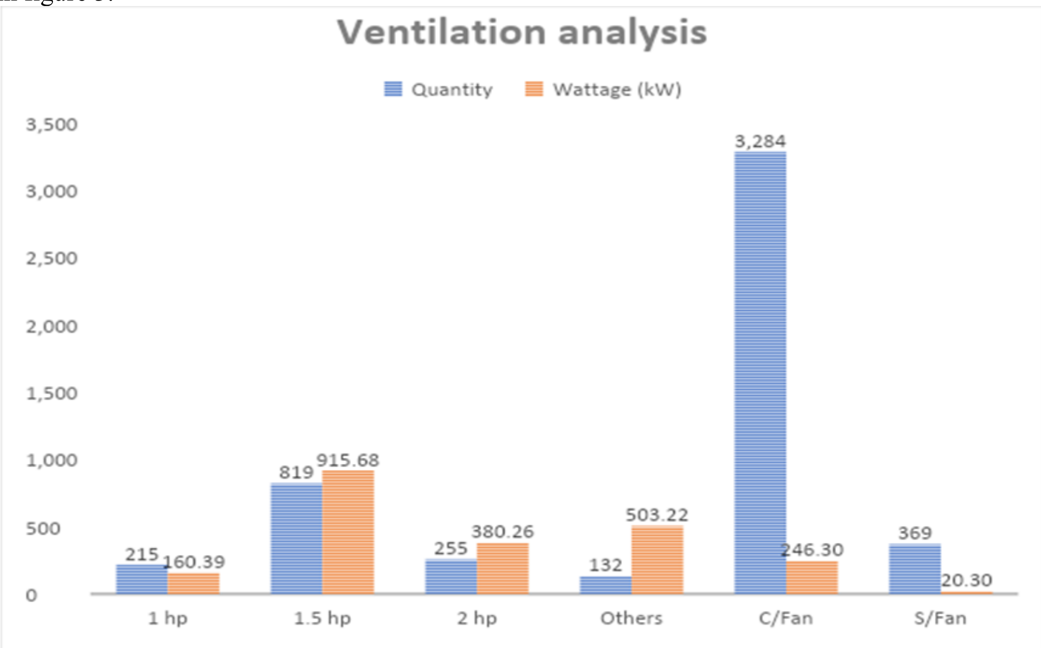


Figure 3: Ventilation Energy Demand Chart for the College of Health Sciences

Table 3: Energy Demand due to Ventilation at the College of Health Sciences

S/No	Fixture	Quantity	Wattage (kW)
1	1 hp	6	4.5
2	1.5 hp	126	140.9
3	2 hp	8	11.9
4	C/Fan	524	39.3
5	S/Fan	126	6.9
6	Others	23	78.2
	Total		**281.7**

Source: Formulated by Researcher (2025)

From the figure above, it can be deduced that;

Air conditioners are the highest energy consumers, with a total annual energy consumption of

328.5 kWh/year. This is significantly higher than the other types of ventilation fixtures.

On the other hand, standing fans have the lowest total annual energy consumption

4.3. AUTOMATIC VOLTAGE REGULATORS

A total of 757 Automatic Voltage Regulators and 353 Uninterrupted Power Supply (UPS) appliances are installed in the University. The College of Health Sciences has 73 Automatic Voltage Regulators. The sizes of the Automatic Voltage Regulators installed in the University are 2 kVA, 5 kVA and 10 kVA, while Uninterrupted Power Supply (UPS) appliances were mainly 1440 Watts. The cumulative totals of Automatic Voltage Regulators and Uninterrupted Power Supply appliances for the University and College of Health Sciences are 830 and 353 respectively. The total capacities of the installed Automatic Voltage Regulators and Uninterrupted Power Supply appliances was estimated at 3,429 kW and consuming 171 kW. Thus total load demand due to automatic voltage regulators and UPS is:

4.4. PLUG LOADS

The University and the College of Health Sciences had an installed plug load energy demand of 1,790 kW. The University's plug load energy demand was estimated at 1,738 kW while the College of Health Sciences had 52 kW. The Labor Markets located each at the East and West Wing Campuses of the University accounted for the most energy demand per unit at a combined sum of

497.25 kW. These markets have stores leased to the public to offer services to staff and students on the university campus. Bulk of the energy demand from plug loads at the Labor Markets was from photocopiers, ice making machines, deep freezers, and laminating machines. At the time of conducting the exercise, the University had concluded plans to install prepaid meters for the markets with the view that, they pay their electricity bills. Aside the Labor Markets, the Water Works unit of the University had the highest energy demand estimated at 140.62 kW. This energy demand is attributed to the various capacities of water pumps installed at the Water Works. The figure 4 below presents a breakdown of the plug loads.

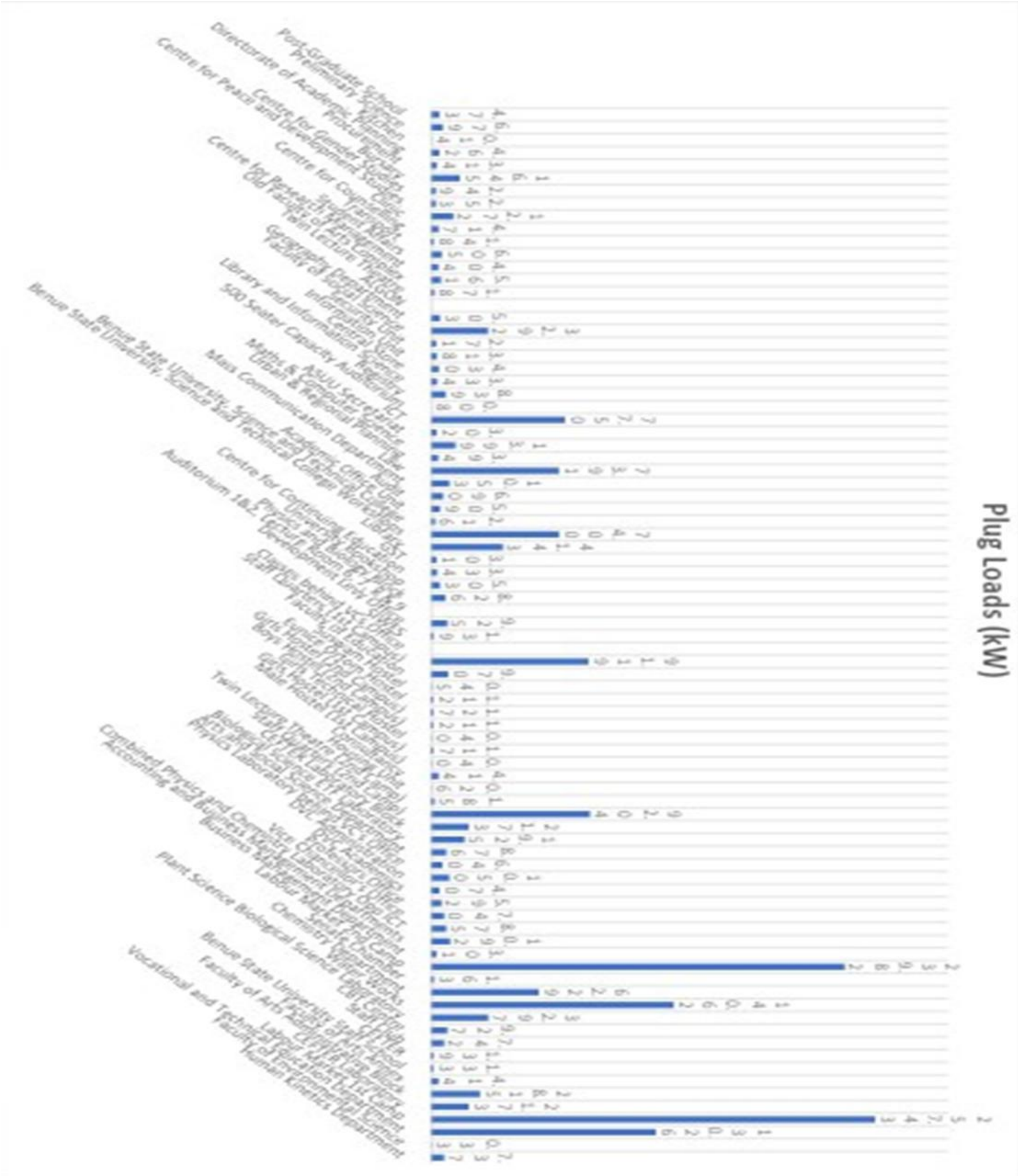


Figure 4: Detailed Breakdown of the Plug Loads

In summary, the energy demand due to plug load is broken down as follows: East and West Wings of the university account for 1738 kW, the college of health sciences: 52 kW, bringing the total plug load to: 1790 kW.

4.5. TOTAL ENERGY DEMAND

The energy audit of Benue State University revealed the distribution of energy demand across various components. Table 4 presents the total load demand.

Table 4: Total Energy Consumption by Fixtures

S/No	Fixture	Wattage (kW)
1	Lighting	324
2	Ventilation	2,508
3	Automatic Voltage Regulators	171
4	Plug Load	1,790
	TOTAL	4,794

Source: Formulated by Researcher (2025)

Consequently, the pie chart in figure 5 gives a pictorial illustration of the proportion of energy consumption for lighting, ventilation, automatic voltage regulators, and plug load.

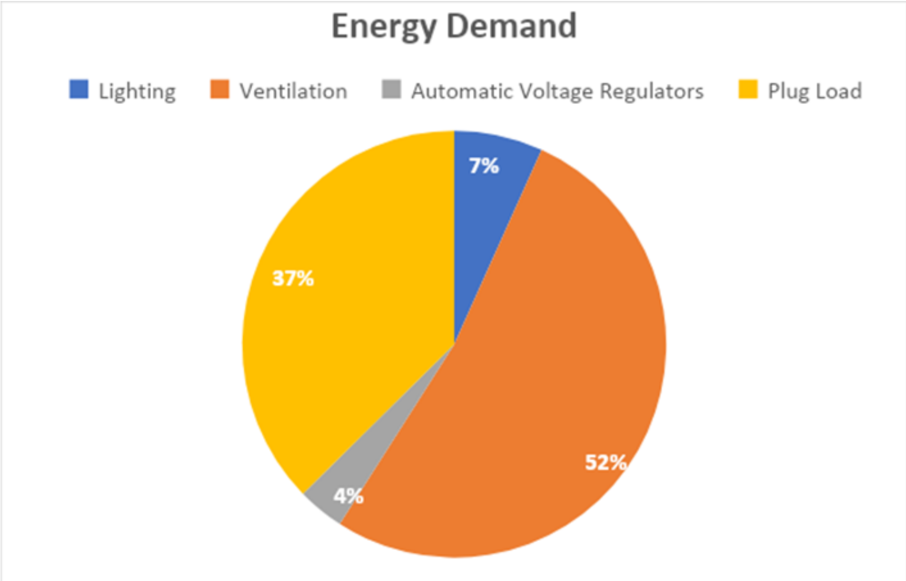


Figure 5: Energy Demand Distribution

From the figure sown above, the percentage composition of load can be shown as follows;

1. Lighting: 7%
2. Ventilation: 52%
3. Automatic Voltage Regulators: 4%
4. Plug Load: 37%

This breakdown highlights that ventilation consumes the majority of energy, followed by plug load, lighting, and automatic voltage regulators. Understanding this distribution helps in identifying key areas where energy-saving measures can be implemented to optimize energy efficiency.

4.6. POWER SUPPLY TO BENUE STATE UNIVERSITY MAKURDI

The main source of energy into the University and the College of Health Sciences is electricity supplied by a public utility company known as the Jos Electricity Distribution Company (JEDC). Electricity is supplied into the University via the 33-kVa transmission line. The 33-kVa line which is classified as high voltage line is stepped down at the Injection Substation of the University and distributed to other feeder stations. The official titles of the feeder stations as obtained from JEDC Utility bill with their transformer sizes is given below:

i.500-kVA Benue State University Along Gboko Road ii.500-kVA Student Hostel 2nd Camp iii.300- kVA Law

iv.500-kVA Benue State University Unity Campus Gboko Road v.500-kVA Postgraduate School

vi.100-kVA Water Intake

vii.300-kVA Chemistry Department

viii.1000-kVA Benue State University Gboko Road ix.500-kVA College of Health Sciences.

All but the 300-kVA Law, 500-kVA Postgraduate School and the 100-kVA Water Intake transformers opted out of estimated billing and have prepaid meters installed. The University is served with eight (8) transformers while the College of Health Sciences is served by a 500-kVa transformer. Due to the Covid-19 pandemic which interrupted activities of the University and subsequent shutdown for majority of the year 2020 (occasioned by industrial actions), the study collected only electricity consumption data for the years 2019 and 2021 of Benue State University. The data collected has been presented in Table 5 below.

Table 5. Electricity Consumption (kWh) at Benue State University for 2019 and 2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (kWh)
BSU Along Gboko Road													
Year 2021	15,361	10,000	7,001	8,000	8,500	9,000	71,342	-	3,303	4,682			137,189
Year 2019	4,053	1,603	1,702	1,904	2,201	2,201	2,759	6,500	5,751	5,000	4,272		37,946
Water Intake													
Year 2021	7,197	9,679	10,647	10,647	15,971	19,165	19,166	935	1,563	469			95,438
Year 2019	7,000	7,920	794	7,200	7,000	7,200	9,025	7,220	7,076	7,784	9,118		77,337
Student Hostel 2nd camp													
Year 2021	20,985	10,308	14,766	16,607	15,209	15,918	15,820	1,521	25,232	7,985			144,351
Year 2019	2,910	5,370	10,384	11,024	12,025	12,000	6,013	7,005	5,301	2,204	3,023		77,259
BSU Unity Campus Gboko Road													
Year 2021	738	993	1,092	1,092	1,638	1,966	1,967	4,071	4,070	5,295			22,922
Year 2019	37,370	43,390	69,660	67,570	68,570	67,580	70,010	50,060	18,820	40,530	47,980		581,540
Chemistry Department													
Year 2021	12,710	13,365	27,063	24,369	21,898	21,316	14,951	17,828	21,310	18,907			193,717
Year 2019	20,007	8,791	8,501	8,703	9,702	8,002	71,506	17,351	17,955	18,001	27,812		216,331
Benue State Uni Gboko Road													
Year 2021	6,851	11,921	18,039	27,355	19,642	18,000	28,210	319	2,354,151	33,780			2,518,268
Year 2019	986	8,154	16,127	15,999	17,005	22,148	18,831	20,088	26,446	27,073	36,182		209,039
Law													
Year 2021	-	3,336	3,336	6,670	-	6,670	-	5,002	6,439	-	6,423		37,879
Year 2019	-	8,532	8,532	8,532	8,532	2,578	-	6,622	-	17,064	-		60,392
Postgraduate School													
Year 2021	-	-	-	-	-	-	-	-	10,359	-			10,359
Year 2019	-	-	-	10,665	-	-	-	10,665	-	-	-		21,330
VC BSU													
Year 2021													
Year 2019	2,575	-	-	2,578	2,578	2,578	6,232	4,986	4,886	5,375	6,300		38,088

In the year 2021, Benue State University, Makurdi was billed the sum of One Hundred and Ninety-Seven Million, Seven Hundred and Ninety Thousand, One Hundred and Ninety-Eight Naira, Eight Kobo (₦ 197,790,198.08 equivalent to $125,660.86) for consuming 3,160,123.20 kWh of electricity.

Bulk of the sum was attributed to the charge of One Hundred and Fifty Million, Six Hundred and Fifty-Three Thousand, Three Hundred and Four Naira, Seventy-One Kobo (₦ 150,653,304.71 equivalent to $95,713.66) obtained from the JEDC electricity bill voucher of September 2021 for the Benue State University Gboko Road feeder station.

In the voucher, Benue State University Gboko Road feeder station consumed 2,518,268 kWh of electricity in the year 2021. However, the University's electricity consumption for the month of September read 2,426,433 kWh.

A rise of over 3560% from the monthly average of 66,292.13 kWh from the Benue State University Gboko Road feeder station for year 2021.

Comparatively, the University paid Sixty-One Million, Seven Hundred and Eight Thousand, Three Hundred and Seventy-Four Naira, Twenty-Three Kobo (₦ 61,708,374.23 equivalent to

$39,204.81) in the year 2019 for 1,319,262.00 kWh of electricity consumed as supplied by the public utility company JEDC. The BSU Unity Campus Gboko Road feeder station recorded the highest amount in electricity consumed while the Postgraduate School feeder station recorded the least with 581,540 kWh and 21,330 kWh respectively.

Table 6: Monthly Energy Consumption for the Years 2019 And 2021

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Total(k Wh)**
2021	63,842.00	59,602.40	81,944.40	94,740.40	82,858.00	92,035.40	151,456.00	29,676.48	2,426,426.95	71,117.77	6,423.40	-	**3,160,123.20**
2019	74,901.00	83,760.00	115,700.00	134,175.00	127,613.00	124,287.00	184,376.00	130,497.00	86,235.00	123,031.00	134,687.00	-	**1,319,262.00**

From the data presented above, for the year 2021, it is noticeable that there is a significantly high spike in energy consumption for the month of September, which is approximately 3,289.68% higher than the average of the other months. The energy consumption in September 2021 shows an exceptionally sharp rise compared to the preceding months.

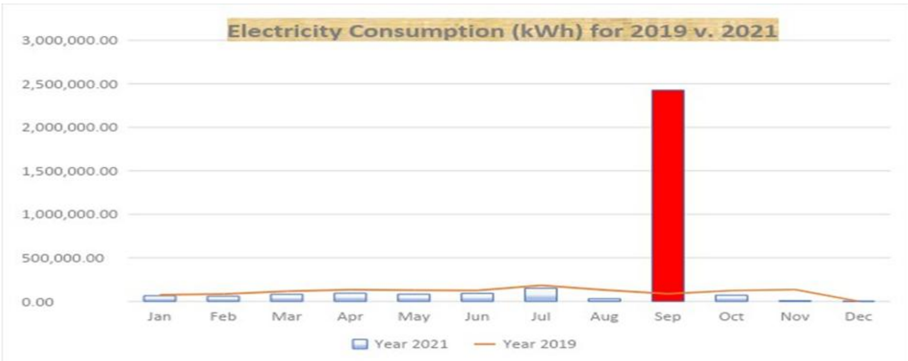


Figure 6. Comparison of Monthly Electricity Consumption (kWh) for Year 2019 and 2021

For both years under consideration, monthly electricity consumption followed similar patterns of increase and decrease (see figure 1 above). Overall, using 2019 as base case, the University recorded a decrease in electricity consumption in each corresponding month of 2021 except the abnormal case of September 2021. Thus, for firmness in analyzing data on the University electricity consumption pattern of the years in consideration, notional removal of September 2021 electricity consumption units will significantly reduce the annual electricity consumption (kWh) and financial cost of 2021 below figures of 2019.

The magnitude of electricity consumption deviation from the average obtained from the electricity bill of September 2021 was alarming.

This substantial increase suggests an anomaly or a significant change in energy usage during September 2021.

4.7. DIESEL AND PETROL

Power shortages have encouraged the use of generators as alternative source of electricity in the University and the College of Health Sciences. This has led to increase in cost incurred to provide electricity for daily operation of the University and the College. A detailed breakdown of the diesel and petrol expenditure is presented below in Table 7.

The University and the College of Health Sciences spent a combined sum of Fifty-Two Million, Two Hundred and Seventy-Nine Thousand, One Hundred and Forty-Nine Naira (₦52,279,149 equivalent to $33,214.20) only in the purchase of 168,306 liters of diesel and 23,328 liters of petrol to run generators at various units in the year 2021. The University spent ₦ 44,662,200 ($28,374.97) in 28 units while the sum of ₦ 7,616,949 ($4,839.23) was spent to procure 46,530 liters of diesel to run the 700 kVA generator at the College in 2021.

Table 7: Diesel and Petrol Expenditure for the Year 2021

S/No	Unit	Petrol (Ltrs)	Diesel (Ltrs)	Amount (₦)
1	Post-Graduate School		4,650	1,069,500
2	Preliminary Science	240		39,600
3	Directorate of Academic Planning	1,440		237,600
4	Centre for Gender Studies	648		106,920
5	Centre for Peace and Development Studies	240		39,600
6	Clinic	360		59,400
7	Centre for Research Management	1,236		203,940
8	Faculty of Social Science		14,400	4,320,000
9	Security Unit	1,824	36,000	14,700,960
10	ICT		2,400	720,000
11	ASUU Secretariat	144		23,760
12	Library		24,000	7,920,000
13	GST	288		47,520
14	Centre for Continuing Education	720		118,800
15	University Bookshop	432	-	71,280
16	Physics and Biology Block	2,400		396,000
17	SIWES	1,440		237,600
18	Faculty of Education	1,464		241,560
19	Arts and Social Science Department	2,784		459,360
20	Professors Office		400	120,000
21	Accounting and Business Management Departments	4,800		792,000
22	Chemistry Department		26,000	7,860,000
23	Water Works		9,600	2,976,000
24	Staff Club	1,200		198,000
25	CEFTER		3,600	1,188,000
26	Benue State University Staff School	480		79,200
27	Vocational and Technical Education Department	288	726	287,100
28	Human Kinetics Department	900		148,500
29	College of Health Sciences		46,530	7,616,949
	TOTAL	***23,328***	***168,306***	***52,279,149***

Source: Formulated by Researcher (2025)

4.8. SUMMARY OF RESULTS

The results section of the energy audit presents the following key findings:

4.8.1. Total Energy Demand: The total energy demand for Benue State University (BSU) is determined to be 4794 kW. Detailed breakdown based on classified load is as follows;

Lighting: 7% of total energy demand, which is approximately 335.58 kW. Ventilation: 52% of total energy demand, which is approximately 2493.88 kW.

Automatic Voltage Regulators: 4% of total energy demand, which is approximately 191.76 kW. Plug Loads: 37% of total energy demand, which is approximately 1772.78 kW.

4.8.2. Labor Market Energy Consumption: The labor market accounts for 497.25 kW, approximately 28% of the total plug load.

4.8.3. FOSSIL FUEL (DIESEL AND PETROL) EXPENDITURE

In 2021, a total of ₦52,279,149 ($33,214.20) was spent on purchasing 168,306 liters of diesel and 23,328 liters of petrol; ₦44,662,200 ($28,374.97) was spent by 28 units of the university while ₦7,616,949 ($4,839.23) was spent on purchasing diesel for the College of Health Sciences.

4.8.4 PUBLIC DISTRIBUTION COMPANY COSTS:

Year 2019: N61,708,374.23 ($39,204.81) for 1,319,262.00 kWh consumed.

Year 2021: N150,653,304.71 ($95,713.66) charged by the distribution company.

4.9 ENERGY CONSERVATION MEASURES (ECMS) AND FINDINGS

Energy Conservation Measures (ECMs) are referred to technologies/practices implemented to reduce the consumption of energy in a building. The ECMs are targeted at the energy demand of loads and practices at the University. Analysis of data collated during the Energy Audit and Load Assessment exercise found the University and the College of Health Sciences to have an estimated energy demand of 4,794 kW (4.794 MW). Further breakdown of the energy demand revealed the College of Health Sciences had 451 kW of installed electrical load while the Main University Campus had 4,343 kW. Table 4 earlier shown, reveals the energy demand per Category of Use i.e., Lighting, Ventilation, Automatic Voltage Regulators and Plug load fixtures.

The proposed Energy Conservation Measures (ECMs) also covered energy consumption metering system of the University. This section of the report further identified areas of energy misuse with recommendations.

4.9.1 LIGHTING SCENARIO: EXISTING CONDITIONS

The lighting scenario and existing conditions of the Benue State University, Makurdi comprise a baseline assessment and critical assessment of the energy saving methods to minimize cost and ensure efficient and effective use of energy.

4.9.1.1 BASELINE ASSESSMENT

Lighting constitutes 7% of the energy demand of Benue State University, Makurdi at 324 kW. The College of Health Sciences has lighting energy demand of 105.4 kW while the East and West Wing Campuses of the University account for 218.9 kW.

The composition of light fixtures in West and East Wing Campuses of the University is illustrated in Table 10 below.

The report exempted the lighting system of the College of Health Sciences in considering energy saving measures because data collated did not segregate installed light fixtures into indoor office lighting, corridor lighting and security lighting.

Table 10. West and East Wing Campuses Light fixtures

		INDOOR		CORRIDOR		SECURITY	
S/No	Fixture	Quantity	Wattage (kW)	Quantity	Wattage (kW)	Quantity	Wattage (kW)
1	LED	5,484	65.0	933	12.4	793	17.8
2	CFL	3,484	53.3	1,165	19.6	575	12.4
3	Incandescent	216	9.4	6	0.4	15	1.4
4	Fluorescent	558	26.7	14	0.4	1	0.0
	TOTAL		**154.4**		**32.8**		**31.7**

Source: Formulated by Researcher (2025)

4.9.1.2 ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

Possible energy saving opportunities exist with the light fixtures. Economic and environmental evaluations of retrofitting Compact Fluorescent Lamps (CFL) installed indoors with Light- Emitting Diodes (LED) lamps offered huge savings as shown in the analysis below.

4.9.1.3 ECONOMIC EVALUATION OF RETROFITTING CFLS WITH LEDS

Assumptions were made to quantify energy saving measures. Indoor lighting was considered with the assumption that:

i. The CFL light fixtures be retrofitted with 10 watts LED fixtures. The LED lamp has an Efficacy of 80%, Lifetime of 50,000 hours {24/24 (5.6 years)}. Overall, the quality of the LED is better than the CFL
ii. Only 80% of CFL fixtures are functional
iii. The CFL light fixtures work from Monday – Friday, 8:00am – 4:00pm during the University working hours
iv. The average daily operating hours electricity is supplied to the University during working hours from the Utility Company is 5 hours
v. The tariff for electricity is ₦ 62.86/kWh

i. Daily energy consumption CFL fixtures = PxTxN/1000 (kWh) Where, P = Power rating of CFL fixtures in watts
T = Time in hours per day CFL light fixtures are in use N = Number of CFL fixtures in use
Daily energy consumption of indoor CFL fixtures, E1 = (53,300 watts x 0.8 x 5 hours x 1) / 1000 = 213.2 kWh
ii. Daily energy consumption of 10w LEDs, E2 = (10 watts x 3484 LEDs x 0.8 x 5 hours x 1) / 1000 = 139.36 kWh
iii. Daily Energy Savings by LEDs = E1 - E2 = 213.2 – 139.36 = 73.84 kWh
iv. Monthly energy savings = Daily energy savings x 30 days (An average of 22 days in a month is assumed)
Monthly energy savings by LEDs = 73.84 kWh/day x 22 days = 1624.48 kWh
v. Monthly energy cost savings = Monthly energy savings x energy cost
Monthly energy cost savings by LEDs = 1624.48 kW x ₦ 62.86/kWh = ₦ 102,114.81
vi. Implementation cost for retrofitting with LEDs = 3484 x 0.8 x Unit Cost of LED = 3484 x 0.8 x ₦ 700 = ₦ 1,951,040
vii. Payback period for Retrofitting with LEDs = Implementation cost ÷ Monthly energy cost saving = ₦ 1,951,040 / ₦ 102,114.81 = 19 months

The payback period for the proposed ECM is 19 months, following which the savings in energy cost appear as profit for the life of the installation as shown in Table 11.

Table 11. Summary Table of Proposed ECM for Lighting

SUMMARY TABLE OF PROPOSED ECM	
OPPORTUNITY TITLE	Retrofitting CFL with LEDs
ESTIMATED ANNUAL ENERGY SAVINGS (kWh)	19,493.76
ESTIMATED ANNUAL COST SAVINGS (₦)	1,225,377.72
ESTIMATED ANNUAL CO_2 SAVINGS ($kgCO_2e$)	10,604.61
ESTIMATED CAPITAL COST (₦)	1,951,040
ESTIMATED PAYBACK PERIOD (Months)	19

(Estimated Annual CO_2 Savings as obtained from The Universities and Colleges Climate Commitment for Scotland (UCCCFS) Communicating Statistics Tool – Campus Energy Use spreadsheet. See Energy Carbon Footprint Section for details)

The Energy Audit and Load Assessment exercise also detected some concerns with the light fixtures/system with recommendations as stated below.

a. Observations

i. There are a lot of unnecessary lights in one single room/ space

ii. Too many lights are assigned to one (1) switch.

iii. Preventable use of Incandescent, Fluorescent and CFL fixtures.

iv. Faulty light fittings left without bulb (Ballast of faulty light will draw power when the lights are ON even though it is not working).

v. Poor behavior/management of lighting by occupants of a building

Figures 7,8 and 9 present some of the issues associated with lighting at the University.

Figure 7. Improper Light Fixtures in a Room

Figure 8. Avoidable Use of Light Fixtures During the Day

Figure 9. Poor Utilization of Hours of Operation of Light Fixtures During Daytime

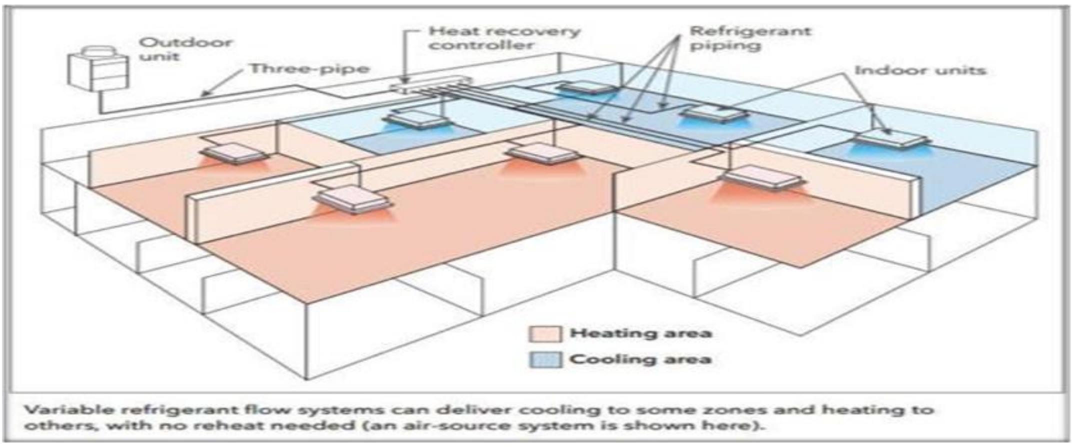
4.9.2. VENTILATION SCENARIO: EXISTING CONDITIONS

4.9.2.1 BASELINE ASSESSMENT

A huge quantity of ventilation fixtures at the University and College of Health Sciences run the duration of work hours and at times left on at closure of work. The Ceiling fan is regarded as a high passive electricity consumer due to the number of hours it runs in a day. The wattage of ventilation fixtures at the University and College of Health Sciences is estimated at 2,508 kW and constitute 52% of the energy demand.

4.9.2.2 ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

Variable Refrigerant Flow Systems (VRF) are versatile and powerful air-conditioners offering a cost-effective system and easy installation as shown in Figure 10.



Variable refrigerant flow systems can deliver cooling to some zones and heating to others, with no reheat needed (an air-source system is shown here).

Figure 10. Systematic Operation of VRF System

The building structure, architectural and mechanical designs of some units at the University encourage easy installation and operation of the VRF system. The Chemistry Department unit for an example is a rectangular shaped, multi floored building with passages and 18 spaces divided by an alley.

The Wall mounted air-conditioning units and the Standing units providing cooling ought to be replaced with Variable Refrigerant Flow (VRF) systems. The audit process kept a count of 40 units of Air-conditioners with varying capacities at Chemistry Department and energy demand of 78 kW.

One (1) unit of LG ARUM120LTES VRF System can be deployed at the Chemistry department. The LG model has a rated power of 33.6 kW with 30 maximum connectable indoor units and sold at £8,208.00 (₦ 4,606,318.93).

4.9.2.3 ECONOMIC EVALUATION OF DEPLOYING VRF SYSTEM

Assumptions: Daily operating hours of existing air conditioners = 5 hours

i. Daily energy consumption air conditioners = PxTxN/1000 (kWh) Where, P = Power rating of air conditioners in watts
T = Time in hours per day air conditioners are in use N = Number of air conditioners in use
ii. Daily energy consumption of air conditioners in Chemistry Department, E1 = (78,000 watts x 5 hours x 1) / 1000 = 390 kWh
iii. Daily energy consumption of ARUM120LTES VRF System, E2 = (33600 watts x 5 hours x 1) / 1000 = 168 kWh
iv. Daily Energy Savings by ARUM120LTES VRF System = E1 - E2 = 390 – 168 = 222 kWh
v. Monthly energy savings = Daily energy savings x 30 days (An average of 22 days in a month is assumed)
Monthly energy savings by ARUM120LTES VRF System = 222 kWh/day x 22 days = 4884 kWh=
vi. Monthly energy cost savings = Monthly energy savings x energy cost

Monthly energy cost savings by ARUM120LTES VRF System = 4884 kW x ₦ 62.86/kWh = ₦ 307,008.24

Note: (Last electricity bill recorded from 300-kVA Chemistry Department feeder station is 18,907 kWh worth ₦ 1,339,546.6

vii. Implementation cost for ARUM120LTES VRF System = (1 x Unit Cost of ARUM120LTES VRF System) + Installation cost = (1 x ₦ 4,606,318.93) + ₦ 1,500,000 = ₦ 6,106,318.93

viii. Payback period for ARUM120LTES VRF System = Implementation cost ÷ Monthly energy cost saving = ₦ 6,106,318.93/ ₦ 307,008.24 = 20 months

Thus, the payback period for the proposed ECM is 20 months, following which the savings in energy cost appear as profit for the life of the installation as shown in Table 12.

Table 12. Summary Table of Proposed ECM for Ventilation Systems

SUMMARY TABLE OF PROPOSED ECM	
OPPORTUNITY TITLE	Deployment of VRF system
ESTIMATED ANNUAL ENERGY SAVINGS (kWh)	58,608
ESTIMATED ANNUAL COST SAVINGS (₦)	3,684,098.88
ESTIMATED ANNUAL CO_2 SAVINGS ($kgCO_2e$)	31,882.75
ESTIMATED CAPITAL COST (₦)	6,106,318.93
ESTIMATED PAYBACK PERIOD (Months)	20

(Estimated Annual CO2 Savings as obtained from The Universities and Colleges Climate Commitment for Scotland (UCCCFS) Communicating Statistics Tool – Campus Energy Use spreadsheet. See Energy Carbon Footprint Section for details)

The Energy Audit and Load Assessment exercise also detected some concerns with the ventilation fixtures/ system with recommendations stated below.

a. Observation(s)

i. Installation of inefficient air-conditioners

ii. Brand and model of fans and air-conditioners not consistent throughout the University

iii. Poor attitude of occupants towards ventilation fixtures (occupants leaving the door(s) open when entering and exiting the room when the air-conditioner is in operation)

iv. Windows and doors of the air conditioned rooms not sealed properly i.e., the use of louvers which is highly not recommended. Benue State University, Makurdi has a lot of places with heat losses/ gains through louvers, broken windows, and ceiling

v. Incorrect sizing of air-conditioners in the rooms.

vi. Poor ventilation of passages at some student hostels to provide good quality air.

Figures 11, 12, 13 and 14 present some of the issues associated with ventilation at the University.

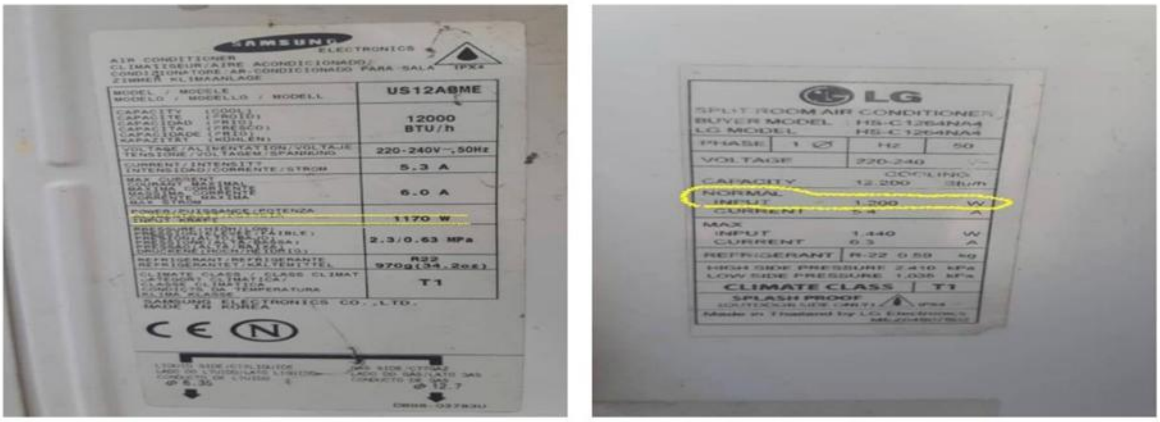


Figure 11. Picture Comparing Input Power of Different Brands of 1.5 hp Air-conditioners

Figure 12. Poor and Inefficient Ventilation System Design

Figure 13. Heat Gains and losses through the windows of a small office

Figure 14. Heat Gains and Losses Through Collapsed Ceiling of an Office

4.9.3. PLUG LOAD SCENARIO: EXISTING CONDITIONS

4.9.3.1. BASELINE ASSESSMENT

The Plug loads at the University have an energy demand of 1790 kW. Notable plug loads of the University are Desktops, Printers, Television, Photocopiers, and Fridges. In all the Units of the University, they were a regular appearance of the Sharp AR 6020 brand of photocopier with a wattage of 1200 watts. The Sharp brand when compared to other models is energy efficient and the setup encouraged ease of operation and maintenance of the photocopiers.

4.9.3.2 ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

Obvious energy saving opportunities exist in the proper use of plug loads. It starts with procurement and installation of efficient brands of plug loads. Also, a severe phenomenon of vampire load exists in the University and the College of Health Sciences. Vampire loads is the consumption of electricity by appliances while in standby mode i.e., consuming electricity at a cost but not doing any work.

a. Observation(s)/ Issue(s):

i. Installation and use of inefficient models and brands of plug loads
ii. Routine practice of keeping appliances on STANDBY MODE that drains power when the appliance is idle and performing no task
iii. Unnecessary installation of printers, photocopiers and other plug loads that can be shared in office spaces

4.9.4. AUTOMATED VOLTAGE REGULATOR SCENARIO: EXISTING CONDITIONS

4.9.4.1 BASELINE ASSESSMENT

These fixtures constitute the least energy demand amongst other loads at 4%. The total capacities of the installed Automatic Voltage Regulators and Uninterrupted Power Supply (UPS) appliances was estimated at 3,429 kW but consuming 171 kW. In most cases, the load capacities of the voltage stabilizers were underutilized.

4.10. ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

Opportunities exist in connection of more plug loads to Automatic Voltage Regulators and Uninterrupted Power Supply (UPS) appliances. The University can save money before and after installation Automatic Voltage Regulators and Uninterrupted Power Supply (UPS) appliances if proper assessment of the need to procure a voltage regulator is done.

4.10. ENERGY CONSUMPTION METER SYSTEM

4.10.2. BASELINE ASSESSMENT

Majority of the feeder stations in the University use postpaid meters. The use of postpaid metering in the University has stirred controversy in issuance and payment of electricity bills. In 2021, the University consumed 3,160,123.20 kWh of electricity, a rise of 139.54 % when compared to 1,319,262 kWh consumed in 2019. The year 2020 wasn't considered due to the disruption caused by the Covid-19 pandemic.

4.10.3 ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

A sensible and constructive Energy Saving Measure for energy consumption meter system exist in the use of prepaid meters. The recent and frequent hike in electricity tariff demands a search for ways to cut cost. Consequently, installation of prepaid metering eliminates estimated billing and gives room for accuracy in the consumption and payment of bills.

The switch from postpaid to prepaid meter at the Water Works Unit remains a practical example in the University. The Unit witnessed a reduction in electricity consumption and billing. The Unit changed to prepaid in July 2021 and experienced a drop by 95.12% of its kWh in the succeeding months (see details in Table 1 in Page 13)

5.0. CONCLUSION

The energy audit of Benue State University, Makurdi has revealed significant opportunities for energy conservation and cost savings. The audit highlights the need for a holistic approach to managing energy consumption across the university's various segments.

5.1. SUMMARY OF FINDINGS

Key findings include the potential for substantial energy savings through lighting optimization and better management of plug loads. Switching to LED lighting in place of fluorescent and incandescent lamps will save up to 18% of the university's total energy demand and 40% of the college's energy demand. Overall, switching to LED lighting across the campus, has a potential of saving up to18% of the total energy demand. The overall energy demand due to lighting could be reduced to 74% of the existing load, translating to a savings of 26%. This would bring the energy demand due to lighting down to 3547.56 kW.

Also, the labor market's significant contribution to the total plug load emphasizes the need for targeted interventions. The labour market accounts for 497.25 kW, which is about 28% of the total plug load. It is recommended to install prepaid meters or meter the feeder supplying the labor market to ensure business owners pay for their energy consumption.

Additionally, the audit underscores the financial burden of fossil fuel usage and electricity costs from the public distribution company. These findings provide a strong case for exploring alternative energy sources and implementing energy-efficient technologies, like solar energy systems since Benue state has abundant solar energy resource.

5.2. INSTITUTIONAL READINESS

5.2.1. BASELINE ASSESSMENT

Opportunities were identified for improvement in energy production, consumption, and efficiency during the Energy Audit and Load Assessment exercise with one case scenario of energy misuse shown in figure 15. However, the University has no unit wholly committed to energy research and management.

Figure 15. Misuse of Energy System

5.2.2 ASSESSMENT OF THE PROPOSED ENERGY SAVING MEASURE

Production and consumption of sustainable energy in the University requires a proactive, organized, systematic coordination of procurement, research, conversion, distribution and use of energy to meet requirements in the University, considering environmental and economic objectives. It is recommended that the establishment of an Energy and Energy Efficiency Unit will be a novel action with the following responsibilities:

- Developing, coordinating, and implementing strategies and policies, aimed at reducing energy consumption
- Creating policies and systems for buying energy and helping with contract negotiations
- Providing technical and practical advice as well as offering training on energy efficiency and management
- Keeping accurate records and regularly collecting energy consumption data
- Carrying out plant inspections, focused on identifying EMOs
- Keeping up to date with legislation and opportunities in the energy sphere

5.3. RECOMMENDATIONS ON USE OF APPLIANCES

5.3.1. LIGHTING FIXTURES

1. Transition to LED Lighting: Replace all fluorescent and incandescent lamps with LED lighting to save up to 18% of the total energy demand.
2. Implement motion sensors and timers in low-traffic areas to further reduce unnecessary energy consumption.
3. Optimize Lighting Usage: Encourage the practice of switching off lights when not in use. Utilize natural daylight as much as possible to minimize the need for artificial lighting.
4. Light be turned OFF when not in use.
5. Reduce the number of lights per switch, to better manage lighting.
6. Reduce the number of excess lights per room, an example of such can be found in the University library
7. Installation of daylighting sensors in buildings and exterior common areas. The University can enforce this practice on new buildings for a start
8. Disconnect the live wire connected to the faulty light bulb (s) to avoid leakage of energy. In addition, magnetic ballast of the fluorescent should be replaced with electronic ballast. A ballast is a mechanism that regulates the amount of electricity required to start a light fixture and maintains a steady output of light. An electronic ballast is more efficient and saves 12% -25% of electricity when compared to magnetic ballast
9. Lighting upgrades and behavioral change of staff attitude towards lighting through Staff Energy Management Training

5.3.2 PLUG LOADS

1. Install Prepaid Meters:Install prepaid meters for individual shops and units, especially in the labor market, to ensure that business owners pay for the energy they consume.
2. Encourage Energy-Efficient Devices: Promote the use of energy-efficient devices such as laptops, which consume less power compared to desktop computers. Regularly audit and replace outdated or energy-inefficient plug load equipment.

5.3.3. AUTOMATIC VOLTAGE REGULATORS

1. Regular maintenance and upgrades: Conduct regular maintenance and inspections to ensure AVRs are functioning efficiently. Upgrade older models to modern, energy- efficient AVRs with advanced features like digital control and real-time monitoring.
2. Optimization of load distribution and integration: Ensure AVRs are appropriately sized for their loads and balance load distribution to enhance efficiency. In the same vein, power quality improvement measures such as use of surge protectors and harmonic filters to support AVR effectiveness should be put in place.

5.3.4. VENTILATION FIXTURES

1. Standardize Brands and Ensure Regular Maintenance: Use the same brand of air conditioners and fans throughout the university to reduce maintenance costs. Service air conditioners quarterly to ensure optimal performance and
2. Optimize Building Envelope and Usage Practices: Install sealed glass windows and doors to prevent air leaks and improve the efficiency of air conditioning systems. Also, place notices on both sides of doors to remind people to always close the door when entering or exiting an air-conditioned room, helping to maintain the desired temperature and reduce energy wastage.
3. Implement Energy-Saving Practices: Encourage switching off air conditioners when not in use and avoid setting them to lower temperatures continuously. In addition, the use electric fans whenever possible as a more energy-efficient alternative to air conditioning should be encouraged, as well as leveraging natural ventilation by using outside breeze when conditions are favorable, turning off the air conditioner completely to minimize electricity costs.
4. Correct Sizing of Equipment: Ensure that air conditioners are correctly sized for the rooms they are installed in to maximize efficiency and minimize energy consumption.

5.3.5 RECOMMENDATION FOR FURTHER STUDIES

Detailed Recording of Generator Repair Costs: To understand energy costs at Benue State University, record all diesel and petrol generator repair costs. This will identify frequent issues, support cost reduction, and improve budgeting and decision-making for maintenance and investments.

Enhance Detailed Energy Demand Analysis: Build upon the current energy demand analysis by incorporating more granular data and real-time monitoring tools. Also, continuously update the analysis to reflect changes in energy consumption patterns over time, considering seasonal and operational variations.

Further Segment Energy Demand: Extend the current classification by identifying sub- segments within the primary categories (e.g., specific types of lighting or different kinds of plug loads). Also, analyze energy consumption at more detailed levels to pinpoint additional opportunities for efficiency improvements.

Compile Comprehensive Energy Consumption Data: Collaborate with the public power distribution company to gather more detailed and long-term energy consumption records. In addition, include real-time data monitoring to enhance the accuracy of consumption patterns and peak demand periods.

Document Costs for Power Purchase of Fossil Fuels: Record detailed expenses for gasoline, diesel, and any other fossil fuels used across the university, and compare these costs with historical data to identify trends and opportunities for cost reduction.

Compare Costs from Different Energy Sources: Perform a detailed cost-benefit analysis of electricity consumed from the grid versus fossil fuel-generated power. Also, identify periods or scenarios where switching energy sources could result in cost savings.

Implement Advanced Power Optimization Techniques: Introduce advanced energy- efficient technologies such as smart lighting systems, occupancy sensors, and automated energy management systems. Regularly maintain and audit electrical infrastructure to prevent energy losses and ensure optimal performance.

Explore and Integrate Alternative Power Supply Options: Assess the feasibility of integrating renewable energy sources such as solar and wind power. Develop a phased plan for transitioning to renewable energy to reduce dependence on fossil fuels and lower overall energy costs.

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DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.