Energy Consumption and Power Quality Assessment in an Institutional Building: A Five-Year Sustainability Assessment

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Astract: The increasing electricity demand in institutional buildings necessitates the adoption of sustainable energy management strategies to improve operational efficiency. This study presents a five-year assessment (2020–2024) of electrical energy consumption and power quality in the Administration Building of Joseph Sarwuan Tarka University, Makurdi, Nigeria, with the objective of identifying major energy-consuming appliances and evaluating the building's electrical performance. An energy audit was conducted using appliance inventory, operational records, electricity consumption data, and power quality measurements. Appliance-level energy consumption, load distribution, and electricity cost were analysed. The relationship between power factor and reactive power was evaluated to assess electrical system performance. The results showed that lighting systems, air-conditioning units, and fans accounted for the highest proportion of electricity consumption, indicating that these load categories offer the greatest potential for energy conservation. Load distribution analysis further revealed that electrical energy demand was concentrated within a limited number of appliance categories highlighting the importance of targeted energy-efficiency interventions. In addition, the power quality assessment demonstrated a strong positive relationship between power factor and reactive power. This suggests a progressive improvement in electrical system performance and more efficient utilization of supplied electrical energy over the study period. The findings showed that integrating appliance-level energy assessment with power quality analysis would provide valuable insights for sustainable energy management in institutional buildings.

Keywords: *Energy Consumption; Power Quality; Energy Audit; Institutional Buildings; Sustainable Energy Management; Energy Efficiency; Power Factor; Reactive Power.*

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I. INTRODUCTION

Over the years, there has been an increasing global demand for energy security, environmental sustainability and efficient energy utilization. This demand comes as a result of the rapid urbanization, population growth, technological advancement, and expanding economic activities (Zeraibi et al., 2025). Amongst the largest consumers of energy worldwide, buildings account for approximately one-third of global final energy consumption (Jørgensen and Ma, 2025). Institutional buildings such as universities, government offices, hospitals and administrative complexes require continuous and reliable energy supply to support lighting, heating, ventilation, air conditioning (HVAC), office equipment, information and communication systems as well as other essential services. Consequently, improving energy efficiency in buildings has become a strategic priority for achieving sustainable development goals, reducing operational costs, and mitigating environmental impacts.

Sustainable energy management has emerged as an effective approach for enhancing building performance. This can be achieved using systematic monitoring, assessment and optimization of energy consumption. Unlike conventional energy management practices which primarily focuses on reducing energy usage, sustainable energy management emphasizes balancing energy efficiency, economic viability, environmental responsibility and occupant comfort (Mustapha et al., 2025). Furthermore, the implementation of energy audits, load profiling, appliance-level performance assessment and power quality evaluation enables facility managers to identify inefficiencies within electrical systems and develop evidence-based strategies for improving energy performance. These amongst other approaches are increasingly recognized as essential components of smart

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building management and sustainable infrastructure development (Alotaibi, 2025). University administrative buildings operate numerous energy-intensive appliances which collectively contribute to substantial electricity demand. As student populations increase, administrative operations become increasingly digitized thereby increasing the electricity consumption within these facilities. Therefore, universities face growing financial pressures associated with electricity procurement while simultaneously striving to improve operational efficiency and meet institutional sustainability objectives. Furthermore, understanding long-term energy consumption patterns becomes a necessity for informed planning, budgeting, and investment in energy-efficient technologies.

Despite these needs, the situation is quite challenging in developing countries such as Nigeria where electricity supply remains constrained. Nigeria has over decades been plagued with inadequate generation capacity, aging transmission and distribution infrastructure, network instability and frequent power interruptions (Olatunde, 2025). These amongst other challenges often compel institutions to rely on alternative energy sources such as diesel generators and hybrid renewable energy systems so as to maintain operational continuity. Although hybrid energy systems have improved electricity availability in many institutions, unreliable grid supply and increasing energy demand continue to affect operational efficiency thereby increasing energy-related expenditures (Ezeugwu et al., 2026). Also, power quality is a critical determinant of building energy performance. Constant electricity supply enhances productivity, protects sensitive equipment and minimizes disruptions to institutional activities (Audu and Zhenseh, 2026). On the other hand, electrical parameters such as power factor and reactive power influence the efficiency of energy utilization within building electrical systems. Poor power factor increases current demand, contributes to higher distribution losses and reduces overall system efficiency (Faleiro et al., 2026). Therefore, continuous monitoring of these parameters provides important information for evaluating electrical system performance and identifying opportunities for improving energy utilization.

Several studies have investigated energy consumption in commercial and institutional buildings through energy audits, appliance-level assessments and optimization techniques (Alhassan and Mauriello, 2026; Alyami et al., 2026). Previous research has shown that lighting systems, heating, ventilation and air-conditioning (HVAC) equipment and office appliances are among the dominant contributors to electricity demand in office buildings. Some studies have explored the application of artificial intelligence, mathematical optimization and building energy management systems to improve energy efficiency thereby reducing operational costs (Olagundoye et al., 2026). While these studies have contributed significantly to the advancement of sustainable building energy management, most focus on short-term monitoring periods or simulation-based analyses with limited operational datasets. Consequently, relatively few studies have examined long-term electrical energy consumption using multi-year operational data from institutional buildings in developing countries. This limits the availability of empirical evidence required to support strategic energy planning, infrastructure investment, and sustainable energy policy development within higher education institutions. Furthermore, there remains limited integration of appliance-level energy consumption, electricity cost analysis, power quality assessment, and power supply reliability within a single long-term evaluation framework. Most available studies emphasize individual aspects of building energy performance without providing a comprehensive understanding of how these factors collectively influence sustainable energy management.

Therefore, this study presents a five-year assessment of electrical energy consumption and power supply reliability in the administrative Building of Joseph Sarwuan Tarka University Makurdi, Nigeria. The study evaluates historical electricity supply data collected between 2020 and 2024, examines appliance-level energy consumption and electricity costs, and assesses key power quality indicators that is the power factor and reactive power. The study provides an evaluation of the building's electrical energy performance and identifies practical opportunities for improving energy efficiency and operational sustainability.

II. MATERIALS AND METHODS

➤ *Study Area*

This study was conducted at the Administrative Building of Joseph Sarwuan Tarka University. The building is the central administrative facility of the institution and accommodates several offices, conference rooms, administrative units, and service sections that require continuous electrical energy for daily operations. Electrical energy within the building is primarily utilized for lighting systems, air-conditioning units, desktop computers, printers, fans, refrigerators, photocopiers, and other office appliances necessary for administrative activities.

➤ *Data Collection*

The data used for this study was obtained from the Administration Building through field measurements, appliance inventory, utility records and operational logs maintained by the university. A work-through energy audit was performed to identify all electrical loads within the administration building and to determined their operating characteristics. Information obtained for each appliance category included; appliance type, number of installed units, rated power (w), average daily operating hour, usage frequency, monthly electrical consumption records, electricity tariff information, annual power factor records, reactive power measurements and historical power supply records between the year 2020 to 2024. The major appliance categories considered in this study include; lightening systems, air-conditioning units, fans, computers, printers, photocopiers, refrigerators and televisions.

➤ *Energy Consumption Profiling*

Energy consumption profiling was performed to evaluate the operational behaviour of electrical appliances within the building. The load demand profile was developed

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based on appliance operating schedules, rated capacities, and average daily usage duration. Furthermore, the relationship between power factor and reactive power within the Administration Building was investigated to assess the influence of reactive power demand on electrical system efficiency.

➢ *Electricity Cost Analysis*

The operational cost associated with each appliance category was estimated using the prevailing electricity tariff applicable during the study period. Electricity cost was computed as the product of energy consumption and unit electricity tariff. The total electricity cost for the Administration Building was obtained by summing the costs associated with all appliance categories. Appliance-level cost analysis was used to identify the major contributors to operational expenditure.

➢ *Power Supply Reliability Assessment*

Power supply reliability was assessed using historical operational records obtained between 2020 and 2024. The analysis focused on evaluating temporal variations in electricity availability and identifying trends in the building's electrical supply performance.

➢ *Power Quality Assessment*

Power quality assessment was carried out using annual power factor and reactive power records collected throughout the study period. Power factor was used as an indicator of the efficiency with which electrical power was utilized, while reactive power was evaluated to assess the contribution of inductive loads to overall system performance.

III. RESULTS AND DISCUSSION

➢ *Energy Consumption Profile of Office Appliances*

Fig 1 presents the annual energy consumption of major office appliances in the Administration Building under two operating conditions; without power factor correction and with power factor correction. A substantial reduction in energy consumption was observed across all appliance categories following power factor optimization. This demonstrates the influence of improved electrical efficiency on overall energy utilization. Lighting systems were the largest consumers of electrical energy. This accounts for approximately 20,500 kWh under without power factor correction operating conditions. Following power factor improvement, lighting energy consumption decreased to approximately 12,200 kWh. This represents the highest absolute reduction among all appliance categories. This significant decrease can be attributed to the extensive number of lighting fixtures distributed throughout the administrative building and their prolonged daily operating hours (Suzuki et al., 2026). Since lighting remains continuously operational during official working periods, even modest improvements in electrical efficiency translate into considerable annual energy savings.

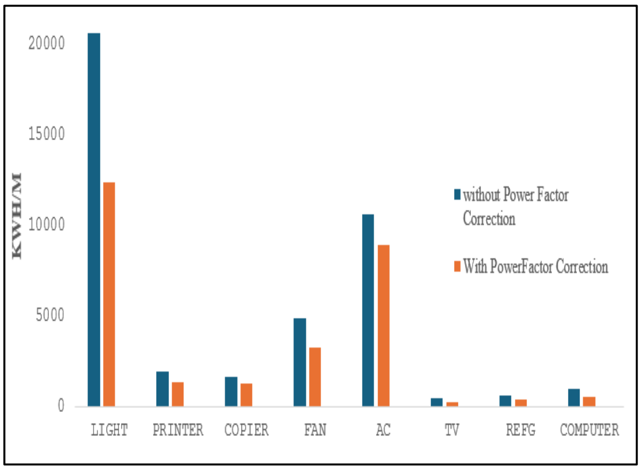

Fig 1 Energy Consumption Profile for Office Appliances

Air-conditioning units constituted the second-largest energy-consuming load with annual electricity demand decreasing from approximately 10,500 kWh to 8,900 kWh. The relatively high consumption is expected because cooling systems possess higher rated power and operate for extended periods, particularly under the prevailing tropical climatic conditions of Makurdi. Fans also demonstrated substantial energy demand decreasing from approximately 4,800 kWh to 3,200 kWh. Also, lighting, air-conditioning and fans accounted for the majority of the building's electricity consumption. This indicates that these three appliance categories provide the greatest opportunities for energy conservation. On the other hand, office equipment such as photocopiers, printers, desktop computers, refrigerators and televisions consumed smaller quantities of electrical energy. Nevertheless, measurable reductions were still achieved following power factor improvement. This indicates that efficiency enhancement benefits both high-power and low-power electrical loads. The observed reductions show that improving electrical operating conditions through power factor correction contributes not only to enhanced system efficiency but also to reduced annual electricity consumption across the entire building.

Furthermore, the results showed that targeted energy management strategies should primarily focus on lighting and cooling systems since interventions within these load categories are likely to yield the greatest improvements in building energy performance and reductions in operational costs. These findings are consistent with previous studies on institutional buildings by Jørgensen etal., (2025) and Mustapha et al., (2025) which have consistently identified lighting and HVAC systems as the dominant contributors to electricity consumption.

➢ *Distribution of Energy Consumption by Load Type*

Figure 2 illustrates the proportional distribution of total electrical energy consumption among the various appliance categories within the Administration Building. The results showed that electricity consumption is highly concentrated in a limited number of end-use categories with lighting having the largest share of the total annual demand. Air-conditioning systems constitute the second-largest followed by fans, while office equipment such as printers, photocopiers, refrigerators,

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computers, and televisions account for smaller proportions of total electricity consumption.

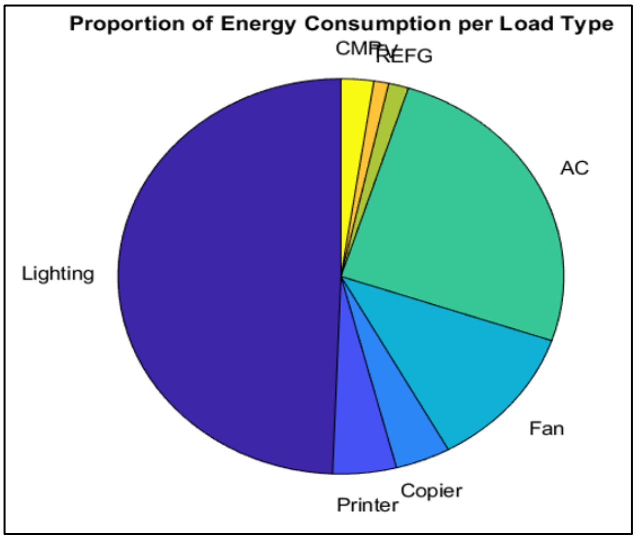


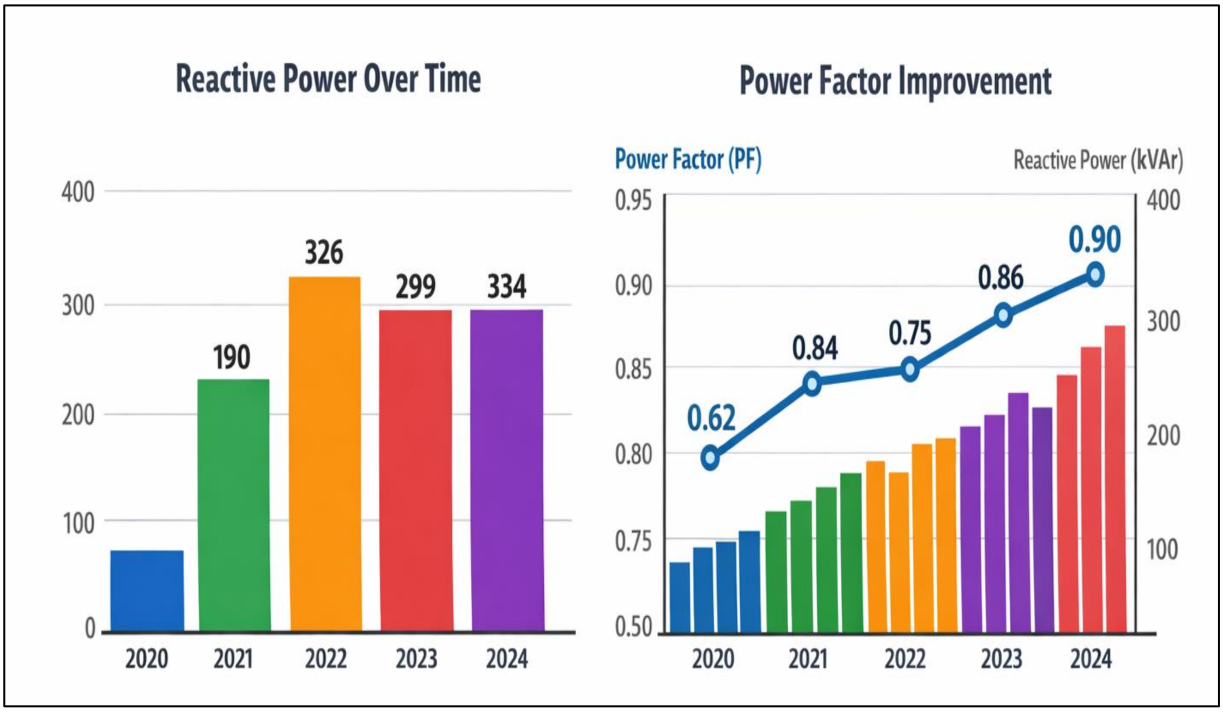
Fig 2 Energy Consumption by Load Type

The dominance of lighting and cooling loads demonstrates the operational characteristics of institutional office buildings. Here, adequate illumination and thermal comfort are essential for maintaining productivity and ensuring a conducive working environment. The extensive operating hours of lighting systems combined with the relatively high-power ratings of air-conditioning units explain their contribution to overall building electricity demand. Although individual office appliances consume relatively little energy, their combined contribution remains noticeable. This is because of the large number of units distributed throughout the building.

From a sustainable energy management perspective, the concentration of electricity demand within a few appliance categories provides a clear basis for prioritizing energy-efficiency interventions. Furthermore, upgrading conventional lighting systems to high-efficiency LED technologies, and implementing occupancy-based lighting controls would go a long way in reducing the buildings energy consumption. Also, inverter-driven air-conditioning units should be adopted and equipment maintenance improved so as to reduce the overall building energy consumption. Therefore, appliance-level energy profiling serves as an effective decision-support tool for identifying the most economically beneficial opportunities for improving energy efficiency in institutional buildings.

➢ *Nexus between Power Factor and Reactive Power*

Figure 3 (a and b) illustrates the relationship between power factor and reactive power within the Administration Building using monthly operational data collected between 2020 and 2024. The scatter distribution together with the fitted trend line demonstrates a clear positive correlation between the two variables. This indicates that variations in reactive power are closely associated with changes in the building's power factor throughout the study period. The results showed that power factor improved progressively from approximately 0.58 - 0.62 during the early stages of the monitoring period to values approaching 0.95 in later years. This improvement reflects enhanced electrical system performance resulting from better load management and the implementation of power factor correction measures. As the electrical network became more efficiently managed, the utilization of supplied electrical power also improved, thereby reducing unnecessary current flow and minimizing losses within the distribution system (Xie et al., 2021).



(a)

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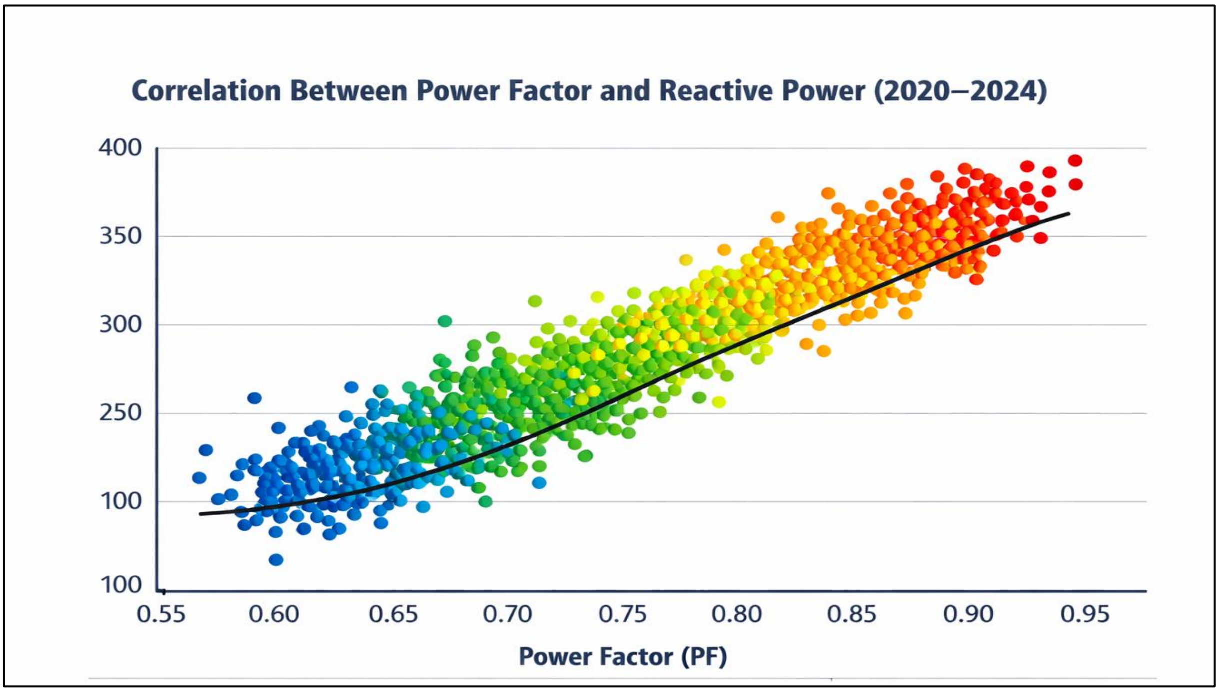

(b)
Fig 3 (a) Analytics of Power Supply to JOSTUM from 2020 – 2024 (b) Nexus between Power Factor and Reactive Power at JOSTUM

The corresponding increase in reactive power observed across the monitoring period should not be interpreted as a deterioration in electrical performance (Sadiq and Antar, 2024). Instead, it reflects the growing electrical demand associated with increased utilization of inductive loads such as air-conditioning systems, electric motors, and other office equipment. Under expanding building operations, higher reactive power requirements are expected because inductive equipment requires reactive energy to establish electromagnetic fields during operation. The concurrent improvement in power factor therefore indicates that reactive power was effectively compensated. This allows the system to accommodate increasing load demand while maintaining acceptable operating efficiency. The relatively tight clustering of data points around the regression line (see Figure 3b) suggests a strong and consistent relationship between power factor and reactive power over the five-year assessment period. This consistency indicates stable electrical operating conditions despite fluctuations in monthly demand and confirms that power quality remained within acceptable operational limits for most of the study period. Such stability is particularly important in institutional facilities where uninterrupted operation of office equipment, information technology infrastructure, and communication systems depends on reliable electrical performance.

The findings emphasize the importance of continuous monitoring of power quality parameters alongside conventional energy consumption indicators. Maintaining a high-power factor reduces apparent power demand, minimizes transmission and distribution losses, improves voltage regulation, increases transformer utilization efficiency, and lowers electricity costs associated with poor power quality. Therefore, periodic assessment of power factor and reactive power should form an integral component of institutional energy management programmes especially in facilities characterized by substantial inductive loads. Furthermore, the observed relationship shows that improvements in energy efficiency cannot be achieved solely through reductions in energy consumption. Effective management of power quality is equally essential for optimizing overall system performance, extending equipment lifespan and supporting the long-term sustainability of institutional energy infrastructure.

IV. CONCLUSION

This study presented a five-year assessment of electrical energy consumption and power quality in the Administration Building of Joseph Sarwuan Tarka University, Makurdi with the aim of identifying major energy-consuming loads and evaluating the energy performance of the building. The results showed that lighting systems, air-conditioning units, and fans were the dominant consumers of electricity accounting for the largest share of the building's total energy demand. Appliance-level energy profiling further showed that electricity consumption was highly concentrated within a few load categories, indicating significant opportunities for targeted energy-efficiency improvements. The analysis of power factor and reactive power showed a strong positive relationship over the study period this suggests progressive improvement in electrical system performance and more efficient utilization of supplied electrical energy. Generally, the findings revealed that integrating appliance-level energy assessment with power quality evaluation provides a framework for sustainable energy management in institutional buildings. It further highlights the importance of prioritizing energy-efficient lighting technologies, optimizing cooling systems, implementing routine power quality monitoring and conducting periodic energy audits to reduce energy consumption and improve operational efficiency. The findings provide valuable guidance for facility managers and university administrators in developing evidence-based energy management strategies and supporting broader efforts toward sustainable and cost-effective operation of institutional buildings.

REFERENCES

[1]. Alhassan, F. M., & Mauriello, M. L. (2026, June). Bridging Energy and Activity: Forecasting Residential Electricity Use with Wearable Activity Tracker Data. In *Proceedings of the 13th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation (BuildSys' 26)*. New York, NY, USA: Association for Computing Machinery.

[2]. Alotaibi, B. S. (2025). Context-aware smart energy management system: A reinforcement learning and IoT-based framework for enhancing energy efficiency and thermal comfort in sustainable buildings. *Energy and Buildings*, *340*, 115804.

[3]. Alyami, F. H., Alshammari, N. F., Alharbi, A. G., Iqbal, S., Shafiullah, M., & Al Dawsari, S. (2026). Forecasting residential demand response potential using thermal-response-derived targets and a mixture of KAN experts. *Mathematics*, *14*(10), 1716.

[4]. Audu, J., & Zhenseh, A. J. (2026). Stable Power Supply as a Catalyst for the Development *Journal of Innovation and Integrity*, *51*, 7-13.of Tertiary Institutions in Nigeria. *Spanish*

[5]. Ezeugwu, B. C., Anthony, E. I., Peter, E. O., Egbujor, O. C., Arome, O. P., Seidu, A., ... & Chidozie, E. C. O. Integrated Load Audit and Hybrid Renewable Energy Optimization for a Space Science Research Facility Using Particle Swarm Optimization and Genetic Algorithm Techniques.

[6]. Faleiro, N., Monteiro, R., Fonseca, A., Negrete, L., Lima, R., & Bonaldo, J. (2026). Comparative Review of Reactive Power Estimation Techniques for Voltage Restoration. *Energies*, *19*(3), 826.

[7]. Jørgensen, B. N., & Ma, Z. G. (2025). Energy efficiency and decarbonization strategies in buildings: a review of technologies, policies, and future directions. *Applied Sciences*, *15*(21), 11660.

[8]. Mustapha, Z., Abilgah, T., & Tieru, C. K. (2025). Enhancing energy efficiency and management in smart buildings: a holistic approach. *Journal of Applied Science and Technology Trends*, *6*(1), 16-24.

[9]. Olagundoye, O. O., Bamisile, O., Joseph Ejiyi, C., Bamisile, O., Ni, T., & Onyango, V. (2026). A Review of Artificial Intelligence Techniques for Low-Carbon Energy Integration and Optimization in Smart Grids and Smart Homes. *Processes*, *14*(3), 464.

[10]. Olatunde, I. (2025) Assessment of Grid Unreliability and Strategies for Improving Electricity Supply in Rivers State, Nigeria AUTHOR INFORMATION. *Optical Technique*, *34*(12).

[11]. Suzuki, T., Shimoda, Y., Matsuura, S., & Shiochi, S. (2026). Improving variable refrigerant flow system operation and energy efficiency: A study of the urban Minoh campus, Osaka, Japan. *Applied Thermal Engineering*, 129738.

[12]. Xie, Jihua, Chen, Chang, Long, Huan, A Loss Reduction Optimization Method for Distribution Network Based on Combined Power Loss Reduction Strategy, Complexity, 2021, 9475754, 13 pages, 2021. https://doi.org/10.1155/2021/9475754

[13]. Zeraibi, A., & Zhao, X. (2025). Enhancing energy security and environmental sustainability in G7 countries: the role of environmental regulations and green energy capacity: A. Zeraibi and X. Zhao. *Environment, Development and Sustainability*, 1-32.