International Journal of Innovative Research in Engineering and Management (IJIREM)
ISSN (Online): 2350-0557, Volume-10, Issue-6, December 2023
https://doi.org/10.55524/ijirem.2023.10.6.4
Article ID IJIR2479, Pages 31-35
www.ijirem.org

Analyzing Energy Consumption Patterns at Mbarara University of Science and Technology: A Case Study of the Academic Calendar Influence

Vicent Rutagangibwa[1], Evarist Nabaasa[2], Johnes Obungoloch[3], and Pius Ariho[4]

[1,2,3,4] Mbarara University of Science and Technology (MUST), Mbarara, Uganda, East Africa

ABSTRACT- This research paper presents a concise and factual analysis of energy consumption patterns at Mbarara University of Science and Technology (MUST) based on historical data from the calendar year 2019. The study focused on the interplay between the academic calendar and energy usage, revealing variations in energy demand. Key findings emphasize the necessity for tailored energy management strategies to accommodate these fluctuations. We introduced a linear regression model for precise energy predictions, highlighting the potential for future refinement. The research offers valuable insights into data-driven energy optimization at the institution, with implications for sustainability and cost-effectiveness.

KEYWORDS- Energy Consumption Patterns, Energy Management, Educational Institutions, Linear Regression Model, Sustainability, Data-Driven Optimization

I. INTRODUCTION

Energy consumption in educational institutions is subject to unique patterns due to the cyclic nature of academic calendars [1] [2]. This research investigates these patterns within the context of Mbarara University of Science and Technology (MUST[1]), with a particular emphasis on the influence of the academic calendar. Understanding and optimizing these energy consumption patterns are critical for sustainability, cost-effectiveness, and environmental responsibility [3].

Mbarara University of Science and Technology (MUST), one of the leading educational institutions in Uganda, is renowned for its dedication to science and technology education [4]. This dynamic university plays a pivotal role in advancing knowledge and innovation in the region. MUST predominantly relies on hydro-electric power as its primary energy source, supplemented by backup generators when necessary. It's important to note that the historical data analyzed in this research specifically pertains to the utility bills associated with hydro-electric power consumption at the university. This energy infrastructure underpins the institution's energy consumption patterns and serves as a noteworthy context for understanding the dynamics of energy usage within the university.

A. Background

1) Problem Statement and Justification

Educational institutions, such as MUST, grapple with substantial fluctuations in energy demand tied to the academic calendar's period [5]. This research aims to comprehend and manage these variations, particularly concerning the academic calendar's role in energy consumption. The problem statement arises from the need to align energy management with academic schedules, optimizing energy usage throughout the year. The justification lies in the potential for cost savings, environmental responsibility, and resource efficiency.

2) Abbreviations

MUST – Mbarara University of Science and Technology, Authors: [a] - 1st author, [b] - 2nd author

3) Research Objectives

The primary objective of this research is to deepen the understanding of energy consumption patterns at MUST, particularly within the context of the academic calendar. To achieve this overarching goal, the following specific objectives guide the study:

- Analyze energy consumption patterns at MUST, considering variations linked to the academic calendar.
- Introduce a data-driven energy prediction model based on historical data to support resource allocation and energy management.
- Recommend strategies for optimizing energy consumption, particularly during recess terms, to maximize energy savings.

4) Research Questions

Aligned with the research objectives, the following research questions steer this investigation:

- What are the energy consumption patterns at MUST, and how do they relate to the academic calendar's influence?
- How can historical data be leveraged to develop a data-driven energy prediction model for MUST?
- What strategies can be recommended for energy optimization during recess terms, and how can they maximize energy savings?

B. Academic Calendar Dynamics

The academic calendar serves as the heartbeat of educational institutions. It orchestrates the rhythm of academic life, delineating periods of heightened activity, such as teaching, examinations, and research, from recess terms, characterized by reduced academic engagements. The cyclic nature of the calendar presents a distinct challenge and opportunity for energy management. When the university is in session, there is an upsurge in energy demand, fueled by bustling lecture halls, research facilities, administrative operations, and student accommodations. However, during recess terms, the campus experiences a palpable lull, with reduced occupancy and academic activities leading to a marked decrease in energy requirements.

C. The Imperative of Energy Efficiency

Efficient energy management within educational institutions is paramount, not only for sustainability and cost-effectiveness but also for reducing environmental impact [6] [7]. The variations in energy consumption observed throughout the academic calendar underscore the need for tailored energy management strategies. Institutions must adapt to these fluctuations and implement measures to minimize energy waste during low-demand periods, all while ensuring the availability of energy when academic activities are at their peak.

II. LITERATURE REVIEW

The influence of the academic calendar on energy consumption patterns within educational institutions has been a subject of extensive research and critical analysis [8] [9]. Existing studies have consistently emphasized the central role of the academic calendar in shaping energy usage patterns at universities and colleges [10] [11]. Researchers in this field have explored the various challenges and opportunities presented by these patterns, offering valuable insights into the potential for cost savings, environmental responsibility, and efficient energy management. Many of these previous works have underscored the fluctuation of energy demand in correspondence with the ebb and flow of academic activities throughout the calendar year. Notably, the peak consumption periods during active semesters have raised concerns about the efficient allocation of resources and the sustainability of energy usage within educational institutions. The significance of addressing these challenges has been highlighted, with scholars and experts proposing tailored strategies and energy conservation measures to accommodate the peak periods and optimize energy consumption [12]. These strategies have been developed with the aim of achieving both economic and environmental goals, underscoring the importance of comprehensive energy management approaches.

In this context, the present research seeks to contribute to the existing body of knowledge by conducting an in-depth analysis of energy consumption patterns at Mbarara University of Science and Technology (MUST). The primary focus is on the influence of the academic calendar and the opportunities for energy optimization within the university setting. The critical analysis of related literature has paved the way for this research, highlighting the need for a more detailed examination of energy consumption trends and providing the foundation for exploring novel research findings in this field. By synthesizing the insights from past studies and considering the unique context of MUST, this research aims to provide a comprehensive understanding of energy consumption patterns and the potential for tailored energy management strategies.

III. MATERIAL AND METHODS

A. Data Collection

The research initiated by requesting and acquiring historical energy consumption data from Mbarara University of Science and Technology (MUST) for the entire calendar year of 2019. The dataset, encompassing monthly records of energy consumption in kilowatt-hours (KWh), associated costs, and cost per KWh, was meticulously acquired from the MUST estates department.

B. Data Preprocessing

In pursuit of data accuracy and consistency, rigorous data preprocessing was undertaken. This phase involved the meticulous cleaning of the dataset to rectify any missing or erroneous entries. Simultaneously, an exhaustive process of standardizing units and structures was conducted, ensuring a dataset with uniform formatting, ready for in-depth analysis.

C. Data Analysis

1) Descriptive Analysis

An extensive descriptive analysis was executed to extract vital insights from the dataset. This encompassed the computation of essential statistical metrics, including mean, median, and standard deviation. These calculations provided an intricate understanding of the central tendencies and variations embedded within the energy consumption patterns.

2) Time Series Analysis

To unveil recurring patterns and trends in energy consumption over time, a comprehensive time series analysis was conducted. This in-depth examination sought to illuminate fluctuations in energy usage, with a particular focus on the influence of the academic calendar.

D. Linear Regression Model

An innovative approach was adopted in the form of a linear regression model to predict energy consumption. Leveraging historical data from 2019, the model was methodically trained to estimate energy consumption for specific months. Variables such as the academic semester, month, and the presence of potential recess terms were factored into the model to enhance predictive accuracy.

E. Scope, Limitations, and Recommendations

The research remains acutely aware of its limitations, stemming primarily from the reliance on a single-year dataset and the exclusion of certain influential factors in energy consumption. In light of these considerations, the study offers robust recommendations for future research. These include the imperative need for multi-year data, a call for comparative analyses, and the exploration of additional variables to refine predictive models and optimize energy management.

F. Theoretical Framework

The analysis of energy consumption patterns at Mbarara University of Science and Technology (MUST) is rooted in a comprehensive theoretical framework. This framework is built on the premise that energy consumption in educational institutions is influenced by various factors [13] [14], with a particular focus on the academic calendar. Understanding these influences is vital for effective energy management.

1) Academic Calendar

The academic calendar in educational institutions like MUST is marked by distinct periods, including semesters, recess terms, and breaks. These periods have a direct impact on the presence of students, academic activities, and overall energy demand. We explore the cyclical nature of energy consumption in relation to the academic calendar and how it varies throughout the year.

2) Practical Developments

While the theoretical framework provides valuable insights into the factors influencing energy consumption, this research paper also introduces practical developments that contribute significantly to the analysis of energy consumption patterns and the formulation of actionable recommendations for energy management.

- *Introduction of a Data-Driven Energy Prediction Model*

  A notable practical development introduced in this research is the implementation of a data-driven energy prediction model. This model leverages historical energy consumption data to estimate and predict energy consumption with a high degree of precision. The integration of this model into the research framework serves as a practical tool to forecast energy demand based on historical trends and related variables. This practical innovation is essential for enhancing the university's energy management capabilities, offering valuable insights for efficient resource allocation and financial planning.

- *Examination of Special Recess Terms and Opportunities for Optimization*

  Another practical dimension of the research focuses on the examination of energy consumption patterns during special recess terms, including the holiday break in December and January, as well as the period between May and August. These findings reveal substantial reductions in energy consumption during these recess terms when campus activities are less intensive. The practical implication of this observation is the identification of opportunities for energy optimization. Recommendations for implementing energy-efficient measures during these periods can lead to significant cost savings and environmental benefits, thereby contributing to more sustainable and responsible energy management.

IV. RESULTS AND DISCUSSION

A. Energy Consumption Trends

The median and mean energy consumption figures (36,257.50 KWh and 35,035.40 KWh, respectively) hold paramount significance in the context of efficient energy management at Mbarara University of Science and Technology (MUST). They offer essential benchmarks that help in gauging and optimizing energy usage. The median serves as a reliable baseline for typical energy consumption, ensuring that day-to-day operations and activities align with sustainable energy practices. Meanwhile, the mean energy consumption figure represents the general average, providing valuable insights for setting energy efficiency targets and enhancing resource allocation. By focusing on these figures, MUST can make informed decisions and take concrete steps towards more sustainable energy consumption

B. Time Series Plot

The Time Series analysis reveals a consistent pattern of higher energy consumption in Semester 1 (August to December), attributed to the academic start, increased occupancy, and heightened energy demands, with particular surges in the early academic year, highlighting the need for targeted energy management strategies during this period.

Significantly, the Time Series graph underscores the pronounced reduction in energy consumption from April to July, directly correlated with academic recess terms. This decline showcases the efficiency and resource conservation achieved during periods of reduced campus occupancy, aligning with sustainability goals and responsible energy management.

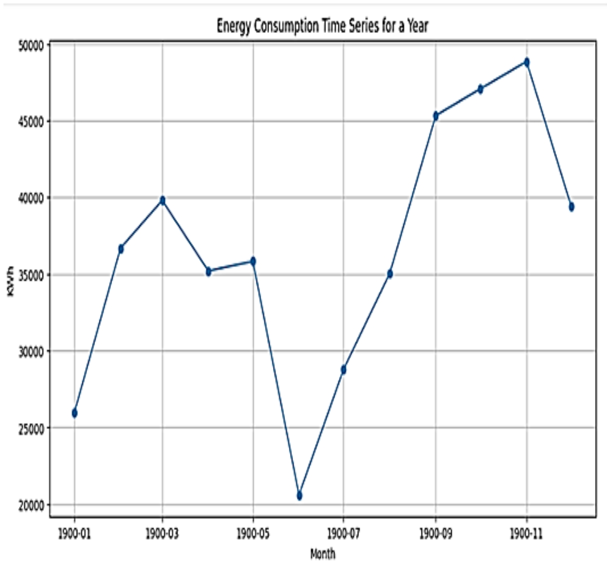

Figure 1: Time series annual energy plot [2019]

C. Bar Chart

The bar chart showcases distinct fluctuations in energy consumption, aligned with the academic calendar. It highlights the higher energy usage during the academic semester, followed by lower consumption during recess terms.

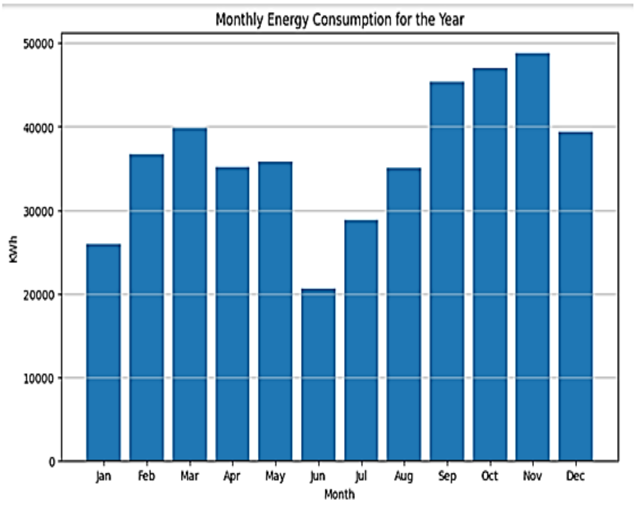

Figure 2: Bar chart showing the annual energy consumption [2019]

D. Box Plot

The box plot reveals a central tendency for energy consumption between approximately 35,000 KWh and 40,000 KWh. This concentration of data signifies that a significant portion of energy consumption falls within this range, reflecting the typical usage pattern during the year. It validates our dataset's findings of seasonal variations, with the lower range corresponding to periods of reduced energy demand, such as academic recess terms, and the higher range associated with the academic semesters.

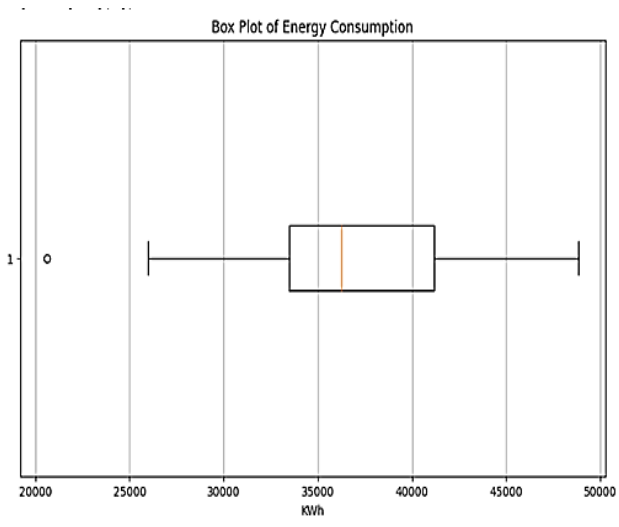

Figure 3: Box plot of annual energy consumption [2019]

V. DISCUSSION

The analysis conducted in this study sheds light on the profound influence of the academic calendar on energy consumption patterns at Mbarara University of Science and Technology (MUST). Several key findings and insights emerge from our research that bear significance for energy management and sustainability at the university.

A. Influence of the Academic Calendar

The academic calendar stands out as a pivotal factor affecting energy consumption. Our analysis vividly illustrates the variations in energy usage linked to the ebb and flow of university activities. It is evident that energy consumption tends to surge during peak academic semesters, notably in the months of August to December and January to May. The increased energy demand during these periods corresponds with the higher presence of students, faculty, and staff actively engaged in teaching, research, and administrative activities. This highlights the need for efficient energy management strategies that can accommodate these peaks and, more importantly, harness opportunities for energy savings during recess terms.

B. Recess Terms and Energy Efficiency

One of the most significant findings of our research pertains to recess terms, such as the break between May and August and the holiday break in December and January. These periods exhibit a marked decrease in energy consumption. The university experiences reduced occupancy levels and reduced academic activities during these times, leading to lower energy demands. This pattern suggests an opportunity for substantial energy savings when the campus is less active. Thus, we recommend implementing energy-efficient measures and strategies specifically tailored for recess terms to maximize energy conservation and cost-effectiveness.

C. Linear Regression Model for Energy Prediction

To further enhance energy management at MUST, this research introduces a linear regression model for energy prediction. This model leverages historical data from the year 2019 to estimate energy consumption for specific months. The inclusion of variables such as academic semester, month, and potential recess terms makes the model adaptable to the university's academic schedule. It serves as a valuable tool for predicting energy needs, aiding in resource allocation, budget planning, and sustainability efforts.

D. Future Directions

While our research provides valuable insights into energy consumption patterns and introduces a predictive model, it is essential to recognize the potential for further refinement. Future research endeavors could explore the inclusion of additional variables, such as weather data or specific building utilization patterns, to enhance the accuracy of energy predictions. Long-term studies, spanning multiple years, would offer a more comprehensive perspective on energy consumption trends and assist in the development of more robust energy management strategies.

VI. CONCLUSION

This research provides valuable insights into energy consumption patterns at Mbarara University of Science and Technology (MUST) based on data from the year 2019. The primary findings and conclusions of the study are as follows:

A. Academic Calendar Influence

The study highlights the substantial impact of the academic calendar on energy consumption at MUST.

Energy demand correlates with the ebb and flow of academic activities, emphasizing the importance of dynamic energy management aligned with the university's academic schedule.

B. Opportunities during Recess Terms

Notably, energy consumption decreases significantly during recess terms, offering opportunities for implementing energy-efficient measures. Implementing energy conservation strategies during these periods can result in substantial energy savings and cost-effectiveness.

C. Data-Driven Energy Optimization

The introduction of a linear regression model for energy prediction is a significant step toward data-driven energy management. This model, based on historical data, provides a tool for estimating energy consumption with precision. The potential for refinement and the inclusion of additional variables to enhance accuracy are evident.

D. Recommendations and Future Directions

The study recommends the adoption of dynamic energy management strategies that accommodate the fluctuations in the academic calendar. Additionally, specialized energy conservation measures during recess terms can maximize energy savings and cost-efficiency. This research underscores the importance of ongoing efforts to address data limitations and improve energy predictions.

In summary, this research deepens our understanding of energy consumption patterns and offers a pathway to more efficient energy management at MUST. By implementing the recommended strategies and engaging in further research, the university can strengthen its commitment to sustainable and data-driven energy practices.

VII. ACKNOWLEDGMENTS

The authors express their gratitude to the MUST estates department for providing access to the historical energy consumption dataset.

Funding: This work was supported by the Deutscher Akademischer Austauschdienst (DAAD) German Scholarship, which provided financial support for the primary researcher's PhD studies. Additionally, Mbarara University of Science and Technology (MUST) facilitated this research by providing the dataset at no cost.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] Zhukovskiy, Y et al, "Development of an algorithm for regulating the load schedule of educational institutions based on the forecast of electric consumption within the framework of application of the demand response," Sustainability, vol. 13, no. 24, p. 13801, 2021.

[2] Sen, G et al, "Achieving sustainability and carbon neutrality in higher education institutions: a review," Sustainability, vol. 14, no. 1, p. 222, 2021.

[3] A. Prashar, "Towards sustainable development in industrial small and Medium-sized Enterprises: An energy sustainability approach," Journal of Cleaner Production, vol. 235, pp. 977-996, 2019.

[4] Tashobya, C et al, "Employee Training and Job Satisfaction in Western Uganda: Empirical Evidence from Mbarara University of Science and Technology," European Journal of Human Resource, vol. 6, no. 1, pp. 1-15, 2022.

[5] Leal Filho et al, "A comparative study of approaches towards energy efficiency and renewable energy use at higher education institutions," Journal of cleaner production, vol. 237, p. 117728, 2019.

[6] S. &. J. R. Ramakrishna, "Addressing sustainability gaps," Science of The Total Environment, vol. 806, p. 151208, 2022.

[7] Papadakis, N et al, "A Review of Energy Efficiency Interventions in Public Buildings," Energies, vol. 16, no. 17, p. 6329, 2023.

[8] Caeiro, S et al, "Sustainability assessment and benchmarking in higher education institutions—A critical reflection," Sustainability, vol. 12, no. 2, p. 543, 2020.

[9] Sun, Y et al, "A review of the-state-of-the-art in data-driven approaches for building energy prediction," Energy and Buildings, vol. 221, p. 110022, 2020.

[10] T. &. d. W. P. Harputlugil, "The interaction between humans and buildings for energy efficiency: A critical review," Energy Research & Social Science, vol. 71, p. 101828, 2021.

[11] Gan, V. J et al, "Simulation optimisation towards energy efficient green buildings: Current status and future trends," Journal of Cleaner Production, vol. 254, p. 120012, 2020.

[12] Pearre, N et al, "Proportioning wind, solar, and in-stream tidal electricity generating capacity to co-optimize multiple grid integration metrics," Applied Energy, vol. 247, pp. 69-77, 2019.

[13] Hu, S et al, "A systematic review of occupant behavior in building energy policy," Building and Environment, vol. 175, p. 106807, 2020.

[14] Xue, C et al, "Clean energy consumption, economic growth, and environmental sustainability: what is the role of economic policy uncertainty?" Renewable Energy, vol. 184, pp. 899-907, 2022.