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Assessing the Nature of Energy Consumption in Institutions of Higher Education

Henry Kwaku Boafo[1], Raphael Akponzele[2], Yvonne Dede Adai Tetteh[3], Romanus Dokgubong Dinye[4]

[1,2,3,4] Centre for Settlement Studies, Kwame Nkrumah University of Science and Technology, Ghana

[1,4]Land Economy Department, Kwame Nkrumah University of Science and Technology, Ghana

ABSTRACT: This paper aims to identify key consumption drivers, evaluate students' awareness of energy conservation, and propose sustainable strategies. A mixed-method approach was employed, using surveys with open and close-ended questions to collect data from 373 students. This paper analyses students' reliance on various energy sources, their engagement in conservation practices, and barriers to efficiency. The findings indicate a heavy dependence on the National Grid with limited adoption of renewable energy sources. Cooking and learning activities were identified as the most energy-intensive, whereas metered billing influenced consumption behaviors. Although students demonstrated a high awareness of environmental impacts, their participation in energy-saving practices varied, particularly in the management of high-energy appliances. Financial constraints, inadequate institutional policies, and limited access to energy-efficient technologies have been identified as the key barriers to conservation. Policy interventions are recommended in terms of investment in renewable energy, LED lighting adoption, and enhanced education on conservation. By addressing these challenges, universities can optimize their energy efficiency, reduce costs, and promote sustainable resource use. The findings contribute to broader sustainability efforts and offer practical solutions for improving energy management in higher education institutions.

KEYWORDS*:* Energy, Energy Consumption, Energy Conservation, Energy Efficiency, Energy Sustainability

1. INTRODUCTION

Assessing energy usage in higher education institutions is vital, as it affects environmental sustainability, financial efficiency, and social responsibility. Universities and colleges are among the largest energy consumers due to their extensive infrastructure, which includes lecture halls, laboratories, residential facilities, and administrative offices. These institutions are centres of learning and hubs of research and innovation, making their energy consumption patterns a matter of global concern. The growing emphasis on sustainability and the need to mitigate climate change have further underscored the importance of understanding and optimizing energy use in higher education institutions (Mastoi et al., 2022).

The nature of energy consumption in universities is complex, influenced by factors such as the size of the institution, the number of students and staff, the types of facilities, and the geographic location. Energy is consumed for various purposes, including lighting, heating, cooling, ventilation, and the operation of electronic devices and research equipment. The residential aspect of universities, where students live in on-campus halls, adds another layer of complexity, as these facilities require continuous energy supply for daily activities such as cooking, bathing, and studying (Kifor et al., 2023).

Specialized equipment in laboratories and research facilities further increases energy consumption (Heubaum & Biermann, 2015). Dormitories and student accommodation require significant energy for heating, cooling, and electrical services (Sanni-Anibire & Hassanain, 2016). Recreational Facilities such as gyms, sports complexes, and other recreational facilities on campuses consume significant energy for lighting, heating, and equipment operation prompting universities to implement energy-efficiency measures to realize significant energy savings and environmental benefits [5].

Globally, higher education institutions are increasingly recognizing the need to adopt sustainable energy practices. Many universities in developed countries have implemented energy efficiency measures and renewable energy projects to reduce their environmental impact. For instance, universities in the United States and Europe have been at the forefront of integrating solar panels, wind turbines, and energy-efficient building designs into their campuses (Moran et al., 2010). These initiatives are often

driven by institutional policies, government regulations, and the growing demand from students and staff for more sustainable practices (Goetzberger & Hoffmann, 2005).

In the United States, the University of California has set ambitious goals to achieve carbon neutrality by 2025, with a strong focus on energy efficiency and renewable energy (Patel, 2020). Similarly, in Europe, the University of Edinburgh has implemented a comprehensive energy management plan that includes the use of smart meters, energy audits, and the installation of solar panels (Wang, 2020). These examples highlight the potential for universities to lead by example in the transition to a more sustainable energy future.

However, the adoption of sustainable energy practices is not uniform across the globe. In many developing countries, universities face significant challenges in implementing energy efficiency measures due to financial constraints, lack of infrastructure, and limited access to renewable energy technologies (Pérez-Lombard et al., 2018). Despite these challenges, there is a growing recognition of the importance of sustainable energy practices in higher education, and many institutions are beginning to explore innovative solutions to reduce their energy consumption and carbon footprint (Berardi, 2019).

In Africa, the issue of energy consumption in higher education institutions is particularly pressing. Many universities in the region face significant challenges related to energy access, reliability, and affordability. The reliance on conventional energy sources, such as grid electricity and diesel generators, is common, but these sources are often unreliable and expensive, leading to frequent power outages and high energy costs (Mwangi et al., 2021). Some African universities are beginning to explore renewable energy options, such as solar power, to reduce their dependence on conventional energy sources. For instance, the University of Cape Town in South Africa has implemented a solar energy project that provides clean energy to parts of the campus, reducing both energy costs and carbon emissions (Ürge-Vorsatz, 2020). These initiatives demonstrate the willingness for African universities to adopt sustainable energy practices, but much more needs to be done to address the region's energy challenges.

According to data from the World Bank, access to electricity in Ghana was reported at 85.1% in 2022. However, the per capita electricity consumption decreased during the same period owing to high costs, making electricity unaffordable for many. Ghana was among the first countries to develop an energy action plan for all initiatives in response to global energy sustainability. Enhancing energy efficiency through building design and smart grid technologies is essential for reducing energy consumption and promoting sustainable development (Kifor et al., 2023). The evolving global energy landscape, driven by rising demand, geopolitical factors, and sustainability efforts, has also impacted universities as major energy consumers. Institutions worldwide are adopting energy-efficient systems and renewable technologies to optimize consumption. In Ghana, universities face unique challenges related to energy reliability and affordability. As a leading technical institution in Africa, KNUST serves as a key case study for examining consumption patterns, inefficiencies, and sustainable solutions.

This paper, a drama from a core study at KNUST, aims to analyse energy consumption patterns in KNUST's on-campus residences, assess the impact of student activities on energy use, and identify opportunities for energy efficiency and sustainability improvements, in alignment with the United Nations' Sustainable Development Goals (SDGs) 7, 11, 12, and 13. The objectives of this paper are to (i) assess students' energy consumption patterns, (ii) analyse students' level of awareness and engagement with energy conservation initiatives, (iii) evaluate how KNUST's policies influence energy use in on-campus housing, (iv) collect insights on student energy habits, and (v) propose measures to enhance energy efficiency and sustainability at KNUST. The findings of this paper will assist in reducing the university's carbon footprint, achieving cost savings, and promoting sustainable resource use.

2. OVERVIEW OF LITERATURE

The main purpose of this paper is to assess the nature of energy consumption in institutions of higher education, with a specific focus on university halls located at Kwame Nkrumah University of Science and Technology (KNUST). The primary objective of this review is to identify the factors that influence energy utilization in university halls and provide an in-depth understanding of the existing knowledge on the topic. According to Heubaum & Biermann, (2015), the energy sector is responsible for approximately 40% of global CO_2 emissions and contributes significantly to climate change. Previous research has highlighted the significant impact of energy consumption on the environment, and it is crucial to adopt sustainable energy practices, particularly in the built environment.

2.1 Energy Consumption Patterns

Energy consumption in university residences represents a significant challenge as institutions strive to enhance sustainability and mitigate their environmental impact. Residential buildings, particularly those used by universities, rank among the largest consumers of energy globally. Key contributors to energy usage in these settings include heating, cooling, lighting, and other electrical appliances, all of which account for substantial portions of total energy consumption (IEA, 2021). According to the United Nations Environment Program (UNEP, 2022), buildings collectively contribute approximately 36% of global energy demand and

are responsible for 39% of CO_2 emissions. This data underscores the pressing need for universities to adopt energy-efficient strategies within student accommodations to address environmental concerns.

Various studies examining energy consumption patterns in university residences indicate significant variations influenced by multiple factors. One of the primary determinants is academic schedules, which heavily influence peak energy demand. Research shows that energy usage tends to peak in the evenings and late at night when students are most engaged in academic and recreational activities (Li et al., 2021). This trend highlights the importance of understanding how daily routines and study habits can impact overall energy consumption.

Seasonal fluctuations also play a critical role in energy demand. During colder months, there is an uptick in electricity use for heating, while warmer months see increased reliance on air conditioning to maintain comfortable living environments (Patel & Wang, 2019). For instance, research by Li et al. (2021) in several Chinese universities found that energy consumption dramatically increases during examination periods. This spike is largely attributed to extended study hours and a heightened reliance on electronic devices, such as laptops and study lamps, as students prepare for their examinations.

Furthermore, the types of electrical appliances utilized by students constitute another significant factor affecting total energy demand. Students frequently use energy-intensive appliances, including electric kettles, irons, televisions, refrigerators, and personal computers, all of which contribute to overall electricity usage in their accommodations (Kariuki et al., 2023). A study conducted at the University of Cape Town revealed that inefficient usage of these appliances led to a staggering 40% increase in energy consumption. This surge was primarily due to students leaving devices powered on unnecessarily or neglecting to use available energy-saving settings (Nyambane & Oketch, 2021).

These findings indicate a dual opportunity for universities: the need to promote energy-conscious behaviors among students and the potential for implementing institutional strategies aimed at the efficient use of appliances. By fostering awareness about energy consumption and providing education on energy-saving practices, universities can substantially reduce their energy usage while contributing to broader sustainability goals. Developing programs that encourage students to adopt energy-saving habits, coupled with the installation of energy-efficient appliances, could result in meaningful reductions in overall energy consumption in university residences.

2.2 Students' Engagement with Energy Conservation

Students' engagement in energy conservation initiatives plays a crucial role in minimizing energy waste within university halls of residence. While the potential for impact is significant, many students demonstrate limited awareness of their energy consumption habits and the broader environmental implications of their usage. For instance, research conducted by (Schleich & Faure, 2019), reveals that only 30% of students surveyed across various European universities were conscious of their daily energy consumption levels. The majority expressed a notable lack of familiarity with effective energy conservation strategies. This gap in awareness presents a barrier to achieving meaningful reductions in energy waste, highlighting the need for targeted educational interventions.

Educational programs aimed at raising awareness and promoting behavioral change have shown promising results in fostering sustainable energy practices among students. A notable example comes from a study conducted at the University of Reading, where it was found that students who participated in sustainability awareness programs successfully reduced their energy consumption by 15% compared to their peers who did not engage in any training (Turner & Gill, 2021). This demonstrates the tangible benefits of education in enabling students to make informed choices regarding their energy use. Furthermore, a behavioral experiment at the University of Toronto illustrated the effectiveness of providing students with real-time feedback on their electricity usage. The results were compelling, indicating a 20% reduction in energy consumption among students who received this feedback (Chen et al., 2020). Collectively, these findings suggest that targeted educational efforts play a pivotal role in enhancing student engagement in energy conservation.

Another critical factor influencing energy-saving behaviors in student residences is peer influence. Research by (Goldstein et al., 2018) indicates that students are more inclined to adopt energy-efficient practices when they witness their peers engaging in similar actions. This social dynamic underscores the importance of fostering a community that values energy conservation. Implementing social norm interventions, such as hosting energy-saving competitions between residence halls, has proven effective in motivating responsible energy consumption habits (Zhou et al., 2021). Such initiatives create a sense of friendly rivalry and enhance collective accountability among students as they strive to outdo one another in reducing energy usage.

Despite the merits of these interventions, challenges persist in sustaining long-term commitment to energy conservation practices among students. Research conducted by (Sun et al., 2022) highlights a common trend where students often revert to their previous, less energy-conscious habits once awareness campaigns conclude. This tendency underscores the importance of establishing ongoing support systems and initiatives that can help reinforce the lessons learned during educational interventions.

By embedding energy conservation practices into the fabric of residence life, universities can create an environment conducive to sustainable behaviors.

To effectively address these challenges, institutions might consider implementing continuous engagement strategies that extend beyond initial awareness campaigns. For example, regular workshops, interactive challenges, and ongoing access to real-time energy consumption data can keep energy conservation at the forefront of student consciousness. Additionally, building a culture of economic and environmental sustainability within university residences through the active participation of both students and staff can encourage a collective commitment to energy-efficient practices. By fostering an environment where sustainable behaviors are regularly celebrated and reinforced, universities can help ensure that energy conservation becomes a lasting part of student life, ultimately contributing to broader sustainability goals and a reduction in environmental impact.

2.3 Institutional Influence on Energy Use

The role of university policies in shaping energy consumption behavior among students is a crucial aspect of sustainability efforts in higher education institutions. Universities serve as microcosms of broader societal energy consumption patterns, and the policies they adopt can significantly influence student attitudes and behaviors toward energy use. Institutions that implement structured energy management policies have been found to achieve substantial reductions in electricity consumption, demonstrating the impact of regulatory frameworks and incentive-based mechanisms (Gillingham et al., 2020).

A notable example of a successful policy-driven intervention is the University of Oxford's Sustainable Buildings and Energy Strategy, which led to a 25% reduction in campus-wide energy consumption over five years. This success was attributed to targeted interventions such as the deployment of smart lighting systems, motion sensor-based controls, and the introduction of metered billing for student residences, which encouraged more mindful energy consumption habits University of Oxford, 2022). Such policy measures create an environment where students are aware of their energy usage and are actively encouraged to adopt more responsible consumption practices.

Universities can exert influence on student behavior through a variety of policy measures, including the establishment of mandatory energy efficiency standards, incentivizing conservation efforts, and integrating sustainability principles into student orientation programs (Evans et al., 2019). The University of Ghana presents another compelling case study, where the introduction of prepaid electricity meters in student hostels resulted in a 35% decrease in 'unnecessary' power usage. This intervention effectively made students more conscious of their energy expenditures, as they could directly feel the financial impact of their excessive consumption (Boateng et al., 2022). Policies such as these leverage behavioral economic principles, wherein users modify their consumption patterns in response to financial costs and visible feedback mechanisms.

However, despite the potential benefits of such policies, a major challenge in their implementation is ensuring compliance and enforcement. Studies suggest that while energy policies may be well-structured, their effectiveness largely depends on proper monitoring, student cooperation, and institutional commitment (Kariuki et al., 2023). In many instances, students may not adhere to energy-saving regulations due to a lack of awareness, indifference, or resistance to behavioral change. Additionally, universities often face financial constraints that limit their ability to invest in energy-efficient infrastructure, such as modernized heating, ventilation, and air conditioning (HVAC) systems or renewable energy installations (Nguyen & Le, 2021). Outdated infrastructure remains a persistent barrier, particularly in developing countries, where institutions may struggle with resource allocation to support large-scale energy efficiency programs.

Addressing these issues requires a multifaceted approach that includes stronger institutional commitment, stakeholder collaboration, and increased investment in smart energy solutions. Universities must adopt a proactive role in formulating policies and ensuring their effective implementation through continuous assessment and adaptation. Collaborating with government agencies, private sector entities, and sustainability-focused organizations can help secure funding and technical expertise for sustainable energy initiatives. Furthermore, integrating economic and environmental sustainability education into curricula and student-led programs can foster a culture of environmental responsibility, ensuring that energy-efficient behaviors extend beyond university residences and into broader society.

By leveraging policy-driven approaches and embracing technological advancements, universities can play a pivotal role in reducing energy consumption and promoting economic and environmental sustainability. These efforts align with global sustainability targets such as the United Nations' Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production). As higher education institutions continue to evolve, their policies and initiatives will be instrumental in shaping the next generation of energy-conscious citizens who prioritize economic and environmental sustainability in their daily lives.

2.4 Behavioral Factors and Energy Use

Behavioral psychology plays a significant and often underestimated role in shaping energy consumption patterns, particularly in student residences. The way individuals perceive energy usage, combined with their attitudes, social influences, and sense of control over their behavior, can either encourage or discourage energy-saving habits. The Theory of Planned Behavior (TPB), developed by Ajzen (2020), provides a robust framework for understanding how these factors influence energy-related decision-making. According to the TPB, an individual's intention to perform a behavior is determined by three key elements: their attitudes toward the behavior, the subjective norms (i.e., social pressures) they perceive, and their perceived behavioral control, or the extent to which they feel capable of performing the behavior.

In the context of student accommodations, applying the TPB reveals how these factors can significantly affect energy consumption. Research indicates that when students perceive energy conservation as a social norm, they are more likely to engage in energy-efficient behaviors (Lindenberg & Steg, 2019). This perception can be cultivated through the active promotion of economic and environmental sustainability on campus, integrating energy-saving practices into student activities, and providing visible feedback that makes energy consumption more transparent. For instance, if students see their peers actively turning off lights or using energy-efficient appliances, they are more likely to adopt similar behaviors due to the social pressure to conform. Conversely, if energy wastage is commonplace and normalized, students may feel less inclined to change their habits.

However, certain common behavioral tendencies often contribute to excessive energy consumption in student residences. These include leaving electrical devices on when not in use, overuse of heating and cooling systems, plugging in multiple gadgets simultaneously and neglecting to adjust appliances to energy-efficient settings (Turner et al., 2021). These behaviors are often the result of a lack of awareness about energy consumption or the perceived convenience of leaving devices running without considering the environmental or financial impact. For example, many students may leave lights or electronics on when they are not in the room simply out of habit or because they do not think about the energy implications. Similarly, the overuse of heating and cooling systems, particularly in shared spaces such as dormitories, often arises from the collective assumption that someone else will address the energy inefficiency.

Addressing these tendencies requires targeted interventions designed to change student behavior. Studies have shown that feedback mechanisms, nudging strategies, and gamification techniques can significantly influence energy-saving behaviors (Cinner et al., 2022). Feedback mechanisms involve providing students with real-time information about their energy consumption, which can raise awareness and encourage more responsible behavior. For example, smart meters that display current electricity usage can motivate students to reduce consumption by highlighting how much energy they are using at any given moment. Nudging strategies, which use subtle prompts to encourage energy-saving behaviors without coercion, have also proven effective. Simple changes, such as placing energy-saving tips near light switches or using signage to remind students to turn off appliances when not in use, can create an environment where energy efficiency becomes the default behavior.

Additionally, gamification techniques, which involve incorporating game-like elements into energy-saving initiatives, have emerged as an effective tool for encouraging student engagement. A study conducted at the University of California demonstrated the power of mobile technology in influencing student energy behavior. By using a mobile app that provided personalized energy-saving tips, the university was able to reduce energy consumption by 12% over a single semester (Martinez & Johnson, 2021). This experiment highlights the potential of technology to engage students in energy conservation by offering tailored recommendations and fostering friendly competition. Students could compare their energy consumption with that of their peers, motivating them to reduce usage to "win" energy-saving challenges or simply to improve their standing in the group.

Ultimately, understanding the behavioral psychology behind energy consumption in student residences can help universities design more effective interventions that promote energy efficiency and foster a culture of economic and environmental sustainability. By incorporating insights from the Theory of Planned Behavior and employing strategies such as feedback mechanisms, nudging, and gamification, universities can encourage students to adopt energy-saving practices that lead to significant reductions in overall energy usage. This approach contributes to lowering carbon footprints and instils lifelong habits that students carry with them after graduation, positively impacting their personal energy consumption behaviors in the future. As universities continue to seek ways to enhance economic and environmental sustainability efforts, integrating behavioral psychology into energy management strategies will be key to achieving lasting change in student energy consumption patterns. By aligning institutional policies with psychological insights and leveraging technology to engage students, universities can create environments that foster responsible energy use while promoting environmental stewardship.

2.5 Policy and strategy development.

Universities have the unique opportunity to take a leading role in sustainable energy use, by reducing their own energy consumption and by setting an example for students, staff, and the wider community. By adopting energy-efficient technologies

and integrating renewable energy systems, universities can significantly reduce their environmental impact, mitigate the effects of climate change, and contribute to the global transition toward a low-carbon future. According to the International Renewable Energy Agency (IRENA, 2023), the integration of renewable energy sources, such as solar panels, wind energy, and smart grid systems, into campus infrastructure has the potential to dramatically decrease reliance on fossil fuels, resulting in long-term energy savings and a reduced carbon footprint.

One prominent example of such integration is the University of Cape Town, which has made significant strides toward economic and environmental sustainability by installing solar photovoltaic (PV) panels on its halls of residence. This initiative led to a 30% reduction in grid electricity demand, showcasing how universities can harness renewable energy sources to power their buildings and reduce dependence on traditional energy grids (Moyo et al., 2021). The adoption of solar PV systems helps reduce the environmental impact and offers financial savings by lowering energy costs. This shift toward solar energy is particularly valuable in regions where sunlight is abundant, making it a cost-effective and sustainable solution for powering university campuses.

A similarly successful initiative is found at Stanford University, which has integrated energy-efficient building designs alongside renewable energy sources, resulting in an impressive 80% reduction in its campus carbon emissions (Stanford University, 2022). The university's commitment to sustainability is reflected in its implementation of energy-efficient technologies such as advanced heating, ventilation, and air conditioning (HVAC) systems, LED lighting, and green building materials, all of which work in tandem with the installation of renewable energy systems, including solar panels and wind turbines. This holistic approach has reduced Stanford's carbon emissions and contributed to its goal of achieving net-zero emissions by 2050.

Stanford’s economic and environmental sustainability efforts are also supported by its commitment to smart grid systems, which are designed to optimize energy usage across the campus by automatically adjusting energy distribution based on real-time demand. These systems can provide valuable data that allows for continuous monitoring and optimization of energy-efficient consumption, helping universities make data-driven decisions about energy management. The implementation of smart grids, when coupled with renewable energy sources like solar and wind, enables universities to create a more resilient, energy-efficient infrastructure that is less vulnerable to power outages or disruptions in the energy supply chain.

In addition to the environmental benefits, these initiatives can also serve as educational tools, providing students with hands-on experience and a deeper understanding of sustainable energy practices. Many universities incorporate renewable energy systems into their curriculum, offering students opportunities to engage with real-world applications of energy-efficient technologies and renewable energy systems. This exposure prepares students for future careers in sustainability and instils a sense of responsibility toward environmental stewardship, empowering the next generation of leaders to adopt and promote sustainable practices in their communities and workplaces.

Moreover, these efforts have economic implications as well. Universities that invest in renewable energy and energy-efficient technologies can often benefit from long-term financial savings due to reduced energy costs and, in some cases, government incentives for adopting green technologies. In the case of Stanford University, the savings from energy efficiency measures have helped offset the initial investment costs of renewable energy systems, making the transition to sustainable energy a financially viable option for higher education institutions.

The potential for universities to become leaders in sustainable energy use is vast, and the examples of the University of Cape Town and Stanford University illustrate how such initiatives can lead to meaningful environmental and economic outcomes. By continuing to adopt innovative technologies, universities can drive the transition to renewable energy and set a precedent for other institutions to follow. In doing so, they contribute to the global effort to combat climate change and foster a culture of sustainability that benefits both current and future generations of students, staff, and the broader community.

As universities increasingly recognize their role in shaping a sustainable energy-efficient future, the integration of renewable energy systems and energy-efficient technologies should be viewed as an essential aspect of campus development. The adoption of such technologies, combined with policies and programs that promote energy conservation, will ensure that universities remain at the forefront of energy-efficient sustainability efforts while simultaneously providing students with the knowledge and tools necessary to contribute to the global transition toward a cleaner, more environmentally sustainable world.

2.6 Contribution to Sustainable Development Goals (SDGs) and Climate Action

The shift toward energy-efficient and environmentally sustainable university residences is an essential step in reducing universities' environmental impact and directly contributes to the achievement of several United Nations Sustainable Development Goals (SDGs). These global objectives serve as a framework for promoting sustainable development and guiding institutions toward responsible practices in energy use and resource management. In particular, this shift supports SDG 7, SDG 11, SDG 12, and SDG 13, each of which addresses different but interconnected aspects of sustainability.

SDG 7, which focuses on affordable and clean energy, is particularly relevant to the integration of energy-efficient technologies and renewable energy systems in university housing. As universities adopt solar panels, wind energy, and energy-efficient building technologies, they make significant strides toward achieving SDG 7 by reducing their reliance on traditional, non-renewable energy sources and promoting the use of cleaner, more sustainable energy alternatives. According to the United Nations Environment Program (UNEP, 2022), the transition to energy-efficient university residences contributes to a more sustainable energy landscape by decreasing carbon emissions and fostering a culture of renewable energy adoption. This aligns with the goal of providing affordable and clean energy to all, which is particularly important in university settings where large populations are concentrated, creating both opportunities and challenges for energy management.

Furthermore, SDG 11, which aims to promote sustainable cities and communities, is directly reflected in efforts to improve student housing infrastructure. Universities have the unique opportunity to serve as models for sustainable urban development by designing and constructing eco-friendly, energy-efficient student residences. Improving housing infrastructure to meet sustainability criteria such as the use of energy-efficient materials, smart technology, and renewable energy sources can help to create more resilient and sustainable communities. By adopting sustainable building practices in university residences, universities contribute to the creation of greener, more sustainable cities and communities, thus advancing SDG 11.

SDG 12, which advocates for responsible consumption and production, is supported through the promotion of resource-efficient behaviors within student accommodations. Encouraging students to reduce waste, recycle, and adopt energy-saving habits aligns with the broader goal of responsible consumption. In university housing, simple practices such as turning off lights when not in use, and utilizing energy-efficient appliances can significantly contribute to reducing the overall consumption of resources. Kumar & Jain, (2020) discuss how education institutions can implement strategies such as awareness campaigns, behavioral nudges, and incentive programs to foster a culture of resource efficiency among students. These practices reduce the environmental footprint of individual students and contribute to broader sustainability goals by ensuring that the resources consumed are managed responsibly and sustainably.

Finally, SDG 13, which focuses on climate action, is directly addressed by reducing the carbon footprint of university campuses through the adoption of sustainable energy practices. The built environment particularly university buildings represent a significant source of greenhouse gas emissions, primarily due to energy consumption for heating, cooling, and electricity. By implementing energy-efficient systems, such as low-energy heating and cooling systems, LED lighting, and smart energy management systems, universities can substantially lower their carbon emissions. As (UNEP, 2023) emphasizes, reducing the carbon footprint of education institutions is a critical step in the fight against climate change. Additionally, integrating renewable energy systems like solar PV panels and wind turbines reduces universities' reliance on fossil fuels and contributes to the global effort to mitigate climate change.

In sum, the shift toward sustainable energy-efficient university residences directly aligns with multiple SDGs, each addressing a key aspect of sustainable development. Universities are uniquely positioned to lead the way in this transition, through the adoption of green technologies and by fostering a culture of sustainability among students and staff. As universities continue to improve their housing infrastructure and integrate more sustainable practices, they contribute to the achievement of SDGs 7, 11, 12, and 13, while simultaneously setting an example for other institutions and communities to follow. This alignment with the SDGs further strengthens the role of higher education institutions as leaders in sustainable development, showcasing their commitment to creating a cleaner, more sustainable future for all. Given the identified gaps in the literature on energy utilization trends and their impacts, this paper employs a mixed-methods approach to comprehensively assess energy consumption patterns in KNUST halls of residence.

3. METHODOLOGY

Kwame Nkrumah University of Science and Technology (KNUST), is the foremost Science and Technology University in the country. It is located in Kumasi the second-largest city in Ghana. Within the period of its existence, it has become an important Centre for the training of scientists and technologists in Ghana, Africa and other countries. The University campus lies to the east of Kumasi, the Ashanti Regional capital. There are six (6) halls of residences and other hostel facilities on campus, as depicted in Figure 1. The halls are the Africa Hall, Independence Hall, Queen Elizabeth II Hall, Republic Hall, Unity Hall, and University Hall. The hostels on campus either belong to the University Staff Associations or Credit Unions of the University. These include the Ghana Universities Staff Superannuation Scheme (GUSSS) Hostels, Graduate Students' Association of Ghana (GRASAG) Hostel, SRC Hostel, and Tek Credit Union Hostel. The University also has several municipal facilities comprising a Hospital, Basic Schools (i.e. Nursery, Primary and Junior High School), a Maintenance Department, an Estate Organisation, a Transport Department, Photocopy Unit, Printing Press, Sports Complex (GUSSS Sports Complex), a Bookshop, a Shopping Mall, Staff Clubs/Canteen, Sports Stadium (Paa

Joe Stadium), Gymnasium, an Olympic size Swimming Pool, Commercial and Banking Facilities, Post Office, Places of Worship and Guest Houses (QAPO, 2023).

KNUST served as the focal point for this paper due to its commitment to academic excellence and sustainable development. As one of the leading technical universities in Africa, KNUST has a large student population, which significantly impacts its overall energy consumption. As of the 2022/2023 academic year (QAPO, 2023), KNUST had a total student population of 89,486, comprising 79,448 undergraduates and 10,038 postgraduates. Among the undergraduates, 26,733 first-year students were enrolled, yet only 7,692 students (29%) were allocated accommodation within the university's traditional halls. The remaining 19,041 students (71%) had to secure off-campus housing. Total in the traditional halls was 7,775 including hall executives.

The university's infrastructure includes various energy-intensive facilities such as lecture halls, laboratories, research centres, administrative offices, and recreational spaces, all of which require significant energy inputs for lighting, air conditioning, office equipment, and specialized research instruments. However, the residential facilities account for a substantial portion of energy consumption. These student residential accommodations require electricity for lighting, ventilation, air conditioning, cooking, and the operation of personal electronic devices such as laptops, refrigerators, and televisions.

Given the growing concerns about energy efficiency and environmental sustainability, understanding energy consumption patterns in halls of residence is critical. This paper focuses exclusively on campus halls of residence because, unlike private campus hostels and off-campus accommodations, these facilities are directly managed by the university and are subject to institutional policies that can influence energy use. Off-campus hostels, being privately owned and operated, do not fall under the university's jurisdiction, meaning developers and managers may not prioritize energy efficiency initiatives or adhere to sustainability policies implemented by KNUST. Therefore, limiting this paper to on-campus halls ensures that the findings and recommendations can be effectively applied within the university's regulatory framework to promote energy conservation and efficiency. This paper employed a structured procedure focusing on data collection, analysis, and ethical considerations to systematically assess energy consumption patterns. A mixed-method approach was adopted to enhance research validity, provide a comprehensive understanding by combining numerical trends with in-depth insights, and address complex questions through triangulation and complementarity (Creswell & Plano Clark, 2018).

Primary data was collected using structured survey questionnaires administered to students residing in on-campus halls of residence. These surveys captured detailed insights into students' energy usage habits, their awareness of sustainable energy practices, and their willingness to adopt energy-efficient behaviors. The survey included both open and close-ended questions. Secondary data was obtained from institutional documents, official reports, and journal articles to provide additional context input for analysis.

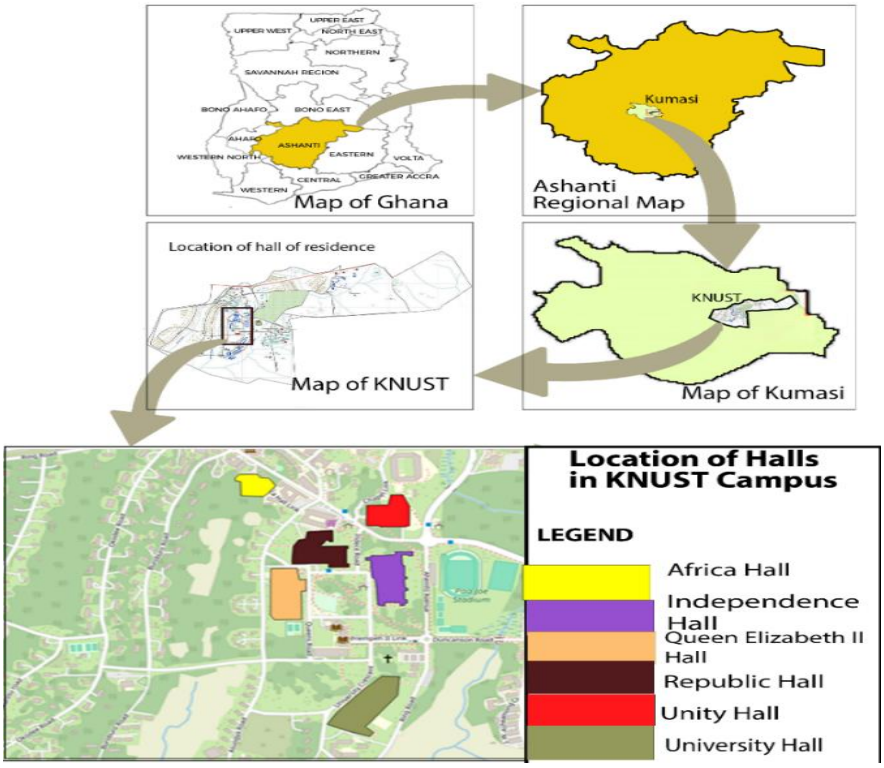

Figure 1: Map of Study

Source: Authors Construct

A critical aspect of this paper was ensuring that the sample size was statistically representative of the target population. To achieve this, Cochran's sampling formula (Cochran, 1963) was used to determine the appropriate sample size based on the total student population, desired confidence level, and margin of error.

Using Cochran's sample size formula for large populations:

$$n_o = \frac{Z^2 . \ p \ . q}{e^2}$$

Where:

- Z = 1.96 (for a 95% confidence level)
- p = 0.5 (population proportion, 50%)
- q = 1 - p = 0.5
- e = 0.05 (margin of error, 5%)

$$n_0 = \frac{(1.96)^2 * 0.5 * 0.5}{(0.5)^2}$$
$$n_0 = \frac{3.8416 * 0.25}{0.0025}$$
$$n_0 = \frac{0.9604}{0.0025}$$
$$n_0 = 384.16 \approx 384$$

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$
$$n = \frac{384}{1 + \frac{384 - 1}{7775}}$$
$$n = \frac{384}{1 + \frac{383}{7775}}$$
$$n = \frac{384}{1 + 0.0493}$$
$$n = \frac{384}{1.0493} \approx 366$$

Since the population size for students in the traditional halls is finite (**7,775**), the finite population correction was applied: Table 1 shows the population size, confidence level, margin of error, and population proportion values used to calculate the sample size. Given a population size of approximately 7,775 students, the calculation resulted in a recommended sample size of 366. However, a pilot survey revealed approximately 85% response rate. 431 questionnaires were thus distributed amongst the 6 traditional halls of residence by proportional representation of their respective populations. In all, 373 were received.

The collected data underwent rigorous analysis using Microsoft Excel and SPSS, with results presented in charts and tables to enhance clarity. Descriptive statistical techniques, including means, frequencies, and percentages, were used to summarize key characteristics of the dataset (Hair et al., 2019).

Table 1. Sample size determination

Parameter	Value/Formula
Population Size	7,775
Confidence Level	95%
Margin of Error	5%
Population Proportion	50%
Sample Size	366
Response Rate	85%
Administered Questionnaires	431
Questionnaires Received	373

Source: Field Survey (2024)

Ethical standards were strictly adhered to throughout the research process. Participants were informed about the paper's objectives, and their consent was obtained before data collection, and maintaining confidentiality. The insights gained highlight key trends, challenges, and opportunities for energy efficiency improvements within the university's regulatory framework.

4. ANALYSIS AND DISCUSSION

This section explores the dynamics of energy consumption patterns within a specific demographic. It delves into the factors influencing energy reliance and usage, offering detailed analysis of the survey data collected. The data provides valuable insights into the respondents' current behaviors and preferences regarding energy sources, painting a comprehensive picture of energy consumption trends.

4.1 Demographics Data Analysis

The Demographic data analysis involves examining statistical information on population characteristics such as age, gender, income, education, and location. Understanding the demographic profile in energy consumption research is crucial for identifying patterns and trends across different population segments.

4.3.1 Gender Distribution

As depicted by Lakens (2013), the study revealed a wide-balanced gender distribution (of more than 10%) among participants. 56.3% male (210 respondents) and 43.7% female (163 respondents). This gender imbalance may influence energy consumption patterns in student residences. Research suggests that the females engage more in energy-intensive activities like cooking and caregiving, while men may use more energy for electronics and entertainment. Additionally, women exhibit greater environmental awareness, promoting energy-saving behaviors more actively than their male counterparts. The lower female representation in student housing could hinder sustainability initiatives, reducing overall engagement in conservation efforts.

4.3.2 Age Distribution

Respondents were categorized into age ranges of under 18, 18-22, 22-27, and above 27. The predominance of younger students (18-22), with 357 respondents, suggests that the university attracts a high number of first-year students. This is reinforced by the university hall's policy, which primarily accommodates first-year students. Younger students may have distinct energy consumption habits, heavily relying on electronic devices for studying and socializing, leading to higher electricity usage, especially in shared living spaces. Students aged 23-27, with 12 respondents, include a mix of first-year and continuing students who are hall executives. Additionally, 4 respondents are under 18, further highlighting the university's youthful demographic. Understanding the age distribution allows for targeted energy management strategies. Energy conservation campaigns can be customized for younger students, focusing on responsible device usage and sustainable living. Older students, particularly hall executives, can promote energy-efficient behaviors and lead by example.

4.3.3 Academic Level of Students

The First-year students (85.8%) form the largest group, indicating their significant influence on energy consumption in university halls of residence. Their limited experience with independent living may lead to higher energy usage due to unfamiliarity with conservation practices. Second-year (8.6%) and third-year students (5.6%) represent smaller portions of the sample. While residing on campus, upper-year students may have developed better energy-saving habits, potentially consuming less per capita than first-year students. Energy efficiency initiatives should focus on first-year students, incorporating awareness campaigns and behavioral interventions to promote sustainable energy use from the start of university life.

4.3.4 Distribution of Respondents by Halls

To maintain anonymity, these halls were represented using alphabets: A, B, C, D, E, and F in no particular order in Table 2.

Table 2. Distribution of questionnaire

Name of Halls	Frequency	Percentage (%)
A	37	9.9
B	57	15.3
C	56	15.0
D	75	20.2
E	93	24.9
F	55	14.7
TOTAL	**373**	**100**

Source. Field Survey (2024)

4.3.5 Room Occupancy

The Data revealed a strong connection between room occupancy and energy consumption patterns (Figure 2). Students residing in rooms with 4 occupants (93.9%) lead to higher total energy use but lower per capita consumption due to shared resources. Smaller groups (1.6% in 3-person rooms, 3.2% in 2-person rooms, and 1.3% in single rooms) may exhibit higher per

capita energy use due to less efficient resource sharing. Energy-saving strategies should focus on optimizing shared usage in high-occupancy rooms and promoting efficiency in low-occupancy settings to reduce overall energy consumption.

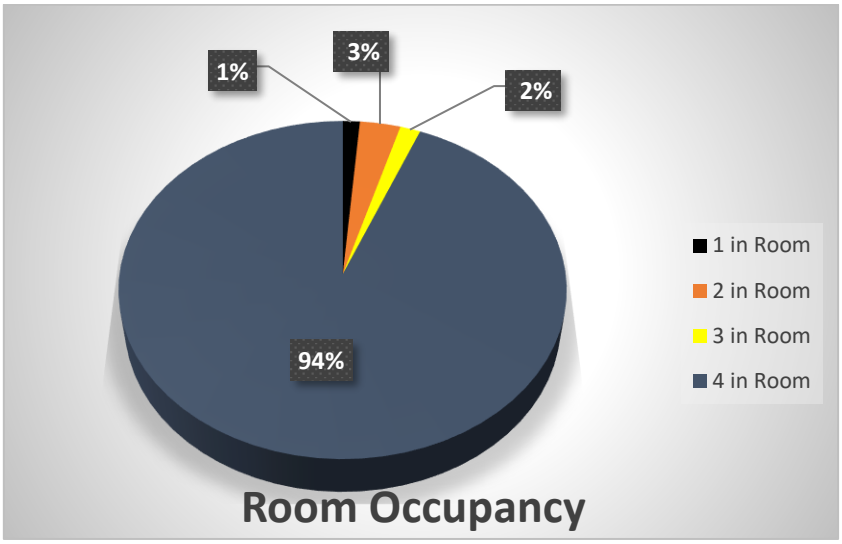

Figure 2. Room occupancy

Source: Field Survey (2024)

4.2 Energy consumption patterns

Analyzing energy consumption patterns reveals trends and behaviors in energy use, considering sources, frequency, and demographics. This insight identifies high-consumption areas, inefficiencies, and conservation opportunities. It informs strategies for sustainable practices, efficiency, infrastructure, pricing, and education, promoting responsible energy usage and driving conservation. Effective analysis guides targeted solutions for a sustainable energy future.

4.2.1 Reliance on Various Sources for Energy Consumption

This section examines students' reliance on different energy sources, revealing an absolute dependence on the ECG (National Grid). The non-use of alternative sources like solar power, biogas, and wind suggests a gap in sustainable energy adoption, likely due to high costs, lack of awareness, or inadequate infrastructure. This heavy reliance on conventional energy raises environmental sustainability concerns, underscoring the need for a strategic energy management approach.

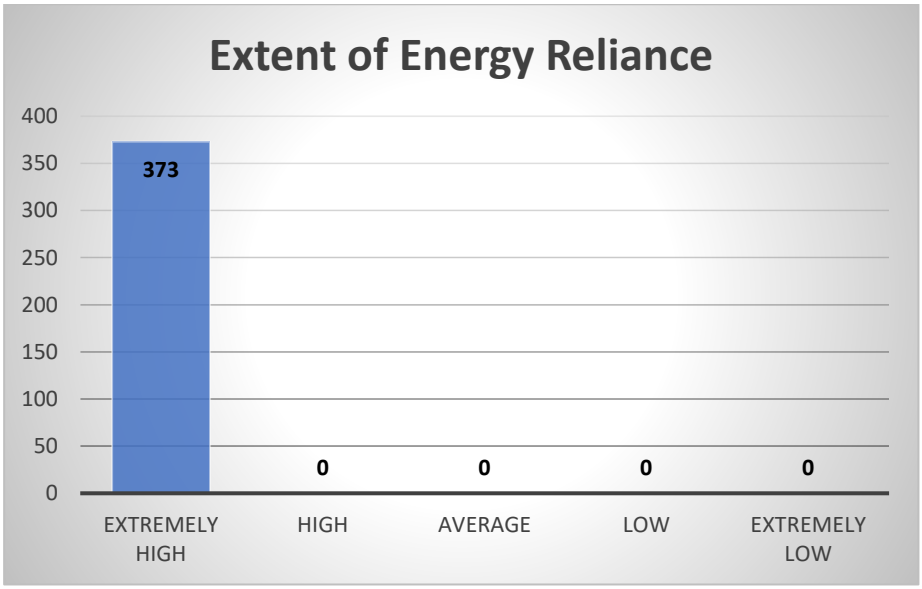

Figure 3. Extent of energy reliance

Source. Field Survey (2024)

4.2.2 Primary Energy Sources for Key Activities

Given the university's reliance on the National Grid, institutional policies mandate the exclusive use of electrical appliances within student halls. This policy, aimed at ensuring safety, inadvertently reinforces the dependency on traditional energy sources, highlighting the need for a strategic shift towards more sustainable practices. The use of LPG is strictly prohibited in university

halls due to safety concerns, including fire hazards and gas leaks. Enforcing an all-electric policy simplifies energy regulation, ensures compliance with safety standards, and aligns with broader sustainability goals aimed at reducing carbon emissions and promoting cleaner energy sources. Consequently, students must rely entirely on electricity for essential activities such as learning, ironing, cooking, and water heating, highlighting the need for investment in renewable energy infrastructure.

4.2.3 Personal Energy Supplement

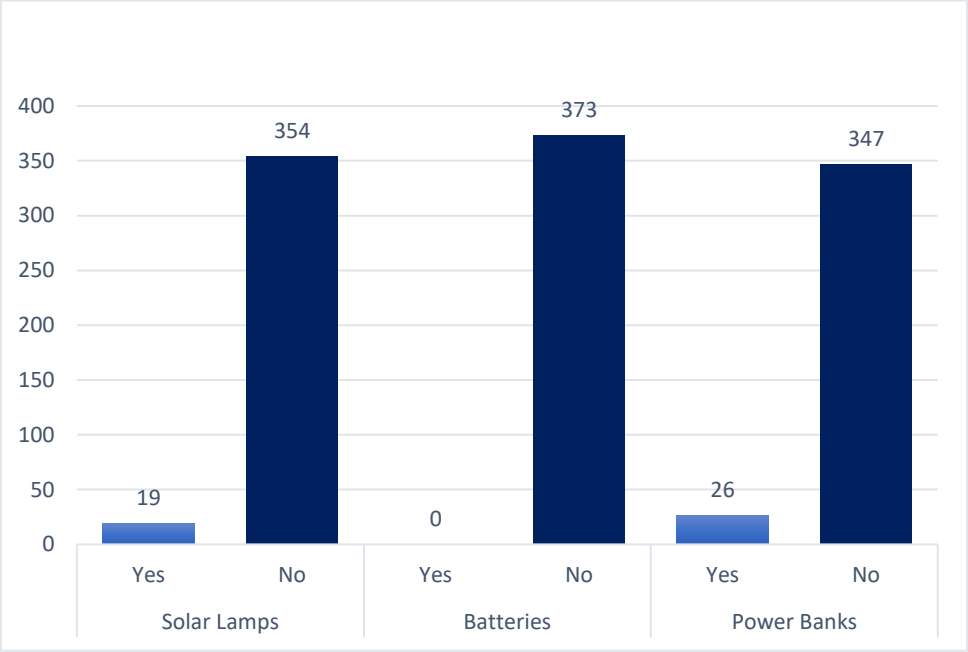

Figure 4. Personal energy supplement
Source: Field Survey (2024)

The data indicates that students use personal energy supplements sparingly to complement their primary energy sources. Solar lamps are used by a small number, suggesting occasional reliance on solar energy for lighting. Power banks are more commonly used, likely for charging devices when traditional power sources are unavailable. Batteries, however, are not used at all, indicating they are not a preferred supplement. Overall, these supplements serve as secondary solutions, with students primarily depending on consistent traditional energy sources.

4.2.4 Payment Arrangements for Energy Consumption

The university covers utility bills for students in the halls of residence, with costs partially included in hall fees and the remainder absorbed by the university. This policy ensures that students have uninterrupted access to essential utilities without the burden of managing individual energy payments. By centralizing utility costs, the university promotes equitable access to energy, preventing disparities in usage due to financial constraints. Additionally, this approach helps regulate energy consumption within the halls, ensuring safety and efficiency while maintaining infrastructure sustainability. Covering part of the utility expenses also aligns with institutional objectives to support students financially and create a conducive learning environment free from concerns about fluctuating energy costs.

4.2.5 Regular Use of Electrical Appliances and Energy Sources

The analysis reveals a total reliance on the National Grid for electricity, with mobile phones being the most universally used device by all 373 respondents. A significant majority, 308 respondents, use pressing irons, while 271 rely on hot plates and 186 use rice cookers, indicating that electricity is a primary source for cooking. Laptops are also widely used by 251 respondents, reflecting a high level of digital engagement. Electric kettles are used by 105 respondents, fridges by 62, and microwaves by only 48, suggesting economic constraints or alternative household practices. The heavy dependence on the grid highlights the need for energy diversification, such as integrating renewable sources, to improve energy security and sustainability.

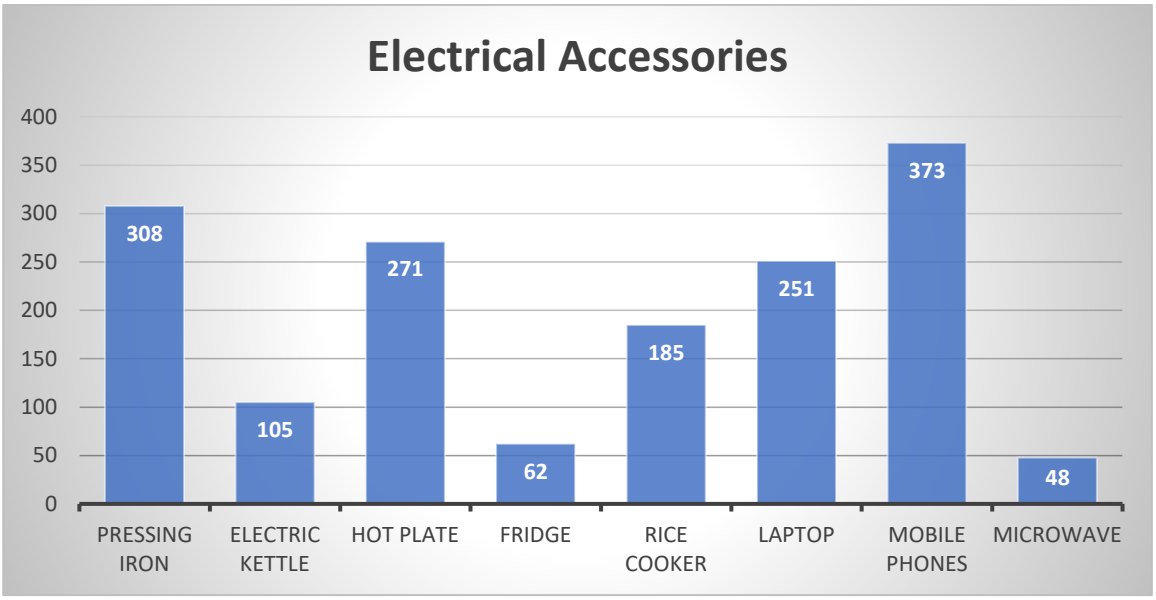

Figure 5. Electrical accessories

Source: Field Survey (2024)

4.2.6 Relationship Between Gender and Accessories Used

Table 3. Relationship between gender and accessories

Accessories	Males	Females	Total	Cramers V
Pressing Iron	157	151	308	0.23
Electric Kettle	46	59	105	0.16
Hot Plate	134	137	271	0.22
Fridge	20	42	62	0.22
Rice Cooker	85	100	185	0.21
Laptop	140	111	251	0.02
Mobile Phones	209	164	373	N/A
Microwave	13	35	48	0.23

Source: Field Survey (2024)

Household/Cooking Accessories (Pressing Iron, Electric Kettle, Hot Plate, Fridge, Rice Cooker, Microwave): All of these show moderate chi-square values (ranging roughly from 9 to 20) and Cramér's V values between 0.16 and 0.23. This indicates a meaningful but not extremely strong association between gender and usage. or household tasks.

Laptop Usage: With a very low chi-square (≈0.09) and a negligible Cramér's V (≈0.02), there is virtually no difference between male and female students' laptop usage. Both groups appear equally reliant on laptops for their academic and personal needs.

Mobile Phones: All students reported using mobile phones, therefore there is no variation to test (hence "N/A" in the table). Mobile phone ownership is essentially universal among both genders.

Overall, while first-year students often rely heavily on university-provided energy and may not consistently practice conservation, these results show that gender-based differences do emerge for certain appliances particularly those used for cooking, heating, or other household tasks where female usage is higher than expected. By contrast, digital device usage (laptops and mobile phones) shows little to no gender gap. These patterns can inform targeted sustainability efforts, such as awareness campaigns focusing on high-energy appliances and policy incentives that encourage more efficient usage across all students.

4.2.7 Energy Awareness and Conservation

Energy awareness encompasses a comprehensive understanding of energy utilization and its environmental repercussions. It fosters an informed recognition of consumption patterns, emphasizing the critical need for sustainable energy practices. In contrast, energy conservation involves deliberate actions aimed at minimizing energy usage. These actions include employing energy-efficient appliances, turning off lights and electronics when not in use, and supporting renewable energy sources. By

cultivating energy awareness and implementing conservation strategies, individuals and communities can significantly reduce energy waste, lower costs, and mitigate environmental impacts, thereby contributing to a more sustainable future.

4.2.8 Impact of High Energy Consumption on the Environment.

Out of 373 students surveyed, 186 (50%) had no idea about the impact of their energy usage on the environment, suggesting a gap in awareness and environmental education among some first-year students. A total of 93 students (25%) agreed that energy use affects the environment, while 55 students (15%) strongly agreed, indicating that some students understood environmental sustainability and its importance. However, 37 students (10%) believed there was no impact, pointing to possible misconceptions about energy consumption and environmental consequences. These findings highlight the need for universities to introduce sustainability education, interactive programs, and awareness campaigns to bridge the knowledge gap and promote responsible energy usage.

4.2.9 Relationship Between Gender and Students' Awareness

Table 4. Relationship Between Gender and Students' Awareness

Awareness level	Males	Females	P values
Strongly Agree	55	49	0.001
Agree	87	92	0.001
Don't Know	54	19	0.001
Disagree	12	3	0.001
Strongly Disagree	2	0	0.001

Source: Field Survey (2024)

The analysis of the data reveals a statistically significant association between gender and students' awareness of the environmental impacts of energy consumption ($(p < 0.001)$ for all categories). This indicates that gender plays a significant role in shaping how students perceive and respond to the issue of energy consumption and its environmental consequences. The females are generally more aware and concerned about the environmental impacts of energy consumption. They are more likely to agree or strongly agree that energy consumption affects the environment, suggesting a higher level of awareness and concerns compared to their male counterparts. The males, on the other hand, responded with "Don't Know", disagree, or strongly disagree. This indicates a gender-based disparity in awareness, with males showing higher levels of uncertainty or skepticism about the environmental impacts of energy consumption. The higher proportion of males responding "Don't Know" suggests that they may have less knowledge or understanding of the issue, while the higher levels of disagreement indicate that some males may be less convinced of the environmental impacts.

4.2.10 Frequency of Engagement in Energy-Saving Practices

Since most of the students surveyed were in their first year, their understanding of energy conservation was relatively low. Out of 373 students, only 74 (20%) claimed to always engage in energy-saving practices such as turning off lights and fans, using daylighting, and unplug electronic devices when not in use. A slightly higher number, 93 students (25%), often practiced these habits. 111 students (30%) did so sometimes, while 55 students (15%) rarely conserved energy, and 37 students (10%) never did. This suggests that energy saving programs need to be intensified among first year students since they may not have been actively responsible for managing their own energy usage before entering the university.

4.2.11 Relationship Between Gender and Students' Willingness

Table 5. Relationship between Gender and willingness

Willingness	Males	Females	Total	p Values
Extremely Willing	76	67	143	0.001
Willing	95	94	189	0.001
Indifferent	35	2	37	0.001
Less willing	4	0	4	0.001
Not willing	0	0	0	0.001

Source: Field Survey (2024)

The analysis of the data reveals a statistically significant association between gender and students' willingness to adopt energy-saving practices ($p < 0.001$) for all categories. This indicates that gender plays a significant role in shaping students' attitudes and motivations toward energy conservation. Females were willing or extremely willing to adopt energy-saving practices. Males, on the other hand, are more likely to be indifferent or less willing to adopt energy-saving practices. This indicates a gender-based disparity in willingness, with males showing lower levels of motivation or interest in energy conservation compared to females. The higher proportion of males who are indifferent suggests that they may not see the importance of energy-saving practices.

Since the university provides for their energy needs, students may not feel a personal responsibility to conserve energy. Despite this, when asked about their willingness to adopt more energy-efficient practices if given the necessary information and resources, 143 students (38%) were extremely willing, and 189 students (51%) were willing. However, 37 students (10%) remained indifferent, while 4 students (1%) were less willing, and no student was not willing at all. This indicates that although many students are open to change, they may need proper guidance and motivation to develop sustainable habits.

4.2.12 Motivational Factors for Energy Conservation.

In terms of motivation, environmental concern was the strongest factor, influencing 130 students (35%), followed by university policies, which motivated 93 students (25%). Peer influence and personal beliefs/habits each motivated 74 students (20%). It showed that students were more likely to save energy if they understood its environmental impact or if the university enforced stricter policies. Given that many students did not see an immediate need to conserve energy, universities could introduce awareness programs and policy-driven initiatives to encourage responsible energy usage among students.

4.3 Challenges in Energy Conservation

Energy conservation at KNUST faces multiple challenges, ranging from behavioral and financial barriers to institutional and infrastructural limitations. Addressing these issues are crucial to promoting sustainable energy management on campus.

One of the most significant barriers to energy conservation is a general lack of awareness among students. Many individuals have limited knowledge of effective energy-saving practices, making it difficult to adopt sustainable habits. Without proper education on conservation strategies, energy consumption remains inefficient, contributing to higher electricity demand. Closely linked to this is a lack of motivation, as many students do not perceive immediate personal benefits from conserving energy. The absence of structured incentives, such as rewards or recognition programs, reduce engagement in sustainable practices. Encouraging conservation through financial or academic incentives could help cultivate a stronger culture of energy efficiency. Financial limitations significantly hinder energy conservation efforts. The high cost of energy-efficient appliances makes it difficult for students and the university to invest in sustainable technologies, despite their long-term benefits. Without financial support mechanisms, such as subsidies or instalment payment plans, transitioning to energy-efficient alternatives remains a challenge.

Additionally, KNUST relies heavily on the Electricity Company of Ghana (ECG) as its primary power source, making it vulnerable to rising electricity costs and supply disruptions. With minimal integration of renewable energy, the university has limited control over its energy expenses and sustainability initiatives. Expanding renewable energy sources, such as solar power, could help reduce reliance on the national grid and lower long-term costs.

Some parts of the halls of residence were not designed with energy efficiency in mind, leading to excessive electricity consumption. Poor solar orientation and inadequate insulation increases reliance on fans and air conditioners, and outdated electrical systems contribute to energy wastage. These were identified as some of the challenges mitigating against energy conservation. Retrofitting buildings with energy-efficient designs, such as LED lighting, and modern electrical systems, could significantly reduce overall consumption.

Additionally, behavioral practices contribute to energy inefficiencies. Despite growing environmental awareness, many students frequently overused high-energy appliances such as electric kettles, irons, and refrigerators. The absence of strict energy conservation policies in student accommodations allows these practices to continue unchecked. Strengthening regulations, combined with awareness campaigns, could encourage more responsible energy use.

A lack of comprehensive institutional policy further hinders energy conservation efforts. While KNUST has taken steps to promote environmental sustainability, there is no clear structured framework enforcing mandatory energy audits, consumption limits, or incentive programs known to the students. Without clear guidelines and accountability mechanisms, conservation measures remain voluntary and inconsistent. Establishing a well-defined energy policy with enforceable regulations, periodic monitoring, and structured incentives would be crucial in promoting long-term sustainability.

These barriers collectively contribute to KNUST's high energy consumption and inefficiencies. Addressing them requires a multi-faceted approach that integrates financial investment, behavioral change, infrastructure upgrades, and strong institutional policies. By implementing targeted awareness programs, incentivizing conservation efforts, investing in renewable energy, and enforcing sustainable policies, KNUST could move toward a more resilient and energy-efficient future.

4.3.1 Energy Consumption Strategies in Halls of Residence

The analysis highlights key strategies and challenges in energy conservation at KNUST, emphasizing the need for a balanced approach that integrates practical solutions, awareness initiatives, and institutional policies.

The installation of energy-efficient lighting emerges as the most widely recognized strategy for reducing energy consumption, reflecting its practicality and immediate impact. Regular maintenance of electrical systems also ranks highly, underscoring the importance of ongoing upkeep in preventing energy wastage.

Educating students on conservation practices is another crucial measure, as awareness plays a vital role in promoting sustainable behaviors. Encouraging the adoption of clean energy sources, such as solar and wind power, is also recognized as a valuable long-term solution, though its implementation may face financial and logistical challenges. Additionally, stricter policies on energy usage are seen as important, but opinions on their immediate effectiveness vary, indicating the need for careful policy design and enforcement. Despite an awareness of conservation strategies, students' energy consumption patterns reveal a total dependence on the National Grid.

Financial constraints remain a major obstacle, limiting the ability to invest in energy-efficient appliances and clean energy alternatives. Additionally, the absence of comprehensive institutional policies weakens conservation efforts, as there are no strict measures to regulate energy consumption in student accommodations.

Addressing these challenges requires a multifaceted approach that integrates practical solutions, education, and institutional support. Investing in energy-efficient infrastructure, expanding renewable energy options, and strengthening policies can help reduce dependence on conventional electricity sources while promoting long-term sustainability. By combining financial incentives, awareness campaigns, and regulatory measures, KNUST can create a more energy-efficient and resilient environment for students dependent on conventional sources while promoting efficiency and affordability in student accommodations.

4.3.2 Preferred Sustainable Energy Sources for Halls Use

As shown in Figure 3, which analyzes hall residents' renewable energy preferences, there was a marked preference for solar power among the student population. This preference underscores the potential for solar energy initiatives on campus. Residents value the long-term financial savings and sustainability of solar energy. While solar power is the leading choice, the analysis also shows interest in other renewable energy sources like wind, hydro-power and biogas.

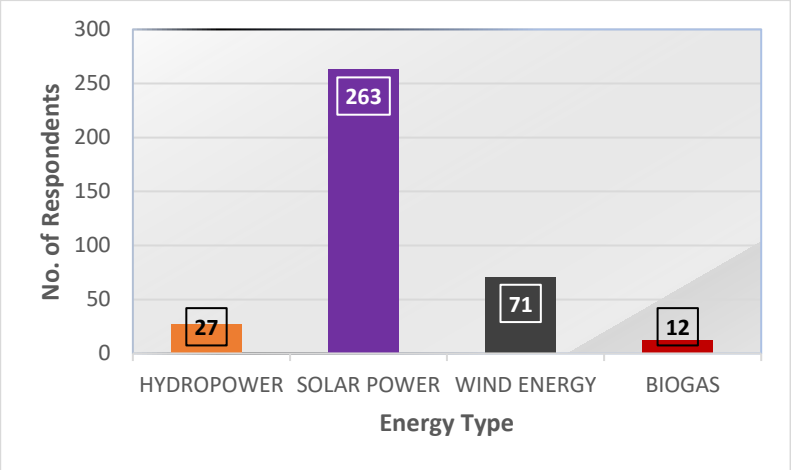

Figure 6. Preferred Sustainable Energy Source

Source: Field Survey (2024)

4.3.3 Incentives for Adopting Energy-Efficient Practices

As depicted in Figure 7, the role of financial incentives, including subsidies and rebates for purchasing energy-efficient appliances, is crucial in motivating residents of student halls to embrace sustainable energy practices. By reducing the upfront costs of energy-efficient technologies, these incentives would make it easier for residents to invest in solutions that lower energy consumption and generate long-term savings. The government of Ghana may have to impose heavy import duties on appliances with poor energy savings so as to discourage its importation. Additionally, recognition and reward programs enhance motivation by fostering a sense of community and shared commitment to sustainability. Educational initiatives further strengthen energy-efficient behaviors by providing residents with practical knowledge of conservation strategies and the benefits of reduced energy usage.

The availability of energy-efficient appliances also supports habit formation, ensuring that residents have the necessary tools to implement sustainable practices. A combination of financial incentives, recognition, and education creates an environment that actively promotes energy conservation, leading to lower energy consumption and a more sustainable hall living experience.

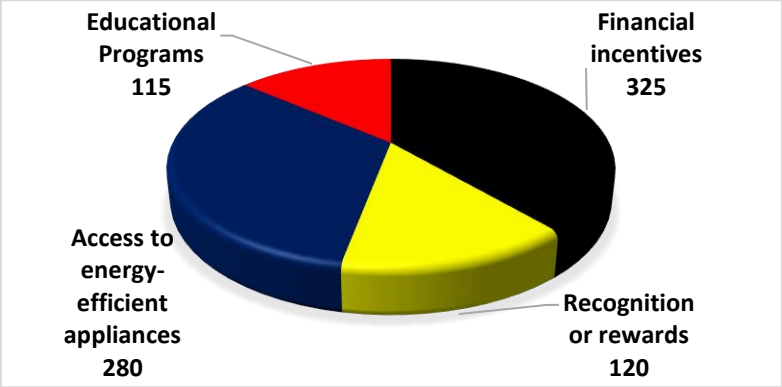

Figure 7. Incentives for Adopting Energy-Efficient Practice

Source: Field Survey (2024)

5. DISCUSSION

This section presents key findings from the field study, addressing critical issues related to energy consumption in university halls of residence and identifying potential solutions. The study revealed a strong dependence on the National Grid, limited awareness of energy conservation, financial constraints, and inadequate institutional policies. Considering the identified heavy reliance on the National Grid and the limited adoption of renewable energy sources, the following policy interventions are recommended to optimize energy consumption patterns

Energy Consumption Patterns and Challenges: The findings indicate that students in university halls primarily rely on the National Grid for their daily energy needs, with little to no integration of renewable energy sources. Institutional policies mandate the exclusive use of electrical appliances while restricting alternatives like LPG for safety reasons. Although this policy reduces fire hazards, it has inadvertently reinforced over-reliance on conventional electricity without offering alternative sustainable solutions. Financial constraints remain a significant obstacle to energy efficiency in KNUST halls. Many students cannot afford energy-efficient appliances, and the university faces budgetary limitations that hinder investments in renewable energy systems. Additionally, inefficient infrastructure, including poor insulation, and outdated electrical systems, contribute to excessive energy consumption. Despite moderate awareness of energy conservation, inconsistencies in student behavior persist. Many students turn off lights and unplug devices when not in use, but high-energy appliances such as electric kettles, refrigerators, and irons remain in continuous operation, contributing to high energy demand. Weak enforcement of energy policies and the absence of structured incentives make conservation efforts largely voluntary and inconsistent. Institutional policies at KNUST lack clear enforcement mechanisms, with no mandatory energy audits, consumption limits, or structured incentives to encourage conservation. As a result, energy management remains a loosely regulated aspect of campus operations, placing the responsibility for sustainable practices solely on students without broader institutional support.

The following recommendations outline practical strategies tailored to KNUST's unique context, ensuring that energy conservation efforts are both effective and sustainable.

Adoption of Energy-Efficient Infrastructure and Appliances: One of the most effective ways to reduce electricity consumption in KNUST halls of residence is by investing in energy-efficient appliances and lighting systems. LED lighting, which consumes significantly less electricity compared to traditional incandescent bulbs, should be widely adopted across campus. These lights have a longer lifespan, reducing both maintenance costs and energy demand. Smart lighting systems that integrate motion sensors and automated scheduling should also be introduced in student halls to prevent unnecessary electricity consumption, particularly in communal areas such as study rooms, hallways, and bathrooms. The transition to energy-efficient refrigerators, and other electrical appliances should be prioritized. Since many students rely on personal refrigerators, implementing policies that encourage the purchase of energy-efficient models could significantly lower electricity consumption. Additionally, the university can facilitate bulk procurement of energy-efficient appliances at subsidized rates, ensuring affordability for students who may otherwise struggle with the high upfront costs of such investments.

Strengthening Renewable Energy Integration: Reducing KNUST's dependence on the National Grid requires a shift toward renewable energy sources such as solar power and biogas. Building on the identified reliance on the National Grid, a strategic shift towards the installation of solar panels on student halls of residence and other campus buildings emerges as a pivotal step towards

sustainable energy use. Given Kumasi's favorable solar radiation levels, harnessing solar energy could be a sustainable long-term solution. The use of biogas should also be explored as an alternative fuel source. Promoting student participation in renewable energy initiatives would enhance sustainability efforts. The university could collaborate with research departments and industry partners to implement pilot projects, allowing students to gain practical experience while contributing to real-world solutions. By gradually transitioning toward renewable energy, KNUST can reduce its vulnerability to power fluctuations and ensure a more reliable electricity supply for its student population.

Implementing Smart Grid Technologies: Introducing smart grid technologies at KNUST would enhance electricity distribution, monitoring, and consumption efficiency. The installation of smart meters in student halls of residence would allow for real-time tracking of energy usage, helping both students and administrators identify areas of wastage. This would promote accountability among students and provide data-driven insights for energy management decisions. Smart grids would further enable better integration of renewable energy sources, ensuring that solar and biogas systems are optimally utilized to meet the university's energy demands. Additionally, incorporating automated energy management systems would help regulate power distribution, preventing excessive consumption during peak hours. By leveraging real-time monitoring and predictive analytics, the university could optimize electricity use across different facilities, reducing overall costs and improving energy reliability.

Enhancing Institutional Policies and Energy Management Strategies: A well-defined and enforceable energy management policy is critical to ensuring energy conservation in KNUST halls of residence. The university should implement mandatory energy audits to track usage patterns and identify areas of inefficiency. Setting clear energy consumption limits for student accommodations would also help regulate excessive use, ensuring that students are more conscious of their energy habits. Introducing structured incentives for responsible energy use could encourage students to adopt conservation practices. For instance, hall residents who consistently maintain low electricity consumption could receive priority access to certain university functions and facilities (e.g. Gymnasium). Additionally, strict enforcement of conservation measures such as penalties for excessive energy usage or mandatory participation in energy awareness programs would help create a culture of accountability.

Strengthening Energy Awareness and Behavioral Change Initiatives: Promoting a culture of energy conservation at KNUST requires continuous education and awareness campaigns. Orientation programs for first-year students should include practical training on energy-saving habits, ensuring that students understand the impact of their consumption choices. Hosting energy conservation workshops, sustainability forums, and inter-hall competitions focused on reducing electricity usage could further enhance engagement. Incorporating sustainability education into academic programs would also reinforce conservation efforts. By offering elective courses or certifications on energy efficiency and climate action, KNUST can equip students with the knowledge needed to implement sustainable practices beyond their university experience.

Encouraging Community Engagement and Collaboration: A holistic approach to energy conservation requires active participation from students, faculty, and external stakeholders. KNUST should establish partnerships with industry experts, renewable energy providers, and government agencies to secure funding and technical support for large-scale sustainability projects. Engaging student organizations and hall leaders in energy conservation programs would also strengthen grassroots efforts, making conservation an integral part of campus life. Providing platforms for students to contribute innovative ideas such as sustainability hackathons or research grants for energy projects would encourage a sense of ownership and responsibility. By fostering a collaborative approach, KNUST can ensure that energy conservation is a shared commitment across all levels of the university community.

Further research should explore the long-term impact of energy awareness campaigns, assessing whether behavioral changes persist beyond short-term interventions. Evaluating the feasibility of integrating renewable energy into student accommodations on a larger scale would also provide valuable insights into cost-effectiveness and implementation challenges. Comparative studies between KNUST and other universities with established sustainability programs could highlight best practices that can be adapted to the local context.

6. CONCLUSION

The research analyses energy utilization in KNUST halls and its environmental impact, highlighting the crucial link between energy usage and sustainability. The paper reveals that halls of residence significantly contribute to environmental degradation due to high energy consumption, but identifies areas for improvement, such as adopting renewable energy sources, implementing energy-saving technologies, and promoting sustainable practices among residents.

Halls residents suggest improving energy management by adopting energy-efficient technologies and practices, such as energy-saving appliances and LED lighting. This showed growing awareness of energy consumption's impact on finances and the environment. Implementing these measures can significantly reduce energy usage, leading to lower costs and a smaller carbon footprint. Residents also recommend regular energy audits to identify areas for improvement and foster a culture of sustainability.

Educational programs, like workshops and informational sessions, can raise awareness about energy conservation and empower residents to make informed decisions. By promoting a sense of responsibility and community engagement, halls of residence can encourage energy-efficient practices and create an environment where sustainability is celebrated. This collective effort can lead to a significant reduction in energy consumption and a more sustainable future.

The research has broader implications for policymakers, educational institutions, and stakeholders in the built environment, advocating for sustainable energy practices and policies to address climate change. The paper serves as a call to action for energy management and environmental protection, inspiring further research and initiatives towards a more sustainable future. Collective efforts are essential to achieve meaningful progress in energy efficiency and environmental sustainability.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTION STATEMENT

Henry Kwaku Boafo initiated the topic, framed the study and supervised the work, Raphael Akponzele and Yvonne Dede Adai Tetteh did the data collection, analyzed the data and did the write up and Romanus Dokgubong Dinye reviewed the data, analysis and discussion of results and report.

DATA ACCESS STATEMENT

The data supporting the findings of this paper are available upon reasonable request from the corresponding author. Due to ethical considerations and institutional policies, the raw data cannot be shared publicly. However, summary statistics and relevant aggregated data can be provided upon request.

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