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Energy Efficiency of Residential Building: Case Study in Tujereng Village the Gambia

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Abstract

The Gambia faces challenges in its energy sector, with limited access to electricity, a reliance on private generators and non-renewable energy sources that produce noise and emissions. These issues contribute to climate change and global warming. To address this, the country plans to implement national energy efficiency strategies in May 2022 to combat energy poverty and improve economic and social well-being. The paper focuses on two key aspects: providing recommendations for policymakers and assessing public awareness of energy efficiency. The results reveal that many Gambian residents lack knowledge about energy efficiency, electricity access, and sustainability, despite government efforts to develop energy-efficient policies. To address this awareness gap, the government should launch an education program through various media channels and workshops. Additionally, the country could enhance energy efficiency by replacing traditional lighting with LED lamps, optimizing street lighting, and supporting equipment procurement. Collaboration between the government, financial institutions, and private stakeholders is essential to provide loans and support well-designed and efficient energy projects. The Public Utilities Regulatory Authority (PURA) should conduct energy audits of public buildings to ensure compliance with energy efficiency measures, both in policy and implementation, with institutional and financial backing. Ultimately, prioritizing energy efficiency can lead to reduced electricity costs, lower carbon emissions, and improved public health. This can be achieved through information and capacity building, financial incentives, and the establishment of relevant laws and regulations.

Subject Areas

Architecture, Civil Engineering

Keywords

Limited Electricity Access, Private Generators, Renewable Energy, Emissions, Climate Change, Energy Efficiency Strategies, LED Lighting, Energy Audits, Policy Compliance

1. Introduction

In the global pursuit of enhancing energy efficiency and reducing environmental impact, residential buildings occupy a central role [1]. This significance holds true for Tujereng Village, located in The Gambia's tropical climate. The optimization of energy usage within residential structures is particularly pertinent in this context due to the unique challenges and opportunities presented by local environmental conditions and construction practices. The aim of this case study is to assess the energy efficiency of residential buildings in Tujereng Village comprehensively. In light of climate change and the ever-increasing energy demands, improving energy efficiency in this community not only promises economic prosperity but also aligns with sustainability goals and efforts to mitigate carbon emissions [2]. Energy's critical role in developing countries, including The Gambia, cannot be overstated. It fuels essential aspects of daily life, ranging from household needs to industrial processes, transportation, and infrastructure development. As the global population continues to grow, energy demand escalates, propelled by factors like urbanization and economic development [3]. The Gambia acknowledges the importance of energy efficiency in meeting its energy requirements and has established ambitious targets through its National Energy Efficiency Strategies (GNEES) [4]. These objectives seek to provide sustainable, reliable, affordable, and clean electricity, with a substantial portion of energy consumption originating from residential households. Residential buildings play a pivotal role in realizing energy efficiency goals, given the ongoing rural-to-urban migration and population growth trends [5]. Understanding how residential structures consume energy, especially through electronic appliances like lighting, heating, and various gadgets, becomes crucial [6]. Effective policy frameworks, awareness campaigns, and implementation strategies are indispensable for maximizing energy efficiency in these buildings. The United Nations Sustainable Development Goals (SDGs) underscore the necessity of energy efficiency policies, including those tailored to residential buildings [7] [8]. To achieve the 2030 SDG targets, a range of approaches is recommended, including raising awareness, implementing regulations mandating energy efficiency enhancements, and providing financial incentives to encourage the adoption of efficient technologies [9]. Previous research highlights the importance of context-specific approaches to energy efficiency in residential buildings. For instance, a study conducted by [10] in a tropical climate zone emphasized the significance of effective insulation, energy-efficient appliances, and well-designed cooling systems in mitigating energy consumption. Furthermore, [11] underscored the impact of occupant behavior and awareness in achieving energy savings in residential settings. While these insights hold value, the existing literature addressing Tujereng Village's unique socio-economic and environmental conditions remains limited. This study seeks to expand upon this knowledge base and provide tailored insights into the energy efficiency of residential buildings in Tujereng Village, with a particular focus on actionable recommendations for local stakeholders. The overarching research question guiding this endeavor is: How can the energy efficiency of residential buildings in Tujereng Village, The Gambia, be optimized within the context of the region's distinctive climate and local construction practices, while simultaneously advancing sustainability and reducing environmental impact? The primary objective is to comprehensively assess the current state of energy efficiency in residential buildings in Tujereng Village, considering factors such as building design, insulation, heating and cooling systems, lighting, and occupant behavior. The efforts of The Gambia to achieve universal access to energy by 2025 involve collaboration with international organizations such as the World Bank, African Development Bank, and initiatives like the West African Power Pool and the hydropower project OMVG [12]. These initiatives aim to interconnect sub-regions, harness renewable energy sources, and diversify the national energy grid [13]. Nonetheless, several challenges persist, including the need for energy education, the implementation of effective measurement and conservation strategies, the provision of financial incentives to support energy-efficient investments, and capacity building in institutions responsible for energy monitoring and regulations [14]. Addressing these challenges is essential to realizing The Gambia's energy efficiency and access objectives [15].

2. Materials and Methods

2.1. Study Area

The research was carried out in Tujereng village, West Coast Region (WCR), which is located in the Kombo South District of The Gambia in West Africa. (**Figure 1**) It is a coastal town in the region, which is 27 km away from the nation's capital, Banjul, and has a population of 7387 people [16].

2.2. Data Collection

A questionnaire was carried out to obtain information from 120 participants in Tujereng, The Gambia, which is one of the urban settlements within the country on their understanding of the energy efficiency of a residential buildingand has access to electricity. Through academic institution, physical survey and review of existing documents from relevant agencies. People were randomly selected and were ask base on the questionnaire.

2.3. Data Analysis

Data was first entered into excel for data analyses. The frequency of the demographic characteristics was obtained and a Chi-square test was performed using

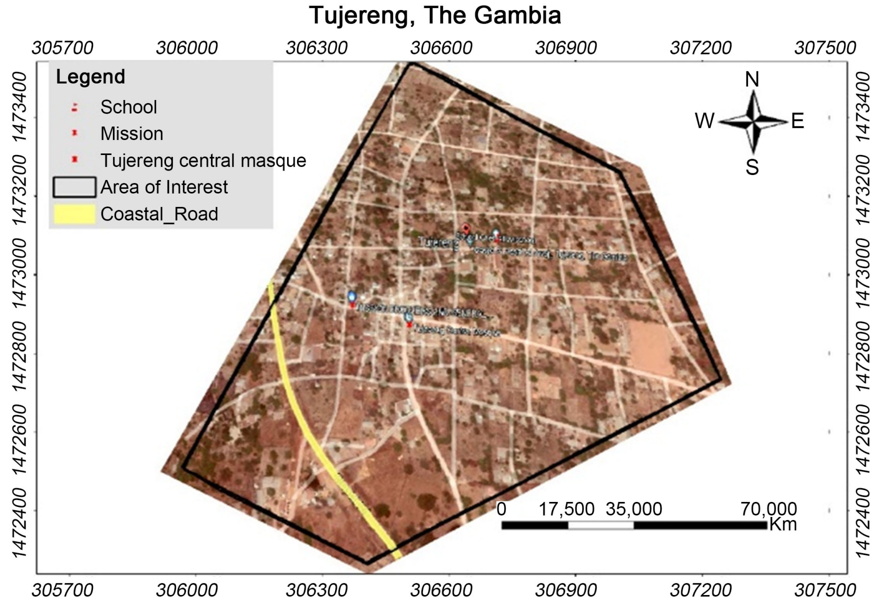

Figure 1. The map of Tujereng Village in West Coast Region.

Cross-tabulation of the various physical parameters of the buildings of learning against the internal equipment in a residential house.

3. Results and Discussion

After conducting our study, we have come to realize that The Gambians are spending a significant amount of energy across various sectors, encompassing residential, commercial, private, and public offices. This energy usage surpasses what is actually necessary for their consumption. This issue can be attributed to several key factors, including the utilization of inadequate equipment, outdated electrical and electronic materials, and outdated production methods. Another contributing factor is the lack of knowledge among some individuals when it comes to purchasing electrical and electronic equipment and their appropriate usage, which results in a significant waste of energy. Furthermore, technical insulation plays a pivotal role in the increased energy consumption of residential buildings. It is important to note that in The Gambia, there is currently no legislation governing or certifying the individuals allowed to perform electrical insulation in residential buildings. **The results** in our study reveal that nearly 47% of respondents indicated that they had never sought the services of a company or government agency for insulation, while only 38% prioritized high-quality electrical insulation. A surprising 15% of respondents reported having no knowledge about this matter. According to [17], proper insulation is of paramount importance as it can lead to a reduction in energy consumption, enhanced comfort, and environmental benefits. In The Gambia, yellow bulbs serve as a primary source of illumination for citizens; however, their consumption patterns are not well understood. Our respondents revealed that 12% used incandescent lamps, which, as indicated in [18], consume a staggering 95% of energy, with the remaining energy being converted into heat for lighting. [19] [20] [21] should be adopted to observed high quality energy saving.

3.1. Socio-Demographic Characteristics of Study Participants

Most of them gender participant where Female 64 (53.33%) the mean age (standard deviation (SD)) was 36.12 (±5) years and ranged from 25 to 45 years. Almost half of the participants educational status 57 (47.5%) were from the tertiary institutions and 157 (36.4%) of the respondents were students by occupational status. by tribes Table 1.

3.2. Physical Analysis of a Building

The provided data from the physical analysis of the building indicates that there is a significant diversity in the types of ceilings used by the building's residents. The participants were asked the type of ceiling used by their residents, and many of them concurred that conventional was (29.2%) and non-conventional was (57.5%), while both indicated (13.33%) as shown in the Table 2 and Figure 2. A substantial majority of the participants, representing approximately 57.5%, reported having non-conventional ceilings in their residences. This category likely includes a wide range of ceiling materials and designs that deviate from traditional or standard options. Non-conventional ceilings can encompass various

Table 1. Demography of participants.

Characteristics	Frequency (n)	Percentage (%)
Sex		
Male	56	46.67
Female	64	53.33
Age		
15 - 25	37	30.83
26 - 35	58	48.33
36 - 45	5	4.17
>45	20	16.67
Educational Status		
Tertiary	57	47.50
High School	53	44.17
Non-Formal Education	10	8.33
Occupational Status		
Student	43	35.83
Teacher	24	20.00
Civil Service	30	25.00
Others	23	19.17

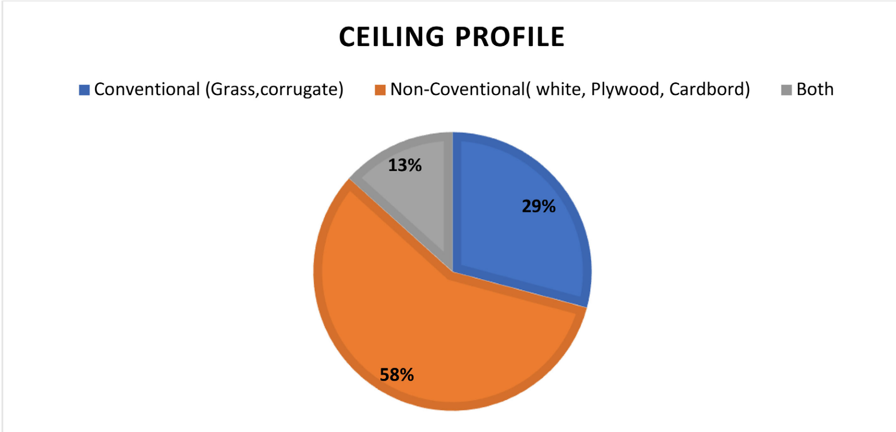

Figure 2. Pie chart showing the response of participant on the type of ceiling.

Table 2. Type of ceilings.

Ceiling	Conventional (Grass, corrugate)	Non-conventional (white, plywood)	both
No. of Participant (%)	29.17	57.5	13.33

creative and innovative choices, which may have been selected for reasons such as aesthetics, functionality, or a desire for unique interior design. Nearly 29.2% of the respondents indicated that they had conventional ceilings in their homes. Conventional ceilings typically refer to commonly used ceiling materials and designs that are standard in residential construction. These choices may prioritize practicality, cost-effectiveness, or adherence to traditional building norms. Both Conventional and Non-Conventional Ceilings (13.33%), a smaller but still notable portion of participants, around 13.33%, reported having both conventional and non-conventional ceilings within their building. This suggests a degree of diversity or hybridization in ceiling choices within the building. Residents might have opted for different ceiling types in different rooms or areas of the building, possibly based on specific needs or preferences. This data indicates a dynamic and varied approach to ceiling selection within the building. The prevalence of non-conventional ceilings highlights a potential emphasis on uniqueness and customization among the residents, while the presence of conventional ceilings suggests a balance between tradition and innovation in the building's design. Further investigation could delve into the specific reasons behind these choices and their impact on the building's overall aesthetics and functionality.

The responses of participants are shown in Table 3 and Figure 3, where the use of external wall concrete was (39%), brick (47%), and wood (6%), indicating that the study area is clearly a highly urbanized region.

In Figure 4 and Table 4, it is evident that 64.4% of the participants expressed a preference for interior wall colors they found aesthetically pleasing, while 24.4% opted for colors they did not consider beautiful. Additionally, 11.1% of the participants were categorized in the "Others" group. These findings offer valuable insights into the participants' interior wall color preferences. The majority of participants chose wall colors that they personally found beautiful or visually appealing. However, a significant minority selected colors they did not perceive as beautiful. The "Others" category revealed a distinct group of participants who did not base their interior decoration choices solely on beauty or non-beauty criteria. Instead, they seemed to prioritize a comfortable and homely ambiance within their homes. This category potentially includes participants with neutral preferences or those who found it challenging to classify their choices into the "Beauty" or "Non-Beauty" categories.

The responses of participants are shown in **Table 5** and **Figure 5**. The result demonstrates that the types of materials used for the ground floor in a building, along with the percentage of participants who reported each option. A majority of the participants, approximately 64.6%, reported that the ground floor of the building is covered with tiles. Tile flooring is a popular choice due to its durability, ease of maintenance, and aesthetic appeal. It's often used in residential and commercial spaces for its versatility and ability to withstand heavy foot traffic. Cement Concrete (26.3%): About 26.3% of the participants indicated that the ground floor of the building is made of cement concrete. Cement concrete is a sturdy and cost-effective flooring material commonly used in various construction projects. It provides a solid and level surface, making it suitable for both indoor and outdoor applications. A smaller percentage, approximately 9.1%, reported using "other" materials for the ground floor. This category could include a variety of materials not specified in the data, such as wood, laminate, or natural stone. The inclusion of this category highlights the potential diversity in flooring choices within the building.

Table 3. Exterior wall.

Exterior wall	Wood	Brick	Concrete	Others
No. of Participant (%)	6	47	39	8

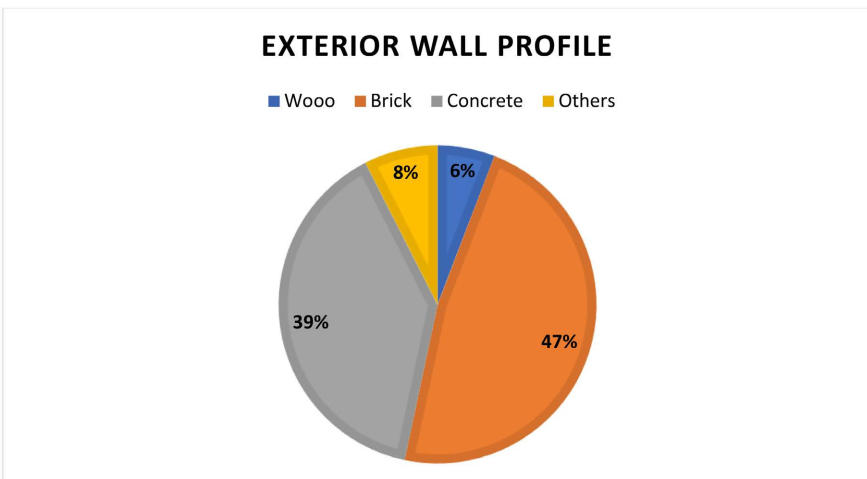

Figure 3. Pie chart showing the response of participant on the type of exterior wall.

Table 4. Interior wall colour.

Interior wall colour	Beauty	Non-Beauty	Others
No. of Participant (%)	64.4	24.4	11.1

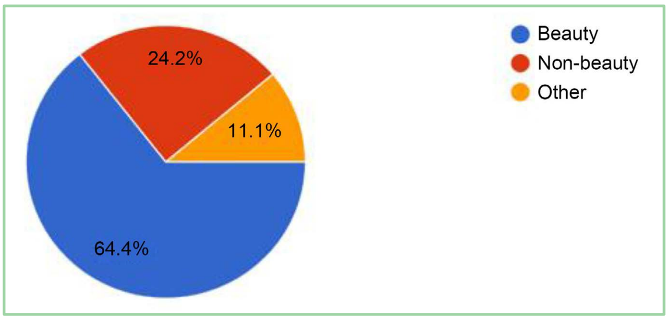

Figure 4. Pie chart showing the response of participant on the nature of interior wall.

Table 5. Ground floor.

Ground floor	Tile	Cement concrete	Others
No. of Participant (%)	64.6	26.3	9.1

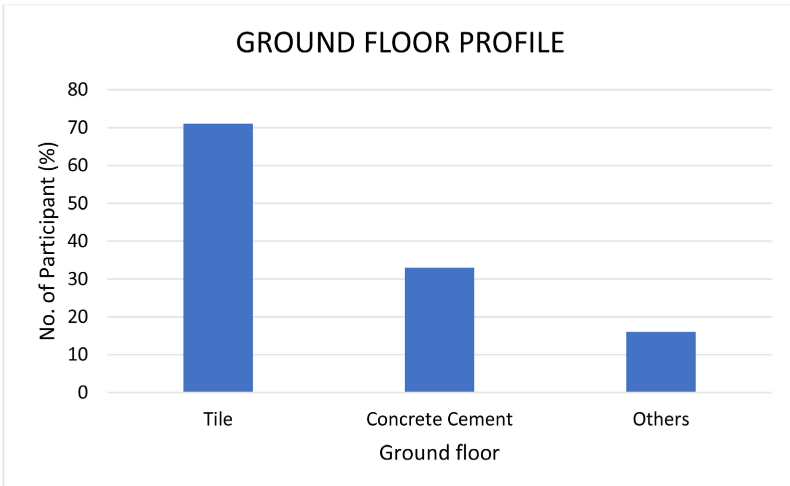

Figure 5. Bar charts showing the response of participant on the question: the type of ground floor use in their residence.

Technical insulation is one type that assists consumers in purchasing new items and replacing old ones as a result of regular appliance inspections. As shown in Table 6 and Figure 6, approximately 38.33% of the participants responded affirmatively, indicating that technical insulation is used in the building. Technical insulation typically involves the installation of specialized materials to control heat transfer, prevent energy loss, or regulate temperature within a structure. This percentage suggests that a significant portion of the building likely employs technical insulation, which can contribute to improved energy efficiency and thermal comfort. A slightly higher percentage, around 46.67%, indicated that technical insulation is not used in the building. This implies that a considerable portion of the building does not have specialized insulation measures in place. The absence of technical insulation may result in challenges related to energy efficiency and temperature control, potentially leading to increased energy consumption and reduced comfort, especially in extreme weather conditions. About 15% of the participants did not provide a clear response regarding the use of technical insulation. It's essential to note that these participants may not have information about the building's insulation status or may have chosen not to respond. Their lack of response may require further inquiry or investigation to ascertain the actual status of technical insulation in the building.

One of the most important parts of this study is the use of light bulbs; our study captured that only 12.1% of households used incandescent lamps. This is because of its yellow nature and the place of its usage; as the study was conducted in an urban area, most of the people are moving away from this yellowish light bulb, as we called it in the Gambia. Our largest response came from energy-saving LED light bulbs, which indicated (58.6%) that this could improve more if the government came up with a policy that could encourage consumers to buy more LED lights. Most of the LED energy-saving light bulbs come in 10 W, 15 W, and 20 W, which could save a lot of energy every hour when used as compared to incandescent and fluorescent light bulbs (18.2%), as shown in Table 7 and Figure 7.

Table 6. Technical insulation.

Technical insulation	yes	No	No answer
No. of Participant (%)	38.33	46.67	15

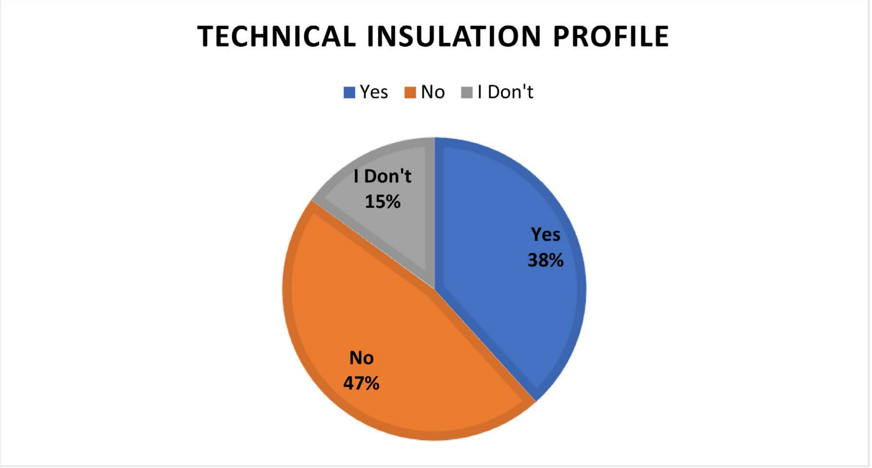

Figure 6. Pie chart showing the response of participant on technical insulation.

Table 7. Light bulb.

Light bulb	Incandescent	LED (energy saving)	Fluorescent	Others
No. of Participant (%)	12.1	58.6	18.2	11.1

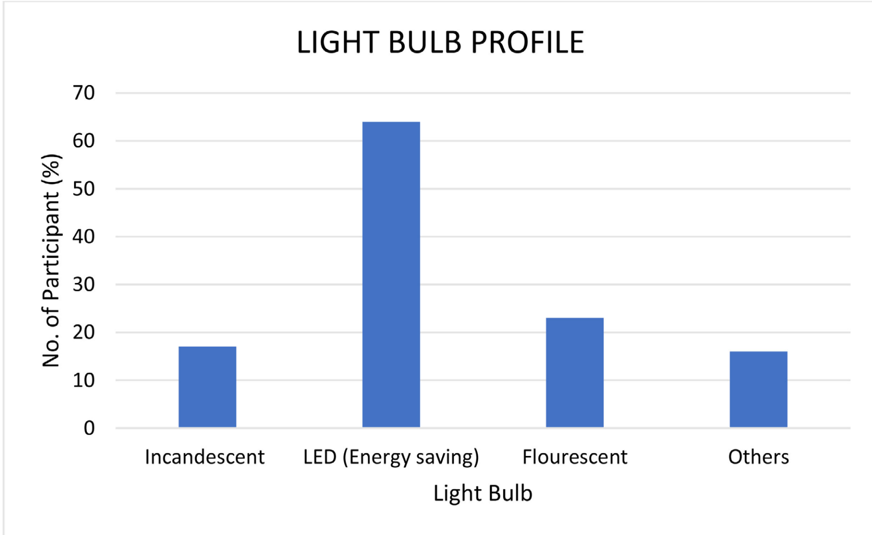

Figure 7. Pie chart showing the response of participant on the type of Light Bulbs.

Respondents were asked about their awareness of government energy policy and legislation, of which 41% agreed, 42% had no knowledge about energy efficiency, and 17% had no answer, as shown in Table 8 and Figure 8. There is a large majority of citizens who do not have a clue about energy policy and legislation; therefore, the regulators, in partnership with stakeholder groups, could create more sensitization.

According to our research (as shown in Table 9 and Figure 9), nearly 32% of Americans have access to electricity for up to 20 hours per day, demonstrating that with a proper energy efficiency policy, we can integrate these ideas into the system.

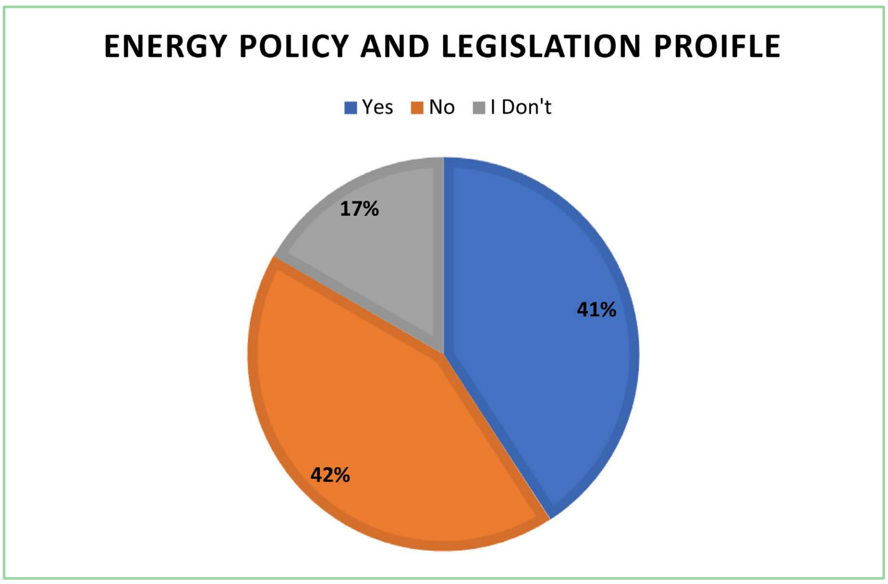

Figure 8. Pie chart showing the response of participant on the Energy policy and legislation.

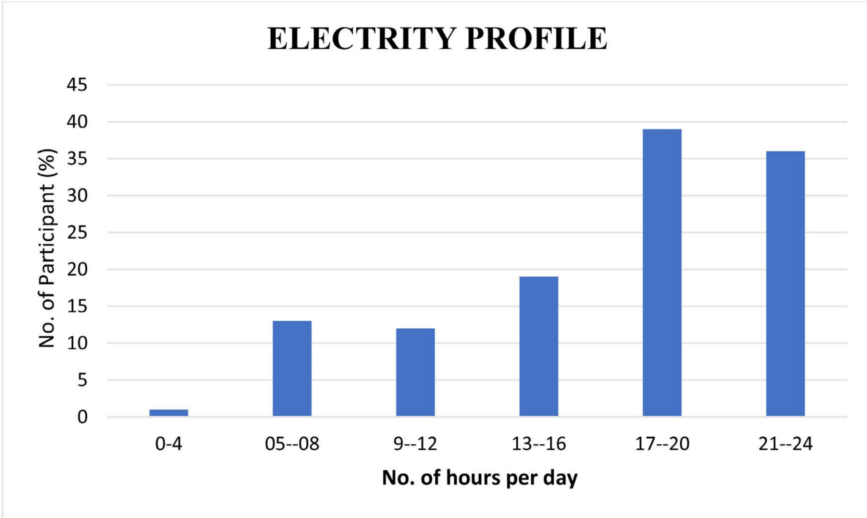

Figure 9. Bar charts showing the number of hours respondents get electricity supply per day.

Table 8. Awareness of Energy Policy and legislation.

Policy and Legislation	Yes	No	No-Answer
No. of Participant (%)	41	42	17

Table 9. Number of hours of electricity supply per day.

Time (hrs)	0 - 4	5 - 8	9 - 12	13 - 16	17 - 20	21 - 24
No. of Participant (%)	1	11	10	16	32	30

Appliances are one of the key elements that play a vital role in determining the energy efficiency of a building. For anyone to reduce his or her annual energy bill, one has to buy an efficient appliance. Our study (**Table 10**) shows that 35.3% of our participants agreed that they consider the price of an appliance before purchasing it. The price of goods and services in the Gambia's economy was determined by supply and demand. Consumers should not only consider price when purchasing an item but also its efficiency. The national regulators should come up with policies that encourage people to buy more efficient appliances. energy rating, which caters to 26.3% of our respondents and which they consider the second-most influential factor when buying an item. According to the study, 9.1% of respondents strongly believe that the size of the appliance is important to them. During the interaction, most Gambian participants claimed that this did not necessarily mean that they consumed more energy but that they needed more appliances. The effect of bigger and smaller size should be a public awareness campaign so that consumers' selection will go in line with energy efficiency. The beauty is the least-reported value (5.1%), while manufacturers also play a crucial role in consumers' selection of appliances; others think that some brands have better items in terms of durability, lifespan, and reliability. Electrical and electronic dealers should explain these phenomena to all customers so that they can make the best purchase decision.

Our national water and electricity company (NAWEC), which is the main supplier of electricity through the use of fossil fuel (oil), shows that 44% of its energy comes from this source, 31% gets it from renewable energy, and 25% indicated they used both sources of energy. (**Table 11** and **Figure 10**)

From **Table 12**, it has been shown that only 11.67% use electricity for cooking, which indicates the cost of using this form of energy for cooking. If manufacturers could produce highly efficient appliances, this would encourage more people to use them, and in return, we could eliminate the use of fossil fuel products such as oil and gas for cooking. GHG reductions will also be lower, accelerating the energy transition. The most energy-dense source for cooking is gas (43.3%), followed by fuel made from biomass products (charcoal, firewood, and sawdust), which is (32.5%).

As the world strives to reduce the global temperature, the use of cooling appliances will be more demanding due to climate change and the adverse effects of temperature. Our participants claimed that most of them used ceiling fans (45.83) to cool their residential houses, stand fan (26.67%), while 15.83% used air conditioners as shown in **Table 13** and **Figure 11**.

During the study, we also visited electrical and electronic shops to compare the physical and external materials of the building materials with their prices, sizes, producers, and equipment. These values could also be subjected to changes (**Table 14**).

3.3. List of Selected Home Base Appliances in the Gambia

During our study, we found a relationship between the energy rating and the price, **Table 15** shows different appliances by price, producer, and power rating. This is the market data that we obtained, but it is subject to change.

Table 10. Factors influencing your choice of appliances.

Appliance	Price	Energy Rating	Size	Beauty	Manufacturer	others
No. of Participant (%)	35.3	26.3	9.1	5.1	13.1	11.1

Table 11. Source of energy.

Energy Source	Non-Renewable	Renewable	Both
No. of Participant (%)	44	31	25

Table 12. Source of energy for cooking.

Source of energy for cooking	Gas	Electricity	Fuel (Charcoal, Firewood, Sawdust)	Others
No. of Participant (%)	43.33	11.67	32.50	12.50

Table 13. Home cooling system.

Cooling System	Air conditioner	Ceiling fan	Stand fan	Others
No. of Participant (%)	15.83	45.83	26.67	11.67

Table 14. The list of prices on Buildings in The Gambia.

No.	Equipment	Producer	Size (Cm or L)	Price ($)
1.	Cardboard	PVC	76.4 cm × 2.7 cm	5.25
2.	Plywood	Juana wood	76.4 cm × 2.7 cm	19.37
3.	Corrugate	Taigang Puxin	76.4 cm × 1.7 cm	300
4.	Tile	Mohawk	20 cm × 20 cm	2
5.	Steel door	Home's Guard	205.74 cm × 104.14	32.28
6.	Glass door	UPvc	203.2 cm × 152.4	8.07
7.	Solid wood	OEM	203.2 cm × 91.44	8.07

Table 15. The list of prices on appliances in The Gambia.

No.	Equipment	Producer	Power (Watt)	Price ($)
1.	Electric kettle	Lifelong	1500	6.62
2.	Electric Iron	USHA Armor	1100	7.24
3.	Blender	HAN RIVER	250	22.37
4.	LED (Energy saving) Bulb	Philips	9	1.04
5.	Incandescent Bulb	GENREE	60	5.00
6.	Fluorescent Bulb	Spiral	45	11.50
7.	Window A.C	Panasonic	2090	590.56
8.	Window A.C	LG	1645	505.00
9.	Window AC	Samsung	920	467.77

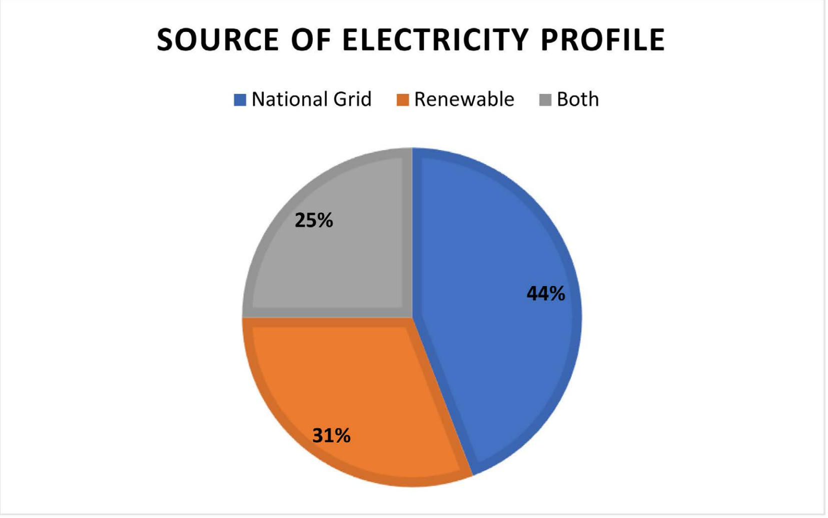

Figure 10. Pie chart showing the profile of participant on "Source of Electricity".

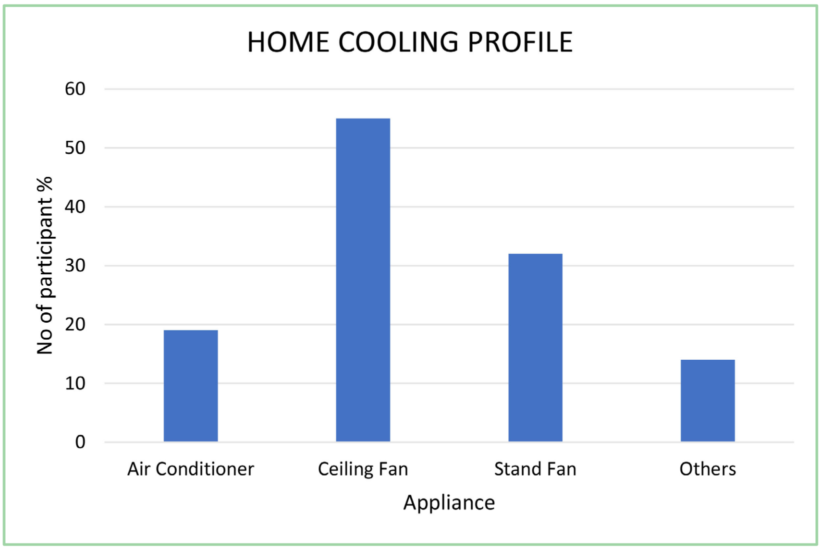

Figure 11. Pie chart showing the response to the question: what type of cooling system do you have at home?

4. Conclusion

As far as human activities are concerned, we cannot do most of the things in this world without energy; its potential has a meaningful impact on the national economies of the world. Assessing energy efficiency and developing models that can assist us in meeting the SDGs by 2030 is a critical role for all of us. This paper mainly focuses on residential, commercial, private, and public buildings and how they can reduce their monthly electricity use through the physical body study of the building and the appliances used there. The materials and the methods used during this study were a comprehensive questionnaire, interviews, and group discussions, with a highly detailed literature review of most of the national documents. From the results, it was indicated that as we used highly rated power consumption appliances, we paid more bills, but this does not mean that high power goes with a higher price.

Recommendation and Limitation

Our research was unable to determine the thermal properties of each material in order to determine the depth of energy consumption. The study could not also reach the rural settlements of the country to assess the same phenomenal behaviour. In The Gambia, the government is yet to come up with standards for determining the efficiency of the various appliances. A policy is needed to address this. However, the Gambia Public Utility Regulatory Authority (PURA) should be properly equipped to define energy efficiency standards. This is because some people consider the efficiency of the appliance before they purchase one.

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Conflicts of Interest

The authors declare no conflicts of interest.

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