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Space Use and Energy Consumption in Living Rooms: A Case Study of ESHDC High-Density Estates, Enugu Capital Territory, Nigeria

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Abstract
This study investigates the relationship between space use and energy consumption in naturally ventilated living rooms within high-density residential estates developed by the Enugu State Housing Development Corporation (ESHDC) in Enugu Capital Territory, Nigeria. Drawing from principles of the Adaptive Comfort Model and Environmental Possibilism, the research explores how occupant behaviour, daily activity patterns, and energy sources interact to influence thermal satisfaction. A cross-sectional survey was conducted using structured questionnaires administered during evening hours (4:00 PM –7:00 PM) in the rainy season across two ESHDC estates, with a proportional sample of 130 housing units. Findings revealed that a majority of occupants spent over three hours daily in their living rooms and rely heavily on electricity and alternative power sources such as generators to achieve thermal comfort. Pearson Product Moment Correlation analysis showed weak but notable associations between electricity supply, space use, and types of evening activities, with a significant negative correlation between activity type and the use of alternative power sources. The results underscore the role of behavioural and contextual factors in shaping domestic energy demands. The study concluded that improving electricity reliability, promoting passive design strategies, supporting energy-efficient technologies, and incorporating occupant behaviour into planning would enhance energy efficiency and occupants' thermal comfort in high-density housing environments.

Keywords: *adaptive behaviour, energy consumption, high-density housing, natural ventilation, space use, thermal comfort.*

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I. INTRODUCTION

Providing comfortable thermal conditions in living rooms within the warm-humid tropical climate of southern Nigeria—without relying on electric energy—has become a significant design challenge due to the high costs associated with operating and maintaining mechanical ventilation systems. Globally, attention is increasingly focused on building energy consumption, as buildings account for approximately 40% of global energy use and contribute significantly to the rise in Earth's surface temperature, commonly referred to as global warming (Sakar & Caliskan, 2019; Santamouris, 2016; Ezema et al., 2016; Fischer et al., 2012).

In many urban areas within tropical climates, buildings frequently experience elevated thermal conditions, prompting occupants to rely on mechanical ventilation systems for thermal comfort (Adebuisi et al., 2018; Olanepekun, 2014; Eludoyin, 2013). Inappropriate design of a space can increase indoor temperatures, thereby raising the energy required for cooling. According to the World Bank (2020), a 1°C rise in temperature can increase energy demand for thermal comfort by approximately 6.7%. Higher operative temperatures also require greater energy input to maintain acceptable indoor conditions. It is therefore essential for the building designers to consider the intended use of a space and the energy needed for thermal comfort at the initial design phase. This enables the identification and choice of appropriate adaptive strategies and controls for naturally ventilated spaces as well.

A living room is an enclosed space in residential buildings, primarily used for receiving guests, relaxation, and social interaction among occupants (Hou, 2016; Marshall, 2012). It portrays image of a host to guests, and it often serves as a central hub in the home, where family members gather to interact, watch television, listen to the news, dine, or engage in indoor games (Rechavi, 2008; Marshall, 2012). Beyond these functions, the living room plays a crucial role in fostering family bonds, shaping character, and promoting cultural integration within a broader society (Ogunola, 2018). Given its importance, ensuring thermal comfort in living rooms is essential for well-being of occupants and for enhancing both thermal acceptability and duration of use (Munonye, 2021; Adunola, 2011).

Preliminary research observed frequent use of mechanical ventilation systems in the living rooms within the Enugu State Housing Development Corporation (ESHDC) high-density estates. These observations suggest that inadequate natural air circulation is a likely cause, prompting reliance on mechanized systems to improve ventilation and occupant thermal satisfaction throughout the day and across seasons (Vallei et al., 2023). The study therefore posits that understanding how a space such as a living room is used can help in an accurate estimation of daily energy needs, encourage flexible use of energy by occupants, and thus making the indoor spaces indeed living rooms for occupant to spend more time in them (Adunola & Ajibola, 2016; Indraganti & Rao, 2010).

There is an increasing scholarly interest in reducing energy consumption for thermal comfort in buildings, particularly in light of rising electricity costs and the need to promote longer occupancy of living rooms in ESHDC estates, especially in the evening hours (Adebuisi et al., 2018; Ezema et al., 2016; African Progress Panel [APP], 2015; Haliu et al., 2021; Santamouris, 2016). Previous studies have shown that, in addition to the six standard thermal variables, a non-thermal factor such as the space use can significantly impact on the patterns of energy consumption in buildings (Alwetaishi, 2016; Ifebi, 2020; Pathirana et al., 2019; Adunola, 2015; Shahzad et al., 2018; Shooshtarian & Ridley, 2018).

This investigation forms a part of the broader research initiative assessing the effect of natural ventilation on the thermal conditions of living rooms in high-density estates within Enugu Capital Territory, Nigeria. To date, no comprehensive study has explored the relationship between space use and energy consumption in naturally ventilated living rooms in the warm-humid tropical climate of southern Nigeria. This gap in human thermal comfort research underscores the need for further investigation. Accordingly, this study investigates the relationship between space use and energy consumption in naturally ventilated living rooms within ESHDC high-density estates in Enugu Capital Territory. The aim is to make recommendations for reducing reliance on mechanical ventilation systems and, consequently, minimizing energy consumption in living rooms situated in the warm-humid climate of southern Nigeria. The hypothesis underpins this study: ‘There is no significant relationship between space use and energy consumption in the naturally ventilated living rooms in the ESHDC high-density estates’.

Area of the Study

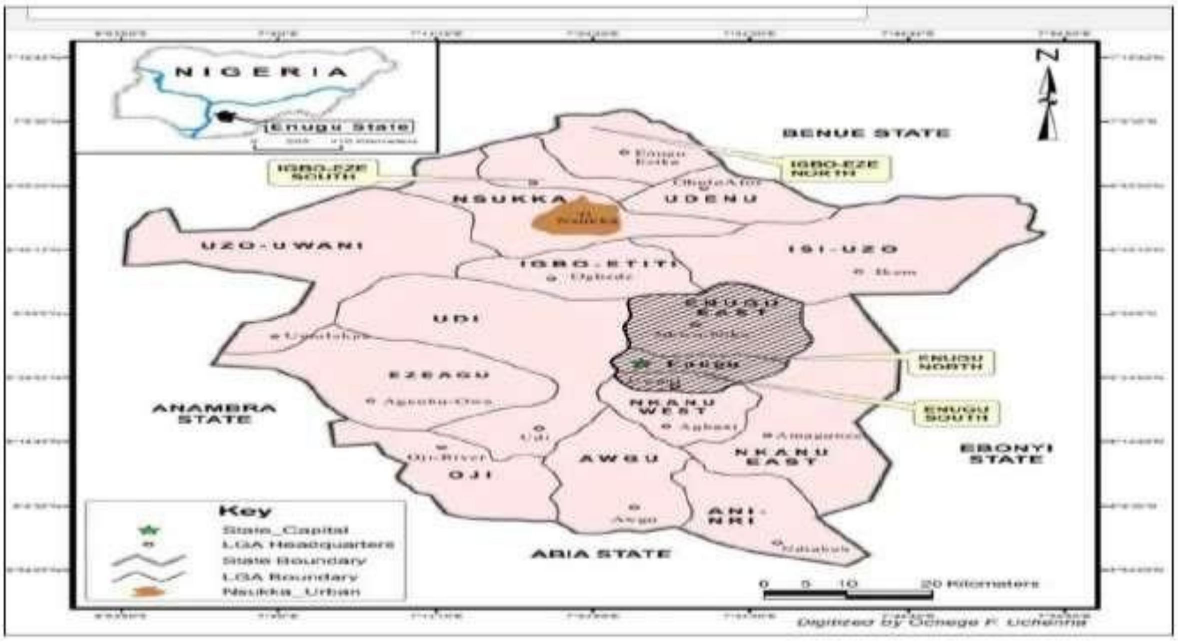

Figure 1: Map of Enugu State (showing the Capital Territory in hatched area)
Source: Enugu State Government Diary (2013).

The study was conducted in Enugu Capital Territory, the capital city of Enugu State, located in the south eastern region of Nigeria. Geographically, it lies approximately between latitudes 06°21″ and 06°30″ N of the equator and longitudes 07°26′ and 07°37″ E of the Greenwich Meridian. Figure 1 shows a map of Enugu State, with the Capital Territory designated by the hatched area. The territory is bordered to the north by Igbo-Etiti and Isi-Uzo Local Government Areas, to the west by Udi, to the south by Nkanu West, and to the east by Nkanu East Local Government Areas.

Known as the "Coal City," Enugu Capital Territory derives its name from its hilly terrain and the discovery of coal in 1909 by British geologists. It is recognized as the oldest urban centre in south eastern Nigeria. According to the National Population Commission (NPC, 2006), the population of the Capital Territory was projected to reach 2 million by 2015, with a population density of

427.6 persons per square kilometre. The Igbo people are the predominant ethnic group, although the presence of other nationalities contributes to cosmopolitan character of the city (Enugu State Government Diary, 2013).
Rapid urbanization, spurred by population influx, has placed considerable strains on housing, public infrastructure and electricity supply. These pressures led to a decline in urban quality and, contributed to elevated thermal conditions experienced in the city throughout the year (Idoko & Ezeodili, 2021; Physical Development Guide, Enugu State, Nigeria, 2016).

1.2 Climatic and Topographic Characteristics of the Study Area

Enugu Capital Territory is situated on undulating hilly terrains, contributing to its distinctive topography. Six rivers - Aria, Asata, Ekulu, Idaw, Nyaba, and Ogbete - traverse the area, and helping to regulate the microclimate. Enugu State is located in the tropical region of southern Nigeria. According to Eludoyin, (2013), the climate is hot and humid, with fairly constant temperature and humidity levels all through the year. Based on the Köppen's global climate classification, Enugu State falls within Tropical Moist Climate (TMC) zone. The region features tropical rainforest vegetation with characteristics of derived savannah. The territory is located at an elevation of approximately 304.7 meters above sea level and is naturally humid. The average maximum temperature is around 34.9°C, while average lows hover around 22.3°C, with an annual mean of about 26.7°C. The climate is marked by two distinct seasons: a rainy season and a dry season (Iloeje, 2001). Figure 2 illustrates the average monthly temperature and rainfall in Nigeria from 1991 to 2021. In the southern regions, including Enugu State, the rainy season spans from March to October, peaking between June and August. During this period, annual rainfall averages between 200 cm and 400 cm, while temperatures range from 25°C to 27°C (World Bank Group, 2021).

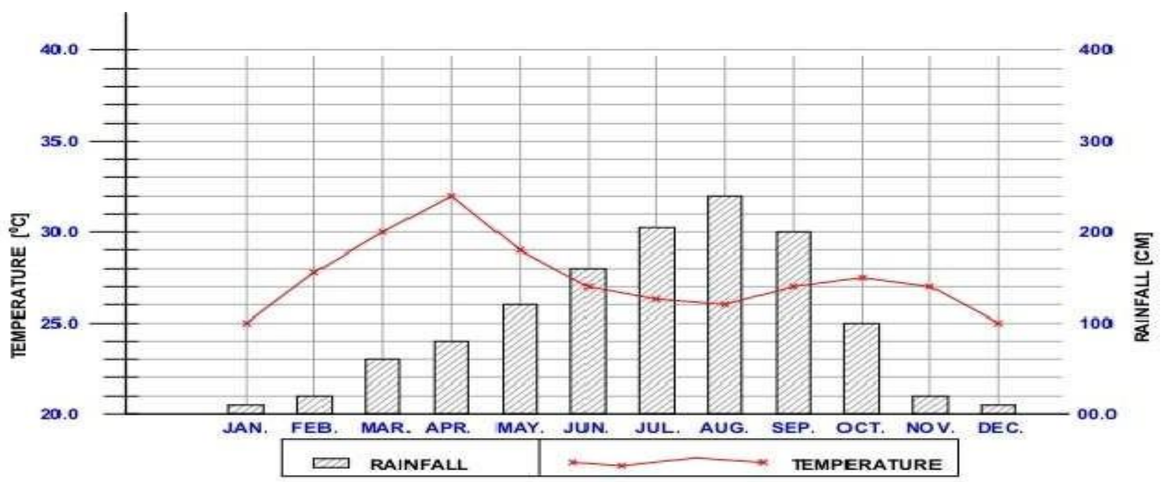

Figure 2: Average Monthly Temperature and Rainfall in Nigeria, 1991 – 2021

Source: World Bank Group, WBG, (2021): Climate Risk Profile, Nigeria.

II. LITERATURE REVIEW

2.0 Adaptive Comfort and Environmental Possibilism

The Adaptive Comfort Model and the theory of Environmental Possibilism acknowledge the significant role of human behaviour in regulating indoor thermal conditions and promoting flexible energy use, particularly in naturally ventilated buildings (Ni et al., 2023; Adebuisi et al., 2018; Humphreys et al., 2018; Li et al., 2015; Ezema et al., 2016). These models recognize that building occupants are not just passive users of space, but active agents who modify their environments and adjust their behaviour to achieve thermal comfort.

2.1 Space Use and Thermal Comfort Factors

The adaptive comfort model highlights that human activities occur within specific spatial contexts, and understanding the function and use of these spaces are crucial for accurate thermal comfort assessment. Daily and seasonal patterns of space use affect the amount of energy required to maintain comfort, especially for occupants who spend long hours indoors (Haliu et al., 2021; Haruna et al., 2018). Furthermore, an understanding of space utilization is essential for estimating energy demand and ensuring efficient building operation with minimal energy use (Alwetaishi, 2016; Hu et al., 2023; Vellei et al., 2023). Similarly, recognizing patterns of space use can also help maximize energy savings and promote flexible energy consumption under variable climatic conditions (Adebuisi et al., 2018; Ezema et al., 2016; Adunola, 2015; Olanipekun, 2014).

Thermal comfort is defined as a person's satisfaction with the surrounding thermal environment (ASHRAE Standard 55, 2017). While environmental factors such as temperature, humidity, and air speed, as well as personal factors like clothing and metabolism, traditionally determine thermal comfort, recent studies suggest that non-thermal factors—such as the space use, thermal history, sociocultural background, and building context—also play a crucial role (Shooshtarian & Ridley, 2018; Jowkar et al., 2020; Fadeyi, 2014; Alwetaishi, 2016). Shooshtarian and Ridley (2016) argue that these non-thermal factors are not incorporated in the PMV/PPD models commonly used for predicting comfort. In contrast, the adaptive comfort hypothesis posits that a non-thermal factor such as space use can influence occupant behaviour and thermal preference (Fadeyi, 2014; Zhang et al., 2023), making it important to consider in energy-efficient design strategies.

2.2 Natural ventilation and Energy Consumption in high- density housing

Thermal satisfaction is influenced by the dynamic interaction between occupants and their indoor environment (Haruna et al., 2018; Yao et al., 2020). The amount of energy needed to maintain a stable core body temperature is a key determinant of comfort. The World Bank (2020) notes that a 1°C increase in temperature can raise energy demand for comfort by 6.7%, underlining the importance of climate-responsive strategies. Higher operative temperatures typically demand extra energy for occupants' comfort expectations. However, adaptive strategies—including behavioural, physiological, and psychological adjustments allow occupants to minimise energy use while maintaining comfort (Yao et al., 2020; Shahzad et al., 2018). The adaptive model is accepted for both naturally ventilated and mixed-mode buildings, and is often considered more acceptable than the PMV/PPD models because it allows for occupant-controlled adaptive opportunities (ASHRAE Standard 55, 2017).

There is an increased yearning for energy-efficient and sustainable housing developments across the globe. Harnessing of natural ventilation is one of the energy conversation strategies in buildings (Chen et al., 2017; Yang & Clements-Croome, 2012). The effectiveness of natural ventilation relates with its capacity to reduce reliance on mechanical ventilation systems thereby limiting energy consumptions for occupants' thermal satisfaction (Ahmed et al., 2021). Findings of previous studies on natural ventilation in buildings in a tropical urban setting have benchmarked on these critical factors for considerations at initial planning phase: 1. Window design parameters;

2. Building orientation; 3. Courtyard design/Minimum spaces between buildings (i.e. 5 times the height of building); 4. Minimizing dark and hard surfaces and replacing bare earth and sandy or rough ground surfaces with grasses and trees to reduce heating up the air and the dust content of the air; 5. Widening urban streets, and eliminating concrete perimeter fences/obstacles; 6. Raising the buildings on pilots can enhance adequate airflow across buildings and mitigate adverse effects of urban heat island associated with urban environments (Akube, 2019; Obiefuna et al., 2020; Kwong et al., 2014; Fischer et al., 2012; Kleiven, 2012; Lawal & Ojo, 2011).

However, contrast is the case as natural ventilation effectiveness is grossly impeded in dense urban housing, due to high settlement densities, coupled with the practice of many town/urban planning authorities that overlook inclusion of the natural ventilation design principles in laying out housing estates (Luciano, 2012; Givoni, 1996). Consequently, many urban housing estates especially those in the warm-humid tropical climate rely on the extensive use of mechanical ventilation systems to attain thermal satisfaction on daily basis.

Additionally, it was also observed that most windows in living rooms were identical in area and size, thus less than 50% WWR basic for natural ventilation performance, hence the reliance on mechanical ventilation systems (Onochie et al, 2025).

Studies have shown that it is possible to provide a thermally comfortable space in the warm-humid region without using mechanical ventilation systems (Ahmed et al., 2021; Chen et al., 2017). Before the advent of industrial revolution in 17th century buildings were constructed in compliance with possible climate responsive principles – local climate, topography and cultures. However, rapid urbanisations, advances in sciences and technology have triggered massive urban housing developments with the attendant higher energy consumptions (Michaelides, 2012). Furthermore, Givoni (1997) submits that how housing estates are planned and designed impact significantly on the energy demand for ventilation and thermal comfort.

Nigeria Energy Support Programme [NESP], (2013) provides the breakdown of estimated energy use in low income households in the Figure 2.1 and the middle income households in the Figure 2.2. The lack of reliable data is apparent in all sectors, and it is more evident in residential buildings, and thus making it difficult to set up local benchmarks for the sector. According to Nebo (2013), more than 55% of households at urban centres are not metered, and they depend on off- grid electricity for their domestic energy consumptions. Prioritizing use of natural ventilation will lessen to a third of the total energy consume by residential buildings, and as well allowing for more energy for commercial, industrial and other sectors in Nigeria (Ezema et al., 2016; Nigeria Electricity Commission [NEC], 2014; Akinbami & Lawal, 2010).

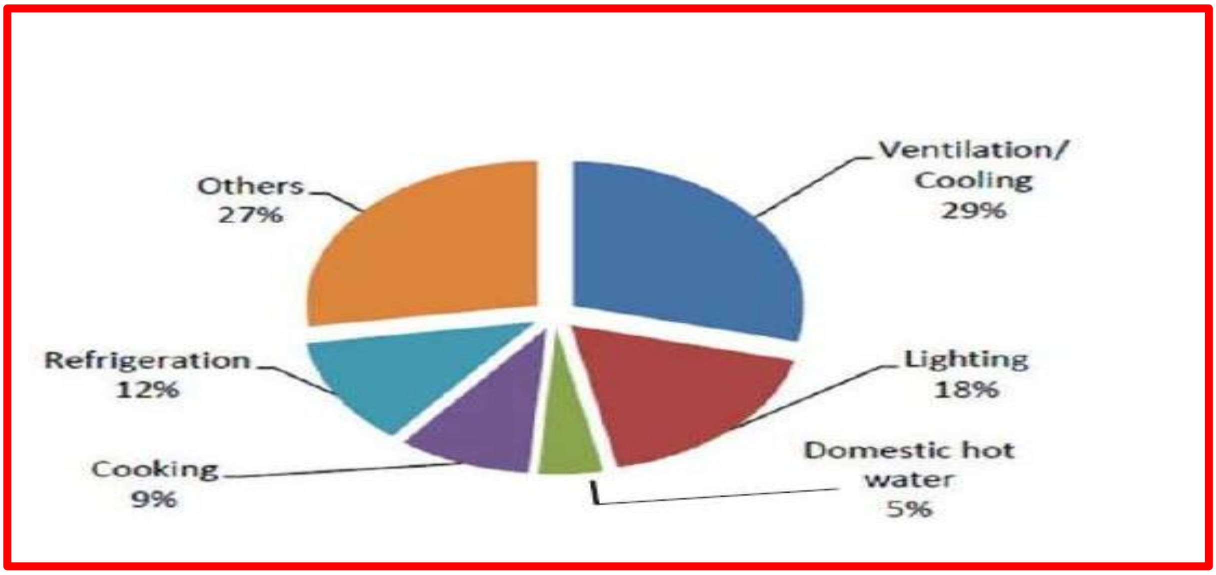

Figure 2.1: Estimated Breakdown of Energy use in low income households in Nigeria.
Source: Nigeria Energy Support Programme (NESP, 2013).

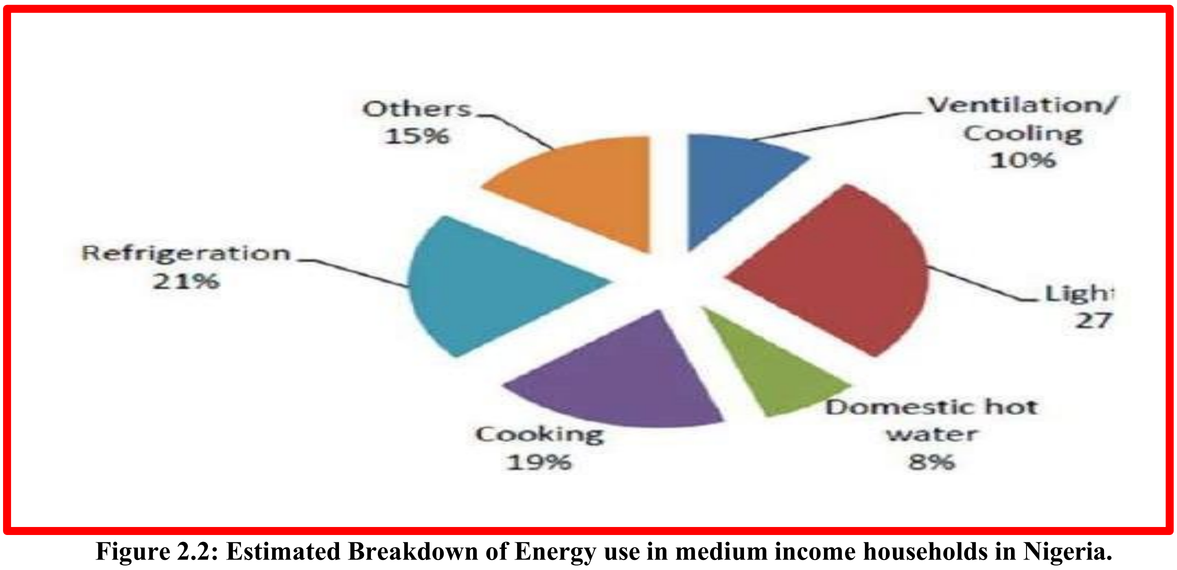

Figure 2.2: Estimated Breakdown of Energy use in medium income households in Nigeria.
Source: Nigeria Energy Support Programme (NESP, 2013).

III. RESEARCH METHODOLOGY

This study adopted a cross-sectional survey. Data were collected using a structured questionnaire, administered to occupants, inquiring about space use and energy consumption patterns. The survey was conducted during the evening hours (4:00 PM to 7:00 PM), during a peak period for indoor activity, between June and August, coinciding with the peak of the rainy season in the southern Nigeria, when the thermal environment is most conducive (World Bank Group, [WBG], 2021).

A stratified sampling technique was employed, based on residential density. The study specifically targeted high-density residential buildings developed by the Enugu State Housing Development Corporation (ESHDC), focusing on three-storey multifamily apartment blocks comprising 2-bed room and 3-bedroom units. The sampling frame included a total of 433 housing units, distributed across two high-density estates, as shown in Table 1.

Table 1: ESHDC High-Density Estates in Enugu Capital Territory

Names	African Real Estate	Maryland Housing Estate	Total
Number of Housing units	109	324	433

Source: Physical Planning Unit, ESHDC (2023).

To determine a feasible and representative research sample, the study applied both the sampling by ratio and percentage proportional allocation techniques. According to St. Olaf College (2023), a minimum ratio of 30% ensures equitable representation. Kothari (2014) also supports percentage proportional allocation for reducing large sample frames to manageable sizes. Applying a 30% random selection to the housing units in each estate yielded a total research sample of 130 housing units. Sampling was proportional to the size of each estate. Both housing units and individual respondents were selected accordingly, as detailed in Table 2.

Table 2: ESHDC High-density Estates in Enugu Capital Territory

Names	African Real Estate	Maryland Estate	Total
Number of Housing units	33	97	130
Number of respondents	33	97	130

Source: Fieldwork, (2023)

IV. DISCUSSION OF FINDINGS

Description of ESHDC High-Density Estates (Multi-Storey Apartments) - Case Study:

The ESHDC high-density estates consist of three-storey apartment blocks (multi-storey condominiums) situated on gently undulating terrain with effective natural drainage. These estates are located in two areas—Uwani and Independence Layout—both within Enugu South Local Government Area, in the Enugu Capital Territory. The buildings are constructed with plastered hollow block walls, operable glazed windows, and reinforced concrete slabs for the ground and first-floor ceilings (soffits). The third-floor ceilings are made of asbestos sheets, while the roof covering consists of aluminium corrugated sheetPlate 1 presents a pictorial view of the Real Estate in Uwani, showing long balconies/terraces, large fenestrations - >10%<30%WWR, exposed bare earth surfaces, an absence of defined parking lots, and evidence of housing modifications. Also visible are water storage tanks, suggesting the absence of a reliable public water supply in the estate.

Plate 1: Pictorial view of Real Estate, Uwani, Enugu South L.G.A

Source: Fieldwork (2024)

Plate 2 depicts Maryland Estate at Independence Layout, highlighting features such as narrow balconies, limited fenestrations – >10%<30%WWR, extensive hard surfaces, unkempt open spaces, narrow streets, defined parking areas, and drainage channels. Water storage tanks are also visible, indicating inadequate public water supply. However, unlike the Uwani estate, there is no clear evidence of housing transformation in Maryland Estate.

Plate 2: Maryland Estate – Views of Multi-storey apartment blocks (condominiums)

Source: Fieldwork (2024)

Analysis of Aggregated Data on Hourly Use of Living Rooms

The data in Table 3 show the distribution of evening use durations of living rooms by occupants in the two ESHDC high-density estates. The analysis reveals that more than one-third (34.1%) of respondents reported spending over 180 minutes in their living rooms during the evenings. Additionally, 29.3% stayed for 31–60 minutes, while 21.1% spent 91–120 minutes. These findings support previous studies suggesting that occupants tend to spend more time indoors when the thermal conditions are comfortable, validating Adunola's (2014) assertion that thermal comfort significantly influences the intensity of residential space use.

Table 3: Hourly Use of Living room in Evenings

Value label	Frequency	Cumulative Percent
0-30 mins	6	4.9
31- 60 mins	36	34.1
61-90 mins	8	40.7
91-120 mins	26	61.8
121-150 mins	4	65.0
More than 180 mins	42	100
Total	122	

Source: Fieldwork (2024)

Analysis of Aggregated Data on Hourly Electricity Supply in the Evenings

Table 4 presents data on evening electricity supply in the sampled estates. The results indicate that a significant majority—91.2% of respondents—received more than 180 minutes of electricity supply in the evenings. This suggests a heavy dependence on electric-powered ventilation systems to achieve thermal comfort. These findings reinforce the conclusions of earlier studies that thermal comfort in residential buildings is closely tied to energy consumption (Alwetaishi, 2016; Ezema et al., 2016; Adunola, 2015).

Table 4: Hourly Supply of Electricity (public power) in Evenings

Value label	Frequency	Cumulative Percent
0-30 mins	2	1.8
31- 60 mins	1	2.7

61-90 mins	2	4.4
91-120 mins	5	8.8
More than 180 mins	103	100.0
Total	123	

Source: Fieldwork (2024)

Analysis of Aggregated Data on Hourly Use of Alternative Power in the Evenings

Table 5 displays data on the duration of generator or alternative power use during evening hours. Results show that 65.1% of respondents used generators or alternative sources for more than 180 minutes, while 23.3% used them for 61–90 minutes. The disparity in usage durations may reflect economic constraints such as the cost of fuel and operating generators, as well as non-thermal factors like socioeconomic status, consistent with findings by Shooshtarian and Ridley (2016), and Zhang et al. (2023).

Table 5: Hourly Use of Alternative power in the Evenings

Value label	Frequency	Cumulative Percent
0-30 mins	3	3.5
31- 60 mins	3	7.0
61-90 mins	20	30.2
91-120 mins	4	34.9
More than 180 mins	56	100.0
Total	96	

Source: Fieldwork (2024)

Analysis of Aggregated Data on Type of Activity done in the Living Rooms

The aggregated data presented in Figure 3 show the distribution of activities carried out by respondents in their living rooms during the evenings across the sampled estates. The results indicate that the most common activity is active sitting (e.g., watching TV, engaging in conversation), accounting for 37.4% of valid responses. This is followed by quiet sitting (e.g., reading, resting) at 23.6%, and reclining at 20.3%. By contrast, sleeping was the least reported activity, with a valid percentage of 4.1%. These findings suggest that evening use of living rooms is predominantly characterized by sedentary, low-energy activities, which aligns with the period's typical relaxation and recovery function in residential settings

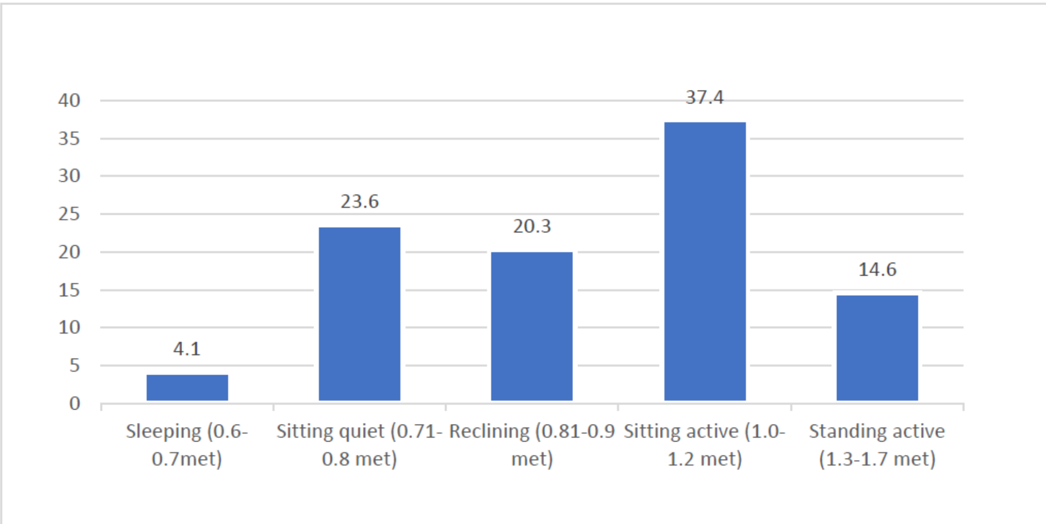

Figure 3: Analysis of aggregated data of Type of Activity in the Living Rooms

Source: Fieldwork, (2024)

Test of Hypothesis

This study investigated the relationship between space use and energy consumption in naturally ventilated living rooms within the ESHDC high-density estates. The key variables considered were:

i. Hourly Use of Living Room in the Evening (HULE)
ii. Hourly Supply of Electricity (public power) in the Evening (HSEE)

iii. Hourly Use of Alternative power in the Evenings (HUAP)
iv. Type of Activity in the Living Rooms (TOA)

Whereas the variable HSEE elicited data regarding supply from the public grid system, the variable HUAP investigated that which the occupants of the estates generated privately to augment the shortfall from the public grid. Because, in some cases, the latter could prove to be substantial in energy-insecure regions like Nigeria, it was thought relevant to investigate both. Equally, whereas, the major focus on space use was the duration of use, the nature of activity was also considered relevant. HULE, HSEE and HUAP are measured on an interval scale; thus, the Pearson Product- Moment Correlation was most appropriate for assessing the magnitude and direction of their relationships. However, TOA is measured on a non-dichotomous nominal scale; thus, for assessing the magnitude and of its relationships with HSEE and HUAP the Correlation ratio tool was used.
The first variable measuring space use - Hourly Use of Living Room in the Evening (HULE) was paired in bivariate tests against the variables measuring energy use: 1) Hourly Supply of Electricity in the Evening (HSEE), 2) Hourly Supply of Alternative power in the Evenings (HUAP). The results are shown in Table 6.

Table 6: Result of Pearson Product-Moment Correlations of HULE, HSEE and HUAP

		Hourly Supply of Electricity in Evening (HSEE)	Hourly Use of Alternative Power (HUAP)
Hourly Use of Living room in Evenings (HULE)	Pearson Correlation	-.012	-.119
	Sig. (2-tailed)	.897	.277
	N	113	86

Source: Fieldwork, (2024)

The results show that correlation between HULE and HSEE yielded a Pearson coefficient of –0.012 with a significance value (p-value) of 0.897. This indicates an extremely weak and statistically non-significant negative relationship between the number of hours occupants spent in their living rooms during the evening and the duration of electricity supply from the public mains. This suggests that fluctuations in electricity availability did not influence how long residents stayed in their living rooms during the evening hours or vice versa.

Similarly, the correlation between HULE and HUAP resulted in a coefficient of –0.119, with a p- value of 0.277. This also represents a weak and statistically non-significant negative relationship, indicating that increased or reduced use of alternative power sources (such as generators) had no meaningful impact on the duration of evening space use in living rooms. Overall, these findings imply that the use of living rooms in the evening is not significantly affected by either the availability of public electricity or reliance on alternative power. This suggests that other factors— potentially behavioural, cultural, or social—may play a more influential role in determining space use patterns within the surveyed high-density residential estates.

To perform the correlation ratio (η or eta) analysis, a one-way Analysis of Variance (ANOVA) was conducted to examine whether the type of activity (TOA), a nominal variable, had a significant effect on the hours of electricity supply in the evenings (HSEE), an interval variable. The purpose was to determine whether differences in occupant activity patterns were associated with differences in evening electricity availability across the sampled households. The result is shown in Table 7.

Table 7: One-way ANOVA table of TOA vs HSEE

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	9.031	4	2.258	1.617	.175
Within Groups	150.809	108	1.396		
Total	159.841	112			

Source: Fieldwork, (2024)

The ANOVA results indicated that the relationship between Type of Activity and Hours of Supply of Electricity in the Evenings was not statistically significant, $F(4, 108) = 1.617$, $p = .175$. This suggests that the variation in electricity supply does not significantly differ across the activity categories reported by respondents. Although some group means may differ numerically, these differences are not large enough to reject the null hypothesis of equal means across activity groups. To assess the practical significance of the result, eta squared (η^2) was calculated as a measure of effect size. Eta squared quantifies the proportion of the total variance in the dependent variable (HSEE) that can be attributed to the independent variable (TOA).

$$\eta^2 = \frac{sum\ of\ squares\ between\ groups}{total\ sum\ of\ squares} = \frac{9.031}{159.841} = 0.0565$$

This result indicates that approximately 5.65% of the variance in evening electricity supply can be explained by differences in activity type. According to conventional thresholds (Cohen, 1988), this represents a small effect size. In summary, while the type of activity undertaken in the evening does not have a statistically significant influence on the hours of electricity supply received, it accounts for a modest proportion of the variability ($\eta^2 = 0.0565$). This suggests that other factors - possibly infrastructural, socioeconomic, or regional - may have a more substantial influence on electricity supply patterns in the study area.

Equally, a one-way Analysis of Variance (ANOVA) was conducted to investigate whether different types of evening activities (TOA), a nominal variable, significantly influence the number of hours electric generators are used in the evenings (HUEE), an interval variable. This analysis aimed to determine if the nature of occupant activity is associated with variations in dependence on generator-powered electricity during evening hours in high-density residential estates. The result is shown in Table 8.

Table 8: One-way ANOVA table of TOA vs HUAP

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	34.845	4	8.711	3.937	.006
Within Groups	179.213	81	2.213		
Total	214.058	85			

The ANOVA results revealed a statistically significant difference in generator usage across activity types, $F(4, 81) = 3.937$, $p = .006$. This indicates that the average number of hours electric generators are used in the evenings varies significantly depending on the type of activity reported by occupants. This finding suggests that some activities may demand longer durations of electricity, prompting increased reliance on alternative power sources during outages or periods of unreliable supply. To further understand the strength of this relationship, the effect size was calculated using eta squared (η^2), which represents the proportion of total variance in generator usage attributable to activity type:

$$\eta^2 = \frac{sum\ of\ squares\ between\ groups}{total\ sum\ of\ squares} = \frac{34.845}{214.058} = 0.163$$

This result shows that approximately 16.3% of the variance in evening generator usage can be explained by type of activity undertaken. According to Cohen's (1988) guidelines, this represents a moderate to large effect size, suggesting that activity type has a meaningful impact on generator use patterns.

The findings demonstrate a significant and practically relevant association between occupant activity types and reliance on electric generators in the evenings. Given the moderate-to-large effect size ($\eta^2 = 0.163$), it is likely that the nature of household activities (e.g., sitting active, reclining, watching television) contributes to variations in energy demand, especially in contexts where grid supply is unstable or insufficient. These results underscore the need for targeted energy planning that considers occupant behaviour and usage patterns in residential energy management strategies.

Post Hoc Analysis: Type of Activity and Evening Generator Use

Following the one-way ANOVA which revealed a statistically significant relationship between Type of Activity (TOA) and Hourly Use of Electric Generator in the Evenings (HUEE), a Games- Howell post hoc test was conducted to determine where specific differences between activity types occurred. The Games-Howell procedure was chosen due to its robustness against violations of homogeneity of variances and unequal sample sizes. This is shown in Table 9

Table 9: Post Hoc analysis results of TOA vs HUAP

Multiple Comparisons						
Dependent Variable: Hourly Use of the Electric generator in the Evenings						
Games-Howell						
(I) Type of Activity	(J) Type of Activity	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Sleeping (0.7met)	Sitting quiet (0.8 met)	.296	.212	.636	-.33	.92

	Reclining (1.0 met)	1.333	.595	.234	-.59	3.26
	Sitting active (1.0 met)	1.500*	.291	.000	.66	2.34
	Standing active (1.7 met)	1.917*	.358	.002	.76	3.07
Sitting quiet (0.8 met)	Sleeping (0.7met)	-.296	.212	.636	-.92	.33
	Reclining (1.0 met)	1.037	.631	.497	-.93	3.01
	Sitting active (1.0 met)	1.204*	.360	.013	.19	2.22
	Standing active (1.7 met)	1.620*	.416	.008	.37	2.87
Reclining (1.0 met)	Sleeping (0.7met)	-1.333	.595	.234	-3.26	.59
	Sitting quiet (0.8 met)	-1.037	.631	.497	-3.01	.93
	Sitting active (1.0 met)	.167	.662	.999	-1.85	2.19
	Standing active (1.7 met)	.583	.694	.914	-1.51	2.68
Sitting active (1.0 met)	Sleeping (0.7met)	-1.500*	.291	.000	-2.34	-.66
	Sitting quiet (0.8 met)	-1.204*	.360	.013	-2.22	-.19
	Reclining (1.0 met)	-.167	.662	.999	-2.19	1.85
	Standing active (1.7 met)	.417	.461	.893	-.93	1.77
Standing active (1.7 met)	Sleeping (0.7met)	-1.917*	.358	.002	-3.07	-.76
	Sitting quiet (0.8 met)	-1.620*	.416	.008	-2.87	-.37
	Reclining (1.0 met)	-.583	.694	.914	-2.68	1.51
	Sitting active (1.0 met)	-.417	.461	.893	-1.77	.93

*. The mean difference is significant at the 0.05 level.

The post hoc results showed several statistically significant pairwise differences in mean generator usage hours between specific activity categories:

i. Sleeping vs. Sitting Active: Individuals engaged in sitting active tasks (e.g., watching television or socializing) used generators 1.5 hours more on average than those who were sleeping. This difference was statistically significant ($p < .001$), with a 95% confidence interval (CI) ranging from 0.66 to 2.34 hours.

ii. Sleeping vs. Standing Active: Similarly, respondents who were standing active (e.g., cooking or performing chores) used generators significantly longer than those sleeping, with a mean difference of 1.92 hours ($p = .002$, CI: 0.76 to 3.07 hours).

iii. Sitting Quiet vs. Sitting Active: A statistically significant difference was also found between those sitting quietly (e.g., reading or meditating) and those sitting actively, with the latter group using generators for 1.20 additional hours on average ($p = .013$, CI: 0.19 to 2.22 hours).

iv. Sitting Quiet vs. Standing Active: Standing active individuals used generators significantly more than sitting quiet individuals, with a mean difference of 1.62 hours ($p = .008$, CI: 0.37 to 2.87 hours).

Other pairwise comparisons, such as those involving reclining activities or between reclining and sitting/standing active categories, did not reach statistical significance, suggesting more moderate or variable levels of energy use for those activity types.

These findings imply that more physically or socially engaging evening activities (sitting active or standing active) are strongly associated with greater use of generator power, likely due to increased need for lighting, appliances, and comfort. In contrast, sedentary or passive activities such as sleeping or quiet sitting demand less electricity, hence lower generator usage. The Games-Howell post hoc analysis confirms that the nature of evening activity significantly affects generator usage, with more active behaviours requiring longer hours of electricity. These results support the broader conclusion that energy demand in residential settings is closely tied to behavioural patterns (space use), especially under conditions of unreliable grid supply systems. Energy planning and demand management strategies should, therefore, consider occupant activity patterns to design targeted interventions, such as demand-side energy efficiency programs and backup power provisions.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

This study investigated the relationship between space use and energy consumption in naturally ventilated living rooms across high-density residential estates developed by the Enugu State Housing Development Corporation (ESHDC) in Enugu Capital Territory. Findings indicate that a considerable number of residents spend extended periods—typically over three hours—in their living rooms during evening hours. This prolonged usage is closely associated with thermal comfort preferences, with many households relying on electricity-powered ventilation systems to maintain satisfactory indoor conditions.

Although most respondents reported receiving over 180 minutes of electricity supply in the evenings, many still resorted to alternative sources such as electric generators whenever public power outage ocurred. This reliance highlights underlying inconsistencies in electricity provision. Pearson Correlation and ANOVA analyses suggest that while the number of hours of electricity did not significantly affect time spent in living rooms, the type of activity performed was significantly related to generator usage. Post hoc analysis confirmed that more physically engaging activities (e.g., standing or sitting active) were associated with higher usage of alternative power sources, likely due to increased cooling and lighting needs. These patterns underscore broader infrastructure deficiencies and behavioural adaptations driven by environmental and social factors. Collectively, the findings affirm the need for a comprehensive and integrated approach to residential energy planning—one that not only improves technical systems but also addresses user behaviour, building design, and socio-environmental contexts.

Recommendations

Based on the study's findings, the following recommendations are proposed to improve energy efficiency, ensure thermal comfort, and enhance living conditions in high-density estates such as those managed by ESHDC:

1. *Enhance Reliability of Public Electricity Supply*: The high dependence on electric generators underscores the need for improvements in the public power infrastructure. Ensuring a stable and consistent electricity supply during peak evening hours would reduce reliance on alternative energy sources that are often costly and, detrimental to environment.
2. *Incorporate Design Strategies*: Urban housing developments should prioritize architectural features that support natural ventilation and passive cooling. These include cross- ventilation, reflective roofing, well-placed windows, adequate shading and ground cover. Existing buildings should be retrofitted where feasible to improve thermal performance and reduce reliance on mechanical systems.
3. *Promote Use of Energy-Efficient Appliances*: Government and housing authorities should encourage the use of energy-efficient devices—such as LED lighting, inverter fans, and efficient cooling units—through public awareness campaigns, incentives, or subsidy programs.
4. *Support Small-Scale Renewable Energy Adoption*: Solar energy systems, particularly those with integrated battery storage, offer sustainable alternatives to generator use. Policies and financing models should be developed to support their widespread adoption, especially in urban high-density contexts.
5. *Integrate Occupant Behaviour into Energy Planning*: Policymakers should recognize that energy demand is shaped by how residents interact with their living spaces. Future energy policies and urban planning frameworks should incorporate behavioural insights, cultural practices, and usage patterns to better align interventions with actual residential needs.

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