

Socio-Behavioural Determinants of Residential Energy Use in a Tropical Context: Evidence from Staff Quarters of a University in Southwestern Nigeria

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Abstract

This study investigates the relative influence of socio-behavioural factors on household energy consumption in residential buildings within a tropical context, using the University of Ibadan staff quarters in Nigeria as a case study. It identifies the key socio-behavioural variables affecting household energy use and quantifies their contributions to overall variance. The study population comprised all heads of households in 1,015 residential buildings categorized into six housing design types. Stratified sampling by housing type and systematic selection of every eighth unit yielded 122 sampled buildings. Data were obtained through a structured questionnaire capturing occupants' socio-economic characteristics, behavioural patterns, energy awareness, and appliance use. Multiple regression analysis was employed to determine the relationship between occupants' characteristics and their energy-use patterns. Results show that behavioural factors ($R^2 = 0.728$) explain a greater share of the variance in energy use than socio-demographic factors ($R^2 = 0.474$). The findings underscore the dominant role of behavioural attributes, particularly ventilation and daylighting practices such as opening blinds and windows, in shaping energy consumption patterns. The study recommends integrating behavioural change strategies into residential energy management policies and awareness programs to promote energy efficiency in tropical urban housing.

Keywords: Energy Use, Residential Buildings, Socio-Behavioural Predictors, Tropical Region, Occupant Behaviour.

Introduction

Energy consumption in residential buildings has become a major concern in the global sustainability agenda. The building sector represents one of the largest energy-consuming domains worldwide and contributes significantly to greenhouse gas emissions. González-Torres *et al.* (2022) reported that buildings account for about one-third of global energy consumption and roughly a quarter of CO₂ emissions, while residential buildings alone contribute nearly 72% of total building energy use. This aligns with the findings of Jensen *et al.* (2017), who observed that residential buildings constitute the highest percentage of energy use within the global building sector. Such statistics emphasize the need to understand the determinants of household energy consumption and to formulate effective strategies for its reduction.

Energy use in buildings is typically classified into two major categories: Embodied Energy and Operational Energy. Embodied energy refers to the energy required for extracting, manufacturing, and transporting construction materials up to the point of building completion, while operational energy encompasses the energy used during the building's life cycle for cooling, heating, lighting, cooking, and operating appliances (Azari, 2019). Empirical studies show that operational energy often outweighs embodied energy, sometimes by a factor of three (Iddon & Firth, 2013; Koezjakov *et al.*, 2018). This makes operational energy a more critical focus area for both research and policy interventions, particularly because it is influenced by factors beyond the physical structure of buildings—such as user behaviour, lifestyle, and socio-economic conditions.

In developing tropical regions, the challenges associated with residential energy consumption are particularly acute. Rapid urbanization, population growth, and rising living standards have driven a steady increase in household energy demand, placing severe pressure on existing electricity infrastructure. This trend has serious implications for energy security, affordability, and environmental sustainability. Understanding what drives household energy consumption in such contexts is essential for designing effective management and conservation strategies.

Previous research has often emphasized environmental predictors as the dominant factors shaping building energy demand. Such factors include temperature, humidity, and solar radiation (Djamila *et al.*, 2015; Baruti *et al.*, 2019). These variables, however, may not fully explain variations in residential energy use in tropical regions, where climatic conditions remain relatively stable year-round. In such settings, energy demand tends to be driven more by human, socio-economic, and behavioural factors than by environmental ones. This shift in emphasis is particularly relevant in tropical contexts, where heating needs are negligible and cooling and plug loads dominate total consumption (Sena *et al.*, 2021; Daud *et al.*, 2023).

Across tropical regions of Asia, Latin America, and Africa, several studies have demonstrated that socio-economic and behavioural factors can explain a substantial proportion of variance in residential energy use. Ali *et al.* (2021) and Abubakar *et al.* (2024) found that variables such as household income, education, gender of household head, and residential location significantly affect energy consumption and appliance ownership. Higher-income households typically consume more electricity, reflecting their ability to purchase energy-intensive appliances and maintain comfort through air conditioning (Sena *et al.*, 2021). Similarly, Daud *et al.* (2023) observed that appliance characteristics and lifestyle factors accounted for over 60% of the variance in energy efficiency among Malaysian households, underscoring the strong influence of consumer behaviour on energy demand.

The role of appliance saturation, that is the number and type of electrical appliances within a household, has also been emphasized in the literature. Cárdenas-Rangel *et al.* (2023)

showed that in tropical Latin American contexts, appliances account for over 70% of household energy use, with air-conditioning alone dominating energy demand in higher-income dwellings. Ali *et al.* (2020) reported similar findings, noting that ownership of refrigerators, air conditioners, and entertainment devices were among the strongest predictors of household electricity use. These studies collectively suggest that as income levels and electrification rates increase across tropical nations, so too does the saturation of energy-demanding devices, contributing to growing energy use intensity.

In addition to economic and technological factors, *occupant behaviour* has emerged as a central determinant of household energy use. Behavioural aspects include how occupants operate windows, blinds, lighting, and cooling systems; the duration and timing of appliance use; and the adoption of adaptive comfort strategies. Paone and Bacher (2018) estimated that behavioural variations alone can account for more than 50% of differences in building energy use. In tropical climates, these behavioural dimensions are particularly significant because small changes in cooling set-points or occupancy hours can substantially alter total electricity consumption. McRae (2023) found in Colombia that actual air-conditioner usage—rather than ownership—was the critical driver of rising residential electricity use. Similarly, González *et al.* (2023) showed that time-of-use patterns and occupant schedules in Panama produced large variations in simulated household energy consumption. A hybrid study by Severiche-Maury *et al.* (2025), combining field surveys with smart-meter data, confirmed that integrating behavioural and occupancy information into energy models greatly improves their predictive accuracy. These findings demonstrate that behaviour-related variables are not only statistically significant but also provide practical entry points for demand-side management and energy policy.

Despite their acknowledged importance, socio-behavioural predictors of energy use remain underrepresented in empirical energy models, especially within tropical regions (Uddin *et al.*, 2021; Krishnan *et al.*, 2022; Banfi *et al.*, 2024). Krishnan *et al.* (2022) attribute this gap partly to privacy concerns, measurement challenges, and the lack of reliable behavioural data. Furthermore, many energy-efficiency frameworks and simulation tools are based on data from temperate climates, where heating dominates energy demand. For instance, Wang *et al.* (2021) observed that in heating-dominated regions, stricter building standards have sometimes led to increased risks of indoor overheating. Applying such temperate-derived models to tropical regions can yield misleading results, as they fail to capture local behavioural practices, socio-economic diversity, and infrastructural constraints.

Another gap in the literature concerns the absence of explicit *ranking* of socio-behavioural factors in terms of their relative significance. While many studies identify correlations—such as between income and electricity consumption—few quantify how much variance each factor explains or determine which variables are the strongest predictors. Such ranking is vital for prioritizing interventions and designing context-appropriate policies, especially in resource-constrained tropical countries where energy costs are rising and the

capacity to expand supply is limited. As Oseni (2017) and Nduhuura *et al.* (2021) noted, fluctuating tariffs and unreliable power supply in many African and Asian cities further complicate consumption patterns, making it even more important to understand which behavioural and socio-economic variables matter most.

In view of these gaps, this study focuses on the relative significance of socio-behavioural predictors of energy use in residential buildings within a tropical context. Using the University of Ibadan staff quarters in Nigeria as a case study, the research aims to provide empirical evidence on how socio-economic and behavioural attributes jointly shape household energy consumption. Specifically, the study seeks to: identify the key socio-behavioural variables influencing household energy use in residential buildings; quantify the extent to which each variable explains variations in household energy consumption; and rank these predictors according to their relative contribution to total variance in energy use. By addressing these objectives, the study contributes to the growing body of knowledge on residential energy demand in tropical regions and provides insights that can guide policymakers, designers, and energy managers in formulating targeted behavioural interventions and energy-efficiency strategies suited to the socio-cultural realities of tropical urban housing.

Study Area

This study was conducted in the residential staff quarters of the University of Ibadan (UI), located in Ibadan, southwestern Nigeria. The university lies approximately on latitude $7^{\circ}26'$ N and longitude $3^{\circ}54'$ E, at an average altitude of about 227 m above sea level. Ibadan experiences a typical tropical climate characterized by relatively high humidity and moderate temperature variation throughout the year. The mean maximum and minimum temperatures are 26.5°C and 21.4°C , respectively, with an average relative humidity of about 75% (Egbinlola & Amobichukwu, 2013). Annual rainfall averages 1,200 mm, distributed mainly between April and October, while the dry season extends from November to March (Alarape *et al.*, 2015). These climatic conditions make the city representative of the humid tropical environment commonly found in many sub-Saharan African regions.

The University of Ibadan occupies about 2,550 hectares, with a substantial portion allocated to staff residential housing. The quarters consist predominantly of low- to medium-density dwellings, including bungalows, duplexes, and multi-unit flats built over several decades. According to the University Physical Planning Unit, there are about 610 houses in the Senior Staff Quarters and 405 in the Junior Staff Quarters. The buildings reflect six main design typologies: twin two-bedroom bungalows, three-bedroom bungalows, twin one-bedroom flats, two-storey twin two-bedroom blocks, two-storey twin three-bedroom blocks, and three-bedroom duplexes. Construction is largely based on sandcrete block walls and

corrugated roofing sheets, with generous window openings designed to promote cross-ventilation—an architectural adaptation to the city’s warm, humid climate.

Electricity supply to the quarters is provided primarily by the national grid through the Ibadan Electricity Distribution Company (IBEDC). However, frequent power outages and voltage fluctuations have made supplementary energy sources, such as petrol or diesel generators, a common feature of household energy use (Adedeji, 2016). This intermittent power situation, combined with increasing appliance ownership and changing lifestyle preferences, may have contributed to diverse energy-use patterns among residents.

The University of Ibadan staff quarters present an appropriate setting for this study. As a controlled institutional environment that accommodates a wide socio-economic spectrum of staff within similar climatic and infrastructural conditions, it allows for meaningful comparison of how socio-behavioural variables—such as income, household size, appliance use, and ventilation habits—influence residential energy consumption. The coexistence of different housing typologies and user profiles within a single tropical location thus provides an ideal context for examining the relative significance of socio-behavioural predictors of household energy use.

Materials and Methods

This study employed a cross-sectional survey design using both primary and secondary data sources. The approach was guided by previous research on residential energy consumption and building performance in tropical environments. The combination of these data sources enabled a comprehensive understanding of how socio-behavioural and demographic variables influence household energy use within a controlled institutional context. Primary data were obtained through a structured questionnaire designed to capture household energy-use characteristics and influencing factors. The questionnaire consisted of four main sections:

1. Socio-economic characteristics of respondents, including gender, age, educational attainment, household size, and income level.
2. Behavioural attributes related to energy use, such as control of windows, blinds, lighting systems, and cooling devices, as well as awareness of energy efficiency practices.
3. Building services information, covering the quantity, power rating, and frequency of use of electrical appliances relevant to lighting, ventilation, and cooling.
4. Household energy consumption, which recorded average monthly electricity use as reported by respondents.

These categories were chosen because energy use for lighting, ventilation, and cooling represents the most significant component of operational energy demand in tropical residential buildings (Giordano *et al.*, 2017; Hamid *et al.*, 2017; Su *et al.*, 2020).

The questionnaire was developed based on validated instruments from previous studies on household energy behaviour and adapted to suit the local context. Content validity was

established through expert review by three faculty members in architecture and environmental design in Obafemi Awolowo University, Ile Ife. Reliability was tested using a pilot survey of 15 households not included in the main study. The Cronbach's alpha coefficient obtained ($\alpha = 0.82$) indicated acceptable internal consistency of the instrument. Although no formal institutional ethical approval was obtained for this study, all procedures adhered to standard ethical principles for social research. The study involved only voluntary adult participants and posed no physical, psychological, or social risk. The data collected related strictly to household energy use and general demographic characteristics, without any personally identifiable or sensitive information. Participation was entirely voluntary, and respondents were informed of the purpose of the research and their right to decline or withdraw at any stage without consequence. Verbal informed consent was obtained before administering the questionnaire, and anonymity and confidentiality were maintained throughout the data collection and analysis processes.

Secondary data were sourced from the Works and Maintenance Department of the University of Ibadan. These included architectural drawings, records of housing typologies, and information on the total number of residential units within the staff quarters. Such data were essential for establishing the sampling framework, verifying the classification of housing types, and ensuring proportional representation across dwelling categories. The study population comprised all heads of households in the 1,015 residential buildings located within the University of Ibadan staff quarters. Six distinct housing design types were identified: twin two-bedroom apartments, three-bedroom flats, twin one-bedroom blocks, two-storey twin two-bedroom blocks, two-storey twin three-bedroom blocks, and three-bedroom duplexes. A stratified sampling technique was adopted to ensure adequate representation of each housing design type. Within each stratum, a systematic selection procedure was applied: after a random start, every eighth housing unit was selected, yielding 122 sampled buildings (approximately 12% of the total housing stock). One household head was surveyed per unit. After screening for completeness and consistency, 117 valid responses were retained for analysis.

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, including frequencies, percentages, and means, were used to summarize socio-economic, behavioural, and building-related data. Estimates of monthly energy consumption for lighting, ventilation, and cooling were computed using the recorded quantity, power rating, and average duration of appliance use. Inferential analyses were conducted to examine the relationships between socio-behavioural predictors and household energy use. A one-way analysis of variance (ANOVA) tested for differences in mean energy consumption across housing types and socio-economic categories. Multiple regression analysis was then used to identify the most significant predictors of energy use among the measured variables. This analytical framework enabled a quantitative

assessment of the relative influence of occupants' behavioural and socio-demographic attributes on residential energy consumption patterns.

Results and Discussion

Socio-economic characteristics of occupants and energy use

The socio-demographic profile of occupants plays a significant role in shaping household energy use patterns, particularly in tropical contexts where behavioural and lifestyle factors strongly influence electricity demand. A descriptive and inferential analysis was conducted to explore how gender, age, education, income, and household size predict variations in household energy consumption within the University of Ibadan staff quarters. The relationships between these variables and energy use were examined using Chi-square tests, supported by Cramer's V and correlation coefficients as shown in Table 1.

Gender of respondents

Male respondents constituted 65.8% of the sample, while females accounted for 34.2%. Although gender distribution was uneven, statistical tests revealed no significant association between gender and energy use ($\chi^2 = 6.755$, $p = 0.149$; Cramer's V = 0.240). This finding suggests that gender does not meaningfully influence energy expenditure in the study area. Similar conclusions were reported by Raty and Carlsson-Kanyama (2010) and Ponichan *et al.* (2023), who observed that while gender may shape appliance preferences or comfort habits, it does not independently determine overall household energy demand. This outcome also reflects the socio-economic uniformity among university staff households, where energy use patterns are shaped more by income and lifestyle than by gender roles.

Table 1: Relationships between socioeconomic characteristics of occupants and energy use

Predictor	Chi-Square Sig.	Cramer's V	Relationship Strength	Interpretation
Gender	0.149	0.240	Weak	Not significant
Age	0.002	0.385	Moderate	Significant
Education	0.000	0.656	Strong	Highly significant
Income	0.000	0.682	Strong	Highly significant
Household Number	0.119	0.251	Weak	Not significant

Age of respondents

Respondents were generally middle-aged, with 51.3% aged 42–53 years and 48.7% aged 54–65 years. A significant association was observed between age and energy use ($\chi^2 = 17.307$, $p = 0.002$; Cramer's V = 0.385), indicating that older occupants tend to consume

more energy. Correlation analyses (Pearson's $r = 0.323$; Spearman's $\rho = 0.342$) confirmed this positive relationship. This pattern aligns with the findings of Sardianou (2007) and Palani *et al.* (2023), who noted that energy consumption increases with age, often due to prolonged home occupancy, increased reliance on cooling appliances, and higher comfort expectations. In this study, respondents aged 54–65 years were more concentrated in higher energy-use categories, reinforcing the observation that ageing may coincide with greater energy dependence and comfort-driven appliance use.

Educational level of respondents

Education emerged as one of the strongest socio-demographic predictors of household energy use. The majority of respondents held tertiary qualifications—29.9% with Bachelor's or HND degrees, 23.1% with Master's degrees, and 12.8% with doctorates. The relationship between educational level and energy consumption was highly significant ($\chi^2 = 201.224$, $p < 0.001$; Cramer's $V = 0.656$). Respondents with higher educational attainment tended to occupy higher energy consumption categories, particularly those with postgraduate qualifications. Although higher education often increases awareness of energy efficiency, as confirmed by Abubakar *et al.*, 2024, it also correlates with higher income and greater appliance ownership, leading to greater total consumption. This supports earlier findings that educational advancement alone does not guarantee energy conservation unless complemented by behavioural change or efficiency-enabling policies.

Income of respondents

Income showed the most substantial influence on household energy consumption. The majority of respondents (59%) earned between ₦201,000 and ₦300,000 monthly, and income was strongly associated with energy use ($\chi^2 = 163.096$, $p < 0.001$; Cramer's $V = 0.682$). Positive correlations (Pearson's $r = 0.525$; Spearman's $\rho = 0.495$) further confirmed that as income increases, energy consumption also rises. Higher-income households were overrepresented in the upper energy-use brackets (265–335 kWh), reflecting their ability to acquire and operate multiple cooling and entertainment devices. These results are consistent with the energy–income elasticity principle, which posits that increased income typically translates into higher household energy demand (Liu *et al.*, 2016; Sarkodie & Adams, 2020). In tropical environments, this relationship is particularly evident, as wealthier households often pursue thermal comfort through mechanical cooling, intensifying overall electricity demand.

Household size of respondents

Most households (74.4%) comprised four to six members, while 25.6% had three or fewer. Despite larger families intuitively using more energy, household size did not significantly influence total energy consumption ($\chi^2 = 7.347$, $p = 0.119$; Cramer's $V = 0.251$). This weak

association suggests the presence of “economies of scale” in household energy use, where additional occupants do not proportionately increase total consumption. Similar findings by Kelly (2011) and Santin (2011) indicate that shared use of lighting, cooling, and appliances often leads to reduced per capita consumption even when household size increases. The relatively uniform dwelling sizes within the university quarters may also contribute to this muted effect.

Summary of socio-demographic predictors

In summary, the results reveal that income, education, and age are the most significant predictors, while gender and household size exert minimal influence. These findings highlight the complex interplay between socio-economic status and behavioural energy practices in tropical institutional housing. In particular, education and income jointly shape both the capacity and the propensity to consume energy, underscoring the need for policies that promote efficiency awareness alongside affordability and behavioural adaptation. The overall pattern suggests that household energy consumption in the University of Ibadan staff quarters is primarily determined by socio-economic capacity and lifestyle orientation rather than demographic composition alone. Higher income and educational attainment foster ownership of energy-intensive appliances, while age influences comfort-driven usage patterns. Conversely, gender and household size exert negligible effects, reflecting the relatively homogeneous housing conditions of the study population. These results reinforce the argument that socio-behavioural predictors, rather than purely physical or environmental factors, are the dominant determinants of residential energy demand in tropical institutional settings.

Behavioural characteristics of the occupants and energy use

A descriptive statistical analysis of occupant behavioural characteristics and awareness levels influencing household energy use was undertaken. The focus was on both passive strategies—such as window and blind operation for natural ventilation and daylighting—and active practices involving the use of lighting, fans, and air-conditioning systems in two key indoor spaces: the living room and the bedrooms. The analysis included standard deviation (SD) values to indicate the variability in responses, offering insight into the consistency of occupant practices. A summary of these behaviours is presented in Table 2. “Not applicable” responses largely reflect households without specific appliances (notably air-conditioning). The final indicator in the table—environmental consciousness—represents awareness rather than behavioural frequency but is included to provide a holistic interpretation of occupant interaction with energy systems.

Overall, the results demonstrate how residents in the study area balance between natural and mechanical means of achieving thermal and visual comfort. About 30.8% of respondents always opened windows in the living room and 31.6% in the bedrooms, while the majority reported doing so “sometimes.” Similarly, 34.2% always opened blinds in the

living room and 22.2% in the bedrooms. These patterns suggest a moderate dependence on natural ventilation and daylighting, both of which are fundamental to passive cooling strategies in the tropics. However, the intermittent use of these passive measures implies behavioural inconsistency, potentially influenced by contextual concerns such as security, privacy, outdoor noise, or insects, which are factors widely reported in tropical residential settings (Gerhardsson & Laike, 2021; Khalid *et al.*, 2025).

Table 2: Frequency of Occupant Behavioural characteristics relevant to Energy Use

Behavioural Indicator	Always (%)	Sometimes (%)	Never / Not Applicable (%)	Standard Deviation
Open all windows (Living room)	30.8	36.8	32.5	.79852
Open all blinds (Living room)	34.2	30.8	34.9	.87815
Switch on lights (Living room)	26.5	41.0	32.5	.76891
Switch on fans (Living room)	53.0	14.5	32.5	.90533
Switch on A/C (Living room)	9.4	30.8	59.8	.66467
Open all windows (Bedrooms)	31.6	68.4	0.0	.46701
Open all blinds (Bedrooms)	22.2	77.8	0.0	.41753
Switch on lights (Bedrooms)	67.5	32.5	0.0	.47031
Switch on fans (Bedrooms)	51.3	45.3	3.4	.56627
Switch on A/C (Bedrooms)	2.6	19.7	77.8	.48965

Note. Regarding consciousness of negative effects of energy consumption, 31.6% were fully conscious, 26.5% were partly conscious, while 41.9% were not at all conscious. The Standard Deviation is 0.85485

The analysis of mechanical and electrical system use further highlights the energy-use dynamics of tropical dwellings. Lighting behaviour was markedly different across spaces: 67.5% of respondents always switched on lights in bedrooms, compared with only 26.5% in living rooms. This difference may be attributed to the evening dominance of bedroom activities and the relatively better daylight access in living areas. High fan usage, that is 53.0% and 51.3% in living rooms and bedrooms respectively, indicates that fans remain the

preferred and affordable cooling device in warm-humid contexts. By contrast, air-conditioning (A/C) use was minimal: only 9.4% of respondents reported always using A/C in the living room and a mere 2.6% in the bedrooms, while the majority (59.8% and 77.8%) indicated they never used it. This limited reliance on A/C may reflect both cost-conscious behaviour and awareness of the high electricity tariffs in Nigeria. These findings align with earlier studies in similar climates, where households demonstrate “adaptive cooling” strategies that rely more on low-energy options such as fans and natural ventilation (Sarkodie & Adams, 2020; Palani *et al.*, 2023).

Regarding environmental awareness, only 31.6% of respondents were fully conscious of the negative environmental effects of energy consumption, while 41.9% reported being “not at all conscious.” This limited awareness indicates a potential behavioural gap that could undermine energy efficiency. Prior studies like Ajzen, (1991) as well as Steg and Vlek, (2009). have emphasized that awareness alone does not always translate into pro-environmental behaviour unless supported by enabling attitudes, perceived control, and social norms—a framework articulated in the Theory of Planned Behaviour (TPB). From this perspective, the low environmental consciousness observed here may explain the inconsistency in energy-efficient actions, despite general awareness of cost implications.

The SD values further clarify the degree of behavioural variability among respondents. Window and blind operations in both living rooms and bedrooms ($SD = 0.42\text{--}0.88$) reflect moderate variation, suggesting differences in personal comfort thresholds and ventilation habits. Lighting and fan usage also show moderate variation ($SD = 0.47\text{--}0.91$), consistent with diverse daily schedules and occupant preferences. In contrast, A/C usage displayed lower variability ($SD = 0.49\text{--}0.66$), indicating uniformly low reliance on energy-intensive cooling. This is likely shaped by comparable income levels and shared perceptions of affordability. The highest variability was observed in environmental consciousness ($SD = 0.85$), reflecting differing levels of awareness and possibly varying exposure to energy conservation campaigns or educational backgrounds.

The findings collectively portray a pattern of adaptive behaviour typical of tropical middle-income households, where cost, comfort, and awareness interact to determine energy choices. Natural ventilation and fan use dominate as primary strategies, reflecting both climatic adaptation and economic practicality. However, the irregular application of passive measures (e.g., inconsistent window/blind operation) reveals untapped potential for reducing mechanical cooling dependence. Within broader tropical energy-efficiency frameworks, this underscores the importance of integrating architectural design with occupant behaviour.

Beyond design considerations, behavioural theory provides a useful lens for interpreting these results. According to the Theory of Planned Behaviour (Ajzen, 1991), energy-related actions are shaped by attitudes (beliefs about outcomes), subjective norms (social expectations), and perceived behavioural control (ease or difficulty of performing the behaviour). In this study, the high prevalence of fan use and low A/C reliance likely stem

from both perceived behavioural control (ease of using fans) and normative constraints (electricity cost). Conversely, inconsistent natural ventilation practices may reflect weak social norms and low perceived efficacy, suggesting that occupants may doubt the comfort benefits of natural ventilation compared to mechanical cooling. Strengthening these behavioural determinants through awareness campaigns, real-time feedback systems, and demonstration of energy-efficient practices could help transform intention into sustained action.

In addition, environmental psychology insights suggest that comfort behaviour is often habitual rather than rational (Steg *et al.*, 2015). Occupants may follow established routines, like switching on lights automatically at dusk regardless of actual daylight levels. This may explain the consistently high bedroom lighting observed. Encouraging reflective behaviour through energy labelling, smart metering, or community education can help occupants become more conscious of habitual energy use and more responsive to contextual indications such as daylight or temperature.

Ultimately, the results demonstrate that technological efficiency alone cannot ensure reduced energy demand; behavioural consistency and awareness are equally vital. In the University of Ibadan staff quarters, the prevailing pattern, consisting of moderate natural ventilation, heavy fan use, low A/C reliance, and limited environmental consciousness, all suggests both opportunity and challenge. There is substantial potential to reduce energy consumption through behavioural change supported by architectural design and policy interventions. Promoting energy literacy, embedding passive design strategies in building upgrades, and encouraging adaptive thermal comfort practices could together enhance household energy efficiency in this study environment and similar contexts.

Relative significance of occupants socio-behavioural predictors of energy use

Two regression models were employed to determine the relative significance of socio-demographic and behavioural predictors of household energy use. The first model assessed socio-demographic predictors, while the second examined behavioural characteristics. The results demonstrate that both dimensions substantially influence residential energy consumption; however, behavioural variables exhibit stronger explanatory power.

The regression model examining socio-demographic predictors of household energy use produced an R value of 0.69 and an R^2 of 0.47, indicating that about 47.4% of the variance in household energy use is explained by gender, age, level of education, monthly income, and household number. The adjusted R^2 of 0.45 reflects a solid model fit, and the F-statistic ($F(5,111) = 19.99$, $p < 0.001$) confirms that these predictors collectively have a significant effect on household energy consumption. Among the individual variables, monthly income ($\beta = 0.53$, $p < 0.001$), level of education ($\beta = 0.32$, $p = 0.001$), and age ($\beta = 0.23$, $p = 0.026$) were significant positive determinants of energy use. This finding implies that higher-income and better-educated occupants are more likely to acquire and operate energy-

intensive appliances to maintain higher comfort standards. These results corroborate Santin (2011) and Abubakar *et al.* (2024), who similarly observed that household income and education significantly affect residential energy consumption patterns in tropical regions.

Conversely, household size ($\beta = -0.34$, $p = 0.002$) exhibited a significant negative relationship with energy use. This suggests that larger households tend to distribute energy demand more efficiently, perhaps through shared appliance usage and collective behavioural adaptations that promote conservation. The finding aligns with studies like Gill *et al.*, (2010) and Kavousian *et al.*, (2013), emphasizing the moderating role of household size in energy efficiency outcomes. In contrast, gender ($\beta = 0.09$, $p = 0.331$) did not have a statistically significant effect, implying that the energy-use behaviour of households is not substantially influenced by whether the head is male or female. Together, these results affirm that income, education, and household size remain the most influential socio-demographic variables explaining energy consumption patterns in this study environment and similar contexts.

The second regression model, which explored behavioural predictors, revealed an even stronger explanatory capacity, with an R value of 0.85 and an R^2 of 0.73, showing that about 73% of the variation in household energy use is explained by behavioural variables. The adjusted R^2 of 0.70 and $F(10,106) = 28.44$ ($p < 0.001$) confirm the robustness and overall significance of this model. This finding highlights the dominant role of occupant behaviour in determining household energy performance. Notably, window and blind operations in both living rooms and bedrooms were significant negative predictors of energy use, reflecting energy-saving habits. Specifically, opening bedroom windows ($\beta = -0.62$, $p < 0.001$) and opening living room blinds ($\beta = -0.82$, $p < 0.001$) had the strongest negative effects, indicating that enhanced use of natural ventilation and daylighting substantially reduces energy consumption.

In contrast, energy-intensive behaviours such as frequent use of air conditioners ($\beta = 0.49$, $p < 0.001$) and lighting in living rooms ($\beta = 0.34$, $p = 0.004$) were strong positive predictors of energy consumption. The use of fans in bedrooms also contributed moderately to energy use ($\beta = 0.13$, $p = 0.046$). These outcomes align with studies by Paone and Bacher (2018), Uddin *et al.* (2021), and Tavakoli *et al.* (2022). The studies consistently showed that occupant behaviour, particularly regarding ventilation, cooling, and lighting, accounts for a significant proportion of variability in building energy use across climates. The findings in this study reaffirm that in warm-humid regions, where passive strategies are viable, behavioural adaptation can substantially reduce energy demand without compromising comfort.

A comparative analysis of both models underscores that behavioural characteristics ($R^2 = 0.73$) explain a substantially higher proportion of variance in energy use than socio-demographic characteristics ($R^2 = 0.47$). This finding implies that occupant behaviour is a more influential determinant of residential energy use than socio-economic status. While

demographic attributes such as income and education determine access to energy technologies and appliances, behavioural practices directly regulate how and when these technologies are used. This confirms the assertion by Delzendeh *et al.* (2017) that behavioural factors often provide the most immediate leverage for achieving energy efficiency in existing housing.

To further synthesize the results, all predictors were ranked according to their standardized beta (β) coefficients. As presented in Table 3, behavioural variables dominate the upper ranks, reinforcing their stronger influence relative to socio-demographic factors. The two most effective energy-saving actions were opening blinds in living rooms and opening windows in bedrooms, while monthly income was the most significant socio-demographic driver of higher energy use. These findings collectively demonstrate that promoting adaptive comfort behaviours, such as natural ventilation and daylighting, could yield more cost-effective and sustainable energy savings than structural or income-based interventions.

Overall, the findings confirm that behavioural interventions can provide immediate and measurable reductions in household energy use, even within existing building stock. Programs that encourage the use of natural ventilation, efficient lighting practices, and awareness of energy costs could be particularly effective in institutional residential settings. In contrast, socio-demographic factors such as income and education, while influential, are less amenable to short-term policy or design interventions. Thus, this study emphasizes the need for occupant-focused energy efficiency strategies, including targeted education campaigns and the integration of behavioural insights into housing design and management policies.

Table 3: Summary of Key Socio-Behavioural Predictors of Household Energy Use

Rank	Predictor	Type	Standardized β	p-value	Direction of Effect
1	Opening blinds in living room	Behavioural	-0.82	0.00	Energy-saving
2	Opening windows in bedrooms	Behavioural	-0.62	0.00	Energy-saving
3	Monthly income	Socio-demographic	0.53	0.00	Energy-increasing
4	Switching on A/C in living room	Behavioural	0.49	0.00	Energy-increasing
5	Switching on lights in living room	Behavioural	0.34	0.00	Energy-increasing
6	Household number	Socio-demographic	-0.34	0.00	Energy-saving
7	Level of education	Socio-demographic	0.32	0.00	Energy-increasing

Rank	Predictor	Type	Standardized β	p-value	Direction of Effect
8	Age	Socio-demographic	0.23	0.03	Energy-increasing
9	Opening blinds in bedrooms	Behavioural	-0.22	0.02	Energy-saving
10	Switching on fans in bedrooms	Behavioural	0.13	0.05	Energy-increasing

Note. All coefficients are standardized (β). Negative β indicates energy-saving behaviour. Model significance: socio-demographic ($F(5,111) = 19.99, p < 0.001$); behavioural ($F(10,106) = 28.44, p < 0.001$).

In summary, this study provides empirical evidence that behavioural factors exert stronger influence than socio-demographic characteristics in explaining variations in residential energy consumption. The study contributes to understanding how user behaviour mediates the performance gap between design intent and operational reality in tropical residential buildings, thereby offering direction for policy and design strategies aimed at reducing energy demand through occupant engagement.

Conclusion

This study investigated the relative influence of socio-demographic and behavioural factors on household energy use in the residential staff quarters of the University of Ibadan. The findings reveal that socio-demographic characteristics explain 47.4% of the variance in household energy use, whereas behavioural factors account for 72.8%. This clearly establishes occupant behaviour as the stronger determinant of energy demand in tropical residential contexts. Among the predictors examined, income emerged as the most significant socio-demographic variable, indicating that higher-income households tend to consume more energy due to greater access to appliances and higher comfort expectations. On the behavioural dimension, window and blind operation, which promote natural ventilation and daylighting, were identified as the most influential energy-saving practices. These findings underscore the pivotal role of passive comfort behaviours in reducing energy intensity in warm-humid climates. This study therefore concludes that while socio-economic capacity determines potential energy consumption, actual energy performance is largely governed by occupants' behavioural patterns. To achieve meaningful reductions in residential energy use, interventions should prioritise behavioural strategies over structural or demographic ones.

Policy implications include:

1. Occupant education and awareness campaigns to promote energy-conscious habits, particularly around ventilation and lighting control.

2. Incentivising passive cooling and daylighting practices through design guidelines and institutional policies that reward energy-efficient behaviours.
3. Integration of behavioural insights into housing management and energy planning, enabling adaptive comfort strategies that align occupant actions with sustainable energy goals.

By focusing on these behavioural controls, energy efficiency initiatives in tropical residential settings can achieve quicker, low-cost, and more sustainable outcomes.

Limitations

This study relied heavily on respondents' self-assessment of how often they engaged in specific behaviours such as opening windows or using air conditioners. This may be prone to recall and social desirability biases that could affect the accuracy of responses. Moreover, since the study was limited to a specific area or institution, the findings may not be generalizable to all tropical regions or socio-economic contexts. To address these limitations in future studies, data collection could adopt a longitudinal approach by measuring the same households across multiple seasons or months to strengthen causal inference, detect seasonal variations, and distinguish between short-term and persistent behavioural patterns. Additionally, combining self-reported data with behavioural sensors, such as door or window sensors, light sensors, temperature and humidity loggers, and occupancy sensors, would help validate responses and capture actual ventilation and usage patterns under real conditions. Expanding the geographical and socio-economic scope of sampling through stratified random sampling across neighbourhoods, income levels, building types, and climatic zones would further enhance the representativeness and generalizability of the findings of this study.

References

- Abubakar, I. R., Alola, A. A., Bekun, F. V., & Onifade, S. T. (2024). Investigating the determinants of household energy consumption in Nigeria: insights and implications. *Energy, Sustainability and Society*, 14(1), 29.
- Adedeji, A. A. (2016). *Spatial exploration and analysis of electricity poverty: a case study of Ibadan, Southwestern, Nigeria* (Doctoral dissertation, University of Leicester).
- Ajzen, I. (1991). The theory of planned behaviour. *Organizational behaviour and human decision processes*, 50(2), 179-211.
- Alarape, A. A., Omifolaji, J. K., & Mwansat, G. S. (2015). Butterfly Species Diversity and Abundance in University of Ibadan Botanical Garden, Nigeria. *Open Journal of Ecology*, 5, 352-360.
- Ali, S. S. S., Razman, M. R., & Awang, A. (2020). The estimation and relationship of domestic electricity consumption and appliances ownership in Malaysia Intermediate City. *International Journal of Energy Economics and Policy*, 10(6), 116-122.
- Ali, S. S. S., Razman, M. R., Awang, A., Asyraf, M. R. M., Ishak, M. R., Ilyas, R. A., & Lawrence, R. J. (2021). Critical determinants of household electricity consumption in a rapidly growing city. *Sustainability*, 13(8), 4441.

- Azari, R. (2019). Life Cycle Energy Consumption of Buildings; Embodied + Operational. In *Sustainable Construction Technologies*. Elsevier Inc. <https://doi.org/10.1016/b978-0-12-811749-1.00004-3>
- Banfi, A., Ferrando, M., Li, P., Shi, X., & Causone, F. (2024). Integrating Occupant Behaviour into Urban-Building Energy Modelling: A Review of Current Practices and Challenges. *Energies*, 17(17), 4400.
- Baruti, M. M., Johansson, E., & Åstrand, J. (2019). Review of studies on outdoor thermal comfort in warm humid climates: challenges of informal urban fabric. *International journal of biometeorology*, 63(10), 1449-1462.
- Cárdenas-Rangel, J., Osma-Pinto, G., & Jaramillo-Ibarra, J. (2023). Energy characterization of residential and office buildings in a tropical location. *Heliyon*, 9(5).
- Daud, S., Wan Hanafi, W. N., Ayodele, B. V., Rajadurai, J., Mustapa, S. I., Ahmad, N. N., ... & Afsarizal, H. A. (2023). Residential Consumers' Lifestyle Energy Usage and Energy Efficiency in Selected States in Malaysia. *Energies*, 16(8), 3514.
- Delzendeh, E., Wu, S., Lee, A., & Zhou, Y. (2017). The impact of occupants' behaviours on building energy analysis: A research review. *Renewable and sustainable energy reviews*, 80, 1061-1071.
- Djamila, H., Ming, C. C., & Kumaresan, S. (2015). Investigation on hourly and monthly thermal comfort in the humid tropics of Malaysia. *Buildings*, 5(3), 1025-1036.
- Egbinola, C. N., & Amobichukwu, A. C. (2013). Climate variation assessment based on rainfall and temperature in Ibadan, South-Western, Nigeria. *Journal of Environment and earth science*, 3(11), 32-45.
- Gerhardsson, K. M., & Laike, T. (2021). Windows: a study of residents' perceptions and uses in Sweden. *Buildings and Cities*, 2(1), 467-486.
- Gill, Z. M., Tierney, M. J., Pegg, I. M., & Allan, N. (2010). Low-energy dwellings: the contribution of behaviours to actual performance. *Building Research & Information*, 38(5), 491-508.
- Giordano, R., Serra, V., Demaria, E., & Duzel, A. (2017). Embodied energy versus operational energy in a nearly zero energy building case study. *Energy Procedia*, 111, 367-376.
- González, J., Mora, D., & Chen Austin, M. (2023). Energy consumption difference found between typical and standard occupancy in residential buildings in a tropical developing country. *Buildings*, 13(9), 2235.
- González-Torres, M., Pérez-Lombard, L., Coronel, J. F., Maestre, I. R., & Yan, D. (2022). A review on buildings energy information: Trends, end-uses, fuels and drivers. *Energy Reports*, 8, 626-637.
- Hamid, M. F. A., Ramli, N. A., & Mohd, N. M. F. S. N. (2017). An analysis of energy performance of a commercial building using energy modelling. 2017 IEEE Conference on Energy Conversion (CENCON), 105-110.
- Iddon, C. R., & Firth, S. K. (2013). Embodied and operational energy for new-build housing: A case study of construction methods in the UK. *Energy and Buildings*, 67, 479-488.
- Jensen, S. Ø., Marszal-Pomianowska, A., Lollini, R., Pasut, W., Knotzer, A., Engelmann, P., ... & Reynders, G. (2017). IEA EBC annex 67 energy flexible buildings. *Energy and buildings*, 155, 25-34.
- Kavousian, A., Rajagopal, R., & Fischer, M. (2013). Determinants of residential electricity consumption: Using smart meter data to examine the effect of climate, building characteristics, appliance stock, and occupants' behavior. *Energy*, 55, 184-194.
- Kelly, S. (2011). Do homes that are more energy efficient consume less energy? a structural equation model of the English residential sector. *Energy*, 36(9), 5610-5620.
- Khalid, H. L., Donn, M., & Merwood-Salisbury, J. (2025). Systematic literature review on the barriers to using operable windows for passive cooling. *Advances in Building Energy Research*, 1-28.
- Koezjakov, A., Urge-Vorsatz, D., Crijns-Graus, W., & Van den Broek, M. (2018). The relationship between operational energy demand and embodied energy in Dutch residential buildings. *Energy and Buildings*, 165, 233-245.

- Krishnan, D., Kelly, S., & Kim, Y. (2022). A Meta-Analysis review of occupant behaviour models for assessing Demand-Side energy consumption. *Energies*, 15(3), 1219.
- Liu, Y., Gao, Y., Hao, Y., & Liao, H. (2016). The relationship between residential electricity consumption and income: A piecewise linear model with panel data. *Energies*, 9(10), 831.
- McRae, S. (2023). Residential electricity consumption and adaptation to climate change by Colombian households. *Economics of Disasters and Climate Change*, 7(2), 253-279.
- Nduhuura, P., Garschagen, M., & Zerga, A. (2021). Impacts of electricity outages in urban households in developing countries: A case of Accra, Ghana. *Energies*, 14(12), 3676.
- Oseni, M. O. (2017). Self-generation and households' willingness to pay for reliable electricity service in Nigeria. *The Energy Journal*, 38(4), 165-194.
- Palani, H., Acosta-Sequeda, J., Karatas, A., & Derrible, S. (2023). The role of socio-demographic and economic characteristics on energy-related occupant behavior. *Journal of Building Engineering*, 75, 106875.
- Paone, A., & Bacher, J. P. (2018). The impact of building occupant behavior on energy efficiency and methods to influence it: A review of the state of the art. *Energies*, 11(4), 953.
- Ponichan, H., Zailani, R., & Azmi, A. M. (2023). Gender and Age Influence on Energy Consumption in A Selected Malaysian Office Building. *International Journal of Academic Research in Business and Social Sciences*, 13(5), 932 – 948.
- Räty, R., & Carlsson-Kanyama, A. (2010). Energy consumption by gender in some European countries. *Energy policy*, 38(1), 646-649.
- Santin, O. G. (2011). Behavioural patterns and user profiles related to energy consumption for heating. *Energy and buildings*, 43(10), 2662-2672.
- Sardianou, E. (2007). Estimating energy conservation patterns of Greek households. *Energy policy*, 35(7), 3778-3791.
- Sarkodie, S. A., & Adams, S. (2020). Electricity access, human development index, governance and income inequality in Sub-Saharan Africa. *Energy Reports*, 6, 455-466.
- Sena, B., Zaki, S. A., Rijal, H. B., Alfredo Ardila-Rey, J., Yusoff, N. M., Yakub, F., ... & Muhammad-Sukki, F. (2021). Determinant factors of electricity consumption for a Malaysian household based on a field survey. *Sustainability*, 13(2), 818.
- Severiche-Maury, Z., Uc-Ríos, C., Sierra, J. E., & Guerrero, A. (2025). Predicting Energy Consumption and Time of Use of Home Appliances in an HEMS Using LSTM Networks and Smart Meters: A Case Study in Sincelejo, Colombia. *Sustainability*, 17(11), 4749.
- Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of environmental psychology*, 29(3), 309-317.
- Steg, L., Perlaviciute, G., & Van der Werff, E. (2015). Understanding the human dimensions of a sustainable energy transition. *Frontiers in psychology*, 6, 805.
- Su, X., Tian, S., Shao, X., & Zhao, X. (2020). Embodied and operational energy and carbon emissions of passive building in HSCW zone in China: A case study. *Energy and Buildings*, 222, 110090.
- Tavakoli, E., Nikkhah, A., Zomorodian, Z. S., Tahsildoost, M., & Hoonejani, M. R. (2022). Estimating the impact of occupants' behaviour on energy consumption by Pls-SEM: a case study of Pakdel Residential Complex in Isfahan, Iran. *Frontiers in Sustainable Cities*, 4, 700090.
- Uddin, M. N., Wei, H. H., Chi, H. L., & Ni, M. (2021). Influence of occupant behavior for building energy conservation: a systematic review study of diverse modeling and simulation approach. *Buildings*, 11(2), 41.

Wang, R., Lu, S., Feng, W., & Xu, B. (2021, August). Tradeoff between heating energy demand in winter and indoor overheating risk in summer constrained by building standards. In *Building Simulation 14* (4), pp. 987-1003. Beijing: Tsinghua University Press.