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Factors Influencing Energy Efficiency of Buildings in Nigeria's Tropical Humid Dry Zone

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Abstract
This study addresses the limitations of Nigeria's National Building Energy Efficiency Code (BEEC) by identifying context-specific factors influencing building energy efficiency in the country's tropical humid dry zone. Using a Delphi approach, the research engaged experts from academia and practice to evaluate and reach a consensus on key factors. The study revealed five critical elements: mechanical factors, lighting, openings, size of features, and height of features. Building material did not emerge as a significant factor. These findings highlight the importance of considering regional climatic variations and sociocultural contexts in developing energy efficiency frameworks. The study revealed the inadequacy of the current one-size-fits-all approach and recommends a more context-specific strategy for improving building energy efficiency in Nigeria. This study contributes to the growing body of knowledge on sustainable building practices in developing countries and provides a foundation for future research on energy-efficient building design in tropical climates

Keywords: Building Energy Efficiency Code, DELPHI, Efficiency, Energy.

1. Background to the Study

The world faces significant environmental challenges due to excessive energy consumption, primarily from fossil fuels and coal (Alhashmi *et al*., 2021; Nunez *et al*., 2019). Buildings are major contributors, consuming up to 40% of global energy resources and accounting for nearly one-third of greenhouse gas emissions (Kasozi and Tutesigensi, 2007; Pearce and Ahn, 2017). This has led to the development of energy efficiency mechanisms and policies worldwide (Mclennan, 2014). In response, Nigeria developed the National Building Energy Efficiency Code (BEEC) in 2017. BEEC aims to provide a pathway to energy efficiency using four indicators: window openings to wall ratio, lighting, roof insulation, and air conditioning. However, it has faced criticism on various grounds, including cost concerns, compliance and enforcement challenges, and issues with variability and regional differences.

A key criticism is that BEEC doesn't adequately account for Nigeria's climatic variability. The country is divided into five climate zones according to the Köppen-Geiger classification, but BEEC doesn't sufficiently consider these differences in its development. Research has shown that it's challenging to design energy-efficient buildings for specific microclimatic areas without studying the context (social, economic, and cultural) and analyzing area-specific data (Ochedi and Taki, 2021). Building materials, influenced by economic capability and sociocultural factors, are also crucial determinants of energy efficiency (Alabi and Fapohunda, 2021; Danso and Obeng-Ahenkora; Musarat *et al*., 2021; Oladipo and Oni, 2012). Understanding these dynamics is essential for developing an effective energy efficiency framework.

The tropical humid dry zone of Nigeria, characterized by high temperatures averaging 32°C and distinct wet and dry seasons, presents unique challenges for building energy efficiency. In this region, buildings typically require significant energy for cooling and ventilation, with air conditioning accounting for up to 60% of total building energy consumption (Oladipo and Oni, 2012). Despite these specific climatic challenges, local building practices often prioritize cost reduction over energy efficiency, resulting in structures that rely heavily on mechanical cooling systems rather than incorporating passive design strategies suited to the regional climate (Ochedi and Taki, 2021). The BEEC has been criticized for downplaying the importance of building orientation, which is a low-cost option to improve occupant comfort and reduce energy consumption (Albatayneh *et al*., 2018; Ochedi and Taki, 2021). Additionally, while BEEC considers roofing, it overlooks building and ceiling height, which can significantly affect thermal comfort and energy use (Yuksek and Karadayi, 2017; Ghafari *et al*., 2018; Ochedi and Taki, 2021). Other key factors missing from BEEC include fenestration, landscaping, building density, and socioeconomic dynamics. Furthermore, BEEC uses an equal weighting approach for its indicators, which has been criticized for not reflecting the unique contribution of each factor to energy efficiency (Winkler, 2015). The study therefore seeks to answer the research question "how can building energy efficiency frameworks in Nigeria be adapted to better reflect local climatic conditions, socioeconomic factors, and technical requirements specific to the tropical humid dry zone? This study aims to identify and prioritize context-specific factors influencing building energy efficiency in Nigeria's tropical humid dry zone using the DELPHI approach, thereby addressing the current BEEC framework's limitations and providing recommendations for a more locally adapted energy efficiency code

2. Literature Review

The literature on building energy efficiency reveals an interplay of factors that influence energy consumption in buildings across various contexts. Ochedi and Taki (2021) developed a framework for energy-efficient residential buildings in Nigeria, though their approach did not fully account for climatic variability and sociocultural factors. In a broader context, Gillingham *et al*. (2021) demonstrated the potential impact of ambitious energy efficiency upgrades in the United States, projecting significant reductions in emissions and potential prevention of premature deaths. The impact of climate change on building energy consumption, particularly for heating and cooling demands, was highlighted by Bazazzadeh *et al*. (2021). This perspective was complemented by Mostafavi *et al*. (2021), who focused on high-rise buildings and identified envelope design, plan layout, and natural ventilation as key factors for reducing energy consumption.

Chen *et al*. (2020) provided a comprehensive categorization of factors influencing building energy efficiency in China, encompassing building characteristics, equipment/technologies, and occupant behaviours. This multifaceted approach was echoed in the work of Qarnain *et al*. (2021), who modelled the driving factors of energy efficiency in buildings, identifying motivation, education/awareness, coercive factors, occupant behaviour, and energy-saving equipment as key elements. In more specific contexts, Azmi *et al*. (2021) assessed factors influencing energy efficiency in Malaysian mosques, while Akande *et al*. (2014) explored sustainable approaches to energy efficiency in Nigeria's Northern Guinea Savanna region. Both studies underscored the importance of considering local climatic and cultural factors in energy efficiency strategies.

The potential for energy efficiency improvements in heritage buildings was examined by Akande *et al*. (2014), who noted that significant energy reductions could be achieved without compromising the unique characteristics of these structures. This idea of context-specific approaches was further reinforced by Awawdeh and Tweed (2011), who emphasized the importance of tailoring building energy codes to reflect the climatic, cultural, and political context of each community. Collectively, these studies highlight the multifaceted nature of building energy efficiency and the need for comprehensive, context-specific approaches that consider climate, building design, occupant behaviour, and local sociocultural factors when developing energy efficiency frameworks and policies.

3. Research Methodology

The primary instrument used for data collection for this study is the DELPHI questionnaire. The Delphi survey method is a group facilitation technique that seeks to obtain consensus on the opinions of `experts through a series of structured questionnaires (commonly referred to as rounds). The questionnaires are completed anonymously by experts (panellists, participants, or respondents) from diverse field of study. As a part of the process, the responses from each questionnaire are fed back in summarized form to the participants (Hasson *et al*., 2000). The Delphi is therefore an iterative multistage process designed to combine opinion into group consensus (McKenna 1994, Lynn *et al*., 1998). The initial questionnaire also collected qualitative comments, which are fed back to the participants in a quantitative form through a second questionnaire.

Therefore, a well-structured closed and open-ended Delphi survey questionnaire were developed to elicit requisite information on indicators and weight of indicators from experts from academia and practice in the southwest region of the country. A total of 15 experts from the built environment and 15 experts from academia with a minimum of ten years' experience in energy efficiency projects were purposively selected. The DELPHI survey focused on identifying and validating various dimensions and indicators of energy efficiency while taking cognizance of the climatic variability in the region. A three-round Delphi survey was proposed for the study, but consensus was achieved at the end of the second round. The descriptive and inferential analytical tool was adopted. The descriptive analytical tool to be used include mean and standard deviation, which will be used to describe the subjective response of the professionals. The data will also be subjected to exploratory factor analysis to extract the core factors or drivers of energy efficiency in residential buildings in the southwest region. Interquartile Range/deviation was used to measure consensus among experts. Values below 1.00 represent consensus, while values above 1.00 means there is no consensus.

Table 1: Levels of Consensus

Quartile deviation (QD)	Level of consensus	Median	Level of importance
Less or equal to 0.5 (QD ≤ 0.5)	High	4 and above (M ≥ 4)	High
More than 0.5 and less than or equal to 1.0 (0.5 ≤ QD ≤ 1.0)	Moderate	3.5 and less (M ≤ 3.5)	Low
More than 1.0 (QD ≥ 1.0)	Low and no consensus	–	–

Source: Adopted from Norizan (2003)

4. Results and Discussion

4.1 Factors Influencing Energy Efficiency of Residential Buildings by Professionals

The result from the first round of assessment by 12 out of 30 invited professionals, seven academia and five practitioners that participated is presented in Table 2. The panel assessment of the six (6) factors was rated to determine the importance of the factors extracted from residents' responses on the energy efficiency of residential buildings. The result of the panel assessment was statistically analysed to determine their consensus based on three (3) defined criteria of Mean score of ≥7 on a Scale of 1 -10, inter-quartile range (IQR) of ≤ 1.5, and Coefficient of Variation (CV) of ≤ 0.3. Items are considered for consensus if they achieve the panellist assessment based on the set criteria.

The Delphi result shows that consensus was reached on four (4) factors -Mechanical factor, Lighting, and Size of feature – that mutually met the three (3) criteria. However, the academic professionals did not achieve panellist consensus on the influence of two factors – Building material (IQR = 2) and height of features (IQR = 2.0), which failed to meet two of the three criteria. Similarly, the result reveals that the panel of professional practitioners achieved consensus on the importance of four (4) factors, Mechanical factor (M = 7.50; CV = 0.08, IQR =1.0), Size of features (M = 8.10; IQR = 1.0), Building Height (M = 7.60; IQR = 1.0) and Lighting d to consensus (M = 8.10; IQR = 1.5). However, Consensus was not achieved for Openings (M = 6.10; IQR = 2.0) and Building Material (M = 6.90; IQR = 2.0). The variability in the opinion of both professionals (Academia and Practitioners) is also reflected in the weight assigned to the factors. The variability in experience and teaching may be a major factor influencing the high degree of variability in the opinion of the experts from academia. Overall, only the 'Mechanical factor', 'Lighting', and 'Size of features' gained consensus in round 1.

Table 2: First Round of Energy Efficiency Factor

	Academic			Practitioners		
Components	Mean	CV	IQR	Mean	CV	IQR
Mechanical Factor	8	0.08	1.5	7.50	0.08	1.0
Lighting	8.18	0.08	1.5	8.10	0.08	1.5
Opening	6.42	0.12	1.5	6.10	0.13	2.0
Size of features	7.92	0.08	1.5	8.10	0.08	1.0
Building Material	7.46	0.08	2	6.90	0.10	2.0
Height of features	7.57	0.08	2	7.60	0.08	1.0

Table 3 shows the Delphi result of the second round of assessment of factors for the energy efficiency of residential buildings. The result indicates that consensus was reached on five (5) out of six (6) factors – 'Mechanical factor', 'Lighting factors', 'Opening factors', 'Size of features', and 'Height of features, – that mutually attained the three (3) criteria for both panellists. However, panellist consensus was not achieved by both the academic professionals and practitioners on 'Building material' (M = 6.20) and (M = 6.50), respectively, as an essential factor due to the mean score < 7.0 on a Likert scale of 1-10 rated. This invariably shows that the panellists agreed that five factors play a significant role in determining the energy efficiency level of residential buildings as against six that were extracted from the response of the households.

Table 3: Second Round of Energy Efficiency Factor

	Academic			Practitioners		
Components	**Mean**	**CV**	**IQR**	**Mean**	**CV**	**IQR**
Mechanical Factor	9.10	0.08	0.8	8.30	0.08	1.0
Lighting	8.50	0.08	1.0	8.40	0.08	1.0
Opening	7.42	0.09	1.0	7.30	0.09	0.3
Size of features	8.30	0.08	1.0	8.30	0.08	1.0
Building material	6.20	0.13	0.8	6.50	0.11	1.0
Height of features	9.30	0.08	1.0	9.00	0.08	1.0

The most intriguing finding is the persistent lack of consensus regarding building materials. Despite two rounds of consultation, neither academic nor practitioner groups rated building materials above the threshold mean score of 7.0 (final scores - Academia: 6.20; Practitioners: 6.50). This divergence is particularly significant given Nigeria's context, where the choice of building materials is often constrained by economic factors, market availability, and the tension between traditional and modern construction practices. Traditional building materials, which often possess natural cooling properties, compete with modern materials that may be perceived as more durable or prestigious, creating a complex decision-making environment for builders and developers.

5. Conclusion and Recommendations

This study sought to identify context-specific factors influencing building energy efficiency in Nigeria's tropical humid dry zone, addressing limitations in the current National Building Energy Efficiency Code (BEEC). Using a Delphi approach, the research achieved consensus on five key factors: mechanical factors, lighting, openings, size of features, and height of features. Surprisingly, building material did not emerge as a significant factor, contrary to initial expectations. These findings demonstrate the importance of regional climatic variations and sociocultural contexts in developing energy efficiency frameworks, highlighting the inadequacy of a one-size-fits-all approach like the current BEEC.

The findings have several practical implications for policymakers and building professionals. First, the BEEC should be restructured to incorporate the weighted importance of different factors rather than its current equal weighting approach. Mechanical factors and lighting, which received consistently high ratings, should be given greater emphasis in the assessment criteria. Second, the code should include specific guidelines for building height and feature sizing, which are currently overlooked despite their significant impact on energy efficiency in tropical climates. Third, while building materials did not achieve consensus, this suggests a need for more detailed investigation into cost-effective, locally available materials that meet both energy efficiency and economic requirements. Future research should extend this investigation to Nigeria's other climatic zones to develop region-specific recommendations for the BEEC. Additionally, economic analyses of different energy efficiency measures would help identify cost-effective solutions for implementation. Studies examining the intersection of traditional building practices with modern energy efficiency requirements could also provide valuable insights for policy development.

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