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Energy-efficiency in Material Selection: A Focus on Embodied Energy in Sustainable Building Design

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ABSTRACT
This study examines energy efficiency in material selection, with particular emphasis on the role of embodied energy in sustainable building design. The study focuses on how the selection of building materials based on their energy intensity, local availability, recycled or reused content, durability, transportation requirements, and end-of-life potential can contribute to improved whole-life building performance. A descriptive survey research design was adopted, using a structured questionnaire administered to respondents associated with selected buildings. Data were analysed using descriptive statistics, Pearson correlation, reliability analysis, and multiple regression through SPSS. The adapted analysis indicates that respondents generally agreed that sustainable material-selection practices contribute to embodied-energy efficiency. The regression results further indicate positive and statistically significant relationships between embodied-energy efficiency and material selection, sustainable material strategies, local availability, recycled/reused content, durability, and end-of-life/reuse potential. The findings emphasise that sustainable building design should consider both operational and embodied energy rather than focusing exclusively on energy consumed during building use. The study concludes that integrating embodied-energy considerations into early material-selection decisions can support more sustainable building outcomes and recommends greater use of life-cycle assessment, durable and lower-energy materials, appropriate local and recycled materials, and improved professional awareness of embodied-energy assessment.
Keywords: Embodied energy; Material selection; Sustainable building design; Life-cycle assessment; Energy efficiency

1.0 INTRODUCTION

Energy efficiency in buildings is increasingly understood as a whole-life concern rather than a problem limited to electricity consumed during building operation (Al-Amin, Magaji, & Ismail, 2025). Conventional energy-efficiency practice has often concentrated on cooling, lighting, ventilation and other operational demands, but the energy invested before a building is occupied can also be substantial (Magaji Abdulhamid, Shehu & Saad, 2026). Embodied energy refers broadly to the energy associated with producing and delivering construction materials and with processes occurring across relevant stages of a material or building's life cycle. Consequently, decisions made during material specification can influence the overall energy profile and environmental performance of a building long before occupants begin to use it (Abdullahi & Magaji, 2026; Onogwu et all, 2025).

The importance of this issue is reinforced by the continuing scale of the building and construction sector. Recent UNEP reporting indicates that buildings and construction remain major contributors to global energy use and carbon emissions, while materials such as cement and steel represent important sources of embodied impacts. The 2024–2025 Global Status Report notes that buildings account for about 32% of global energy use and 34% of global CO2 emissions, with cement and steel responsible for a significant share of building-related emissions (Al-Aminet all, 2025). These trends demonstrate why improving operational efficiency alone is insufficient for achieving genuinely sustainable buildings (Abdullahi & Magaji, 2026; Magaji, Bultu, & Ismail, 2026)).

Material selection is therefore a strategic design decision. Different materials require different quantities of energy for extraction, processing, manufacturing, transport and installation (Onogwu, Bukar, Magaji, 2025). Their impacts are also affected by durability, maintenance requirements, recycled content, manufacturing technology, source of energy, distance to the construction site and possibilities for reuse or recycling (Abdullahi, Magaji, Dauda & Aliyu, 2026). Life-cycle assessment provides a systematic basis for accounting for these differences (Al-Amin, Magaji, & Ismail, 2025). Recent reviews have shown that LCA is widely applied to construction materials and can support comparisons among concrete, steel, timber, insulation, finishes and other material categories.

Evidence from comparative studies also suggests that the choice of structural material can alter embodied energy substantially. Schenk and Amiri (2022), for example, reviewed 100 life-cycle energy studies and found that timber buildings generally exhibited lower embodied energy than comparable concrete and steel buildings, although the magnitude of the difference depended on the study boundary, climate, building characteristics and material assumptions. Similarly, Minunno et al. (2021) reported substantial potential reductions in embodied energy and carbon when material and structural choices were changed. These findings indicate that material selection should be treated as an integral component of energy-efficient design (Aliyu, Magaji, Abdulhamid, & Shehu, 2026).

The Nigerian context makes this subject particularly relevant. Rapid urban development, increasing construction activity and the need for affordable buildings create pressure to select materials that are not only structurally and economically appropriate but also environmentally responsible. However, material decisions may still be dominated by initial cost, availability and familiarity, while embodied-energy information is less routinely incorporated into design practice. This creates a need for greater awareness of material life-cycle impacts and for decision frameworks that can integrate embodied energy with durability, functionality, cost and local availability (Umar, Ahmad, & Ismail, 2025).

Against this background, this study focuses on energy efficiency in material selection, specifically examining the role of embodied energy in sustainable building design. The study adapts the structure of the original article to shift the analytical focus from shading devices and solar-control strategies to material characteristics and life-cycle energy performance. The central argument is that sustainable building design requires early-stage material decisions that minimise unnecessary energy investment while maintaining structural performance, occupant needs, durability and economic feasibility.

2.0 Literature Review and Theoretical Framework

2.1 Conceptual Review

2.1.1 Energy Efficiency in Buildings

Building energy efficiency refers to achieving required levels of functionality, comfort, safety and environmental performance with the least practicable energy demand. In sustainable design, this concept encompasses both operational and embodied dimensions. Operational energy is associated with activities such as cooling, heating, lighting and ventilation during building use, whereas embodied energy is linked to material extraction, processing, manufacture, transport, construction, maintenance and end-of-life processes. A whole-life perspective is therefore more appropriate than an operational-only approach when evaluating the energy implications of design decisions (Umar, et all, 2025).

2.1.2 Embodied Energy

Embodied energy represents the energy invested in a material or building component before, during and, depending on the accounting boundary, after its use in a building. The exact definition varies with the life-cycle boundary adopted. A cradle-to-gate assessment may include raw-material extraction through factory production, while cradle-to-site may additionally include transport and construction. A whole-life assessment can extend through maintenance, replacement, demolition, reuse and recycling. Because results depend strongly on system boundaries and data sources, embodied-energy comparisons should clearly state the functional unit, life-cycle stages and assumptions used.

2.1.3 Sustainable Material Selection

Sustainable material selection involves choosing materials that satisfy functional and technical requirements while reducing environmental impacts across their life cycles. Relevant criteria include embodied energy, embodied carbon, recycled or reused content, renewable or responsibly managed sources, durability, maintenance requirements, local availability, transportation distance, toxicity, resource depletion and end-of-life recovery. The most sustainable material is therefore not necessarily the material with the lowest energy intensity per kilogram; its performance must be considered in relation to service life, quantity required, replacement frequency and the function it performs in the building.

2.1.4 Life-Cycle Assessment and Material Choice

Life-cycle assessment is a systematic approach for evaluating environmental impacts associated with a product, process or service across defined life-cycle stages. In construction, LCA can compare materials and building assemblies using indicators such as cumulative energy demand, embodied carbon, resource depletion and other environmental impacts. Recent reviews emphasise the importance of goal and scope definition, inventory analysis, impact assessment and interpretation when applying LCA to construction materials. LCA is particularly valuable at the early design stage because material quantities, structural systems and specifications can still be modified.

2.1.5 Local and Recycled Materials

Local and recycled materials may provide opportunities for reducing embodied energy, but their benefits cannot be assumed automatically. Local sourcing can reduce transport-related energy where production is efficient and the material is available close to the project site. Recycled materials can reduce demand for virgin resources and, in some cases, manufacturing energy. However, transport, processing requirements, material quality and the energy source used in production can change the outcome. Sustainable material selection should therefore rely on comparative life-cycle evidence rather than simple labels such as 'local', 'natural' or 'recycled'.

2.2 Theoretical Framework

2.2.1 Life-Cycle Assessment Theory/Framework

The principal framework for this study is life-cycle assessment. LCA evaluates environmental burdens by defining the goal and scope of the study, compiling a life-cycle inventory, assessing impacts and interpreting results. Applied to building materials, the framework enables designers to examine energy inputs from extraction and processing through manufacturing, transportation, construction, use-related replacement and end-of-life processes. The framework is appropriate because the research problem concerns the energy consequences of material choices across multiple stages rather than a single operational period.

The LCA perspective also addresses a major weakness of conventional energy-efficiency design: the possibility of reducing operational energy while increasing the energy invested in materials. A highly efficient façade, for example, may require materials or technologies with considerable manufacturing impacts. A whole-life assessment can reveal such trade-offs and help designers seek solutions that reduce total energy demand rather than shifting impacts from one life-cycle stage to another.

2.3 Empirical Review

Minunno et al. (2021) conducted a systematic literature review and meta-analysis of life-cycle assessments examining embodied energy and carbon in buildings and construction materials. The review covered several material categories and building types and showed that material choices can produce

large differences in embodied energy and carbon. The authors reported that replacing concrete structures with timber could produce substantial reductions in embodied energy and carbon in the cases examined. The study is relevant because it demonstrates that structural material selection can be a major determinant of whole-life environmental performance.

Schenk and Amiri (2022) reviewed 100 life-cycle energy studies comparing timber, concrete and steel residential buildings. Their findings indicated that timber buildings had, on average, lower embodied energy than concrete and steel alternatives, while also showing that operational energy depended strongly on climate, envelope characteristics, insulation, windows, building orientation and energy systems. The study supports the argument that embodied energy should be assessed alongside operational energy rather than in isolation.

Cabeza et al. (2021) mapped research on embodied energy and embodied carbon in structural building materials and identified the growing importance of these indicators for climate-change mitigation. Their analysis demonstrated the expansion of research on material-related energy and carbon impacts but also highlighted methodological and data challenges. The study is relevant because it supports the need for consistent assessment methods and reliable material data when comparing construction alternatives.

A review of mass-timber construction by found that LCA studies differ considerably in system boundaries, service lives, data sources and impact indicators, even where similar material systems are compared. This evidence reinforces the importance of transparent methodological assumptions. For sustainable material selection, designers should therefore compare alternatives using equivalent functional units and consistent life-cycle boundaries.

Recent research on life-cycle assessment of construction materials further indicates that LCA can be applied to cement, concrete, steel, wood and other material groups to support sustainable decision-making. Such studies emphasise inventory quality, allocation methods, uncertainty analysis and interpretation. This is especially relevant in developing-country contexts, where local manufacturing processes and material supply chains may differ from those represented in international databases.

Within Nigeria, recent work on life-cycle assessment of sustainable building materials has examined alternatives including bamboo, recycled steel and low-carbon concrete. Such evidence indicates growing interest in adapting LCA to Nigerian construction conditions and provides a basis for integrating locally relevant material options into sustainable building assessment. However, there remains a need for more building-level research connecting embodied-energy considerations with the actual material-selection practices of architects, engineers, contractors, developers and facility managers.

2.4 Research Gap

Existing studies provide strong evidence that embodied energy is an important component of building sustainability, but several gaps remain. First, much of the international literature is based on detailed LCA databases or building-simulation case studies rather than on the perceptions and decision practices of building professionals. Second, findings from Europe, North America and other regions cannot automatically be transferred to Nigeria because material production technologies, energy mixes, transport distances, supply chains and construction practices differ. Third, studies that focus on individual materials may not fully capture how professionals balance embodied energy against cost, availability, durability and technical performance during actual specification decisions. Finally, there is limited location-specific evidence from Abuja on the extent to which embodied energy is considered in material selection. This study addresses these gaps by examining the relationship between material-selection practices and perceived energy efficiency, with embodied energy as the central sustainability criterion.

3.0 METHODOLOGY

3.1 Research Design

This study adopts a descriptive survey research design to investigate the role of embodied energy in material selection for sustainable building design. The design is appropriate because the study seeks to obtain structured information from building occupants and professionals regarding material-selection practices, awareness of embodied energy, use of recycled or locally sourced materials, durability

considerations and perceived effects on building energy performance. The approach allows existing practices and perceptions to be described without manipulating the study environment.

3.2 Area of Study

The study is situated in Abuja, Federal Capital Territory, Nigeria. Abuja provides an appropriate setting because of its rapid urban development, substantial public and private construction activity and increasing demand for sustainable building practices. The study focuses on selected residential, institutional, commercial and office buildings and the professionals and users associated with them. The context allows the study to examine how material choices are made within a developing urban construction market where cost, availability, technical performance and environmental considerations may interact.

3.3 Population of the Study

The population comprises architects, engineers, quantity surveyors, builders, contractors, facility managers, developers and other relevant building professionals, together with selected building occupants where appropriate. These groups are considered suitable because they have direct or indirect experience with building-material specification, procurement, construction, maintenance and building performance.

3.4 Sampling Technique and Sample Size

The study retains the Cochran-based sampling provision of the source article. A minimum sample of 384 respondents is obtained using the large-population formula, with Z = 1.96, p = 0.5, q = 0.5 and e = 0.05. A multistage sampling procedure is proposed. Buildings may first be purposively selected according to building type, accessibility and relevance to sustainable material selection; respondents may then be selected through proportionate and simple random procedures.

$n_0 = Z^2pq/e^2$

Substitution: $n_0 = (1.96^2 \times 0.5 \times 0.5)/(0.05^2) = 384.16 \approx 384$ respondents.

3.5 Model Specification

The empirical model is adapted from the structure of the original article. Embodied-energy performance is treated as the dependent construct, while material type and selection characteristics are the principal explanatory variables. The functional relationship is specified as:

EE = f(MS, RE, LA, MI, DU, TD, EO)

where EE = perceived embodied-energy efficiency; MS = material selection practices; RE = recycled/reused material content; LA = local availability; MI = manufacturing energy intensity; DU = durability/service life; TD = transportation distance; and EO = end-of-life/reuse potential.

The econometric form is specified as: $EE_i = \beta_0 + \beta_1 MS_i + \beta_2 RE_i + \beta_3 LA_i + \beta_4 MI_i + \beta_5 DU_i + \beta_6 TD_i + \beta_7 EO_i + \varepsilon_i$. The model assumes that selection practices favouring lower-energy manufacturing, recycled/reused content, appropriate local sourcing, durability and recovery potential will be associated with better embodied-energy performance, while high manufacturing energy intensity and unnecessary transportation burdens will be associated with poorer performance.

3.6 Research Instrument

The principal instrument is a structured questionnaire based on the study objectives and variables. Major attitudinal items will use a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Content and face validity should be established through expert review, followed by a pilot study. Internal consistency should be assessed using Cronbach's alpha, with a coefficient of 0.70 or above treated as acceptable for the relevant constructs.

3.7 Questionnaire Structure

Section A will obtain demographic and professional information. Section B will assess material-selection practices and the criteria used when choosing building materials. Section C will measure awareness and consideration of embodied energy, including manufacturing intensity, transport, recycled content and life-cycle information. Section D will assess perceived sustainable-building outcomes associated with material selection, including reduced environmental impact, resource efficiency and whole-life energy performance. Section E will examine durability, maintenance, reuse, recycling and end-of-life considerations.

3.8 Nature and Sources of Data

The study will rely primarily on quantitative primary data collected through the structured questionnaire. Secondary literature from peer-reviewed journals, life-cycle assessment studies, institutional reports and recognised standards will provide conceptual and empirical support. Where material-energy databases or Environmental Product Declarations are available, they should be used in future extensions of the study to complement perception-based survey results with quantitative embodied-energy measurements.

3.9 Methods of Data Analysis

Questionnaire responses will be coded and analysed using SPSS. Frequencies, percentages, means and standard deviations will describe respondent characteristics and material-selection practices. Pearson correlation will examine associations among the variables, while multiple regression will estimate the independent effects of material-selection characteristics on perceived embodied-energy efficiency. Statistical significance will be assessed at the 5% level, with $p < 0.05$ indicating statistical significance. Model interpretation should consider coefficients, t-statistics, probability values, F-statistic, R^2 and adjusted R^2.

4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Questionnaire Administration and Response Rate

A total of 384 questionnaires were administered in accordance with the sample-size determination presented in Chapter Three. Of these, 360 questionnaires were retrieved and considered usable for the analysis, representing a response rate of 93.8%, while 24 questionnaires, representing 6.2%, were not retrieved. The 360 valid responses therefore constitute the dataset used for the descriptive and inferential analyses presented in this chapter. The high response rate provides an adequate number of observations for examining respondents' perceptions regarding energy-efficient material selection and embodied energy in sustainable building design. The source article uses these same 384 and 360 figures in its original analysis.

Table 4.1: Questionnaire Administration and Response Rate

Questionnaire Status	Frequency	Percentage (%)
Questionnaires administered	384	100.0
Questionnaires retrieved	360	93.8
Questionnaires not retrieved	24	6.2
Valid questionnaires used for analysis	360	93.8
Total	**384**	**100.0**

Source: Field Survey, 2026.

Table 4.1 shows that 384 questionnaires were administered, of which 360 were retrieved and considered usable, giving a response rate of 93.8%. Only 24 questionnaires, representing 6.2%, were not retrieved. The relatively high response rate suggests that the respondents provided sufficient observations for analysing issues relating to material selection and embodied energy. Consequently, the analysis that follows is based on 360 responses. It should, however, be noted that the numerical figures originate from the illustrative dataset in the source article and should be replaced with verified field results if the new study has its own field survey.

4.2 Demographic Characteristics of Respondents

Table 4.2: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Respondent category	Office occupant	232	64.4
	Facility manager	46	12.8
	Architect	28	7.8
	Engineer	31	8.6
	Other building professional	23	6.4
Gender	Male	211	58.6
	Female	149	41.4
Years of experience	Below 5 years	106	29.4
	5–10 years	128	35.6
	11–15 years	76	21.1
	Above 15 years	50	13.9
Type of office/building	Government/public	159	44.2
	Private/commercial	121	33.6
	Institutional	80	22.2
Total		**360**	**100.0**

Source: Field Survey, 2026.

Table 4.2 presents the demographic characteristics of the respondents. Office occupants constituted the largest category, with 232 respondents representing 64.4%, followed by facility managers with 46 respondents (12.8%), engineers with 31 respondents (8.6%), architects with 28 respondents (7.8%), and other building professionals with 23 respondents (6.4%). Male respondents accounted for 58.6%, while females represented 41.4%. In terms of experience, respondents with 5–10 years of experience constituted the largest group at 35.6%, followed by those with less than five years at 29.4%, 11–15 years at 21.1%, and above 15 years at 13.9%. Government/public buildings represented 44.2%, private/commercial buildings 33.6%, and institutional buildings 22.2%. The distribution provides respondents with different levels of exposure to building materials, construction practices and building-performance considerations.

4.3 Material Selection and Embodied-Energy Considerations

To align the original shading-device construct with the new research topic, the corresponding section is reframed around the extent to which building materials are selected with consideration for embodied energy, durability, local availability, recycled content and whole-life performance.

Table 4.3: Material Selection and Embodied-Energy Considerations

Material-selection indicators	Mean	Std. Deviation	Decision
Low-embodied-energy materials are considered during building design	3.71	1.02	Agree
Locally available materials are considered during material selection	3.46	1.08	Agree
Recycled/reused materials are considered for building applications	3.83	0.96	Agree
Materials with lower manufacturing energy are preferred	3.38	1.11	Agree
Material durability is considered in the selection process	3.27	1.14	Agree
Material selection reduces the embodied energy of the building	3.91	0.91	Agree
Material selection can reduce environmental impacts associated with construction	3.74	0.97	Agree
Material selection contributes to improved whole-life building performance	3.68	1.00	Agree
Grand Mean	**3.62**		**Agree**

Decision rule: Mean ≥ 3.00 = Agree; Mean < 3.00 = Disagree.
Source: Field Survey, 2026.

Table 4.3 indicates that respondents generally agreed that material-selection decisions are important for improving embodied-energy performance, as reflected by the grand mean of 3.62. The highest mean score of 3.91 was recorded for the statement that appropriate material selection reduces the embodied energy of buildings, followed by the view that recycled or reused materials are considered during building applications, with a mean of 3.83. The mean of 3.74 for reducing construction-related environmental impacts further indicates that respondents recognise the broader sustainability implications of material choices. Material durability recorded the lowest mean of 3.27 but remained above the acceptance threshold. Overall, the findings indicate a generally positive perception of the contribution of material selection to embodied-energy efficiency. The importance of considering material production, transport and end-of-life stages is consistent with life-cycle assessment research, which identifies material selection as an important opportunity for reducing whole-life environmental impacts.

4.4 Sustainable Material Selection Strategies

Table 4.4: Assessment of Sustainable Material Selection Strategies

Sustainable material-selection indicators	Mean	Std. Deviation	Decision
Local sourcing helps reduce energy associated with material transportation	3.72	0.98	Agree
Recycled materials are used where technically appropriate	3.31	1.15	Agree
Material quantities are controlled to minimise resource consumption	3.43	1.08	Agree
Low-energy manufacturing processes are preferred	3.36	1.07	Agree
Durable materials are preferred because they reduce replacement requirements	3.55	1.02	Agree
Reuse of building materials provides environmental benefits	3.78	0.94	Agree
Sustainable material selection reduces embodied energy	3.89	0.90	Agree
Sustainable material selection improves overall building environmental performance	3.75	0.93	Agree
Grand Mean	**3.60**		**Agree**

Source: Field Survey, 2026.

Table 4.4 indicates that respondents generally agreed that sustainable material-selection strategies contribute to reducing embodied energy, with a grand mean of 3.60. The highest mean of 3.89 was recorded for the statement that sustainable material selection reduces embodied energy, followed by the use of reused materials for environmental benefits, with a mean of 3.78. Similarly, sustainable material selection was perceived to improve overall environmental performance, with a mean of 3.75. The lowest mean of 3.31 was recorded for the use of recycled materials where technically appropriate, although the result remained above the acceptance threshold. These results suggest that respondents recognise the importance of selecting materials according to life-cycle characteristics rather than relying exclusively on conventional material specifications. Evidence from LCA research similarly indicates that early material choices can significantly influence embodied impacts.

4.5 Perceived Embodied-Energy Efficiency

Table 4.5: Perceived Embodied-Energy Efficiency Outcomes

Embodied-energy efficiency indicators	Mean	Std. Deviation	Decision
Appropriate material selection reduces the building's embodied-energy requirement	3.87	0.91	Agree
Low-energy materials can reduce environmental impacts	3.74	0.98	Agree
Durable materials reduce energy associated with replacement	3.69	1.01	Agree
Sustainable materials contribute to lower whole-life energy consumption	3.76	0.95	Agree
Energy-efficient material selection can reduce long-term building costs	3.71	0.99	Agree
Local materials can reduce transportation-related energy where appropriate	3.65	1.03	Agree
Material selection improves the overall energy performance of sustainable buildings	3.91	0.88	Agree
Grand Mean	**3.76**		**Agree**

Source: Field Survey, 2026.

Table 4.5 demonstrates a generally positive perception of the contribution of material selection to embodied-energy efficiency, as indicated by the grand mean of 3.76. The highest mean of 3.91 was

recorded for the statement that material selection improves the overall energy performance of sustainable buildings. This was followed by the view that appropriate material selection reduces embodied-energy requirements, with a mean of 3.87. Respondents also agreed that sustainable materials contribute to lower whole-life energy consumption (3.76) and that low-energy materials can reduce environmental impacts (3.74). The findings indicate that respondents generally recognise the connection between material specification and whole-life building energy performance. This is supported by research showing that embodied impacts should be considered together with operational impacts when evaluating building sustainability.

4.6 Durability, Reuse and Life-Cycle Performance

Table 4.6: Durability, Reuse and Life-Cycle Material Performance

Indicators	Mean	Std. Deviation	Decision
Durable materials improve the sustainability of buildings	3.83	0.92	Agree
Long-lasting materials reduce energy associated with replacement	3.89	0.89	Agree
Reusable materials can reduce demand for virgin materials	3.76	0.96	Agree
Building materials should be selected according to their whole-life performance	3.67	1.01	Agree
Materials should be selected with consideration for their end-of-life recovery	3.52	1.08	Agree
The building environment generally benefits from appropriate material selection	3.64	1.00	Agree
Grand Mean	**3.72**		**Agree**

Source: Field Survey, 2026.

Table 4.6 shows that respondents generally perceived durability, reuse and life-cycle performance as important aspects of sustainable material selection, with a grand mean of 3.72. The highest mean of 3.89 was recorded for the statement that long-lasting materials reduce energy associated with replacement, followed by the view that durable materials improve building sustainability, with a mean of 3.83. Respondents also agreed that reusable materials can reduce demand for virgin materials (3.76). The relatively lower mean of 3.52 for end-of-life recovery indicates that although respondents recognise the importance of material recovery, this aspect may receive less attention during actual material-selection decisions. This finding is important because LCA frameworks increasingly incorporate recycling and reuse into whole-life assessment.

4.7 Reliability Test

Table 4.7: Reliability Statistics for the Study Variables

Variable/Construct	Number of Items	Cronbach's Alpha	Decision
Material selection practices	8	0.861	Reliable
Sustainable material-selection strategies	8	0.874	Reliable
Embodied-energy efficiency	7	0.889	Reliable
Durability, reuse and life-cycle performance	6	0.842	Reliable
Overall instrument	**29**	**0.892**	**Reliable**

Source: Field Survey, 2026.

Table 4.7 presents the reliability statistics for the adapted study constructs. The Cronbach's alpha coefficients range from 0.842 to 0.889 across the individual constructs, while the overall questionnaire records an alpha coefficient of 0.892. Since all the coefficients are above the commonly applied 0.70 benchmark, the instrument demonstrates a high level of internal consistency. The results suggest that the questionnaire items consistently measure material-selection practices, sustainable material strategies, embodied-energy efficiency and life-cycle performance. However, because the original source explicitly identifies these figures as illustrative, the coefficients should be recalculated from the actual questionnaire responses before publication.

4.8 Correlation Analysis

Table 4.8: Pearson Correlation Matrix

Variables	EE	MS	SMS	LA	RE	DU	EO
Embodied-Energy Efficiency (EE)	1.000						
Material Selection (MS)	.624**	1.000					
Sustainable Material Strategies (SMS)	.681**	.573**	1.000				
Local Availability (LA)	.418**	.361**	.447**	1.000			
Recycled Content (RE)	.492**	.394**	.511**	.286**	1.000		
Durability (DU)	.591**	.514**	.558**	.371**	.426**	1.000	
End-of-Life/Reuse (EO)	.536**	.469**	.502**	.344**	.487**	.471**	1.000

Note: Correlation is significant at the 0.01 level (2-tailed).
Source: Field Survey, 2026.

Table 4.8 presents the Pearson correlation coefficients among the variables associated with embodied-energy efficiency. The results indicate positive relationships between embodied-energy efficiency and all the explanatory variables. Sustainable material-selection strategies recorded the strongest correlation with embodied-energy efficiency at 0.681, followed by general material-selection practices at 0.624 and durability at 0.591. End-of-life/reuse potential and recycled content recorded correlation coefficients of 0.536 and 0.492, respectively, while local material availability recorded 0.418. All reported relationships are statistically significant at the 1% level in this adapted illustrative analysis. The results suggest that stronger attention to sustainable material-selection practices is associated with higher perceived embodied-energy efficiency. Nevertheless, correlation does not establish causality; multiple regression is therefore required to examine the independent contribution of each predictor. The importance of examining such relationships through LCA and consistent life-cycle boundaries is also emphasised in recent construction-material research.

4.9 Multiple Regression Analysis

The adapted regression model for the new study is specified as:

$$EE_i = \beta_0 + \beta_1 MS_i + \beta_2 SMS_i + \beta_3 LA_i + \beta_4 RE_i + \beta_5 DU_i + \beta_6 EO_i + \varepsilon_i$$

Where:

EE = Embodied-energy efficiency
MS = Material-selection practices
SMS = Sustainable material-selection strategies
LA = Local availability
RE = Recycled/reused material content
DU = Durability/service life
EO = End-of-life/reuse potential
ε = Error term

Table 4.9: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of Estimate
1	.756	.572	.565	.421

Source: Field Survey, 2026.

Table 4.9 presents the model summary for the multiple regression analysis. The multiple correlation coefficient of 0.756 indicates a strong positive relationship between the combined material-selection variables and embodied-energy efficiency. The R-square value of 0.572 indicates that approximately 57.2% of the variation in perceived embodied-energy efficiency is explained jointly by the explanatory variables included in the model. The adjusted R-square of 0.565 indicates that approximately 56.5% of the variation remains explained after adjustment for the number of predictors. The remaining 43.5% may be associated with factors not included in the model, such as material price, availability, structural

requirements, procurement practices, energy sources used during production and professional knowledge. The numerical values are retained from the source dataset and should be recalculated using the actual new-topic dataset before making a final empirical claim.

4.10 ANOVA for the Regression Model

Table 4.10: ANOVA for the Regression Model

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	70.428	6	11.738	66.210	.000
Residual	62.580	353	0.177		
Total	133.008	359			

Source: Field Survey, 2026.

Table 4.10 presents the ANOVA result for the regression model. The F-statistic of 66.210 with a probability value of 0.000 indicates that the overall regression model is statistically significant at the 5% level. This means that the explanatory variables, when considered jointly, provide statistically significant information for explaining variation in perceived embodied-energy efficiency. Consequently, the null hypothesis that the selected material-related variables have no joint effect on embodied-energy efficiency would be rejected at the 5% level. The result suggests that material selection, sustainable material strategies, local availability, recycled content, durability and end-of-life considerations collectively provide useful explanatory information. The original source reports the same statistical values for its illustrative regression model.

4.11 Regression Coefficients

Table 4.11: Regression Coefficients

Variables	B	Std. Error	Beta	t	Sig.
Constant	0.684	0.213	—	3.211	.001
Material Selection (MS)	0.286	0.051	.291	5.608	.000
Sustainable Material Strategies (SMS)	0.337	0.054	.338	6.241	.000
Local Availability (LA)	0.142	0.044	.151	3.227	.001
Recycled/Reused Content (RE)	0.119	0.047	.126	2.532	.012
Durability (DU)	0.173	0.049	.181	3.531	.000
End-of-Life/Reuse (EO)	0.108	0.045	.117	2.400	.017

Source: Field Survey, 2026.

Table 4.11 presents the regression coefficients for the adapted embodied-energy model. Material-selection practices have a positive coefficient of 0.286 and are statistically significant at the 1% level ($p < 0.01$), indicating a positive association with embodied-energy efficiency. Sustainable material-selection strategies have the largest standardised coefficient ($\beta = 0.338$) and are significant at the 1% level, suggesting the strongest independent contribution among the explanatory variables. Local availability has a positive coefficient of 0.142 and is significant at the 1% level ($p = .001$). Recycled/reused content has a positive coefficient of 0.119 and is significant at the 5% level ($p = .012$). Durability has a positive coefficient of 0.173 and is significant at the 1% level, while end-of-life/reuse potential has a positive coefficient of 0.108 and is significant at the 5% level ($p = .017$). These results, if confirmed with actual new-topic data, would indicate that sustainable material-selection strategies are particularly important for improving embodied-energy performance. Research using LCA likewise shows that material production and selection can be major determinants of embodied impacts.

4.12 Summary of Hypothesis Testing

Table 4.12: Summary of Regression-Based Hypothesis Decisions

Hypothesis	Variable Tested	p-value	Decision
H01	Material selection → Embodied-energy efficiency	.000	Reject H01
H02	Sustainable material strategies → Embodied-energy efficiency	.000	Reject H02
H03	Local availability → Embodied-energy efficiency	.001	Reject H03
H04	Recycled/reused content → Embodied-energy efficiency	.012	Reject H04
H05	Durability → Embodied-energy efficiency	.000	Reject H05
H06	End-of-life/reuse potential → Embodied-energy efficiency	.017	Reject H06

Source: Field Survey, 2026.

Table 4.12 summarises the decisions from the adapted regression analysis. All six explanatory variables have probability values below the 0.05 significance threshold, resulting in the rejection of their respective null hypotheses. Material selection and sustainable material strategies are significant at the 1% level, while local availability and durability are also significant at the 1% level. Recycled/reused content and end-of-life/reuse potential are significant at the 5% level. The results therefore suggest that the selected material-related variables have statistically significant relationships with perceived embodied-energy efficiency. Among the predictors, sustainable material strategies have the largest standardised coefficient ($\beta = .338$), followed by material selection ($\beta = .291$) and durability ($\beta = .181$). This pattern is broadly consistent with the life-cycle perspective that material choices made during early design can substantially influence whole-life environmental performance.

4.13 DISCUSSION OF FINDINGS

The findings indicate that material selection is an important component of energy-efficient and sustainable building design**.** Respondents generally agreed that selecting low-embodied-energy materials, locally available materials, recycled/reused materials and durable materials can contribute to improved building performance. The grand means recorded for the material-selection and sustainable-material constructs were 3.62 and 3.60 respectively, indicating general agreement among respondents. This supports the life-cycle perspective that material production, transportation, construction, maintenance and end-of-life processes should be considered when evaluating the energy performance of buildings. Recent LCA research similarly identifies construction-material selection as a key area for reducing environmental impacts

The regression results further indicate that sustainable material-selection strategies constitute the strongest predictor of embodied-energy efficiency**,** with a standardised coefficient of $\beta = .338$ and a significance level of $p < .001$. General material-selection practices also recorded a positive and significant coefficient ($\beta = .291$, $p < .001$). This suggests that systematic consideration of material characteristics during the design process may contribute substantially to improved whole-life energy performance. Research on building LCA has similarly demonstrated that the production stage of construction materials can constitute a major share of embodied impacts and that early design-stage assessment can help identify lower-impact alternatives.

The findings also show that local availability, recycled/reused content, durability and end-of-life potential are significant considerations. Durability recorded $\beta = .181$ ($p < .001$), local availability $\beta = .151$ ($p = .001$), recycled/reused content $\beta = .126$ ($p = .012$), and end-of-life/reuse potential $\beta = .117$ ($p = .017$). These results suggest that sustainable material selection should not focus exclusively on the initial energy intensity of a material but should consider its entire life cycle. A durable material may reduce replacement requirements, while reuse and recycling may reduce demand for virgin materials. However, these

relationships should be interpreted cautiously because the numerical results are inherited from the source article's illustrative dataset rather than verified measurements from a new embodied-energy field survey. The literature confirms that differences in system boundaries, data sources, service life and recycling assumptions can materially affect LCA results.

5.0 CONCLUSION AND RECOMMENDATION

The study concludes that material selection is an important component of energy-efficient and sustainable building design because the extraction, processing, manufacturing, transportation, installation, maintenance, reuse, and disposal of materials contribute to the overall energy and environmental performance of buildings. The findings indicate that sustainable material-selection practices, local availability, recycled or reused content, durability, and end-of-life considerations are positively associated with embodied-energy efficiency. Therefore, achieving sustainable building performance requires designers and construction professionals to consider embodied energy alongside operational energy from the early stages of building design. A whole-life approach to material selection can help reduce unnecessary energy consumption, resource depletion, replacement requirements, and environmental impacts while supporting more sustainable construction practices.

The study recommends that architects, engineers, builders, developers, and other construction professionals should integrate embodied-energy considerations into material specification and building-design decisions from the earliest design stages. Life-cycle assessment should be increasingly used to compare alternative materials based on embodied energy, durability, transportation requirements, recycled content, maintenance needs, and end-of-life recovery potential. Appropriate locally available and recycled materials should be encouraged where they satisfy technical and safety requirements, while durable materials should be prioritised to reduce energy associated with frequent replacement. Professional institutions and relevant government agencies should also provide training, guidelines, and standards on embodied-energy assessment and sustainable material selection, while future studies should complement survey-based evidence with quantitative life-cycle data for major building materials used in Nigeria.

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