



Sustainable and Renewable Energy Strategies in Residential Buildings in Akure, Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Given the rising demand in building services and high level of energy consumption in buildings, sustainable issues have remained top agenda in developmental discuss. This study examines the level of adoption, barriers and willingness to adopt renewable energy and sustainable building strategies in Nigeria. The mean score ranking technique was employed to rate the relative weight of level of adoption of sustainable strategies considered. Natural lightning, shading devices, locally sourced materials, energy efficient lighting LED and photovoltaic solar panel were the most adopted strategies by professionals. Adoption of renewable and sustainable building strategies was constrained by lack of training, lack of expertise and financial scheme. Willingness to adoption the renewable energy and sustainable building strategies, were most pronounced with respect to renewable energy practices. However, the paper suggests that transition to the use of energy efficient and sustainable building materials as evident in top ranked efficient strategies. Finding contributes to empirical benchmarking for sustainable environment while policy options towards adoption were proffered.

Keywords: Adoption; barriers; renewable energy; sustainable building; willingness.

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1. INTRODUCTION

Stimulated by recent technological improvements, rising demand in building services and increasing urbanization activities, sustainable environment and energy issues have remained central in developmental discuss. The concept of sustainable building strategies and renewable energy has received major attention in modern constructions due to its implication on safe and healthy environment [1]. Across building professions, sustainability is increasingly becoming a key consideration in building practice as the world tends towards zero-energy construction. The construction industry accounts for about 32% of the total global energy consumption, of which buildings are responsible for about one-third of the world's greenhouse gas (GHG) emissions and the generation of over 45% of global wastes [2,3,4,5]. As a result of this higher demand and likely devastating environmental impacts of the construction industry, the adoption of sustainable building practices is much relevant to pursue a balance between economic, social, and environmental dimension of sustainability. Thus, the adoption of sustainable practices toward improved building condition has become indispensable world over.

It is anticipated that world population will increase by over 50%, while global economic activity and energy consumption will have increased by fivefold and nearly threefold by 2056 [6]. The building sector has been identified as one of the most resource-intensive industries in energy use and contributes significantly to environmental pollution [7]. This is evident in its energy consumption with respect to production of building materials, during the construction phase and at the completion stage in terms of heating, lighting, power and ventilation. Rapid economic growth, increasing energy resource depletion, rising building service demands in most developing economies contributes to the rising energy demand and this will account for the major increase in energy consumption [8]. Increasing public concern on the negative impacts of construction activities has necessitated the need for sustainable building development in buildings [9,10]. In this sense, renewable energy (RE) and sustainable building (SB) strategies projects and initiatives is a way to achieve low-cost emissions in most developing countries. Understanding the level of adoption of renewable energy and building strategies in mitigating greenhouse gas emissions' reductions will help close the emissions gap needed to

meet the 2°C global temperature goal by 2050 [11].

Renewable technologies are considered as clean sources of energy with which adequate use will enhance positive environmental impact [12]. Akinola and colleagues [13] noted that the use of renewable energy is most applicable in buildings, as such, low energy houses use less energy from the design, technologies and building products. Likewise, sustainable building (SB) strategies entail the use of more resource-efficient materials during construction and completion with minimal adverse impacts on human health and the environment [14]. Therefore, Sustainable building materials and renewable energy such as green roof and wall technologies, solar system technology, energy metering and energy efficient lighting LED are incorporated into building design and construction to make the end product sustainable. These technologies tend to address the environmental concerns that emerged as a result of greenhouse gas emissions owing to non-renewable energy use.

Incorporating them into buildings provides a consistent supply on a sustainable basis because they cannot be depleted [15]. As global climate change and sustainable development remains sensitive, integration of sustainable energy and building strategies must be all encompassing as it considers the environmental impacts (which include energy consumption) of buildings, but the social (which include occupants' health and well-being) and economic (which include a building's lifecycle costs) [16,17].

Despite the enormous importance of RE/SBS in sustainable environment, efficient energy services remain an enormous task in most African countries owing to its impact on socioeconomic development and adaptation for climate change. However, in the case of Nigeria, rapid population growth and the associated socioeconomic changes in the living standard in Nigeria has been responsible for the upsurge in total energy demand. The gap cannot be met mainly by fossil fuel, coal [15] as about 40-50% of the generated energy resources in Nigeria is consumed by residential buildings. Also, poor and inefficient energy supply often characterized installation and distribution of the energy for usage. In addition, economic wastes could be attributed to vandalization of energy equipment. In this regard, sustainable means of energy use

with minimal adverse effect on livelihood and the economy should be appropriated in the national energy policy by relevant stakeholders in Nigeria considering the rich natural resources in the country. Therefore, strategies to adopt renewable energy in buildings are a veritable tool.

Consequently, many studies have been conducted on the sustainable energy and building strategies in different countries. For instance, bin Esa et al. [18] attributed lack of information, awareness and education as major constraints reported by majority of consultants, clients and architects as the topmost challenges facing the advancement of green construction in Malaysia. Rodriguez-Nikl et al. [19] identified lack of information as a major barrier for structural engineers in the US to adopt green building practices. According to Persson and Grönkvist [20], lack of knowledge of energy-efficient technologies presents the biggest challenge for construction professionals to adopt green building in Sweden. Darko and colleagues [21] categorized barriers into government-related, human-related, knowledge-related, market-related and cost and risk-related barriers. On the other hand, Darko et al., [4] also identified environment-related, company-related, economy and health-related, cost and energy-related, and industry-related forces as important drivers of green building technology adoption in Ghana. Rabbe [22] considered the need for integrated research as the essential requirements for developing sustainable construction in developing countries while Akadiri, et al. [7] presented a conceptual framework aimed at implementing sustainability principles in the building industry.

In Nigeria, Akinola, et al. [13] examines architect's awareness and adoption of building envelope technologies (BET) for energy efficient housing in Lagos State, Nigeria. The extent of architect's knowledge of using the technologies was influenced the adoption of energy efficient technology in which energy efficient using LED lightning, window attachments, external overhangs and photovoltaic roof were the most used strategies of building envelope technologies for energy efficient housing units. Amasuomoa et al. [23] observed that measuring the environmental performance of buildings and control of building construction process are ways of reducing rapid degradation of the environment and excessive reliance on unsustainable energy in Nigeria. In other word, integrating sustainability principles (economic, social and environmental) into construction projects right from the

conceptual stage has considerable potential to accelerate the understanding and implementation of sustainability in building construction. Indeed, the adoption of sustainable energy and building strategies represent a channel for green building delivery.

Till date, studies that examine the issues on renewable energy and sustainable building strategies in Nigeria is rather limited. Hence, this paper examines the level of adoption of renewable energy and SBS, barriers and the willingness to adoption of renewable energy and sustainable building strategies in Akure, Ondo State. This study will provide possible explanations on the underlying factors for RE/SB strategies and prospects of sustainable strategies in residential buildings in Nigeria. In addition, this study will improves understanding of the constraints to major adoption which can be a valuable reference point for practitioners and policy makers in project conception and formulation of national energy policy. The remainder of the paper is organized into the following sections. Methodological aspect is provided in section 2. In section 3, a detailed discussion of results while conclusion and possible policy recommendation is presented in Section 4.

2. METHODS

The parameters used in the selection of construction firms that constitutes the sample for study are; academic qualification of the professionals, types of organization, years of experience and type of project handled. This would produce a good suitable result for analysis and to reach a reasonable conclusion that will give answers to the research question. The research population comprised all industry practitioners with knowledge and understanding of sustainable building experience Akure, Ondo State. The study area is Akure the Ondo state capital had higher number of different residential building. Through a questionnaire survey with 165 professionals, key information was sourced. The questionnaire is in two sections, section A included background information of the respondents while the other sections focused on matters relating to the three objective of the study. Questions inherent in structured questionnaire were asked on adoption, barrier and willingness on a five point Likert scale for ease and uniformity of response. This study adopted the five-point Likert scale because it provides unambiguous results that are easy to interpret. Its application implied that most part of

the data analysis was based on a scoring system. Level of adoption by respondents was captured by extent of frequency of which 5= most times to 1= never. Structured questions prepared on barrier and willingness to adopt reflect respondents' level of agreement which was measured on a five point Likert scale ranging from 5= strongly agree to 1= strongly disagree. The Five point Likert type scoring system revealed the perceived respondents' level of agreement. The mean score ranking technique was used to determine the relative ranking of selected RE/SBS variables in descending order of importance.

In this paper, the principal types of renewable energy sources considered include solar, thermal, photovoltaic, bioenergy, hydro, tidal, wind, wave, and geothermal. The sustainable buildings strategies are based on the evaluation of their impact on the environmental impacts, the users' comfort and other social benefits and the life-cycle costs). Data was analyzed using simple percentage and charts to show frequency distribution of respondents' characteristics while descriptive statistics such as mean, ranks explain respondents' perception of RE/SB strategies. The mean score ranking technique ranks the relative importance of specific factors under consideration. The mean score ranking technique was used to determine the relative ranking of the 16 RE/SBS strategies for adoption in according to order of frequency of usage.

3. RESULTS AND DISCUSSION

3.1 Demographic Characteristics of Respondents

The survey respondents consisted of experienced professionals in the industry as shown in Fig. 1, with varying years of experience. The majority of respondents had less than 5 years, whereas about 11% had more than 10 years of experience. There was a reduction in percentage distribution as years of experience increases. This suggests the professionals are young and agile in the industry. Considering respondents' professional type, their distribution was representative for of important actors in construction setting which guarantee the reliability of the findings. Among the professionals, Mechanical and Electrical (M/E) engineers (26%) formed the majority followed by Architects (23%). These professionals are responsible for energy issues and construction material aspects in building process. With respect to their educational status, greater

percentage had M.Sc. (36%) which suggests that most respondents are highly knowledgeable professionals in their respective fields.

3.2 Adoption of Renewable Energy and Sustainable Building Strategies

The results of mean score revealed that the top five for adoption of RE/SB strategies were natural lightning (M=4.45), shading devices (M=4.03), locally sourced materials (M=3.95), energy efficient lighting LED (3.89), and photovoltaic solar panel (3.78). These were the most adopted strategies by professionals. These five strategies are discussed below.

The research finding suggests that the top three ranked strategies are passive RE/SB strategies which can achieved through architectural design solution based on established benchmarks for sustainable environment. Use of natural lighting and shading devices as the most adopted since they enhance health and comfort of occupants. This concurs with Thatcher and Milner [24] who noted that health and well-being was an important motivator for their adoption. Therefore, passive design strategies can help improve the health and well-being of occupants thus seems very attractive to construction professionals most especially architects.

The energy efficiency lighting ranked as fourth revealed a drive towards greater energy efficiency and conservation. The adoption can be credited to the cost savings from lower utility bills resulting from the greater energy efficiency. This is a way of minimising electricity distribution sector which has been burdened with difficulties vis-a-vis power quality and supply. Energy efficiency is indeed a high priority for national development in both developed and developing countries [25]. Therefore, given the high level of energy consumption in buildings, adoption of efficient lighting LED materials now plays an essential part in national development and helps improve the energy efficiency situation in Nigeria. Lessons from other developing countries as reported by Darko et al. [4] in Ghana, revealed that adopting high energy efficient windows and green wall technology in buildings development saved a higher percentage of operational energy [26] while the use of light emitting diode (LED) bulbs saved about 70-80% of electricity usage [27]. This finding was in line with the Manoliadis, Tsolas, and Nakou [28] and Ahn, Pearce, Wang, and Wang [29] where energy conservation was identified as a major driver for implementing sustainable construction practices.

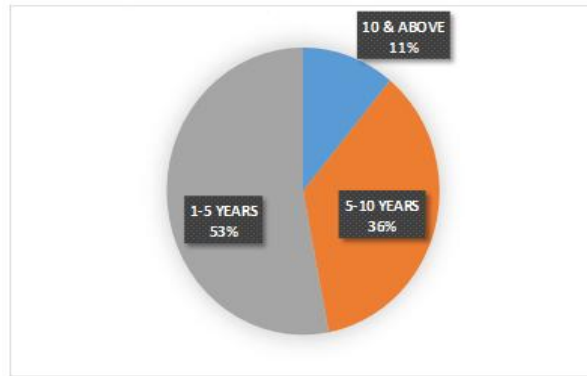


Fig. 1. The respondents' years of experience

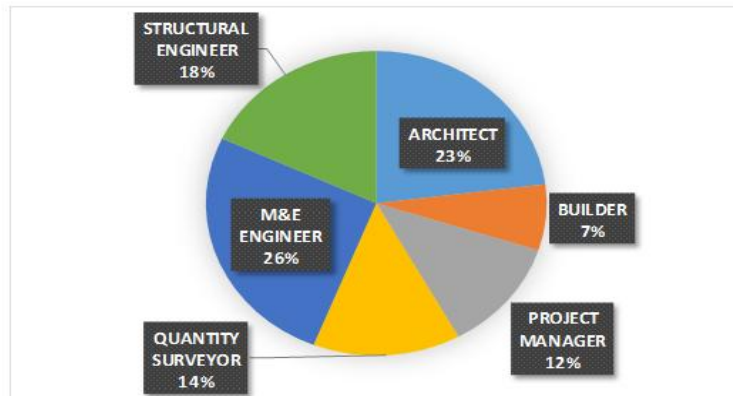


Fig. 2. Respondents type of profession

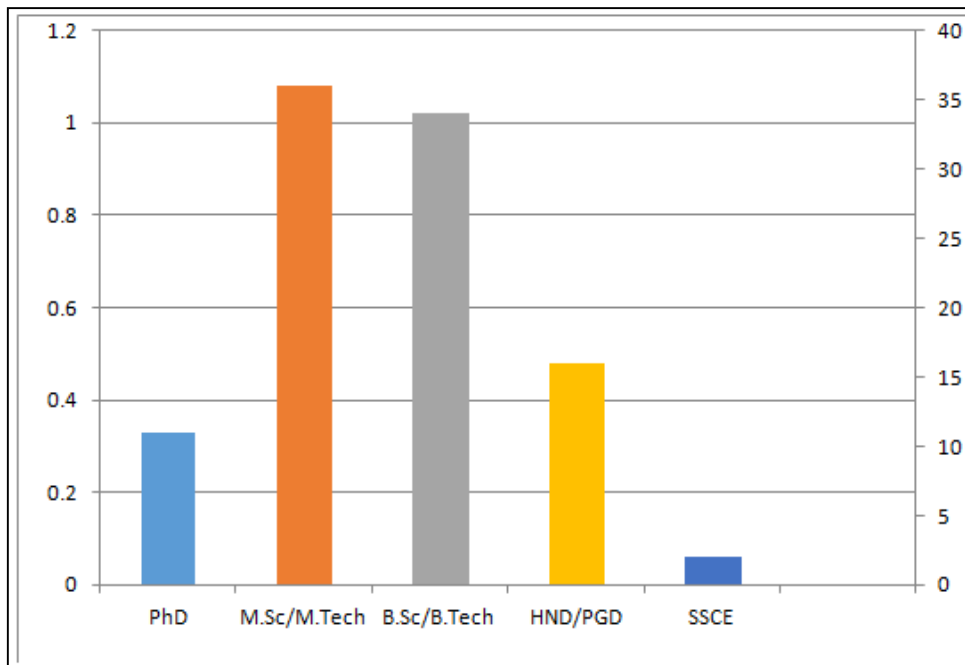


Fig. 3. Bar chart showing the level of education of respondents

Table 1. Summary statistics for the adoption of renewable energy and sustainable strategies

S/N	Adoptions	5	4	3	2	1	Mean	Std. Deviation	Rank
1.	Natural lighting/ventilation	57%	36%	4%	1%	2%	4.4500	.7961	1 ST
2.	Shading devices	28%	56%	9%	5%	2%	4.0300	.8698	2 ND
3	Locally sourced material	31%	47%	10%	7%	4%	3.9495	1.0338	3 RD
4	Energy efficient lighting LED	22%	50%	23%	5%	-	3.8900	.8027	4 TH
5	Photovoltaic solar panel	19%	59%	11%	3%	8%	3.7800	1.0500	5 TH
6	Extensive landscape	19%	49%	23%	5%	3%	3.7677	.9239	6 TH
7	Insulated wall panels	9%	44%	32%	11%	4%	3.4300	.9455	7 TH
8	Energy efficient HVAC	7%	42%	38%	4%	8%	3.3636	.9737	8 TH
9	Energy metering	13%	9%	68%	7%	2%	3.2424	.8462	9 TH
10	Green wall/roof	2%	37%	29%	9%	23%	2.8600	1.2062	10 TH
11	Photovoltaic walls, windows or doors	1%	18%	38%	29%	13%	2.6465	.96164	11 TH
12	Biogas/ bio-water digester	1%	14%	46%	12%	26%	2.5152	1.0629	12 TH
13	Smart windows	3%	9%	38%	31%	17%	2.4898	.9869	13 TH
14	Recycling/ harvesting of water	-	13%	33%	39%	14%	2.4545	.8953	14 TH
15	Sealant for air leakage	3%	4%	17%	51%	24%	2.1010	.9202	15 TH
16	Wind Turbine	-	3%	13%	36%	47%	1.7172	.8086	16 TH

Note: 5= most times, 4= sometimes, 3= not very often, 2= rarely, 1= never

Adoption of photovoltaic solar panel as an alternative way to power offers a promising way to ensure the sustainable use of energy in residential buildings. It helps to reduce the whole weight placed on electricity as source of power in Nigeria and would significantly reduce air pollution through non-renewable energy sources like fossil fuels that accounts for large amounts of GHGs. The least ranked strategies recycling of water, sealant air leakage and wind turbine occupied the fourteenth, fifteenth and last position, respectively. The low level of adoption might be as a result of expertise and technicalities involved in its operation with associated cost of installation and operation of these strategies in residential buildings. In light of the above discussion, it can be summarized that the level of adoption revealed the transition process to sustainable energy and building strategies as evident in most ranked ones although at the preliminary stage and at slow pace. It presents a stand that professionals and stakeholders can embrace RE/SB strategies if incentives are provided and awareness level is

broadened. Thus, the government and advocate need to formulate and implement good strategies to educate and increase the public's knowledge and awareness of these benefits in order to promote the more widespread adoption of sustainable materials.

3.3 Barriers of Renewable Energy and Sustainable Building Strategies

Results from Table 2 presents the extent to which all the selected barriers influenced the adoption of renewable energy and sustainable building strategies. The top three ranked barriers which are lack of training, lack of expertise and financial scheme are institutional in nature. Thus suggest role of public policy in embracing sustainability practices in construction practices by professionals. However, lack of training/education and expertise with a very high mean score (M= 4.2; M=4.14) could be as a result of poor enlightenment on education and research, technical know-how and awareness required towards RE/SB strategies adoption by

professionals. This might be responsible for the dearth of the right information to guide sustainability actions by clients as shown by the fourth ranked strategy (lack of awareness of benefit of renewable energy). However, this result is related with the viewpoint of Darko and Chan [9] that lack of information as a result of insufficient education and reliable research constraints level of adoption and also decreases public awareness of sustainable green building strategies. Lack of financing scheme with mean score of 4.03 revealed the concern about the high cost premium of RE/SBS materials which remains a critical barrier to its adoption. Likewise, this finding was corroborated by Mulligan et al., [30] and Opoku and Ahmed, [31] that high cost of accessing sustainable materials remains an obstacle in construction practices. Therefore, implementation of subsidy/incentives on these sustainable strategies by relevant stakeholders

(for instance, the government) would enhance level of adoption and thereby increase the interest and acceptance of these products by users. This result has also shown lack of code and regulation as the least most reported barrier to adoption. The least ranked barrier suggest codes and regulation might not be that important in adoption of RE/SB strategies among professionals in the study area.

3.4 Willingness to Adopt Strategies of Renewable Energy and Sustainable Building

Table 3 presents the level of agreement of respondents' willingness to adopt renewable energy and sustainable building strategies. In the highly rated RE/SB strategies which the respondents desire to adopt include the use of innovative energy efficient materials such as

Table 2. Selected barriers of renewable energy and sustainable building strategies

S/N	Barriers	5	4	3	2	1	Mean	Std. Deviation	Rank
1.	Lack of training and education	26%	68%	6%	-	-	4.2000	.53182	1 ST
2.	Lack of expertise	25%	65%	9%	1%	-	4.1400	.60336	2 ND
3.	Lack of financing schemes/cost	20%	65%	14%	-	1%	4.0300	.65836	3 RD
4.	Lack of awareness of benefit of Renewable energy	21%	62%	11%	6%	-	3.9800	.75183	4 TH
5.	Lack of expertise/skilled labour	22%	60%	12%	3%	2%	3.9798	.80787	5 TH
6.	Unfamiliarity with renewable energy technologies	19%	63%	15%	2%	1%	3.9700	.71711	6 TH
7.	Lack of Government incentives and regulations	19%	62%	16%	2%	1%	3.9600	.72363	7 TH
8.	Cost (too high)	19%	60%	17%	3%	1%	3.9300	.75552	8 TH
9.	Lack of interest and market demands	13%	68%	15%	4%	-	3.9000	.65905	9 TH
10.	Unavailability of approved green materials & technologies	16%	51%	26%	6%	1%	3.7500	.83333	10 TH
11.	Limited experience with the use of non-traditional procurement methods	7%	41%	48%	3%	1%	3.5000	.71774	11 TH
12.	Lack of codes and regulations	10%	38%	48%	3%	1%	3.5300	.75819	12 TH

NB: 5=strongly agree, 4= agree, 3= neutral, 2=disagree, 1= strongly disagree

Table 3. Assessment of respondent to willingness to adopt the strategies of renewable energy and sustainable building

S/N	Willingness	5	4	3	2	1	Mean	Std. Deviation	Rank
1.	Use innovative energy efficient materials such as energy saving bulbs	56%	36%	8%	-	-	4.4800	.64322	1 ST
2.	Use natural and renewable energy sources such as solar energy	50%	40%	8%	1%	1%	4.3700	.76085	2 ND
3.	Use gas instead of diesel or petrol to power construction plants	21%	43%	31%	4%	1%	3.7900	.85629	3 RD
4.	Support government policies on climate change	9%	54%	34%	3%	-	3.6900	.67712	4 TH
5.	Support ethical measure and regulation on the environment	8%	49%	40%	1%	2%	3.6000	.73855	5 TH
6.	Reduce use of CO ₂ emitting materials such as concrete and steel	10%	43%	38%	6%	3%	3.5100	.87033	6 TH
7.	Use of traditional materials such as stabilized clay bricks and bamboo	11%	27%	57%	3%	1%	3.4444	.77225	7 TH
8.	Use de-materialization (light materials) to reduce the rate of material consumption.	7%	30%	61%	1%	-	3.4343	.64145	8 TH
9.	Use timber as structural material instead of concrete and steel	8%	24%	57%	7%	3%	3.2727	.83076	9 TH

NB: 5=strongly agree, 4= agree, 3= neutral, 2= disagree, 1= strongly disagree

energy saving bulbs having the mean of 4.48 ranked first, followed by the use of natural and renewable energy sources such as solar energy (M= 4.37) and use of gas instead of diesel or petrol to power construction plants (M=3.79). However, issues on policy aspects such as support of government policies on climate change (4th), support ethical measure and regulation on the environment(5th) and reduction in use of CO₂ (6th) were next rated category. The least ranked strategies which the respondents were willingly to are related sustainable building materials. These include use of traditional materials such as stabilized clay bricks and bamboo (7th), use de-materialization (light materials) to reduce the rate of material consumption (8th) and use of timber as structural material instead of concrete and steel (9th). The low level in willingness to adopt alternative building materials might be linked to low level of

familiarity with new innovative SB materials. In addition, deforestation issues as regards use of timber in Nigeria might also be responsible. The three most ranked strategies suggest respondents' willingness to switch to renewable energy at a faster rate than other sustainable building materials which was among the least ranked.

4. CONCLUSION AND RECOMMENDATION

This study examined the level of adoption of sustainable energy and building strategies among construction professionals in Nigeria. Using a cross sectional data from 165 professionals in building practices, level of adoption, barriers and willingness to RE/ SB strategies were rated based on five point Likert type scale. From the results natural lighting,

shading devices, locally sourced materials, energy efficient lighting LED, and photovoltaic solar panel were the top five adopted sustainable devices by professionals. The three top ranked materials are passive design strategies and architectural solutions for sustainable environment. Major constraints identified by this study to adoption of renewable and sustainable building strategies are lack of training, lack of expertise and financial scheme. Across the categories, willingness to adoption of RE/SBS, were most pronounced with respect to renewable energy practices. This revealed the respondents' willingness to switch to renewable energy at a faster rate than other sustainable building materials which was among the least ranked. Given the high level of energy consumption in buildings, adoption of efficient lighting LED materials could play an essential part in national development and help improve the energy efficiency situation in Nigeria. In sum, the level of adoption of RE/ SB strategies revealed the transition process to sustainable energy and building strategies as evident in most ranked strategies although at the preliminary stage and slow pace. In promoting adoption level in RE/SB strategies, effective collaboration between governments (policy maker), relevant stakeholders in construction industry is highly essential. It will present a common ground for all stakeholders to formulate and implement policy strategies and incentives towards adoption of sustainable materials. This would help in meeting the future energy needs, reduction in GHG emissions and conservation of the environment.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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