Evaluating the Factors Affecting the Cost of Building Applied Photovoltaic (BAPV) System in Building Projects in South-Eastern Nigeria[1]

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Abstract

Over the years, the use of photovoltaic technologies in the building sector in South-East, Nigeria is however very low due to perceived high cost. This study examined the factors affecting the cost of building applied photovoltaic (BAPV) in Nigeria. In South-East Nigeria, a survey study employing a purposed design questionnaire with 508 participants (including construction professionals, PV contractors, and building contractors) was carried out. 376 completed surveys were utilized for analysis in the exercise. Descriptive statistics of frequency, basic percentages, and inferential factor analysis are the data analyses used. The findings indicate that the cost of BAPV is significantly influenced by seven key aspects, including a lack of local skills, inaccessible local technologies and expertise, component design life, and full life cycle cost elements. These elements make up the pertinent cost drivers for installing building applied photovoltaic systems. It follows that implementing optimization techniques in these areas might greatly reduce the present cost of constructing a solar system in South-East Nigeria. The study suggests implementing pertinent tactics in a comprehensive manner that have been validated by the study in order to increase cost performance and disperse the usage of PV technology in the South-East. In order to improve the shared experiences among project developers, PV contractors, policy makers, and regulators at the regional level; the research also suggests that a collaborative PV supply chain be encouraged. This will improve the critical analysis of the BAPV cost structure and the ways in which the circumstances inside the country impact the cost structure.

Keywords: *Photovoltaic, Solar, Building Applied Photovoltaic, Sustainable Energy, Cost Factors, South-East Nigeria.*

[1] How to cite this paper: Orji, O.S., Amuda, O.A., Ohamma, V.O., Okere, G.O. (2025). Evaluating the Factors Affecting the Cost of Building Applied Photovoltaic (BAPV) System in Building Projects in South-Eastern Nigeria; *PM World Journal*, Vol. XIV, Issue IX, September.

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Introduction

Building structures utilise the significant proportion of global energy stock. Energy sources to building over the years come from conventional electricity transmitted over distance to the point of use. Numerous sources of renewable technologies are obtainable but photovoltaic solar has gain widespread endorsement based on its numerous benefits (Izam et al., 2022). These benefits therefore situate it as one of the approaches for reducing fossil-based energy consumption for sustainable development (Adebiyi & Moloi, 2024). The term photovoltaic therefore describes technologies that convert solar to electricity (Marques Lameirinhas et al., 2022).

Based on in-country's assessment, indications are ripe that Nigeria retains a good potential to maximise photovoltaic energy for use in buildings. However, accessibility in Nigeria is still largely dependent on oversea market inputs with inferred high cost (Sesan et al., 2024). It is therefore more expedient now than ever to explore mechanisms to ensure accessibility of renewable energy technologies in the critical building sector through cost mitigation. The application of photovoltaic system is till date restricted to certain class of the society among Nigerian populace. Competition resulting from the niche PV system market has not also contributed to mitigate cost (Nduka, 2023). High capital cost therefore stand-out undisputed whenever the decision to adopt PV system is evaluated (Nduka, 2023).

A true picture of the scenario is the fact that the growth of BAPV application is bedeviled by high capital cost (Lawani et al., 2024). Beiter et al. (2021) maintained that cost is a key criterion in renewable energy system procurement**.** Energy poverty, high energy cost, erratic power supply, reliance of fossil-based portable generator are among the key factors influencing renewable energy technologies in the Nigerian building sector (Adeyemi-Kayode et al., 2022). Many African countries have chronic power shortage leading to outages and the need for expensive high cost back-ups power generation. Within her population, over 600 million people in Africa lack any form of access to electricity. In Nigeria, 55% of Nigerian household do not have access to power supply (Ibrahim & Ayomoh, 2022).

Population increase therefore means that energy supply challenges will continue into the next decades. Amidst the envisage challenge, clean and sustainable energy supply is considered the only way Africa could attain its full potentials (Nyasapoh, Elorm & Derkyi, 2022). However, inherent barriers to this pathway remain. Schwerhoff and Sy (2019) observed that targeted transformation in the energy sector by poor institutional capabilities, non-institutionalization of financing mechanisms and poor generic business sector improvement. Again, the cost structure for communicating the benefits photovoltaic to the stakeholders, policy makers and end-users are vastly unstructured. Allouhi et al. (2022) observed that there is total lack of up-to-date data on the true cost of PV in Nigeria and other parts of Africa. Absent of comprehensive data on the cost of PV inhibits efficient policy making towards expanding adoption rate (Heath & Drahi., 2024). Existing cost information is further plagued by optimistic assumptions, expert and non-expert judgments extrapolated from experiences outside the continent (Abdullahi et al., 2022). Reliability of these cost information is also low and can result in misleading cost estimates.

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It is also in the public domain that systematic cost data management is not the norm for Africa (Abdullahi et al., 2022). Data collection process for real-life solar PV project is faced with inherent challenges of the construction industry including small scale fragmented characteristics as well as confidentiality concerns and information hoarding (Mulopo, 2022). According to Olanite et al. (2024), PV cost data in Africa are not analytically organised and are not readily available to policy makers. The development is largely responsible for the inability to formulate realistic policy supports that are adequate to promote renewable energy application in the tropics. The quality of data also varies largely because of inability to organise these data into applicable cost structure useful in the construction industry (Abdullahi et al., 2022). It is therefore not in doubt that existing cost data on PV cost lack appropriate framework and breakdown structure to facilitate cost management of future projects (Allouhi et al., 2022). The increasing mismatch between perceived costs and actual cost structures generates misperception and unrealistic expectations which has chronic implications on deployment rate (Allouhi et al., 2022). This study therefore primarily addressed dearth of reliable cost information about the true cost of solar PV incorporated in building in South-East, Nigeria by looking at the factors affecting the cost of building applied photovoltaic (BAPV) system

LITERATURE REVIEW

Concept of Photovoltaic System

According to Yeung et al. (2017), the word "photovoltaic" can be traced back to Greek, where "photo" refers to light and "Volta" refers to an Italian physicist who invested in a chemical battery in 1800. As a result, the photovoltaic effect is a straightforward transfer of solar energy to electrical energy. Panels are made of a polymer that causes electrons to be liberated from their atoms when exposed to light (Ali et al., 2025). That the current flows in one direction, as it does in a battery, the power is referred to as direct current (DC).A photovoltaic system is one that generates electricity using green solar energy. PV cells are grouped into modules, which are then assembled to form an array. To absorb light, arrays are fixed to the roof (mostly) in BAPV adoption. It belongs to the clean energy family of technology. Renewable energy technologies are energy flows from sources that are replenished at a rate that is comparable to the rate at which they are used (Manohar et al., 2015). Solar thermal, wind, and hydro-electric technologies are examples of other alternative energy sources.

According to Yeung et al. (2017), there are three types of photovoltaic cell technologies available on the market: copper indium diselenide (CIS) thin film technology, amorphous silicon, and mono-crystalline/polycrystalline silicon. One type of single-crystal silicon with a high efficiency level of more than 15% is called mono-crystalline silicon (Yeung et al., 2017). Polycrystalline silicon has a larger surface area than monocrystalline silicon made from a cast block. The conversion efficiency of polycrystalline is 10-15%. (Yeung et al., 2017). With a conversion efficiency of around 4-7 percent, amorphous silicon has the lowest conversion efficiency of all technologies. PV cells (panels) are the most important part of a PV system, and their costs are being steadily related to the overall system's costs (Fazal & Rubaiee, 2023). As a result, the advancement of cost accounting considers crystalline silicon production to be more costly, and other approaches, such as thin film with lower efficiency, are direct responses to offset costs (Fazal & Rubaiee, 2023).

Classification of Solar Photovoltaic System

Photovoltaic (PV) and concentrated solar power (CSP) are two forms of solar technology defined by Vodapally and Ali (2022). (CSP). CSP devices use mirrors to direct sunlight into a receiver, which then heats a fluid to a high temperature, which is then transformed to electricity. Photovoltaic panels are the most common in the commercial field. The panels may be installed on the roof or built into the structure. The energy generated can be used immediately or deposited in a battery for later use.

There are three types of PV systems: hybrid, grid-connected, and stand-alone (Figure 1). It is categorised according to how it is used and put into practice. Batteries are necessary for extra storage systems in stand-alone systems, but they are not needed in grid-connected systems as the generated power is sent directly into the main grid or loads (Vodapally & Ali, 2022). When PV technology is supplemented by another power source, like wind or a diesel engine, hybrid systems are put into place. However PV-generated electricity is divided into two categories: grid-connected and off-grid. Grid-connected systems link to the national delivery network directly. The excess energy produced is pumped into the grid, and the home-based PV system acts as a mini-power generation facility, according to this understanding. Off-grid PV systems provide the majority of the energy required by a household at any given time, with the remainder being deposited in a battery for potential usage. As a result, it is undeniable that solar energy will displace a significant portion of fossil fuels (Vodapally & Ali, 2022).

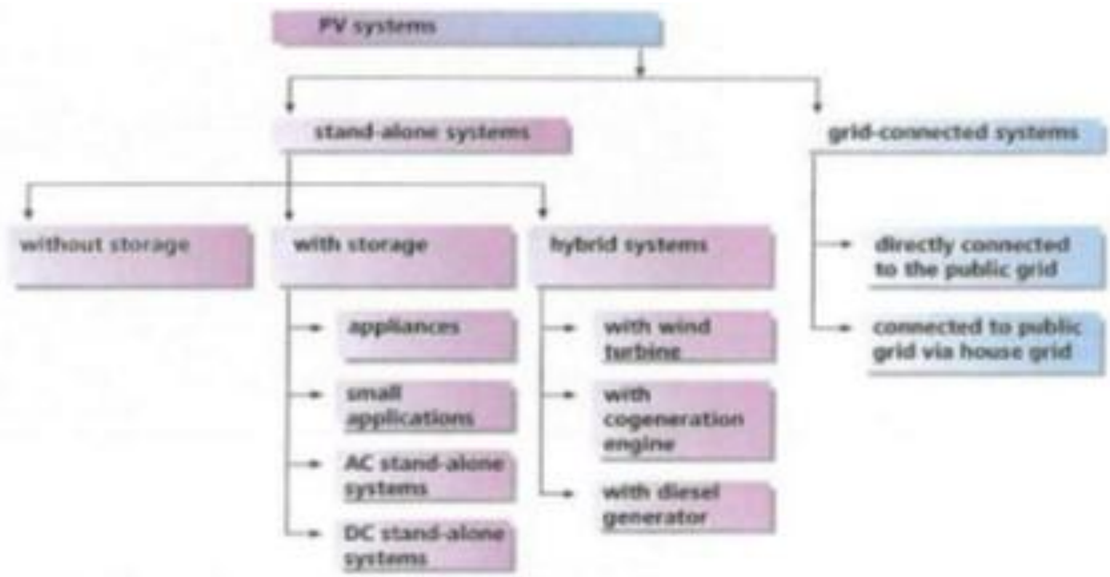

Figure 1: Types of PV systems (Vodapally & Ali, 2022)

Building-attached and building-integrated photovoltaic systems were described in another classification scheme used in cost control literature. BIPVs are built into the construction fabric to replace conventional building materials or elements (Maghrabie et al., 2021). The distinction between the two systems is that BIPV is an aspect of the building that performs structural or other functions in addition to delivering solar power to the structure, while BAPV is connected to the finished structure. BAPVs are called add-ons to the building layout and are not specifically relevant to the building element's functional perspective (Ekung, 2022). Roof cladding, wall integrated, and curtain walling photovoltaic panels are all examples of building integrated photovoltaic systems (BIPVs). BAPVs are a more appealing choice due to their versatility in terms of land space and longer service life (Ekung, 2022). As a result, BAPV is more widely used than BIPV, especially in developed countries such as the United States of America (Maghrabie et al., 2021). The complexity of convergence associated with the use of BIPV is another reason for the preference for BAPV technologies (Maghrabie et al., 2021). BAPV materials are also adaptable, making them ideal for regenerative and retrofit programs (Ekung, 2022).

Factors Affecting the Cost of Building Applied Photovoltaic (BAPV) Systems

The cost-effectiveness of a PV system is heavily influenced by the location of the solar panels (Qureshi et al., 2024). The biggest impediment to widespread acceptance of photovoltaic technology is a lack of knowledge (Karakaya & Sriwannawit, 2015; Schulte et al., 2022). Other issues include a lack of awareness of BAPV's advantages and a lack of appreciation of additional values. The lack of industry subsidies and low infrastructure and institutional structure are still alarmingly strong. Low energy efficiency, a lack of government funding, high construction costs

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for customized systems, limited market awareness and cost expectations, and the price of traditional power are all risks and obstacles (Mustafa et al., 2024). The measurements of batteries are not intended for longer life; there is no interface (integration of conventional building processes), there is no universal vocabulary, there is mismatched potential, uncertain efficiency, and there is no economic analysis within the design process. Ahmed et al. (2025) conclude that availability, a low degree of research and growth, low understanding, a lack of technology know-how, government policy, building regulations, and component failure are all factors that limit the cost-effectiveness of photovoltaic systems in Nigeria. Cost of production, burglary and vandalism, and technological issues are among the others. The lack of knowledge and familiarity with BAPV systems in the construction industry accounts for a large portion of the reasons (Alnusairat & Abu Qadourah, 2025). Restricted zoning regulations and metering arrangements are also important considerations. Long-term strategies, on the other hand, have been shown to boost the cost-effectiveness of the BAPV system and thus increase acceptance, especially in the tropics. According to Ding et al. (2023), the high costs of BAPV systems are due to drivers in the dimensions of customer procurement, authorization, testing, and interconnection, funding, construction labour expense, and non-hardware.

Cost Structure of Building Applied Photovoltaic (BAPV) System

Hadavinia and Singh (2019) modelled BAPV system costs into three principal components covering (i) the price of the solar array (modules and supporting structures included); (ii) the balance of system (BOS) expenses, which include the price of the batteries, inverters, and other electrical equipment utilised; and (iii) other expenses like overhead. Other studies recognised maintenance cost; maintenance costs include (i) maintenance of the array, (ii) cost of replacement of inverters and batteries, (iii) insurance (estimated at 25%) (Hadavinia & Singh, 2019), and (iv) inspection and periodic adjustment of the system (or training to do this tasks). According to Sozer and Elnimeiri (2003), BAPV system costs consists of PV modules, Balance of system (BOS), labour cost, utility interconnection cost (for grid-connected system), building permit costs, and salvage value/costs. Studies within the Nigerian context adopt related classification which identifies the PV module as separate cost element and the Balance of System (BOS) components (batteries, inverters, structures, and controller (Udoakah, 2023). Udoakah (2023) argued that, all the components may not be necessary in every system (See figure 2).

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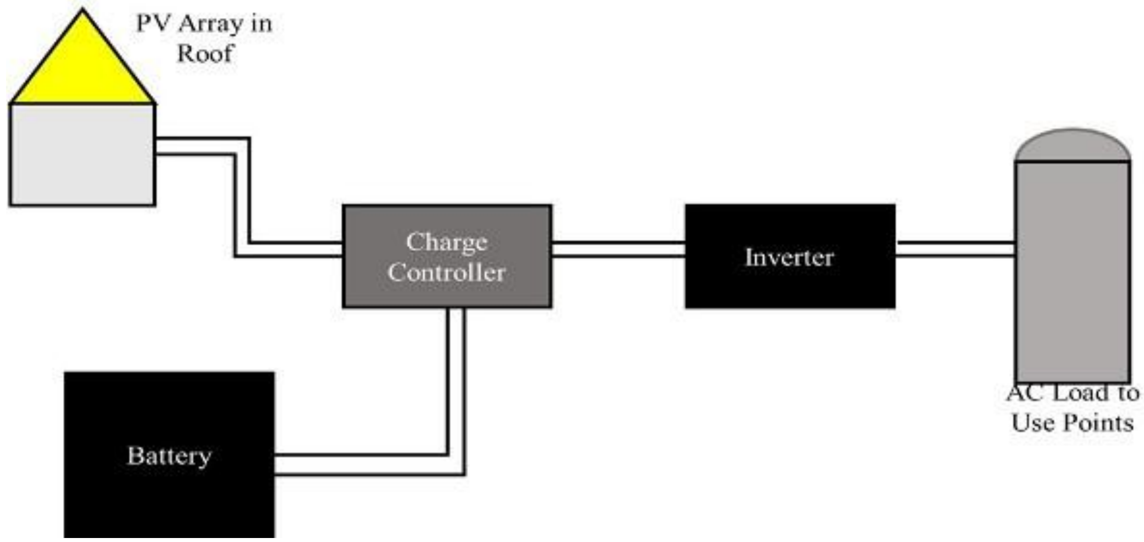

Figure 2: Block Flow Diagram of Solar Photovoltaic System Applied in Buildings
(Udoakah, 2023)

Theoretical Framework

One of the key concerns for researches seeking to promote sustainable building practices is to fast track the rate of adoption. In theory, the rational consumer's objective plays a crucial role in explaining the uneven uptake of photovoltaic systems. The objective of a logical consumer is to acquire things that may fulfil their needs in the most economical way possible (Schumpeter & Swedberg, 2021). Accordingly, the cost of BAPV in this work is examined from the standpoints of transaction cost economics (TCE).

Transaction Cost Economics

From theoretical viewpoint, a considerable number of salient theories have been developed in the general organizational management perspective for exploring several management practices within the firm including cost. Additionally serving as the theoretical basis for sustainable cost management, a few of these models have application in the field of building cost management. Research on construction cost management has seen a rise in the use of theoretical models such as transaction cost economics (TCE), resource-based perspective, agency theory, actor network theory, contingency theory, industrial network approach, and structuration theory (Abdul-Aziz & Zaini, 2022). However, transaction economics, contingency theory is widespread. The resource-based view strengthens firms' pursuit of competitive advantage by control over factors of production (Varadarajan, 2023). Contextually, no individual or organisations hold control monopoly on production factors involved in building construction; this theory will not support cost reduction. Industrial network approach (INA) and notably Social network theory (SNT) emphasis enhancement rather than reduction (Vahidzadeh et al., 2021). SNT is therefore not suitable for a study seeking cost reduction and optimisation.

Since the firm does not hold a monopoly of control over construction resources; rather these resources are jointly control across sectors covering project environment, the firm and suppliers and manufacturers. The interface between these exchanges can be illustrated by transaction cost economics (TCE) (Vahidzadeh et al., 2021). The transaction properties include uncertainty and asset specificity (Luo & Chen, 2023). The key and the starting issue for TCE are the transaction interface properties identification. The transaction interface properties in sustainable buildings are the critical cost drivers and the inhibitors to cost economy. The most effectual framework for cost reduction is therefore a product of matching the features of the cost drivers (transactions) with the most economic practice of governance (optimisation) (). The efficiency of the governance (cost optimisation) is measured by how well the production and transaction costs are minimized or improved.

Application of Theory

Williamson (2010) offered brief on why transaction cost exists. Two factors are however largely responsible that is, human factors and environmental factors. Human factors are explained by ‘bounded rationality and opportunism’. This translate to stakeholders’ interests which is one-directional and everyone tend to focus on self-gains. The bounded rationality aligns the skills and knowledge issues that enthrall high first cost premium in sustainable buildings. The environmental factors on the other hand are defined by uncertainty and the complexity of the construction property market (Yau et al., 2021). Environmental factors are therefore not products of stakeholders’ interaction but macro-economic and natural factors (Oke et al., 2024). Till date, Scholars positions about what actually constitute the extra cost is embellish in uncertainty.

From the foregoing, the implications are that cooperation between various interfaces in the sustainable building delivery chain can generate transaction costs reduction, promote economic efficiency by limiting ‘bounded rationality and uncertainty. This fundamental is co-opted in the development of the conceptual model for sustainable building cost optimisation in Nigeria. Literature position about the roles of integrated project delivery approach to cost reduction in sustainable building is seminal (Oke et al., 2024). Integrated delivery is introduced as synergy builder across differing project participant’s domains. The objective is to attain hybrid transaction governance utilizing market transactions and procedural transactions that will resolve the human and environmental towards efficient transaction costs (Oke et al., 2024). This is clearly evidence by elimination of transaction costs involve in appointment, evaluation and selection of consultants, suppliers and contractor using integrated project framework. The Transaction Cost Economic is therefore the adopted theoretical framework for cost optimisation used in this study. By its tenets, transaction cost (critical cost driver and cost economy inhibitors) governance is placed at the visible point.

Conceptual Framework

A conceptual framework is an integrated collection of ideas (theories) regarding how certain phenomena work and are related to each other. This was described by Akintoye (2015). The goal is to comprehend how different domains (concepts and variables) are affected by causation or correlation. The conceptual framework used in this study adopts idea mapping and builds upon earlier theory that was discovered during the investigation. According to Akintoye (2015), there are three fundamental approaches that may be used to construct a conceptual framework: previous theory (formed hypotheses); experience knowledge; and prior research (patterning to published works). The conceptual framework is predicated on earlier theory as both theoretical and conceptual frameworks emerge from the study comprehension and synthesis of conflicting theories. These variable groups include: (1) factors affecting cost of BAPV.

BAPV Cost Factors: This variable group is defined using 46 sub-factors grouped into three categories as follows: technical factors; economic factors; and cost drivers (see Table 1).

Table 1: Matrix of Factors Affecting the Cost Performance of BAPV

S/N	Technical Factors	1	2	3	4	5	6	7	8	9	10	11
TEC1	Solar potential of the site and accessibility	X										
TEC2	Availability of sufficient surface area for installation	X										
TEC3	Location and direction of space available for installation	X										
	Types of roof structure and roofing materials											
TEC4	Building form and aesthetics	X										
TEC5	PV cell type and its combination	X										
TEC6	Inclination angle of PV	X										
TEC7	Operating temperature	X										
TEC8	Confusing rules on permit		X									
TEC9	Lack of consumer understanding of technologies		X		X							
TEC10	Dearth of trained installers		X									
TEC11	Lack of accessible technologies and know-how			X	X							
TEC12	Poor planning			X								
TEC13	Operational inefficiency and component failure			X	X							
TEC14	Lack of research			X	X							
TEC15	Over dependency on importation			X								
TEC16	Building regulation				X							
TEC17	Government regulation				X							
TEC18	Lack of tangibly quantifiable benefits					X						
TEC19	Newness of Technology and Dependence on Technology Import											
TEC20	Scarcity of local competencies						x					

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TEC21	Solar PV technology rating (efficiency)		X					
TEC22	Design life of components and technologies		X					
TEC23	Construction period		X					
TEC24	Durability and adaptability of technologies		X					
TEC25	Availability and skill levels of installers							
TEC26	Poor and improper planning			X				
TEC27	Technological gap and operational challenges							
TEC28	Late integration of BAPV needs in project development				X			
TEC29	Lack of awareness					X		
TEC30	Lack of research and development					X		
TEC31	Overdependence on importation					X		
TEC32	Theft and vandalism							X
TEC33	Lack of affordability							X
	Economic Factors							
ECO1	High Life cycle cost (due to cost replacement & Maintenance)		X					
ECO2	Long payback time		X					
ECO3	Lack of government incentives		X					
ECO4	Lower comparative utility tariffs		X					
ECO5	High cost of maintenance & replacement		X					
ECO6	Availability of cheap fuel-based generator		X					
ECO7	Discount rate		X					
ECO8	Escalation and Inflation rate		X					
	Cost Drivers							
CDS1	Cost of acquisition (advertisement, marketing & project analysis)	X						
CDS2	Permitting, inspection and interconnection (delay & study time)	X						
CDS3	Financing (financing costs)	X						
CDS4	Installation Labour (Availability and skill levels of installers)	X						
CDS5	Hardware (PV modules, inverter, batteries & PV racks)	X						

1 = Yeung (2007); 2 = McGraw Hill Construction (2007); 3 = Elusakin, Olufemi and Chuks (2014); 4 = Akinboro, Adejumobi and Makinde (n.d); 5 – Kahnman (2011); 6 = Lawton (2014); 7 = Luong, Liu and Robey (n.d), Trovalla and Trovalla (2013) and IRENA, 2016; 8 = Elusakin, Olufemi and Chuks (2014); 9 = Ref PHD; 10 = Uyigue, (2009); and 11 = Aji, Gutti, Highina and Hussaini (2015).

Methodology

The present investigation used correlational field research methodology to examine the relationship between dependent and independent variables, namely the factors affecting the cost of BAPV. The main goal of the study is to find solutions to the research issues based on the geopolitical setting of the South East Nigeria. The states of Abia, Anambra, Ebonyi, Enugu, and Imo made up the zone. The latitudes 4°57.5358′ N and longitude 8°19.617′ E, as well as Latitude 6°20.289′ N and longitude 5°37.545′ E, comprise the South-East geopolitical zone (Udo, 2023). The area is partially classed as a Tropical Wet and Dry and Tropical Wet climate zone, with typical

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temperatures ranging from 23.1 to 31.3 degrees Celsius and 22.4 to 31.1 degrees Celsius, respectively, with relative humidity levels between 82.6% and 83.9% (Udo, 2023).

The design and construction of buildings are significantly influenced by the climate of the location. According to Akande et al. (2015), "meteorological conditions" have a major role in determining the use of energy-efficient solutions in building design. At the coastal area, the zone's yearly solar radiation is 3.5 kWm2/day (Figure 3); nevertheless, this energy dimension is only accessible for 26 percent of the day (Ekung et al., 2020).

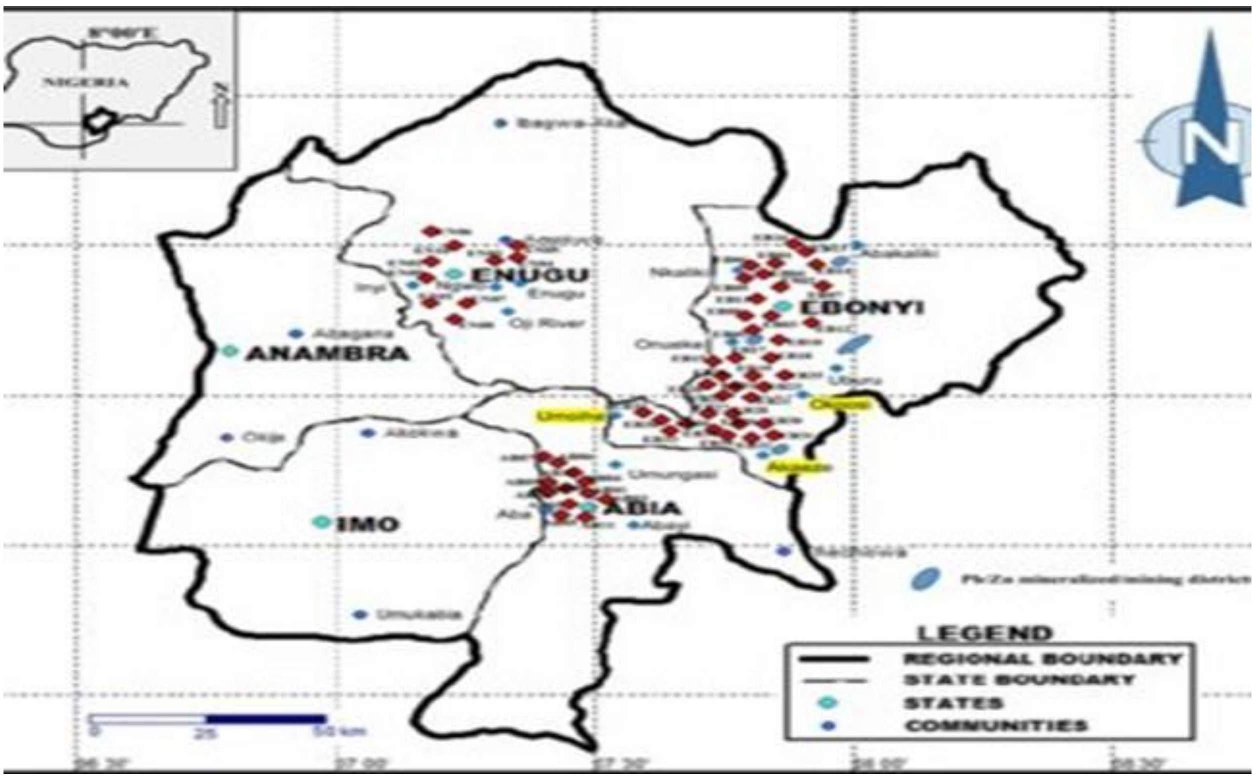

Figure 3: Map of South Eastern Nigeria

The population of this study comprises PV contractors, and selected registered construction professionals (Quantity Surveyors, Builders, Architects, and Services Engineers). Listed PV contractors have both knowledge of engineering performance of BAPV as well as their cost. The directory of practicing firms of the relevant professional bodies, V.connect.com, and preliminary investigations were the primary sources used to establish the demographic frame. The State Chapter Chairpersons or Secretaries of the relevant professional bodies were contacted via phone and in-person visits during the first inquiries. Online search through *V.connect.com* and professional websites of the selected professional bodies were also conducted. The combined strategies revealed 1200targeted respondents in the zone.

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Simple random and purposive sample approaches are applicable to this study in order to guarantee adequate equilibrium and evidence of comprehension and skill. Based on the heterogeneous data requirements of the investigation, both approaches are deemed appropriate. Random sampling is used to select subjects for the quantitative phase.
The sample size of each target was obtained using Kish (1965) equation adopted in Enshassi, Arain and Tayeh (2012):

$$n = \frac{n'}{1 + n'/N} \qquad \text{(Equation 3.1)}$$

Where n' is sample size from infinite population, obtained from the formula ($n' = S^2/V^{2)}$.

The variables are assigned the following definitions:

n = sample size from population

N = total population

V = standard error of sample population equal 0.05 for the confidence level 95 percent, t = 1.96

S^2 = standard error variance of population elements, $S^2 = P(1-P)$; maximum at P = 0.5

The sample of the study is 508 respondents.

The research instrument for this study is structured questionnaire. The study prioritised face-to-face administration and web-based administration to obtain a wider reach. The design of questionnaire adopts close ended questions. Part A has response from which research subjects are expected to choose from-closed questions. Part A has eight questions; five questions elicit background information of sample respondents such as educational and professional qualifications, location and years of experience. The next question which is in part B determined the factors affecting costs of BAPV.

In order to improve the platform for drawing conclusions about the study issues, statistical methods are applied to field data (Saunders et al., 2019). The scale and degree of measurement have a considerable impact on the data analysis approach that is used. Both parametric and non-parametric statistics are used in the data analysis for this investigation. SPSS version 23 was used in the development of the database management system using a coding system. For the factors, a known dimension reduction technique for figuring out the criticality, rankings, and benefits of components that need to be assessed is exploratory factor analysis (EFA) (Zhang et al., 2017). The tool classifies and perceives relationships among variables using ties.

Results

Questionnaire Administration

Five states in South-East Nigeria received a total of 508 surveys. A total of 376 legitimate replies, or 74% of the total, were found and deemed suitable for examination. This survey milestone is noteworthy, as it surpasses the standard of 30% recorded for built environment research (Hoxley, 2008). The result is presented in figure 4 and table 2.

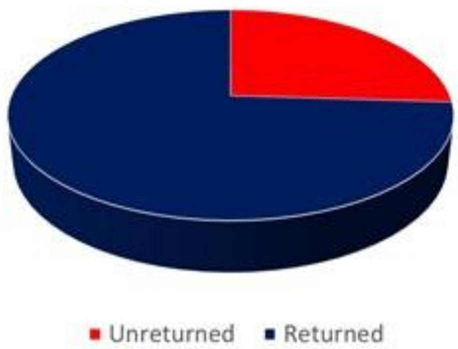

Figure 4: Chart showing status of questionnaire

Table 2: Questionnaire Distribution

S/N	Status	Freq.	Perc. (%)
1	Unreturned Questionnaire	132	25.98
2	Returned Questionnaire	376	74.02
	Total	508	100

Table 2 shows that a representative sample of 376 completed questionnaires was used to assess respondents' opinions in the current study.

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Table 3: General information of participants

	Variables	Freq.	(%)
Educational Qualification	First Degree/HND	302	80.3
	M.Sc& Above	74	19.7
	Total	**376**	**100.0**
Professional Qualification	Registered	265	70.5
	Not Registered	111	29.5
	Total	**376**	**100.0**
Level of Experience	1-5 years	288	76.5
	6-10 years	88	23.5
	Total	**376**	**100.0**
Job Role	Quantity Surveying	28	7.45
	Construction professional	22	5.85
	Vendor/Distributor	41	10.91
	Electrical Engr.	31	8.24
	PV contractors	44	11.71
	Design consultant.	26	6.91
	Building	34	9.04
	Project Manager	17	4.52
	Building contractor	48	12.76
	Others	85	22.61
	Total	**376**	**100.0**

Source: Field data (2024).

The study assessed the qualification of the respondents to provide valid views about cost performance of BAPV at four levels namely: educational qualification, professional qualification, level of experience, and job role (Table 3). The sample respondents include a diverse group of people with varied educational backgrounds; 80 percent have first degrees and above National Diplomas, while the remaining 10 percent have master's degrees or above. According to this statistics, having a degree is essential for sustained business in the market for renewable technology. The degree of technical and engineering study that goes into component sizing,

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installation, testing, commissioning, and post-construction monitoring might be an indication of this. It also shows that the data from this sample reflects a legitimate and knowledgeable audience, which means it may be used to draw legitimate conclusions. In addition, more than half of the research sample consists of qualified experts from a variety of fields, including electrical engineering, building, and quantity surveying. The implication is that, the solar PV market equitably represented by respective professionals in construction related field. It could also means that, the niche market created by renewable technologies application in building has gained the interests of both construction and non-construction entrepreneur. This however, calls for caution and regulation to checkmate quackery and proliferation of non-standard and unethical practice such as vending unregulated products and specification.

Construction professionals therefore need to utilise the haven of business opportunities created by sustainable development to benefit the built environment. The representation of requisite professionals in the building sector as significant 46% of market operators in the solar PV market are represented by non-construction professionals. Another relevant yardstick to measure the quality of data is the years of experience. The sample data revealed that, significant 76% of the sample is relatively new in the renewable energy technology market with years in business less than five years. The other 24% have spent at least six years; this is a significant low. The outcome is however, not a surprise, granted that, the mechanics of sustainable development is yet nascent and vastly not widespread. This therefore shows that, entrepreneurial development in the niche market of renewable and low and zero carbon technologies is far from being extensively developed.

To further ensure quality of data, respondents position in their respective market segments were evaluated. The data reveals that 77% of the sample occupies strategic positions in their firms. This strategic position equips respondents to provide, participate and acquaint with relevant market variables in this sector. Quantity surveyors constitute 7.5%, construction professional (5.85%), vendor/distributor (10.91%), electrical engineers (8.24%), PV contractors (11.71%), design consultant (6.91%), building (9.04%), project manager (4.52%), and building contractor (12.76%).

Factors Affecting the Cost of Building Applied Photovoltaic (BAPV) System

The study evaluated the perception of respondent about the severity of the factors generated individually and collectively across literatures using qualitative ranking. Due to the large number of the related variables; the study applied dimension reduction tool to extract principal factors contributing to high cost of BAPV in the Nigerian construction industry. The result was evaluated under three parts namely: communality test, explained variation for principal components, and rotated principal component matrix as seen in the following sections.

Dimension Reduction: Finding fewer underlying hidden variables that may explain the bulk of observed variables is one of the important aspects of factor analysis (Lee & Seung, 2017). Using the Kaiser-Meyer-Olkin (KMO) test of sample adequacy and the Bartlett tests of sphericity,

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variable correlation was used to assess if the data were suitable for EFA analysis (Marnewick, 2017). The closer the variables are to one another, the higher the test values are from the given benchmarks. The value of KMO > was accepted by the research. 0.9—Superb, KMO > 0.8—Very good, KMO higher 0.7—KMO > Acceptable KMO < 0.5 is unacceptable, while 0.6 is questionable (Cao, Li, Wang, & Huang, 2017). The result showed KMO value of 0.745 with significance (Sig.) of 0.000, indicating the data were appropriate for EFA. To embed rationality also, the study adopted communalities benchmark of 0.4 and above (Lee & Seung, 2017) (Table 4).
EFA was conducted to extract the hidden factors underpinning a large number of variables (Shan et al., 2017); and principal component analysis (PCA) is applied in this study. Communalities of the cost performance influences attained 65% except 11 factors namely: TEC1; 2; 3; 5; 6; 11; 13; 14; 18; 20; and ECO7. The implication is that nearly 65% of each index is explained by the latent factors retained except factors listed above with communalities values between 45.68% - 62.33%.

Table 4: Communalities of Factors Affecting PV Costs

Code	Technical Factors	Initial	Ext	Code	Technical Factors	Initial	Ext
TEC1	Availability of sufficient surface area for installation	1.00	0.46	TEC18	Construction period	1.00	0.60
TEC2	Types of roof structure and roofing materials	1.00	0.62	TEC19	Late integration of BAPV needs in project development	1.00	0.78
TEC3	Building form and aesthetics	1.00	0.50	TEC20	Lack of awareness	1.00	0.64
TEC4	PV cell type and its combination	1.00	0.67	TEC21	Theft and vandalism	1.00	0.81
TEC5	Confusing rules on permit	1.00	0.61	TEC22	Lack of affordability	1.00	0.67
TEC6	Lack of consumer understanding of technologies	1.00	0.63	ECO1	Overall high Life cycle cost	1.00	0.72
TEC7	Dearth of trained installers	1.00	0.76	ECO2	Long payback time	1.00	0.70
TEC8	Lack of accessible technologies and know-how	1.00	0.79	ECO3	Lack of government incentives	1.00	0.82
TEC9	Poor planning	1.00	0.67	ECO4	Lower comparative utility tariffs	1.00	0.72
TEC10	Component failures	1.00	0.70	ECO5	High cost of maintenance & replacement of components	1.00	0.72

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TEC11	Lack of research	1.00	0.62 6	ECO6	Availability of cheap fuel-based generator	1.00	0.84
TEC12	Over dependency on importation	1.00	0.73	ECO7	Discount rate	1.00	0.74
TEC13	Building regulation	1.00	0.60	ECO8	Escalation and Inflation rate	1.00	0.88
TEC14	Lack of tangibly quantifiable benefits	1.00	0.64	CDS1	Cost of acquisition (advertisement, marketing & project analysis)	1.00	0.67
TEC16	Solar PV technology rating (efficiency)	1.00	0.82	CDS3	Financing (financing costs)	1.00	0.66
TEC17	Design life of components and technologies	1.00	0.76	CDS4	Installation Labour (Availability and skill levels of installers)	1.00	0.79

The Eigenvalues, percentage of variance and total variance of variables with significant communalities is presented in Table 5. Eigenvalues depict standard variable contribution to the principal components (Marnewick, 2017); and eigenvalues greater than one was adapted to determined important variable. This suggests that, variable with eigenvalues less than one are discarded, and the total variance should add up to 40% (Shan et al., 2017). The study also takes into account, the slope of the Scree Plot. Seven latent factors were extracted from the data and cumulative variance attained 76.54% when seven factors are retained. This means that, seven factors retained can explain 76.54% important information about the 28 variables not accounted for by the cut-off using scree plot. After rotation, the cumulative variance still attained variance of 76.54%, and component emerged most significant with explained variance of 17.450%.

Table 5: Total Variance Explained for Principal Components Extracted

	Initial Eigenvalues			Extraction Sums of Squared Loading			Rotation Sums of Squared Loadings		
Comp	**Total**	**% of Variance**	**Cum**	**Total**	**% of Variance**	**Cum**	**Total**	**% of Variance**	**Cum**
1	7.605	31.230	31.230	7.605	31.230	31.230	7.605	31.230	31.230
2	3.520	15.211	46.441	3.520	15.211	46.441	3.520	15.211	46.441
3	2.040	8.660	55.101	2.040	8.660	55.101	2.040	8.660	55.101
4	1.911	8.540	63.641	1.911	8.540	63.641	1.911	8.540	63.641
5	1.642	7.020	70.661	1.642	7.020	70.661	1.642	7.020	70.661
6	1.312	2.345	73.006	1.312	2.345	73.006	1.312	2.345	73.006
7	1.065	5.045	3.534	1.065	5.045	3.534	1.065	5.045	3.534

Extraction Method: Principal Component Analysis; Comp. = Components; Cum = Cummulative

Hypothesis Test

HO_1: The factors affecting the cost of photovoltaic systems applied to buildings in South-East are not significantly different.

This section seeks to determine hypothesis one of the study. The hypothesis one states that identified factors affecting the cost of PV technology applied to buildings in South-East are not significant. The objective was to determine whether qualitative ranking perceptions of respondents are statistically significant. The statistics involved communalities criteria in factor analysis using cut-off point 65% explained variance and above (Lee & Seung, 2017). This means that, the significant must explain about 65% of each index of the latent factors retained in the analysis. The result is seen in Table 6. The result revealed that 30% of the factors are insignificant determinants of the cost PV system applied to buildings in South-East; while 70% other factors are significant determinants of PV cost. The conclusion is that identified factors based on 70:30 validity ratio are significant determinant of PV cost in South-East.

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Table 6: Tests of Hypothesis One

Code	Technical Factors	Communality	Decision	Hyp. Validity
TEC1	Availability of sufficient surface area for installation	0.46	Not Sig.	Accept Ho
TEC2	Types of roof structure and roofing materials	0.62	Not Sig.	Accept Ho
TEC3	Building form and aesthetics	0.50	Not Sig.	Accept Ho
TEC4	PV cell type and its combination	0.67	Sig.	Reject Ho
TEC5	Confusing rules on permit	0.61	Not Sig.	Accept Ho
TEC6	Lack of consumer understanding of technologies	0.63	Not Sig.	Accept Ho
TEC7	Dearth of trained installers	0.76	Sig.	Reject Ho
TEC8	Lack of accessible technologies and know-how	0.79	Sig.	Reject Ho
TEC9	Poor planning	0.67	Sig.	Reject Ho
TEC10	Component failures	0.70	Sig.	Reject Ho
TEC11	Lack of research	0.62	Not Sig.	Accept Ho
TEC12	Over dependency on importation	0.73	Sig.	Reject Ho
TEC13	Building regulation	0.60	Not Sig.	Accept Ho
TEC14	Lack of tangibly quantifiable benefits	0.64	Not Sig.	Accept Ho
TEC16	Solar PV technology rating (efficiency)	0.82	Sig.	Reject Ho
TEC17	Design life of components and technologies	0.76	Sig.	Reject Ho
TEC18	Construction period	0.60	Not Sig.	Accept Ho
TEC19	Late integration of BAPV needs in project development	0.78	Sig.	Reject Ho
TEC20	Lack of awareness	0.64	Not Sig.	Accept Ho
TEC21	Theft and vandalism	0.81	Sig.	Reject Ho
TEC22	Lack of affordability	0.67	Sig.	Reject Ho
ECO1	Overall high Life cycle cost	0.72	Sig.	Reject Ho
ECO2	Long payback time	0.70	Sig.	Reject Ho
ECO3	Lack of government incentives	0.82	Sig.	Reject Ho

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ECO4	Lower comparative utility tariffs	0.72	Sig.	Reject Ho
ECO5	High cost of maintenance & replacement of components	0.72	Sig.	Reject Ho
ECO6	Availability of cheap fuel-based generator	0.84	Sig.	Reject Ho
ECO7	Discount rate	0.74	Sig.	Reject Ho
ECO8	Escalation and Inflation rate	0.88	Sig.	Reject Ho
CDS1	Cost of acquisition (advertisement, marketing & project analysis)	0.67	Sig.	Reject Ho
CDS3	Financing (financing costs)	0.66	Sig.	Reject Ho
CDS4	Installation Labour (Availability and skill levels of installers)	0.79	Sig.	Reject Ho

Comm = Communality Indices; Sig. = Significant; Not Sig. = Not Significant, Ho = Identified factors affecting the cost of PV applied in buildings in South-East are not significant

The primary cost performance inhibitors were identified by suppressing loading below 0.40 by the application of factor rotation. Because it is thought that the components are connected, oblique rotation was utilised in the investigation. Consequently, seven factors are inserted into the component matrix (Table 7). After looking through the loading of the different elements, the most important loading in factor one, which is related to the lack of skilled installers and the paucity of local competences, has a score of 0.738. As a result, the first component chosen by the study was the frame "dearth local competencies." The frame "lack of accessible technologies and know-how" is chosen for factor 2 and corresponds to low level of technologies, with the most significant loading under factor 2 having a value of 0.764. The third factor's most important inhibitive factor (0.820) has to do with the components' limited lifespan. For this reason, the frame "Design life of components and technologies" was chosen. The full life cycle cost (0.893) is the subject of the fourth component. The fourth concern is the frame's high cost of component replacement and maintenance. Since the fifth component (0.872) addresses economic threats, the phrase "inflation and cost escalation" is appropriate. The sixth aspect, "customer acquisition," is framed by the cost of marketing, promotions, and project management (0.754). Hardware is the subject of the seventh factor (0.921); the frame hardware is chosen.

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Table 7: Rotated Principal Component Matrix

S/N	Cost Performance Inhibitors	Component 1	2	3	4	5	6	7
1	Dearth of local competencies	0.738						
2	Lack of accessible technologies & know-how		0.764					
3	Design life of components and technologies			0.820				
4	High cost of maintenance and replacement of components				0.893			
5	Inflation and cost escalation					0.872		
6	Customer acquisition						0.754	
7	Hardware (PV modules, inverter, batteries, and PV racks							0.921

Discussion

Factors Affecting the Cost of PV System

Technical and Economic Factors: Issues related to technological know-how, lack of awareness and understanding of solar technologies lead other technical factors influencing cost performance of building applied solar PV systems. Lack of accessible technology, awareness, and skill dearth concerns are also linked to lack of adequate solar initiative related research. Ahmed and Gidado (2018) and Ogbodo-Nathaniel et al. (2024) documented that lack of understanding affects the performance of solar PV system. Similarly, Ekung et al. (2024) attributed the laggard adoption of solar architecture in Nigeria to ignorance and lack of awareness and understanding. The impact of low awareness, lack of understanding and research on cost performance of BAPV is the incidental misconception about the accurate cost of solar PV incorporation in design. The second perspective is visible in the absent of locally manufactured or developed solar components. This means that technological, environmental, social and economic dimensions are interrelated with cost performance (Izam et al., 2022). Improving cost performance therefore requires the development of the tripartite dimensions simultaneously. The survey of solar PV installation in the study revealed that, two out of three technical factors on the principal component lists are slightly lower than economic and cost drivers' related factors.

The component indices for technical factors 'dearth of local competencies' and lack of accessible technology' and know-how (0.738; 0.764) are slightly lower than the third factor 'design life of components' (0.820). The implication suggests that, improving existing technologies underlying BAPV components can improve the life cycle cost of components. This means that, when component such as batteries with an average life span of three years is designed to last longer, the

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replacement cost would reduce significantly. The country of component's origin determines its cost and its durability. The sector also lack trained and skilled workmen, over 98% of existing skills such as installers are conventional entrepreneurs who learn the art from the informal sector.

Skill dearth in the construction is not new and associated contribution to the overall cost of BAPV is significant. Installation costs contribute on average, \$0.59/W to the overall cost in the US (Xu, 2024). Related studies in Nigeria are not precise about the cost of installation because stakeholders adopt lump sum addition for installation. The associated cost also varies from region to region. According to Xu (2024), installing a PV system in the US requires more manpower than a comparable quantity in Germany. The main factors influencing differences in installation costs are variations in roof materials and design as well as non-standardization of PV modules (Xu, 2024). Other roof-related tasks, such installing shaded roofs or modifying the current roof to support a greater weight, are other pertinent causes of unforeseen expenses. Technical factors not only increase costs but also create delivery time delays.

Strong governmental incentives are therefore required to reduce the cost of solar PV components through waivers on tariff, payment for installation costs, research and sponsoring of initiatives that will foster locally accessible technologies. Technical challenges are significant barriers to renewable energy sustainability in Nigeria (Onuh et al., 2024). Current practice in PV market follows a bespoke application whereby similar methodologies are adopted in the design and analysis for every project. This practice is counterproductive and possible triggers of inefficiency in the future; and rare repetition of building designs offer no assistance to mitigate these effects. Tahir et al. (2024) estimated cost of design and energy requirement analysis and project management cost as 10% of the overall project cost. The validated technical and economic influences on cost performance of BAPV are dearth of local competencies (lack of understanding of energy requirement, lack of skilled labour, and lack of research to adapt technologies to local conditions. Others include lack of accessible technologies, design life of components, high cost of maintenance and replacement of components and inflation.

Customer Acquisition: The majority of soft expenses associated with the supply of a solar system are related to customer acquisition (Xu, 2024). The following aspects are driving additional components under this component: project viability analysis; marketing and promotion costs; and design and analysis of energy systems. Marketing and promotion would involve many expenses including creditworthiness, site visits, energy engineering, analysis, and design, as well as utility (phone call) costs. The cost of energy analysis could be significant when it is conducted when actual demand is not ready. These costs are borne by the installers (suppliers/contractor) even before a contract is signed. These costs amount to the pre-contract transaction costs borne by the contractor, and pass on to other project when the bids are unsuccessful, or passed to the client when it is successful. Customer acquisition costs contribute \$0.67/W to \$1.00W, according to a survey of US practices. Xu (2014) discovered that \$0.33/W, \$0.11/W, and \$0.23/W of this expected budget go towards marketing and advertising, system design, and other customer acquisition expenses. According to Tahir et al. (2024) estimate, the logistics of shipment and installation might account for 10% of the PV system's installed cost.

Hardware: This cost element is significant and easily accounted for in much respite than other factors influencing cost performance. PV modules, batteries, charge controllers, inverters, and racks for PV panels are all included in the hardware. The more advanced of these components raises the total cost, although the less sophisticated ones also have a lower cost potential. For example, the rack system may consist of fixed-tilt or flexible tracking devices. According to Xu (2024), a less than 10KW installation might cost $1.2/W, or around 20% of the overall installed. PV array structural costs are estimated by Khan et al. (2024) to be 12% of overall module costs. An inverter may increase a PV project's output by up to $0.30/W, or around 5% (Saurabh et al., 2025). About 40% of the cost of a PV module goes towards the inverter, and 10% goes towards the power charge controller (Väisänen et al., 2010). The cost of battery is 33% of the PV module costs. Annual maintenance cost of 2% is prevalent among emerging literatures in Nigeria e.g. Ekung et al. (2022). Hardware is the most significant cost performance driver in BAPV systems in Nigeria.

CONCLUSION

Building structures consume significant proportion of global energy resources. In the past decades, the main source of energy in building remained dominantly fossil-based electricity transmitted over distance to the point of use. The environmental impact of the conventional energy is alarmingly high including carbon (CO) emissions and related climate change impacts. In order to mitigate environmental impact therefore, the use of renewable energy technologies is increasingly advocated. The use of these technologies in the building sector in South-East, Nigeria is however very low due to perceive high cost. The aim of the study was to examine the factors affecting the cost of BAPV. The result of the study based on component rotation outlined seven principal factors inhibiting the cost performance of building applied photovoltaic system. The factors include dearth local competencies; lack of accessible technologies and know-how, design life of components, and whole life cycle cost concerns. Others include high cost of maintenance and replacement of components, inflation and cost escalation, customer acquisition, and hardware. These factors constitute the relevant cost drivers in building applied photo-voltaic systems. The implication is that applying optimisation strategies in these areas could significantly in improve current cost of building applied photovoltaic system in South-East, Nigeria.

Recommendations

Based on the summary of findings and conclusion above, the following are the recommendations:

1. Strong government policy and intervention is needed to drive other key actions from other stakeholders to stimulate PV market in the region with a view to reduce overall cost and widespread adoption. Strong government incentives is also required to mitigate

customer acquisition cost; permitting, inspection and interconnection costs, financing cost, and provision of incentives to importers, manufacturers and users.

2. Collaborative PV supply chain must be promoted to enhance shared experiences across regional level between project developers, PV contractors, policy makers and regulators. This will enhance critical examination of BAPV cost structure; and how the cost structure is influenced by in-country's circumstances.

3. Education, training and research must be strengthened to reduce cost and improve awareness. Appropriate information services, awareness and capacity building programmes can be beneficial in a number of ways. It will improve the level of understanding and awareness, raise awareness to understand the technology, its benefits and ecological significance, purpose and functions. To achieve this deep awareness advantage, deep and extensive education campaign and capacity building programmes is needed.

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