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Cost factors in Zero-Carbon Technologies Applied in Buildings: Nigeria's Perspective

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Abstract
The integration of renewable energy technologies in buildings across Africa is low. Enormous improvements to intrinsic cost drivers affecting their affordability are therefore prerequisite to achieve diffused adoption. In a search for the relevant strategies to improve the adoption of these technologies, this paper appraised critical cost factors inhibiting the affordability of solar photovoltaic (PV) in Nigeria. The research adopted a structured questionnaire survey administered to 480 stakeholders in the building sub-sector and PV value chain. Data reduction tool (factor analysis) determined the components of principal factors critical to the affordability of PV in the research environment. The result showed that the dearth of local competencies, lack of skilled labour, lack of research, lack of locally accessible technologies, high cost of maintenance, foreign exchange fluctuation, and inflation are important drivers of PV costs that must improve to facilitate PV integration in buildings. The strategies to improving PV adoption must stimulate affordability by mitigating technical and economic cost factors. The study recommends strong government incentives using waivers on tariff, education and awareness, training in requisite skills, and local manufacturing of components as prerequisite drivers needed to improve affordability.

Keywords: affordability, building, barriers, cost, emerging market and photovoltaic

1. Introduction

The energy utilised by buildings is significant and account for over 40 percent of the global energy stock [1], [2]. The main source of energy in buildings in many developing countries is fossil-based electricity. Fossil-based energy has tremendous effects on environment and sustainable development through carbon emission, climate change and greenhouse gas emissions. The use of fossil fuel for energy in Nigeria has escalated CO_2 emission from 0.0K in 1960 to 82.634.2Kt in 2016 [3]. Despite these implications, the use of renewable energy is negligible, estimated as 0.7 percent of total energy consumed among league of developing markets [4], and 1.83 percent of Nigeria's 3500 MW most consistent electricity output in recent times [3]. The imperfect state of the energy market and available solutions, low efficiency of power supply and increased tariff amidst poor services have not contributed to increased integration of renewable energy technologies in buildings. Power supply to households is also low, 60 to 75 percent of the populace have no access to electricity [5], while the availability of supply averages 4-6 hours daily [6; 7]. The number of blackout per day is also alarming, while the contribution to CO2 emission is over 0.7 tons per capita [8]. These consequences contribute to the expanding push to adopt renewable energy technologies in buildings.

Nigeria's expanding interest in low-carbon energy adoption notably, solar photovoltaic (PV) technologies, is however, not widespread [9; 10]. The institutional reforms across developing countries through research and development favour solar PV to achieve expansive market spread [11; 12]. In 2014, the global PV market

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engulfed $476.3Billion, and projection looks to $777.6 Billion by the end of 2019, based on Compound Annual Growth Rate (CAGR) of 10.3 percent [13]. This expanding growth momentum suggests that PV technologies are strategic solution to Africa's energy problems [13]. Inherent in the PV market growth path in developing countries, are costs related barriers that are strategic to their degree of adoption ([14]. Chen and Riffat [15] called for further research into cost reduction strategies to optimise PV adoption. This study seeks to develop in-country data for the assessment of PV performance in the building sector. The study aimed to explore critical cost drivers affecting the affordability of PV technologies in buildings (PTAB). The research is premise on the significant of spread of PV in developed markets [16], while emerging markets is insignificant, estimated as 1.83 percent in Nigeria [3; 4]. The slowpoke in the uptake of PV in Nigeria is due to a number of inhibitors [12; 17]. Several studies have examined these barriers generally [12; 17] using institutional literature, focusing on generic energy sector viewpoints. Few literature narratives however exist that account for the critical costs drivers inhibiting PV adoption in the building sectors of the emerging markets. The study is important to developing in-country data for assessing PV performance and developing strategies to mitigate their costs across market segments.

2. Literature review

2.1 Solar energy potential and application in Nigeria

Nigeria is located on latitude 4-14^{0}North of the equator with lots of solar potential [18]. Nigeria's annual daily sunshine average is 6.25 hours, with 3.5hours at the coastal areas and 9.0 hours at the far northern hemisphere [1]. The annual solar radiation is 5.25KW/m2/day; 3.5 kWm2/day at the coastal area, 7.0kW/m2/day at the northern boundary and the total energy per day from the sun is 4.851 x 10^{12} KWh. When compared with energy from oil, it is equivalent to 1.082 million tons of oil (mtoe) [19]. This scale of energy is available only during 26 percent of the day. With the land area of 924 x 10^3 km^2, the average of 5.535 kWh/m^2 is significant, while the annual incident solar energy is 1.804 x 10^{15} kWh. Manzuma and Mbamali [20] posited that solar PV is widely received by stakeholders in the Nigerian building sector. Government policies in Nigeria have further identified that alternative source of energy supply lies in renewable solar sources [21]. Abundant opportunities therefore abound for the development and deployment of solar PV technologies in Nigeria.

2.2 Factors influencing the cost of PV technologies in buildings

The literature on the application of PV technologies embeds several grouping of barriers affecting costs such as human resource, information, technical, economic, and policy [21a]. The economic, technological and finance-related factors grouping also restraint the spread of bioenergy in Russia [21b]. Barriers such as limitation in expertise, the lack of promotion, subsidies, finance and incentives, and unreliable technologies inhibited PV adoption in the Malaysian housing sector [21c]. Cost-related factors influencing the performance of PV as *inter alia* mentioned, has attracted considerate attention across literature. However, the dimensions of performance discussed also vary across studies. Luong *et al.* [22] assessed the economic performance of Zero-Carbon Energy Technologies Applied in Building (ZETAB) using metrics related to capital cost, payback time, government incentives, comparative utility bills payment, annual return on investment, and maintenance costs. The technical performance of ZETAB are also available including issues related to the rating of the technology, design life, construction period, durability and adaptability [23]. Other technical influences on the cost performance of ZETAB include availability of sufficient surface area for installation, building form and aesthetics [24]. IRENA [13] discussed cost determinants in PV systems dealing with discount rate, escalation rate and inflation rate. Adverse weather and other environmental factors trigger performance decline in PV technologies [25]. Elusakin *et al*. [26] stated that poor planning, technological gap and operational challenges in off-grid power projects are critical problems in Nigeria. Uyigue [6] added the lack of awareness, lack of trained professionals, skills dearth, and lack of research and over dependency on importation. Gyoh [27] likewise outlined factors related to the lack of awareness and high cost of components. Kahneman [28] criticised absent of provable financial benefits in the application of solar PV system, but recent studies shows absent of financial incentive does not essentially deter PV market spread [29]. Technical and security challenges emerged most significant hindrances inhibiting energy sector sustainability in Nigeria [30]. Olaoye *et al.* [31] pitched the slow popularity of the renewable energy in developing countries on the saturation of cheap fuel-based generators in the market, while Ochedi *et al.* [19] blamed energy poverty and high costs of energy on the high cost of technologies

Another perspective to understand critical cost drivers of ZETAB is to examine the underlying constituent cost items. The cost of a system comprised of soft and hard costs components. Soft cost however, is the most important cost attributes of the total installed costs of sustainable features in buildings [16] and increases with decrease in installed capacity. Smaller installed capacity attracts high soft costs, while larger installed capacity attracts lower installed cost [13]. McGraw Hill Construction [32] identified cost drivers related to confusing rules on permits, lack of consumer understanding of technologies, dearth of finance, and shortage of trained installers. Other soft costs drivers of ZETAB include cost of acquisition, permitting, inspection and interconnection, financing, cost of installations and hardware components. Efurumibe [33] identified factors related to lack of manpower/technical expertise, high upfront capital cost of materials, and inconsistent government policy. Bryne [34] identified hardware cost drivers such as array (modules and supporting structures) and balance of system (BOS - inverters, batteries and other electrical equipment). Similarly, Sozer and Elnimeiri [35] noted the cost drivers such as PV modules; balance of system, installations, utility interconnection cost (for grid-connected system) and building permit issues overarches. The PV cost drivers therefore cut across several literature [36; 37; 38].

Inferences from the above literature led to the development of the conceptual framework of factors influencing the cost performance of PTAB in the Nigeria building sector (Figure 1). Figure 1 depicts three perceived critical dimensions to the influences on cost performance of PTAB namely: technical, economic, and system factors. The three dimensions are however, interrelated and in addition, suggesting their influences intervolve. The variables in Figure 1 formed the crux of field survey with narration in the following sections.

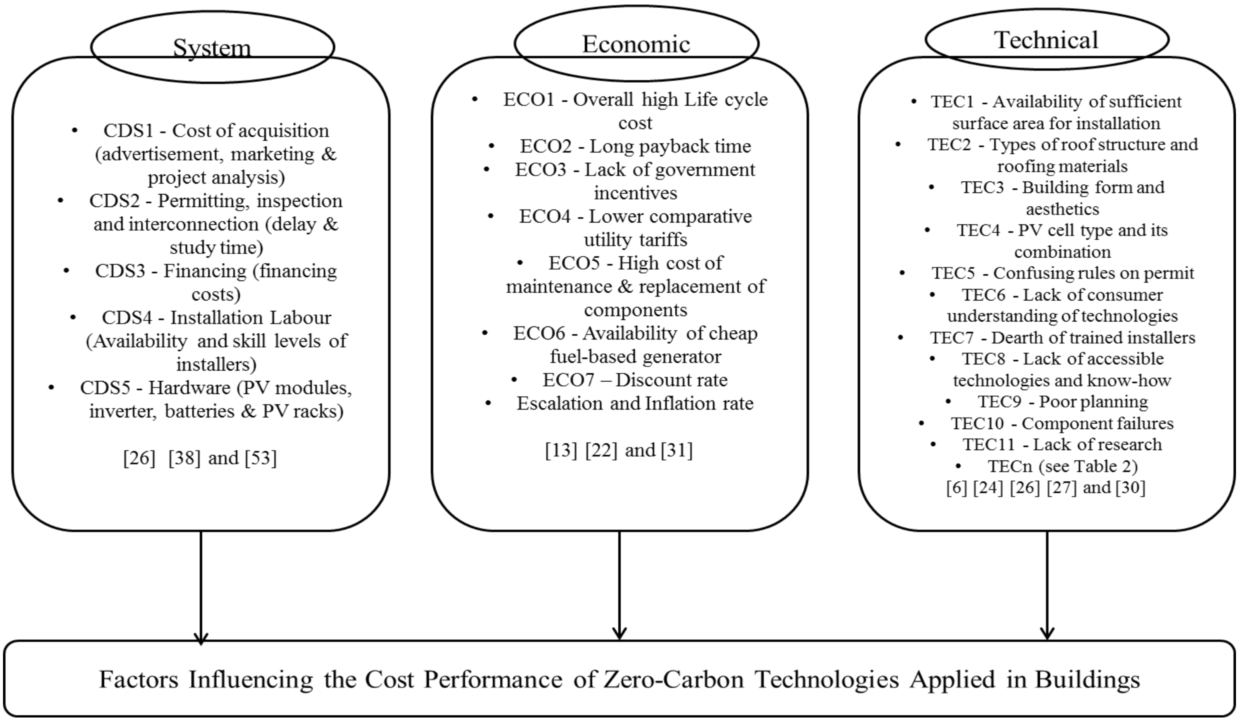

Fig. 1. Factors influencing the cost performance of ZETAB

3. Research Methodology

The study engaged PV contractors, building professionals, PV distributors and electrical engineers in the Nigerian construction industry in a descriptive survey using structured self-study questionnaire. The sample frame consists of building services engineers, other construction professionals and listed PV contractors. The sample size of 480 respondents was obtained from the population of 1010 respondents using Leslie Kish formula. The study was conducted in six Geo-Political Zones of Nigeria: Abuja, Lagos, Port Harcourt, Dutse, Gombe, Calabar, Uyo, and Owerri using contacts of respondents generated from the database of each group. The research instrument (questionnaire) consists of two parts, the first part contained questions relating to the respondents background information, while the second part asked questions about the influences of identified factors on the affordability of PTAB. The first section of the questionnaire consists of multiple-choice questions, while the second part was constructed using a 5-point Likert scale. The highest point of the scale, 5- indicated very high impact, while the least point 1- indicated very low impact. The respondents, therefore, ranked the degree of impact of identified factors on the affordability of PTAB in their domain. The administration of the research instrument involved face-to-face strategy and email. The administration and retrieval procedures yielded a response rate of 60.34 percent.

The study also evaluated the dimensions of reliability and validity of the research instrument and measurement constructs because; previous studies adopted literature synthesis. Cronbach alpha test of the cost drivers, yielded strong reliability (scores between 0.78 and 0.92). The dimension of validity was determined using the extent in which the results obtained represent valid conclusion of the research objective. Analysis of data employed factor analysis. Exploratory and principal component factors analyses streamlined the number of most critical cost drivers influencing the affordability of PTAB. Exploratory factor analysis (EFA) is a vastly applied dimension reduction tool used to determine the criticality of factors evaluated by a study [39]. The tool classified the relationships among variables using ties and compressed a large number of variables into a few common hidden factors [40]. Test statistics in EFA used in the study include communality, variance, and the degree of factor loading [39].

4. Results

4.1 Descriptive statistics of respondents

The study assessed the qualifications of the respondents to provide valid opinion about factors influencing the cost performance of PTAB at two levels, educational and professional accreditation. The result in Table 1 shows that the sample comprised individuals with varying level of education. Eighty (80) percent are holders of Higher National Diplomas and First degrees, while others have various postgraduate degrees. This data reveals that educational qualification is important to participation in renewable technologies value chain. Relevant education is necessary to undertake high-level technical and engineering analysis involved in component sizing, installation, testing, commissioning and performance monitoring. The data emerging from the sample also represents valid and informed views of the relevant stakeholders in the Nigerian PV market value chain. Over half of the study samples are also certified professionals in various fields represented by quantity surveying, building, electrical engineering and others.

Another relevant yardstick to measure the quality of the study data is the years of experience of respondents. Eighty (85) percent of the respondents are relatively new in the PV market with less than five years in the business. This population comprised of young graduates exploring entrepreneurial opportunities in the PV market. Another 15 percent have years of experience averaging seven and half. The outcome is however, not a surprise, granted that the mechanics of sustainable development is still very nascent and not significantly embedded in regional policies in the research environment. However, given an average of six and half years of experience, it is inferred that actors in the sample have practical experiences to contribute significantly to the evaluation of influences on affordability of PTAB.

Table 1. Respondents background information

Educational qualifications			**Professional qualifications**			**Years in related business**		
Variables	**N**	**%**	**Variables**	**N**	**%**	**Variables**	**N**	**%**
First Degree/HND	180	80	Registered	120	54	0-5 years	190	85
MSc & Above	44	20	Not Registered	104	46	5-10 years	34	15
Total	**224**	**100**	**Total**	**224**	**100**	**Total**	**224**	**100**
Profession related PTAB			**Position in the organisation**			**Nature of PV engagement**		
Variables	**N**	**%**	**Variables**	**N**	**%**	**Variables**	**N**	**%**
Q. Surveying	5	2	Director	105	47	Vendor/Distributor	40	18
Services Engr.	85	38	Manager	20	9	Design consultant	85	38
Building	10	5	Other employee	14	6	Project Manager	29	10
Others	124	55	Design Consultants	85	38	Building Contractor	70	31
Total	224	100	Total	224	100	Total	224	100

4.2 Dimension reduction

One of the significant components of factor analysis is to obtain reduced number of underlying hidden variables that can explain majority of observed variables [41]. Variable correlation conducted to determine suitability of the data for EFA analysis [42], [43], involved Kaiser-Meyer-Olkin (KMO) test of sampling adequacy, and Bartlett tests of sphericity. The theoretic of these tests states that the larger the value of the result than the stated benchmarks, the closer the variables is to one another. The study adopted the benchmarks, KMO > 0.9 - Excellent, KMO > 0.8 -Good, KMO > 0.7 - Acceptable, KMO > 0.6 - Questionable and KMO < 0.5 - Unacceptable [44]. The result shows KMO value of 0.745 with a significance level (Sig.) of 0.000; and the implication is that the data was appropriate for EFA.

Communalities of the critical cost drivers influencing the affordability of PTAB attained the 65percent benchmark [42], except 10 factors namely: TEC1, 2, 3, 5, 6, 11, 13, 14 and 18 (Table 2). This implies that 65percent of the drivers of PV cost is explained by the latent factors retained except the 10 variable factors listed above, which communalities values is less than 65percent (that is, 45.70 - 63.40 percent (see also Table 2). Seventy four (74) percent, that is, 28 factors are critical drivers of PV cost. The six most important factors are hardware (98 percent), lack of awareness (93.5 percent), cost escalation and inflation (88 percent), availability of cheap fuel-based generators (83.6 percent), lack of government incentives (82 percent) and PV efficiency (82 percent). The review of these results in line with the conceptual framework (Fig.1) shows economic and system related cost drivers emerged the overall most important factors. All the factors in both variable groups, system and economic obtained communality score > 65 percent and could explain 77 percent of PV cost on the average.

Table 3 presents the Eigenvalues; percentage of variance and total variance of the variables with significant communalities score. The Eigenvalues depict the contribution of each variable to the principal components [43]; and eigenvalues greater than one was adapted to determined important variables. The analysis therefore discarded variables with eigenvalues less than one, and the total variance of the important variables add-up to 40 percent [42]. Seven latent factors extracted from the data obtained cumulative explained variance of 78.051 percent (Table 3).

Table 2.Communalities test

Code	Technical Factors	Initial	Ext	Code	Technical Factors	Initial	Ext
TEC1	Availability of sufficient surface area for installation	1.00	0.457	TEC18	Construction period	1.00	0.602
TEC2	Types of roof structure and roofing materials	1.00	0.623	TEC19	Late integration of PTAB needs in project development	1.00	0.775
TEC3	Building form and aesthetics	1.00	0.502	TEC20	Lack of awareness	1.00	0.635
TEC4	PV cell type and its combination	1.00	0.670	TEC21	Theft and vandalism	1.00	0.809
TEC5	Confusing rules on permit	1.00	0.607	TEC23	Lack of affordability	1.00	0.665
TEC6	Lack of consumer understanding of technologies	1.00	0.634	ECO1	Overall high Life cycle cost	1.00	0.715
TEC7	Dearth of trained installers	1.00	0.760	ECO2	Long payback time	1.00	0.698
TEC8	Lack of accessible technologies and know-how	1.00	0.786	ECO3	Lack of government incentives	1.00	0.820
TEC9	Poor planning	1.00	0.667	ECO4	Lower comparative utility tariffs	1.00	0.718
TEC10	Component failures	1.00	0.700	ECO5	High cost of maintenance & replacement of components	1.00	0.723
TEC11	Lack of research	1.00	0.626	ECO6	Availability of cheap fuel-based generator	1.00	0.836
TEC12	Over dependency on importation	1.00	0.725	ECO7	Discount rate	1.00	0.742
TEC13	Building regulation	1.00	0.603	ECO8	Escalation and Inflation rate	1.00	0.880
TEC14	Lack of tangibly quantifiable benefits	1.00	0.643	CDS1	Cost of acquisition (advertisement, marketing & project analysis)	1.00	0.668
TEC15	Scarcity of local competencies (trained installers & engineers)	1.00	0.767	CDS2	Permitting, inspection and interconnection (delay & study time)	1.00	0.713
TEC16	Solar PV technology rating (efficiency)	1.00	0.820	CDS3	Financing (financing costs)	1.00	0.656
TEC17	Design life of components and technologies	1.00	0.760	CDS4	Installation Labour (Availability and skill levels of installers)	1.00	0.788
				CDS5	Hardware (PV modules, inverter, batteries & PV racks)	1.00	0.980

Ext = communality score; significant factor > 65 percent or 0.65.

Table 3. Total variance explained

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	78.051	1.065	5.045	78.051

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

The factor rotation conducted to suppress loadings less than 0.40 generated seven principal cost drivers, using oblique rotation. Seven factors are therefore loaded unto the component matrix (Table 4), and a scan through the various factors loading indicates the most significant loading in component one has the score 0.738 and this relates to dearth of trained installers and scarcity of local competencies. The study therefore selected the framing ‘dearth of local competencies’ for the first component. Under the second factor, the most significant loading has the value 0.764 and this relates to low level of technologies and the frame ‘lack of accessible technologies and know-how’ is selected for this component. The most significant cost driver under the third component relates to short life span of components (0.820). The framing ‘design life of components and technologies’ is selected for the third component. The fourth component relates to ‘whole life cycle cost (0.893), and the frame high cost of maintenance and replacement of components’ is adopted for the fourth component. The fifth component deals with economic risks (0.872) hence, the frame ‘inflation and cost escalation’ is adequate for the fifth component. The sixth component relates to marketing, promotional and project management costs (0.754); the frame for this factor is ‘customer acquisition’. The seventh factor relates to hardware (0.921); and the frame hardware best suits the seventh component.

Table 4. 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

5. Discussions

Critical drivers of PV costs from the data analysis include dearth of local competencies, lack of accessible technologies and expertise, design life of components and technologies, high cost of maintenance and replacement of component, inflation and cost escalation, customer acquisition and hardware. Bonomo *et al*. [45] found related factors to influence module quality and reliability, appropriateness of installation procedures, proper maintenance and energy optimisation, thereby providing further evidence to validate the results of the study. The discussion of findings in the following adopts three principal framings, aligned to the following themes: technical and economic, customer acquisition and hardware.

Technical and economic influences: Issues relating to technological expertise, lack of awareness and understanding of PV technologies lead other technical factors influencing cost performance. Lack of accessible technology, awareness and skill dearth concerns are outcomes of inadequate solar related research initiatives. The results agrees with findings reported in Ahmed and Gidado [46] and Efurumibe [33], both studies noted that the lack of understanding of PV technology contributes to cost performance, and deters adoption. Another study Nwofe [1] attributed the slow incorporation of PV technology in building design in Nigeria to ignorance (lack of awareness). The impact of low awareness, lack of understanding and dearth of research on cost performance of PTAB results in the incidental misconceptions about the accurate cost of incorporating PV technology in design. The second most significant factor influencing the cost of PV in this category is absence of locally manufactured or developed PV components. Arising from these results, technological, environmental and economic factors therefore interwove to drive high cost of PV experienced in emerging markets [46]. Developing strategies to improve technological, environmental and economic factors is synonymous with PV cost reduction. The technical factors, dearth of local competencies and lack of accessible technology and expertise (0.738; 0.764) obtained lower performance indices than the third factor, design life of components (0.820). The combined effects of improving local competencies and technology to aid the manufacture of efficient PV components is more effective to eliminate the impact of short life span of component on life cycle costs. Developing components such as batteries to have longer life span would eliminate replacement cost and the extended implications on life cycle cost.

Skills dearth in the construction sector is not new, and its contribution to the overall cost of PTAB is significant. Lawton [38] studies agreed with this result and noted that installation costs contribute on the average, $0.59/W to the overall installed costs of PV in the US. In Nigeria, studies are not precise about the overall contribution of skill dearth to installation costs; the cost of PV are grouped together [47]. The costs of installations also vary from region to region; the amount of labour needed to install PV system in the US is higher than comparative costs in Germany [38]. The causes of discrepancy in the installation costs of PV across regions is due to non-standardisation of PV modules and variation in roof design and materials [38]. Varying roof design, materials and their conditions are associate of differing degree of productivity losses and additional cost in terms of repairs during PV installations and accessories used. Other factors responsible for variation in the installation costs of PV technology include additional works to roofs, such as shaded roofs and retrofitting existing roof to undertake increased load among others. The technical and economic influences do not only add to cost, but also causes delays in delivery time. Strong governmental incentives are therefore required to mitigate these drivers for improved cost performance. Government incentives may include waivers on tariff, education and training in requisite skills, subsidising payment for installation costs, research and initiatives that will promote local assembly and manufacture of PV components [30], [38].

Customer Acquisition: Customer acquisition accounts for the largest share of softs costs in the delivery of photovoltaic system [38]. Factors driving additional costs under this factor group include marketing and promotion charges, project analysis for viability and energy system analysis and design. Marketing and promotion attract sundry expenditures such as utility (telephone calls charges), site visit, engineering analysis and design. The cost of energy analysis are pre-contract transaction costs borne by the contractor, these costs passed to other projects when the bids are unsuccessful. A study of the US practices revealed that customer acquisition cost contributed $0.67/W to $1.00W to the overall installed costs of PV/watt. Within this estimated budget, Lawton [38] found that $0.33/W is dedicated to marketing and advertising, $0.11/W to system design and $0.23/W for other customer acquisition costs. Prasanna *et al.* [48] estimated that transportation and installation logistics could amount to 10percent of the installed costs of PV system in the context of developing countries.

Hardware: The cost of hardware components is the most significant cost driver influencing PV cost performance. The hardware includes racks for PV panels, inverters, batteries, charge controllers and PV modules. The level of sophistication of these components adds to the overall costs, whilst the less sophisticated once equally represent lower additional costs. The rack system for instance, could be flexible tracking equipment or fixed-tilt. Seel *et al.* [49] reported that an installation less than 10KW could add up to $1.2/W in PV rack approximating to 20percent of the total installed costs. Tamer [50] estimated the cost of PV array structure at 12percent of total module costs. Inverter adds $0.30/W or about 5 percent of total installed cost to an average PV project [51]. In Nigeria, inverter cost is approximately 40percent of installed costs in Nigeria, power charge controller is 10 percent of the PV module costs, the cost of battery is 33percent of the PV module costs, while annual maintenance cost of 2percent [52]. Hardware is therefore the most significant principal factors influencing the cost performance of PTAB in Nigeria. The Pakistanis studies revealed high-costs prevented stakeholder integration of solar PV [54; 55]. However, the stakeholders attributed the cost barrier to diverse factors associated cost PV modules, dearth of information and the poor quality of PV component [54]. The participants in a related study also corroborated the significance of PV modules as significant cost factor as well as installations, dearth of technician and suppliers [55]. Palm [56] also validated investment costs barrier adoption and attributed the cost to the dearth of market information.

6. Conclusion

Interests in low-carbon energy technologies across the building sector in Nigeria have gained significant impetus in recent times, although, the rate of adoption is laggard. In order to advance targeted transformation towards renewable energy technologies market penetration in the building sector in Nigeria, constraints to its performance requires in-depth evaluation. This study examined the influences on cost performance of PV technology applied in buildings in a typical emerging market, Nigeria. The results showed that dearth of local competencies, lack of awareness, lack of accessible technologies to promote local manufacturing of components, design life of components, high cost of maintenance, inflation and cost escalation are critical drivers of PV costs in emerging markets. These factors underscore about 77 percent problems underpinning the high cost of PV and delays in the delivery time of PV projects. The affordability of PV in the building sector therefore depends on optimising technical, economic and systems variables influencing their costs. Efforts to optimise the cost performance of PV technologies must improve the understanding of energy requirements by various buildings, optimise installation and other skills, and enhance research to adapt technologies to local conditions and life span of components and mitigating the cost of customer acquisition. Based on these results, strong government incentives are prerequisite intervention parameters for improving the cost drivers of PV towards diffused adoption in the building sector. Requisite incentives include waivers on tariff, education and awareness, training in requisite skills, subsidizing PV costs and research to grow local assembly and manufacture of PV components. The study provides useful insights into underlying factors influencing the cost performance of PV technologies in search of relevant strategies to enhance increase adoption in developing country.

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