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Article

Proposing an Approach for the Diffusion of Building Integrated Photovoltaics (BIPVs)—A Case Study

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Abstract: Consistent probing into building integrity has led to the exploration of clean energy options such as building integrated photovoltaic (BIPV). BIPV has proven to be aesthetically pleasing, architecturally feasible, and capable of making buildings energy producers instead of mere energy consumers. Despite the enormous benefits of BIPV, its adoption and diffusion have been relatively sluggish and remain far below expectations, especially in developing countries like Ghana. This empirical study aims to assess the impact of advertising on BIPV awareness in Ghana. It also highlights the aesthetic preferences of various respondents. The study uses online surveys to gather quantitative data from 412 respondents across all 16 regions of the country. An initial study conducted on the awareness of BIPV in Ghana indicated a low rate of awareness. Therefore, a sensitisation poster and architectural visualization (AV) were adopted to boost awareness across all 16 regions of the country. Awareness of BIPV increased from 18% to 79.5% after the introduction of the sensitisation poster. Also, 88.8% of the respondents preferred BIPV to Building Applied Photovoltaic (BAPV) mainly because of aesthetics (beauty) and the cost benefits. The respondents indicated that aesthetics is paramount when choosing solar panels for their homes. This study therefore recommends high investment in awareness creation, development of specific design guidelines for BIPV applications and establishment of demo projects in developing countries. The findings of this study contribute to the existing literature on BIPV adoption and may be useful for BIPV manufacturers, marketers, government, and other stakeholders as it provides evidence on the often-neglected approach to BIPV diffusion.

Keywords: building integrated photovoltaic (BIPV); awareness; aesthetics; advertising; diffusion; adoption

1. Introduction

The hope for sustainable and clean energy has heightened global interest in renewables as a viable alternative to fossil fuels. The impact of climate change keeps worsening [1,2] hence a practical approach to reducing global carbon dioxide (CO_2) levels is not an option anymore, but a necessity. Practical political measures such as the 1985 Vienna Convention, 1992 United Nations Framework Convention on Climate Change (UNFCCC), 1997 Kyoto Protocol, 2015 Paris Agreement, COP 26, and the recent COP 27 [3,4] are all aimed at proposing viable interventions to reduce the impact of climate change on human lives and the environment. The bottom line for all these huge steps is to re-image a carbon-free future for our planet.

One of the counter-solutions to discontinuing the use of cruddy fossil products is the adoption of clean energy such as renewables [5] . Sceptics opposed the idea of exchanging reliable energy (fossil fuel) with an intermittent energy source (renewables), however, technological advancement has proven that renewables are capable of fully replacing fossil fuels [6] . One of the most popular types of renewables is solar energy. Abundant sunlight makes solar an incomparable energy source as the sun shines in almost all parts of the world.

Solar technology has evolved over the years from basic photovoltaic applications to modern ways of integrating them into buildings such that they form part of the building envelope after construction. This is technically known as Building Integrated Photovoltaics (BIPV) as seen in Figure 1. The principal idea is to make buildings produce all or part of the energy they consume. BIPV has several advantages; for instance, it saves land space, reduces cost and, above all, improves the aesthetics of the building [7–10].

Figure 1. Building integrated photovoltaics (authors construct).

Building Applied Photovoltaic (BAPV) has dominated the solar market globally. For many buildings, solar Photovoltaic (PV) are mounted on rooftops to generate electricity. BIPV on the other hand, is relatively new in the solar market and appears to be very promising considering the overarching benefits it comes with. Recently, its uptake has increased especially in many advanced economies. It is estimated that the market share of BIPV is to grow at 21% between 2022–2032. In terms of market size, BIPV is projected to grow from US$ 16.5 billion (2021 levels) to US$ 134.31 billion by 2032 [11]. The prospects are enormous considering the quest to transition into a sustainable built environment.

However, despite the identified benefits of BIPV, its adoption has been dawdling due to several limitations, especially in developing countries. Key among these limitations are economic factors, high cost, product efficiency and design, public awareness, and inadequate demo projects [12] . In many developing countries such as Ghana, BIPV remains novel and non-existent in the architectural space. The little talk about BIPV is at the research stage and on policy papers, yet to materialise in principle. There is no evidence of an existing project to demonstrate the outlook and efficiency of BIPVs within the Ghanaian context. This could be attributed to the lack of awareness when it comes to BIPVs in Ghana [13] . Awareness is key in the adoption and widespread of any new product. In other words, underestimating the power of awareness could have a direct impact on the adoption of any product as consumers often buy what they know [14] . One of the fundamental tools for creating awareness is the use of advertising. Advertising has a direct manipulative impact on consumer culture and constantly impinges on the daily livelihood of individuals [15] . Several scholarly works have attempted to find a practical solution to the reluctance to adopt solar technology in Ghana. However, most of these studies mainly focused on the cost limitations, policy, and general barriers to the adoption of solar energy in general [16–19]. To date, no study has focused on the awareness of BIPV in Ghana and the prospects of advertising in promoting its adoption.

The inclusion of BIPV is critical if the estimated target set by the Ghana government to achieve 10% renewables in its energy mix by 2030 is anything to go by [20] . Buildings must be made energy producers instead of energy consumers. This paper thus investigates the impact of advertising on BIPV awareness and adoption in Ghana. It adopts a quantitative approach to establish the impact of adverts in creating awareness of BIPVs. Survey questionnaires were administered to 412 respondents from all 16 regions of the country. The results are analysed and displayed using tables and graphs. This study is novel in Ghana and the world at large, hence can serve as a resourceful literature base for future studies. Stakeholders and the government may also rely on it to make informed decisions to promote the adoption of BIPVs.

Our study is hugely motivated by the growing quest to expand solar energy adoption in Ghana's built environment. This novelty particularly focuses on BIPVs, which are uncommon in Ghana and most developing countries, hence it is expected to provide valuable evidence for future studies in other regions. It is a direct

contribution towards state-of-the-art research relating to practical approaches to boost BIPV adoption, especially in developing countries.

Domestically, the findings of this study are very critical for the full uptake of BIPV in Ghana. It gives a clear indication of the extent to which advertisement can boost the adoption of GBTs such as BIPV hence critical for policymakers, PV manufacturers and traders. From a much broader perspective, this research contributes directly towards deepening understanding of divergent policies to boost solar adoption, a major contributor to net-zero targets set by various countries.

This paper is structured into five sections. Section 2 captures background theory related to BIPV in Ghana, product awareness, and advertising. Section 3 highlights details of the method adopted in this paper. Section 4 presents the findings of the study. This section uses charts and tables to display the retrieved data. Section 5 focuses on discussing the findings of the study. The paper is concluded in Section 6 with recommendations for various stakeholders.

2. Background Theory

2.1. Building Integrated Photovoltaic (BIPV) in Ghana

Buildings consume over 40% of the energy produced globally and account for about 36% of GHG emissions [21 , 22] . This called for practical interventions to convert buildings from mere energy consumers to energy producers, hence the idea of integrating photovoltaic materials into buildings. At least buildings can produce all or some of the energy consumed [23]. BIPVs appeared on the scene in the early 1990s, according to sources [24]. As society advances, solar energy adoption in buildings is gradually evolving from a basic application to a modern way of integrating them into buildings such that they form part of the building envelope after construction [25] . The integration can be on the rooftop, balcony, curtain wall, sunshade, and wall, as seen in Figure 2 below.

Figure 2. BIPV integration in buildings [26].

The advantages of BIPV are numerous. For instance, they are aesthetically pleasing, architecturally friendly, and save money and land space [7,27]. BIPV has gained a lot of popularity recently partly because of the growing concerns about land space for mounting regular PVs [28–30] . Like in many other developing countries, BIPV remains in policy books and on research desks in Ghana. Basic PV applications in buildings, such as building-applied photovoltaics (BAPV) still dominate the solar industry in Ghana. However, studies conducted by Awuku et al. [31] indicate that BIPV could thrive in the Ghanaian market by merging traditional adinkra symbols and improving aesthetics through the introduction of other shapes, textures, and colours. A cost analysis conducted by Gyimah [32] also proves that the average breakeven period of BIPV in Ghana is under 5 years given certain parameters. BIPV, therefore, has the tendency to augment the energy-generating capacity of buildings in Ghana.

2.2. Stages of Product Adoption

It is essential to consider the literature on product adoption because this paper focuses on practical approaches to promote awareness and adoption of BIPV. Just like any other product, BIPV awareness follows essential product adoption and marketability approaches. Apart from the major elements identified in Roger's Diffusion of Innovation theory (DOI) [33] ; innovation, communication channels, social factors, time and the rate of adoption, there are five other key factors that underpin the diffusion process [34] as seen in Figure 3. These

are Awareness, Persuasion, Decision, Implementation and Continuation. It is evident that awareness comes up as the fundamental factor on the list, hence must not be underestimated in the adoption of BIPV.

1. Awareness: Awareness is paramount in the adoption of an innovation. This stage orients the user to the innovation. Here, the adopter becomes privy to the existence of the product. Basic knowledge of the product is given at this stage.
2. Persuasion: Once awareness is created, the adopter begins to develop a stance towards the innovation. Fundamental questions are asked, and further details are sought to make informed decisions if a favourable attitude is developed towards the innovation.
3. Decision: This is where the potential adopter makes a clear resolve to adopt or reject the innovation. Here, the product's critical analysis, such as Strengths, weaknesses, opportunities, and threats (SWOT analysis), is made to ascertain its viability.
4. Implementation: At the implementation stage, the innovation is finally accepted, and adopted. Adopters may not fully understand the innovation yet but would have gone for it with high hopes and expectations.
5. Continuation: Once the innovation has been implemented, the decision to continue or quit usage depends on the expectations of the adopter. Unmet expectations may influence the adopters to decide to discontinue using or otherwise.

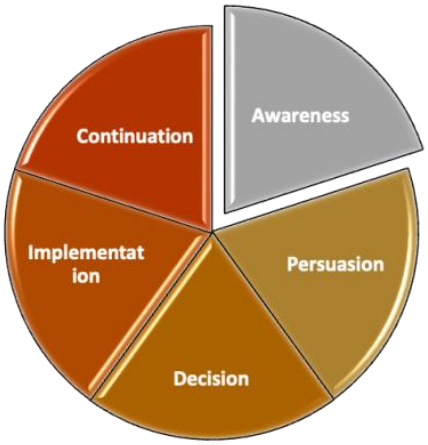

Figure 3. Five-factor wheel for diffusion of an innovation. Authors construct, curled from [34].

2.3. Product Awareness

One of the fundamental goals of marketing a product is to create and sustain brand awareness [35]. In cases where the specific target audiences are less interested in conducting an active search to select products, manufacturers have the onus to promote their products by constantly creating awareness. It is often argued that brand awareness has a direct bearing on the decision-making of consumers [36,37].

Product awareness is usually in tandem with adoption. The adoption process involves an individual's mental steps to settle on a new product. It is said that adoption happens after awareness and acceptance of a product [38,39]. Most buyers may likely have a similar need; however, some may differ. In marketing, awareness is categorised as a fundamental step when it comes to the adoption of a new product. As a general principle, product awareness directly affects willingness to adopt, and the same can be said for solar energy, especially BIPV.

In a more specific context, the findings of a quantitative study conducted by Yang et al. [40] on the acceptance of renewable technology in Ghana indicate that environmental awareness is one of the critical factors impeding the adoption of renewable technology in Ghana. Asante et al. [41] also highlighted public awareness as a major limitation for the uptake of renewables in their study on the barriers to renewable energy adoption. Also, a study conducted by Asante et al. [42] on strategies to eliminate barriers to renewable energy adoption in Ghana suggests education is a fundamental tool. All these findings further indicate the strategic place of awareness in the promotion of renewables such as BIPV, especially as it is relatively new in Ghana.

However, very few studies examine the impact of solar awareness on adoption [43–46]. Existing research on consumer behaviour tends to focus on branding, costing and attitude [47–49]. Interestingly, a fundamental marketing study conducted in 1984 by Hoyer [50] indicated that most consumers barely pay detailed attention when choosing products. In many instances, consumers rely on basic heuristics such as brand, product cost or perhaps packaging.

Technology keeps evolving; hence it is practically difficult for consumers to keep up to date with the trends. Identifying the pros and cons, cost differentials, etc., is often challenging and time-consuming; hence many are tempted to stick to what is known. Awareness has therefore become a necessary tool for both manufacturers and consumers. The more information is passed on to the consumer about a particular product, the easier it is to make decisions.

2.4. Impact of Advertising on Product Awareness

Adverts have been known to be primal in creating product awareness. The history of advertising can be traced back to prehistoric times [51]. There was evidence of adverts in the early civilisation of Egypt, Greece, and Rome mainly for directions and the sale of books. Advertising has grown through the Industrial Revolution, the 19th century, post-World War II and current times [52]. Today, adverts are showcased through many mediums, ranging from multimedia (TV & radio), print (newspapers and magazines) and the internet (social media and web pages).

Existing marketing literature duly acknowledges the impact of advertising on the consumer purchasing decision. Adverts aim to create awareness, and thus provide consumers with adequate information to make an informed choice in an optional market. Therefore, advertising offers the consumer room for options to choose from and gives the producer room to showcase their product [53]. Beyond the consumer and producer affair, adverts can benefit society as they convey critical information to the public. Table 1 shows some benefits and limitations of advertising.

Table 1. Benefits and limitations of advertising [54].

Benefits	Limitations
Leads to an increment in sales and revenue	High cost
Increases exposure and competitive advantage	Promotes monopoly
Helps in market expansion	Can sometimes communicate misleading information
Improves brand recognition	Overall impact on sales is uncertain
Empowers customers by providing essential information	Negative publicity risk

In a broader context, advertising can be regarded as (a) a product cognisance tool for providing adequate information to consumers; (b) convincing the target audience that an advertised service/product is better and worth buying compared to other rivals; (c) stimulating consumer emotions by creating some level of excitement and positive expectation of a product/service [55].

Advertising and aesthetics have a role to play in the promulgation of sustainable building materials such as BIPVs. For instance, a study conducted by Alamsyah et al. [56] indicates that advertising tends to promote the adoption of green building technologies (GBT) among Indonesians. A conscious effort to advertise BIPV products can therefore go a long way to increase awareness among consumers because BIPV also serves as an auxiliary building material.

3. Method

This study aims to investigate the aesthetic preferences and impact of advertising on BIPV adoption using Ghana as a case study. A range of methods is mostly applicable when it comes to research which involves the investigation into product preferences, consumer satisfaction and brand awareness [56,57]. This study thus relies on a quantitative methodology through the administration of survey questionnaires in Ghana. This study is

novel and projected to inform similar research on demographic information, statistical focus, and methodological exploration. The quantitative survey questionnaire approach was adopted because it tends to reach out to a lot of respondents at scattered locations and provides numerical data useful for statistical analysis. An initial study with no visual aids was conducted on 100 respondents. The outcome of the first study offered lessons for the second study.

The second study reached out to 412 respondents across all 16 regions of Ghana with data collected between January and May 2022. The survey questionnaire was prepared based on an extensive literature review on BIPV and related variables to reach out to individuals who were homeowners or aspired to own houses in the immediate future. Table 2 shows the empirical basis for the questionnaire.

Table 2. The empirical basis for survey questions.

Variables	Questions	References
Demographics	What is your age range? What is your gender? What is your occupation? What is your income range? What is your level of education?	[43,58–60]
Impact of Advertising and BIPV Awareness	Have you heard of Building Integrated Photovoltaics (BIPV)? Did the adverts above aid in your awareness of BIPV? Looking at the following images (A) and (B), which one are you likely to adopt for your home? (The main difference is the way the solar panels have been arranged)	[27,45,47,61–63]
The Value of Aesthetics	Do you think Aesthetics (beauty) matter when it comes to solar application for your home? Are you likely to adopt Building Integrated Photovoltaics (BIPV) for your home if there are variety of colours and shapes to replace wall tiles, roofing materials and windows?	[7,64–70]

Respondents were also given room to offer some qualitative responses to support the quantitative data retrieved. The questions covered demographics and BIPV adoption. Since BIPV is a relatively new phenomenon in Ghana, the researchers developed sensitisation materials to educate the respondents on its meaning ahead of the survey. Adobe Photoshop and Illustrator were used for the rendering of the sensitisation materials as seen in Figure 4. This was to ensure a better understanding and relatability to the questions asked, as artworks have been known to be one of the best awareness-creation mechanisms [71–73]. Also, a cross-section of selected buildings in Ghana was illustrated and included in the questionnaire to facilitate understanding by the various respondents.

Figure 4. Illustrations adopted for the survey design (authors construct).

The questionnaire was prepared in English language using a survey tool called JISC. Printed copies of the survey were also distributed to respondents in remote areas who required assistance to complete the survey. The survey was distributed through convenient sampling, to reach out to as many respondents as possible. The convenient sampling technique is known to be cost-effective and has fewer rules. However, this approach is known to be biased and may also have limited external validity. This can be attributed to the fact that the

outcome of the study cannot be easily generalized to populations with characteristics that are different from the population that was conveniently accessible, where the study sample was drawn [57].

The survey was also distributed through various social media platforms such as WhatsApp, LinkedIn, and emails. The obtained results were edited and analysed using Statistical Package for Social Scientists (SPSS) and Microsoft Excel, and data were displayed using tables and charts. The data were further analysed using multiple regression and the Chi-square test to establish the relationship between selected variables. A diagrammatic representation of the structure of the methodology is shown in Figure 5.

The quantitative method aligns with the objectives of the study because it provides a systematic approach to collecting, analysing and interpreting data on a relatively new research area in Ghana. Considering the novelty of this study and the fact that the majority of the respondents had little knowledge of BIPVs, this approach offered specific measurable and quantifiable variables, enabling the justification of set hypotheses. It also provided an opportunity to reach a larger sample for analysis. This allows the generalisation of the research findings to the wider population or predictions about future trends.

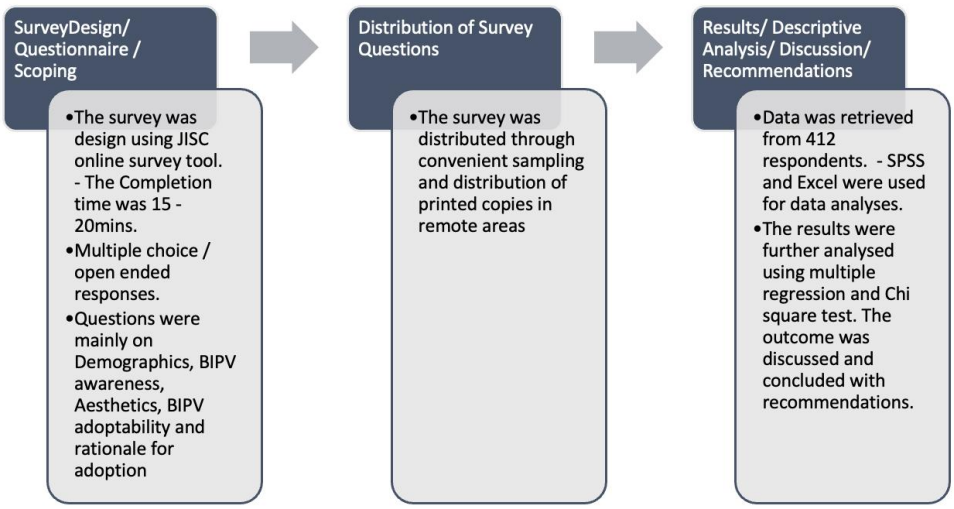

Figure 5. Framework from the design of the questionnaire to recommendations.

4. Survey Results

The data retrieved from the 412 respondents were categorised into three major aspects. Firstly, a general demographic enquiry was made to determine the age, gender, income range and level of education of the various respondents. The second aspect covered BIPV awareness and the third highlighted BIPV adoption. A qualitative response was also gathered to supplement the quantitative feedback from the respondents.

4.1. Respondent's Demographics (n = 412)

Demographics form the basis of many statistical analyses as it provides background information about the respondents [58].

4.1.1. Gender

In terms of gender, 59% of the respondents were males while 39% were females as shown in Figure 6. A smaller percentage preferred not to say. Several studies have proven that males are more likely to take part in field research that involves a new technology in Ghana [59–61].

4.1.2. Age Range

Age is known to have an adverse effect on the adoption of solar products [62]. The older people become, the less interested they become in trying new products, especially other energy alternatives. The survey targeted adult (18+) respondents, who had houses or had the intention to own houses. A large percentage of the

respondents were within the youthful category (20–59) as shown in Figure 7. This indicates that they may be in the working class, hence able to afford BIPV products should they decide to.

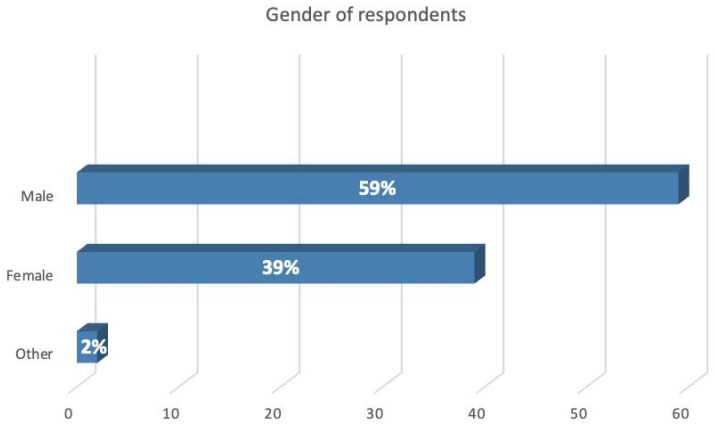

Figure 6. Gender of respondents.

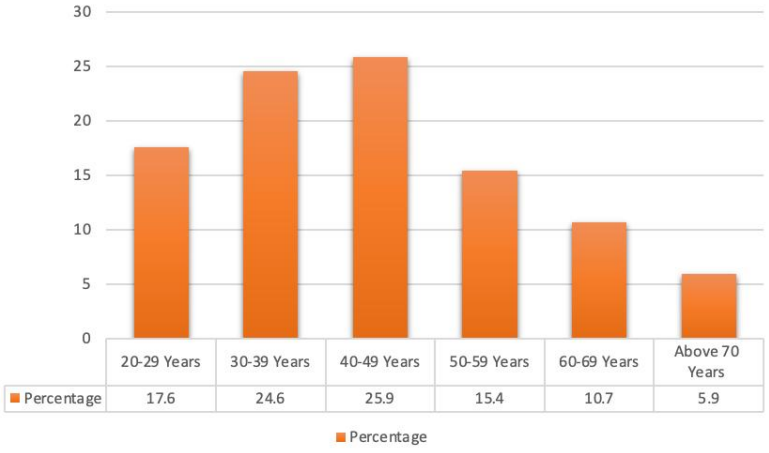

Figure 7. Age range.

4.1.3. Education

Considering the nature of the study being carried out, the respondents were expected to have at least some level of education to be able to appreciate and fully understand the questions. A conscious effort was therefore made to target respondents who had at least a high school education. This is reflected in the survey outcome, as 87.6% of the respondents had at least a high school education. The breakdown is shown in Figure 8.

Education greatly impacts the adoption of a new product [63]. In this study, most of the respondents had bachelor's and master's degrees. This can be attributed to the survey targeting people within the working-class category.

4.1.4. Income Range

Figure 9 indicates that the income ranges of Ghanaian workers are sparsely distributed, with some people earning below the average minimum wage (GH¢14.88/day). According to Figure 9 generated from the survey, thirty-nine (39) representing 9.5% of the respondents receive less than GH¢ 10,000 per annum and GH¢20,000, sixty-three (63) representing 15.5% receive between GH¢ 20–30,000, sixty-eight (68) representing 16.6% receive GH¢ 30,000–40,000, fifty-six (56) representing 13.7% receive GH¢ 40,000–50,000, forty-three (43) representing 10.5% receive 60,000–80,000, thirty-six (36) representing 8.8% receive GH¢ 80,000-120,000, forty (40) representing 9.8% receive GH¢ 120,000 and above per annum respectively. However, twenty-six (26) representing 6.3% preferred not to disclose their income. Figure 9 shows that most of the respondents earned between GH 30,000 and GH 40,000 (about USD$ 3,000–4,000).

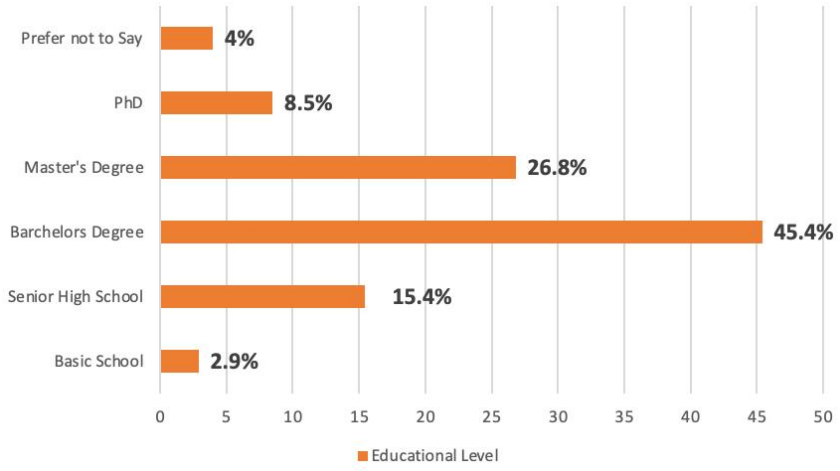

Figure 8. Educational level.

The average income value of the respondents as shown in Table 3 sampled for the study was 4.69 with a standard deviation of (SD = 2.32). The results show that with the necessary support respondents' income could position them to consider adopting BIPV and solar energy for their homes.

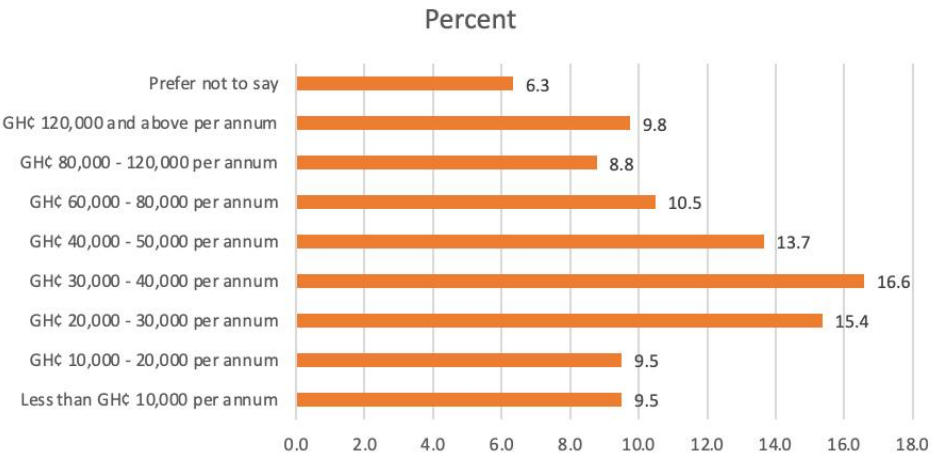

Figure 9. Income range.

Table 3. Income range.

Item	N	Min	Max	Mean	Std. Deviation
Income range	412	1	9	4.69	2.324
Valid N (listwise)	412	-	-	-	-

4.2. BIPV Awareness and Aesthetics

BIPV is virtually non-existent in Ghana, hence very little knowledge and awareness existed among the respondents. The survey adopted an Architectural visualisation (AV) approach, with sensitisation designs to introduce BIPV to the respondents (see Figure 3). The initial study indicated that most of the respondents had no idea about BIPV and hence could not make any further contribution. This informed the researchers to sensitise the various respondents ahead of the survey to help them make meaningful contributions. The AV designs served as a sensitisation mechanism to orient respondents. After the sensitisation materials were introduced, BIPV awareness rose from 18% in the pilot study to 79.5% as seen in Figure 10. This indicates that posters and other

visual aids positively impact awareness of BIPV in Ghana. Like many other products, advertising tends to boost awareness [64] . Therefore, awareness is an essential aspect of product adoption that cannot be underrated, especially when it comes to a new product such as BIPV on the Ghanaian market.

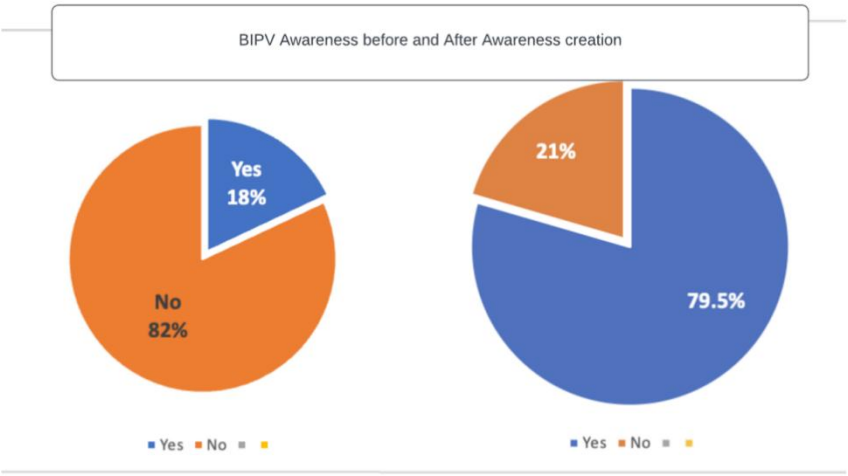

Figure 10. Difference in BIPV awareness.

It is evident that the use of the sensitisation tools greatly influenced the awareness rate of the respondents. In the initial study, some of the respondents were disinterested, so could not complete the survey. This is because they struggled to understand the meaning of the concept. A picture explains a thousand words, hence after the introduction of the AV designs, respondents could relate better to the questions and subsequently took a keen interest in the second survey.

Under the BIPV Aesthetic Images (IMG) construct (Table 4), three key questions were asked: i. Knowledge of BIPV ii. Likelihood to adopt BIPV or BAPV and iii. Value of aesthetics in solar applications. The descriptive statistics for BIPV and aesthetics images in the study reveal an overall mean score of 1.24 with a standard deviation of (SD = 0.354). This suggests a positive perception of awareness of BIPV and aesthetics amongst the respondents and their willingness to adopt.

Table 4. BIPV awareness and aesthetics construct.

Item	N	Min	Max	Mean	Standard Deviation
Knowledge of building integrated photovoltaics (BIPV) (IMG1)	412	1	2	1.20	0.403
Likely adoption of BIPV (A) or BAPV (B) for your home	412	1	2	1.12	0.321
If A (IMG3)	412	1	3	1.36	0.556
Do you think aesthetics (Beauty) matter when it comes to solar application for your home? (IMG4)	412	1	2	1.07	0.260
If yes (IMG5)	412	1	3	1.45	0.536
IMG	412	1.00	2.40	1.24	0.354
Valid N (listwise)	412				

4.2.1. Hypotheses Testing 1

A set of hypotheses were tested to (a) Establish the relationship between education and awareness of BIPV among the respondents, and (b) Establish the association between advertising and BIPV awareness in Ghana.

One would easily assume that education has an association with BIPV awareness. To establish whether there is an association between educational level and awareness of BIPV, the following hypotheses were formulated.

H_0: There is no significant association between educational level and awareness of BIPV.

H_1: There is a significant association between educational level and awareness of BIPV.

The chi-square statistic was used to test the association between the variable's educational level and awareness of BIPV. The results reveal that there is an association of 5% significance between educational level and awareness of BIPV by respondents ($X^2 = 246.152$, $df = 5$, $p = 0.000$). Therefore, H_1: is supported. This shows that awareness of BIPV is dependent on respondents' level of education (see Tables 5 and 6).

Table 5. Chi-Square tests.

Item	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	246.152	5	0.000
Likelihood ratio	265.814	5	0.000
Linear-by-linear association	183.176	1	0.000
N of valid cases	412		

Table 6. Cross tabulation.

Item			Awareness of BIPV		Total
			Yes	No	
Level of education	Basic level	Count	12	0	12
		Expected count	9.6	2.4	12
	Senior high school level	Count	63	0	63
		Expected count	50.2	12.8	63
	Bachelor's degree level	Count	186	0	186
		Expected count	148.1	37.9	186
	Masters level	Count	67	45	112
		Expected count	89.2	22.8	112
	Ph.D. level	Count	0	35	35
		Expected count	27.9	7.1	35
	Prefer not to say	Count	0	4	4
		Expected count	3.2	0.8	4.0
Total		Count	328	84	412
		Expected count	328	84.0	412

4.2.2. Hypotheses Testing 2

To test whether advertising (ADVRT) could influence BIPV awareness in Ghana.

H_0: There is no significant influence of advertising on BIPV awareness in Ghana.

H_1: There is a significant influence of advertising on BIPV awareness in Ghana.

The hypothesis tests whether advertising influences the awareness of BIPV in Ghana. The dependent variable BIPV measured by level of education was regressed on predicting variable advertising (ADVRT) to test the hypotheses. ADVRT significantly influenced BIPV awareness in Ghana, $F(1, 411)$, $P < 0.05$, which indicated

that advertising obviously influences the awareness of building integrated photovoltaics and solar energy usage in Ghana. The results point to a direct positive influence of advertising on BIPV awareness in Ghana and the need to institute and sustain advertising campaigns to increase BIPV awareness and adoption. Moreover, the R^2 depicts that the model explains 22.2% of the variance in BIPV awareness. Table 7 shows a summary of the findings.

Table 7. Link between advertising and BIPV awareness.

Hypothesis	Regression Weights	Beta Coefficient	R^2	F	t-value	p-value	Hypothesis Supported
H_1	ADVRT→BIPV	2.034	0.222	117.140	10.823	0.000	Yes

Note: P < 0.05 ADVRT, BIPV.

4.3. BIPV Adoption

Respondents were given the option to choose between BIPV and its counterpart Building Applied Photovoltaics (BAPV). Visual aids were made available to help recognise the differences, and a larger percentage, 88.8%, preferred BIPV as seen in Figure 11. The respondents backed their choice mainly with the aesthetics that come with BIPV as shown in Table 1. This indicates that Ghanaians place value not just on the efficiency of energy produced by solar panels but also its aesthetics, especially for buildings. Several studies have confirmed that the aesthetics of BIPV and its ability to seamlessly blend into the building envelope is one of its major trade points [7,65,66] . Understandably, efforts have been made to create aesthetic diversity when it comes to the shapes, colours, and texture of BIPV, especially as it competes with existing building materials [7]. A novel study conducted by Awuku et al. [13] indicates that symbolism could also improve the aesthetics and adoption of BIPVs in a cultural society like Ghana. The high rate of BIPV adoption demonstrated in the survey, has proven that BIPV has a high potential considering the aesthetic milestones achieved so far [67].

Figure 11 shows that most of the respondents (88.8%) prefer BIPV to building applied photovoltaics (BAPV) because it looks beautiful and is well organised considering the cost benefits it comes with. Previous studies on renewable energy adoption in Ghana indicate that solar energy awareness increased especially during times of power crisis (dumsor) when people were keen on finding alternative energy options [68,69]. However, existing literature has identified land space especially within busy cities as a limitation to adopting solar energy. This study indicates that the BIPV alternative could be a reliable option, especially in areas where land space is a limitation. The study adopts a multiple regression analytical approach to establish the influence of aesthetics on BIPV awareness and adoption as seen in the hypothesis below.

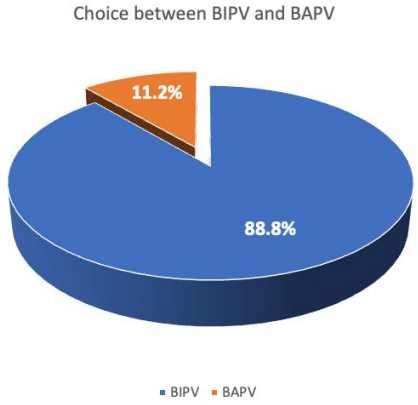

Figure 11. Choice between BIPV and BAPV.

4.3.1. Hypothesis Testing 3

To test whether aesthetics could potentially influence BIPV adoption in Ghana.

H_0: There is no significant influence of aesthetics on BIPV adoption in Ghana.

H_1: There is a significant influence of aesthetics on BIPV adoption in Ghana.

The hypothesis tests whether aesthetics could influence the adoption of BIPV in Ghana. The dependent variable BIPV measured by level of education was regressed on predicting variable aesthetics to test hypotheses H_0 and H_1. The independent variable aesthetics significantly influenced BIPV adoption in Ghana, F (2, 411), $P < 0.05$, which indicated that colours, patterns, scale, shapes, and visual weights clearly influence the adoption of building integrated photovoltaics and solar energy usage in Ghana. The results clearly point to a direct positive influence of aesthetics on BIPV adoption. Moreover, the R^2 depicts a 40.1% of the variance in BIPV adoption. Table 8 shows a summary of the findings.

Table 8. Aesthetics and BIPV awareness and adoption.

Hypothesis	Regression Weights	Beta Coefficient	R^2	F	t-value	p-value	Hypothesis Supported
H_1	AEST1→BIPV	0.571	0.401	136.652	2.500	0.013	Yes
	AEST2→BIPV	1.513			8.033	0.000	

Note: $P < 0.05$ ADVRT, BIPV.

In summary, this section has displayed the outcome of the data retrieved from 412 respondents across all sixteen regions of Ghana. The demographics show a higher number of males compared to females and a youthful population with 87.6% having at least a high school education. In terms of BIPV awareness, the sensitization tool increased the rate of awareness among respondents up to 79.5%. H1 revealed a significant association between educational level and awareness of BIPV, while H_2 also justifies that there is a significant influence of advertising on BIPV awareness in Ghana. In terms of BIPV adoption, a higher percentage of the respondents (88.8%) preferred BIPV to BAPV mainly because of aesthetics. The critical role of aesthetics in the adoption of BIPVs cannot be overstated. It plays an important role in the public acceptance and perception of solar energy, especially in the built environment.

5. Discussions

This study has fundamentally explored how advertising can boost BIPV awareness by using Ghana as a case study. It has further explored the willingness of the respondents to adopt BIPV and the rationale for adoptability. A survey questionnaire was distributed in all 16 regions of Ghana between January and May 2022 with a focus on the demographics, awareness, and adoptability of BIPVs.

In recent times, there have been direct efforts made in the EU and other advanced countries to boost the adoption of green building technologies (GBTs), particularly the use of renewables in buildings [70] . As technology advances and the quest for aesthetic salience increases, renewables such as solar applications have also evolved. These days, solar PVs have moved from traditional applications on buildings (BAPVs) [71] to sophisticated ways of applying them on buildings (BIPVs) such that they form part of the building envelope after construction [72,73]. BIPVs are aesthetically pleasing and hence have become the new norm in the architectural world especially when it comes to solar for roofing and cladding [74] in advanced countries. However, despite the seeming popularity of BIPV, it is literally non-existent in African countries including Ghana. The hope for a green built environment and its consequent impact on climate change is a collective effort, hence GBT does not come up as an option anymore but a necessity. It is therefore important to recognise the potential contribution of BIPV to boost renewable adoption in Ghana.

Considering the recent global hype in BIPV adoption, critical questions arise: What is the level of awareness of BIPVs in Ghana and how can it be increased? And are Ghanaians willing to adopt BIPV after being made aware? Although not in the same context, essential components of the answers to these questions are highlighted in similar research conducted by Goh et al. [75] in Malaysia, Rababah et al. [76] in Southeast Asian countries and Albattah and Attoye [77] in the United Arab Emirates.

The first objective of this research is to provide a quantitative representative sample of Ghanaians on BIPV awareness. Contrary to the study conducted by Albattah and Attoye [77], where most respondents (92.4%) were fully aware of BIPV, our results prior to the introduction of the awareness tools indicate a very low rate of awareness in Ghana (18%). However, after sensitizing the respondents, awareness increased from 18% to 79.5%. This implies that the adoption of the sensitisation materials had a direct impact on BIPV awareness in Ghana. Our

study is therefore a true representation of the fact that advertising BIPV could greatly impact awareness, hence boosting adoption. The Chi-square statistic between education and awareness indicates a significant correlation between education and awareness of BIPV in Ghana. Since most of the respondents (over 80%) were highly educated, at least up to a first degree, it was easy to read, understand and relate better with the sensitisation poster, hence the increase in adoption. As demonstrated in the analysis, there is an association of 5% significance between educational level and awareness. This implies that an educated population is likely to relate better to BIPV advertising and awareness materials.

The second objective was to establish the adoptability of BIPV in Ghana. Respondents were offered the option to choose between BIPV and its counterpart BAPV. Figure 10 indicates that 88.8% of the respondents preferred BIPV to BAPV, which clearly reflects that Ghanaians place a premium on beauty and not just the efficiency of solar panels. The section further explored the influence of aesthetics on BIPV adoption. The outcome clearly indicated a positive correlation between aesthetics and BIPV adoption. Being offered variety in colours, shapes, textures, patterns, and visual weight has the tendency to boost the adoption of BIPV in Ghana. This finding reaffirms a study conducted by Awuku et al. [7] which highlights the power of aesthetics in BIPV adoption.

The outcome of this study has proven that sensitising consumers about BIPV can play a crucial role in aiding their understanding and adoption of this innovative technology. It raises awareness and creates market demand. It also highlights the overall benefits of adopting the product. Consumers can therefore make informed decisions about adopting BIPVs.

Aesthetics on the other hand plays a crucial role in the adoption of BIPVs as they directly influence perception and acceptance. When BIPV systems are aesthetically pleasing and seamlessly integrated into a building's design, they can enhance its overall attractiveness. This positive visual impact can generate interest and curiosity among individuals who may not have previously considered adopting solar energy solutions. Public perception and social acceptance are greatly influenced by aesthetics. A seamless integration of BIPV systems tends to dispel the notion that renewable energy is solely associated with bulky and unattractive installations. Prioritizing aesthetics in the development of renewable energy technologies can effectively change the narrative and inspire a greater number of people to embrace a sustainable future.

The adoption of BIPV in Ghana's renewable energy landscape holds immense significance for the country's sustainable development goals. As a rapidly growing economy with a rising electricity demand, Ghana faces the challenge of meeting its energy needs while reducing its carbon footprint. BIPV offers a unique solution by seamlessly integrating solar panels into building materials such as roofs, windows, and facades. This innovative technology not only generates clean and renewable energy but also enhances the aesthetic appeal of buildings. By incorporating BIPV into new construction projects or retrofitting existing structures, Ghana can effectively harness solar power without compromising on architectural design. BIPV has the advantage of offering decentralised energy production, which could reduce the overall load on the national grid. Adopting BIPV sets Ghana on the pathway to making buildings energy generators instead of mere energy consumers, thereby contributing to its net zero carbon commitment.

In summary, the survey's outcome confirms that advertising greatly impacts the adoption of any new product including BIPV in Ghana. The initial study conducted ahead of the main study was the first step in assessing BIPV adoptability in Ghana. However, most of the respondents were unable to understand the concept. The second study, therefore, adopted advertising materials to demystify the "complex" concept to the respondents since adverts are perceived as useful for explaining complex texts [78]. The contrast is evident, as the awareness level of BIPV increased drastically (from 18% to 79.5%). After BIPV awareness grew amongst the respondents, the survey further probed into the rationale for adopting BIPV over BAPV given a set of visual aids. BIPV appears to have high prospects in Ghana mainly because of its cost advantage and aesthetics. This study is novel and expected to contribute to the literature on BIPV in developing countries. Future studies could qualitatively explore aesthetic perceptions of BIPV, affordability of BIPV, adaptability to local conditions and regulatory frameworks governing BIV in developing countries.

6. Conclusions and Recommendations

This study has explored the role of advertising and aesthetics in the adoption of BIPV. An initial study on BIPV adoption was conducted in Ghana without the use of visual aids and most of the respondents showed a lack

of understanding and, hence could not make further contributions despite the textual explanations offered. After the introduction of a sensitization poster in the main study, awareness rose from 18% to 79.5%. This is a clear indication that awareness through visual aids tends to boost BIPV adoption in Ghana. 88.8% of the respondents also preferred BIPV to BAPV after being presented with visual aids to choose from. The aesthetics of BIPV was the major reason for its preferability. A further probe also indicates that the ability of BIPVs to replace building materials, thereby relinquishing the need for extra land space is a key factor for adoption. The quest to make building skin generate energy for consumption is primal considering the scarcity of land especially within the major cities where most industrial buildings and offices of many companies reside. Adopting BIPV could fully or partially convert all these huge building skins into energy-generating fields which will go a long way to reduce over reliance on the national grid.

This study is novel and exemplary as it highlights the role of advertising in BIPV adoption and highlights the value of aesthetics. The following recommendations have been identified based on the findings of this study:

1. Investment in Awareness creation: Often, the focus has mainly been to invest massively in various renewable energy products without the necessary sensitization. The study is evidence that media (posters, web, and internet marketing) are capable of increasing awareness of BIPV and similar green building materials not just in Ghana, but the world at large. Care must be taken though, to carefully consider rural dwellers and less educated people in advertising campaigns.
2. Increase BIPV investment in Africa: Considering the rate of industrialization and economic growth, it is imperative that stakeholders begin to consider making buildings energy producers instead of mere energy consumers to help nations achieve their renewable targets, and to shape the future of clean energy in the built environment. A direct increase in BIPV investment in Africa can have a significant impact on achieving sustainable development goals. One of the key sustainable development goals is to ensure access to affordable, reliable, sustainable, and modern energy for all (SDG 7). Africa faces significant energy challenges, with a large portion of its population lacking access to electricity. By increasing BIPV investment, more buildings across the continent can become self-sufficient in generating electricity from solar energy. This not only helps meet the energy needs of communities but also reduces reliance on fossil fuels and contributes to mitigating climate change.
3. Develop specific Design Guidelines: BIPV Stakeholders, government and other regulatory agencies must establish collaboration with urban planners, architects, artists, and other industry experts to project a statutory guideline for acceptable BIPV design and installation. The focus should be on ensuring BIPVs are integrated into building designs seamlessly without distorting environmental aesthetics.
4. Fostering collaboration among stakeholders: It is essential to bring together various stakeholders involved in the construction and renewable energy sectors. These stakeholders include architects, engineers, developers, manufacturers, policymakers, investors, and end-users. Fostering collaboration among these diverse groups can ensure direct knowledge sharing and innovation.
5. Establishment of Demo Projects: An existing project will go a long way to provide potential consumers with real-life and practical evidence. They might as well have first-hand experience and observe how BIPVs work, which can in turn influence their decision to adopt.

Author Contributions

Samuel A. Awuku: Conception; data collection; investigation; analysis; writing—original draft preparation. Amar Bennadji: conception; supervision; verification; writing—review and editing. Firdaus Muhammad-Sukki: conception; supervision; verification; visualisation; writing—review and editing. Radhakrishna Prabhu: conception; supervision; verification; writing—review and editing. Nazmi Sellami: conception; supervision; verification; writing—review and editing. All authors read and approved the final manuscript.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of Robert Gordon University, UK on the 26 June 2022.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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