Colours and Shapes–Perspective from Ghanaians on BIPV Aesthetic Optimisation

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***Abstract*—Colours, texture and shapes of Buildings Integrated Photovoltaic (BIPV) have been fully explored in recent times to match mainstream architectural aesthetics. This study aims at getting some perspectives from Ghanaians when it comes to the colours and shapes of BIPVs. A quantitative method was used to reach out to 410 respondents in Ghana. 94.1% of the respondents agreed to adopt BIPV should there be a variety of colours, textures and shapes. The outcome indicates that aesthetic optimisation, in terms of introducing a variety of colours and shapes, tends to increase adoptability. Colours could be a top priority when it comes to BIPV in Ghana, as indicated by 65.8% of the respondents. 68.9% prefer bright colours, while 31.1% prefer dark colours. This study is expected to advise BIPV stakeholders on the aesthetic interest and preferences of consumers.**

***Keywords*—Buildings Integrated Photovoltaic (BIPV), solar energy, aesthetics**

I. Introduction

Climate change and its catastrophic repercussions call for a pragmatic approach to convert the world into a clean space, where carbon levels will reduce, and sustainable practices shall become the new norm. The built environment alone contributes to about 40% of CO2 emissions, therefore, requires immediate intervention. Enforceable laws have been enacted in Europe and other countries to ensure buildings meet a specific standard; however, the level of success is debatable [1]. One approach is the introduction of Building Integrated Photovoltaics (BIPV), where solar photovoltaics are used to replace conventional building materials, either for roofing or facade.

One of the major differentiating factors between BIPV and its counterparts building applied photovoltaics (BAPV) is architectural salience [2]. In other words, BIPV blends into the architectural envelope of the building; hence consumers are more conscious of its appeal. The real need goes beyond mere energy efficiency as the PV functions as both a building material and a source of electricity [3]. In the BIPV world, the aesthetic is indispensable, hence it is critical to consider consumer perspectives when it comes to fundamental elements of design; colour, shapes, and texture and how they affect adoption. In general terms, product preference has been mostly accompanied by appearance [4]. Consumers are keen on the appearance of everyday consumables and technical products [5]. The aesthetic outlook of a particular product engages the emotions of consumers and can convey the efficiency of a product. Interestingly studies have proven that products perceived to be beautiful are believed to be better without necessarily using the product to verify [6]. Product aesthetics has therefore been prioritised as much as functionality considering its stakes in adoption, including building materials.

II. Literature Review

For facades, the aesthetic outlook of BIPV is critical and remains challenging for developers as the demands keep changing [7]. In the minds of consumers, elements of aesthetics such as colour, texture, and shape are critical to select BIPV for their buildings. Several studies have identified architectural aesthetics as a major limitation for BIPV adoption [8]–[10], with a particular focus on colours. Thanks to advancements in technology, BIPV colours, texture and shapes have been explored in a broader context to match or perhaps overtake modern architectural materials, as seen in Figs. 1 and 2.

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Figure 1. Variety of BIPV colours [11]

Figure 2. Variety of BIPV Texture [11]

In many cases, most coloured or textured BIPV modules come in a multilayered structure, where the layer containing the colour or texture is formed on top of the existing PV module [12]. Technically, because the colour layer absorbs or reflects some amount of the light received, energy efficiency is reduced up to over 40% compared to the conventional modules [13]. This appears to be a significant loss, hence of critical concern to various stakeholders. The focus has been to have the layer built-in to reduce energy losses. A study conducted by [13] highlights the additive method of manufacturing coloured BIPVs to minimise losses. Despite the potential energy loss after the introduction of coloured layers on PVs, it remains the choice for some consumers because of its beauty. For BIPVs to gain full acceptance in the architectural world, it is critical to consider the core elements of aesthetics – colour, texture, and shapes. The market perception about these elements is necessary to inform developers. Very few studies consider the aesthetics or visual appearance of solar applications in buildings [4], hence the need to fill the literature gap. This study thus presents the outcome of a survey conducted among Ghanaians to establish the aesthetic perceptions of BIPVs.

III. Materials and Methods

This study adopts a quantitative method to assess Ghanaians' preferences regarding the aesthetics of BIPVs. Research questionnaires were designed and distributed mainly through surveys. An initial pilot survey was conducted to about 100 respondents mainly from Ghana. However, the feedback indicated little or no understanding of the subject due to the novelty of BIPV in Ghana. The researchers, therefore, introduced infographics and demystified complex words to enable understanding, as indicated in Figs. 3 and 4. Respondents were also given the room to make qualitative entries to support the quantitative data provided.

The survey was distributed through social media, direct emails, and snowballing approach, where participants shared the survey within their circles to reach as many respondents as possible. Respondents in remote areas who could not have access to the internet were offered paper copies to enable them to make their inputs. The retrieved data were statistically analysed by using SPSS and Excel to generate tables and graphs.

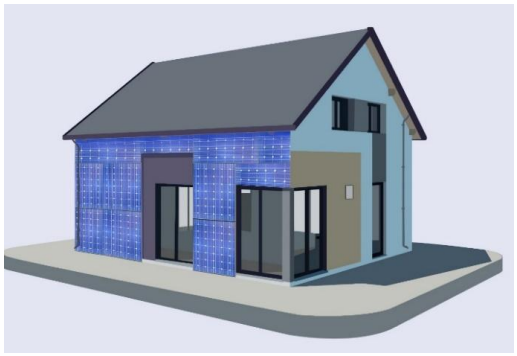

Figure 3. BIPV used for fa çade (Authors construct)

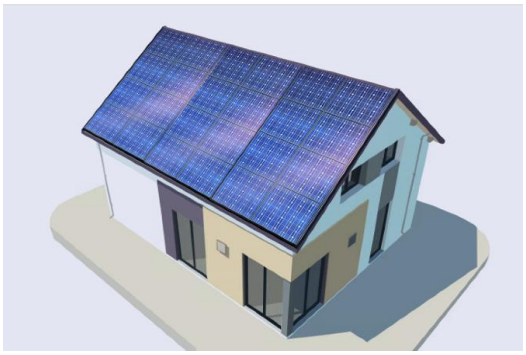

Figure 4. BIPV roofing (Authors construct)

IV. Result and Discussion

The retrieved data were categorised into two fundamental areas. Firstly, the demographics, which mainly captured the age and gender of the respondents. The second part of the survey focused on the aesthetics of BIPV and the Likelihood of adoption. Respondents provided qualitative feedback, which was used to support the quantitative results.

A. Demographics

Gender and age are fundamental factors when it comes to product choice. The age and gender of the respondents have been displayed in Figs. 5 and 6 below. Clearly, majority of the respondents were males (58.8%) and within the youthful ages (between 20–49 years).

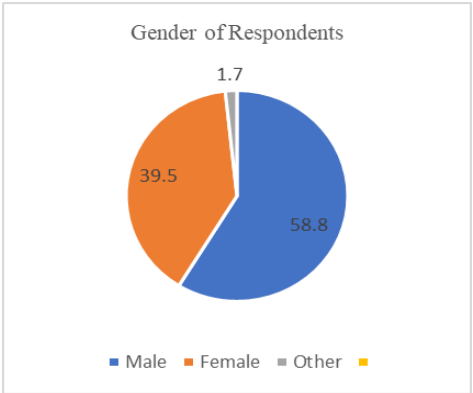

Figure 5. Gender of respondents (Survey data)

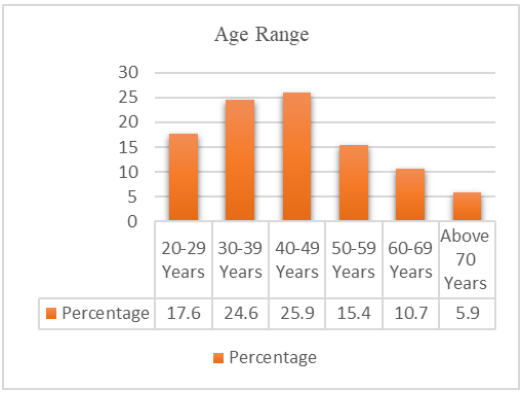

Figure 6. Age of respondents (Survey data)

B. Aesthetics Preferences of BIPV

1) Likelihood to adopt BIPV because of Aesthetics

Although the primary aim of solar PV is to generate energy, BIPV has crossed carpets to become a fundamental architectural material, hence requiring meeting aesthetic specifications [7], [14]. Respondents were asked if aesthetics mattered at all when it came to their decision to adopt BIPV. 94.1% responded yes, and 5.9% said it does not matter, as seen in Fig. 7.

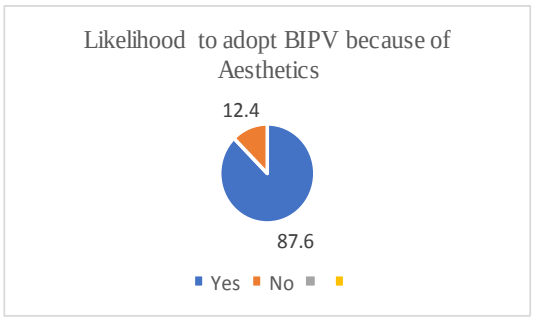

Figure 7. Likelihood to adopt BIPV because of Aesthetics (Survey data)

2) Likelihood to adopt BIPV if there are a variety of colours, textures, and shapes

One of the most outstanding features of BIPVs is the variety of colours and shapes that it offers. Respondents were asked if colours and shapes mattered when it came to BIPV adoption for their homes. Table I shows that 94.1% responded yes, while 5.9% responded no.

TABLE I. LIKELIHOOD TO ADOPT BIPV IF THERE ARE A VARIETY OF COLOURS AND SHAPES

		Frequency	Percent
Valid	Yes	386	94.1
	No	24	5.9
	Total	410	100.0

3) Colour and shape preference

Over 10 million shades of colour are estimated to be visible to the human eye [15]. In this study, colours were put into two main categories, dark and bright colours, to reduce any ambiguity. A more significant percentage (68.9%) of the respondents preferred bright colours, while 31.1% preferred dark colours for their buildings, as seen in Fig. 8. In terms of shapes, respondents were asked whether they preferred BIPV to appear in various shapes or the regular mainstream rectangular shapes. 89.2% preferred BIPV to appear in various shapes, such as triangles, circles, and other asymmetrical shapes. However, 10.8% of the respondents preferred the regular rectangular PV shapes, as shown in Fig. 9.

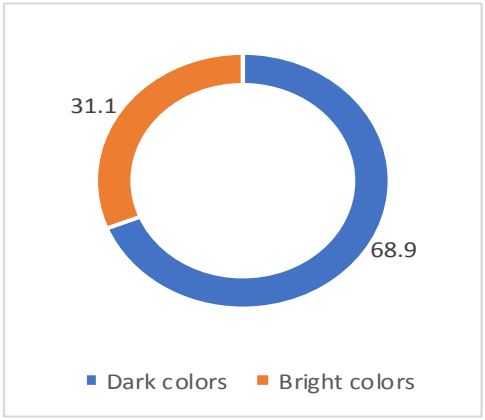

Figure 8. Colour Preference (Survey data)

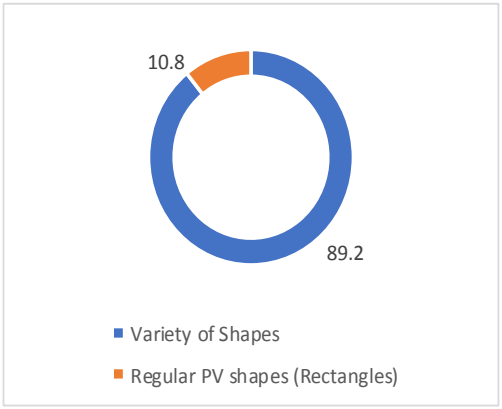

Figure 9. Shape Preference (Survey data)

C. Qualitative Data–Shapes and Color Consideration When it Comes to BIPV Adoption

Respondents were given the room to make qualitative input. 13 respondents commented on their preferences when it comes to shapes and colours for BIPVs and their rationale. In Table II below, respondents have been represented with R (R1–R13).

TABLE II. QUALITATIVE RESULTS

R1	Any shape that will fit the design is fine. Just like building materials have different colours and shapes, BIPV must also have variety
R2	Because it will open up my options. I can have room to choose what I like for my building
R3	Depending on my home design, I can choose the right colours and shapes that fit
R4	Design needs to blend well into the building to give a unique appeal and feel. Flexibility is key
R5	I don't mind, as far as it produces enough energy for my household
R6	I prefer missed colours depending on the design and so far as it is beautiful and classy

R7	I prefer the colours to be available according to needs and modular shapes to meet my architectural design. I also think the architects need to consider the shapes from the very beginning to avoid problems later
R8	If all colours are available, whether dark or bright, consumers will have alternatives to choose from. Depending on the design I will prefer both (dark and bright) so far as it is appropriate
R9	If only there were varieties of solar panels, I think the market would be more interested. Some people prefer colourful finishing
R10	It must blend with the entire house design
R11	I would blend both light and dark colours, depending on the design I want for my building. Variety will bring out beauty
R12	So far as there are different designs or alternatives to choose from
R13	It is important to have a variety of colours depending on the location of the house and considering issues such as culture. Colours have different meanings in different cultural settings. It is important to know the exact location before making a colour choice

Table II indicates that a variety of colours and shapes is critical for the full adoption of BIPV in Ghana. It is imperative for stakeholders to put aesthetics as a cardinal feature because BIPV looks beyond mere energy production. Another important factor that was raised is the cultural context of colours. The culture of the people is important when it comes to a product for buildings since buildings form a major component of the environmental space.

The findings displayed in this study provide valuable lessons relevant to especially BIPV manufacturers, not just within the context of Ghana but across the board. First, the study suggests that aesthetics are of great importance to BIPV consumers. 87.6% of the consumers were happy to adopt BIPV mainly because of aesthetics. This finding is in line with a study conducted by [16], which determined the acceptance rate of BIPV in the context of aesthetics and utility. Consequently, manufacturers need to fully prioritise a variety of colours when it comes to BIPVs, especially dark panels, as indicated by 68.9% of the respondents. This result also aligns with a study conducted by [4] on the colour preference of residential solar panels. Obviously, the distinct feature of BIPVs requires panels to be presented in various shapes, as 89.2% of the respondents opted. Having a general appreciation of these preferences by BIPV manufacturers could potentially increase its adoption.

V. Conclusion

This study aims to explore aesthetic optimisation options when it comes to BIPV adoption in the Ghanaian context. This study considers the need for a variety of colours and shapes of BIPVs. Drawing from the inputs of respondents, colours and shapes have the tendency to boost the overall adoption rate of BIPV. Consumers seek to replace their major building components such as façade or roofs with BIPV, hence the desire for variety in colours and shapes. Even though the BIPV market is small in Ghana and Africa, a keen consideration of these fundamental aesthetic factors could go a long way to help ease market penetration.

This study is expected to inform BIPV stakeholders, especially manufacturers, about taste preferences and some perspectives from consumers.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SA conducted the research and prepared the first draft; NS edited and prepared the final draft; all authors contributed to the design of the research and approved the final version.

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