Building integrated photovoltaics in Ghana: aesthetics and policy.

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BUILDING INTEGRATED PHOTOVOLTAICS IN GHANA; AESTHETICS AND POLICY

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BUILDING INTEGRATED PHOTOVOLTAICS IN GHANA; AESTHETICS AND POLICY

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A thesis submitted in partial fulfilment of the
requirements of
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DECLARATION

I hereby declare that this thesis is original and has been completed independently by the researcher (Samuel Amo Awuku) under the supervision of:

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ABSTRACT

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Title: Building Integrated Photovoltaics in Ghana; Aesthetics and Policy

Buildings are known to account for over 40% of CO_2 emissions globally, a number which is likely to increase if no feasible interventions are adopted. One sure way is the adoption of advanced solar applications such as Building Integrated Photovoltaics (BIPV), intending to make buildings energy producers instead of mere energy consumers. BIPV has benign energy-generating capability and aesthetics concomitantly. Despite the seeming hype and significance of BIPV, its adoption has been relatively sluggish in developing countries. This study considers BIPV adoption in Ghana, focusing on Aesthetics and Policy. Considering the topography, climatic advantage, electricity supply challenges and advancement in the built environment, Ghana is a strategic location for BIPVs, especially as it serves as the gateway to Africa. Currently, there is no evidence of research on BIPV in Ghana, as the focus has been on regular building applied photovoltaics (BAPV).

This thesis, therefore, adopts a mixed method by relying on a blend of quantitative and experimental analysis to investigate the prospects of BIPV in Ghana with a focus on Aesthetics and Policy. Survey questionnaires were administered to respondents to test their level of BIPV awareness, willingness to adopt solar energy and BIPV, aesthetic preferences and policy perspectives. An initial pilot study indicated a low level of awareness hence architectural visualisation (AV), and adverts were used to sensitise respondents ahead of the main survey. Awareness increased significantly (from 18% to 79.5%), indicating the impact of AV and advertising on BIPV diffusion in Ghana. In terms of Aesthetic preferences, the respondents preferred bright colours and a variety of shapes in BIPV design. The study also indicates a high willingness to adopt BIPVs after simulating traditional Adinkra symbols in BIPV design. A further experiment was conducted using the Screen-printing approach to print Traditional Adinkra symbols on solar cells. It examined these symbols' benefits, printing limitations, and characterisation and suggested some enhancement techniques.

The findings reveal that custom patterns for the top contact design of solar cells are achievable through direct printing. However, the outcome showed a lower efficiency due to conductivity issues. Challenges from the printing process, such as thicker line widths and imperfect metal ink bonding, high curing temperature led to shading losses and decreased efficiency. The research suggests optimizing printing parameters, addressing metal ink bonding issues, and minimizing the shading losses by thin line width at the top contact to enhance performance and efficiency. The key findings of this study reveal that BIPV has excellent prospects in Ghana, especially when customised with Adinkra symbols. Key policy areas are ensuring that measures are implemented to boost awareness and providing incentives/financial aid to increase adoption.

This research intersects solar energy, aesthetics, architecture, and policy in Ghana. It highlights the potential of BIPV to transform buildings into energy producers, enhancing both energy efficiency and visual appeal. The study addresses the low awareness of BIPV in developing countries, proposing customized designs using traditional Adinkra symbols to increase acceptance. By focusing on aesthetic preferences and policy, the study informs both green building technologies and policy frameworks aimed at reducing CO_2 emissions and advancing sustainable architecture.

Keywords: Building Integrated Photovoltaics, Aesthetics, Traditional Symbols, Ghana, Innovation, BIPV Adoption

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WORKING PAPERS

W1) Awuku, S.A., Bennadji, A., Muhammad-Sukki, F., Prabhu, R. and Sellami, N. Characterisation of Customized Solar Cell Top Contact – A New Pathway for BIPVs?

W2) Awuku, S.A., Bennadji, A., Muhammad-Sukki, F., Prabhu, R. and Sellami, N. The Prospects of BIPVs in Ghana: An Application of Diffusion of Innovation (DoI) Theory

W3) Awuku, S.A., Bennadji, A., Muhammad-Sukki, F., Prabhu, R. and Sellami, N. An Evidence-to-Decision (EtD) Framework for BIPV Policy in Developing Countries; The Case of Ghana

W4) Awuku, S.A., Bennadji, A., Muhammad-Sukki, F., Prabhu, R. and Sellami, N. An Empirical Study on the Impact of Education on the Willingness to Adopt (WTA) Solar Energy

Table of Contents

LIST OF ABBREVIATIONS

Aesthetic Theory	AT
Bui Power Authority	BPA
Building Applied Photovoltaics	BAPV
Building Integrated Photovoltaics	BIPV
carbon dioxide	CO_2
Demand side management	DSM
Diffusion of Innovation Theory	DOI
Electricity company of Ghana	ECG
Feed in Tarrifs	FITs
Fill factor	FF
Green Building Technologies	GBTs
Green House Gas	GHG
Ghana Grid Company	GRIDCO
Independent Power Producers	IPP
International Energy Agency	IEA
Liquified Petroleum Gas	LPG
Maximum Power Point	MPP
Net zero energy building	NZEB
Photovoltaic	PV
Public Private Partnerships	PPPs

Renewable Energy Technologies	RETs
Scanning Electron Microscopy	SEM
Selectively Modulated Aesthetic Reflectors Technology	SMART
Technology acceptance model	TAM
Theory of Reasoned Action	TRA
Unified Theory of Acceptance and Uses of Technology	UTAUT
United Nations	UN
United Nations Sustainable Development Goal Seven	UNSDG7
Uses and Gratification Theory	U&G
Willingness to Accept	WTA

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.0 General Overview

Although a remarkable margin of success has been attained in the quest to improve global access to electricity and the adoption of renewables, the United Nations (UN) indicators report that there is still a significant lack of reliable and clean energy for all. Nations have shown commitment in line with the United Nations Sustainable Development Goal Seven (UNSDG7) which is to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2021). By 2030, interim targets set by the UN towards achieving this goal make it incumbent on nations to ensure affordable, reliable, and modern energy and particularly increase the share of renewables.

There is a growing global awareness of the ramifications of climate change due to visible signs (Chapman, 2015; Schwartz, 2020), hence a sustainable approach towards reducing greenhouse gas (GHG) emissions is imminent. The looming dangers are threatening and if life goes on with the 'business as usual' disposition, the consequences promise to be dreadful. For instance, it is estimated that about 35 million people were affected by floods and 1600 people died due to heat waves in 2018 as shown in Figure 1.

Diversity in the energy portfolios of nations has become a global demand partly due to issues of climate change and increasing energy demand. The quest for nations to variegate energy sources and find replacements for high GHG emitters, particularly carbon dioxide (CO_2) has been the major motivation for adopting cleaner sources.

Figure 1. State of Climate Change Effects (World Meteorological Organisation, 2023)

On the other hand, many countries, especially in the developing world, are faced with various degrees of electricity crises, which impede economic growth and development (Boamah et al., 2021; Ebhota and Inambao, 2016; Kaseke and Hosking, 2013; Murshed and Ozturk, 2023).

Renewable energy Technologies (ReTs) have been championed as the most reliable energy option, especially as the push to evict fossil fuel increases. Popular renewables are solar, hydro, tidal, wind, biomass, marine energy and geothermal (Ellabban et al., 2014). Undeniably, solar remains one of the top options, especially in areas where sunlight is abundant (Khan and Arsalana, 2016). Solar energy has proven to be a capable and reliable source of electricity that can replace cruddy energy sources such as fossils (Kabir et al., 2018).

Photovoltaic (PV) technology, after its emergence in the 19^{th} century, has gone through massive growth in areas of efficiency, aesthetics, market penetration and cost, (Kannan and Vakeesan, 2016; Shubbak, 2019; Williams, 2016). PV technology works in a very simple way; by converting sunlight into electricity through semiconductors. Figure 2 gives a visual representation of how solar PV works. PV application has evolved over the years, from large-scale PV farms and PV integration in vehicles to domestic appliances such as TV sets, radios, air conditioners and torches (Kube Afrika, 2020). Advancements in solar technology have led to the nascency of Building Integrated Photovoltaics (BIPV) like its counterpart Building Applied Photovoltaics (BAPVs) (Petter et al., 2012) . This study focuses on BIPV and the dilemma surrounding its prospects in Ghana.

BIPV simply means using solar PVs to replace conventional building materials such as roofs, windows, and façade so that they form part of the building envelope after construction. Here, the cost of the original building material is completely bypassed, and the general appearance of the building is enhanced (aesthetics) making BIPV advantageous over others (Debbarma et al., 2017).

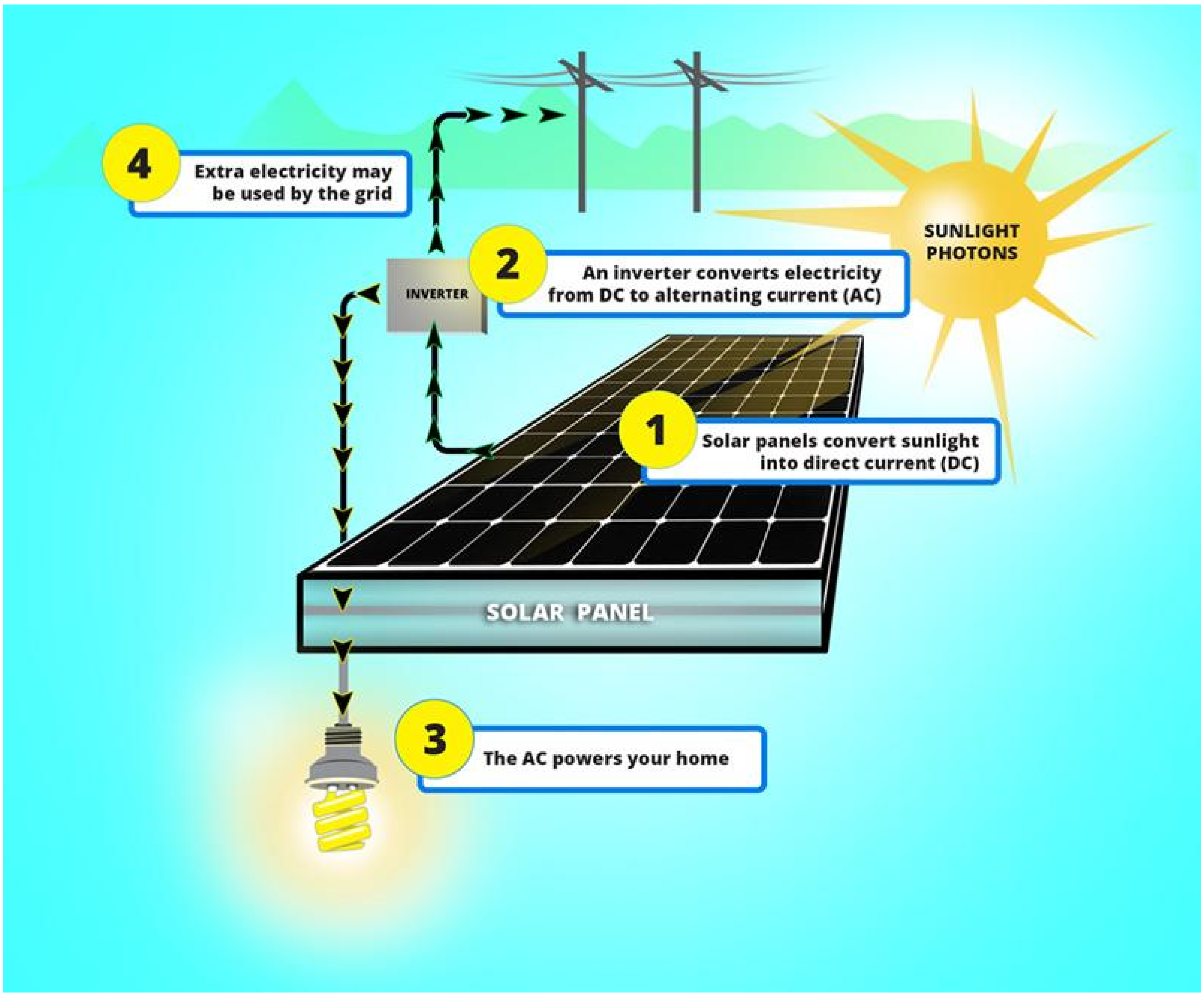

Figure 2. How solar PV works (Keskin, 2020)

BIPVs have great prospects as the push for Net Zero Energy Buildings (NZEB) and Green Building Technologies (GBTs) advances globally. General concerns about the aesthetics of solar PV applications on environmental landscapes and especially on modern architecture have been one of the major drivers of BIPV. Many industry players and researchers opine that BIPVs have not reached their peak of acceptance and adoption partly due to issues such as cost, reliability, sociocultural factors, psychological factors, and aesthetics (Curtius, 2018; Heinstein et al., 2013; Janusz, 2023; Linghui and Dai, 2024). It is often the case that aesthetics do not come up as the foremost consideration when it comes to solar energy adoption, however, research shows that it forms a crucial part of BIPV advancement (Crolic et al., 2019; Patrick, 2016; Venkatesh and Meamber, 2008).

The idea that PVs can harmoniously blend into the building envelope without sticking out or becoming an add-on comes off as welcoming news for homeowners and architects. BIPVs are gradually emerging as the new sensation when it comes to modern architectural finishing and promoting sustainable energy in buildings. The BIPV market is expected to grow exponentially and enjoy reduced costs due to economies of scale in the coming years (Kuhn et al., 2021). Sustainable mechanisms to boost BIPV adoption are therefore incumbent. The next topic gives a brief context and background to the study.

1.1 Background of the Study

Buildings account for nearly 40% of the energy consumed globally and contribute about 33% to GHG emissions (Tricoire, 2021). These figures indicate danger if climate change predictions are anything to go by. The quest to re-orientate traditional buildings from energy-consuming to a self-generating capacity is primal. Since the adoption of PVs, architectural and aesthetic values have been keenly desired by manufacturers and end users. BIPVs had already started penetrating the market as early as the 1990s with traces of PV materials being used to replace conventional building façades and walls in parts of Europe (Heinstein et al.,2013).

Apart from the electrification ability derived from BIPVs, it reduces the overall cost of a building. Since an entire building component can be replaced with PV material, a considerable amount of money is saved on conventional building materials and at the same time guaranteeing electricity. Other advantages include the provision of lighter materials for building, comfort, "heat insulation, electromagnetic shielding and thermal insulation" (Heinstein et al., 2013; Gholami and Røstvik 2020). In many instances, it is difficult to tell the dissimilarity between the conventional building materials and the PV material swap in BIPV applications (Peng et al., 2011). Indeed, BIPV systems tend to give a pleasant visual effect and an architectonic face-lift to buildings if applied aesthetically.

The idea of BIPV has been embraced by many countries, especially in Europe, America, and Asia (Curtius, 2018). This has stimulated its widespread in many other parts of the world although at a very gradual pace and with many others warming up to embrace it. BIPVs have been very essential in reducing building emissions in many States considering all the advantages it comes with. It is imperative that an investigation is conducted into the potential adoption of BIPV in Ghana, considering its topographical location, fast-paced industrialisation, and economic growth. The recent strides made in Ghana's solar sector indicate an unflinching commitment by various governments to make it a stable energy source. BIPV fits perfectly into Ghana's future energy needs to aid homeowners and industries gain "grid independence" by having the ability to be "self-energy generators" instead of over-reliance on the national grid system.

Again, although Ghana has shown great commitment towards adopting solar technology, fundamental issues such as the inflated cost of land have inhibited progress in public-private partnerships (PPPs) (Awuku et al., 2021). This ends up skyrocketing the overall cost of solar projects making it uncompetitive, especially in bigger cities where land is costly. For instance, in Accra, the average price of a piece of plot (80x100ft) ranges between USD 7000 – USD 45,000 (Ghana Property Centre, 2024). BIPV, therefore, promises to be the lasting solution to promote solar PV adoption in Ghana's built environment while preserving the beauty of buildings and landscapes.

Culture is considered a fundamental factor when it comes to the adoption of solar technology (Lin and Kaewkhunok, 2021). It influences design choices, aesthetic preferences, and social acceptance. Cultural elements can enhance public appeal and acceptance, especially in areas where traditional architecture and symbols are valued. For instance, aligning BIPV designs with local visual symbolism such as colour, pattern and shape has the tendency to make the technology more relatable, therefore promoting its wider adoption while preserving cultural identity.

The fundamental aim of BIPV is to introduce beauty in PV applications in the built environment (Attoye et al., 2017; Awuku et al., 2021; Kryszak and Wang, 2020; Peng et al., 2011; Shukla et al., 2017; Soman and Antony, 2019). Ideally, BAPV plays its role of providing clean energy perfectly. However, it is often said to compromise the beauty of buildings, hence the need for BIPV (Attoye et al., 2017). Aesthetics in the Ghanaian context comes in different forms. By nature, Ghanaians are cultural and identify with symbols and totems with deep proverbial meanings irrespective of their location. Famous amongst these are Adinkra symbols. Adinkra symbols are known to be ubiquitous aphorisms which serve as a major national identity in Ghana (Blount and Brookins, 2021). Adinkra symbols have been known to promote product adoption in Ghana. Empirical points to the fact that there is a positive correlation between Adinkra symbols and product adoption (Ofori-Amoah, 2019). For instance, Adinkra symbols have been known to boost the adoption of furniture, textiles, architectural components, artefacts, and other products among Ghanaians (Sleet, 2016; Aboagyewaa-Ntiri et al., 2018; Aboagyewaa-Ntiri et al., 2019; Deng and Nanor, 2021; Inkum et al., 2021; Ampadu et al., 2022). This study, therefore, leverages the power of Adinkra symbols to boost BIPV adoption in Ghana. It explores the nexus between traditional symbolism and BIPV adoption. BIPV promises to make a great difference in Ghana's built environment and further boost the adoption of solar energy (Awuku, 2021).

1.2 Brief Background of Ghana

Ghana is a resource-rich nation located in West Africa mainly bordered by Togo, Burkina Faso, Ivory Coast, and the Gulf of Guinea as shown in Figure 3 (Boateng et al., 2024). Being the first country to break away from colonial rulership in the Sub-Saharan, Ghana is considered a beacon of democracy and infrastructural development among its peers (Political Desk Report, 2021). Ghana's population is around 34,654,108 (Worldometer, 2024). In total, the country is demarcated into 16 administrative divisions (regions).

Figure 3. Map of Ghana indicating bordering countries (Boateng et al., 2024)

Ghana has a total land space of about 227, 540km^2 (The World Bank, 2022) and lies at latitude 8° 00 N and 2° 00 W (Maps of World, 2022). Ghana has high solar irradiation as it lies between 15° North and 15° South parallels in the equatorial belt making it an excellent destination for solar technology to thrive (Atsu et al., 2016).

1.3 Research Problem

Although BIPVs have been touted as the future of solar PV applications in buildings, their adoption has been relatively slower than expected. Fundamental limitations such as technical barriers, the issue of efficiency, design and aesthetics, public perception, awareness and education, economic limitation, social acceptance, and limited demo projects have been identified as key limitations to its adoption (Attoye et al., 2017; Imenes, 2016; Petter Jelle et al., 2012; Sackey et al., 2020; Shukla et al., 2017). The BIPV concept is novel in developing countries such as Ghana, unlike its counterparts BAPVs and mini grid-tied farms (Asumadu-Sarkodie and Owusu, 2016). As of the time of this study (2024), there was little evidence of studies in Ghana on the adoption of BIPV. This knowledge gap presented a significant opportunity for this study to contribute valuable insight into the current state of BIPV awareness, aesthetics, and policy perspectives in Ghana.

The current population growth rate and the level of industrialization in Ghana amidst increasing energy demand have given cause to consider lasting and sustainable energy options. Past and present governments have attempted to adopt policies to ensure that sustainable energy options such as solar get an adequate representation in the energy mix of the country. For instance, the adoption of the "National Renewable Action Plan" to increase the share of renewables (Energy, 2019). However, the extent of success is debatable. A bigger plight for the government is to meet the country's growing energy needs. It is common knowledge that there is a direct correlation between energy paucity and high poverty levels, rural-urban migration, mortality rate and illiteracy (Lipton and Ravallion, 1993).

Naturally, people will migrate to urban areas where electricity is available and may have access to basic amenities. In many remote communities in Ghana, asking for the "basic erratic electricity supply" is a challenge. Indeed, in recent times, the government and similar organizations have made some considerable attempts to expand rural electrification and energy stability even in the urban centres yet over 1.2 million households still live in darkness (USAID, 2020). The expensive nature of land in Ghana, especially in urban areas makes investments in Solar projects exorbitant (Awuku et al., 2021). For instance, Ghana's 13 MW Kaleo solar project is estimated at £22.8 million (African Energy Portal, 2020), whereas a similar one in Cyprus is around £14 million (Balkan Green Energy News, 2020). Part of the overburdening cost can be attributed to the high cost of land which BIPVs eliminate. Understandably, various economic circumstances come into play when it comes to pricing such projects, however, the bottom line is finding a cost-efficient approach to executing these projects.

Also, the power of aesthetics has been underrated in many countries, especially in areas of solar PV applications (Sánchez-Pantoja, 2018). This has given rise to a growing concern about landscape design and environmental beauty (Daniel, 2001; Jenkins, 2020; Lothian, 1999; Sánchez-Pantoja et al., 2018) . The regular scanty nature of PV setup, which sometimes ends up stealing the 'glory' of beautiful architectural edifices has been the norm. This has resulted in an outcry from both consumers and other stakeholders who are especially particular about beauty. Aesthetics do not just play a fundamental role in PV adoption but serve as the basis for many modern architectural green building plans. The narrative remains that Aesthetics have been least considered in the adoption of PVs and until critical attention is given, its adoption in a country like Ghana may remain fictitious, especially as the appetency for architectural beauty grows in many urban areas.

On the flip side, aesthetics forms a critical part of the consumer decision-making process but has been replaced completely with factors such as cost, quality, and ergonomics. The discussion about building and landscape distortion (Daniel, 2001; Lothian, 1999; Sánchez-Pantoja et al., 2018) especially in urban areas remains an issue of concern. The idea that the beauty of the environment, landscapes and buildings is gradually being compromised due to the adoption of 'clean energy' is burdening. Several studies have highlighted growing concerns about aesthetics in renewable adoption in various countries (Awuku et al., 2021; Daniel, 2001; Lothian, 1999; Pantoja et al., 2021; Sánchez-Pantoja et al., 2018), hence worthy of consideration in Ghana.

Indeed, the hysteria about renewables by many egalitarians, green-agenda pushers and academics has gradually compromised and side-lined other basic factors such as aesthetics. Without aesthetics, proper layout, and plan, the future of PV adoption in buildings may likely be undesirable. As modernity increases, the exigencies of the ethics of aesthetics become pre-eminent by the day, especially in BIPV applications and power line transmissions (Wuebben, 2017). No matter how attractive Photovoltaics are presented as a viable source of electricity in the architectural world, aesthetics cannot be compromised. Considering the critical limitations highlighted above, the adoption of BIPV in Ghana is primal. Although BIPV has many aspects worthy of investigation, this current study focuses on its market adoption, aesthetic considerations, and policy in Ghana (Awuku, 2021).

1.4 Justification of Study

The growing energy demands of Ghana; partly due to peri-urban migration, population growth and industrialisation as well as its topographical location make it a viable location for solar energy within the sub-Saharan region. The commitment shown by present and past governments towards adopting various renewable energy options especially solar makes it a fertile ground to propose an advanced option such as BIPVs.

Several studies have been conducted on solar energy systems, especially in the areas of BAPVs and solar for rural electrification in Ghana (Atsu, et al., 2016; Asumadu-Sarkodie, 2016; Owusu and Obeng et al., 2008). However, there is a lack of knowledge of BIPVs in Ghana. From a broader perspective, Solar as a viable RE option has received immense attention from the government, homeowners, and investors (Serwaa-Mensah et al., 2014), but BIPVs have been given very little attention. Instead, applying a few basic solar panels on one's roof (BAPV) and establishing utility-scale grid-connect mini solar farms has been the centre of focus (Mensah et al., 2019). It is expected that considering the looming repercussions of climate change and increasing energy demand, sustainable energy options such as BIPVs could be adopted within the built environment to reduce emissions and reduce over-reliance on the national grid. The result of this project will provide significant knowledge on the adoption of BIPVs in Ghana. Apart from shedding light on the possibility of adopting BIPVs in Ghana, this project seeks to offer an understanding of the Aesthetic values as well as policies related to BIPVs (Awuku, 2021).

1.5 Aim of Research

This study aims to adopt a mixed research method to critically examine the challenges and prospects of BIPV in Ghana, with a focus on proposing an optimal BIPV policy framework. In pursuit of this aim, the research considers the critical relevance of aesthetics in the conceptualization, design, and implementation of relevant BIPV policies in Ghana. In short, this study aims to Investigate the prospects of BIPV in Ghana with a focus on Aesthetics and Policy (Awuku, 2021).

1.6 Research Objectives

The Cliché SMART (Specific, Measurable, Assignable, Realistic and Time-related) became popular after its inception in 1981 (Doran, 1981). As the name implies, it provides a realistic model for setting attainable objectives (Ogbeiwi, 2017). This study, therefore, relies on the SMART model to develop four realistic objectives which are:

A. To determine the effectiveness of architectural visualisation and advertising in raising BIPV awareness in Ghana.

B. To establish the nexus between Adinkra symbols and BIPV adoption in Ghana.

C. To use screen-printing techniques to transfer traditional Ghanaian Adinkra symbols on solar cells and examine their characterisation.

D. To identify and propose favourable policies to promote BIPV adoption in Ghana.

1.7 Research Hypotheses

The following hypotheses have been formulated:

Hypothesis 1

To establish whether there is an association between the level of education and knowledge/awareness of solar energy, the following hypotheses were formulated:

H_0: There is no significant association between the level of education and knowledge/awareness of solar energy of the respondents.

H_1: There is a significant association between the level of education and knowledge/awareness of solar energy.

Hypothesis 2

To establish whether there is an association between the level of education and the adoption of solar energy, the following hypotheses were formulated:

H_0: There is no significant association between the level of education and the adoption of solar energy.

H_1: There is a significant association between the level of education and the adoption of solar energy.

Hypothesis 3

To establish whether there is an association between educational level and the adoption of solar energy because of the availability of a flexible loan scheme, the following hypotheses were formulated:

H_0: There is no significant association between educational level and adoption of solar energy because of the availability of a flexible loan.

H_1: There is a significant association between educational level and adoption of solar energy because of the availability of a flexible loan.

Hypothesis 4

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.

Hypothesis 5

To establish whether there is an association between educational level and the willingness to adopt BIPV, the following hypotheses were formulated:

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

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

Hypothesis 6

To establish whether there is an association between educational level and the adoption of BIPV because of aesthetics, the following hypotheses were formulated:

H_0: There is no significant association between educational level and adoption of BIPV because of aesthetics.

H_1: There is a significant association between educational level and adoption of BIPV because of aesthetics.

1.8 Research Scope

Although extensive research has been conducted on solar energy in Ghana and its preponderance, the adoption of BIPVs by homeowners, architects and other stakeholders has been barely discussed. This leaves very little information on BIPVs in the Ghanaian context, especially when it comes to aesthetics and policies that surround its adoption. The overall aim of this thesis is to investigate the opportunity for BIPV adoption in Ghana with a focus on aesthetics and policy. This research is relevant to all stakeholders, as it carries substantial knowledge on the topic and makes clear-cut policy recommendations. For this research, the geographical location for data collection and analysis is Ghana. This research is limited to collecting data from 412 home/potential homeowners with survey questionnaires. Part of the research also relies on an experimental design (Awuku, 2021).

1.9 Structure of the Thesis

The thesis has been grouped into seven major chapters. Fundamentally, the various chapters are interrelated to ensure a flow and vivid understanding of the entire thesis. A summary of the various chapters is provided below:

Chapter One: This chapter subsumes the general overview, background, and context. Other cardinal aspects such as research problem, aim of study, objectives, research questions scope of study and structure of thesis have been highlighted.

Chapter Two: This chapter offers exclusive insight into the various dimensions of related literature to identify the knowledge gap and further validate the study. The literature covers aspects related to the theory of BIPVs, product adoption in Ghana, aesthetics, and other pertinent topics.

Chapter Three: This chapter contextualises the various research approaches adopted for the study. It highlights the framework, source of data, strategies, sampling, data analysis approach, data validation and ethical considerations.
Chapter Four: This chapter presents the retrieved data from the survey and provides an analysis of the findings. It utilises SPSS as the major statistical tool. Here, various characteristics of the survey such as demographics, and adoption, among other dependent and independent variables are statistically presented. It further provides validity and normality tests, the margin of error and presents qualitative data retrieved from the survey. It also presents the outcome of the experiment conducted on printing Adinkra symbols on solar cells.
Chapter Five: This chapter offers an extensive discussion of the empirical findings of the study. It presents the major findings and discusses the Policy implications as well as Policy lessons for BIPV adoption in Ghana. It also provides a summary of the thesis. The chapter also highlights the conclusions, originality, and contribution to the body of knowledge. It also makes recommendations for future studies.

1.10 Chapter Summary

This chapter serves as the gateway to the thesis. It highlights the introduction and justification of the thesis. It gives an insight into the main research aim, objectives, and questions. It further highlights the scope and provides a summary of the various chapters in this thesis. Due to the novelty of the study especially in Ghana, the research mainly relies on mixed methods to achieve selected objectives. Pertinent literature related to BIPVs, product adoption in Ghana, and Aesthetics has been carefully studied to establish the knowledge gap. It further identifies how aesthetics and traditional Adinkra symbols can be used as drivers to boost BIPV adoption in Ghana. The end game is to provide attainable and realistically impactful policies to make BIPV adoption a reality in Ghana in the immediate future. The next chapter explicitly presents pertinent literature related to the study.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This study adopts a blend of narrative and theoretical literature review approaches. The narrative review approach is one of the most traditionally adopted for scientific and social science research. It critiques existing literature and summarises core issues (Jahan et al., 2016; Pautasso, 2019). The narrative review approach usually sets out to discuss and draw conclusions on a specific topic according to the findings while identifying existing gaps, therefore proving justification for the current study. Theoretical review on the other hand delves into the review of applicable theories that underpin a study (Larabee, 2022). This research is positioned within key bodies of literature on solar energy, architecture, aesthetics, and policy. It contributes to the existing literature on solar energy by exploring the sustainability, efficiency, and adoption of BIPV in Ghana. In architecture, the study demonstrates how BIPV technology can seamlessly blend into building designs, thereby enhancing both aesthetics and functionality. Additionally, it contributes to policy discourse by identifying measures to enhance BIPV adoption through aesthetic improvement, public awareness, and incentives.

Research on renewable energy technology, its marketing, economics, and policy has been embraced across the academic spectrum. However, emerging areas such as BIPV adoption, its aesthetics and policy appear understudied, especially in developing countries such as Ghana. Few empirical pieces of evidence can be traced from various research archives. This chapter, therefore, delves into the existing literature on BIPV adoption, especially in Ghana. Pertinent topics that concatenate have been extensively explored to highlight the need for BIPV in Ghana's built environment. Related articles and data have been carefully selected from credible sources to make the facts presented verifiable.

This review demonstrates a clear synthesis, critical scrutiny, critique, and acknowledgement of the data used. Preliminary topics such as Ghana's energy problem and the issue of climate change have been explored to set the premise for the study. Further topics on renewables, solar energy and BIPV have been reviewed. A fundamental theory of adoption; diffusion of innovation theory (DOI) has been reviewed to set the theoretical pathway for the study. Literature is also provided on the theory of aesthetics and screen-printing techniques. Finally, an empirical review of BIPV in Ghana and Africa has been conducted to purposefully highlight the gaps in the literature. This study is purported to augment existing literature on the aesthetics of BIPV and its adoption in Ghana. Although the results and findings provided are based on Ghana, they may be applicable in other countries, especially in Africa. The literature adopts a story-telling and systematic approach to ensure easy flow and comprehension. Figure 4 shows the conceptual flow for the literature review.

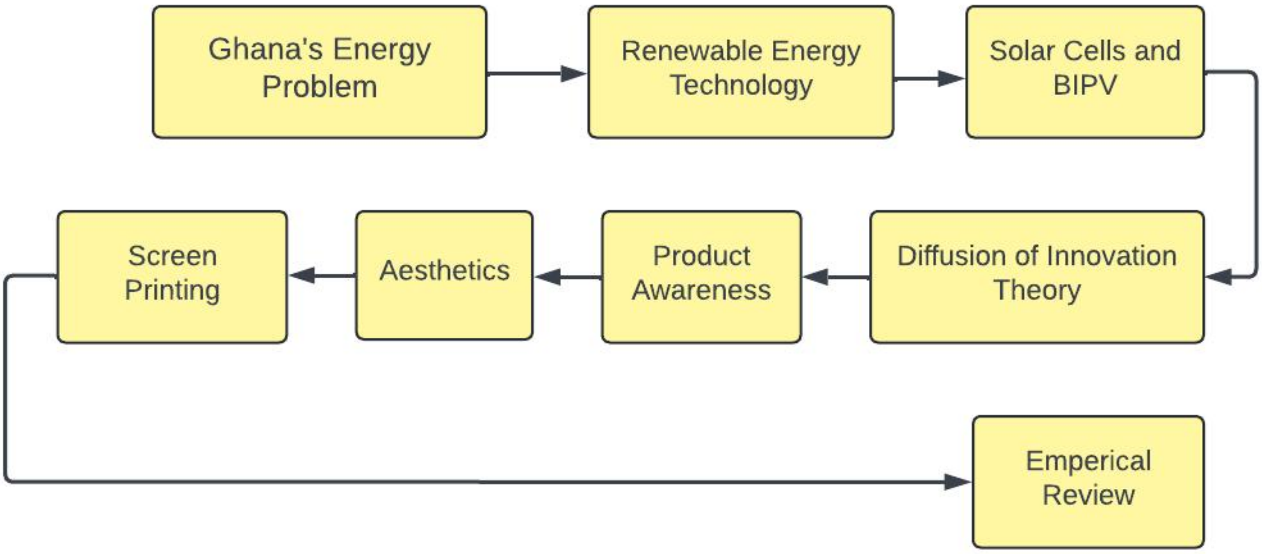

Figure 4. The Conceptual Flow of Literature Review

2.1 Ghana's Energy Problem

The core aim of this section is to understand Ghana's energy problem. It gives direct relevance to the need for alternative energy solutions such as BIPVs by shedding light on the past and current energy challenges.

The appetite for varied energy sources has aggravated considering the ever-growing quest for energy diversification due to the economic boom, urbanisation and accelerated industrial activities (Gyamfi et al., 2015; Kumi, 2017). This has led to the exploration of other energy sources such as renewables. Although some nations have made great strides in terms of energy security, it cannot be said that their successes are everlasting especially as cost and environmental dynamics keep changing. Evidently, the global energy hurdles across the board are affordability, accessibility, availability, and acceptability (Cherp and Jewell, 2014).

These hurdles remain the bane of many nations including Ghana. There is a direct correlation between access to energy and the advancement of humans. Nonetheless, it is estimated that globally about 1.3 billion people lack electricity and about 3 billion lack clean cooking fuel. Interestingly, about 95% of people without access to electricity are from Sub-Saharan Africa and developing Asia (World Energy Outlook, 2019; IEA 2019; Ritchie and Roser, 2019).

On a general outlook, electricity generation and distribution in Ghana is primarily the role of the Volta River Authority (VRA), a State-owned entity born in 1961 and its subsidiary; Ghana Grid Company (GRIDco). About 70% of electricity is expected to be generated by VRA, until the recent decline in generation capacity. The remaining 30% is sourced from other subsidiary generation plants such as the Bui Power Authority (BPA), with 10% capacity and Independent Power Producers (IPP) accounting for the remaining 20% (Volta River Authority, 2021) . At face value, this estimate seems perfect, yet Ghana still struggles for sufficient and sustainable energy. Droughts resulting in reduced water levels in the Akosombo dam, reduced rainfall, and gas procurement challenges have been identified as key contributors to Ghana's electricity generation challenge. The economic implications are incalculable, for instance in a study conducted by the Institute of Statistical, Social and Economic Research, Ghana is expected to lose around 320 to 924 million dollars per annum in its production sector due to inconsistency of electricity supply (Oxford Business Group, 2021).

Ghana is considered a beacon among its counterparts in Africa as about 87% of its residents have access to electricity (Ghana Energy Commission, 2022). Regardless, this leaves a whopping 13% of its populace in darkness. Figure 5 shows the electricity map of Ghana. Despite efforts being made by the government to expand electrification (Bukari et al., 2020), the problem still staggers due to rapid urbanisation, industrialisation, and population growth.

Figure 5. Electricity access map of Ghana (Ghana Energy Commission, 2022)

In history, Ghana has been hit by load shedding in 1983, 1998, 2006/7, 2012-15 and in 2021 (Caterina, 2016; Lartey, 2021) . The bulk of Ghana's power crises have been attributed to shortfalls in supply, theft, high cost of transmission and distribution and inability to properly price and monitor revenue generated from the sector (Gyamfi et al., 2018). The intermittency and erraticism of electricity supply in Ghana have become an enduring perennial hurdle that threatens the stability of the economy by impeding growth, productivity, and development. Rationing electricity in ‘tots’ halts business and social activities, leaving grave repercussions on the economy.

The dearth of electricity in Ghana has resulted in the Electricity Company of Ghana (ECG) strategically rationing power in areas of the country. Figure 6 shows a typical rationing schedule for selected areas in Ghana (Arhinful, 2021).

GROUP A	GROUP B
Nsakina, Oduman, Odokor Official Town, Awoshie, Odorgonno, Mallam Abease, Kokompe, Zamrama line, Banana Inn, Chorkor, korle Gonno, Gbegbeysee, Shiabu, Kwashi-Bu, Abeka Lapaz, Nii Boye Town, Alhaji, Sowutuom, Ablekuma New Town, Top Base, Dansoman Control Market, GBC Staff Quaters, Old barrier, Opeikuma, Ashalaja, Lamptey Mills	Lower McCarthy, Mallam, Gbawe, Agape Juntion, Bubiashie, Demod, Abossey Okai, Santamaria, Mataheko, Bortianor Red Top, New Aplaku, Dansoman SSNIT Flats, Glefe, Nyanyanso, Nyanyanso Kakraba, Iron City, Breku, Tuba
OUTAGE DAYS AND TIME	**OUTAGE DAYS AND TIME**
10TH MAY, 2021 - 6AM TO 6PM **12TH MAY, 2021 -** 6PM TO 6AM **14TH MAY, 2021 -** 6AM TO 6PM **16TH MAY, 2021 -** 6PM TO 6AM	**10TH MAY, 2021 -** 6PM TO 6AM **12TH MAY, 2021 -** 6AM TO 6PM **14TH MAY, 2021 -** 6PM TO 6AM **16TH MAY, 2021 -** 6AM TO 6PM
GROUP C	**GROUP D**
Sakaman, Hansonic, Upper McCarthy Hill, Tettegu, Melcom Plus Industrial Area, Abeka Market, Lartebiokorshie, Tantra Hill, Nyamekye, Pokuase ACP Estates, Amasaman, Anyaa, NIC, Nsumfa, Antieku, Bortianor, Wesley Grammar, Ayigbe Town, Korkordzor, Banana Inn, Mamprobi New Town	Odokor, St. Anthony, Djaman Township, Oblogo, Salaga Market, CMB Flats, Mamprobi, Soko, Taifa, Ofankor, Asafo, Alhaji, Tabora, Chantan, Isreal, Fadama, North Kanashie, Joma, NIC Top, Seminary, Sowutuom Last Stop, Ablekuma Curve, Russia, Sukura, Kokrobite, Bortianor, Osofo Dadzie, Datus
OUTAGE DAYS AND TIME	**OUTAGE DAYS AND TIME**
11TH MAY, 2021 - 6AM TO 6PM **13TH MAY, 2021 -** 6PM TO 6AM **15TH MAY, 2021 -** 6AM TO 6PM **17TH MAY, 2021 -** 6AM TO 6PM	**11TH MAY, 2021 -** 6PM TO 6AM **13TH MAY, 2021 -** 6AM TO 6PM **15TH MAY, 2021 -** 6PM TO 6AM **17TH MAY, 2021 -** 6PM TO 6AM

Figure 6. Electricity rationing scheduled for May 2021 (Arhinful, 2021)

A 2021 World Bank economic review shows that firms and individuals have found strategic ways to respond to these outages in the past but have proven detrimental. For instance, firms reduced their working capacity and shifts, resorted to using generators, reduced the number of operating hours, alternated production periods, suspended production and laid off workers (Abeberese et al., 2021).

Some proponents opine that the electricity problem in Ghana can be subsided if the interval between demand and supply is reduced through demand-side management techniques (DSM). DSM is a management technique where the activities of electricity consumers are planned and monitored to reduce consumption. In this case, consumers are advised to reduce power usage during peak times (Gelazanskas and Gamage, 2014). This has been the practice in Ghana for some time now. However, the extent of success is debatable as, from all indications, a stable electricity supply remains a challenge. Finding the balance between supply and consumption is important for sustainability. Ghana's energy problems cannot be underrated as they have proven to be chronic and require swift attention.

On the flip side, spreading the energy tentacles of the nation with a focus on especially solar energy has been identified as the 'game-changer' for Ghana's energy sector (Atsu et al., 2016). Current solar trends in Ghana point to two key classifications: Independent Power Producers (IPPs) - (these are firms given the capacity to generate their electricity and sell back to the national grid) (Oxford Business Group, 2021) and Independent solar companies - (these are companies that retail and install solar products for consumers).

The demand for solar technology in Ghana is on the rise as people are desperate for sustainable energy options considering the intermittent chronic energy dilemma (Kuada and Mensah, 2020). However, the solar industry has its own 'bottlenecks and barriers that impede its development. Key ones among them are cost, poor marketing strategies, architectural concerns (aesthetics), low level of awareness, social acceptance, and perceptions (Atsu et al., 2016). The obvious expectation is that solar energy will become Ghana's energy saviour in the immediate future. Considering the growing energy demand and upward trend of the solar industry amidst the erratic power supply from the national grid, solar stands a chance of being the energy saviour of Ghana.

2.1.1 Growing Energy Demand in Ghana

In recent years, the unwavering role of energy for domestic and industrial usage has been heightened in Ghana like many developing countries partly due to economic growth and an increase in population. Divergent sources of energy are required to sustain the energy required for transport, electrification, and cooking, among others (Mensah et al., 2016). The situation in Ghana is not different from that of many other developing countries where demand exceeds supply, leaving a marginal energy deficit that results in intermittent power shortages and load shedding. Ghana’s inability to fully explore various modern energy sources to augment mainstream traditional sources has gradually increased the energy gap, especially in rural communities and off-grid areas. It is estimated that about 76% of Ghanaians partly depend on traditional biofuel for domestic activities such as cooking and heating (Mensah and Adu, 2015). Gradually, awareness and concerns about the dreadful implications of traditional biomass on the environment and health of users are increasing. However, due to the urgency of energy needs to be met, the average user has no other option but to rely on these traditional sources of energy.

Almost every government in Ghana since independence has attempted to implement various policies to improve the energy situation in Ghana, whether for electrification or cooking. For instance, they champion the use of Liquified Petroleum Gas (LPG), and attempt to reduce the prices of these energy sources (Mensah and Adu, 2015). Although the price of LPG is relatively low, the income of consumers and urbanisation have been identified as the major drivers for switching to modern LPG fuel sources. There has been a significant success partly due to awareness, education, and price falls. For instance, between 2008 to 2019, petroleum became the dominant energy source in the energy mix of Ghana. Figure 7 shows Ghana's energy consumption between the years 2000 and 2019 (Ghana Energy Commission, 2020).

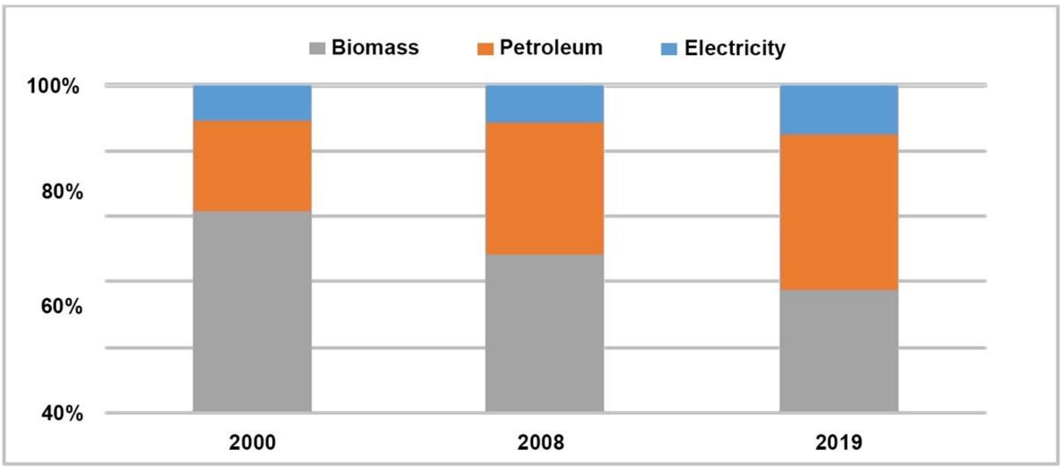

Figure 7. Energy consumption of Ghana between the years 2000 to 2019 (Ghana Energy Commission Ghana, 2020)

The government of Ghana in the quest to bridge the growing energy gap is planning to invest about 1.5GW in wind farms by 2030, increase solar energy installations and aim to increase the production capacity of its oil reserves by 2025 (Ghana Energy Commission, 2020).

The growing energy demand of Ghana cannot be halted as the population keeps increasing and all the other demand drivers keep moving. A more formidable and sustainable approach is therefore required to keep up with this trend.

2.1.2 Global Growing Energy Demand

Understandably, as industrialisation increases, urbanisation is fast-paced and other economic activities boom, the relative energy consumption is expected to increase. The growing concerns of stakeholders and the public are overwhelming, especially considering the environmental complications, global warming concerns, challenges in meeting energy supply and gradual depletion of exhaustible energy reserves. The petrifying data shown by the International Energy Agency (IEA) indicate a projection of significant growth in energy consumption especially with developing countries (Africa, Asia, South America, and the Middle East) at an average of 3.2%. Figure 8 shows a projection of the global energy consumption by region.

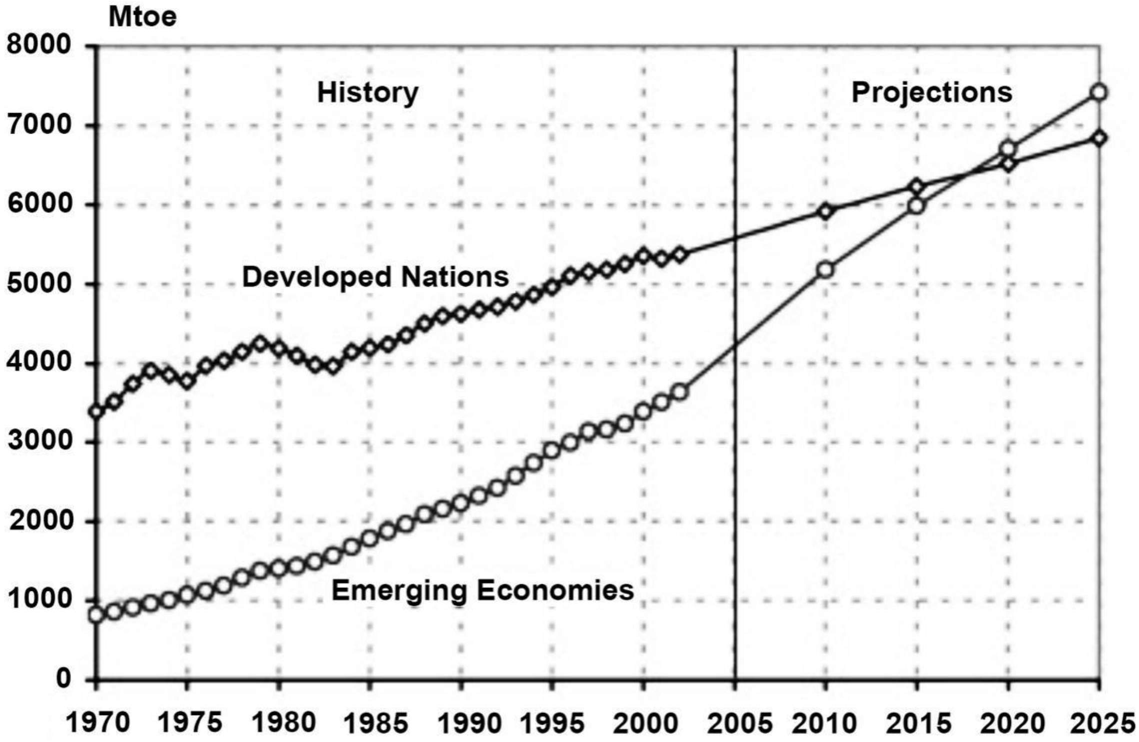

Figure 8. Projection of Global energy consumption by region (EIA, 2022).

Energy consumption and CO_2 emissions have increased significantly especially in areas of road transport, household consumption and manufacturing sectors globally (Ahmed et al., 2023; Pérez-Lombard et al., 2008) . Figure 9 shows the global carbon dioxide emission by sector. The key areas are transportation, industry, and the built environment The next subhead shall elaborate on the CO_2 emission in the built environment.

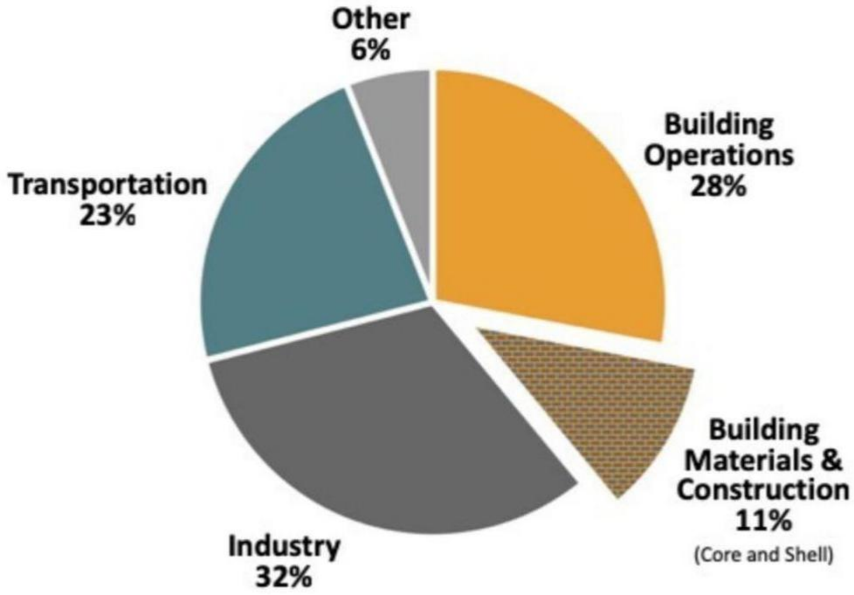

Figure 9. Global CO_2 emissions by sector (Global Alliance for Building and Construction, 2018)

2.1.2.1 The Built Environment

The built environment alone constitutes nearly 40% of global greenhouse gas (GHG) emissions. This is a significant figure that needs drastic attention. The increase in population, appetite for luxurious homes, comfort and the overall time spent in homes is on the rise, giving credence to the spike in energy consumption and CO_2 emissions. With the targets rolled out in the Paris Agreement (UNFCC, 2015), GHG emissions are expected to be completely net-zeroed by 2040. It is estimated that at least two-thirds of the buildings in existence today will hopefully be around in 2050. This gives urgency to a pragmatic energy-efficient approach in buildings through renewable integration. It is also projected that globally, buildings in urban areas are going to increase since about two-thirds of the global population is expected to migrate to urban areas (over 10 billion people) by 2060. To accommodate this tremendous growth, it is estimated that a land portion of about 2.48 trillion square feet must be added to the built environment space (Global Alliance for Building and Construction, 2018). Figure 10 shows the projected global floor space.

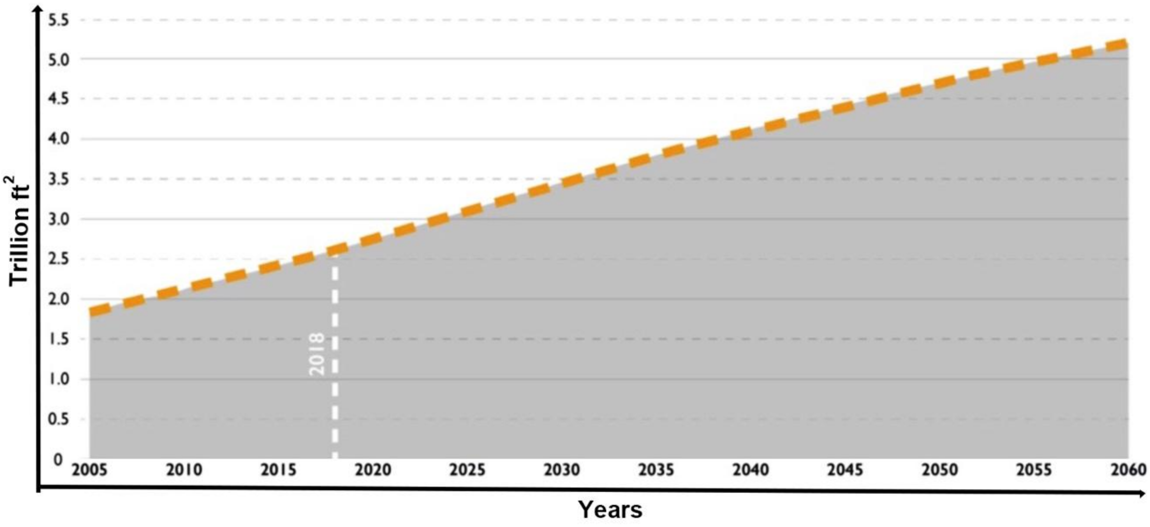

Figure 10 Global floor area space (Global Alliance for Building and Construction, 2018)

The service sector, which covers buildings such as schools, hospitals, social centres, museums, and hospitality outlets among many others is expected to be on the rise. It is expected that as economies grow and the population increases, the demand for services is also affected (Pérez-Lombard et al, 2008) which has a direct bearing on energy consumption and CO_2 emissions. This gives credence to the growing need and calls for cleaner energy options in the building sector.

These new buildings are expected to meet modern energy-efficient and environmentally friendly standards (Net Zero Energy Buildings (NZEB)). The new standard: NZEB has become popular especially in the 21st century to correct the outgrown energy consumption and emission status of buildings and as well create a sustainable energy system for future buildings (Voss et al., 2011).

Climate change has been identified as one of the principal factors to consider in sustainable environmental practices. The issue of climate change has been a major driver for crucial environmental policies in various countries. Key amongst them is the migration towards sustainable buildings. The next topic shall highlight the issue of climate change and how it has influenced the adoption of green building technologies (GBTs) such as solar.

2.1.3 The Issue of Climate Change

Premonition about climate change has been heightened especially in recent years as clear evidence has been seen across the world (Royal Society, 2021). Gone are the days when climate change was just a talk in a few places amongst smaller groups of people. Currently, the entire world is threatened by the repercussions of climate change, hence proactive measures need to be undertaken to circumvent possible disasters. A key contributor to climate change is the emission of CO_2 into the atmosphere using fossil fuels for human energy needs. For instance, it was recorded that in 2018 about 89% of CO_2 emissions came from fossil fuel exploration and industrial activities (Client Earth, 2022) . Spatial planning has been identified as one of the key approaches to relinquish the looming danger of global warming (Campbell, 2006) . Understandably, various governments have demonstrated through policies and strategies to manage energy demand to a more sustainable level, however, as population and industrialisation increase, energy demand is pushed to jibe with the growth.

Climate change has dreadful implications for food security, energy security, industrialisation, and human lives (Miraglia et al., 2009; McComas and Shanahan, 1999) . The expectation is to adopt sustainable human behaviours to correct emerging crises. Notable among these correctional measures have been to discovery of alternative clean energy sources such as renewables (Hof et al., 2017), to reduce CO_2 emissions.

2.2 Renewable Energy Technologies

Renewables have come up as a “saviour” in the energy landscape, sustainable development and as a significant contributor to climate change mitigation in this era (Lund, 2007). As the quest to find alternative energy sources increases partly due to population growth, sustainability and climate change issues, renewables have gradually become the most feasible energy option (IPCC, 2021). Renewables mean clean energy that can be renewed. In other words, the inexhaustible energy (Sims, 2004) . Today, renewables are tagged as “green” because of their sustainable and eco-friendly nature. Popular renewable energy sources include wind, solar, hydroelectric, ocean, geothermal, tidal and biomass

(NRDC, 2021) as shown in Figure 11. Renewables have become a significant energy source for humanity for several reasons. For instance, it is economically beneficial, especially in the long run, it is a reliable energy option for off-grid and rural communities, it is environmentally friendly, it is an answer to energy scarcity and securitisation, and finally, it provides a sustainable and practical approach to reduce CO_2 emissions which intend helps in the climate change fight (Renewable Energy World, 2021).

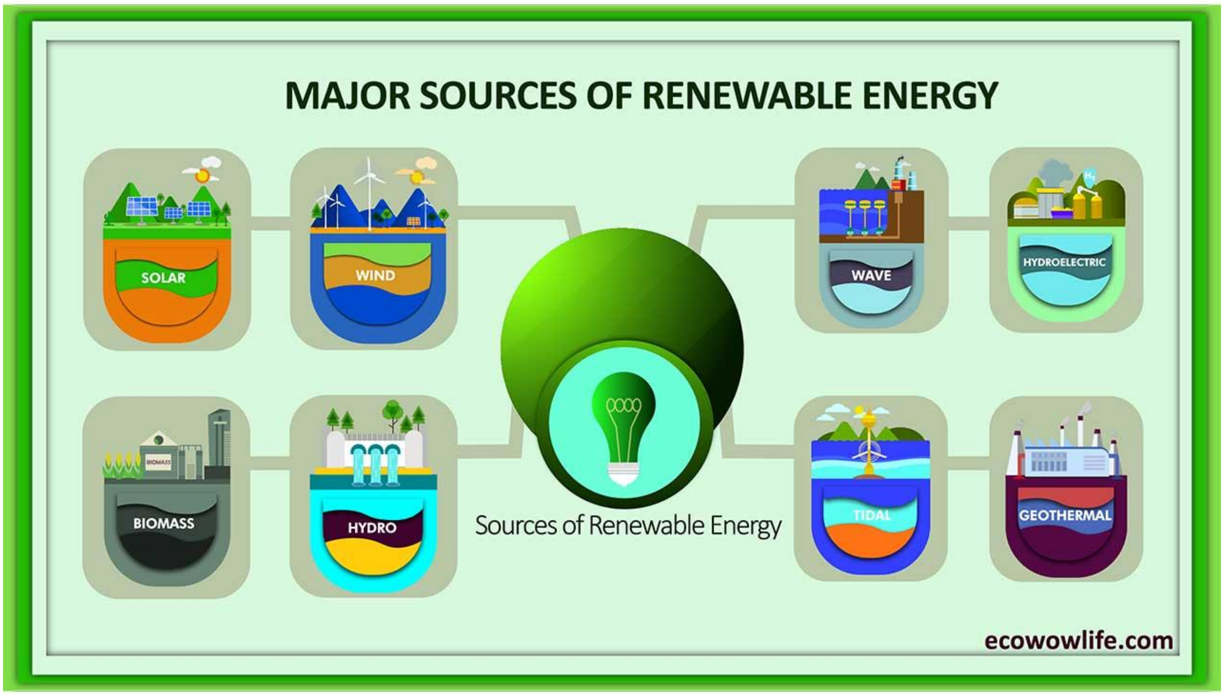

Figure 11. Sources of renewable energy (Renewable Energy World, 2011)

The history of renewable energy can be traced to the beginning of mankind. As early as 200 BC, renewables in various forms had already been explored which has laid a solid foundation for today's technological advancement (Belessiotis and Papanicolaou, 2012). Today, renewables have been adopted across the globe and many nations are making determined efforts to increase their share of renewables. For instance, even in the year 2020, which was marred by a global crisis (COVID-19) (Zambrano-Monserrate et al., 2020) , where almost all businesses and economies were affected, there was still a significant increase in renewable energy projects. The global installation of renewables in 2020 increased by 260GW, which is unprecedented, while there was a fall in fossil fuel additions by over 6% (IRENA, 2023).

Renewables can substitute cruddy sources of energy such as coal and fossil fuels (Tierney and Bird, 2020). These days, many buildings aim at comfort, utilisation of sustainable materials and the use of renewables for their energy needs. This has informed policymakers to develop policies on sustainable building systems, for instance, the adoption of net zero energy buildings (NZEB) and green buildings (GB) (Sartori et al., 2012).

Just like any other technology, renewables have various barriers that inhibit their adoption and efficient utilisation. Typical examples of some of these barriers are technical challenges, issues of awareness, high cost, policy limitations, sociocultural barriers, and market limitations (IRENA, 2018; Wiseman and Luckins, 2013; Oryani, 2021; Peimani, 2018; Reddy and Painuly, 2004). Despite these limitations, renewables remain the best option for energy independence and transition to a cleaner energy future.

As mentioned above, a key RE technology that has become a bedrock to the energy needs of many countries, especially in temperate areas is solar. As opined by many researchers, solar technology has evolved heavily over the years and has now become more efficient, reliable, and cheaper than many other sources of energy (Kabir et al., 2018; Li et al., 2007; Tyagi et al., 2013). It is also regarded as a tool to champion the energy needs of many countries, especially off-grid and rural dwellings in developing nations (Kannan and Vakeesan, 2016). Solar energy has come up as a solution to energy problems, especially in this era. The next session shall discuss this further.

2.2.1 Solar Energy as a Solution to Energy Problems

Finding a practical solution to one environmental problem may end up aggravating another one (Van den Bergh et al., 2015). The shift to finding a sustainable approach to energy needs has often been challenging especially as concerns about the environment and energy security heighten (Bang, 2010). Solar has proven to be a reliable solution to the energy problem of many nations. The major advantage that puts solar at a competitive edge is the fact that; it has recently become relatively affordable, nondepletable, clean, available, and usable (Nansen, 2021). Solar photovoltaic technology can also be applied in several ways to create lasting solutions to energy needs and household appliances. For instance, PV can be used for street lighting, water pumping and purification machines, telecommunication, BIPV applications, and home appliances such as TVs, air conditioners and radios (Sampaio and González, 2017). An increase in population and economic boom among other factors have a direct impact on the energy demand of nations, hence a sustainable energy option such as solar. As far as there is abundance and inexhaustible sunshine, solar continues to provide clean energy for domestic and industrial energy needs. The growing energy demand of nations, and the lack of electricity in especially rural and off-grid communities in developing countries renders solar energy a practical solution to electrification (Bugaje, 2006).

Understandably, just like any other technology, solar has its limitations. These include high initial cost, reliance on the weather, installation space and its general appearance (aesthetics) (Gromicko, 2021) . Irrespective of these seeming disadvantages, solar has still managed to cross carpets. Now, due to technological advancement and social acceptance especially in the call for climate response actions, solar has been able to overcome most of these challenges to a large extent. For instance, panels have been made cheaper and more efficient, aesthetics have improved, the introduction of BIPV provides an answer to the “large space” required for installation and the use of batteries for storage during peak times also answers the issue of reliance on the weather (Li et al., 2017; Matlis 2010; Shukla et al., 2017).

Solar energy has indeed been instrumental in the “new energy world” of renewables. It has served many countries by providing a solid backbone to ensure energy security, for instance, in China, USA, Japan, Germany, India, Morocco and South Africa (NS Energy, 2021) . Solar installations continue to grow across various nations and their social acceptance has increased relatively. It is therefore expected that solar energy will grow exponentially to over 8000 gigawatts globally by 2050 to serve as a reliable energy alternative (IRENA, 2019).

2.2.2 Solar Energy in Ghana

Diversification of energy sources and the constant reminder of the looming danger of climate change have heightened the quest for solar energy in the energy mix of various nations. Solar energy has proven to be the most abundant clean energy humanity has discovered. The sun shines constantly and can cater for the energy needs of the entire globe. It is believed that the amount of energy radiated from the sun within an hour is plenteous enough to cater for the yearly energy demand of the world (Bauer, 2015). Solar energy has advantages such as zero emissions, reliability, cost-effectiveness, and the ability to alternate with other sources of power (Rekioua and Matagne, 2012) . Electricity from solar photovoltaics has recently gained traction in Ghana due to intermittent power outages and rationing (dumsor).

Solar has always appeared to be the best alternative energy option for Ghanaians. The government and private entities have therefore attempted to adopt various solar systems to supplement the energy needs of the country and individual households. The most common solar systems in Ghana are mini-grid, off-grid, utility-scale, solar home systems and appliances (SmartSolar, 2019). Despite the numerous advantages of solar energy such as reduced energy bills, a cleaner source of energy, flexibility of application, and low maintenance cost, there are still some identified limitations that need to be addressed.

However, advancements in solar technology over the years, as well as solid economic policies, have gradually narrowed its pitfalls. Now, solar PVs are arguably the cheapest source of electricity due to the low cost of panels and the economies of scale consumers and manufacturers enjoy (GreenMatch, 2021) . Ghana may not have enjoyed the full advantages of solar yet, however, the country stands a greater chance of being one of the front-liners in solar energy especially in Africa considering the current energy trends. Various proponents have opined that given the topographical climate advantage, cost benefits, and appropriate policy consideration among others, Ghana is set to be amongst the top solar energy users in Africa and the world at large (Kuamoah, 2020).

2.2.3 Brief History of Solar Energy in Ghana

Solar energy has been part of Ghana's alternative energy options for at least the past 30 years. Although not on a commercial scale, solar has still managed to serve people, especially in remote and off-grid communities. Figure 12 depicts the solar trends of Ghana from 1990 to 2021. During the early years of adopting solar in Ghana, the focus was to provide basic electrification for remote and off-grid communities, store vaccines and medication, and basic communication and water purification (Kemausuor et al., 2011) . As Ghana's population increased and economic activities started booming in the early 1990s, the need for alternative electricity heightened. As of 1991, there were already 335 installed solar systems all amounting to 160 peak kilowatts. The acceptance of solar energy has been appreciated especially in recent times, as discussions about climate change and the need for alternative energy options get heightened due to power fluctuations and unreliability. Ranging from stand-alone solar systems to solar gadgets such as air conditioners, television sets, torchlights, radio sets, and off-grid and utility-scale solar systems; solar has gradually been embraced by Ghanaians as a traditional source of energy, although not on the same scale as biomass and hydro. Ghana is privileged to have an abundance of sunlight considering its geographical location throughout the entire country almost all year round (Obeng and Evers, 2010). As of 2021, the installed solar capacity had risen to 49 MW (Sasu, 2022). Although the figures are still relatively low, there is still an indication of an upward trend in solar generation.

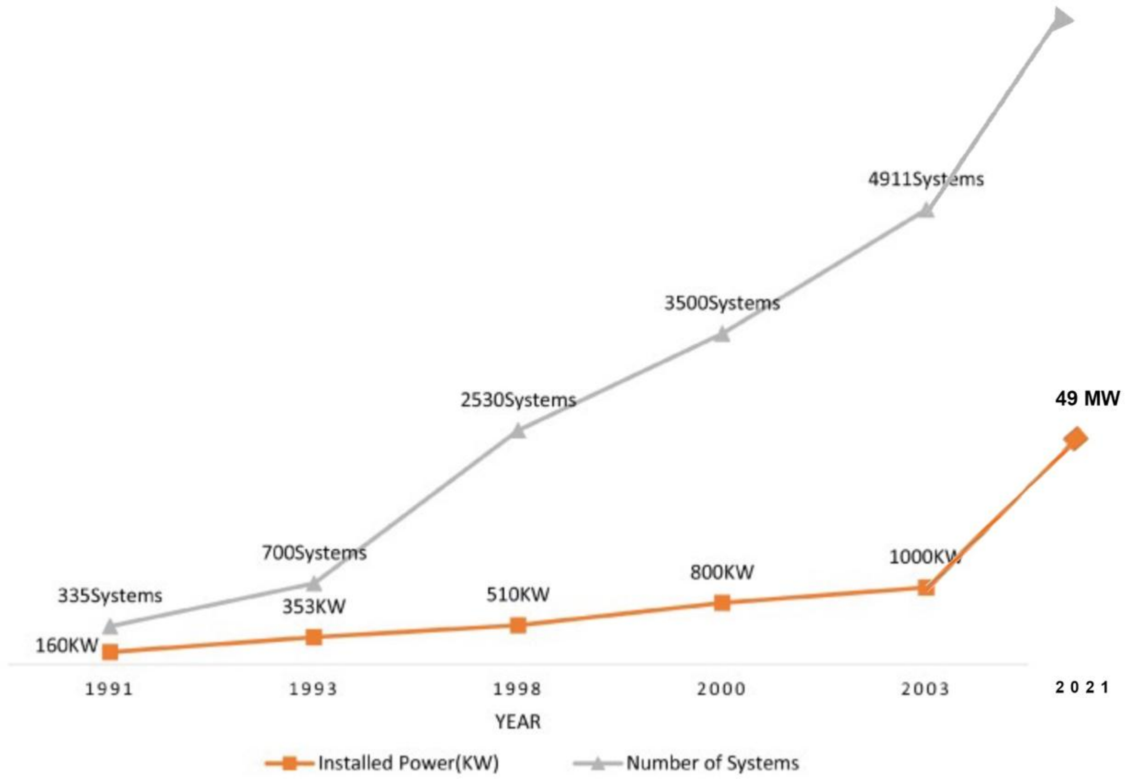

Figure 12. Growth of solar systems in Ghana from 1991 to 2021 (Obeng et al., 2008; Sasu, 2022).

2.2.4 Established Barriers to the Adoption of Solar Energy in Ghana

Like other developing countries, Ghana's energy sector has many contentions. Most of these issues have lived with the country for many decades, and various governments have attempted to partially circumvent them, however, they still linger on. Solar energy is expected to be one of the major energy "breakthroughs" for Ghana, but the level of adoption is relatively low. The quagmire that surrounds its assimilation into the energy mix of the country is enormous, therefore a practical market-driven approach and favourable policies are required for sustainable growth in the sector. Major hurdles such as the lack of a robust public-private partnership (PPP) framework, failed market-push mechanisms, low level of awareness, visual appeal/aesthetics, lack of technical expertise, the social-cultural attitude of Ghanaians and relatively high cost (Atsu, et al., 2016) need to be overcome. These factors have been further explained in the subsequent paragraphs.

A. Lack of a Robust Public Private Partnership (PPP) Framework

PPP has been a vital mechanism through which various developmental projects have been undertaken especially in developing countries. PPPs can appear in varied sizes, structures and shapes and are mainly utilized in the generation and transmission when it comes to Energy (Energy and Power PPPs, 2021). Ghana adopted a PPP policy in 2011 under its Ministry of Finance and Economic Planning with the core aim of providing a bedrock for boosting infrastructural development within the various sectors of the economy (Government of Ghana, 2011). Although the policy exists "on paper," it does not offer explicit details on PPP rollout in the country. This leaves room for various stakeholders to manipulate the chain, thereby resulting in discrepancies. For instance, issues such as corruption, the politicisation of various PPP agreements, poor bargaining abilities, and cases of accountability and transparency have been identified as hindrances to a robust PPP operation in Ghana (Alidu, 2018). The solar industry in Ghana has been partly pioneered by the private sector especially in rural and off-grid communities despite the loopholes in PPP policies. A robust PPP framework will not only ensure effective collaboration between investors and government but also relieve energy consumers of the burden of low shedding and power intermittency.

B. Failed Market-Push Mechanisms

Growing a solid market for every product is essential for its sustainability and equally important as production. The lack of research and strategic marketing roadmap for solar in rural communities especially in developing countries is a major hindrance to its widespread in Ghana (Awuku et al., 2021; Erickson and Chapman, 1995; Steel et al., 2016). Understandably, marketing goes in tandem with affordability, therefore higher cost of PVs naturally may not appeal to consumers, especially in rural communities. Fundamental marketing tools such as promotion, awareness creation and distribution are mostly overlooked. Less attention is given to this sector, yet businessmen and manufacturers are producing and importing massively. Major popular advertising mediums such as print posters, newspapers, banners, billboards, souvenirs, magazines, fliers;

electronic; Television adverts, radio, and internet adverts (Kipphan, 2001) have been useful largely in promoting various products. However, studies have shown that, even though these media are useful, their coverage varies depending on the target audience (Potter and Stapleton, 2011). For instance, in remote areas where reading is a challenge, magazines and posters cannot be of use and in a place where there is no access to electricity, TV commercials and radio ads are irrelevant. A generalised approach to the marketing of products is limiting rather than targeting specific groups and meeting their individual marketing needs. Face-to-face, seminars and workshop approaches may work best for rural dwellers (Kotler and Lee, 2007).

C. Low level of Awareness

Despite the seemingly popular nature of solar in Ghana, studies have shown that awareness remains a major limitation to its widespread (Atsu et al., 2016) as many Ghanaians, especially in remote communities have very little or zero knowledge. The threatening effects of climate change, sustainability, and environmental concerns hence the need for renewables are virtually unknown to many potential consumers. The low levels of awareness can however be attributed to poor marketing and dissemination of information. A study conducted by (Mahama, et. al, 2020) indicates that lack of awareness is a major setback for renewable energy deployment in Ghana. The study further revealed that the portion of the public who were partly aware had a misconception about the cost of solar without considering the long-term benefits. It was also apparent that many people relied on the impressions of friends and family and outrightly concluded to adopt solar without expert advice. Evidently, the gap in the advertisement has been filled by prejudices of people who do not have enough knowledge of the technology. Sudhakar et al., (2004) confirm how Renewable Energy Technologies (RETs) are assessed by consumers and the factors that inform their decision to purchase them (Reddy and Painuly, 2004). Rural dwellers, households and small industries struggle to access information and materials on solar and other RETs at their level. This impedes the growth of solar technology in Ghana.

D. Visual Appeal/Aesthetics

The idea of introducing solar panels to existing or new buildings means a direct temper with the overall outlook of the building; hence it is imperative to consider aesthetics. In Ghana, building aesthetics and architectural heritage preservation (AHP) are valued, especially when it comes to commercial and landmark buildings (Twumasi-Ampofo et al., 2020). Gradually, Ghanaians have become more conscious about the overall aesthetics of their buildings (Gallagher et al., 2021), hence considering the impact of PV application. The aesthetic limitation can be said to be deeply rooted in cultural perceptions and preferences. Irregularities and visual distortions caused by the haphazard application of BAPV systems in Ghana sometimes make it an unappealing option for architecturally sensitive consumers. Also, the perception that solar panels are unsightly and industrial-looking inhibits potential adopters in Ghana as it is rather regarded as a reserve for commercial purposes (Aboagye et al., 2023). It is therefore imperative to consider aesthetically pleasant solar panels with the potential to blend seamlessly with traditional designs and architecture.

E. Lack of Technical Expertise

Studies have shown that Ghana lacks technical expertise especially when it comes to RETs (Mahama et al., 2020) . A major contributor is the lack of established facilities to offer technical training and assistance to individuals willing to learn. Neglecting this aspect naturally threatens the adoption of solar technology since many users may end up without access to technical assistance in case their systems become faulty. Limited personnel in the construction, maintenance and management of solar systems are major barriers in Ghana, therefore potential consumers are reluctant because they cannot guarantee the safety of their installations (Kuamoah, 2020).

F. Socio-cultural Attitude

The conservative nature of Ghanaians (Agyekum et al., 2019) runs through the adoption of every technology including solar energy. People are passively used to the mainstream energy sources for electrification hence unable to easily make room for an alternative option. This lock-in effect (Perkins, 2003) has made it challenging for solar technology to break ground, especially in rural and peri-urban settings in Ghana. There is a natural tendency to decline a move to an uncertain source of electrification especially if there is a "tried and tested" alternative. The uncertainties and fear that come with the adoption of solar is a major setback for Ghanaians.

G. High Cost

The initial high cost of solar systems is a major limitation for many potential adopters. Since the average income among Ghana's working class is between 900 – 1,500 Ghana Cedis (Sasu, 2021), an average person cannot afford solar PV which can have a significant impact on household electrification. The overall diffusion of solar energy in Ghana is partly dependent on the cost of other sources of electricity. Understandably, the seemingly "initial lower monthly cost of mainstream electricity makes it bewildering for the ordinary consumer to choose solar energy as an alternative option. Until recently, when prices of PVs have been reduced due to improvements in technology and production capacity, PVs were always tagged as costly.

These barriers have been prevalent in Ghana's solar sector for many years despite attempts by policymakers, researchers, and stakeholders to quell them. Indeed, the challenges faced by the solar industry are potential threats to the adoption of BIPVs as well. The following topics review the theory of solar and BIPV.

2.2.5 The Concept of Policy

Policy encompasses a set of guidelines and regulations formulated by governments or organizations to guide decision-making and actions in various sectors (Gao, 2018). It is essential for structuring how resources are allocated, services are delivered, and objectives are achieved. Policies provide a framework within which organizations and individuals operate, ensuring consistency and stability in addressing societal needs and challenges. Typically, there are five stages: "a) issue/ problem identification; b) setting agenda; c) policy formulation or policymaking; d) policy execution; and e) policy evaluation" (Adeniran et al., 2023). In the context of public policy, this includes laws, regulations, and programs designed to address issues such as energy needs, healthcare, education, and environmental sustainability. For instance, environmental policies may set standards for emissions, incentivize renewable energy adoption, and establish conservation practices.

Effective policies are informed by research and evidence, aiming to balance competing interests and achieve desired outcomes (Gao, 2018). They often involve stakeholder consultation to ensure they address real needs and are practically implementable. Policymaking also includes monitoring and evaluation to assess policy impacts and make necessary adjustments. In summary, policy is a critical tool for guiding actions and decisions, addressing complex issues, and shaping the direction of societal development. It provides the necessary structure for achieving goals, managing resources, and responding to emerging challenges.

2.3 Understanding Solar Cells and an Overview of BIPV

2.3.1 Theory of Solar Cell

To have a full understanding of solar energy and even BIPVs, it is important to have a generic idea of how the solar cell works. A solar cell is a term given to any device that can convert the sun's energy to electricity through the photovoltaic effect. Sometimes, solar cells can convert the sun's energy through indirect means, where it is initially converted to heat or chemical energy (Swami, 2012). Figure 13 shows the solar cell (Britannica, 2021).

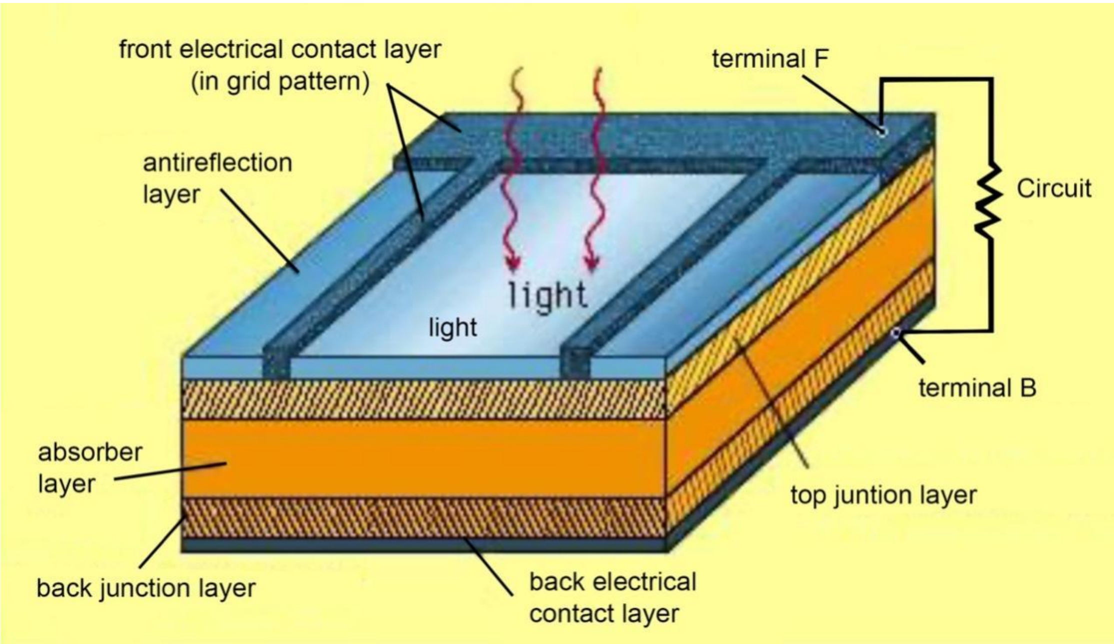

Figure 13. Diagrammatic representation of the solar cell (Britannica, 2021).

A collection of solar cells forms a solar panel which is directly used to harness energy from the sun for electricity production in homes. Solar cells are mainly fashioned from silicon due to their abundant nature and low cost hence reflecting in the increasing reduction in solar panel prices apart from large-scale production in China, Europe, and America (Green, 2019) . Solar cells can be sometimes described as non-mechanical devices with the capability to convert sunlight to electricity. The light could also be from artificial sources. Naturally, the amount of electricity generated partly depends on the surface area of cells available, the type of material used and more importantly the amount of sunlight received by the cells (Swami, 2012).

Solar cells have evolved over the years. Now there are first, second and third generations of solar cells. The first-generation solar cells are basically produced on the wafer and are the most used due to their efficiency. Second generation on the other hand is aesthetically pleasant, easy to use and less costly than first generation cells. The disadvantage however is that they are less efficient than the first generations of solar cells. Third-generation solar cells are considered the newest on the block. Some third-generation solar cells are considered novel and are still being tested for commercial bases. Diversified technologies such as dye-sensitized cells, and concentrated solar cells which are widely accepted and used these days have emerged from third-generation solar cells (Kibria et al., 2014) . This promises to be the hope for solar technology diversification especially for BIPVs in the immediate future as there is a direct attempt to enhance efficiency and reduce the overall cost. Figure 14 shows the various generation of PVs.

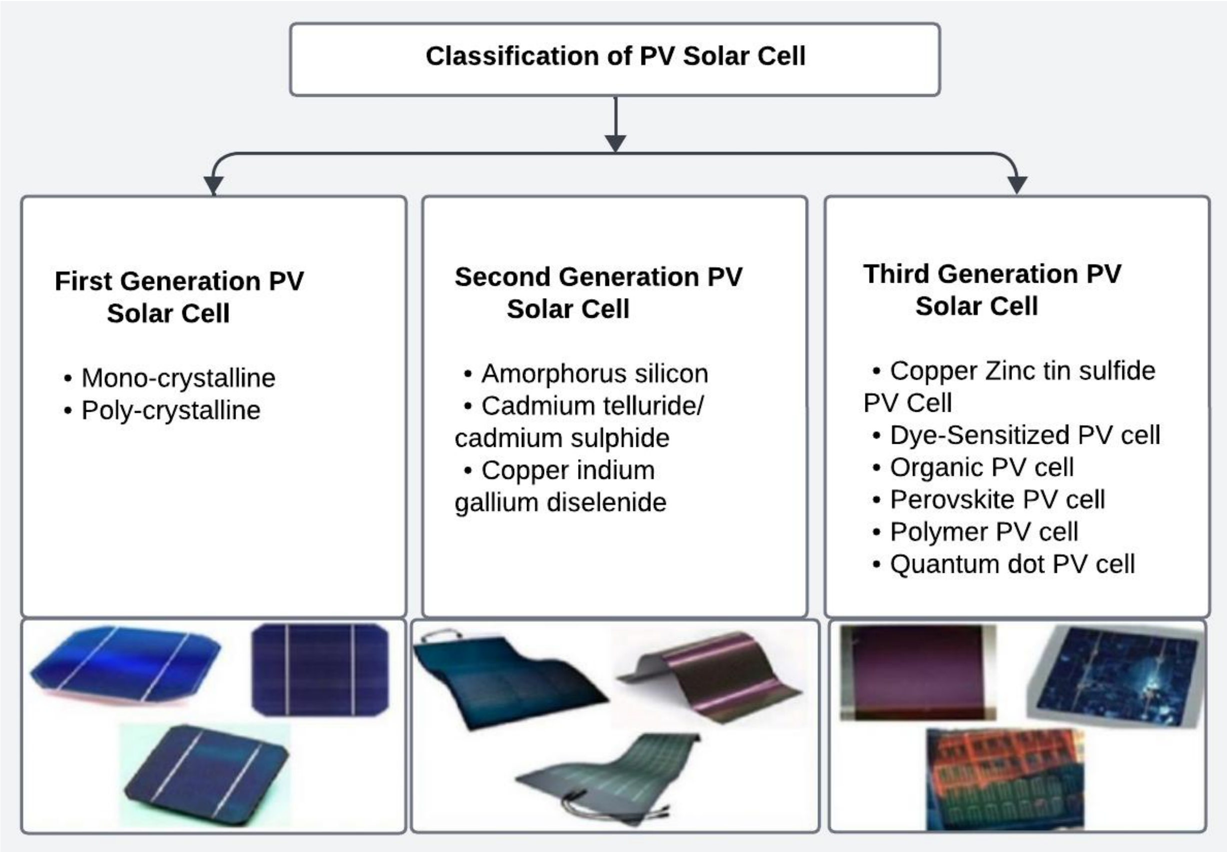

Figure 14. Classification according to generations of PV (Shukla et al., 2016)

2.3.2 Meaning, Overview, and Brief History of Building Integrated Photovoltaics (BIPV)

Once upon a time, solar energy for homes could only be identified with "sprouted" panels on rooftops and compounds in rigid plastic frames. These days, thanks to advancements in technology and modernity, solar technology has transformed into a more sophisticated and architecturally salient mode of application. Building Integrated Photovoltaics, BIPV for short refers to the use of photovoltaic materials to replace conventional building materials such that they form part of the building envelope (Peng et al., 2011), for instance in Figure 15.

Figure 15. Example of BIPV roofing (Bungane, 2017)

Whether as a primary or auxiliary source of electricity, BIPV has gradually become an integral energy source for buildings. The advantages are numerous, for instance; the offset of the cost of original building materials and reservation of land space and aesthetics (Top Solar Mounting System, 2020). In this study, the overall advantages of BIPV shall be categorised into four; Environmental, Economic, Social and Design as shown in Table 1.

Table 1. Advantages of BIPV

Environmental Benefits of BIPV	Social Benefits of BIPV	Economic Benefits of BIPV	Design Benefits of BIPV
- Cuts down the cost of electricity transmission (Bakos et al., 2003; Sharples and Radhi, 2013)	- Provides an environmentally friendly alternative building material (Awuku, et al., 2022) - Demonstrates	- Saves cost on conventional building materials (Abdullah et al., 2012) - Reduces overall cost of labour	- Beautifully integrates into the building envelope (Awuku et al., 2021) - Provides an awesome view and daylighting

- Cuts down the need for extra land space for mounting solar PV (Bakos et al., 2003)	the pride in adopting sustainable building materials - The overall Social Cost of Carbon (SCC) is totally reduced, thereby aiding environmental preservation (Yang and Zou, 2016)	(Jelle, 2015) - Total cost of building is reduced and potentially generates additional income (Gholami and Røstvik, 2020)	(Do et al., 2017) - Can conceal noise (Hasmaden et al., 2022) - Controls temperature (Hamed et al., 2019) - Can be customised to suit building (Pagliaro et al. 2010; Chiko Solar Mounting System 2020)

The hope for a NZEB as the future of architecture partly rides on BIPV exploration, especially in areas of abundant sunlight.

The debate of BAPV against its counterpart BIPV has lingered since its inception. The conservatism and track record BAPV have enjoyed naturally give it a lead over the "new entrant" BIPV in the building and construction industry. Social acceptance, technological problems and cost have been cardinal limitations to the wide spread of BIPVs in the past (Krenz et al., 2019). However, in recent times the dynamics are changing, as BIPVs are making headway in the architectural world. The emergence of BIPVs in the early 1970s introduced the use of basic aluminium-framed solar panels to be integrated into parts of building skins, especially in remote off-grid areas. Fast track to the 1990s, BIPV blew up on a commercial scale and has since been championed by various stakeholders (Shukla et al, 2016).

The first largest BIPV production installation emerged in Germany by Pilkington in 1993. Gradually, BIPV continued to receive a lot of attention and became an attractive monument for early adopters (Benemann et al., 2001). The solar idea thrived "beyond the roof" and gradually found its way into the skin of various buildings, either forming the façade, cladding or windows. Roof top-mounted applications still dominate in the BIPV world, as about 80% of BIPVs are mounted on the roof and the remainder on the façade. Figure 16 shows the market segmentation of BIPV (Shukla et al., 2017). This naturally means the market segment for BIPV roofs is relatively higher than the others. Although the initial idea of BIPV seemed out of earth and technically challenging, gradually, the technology has improved to cater for its limitations. Now that talks about NZEB have been heightened, the future of BIPV seems more promising. BIPV companies are increasing production capacity whereas designers and engineers also explore various creative means of BIPV designing and application.

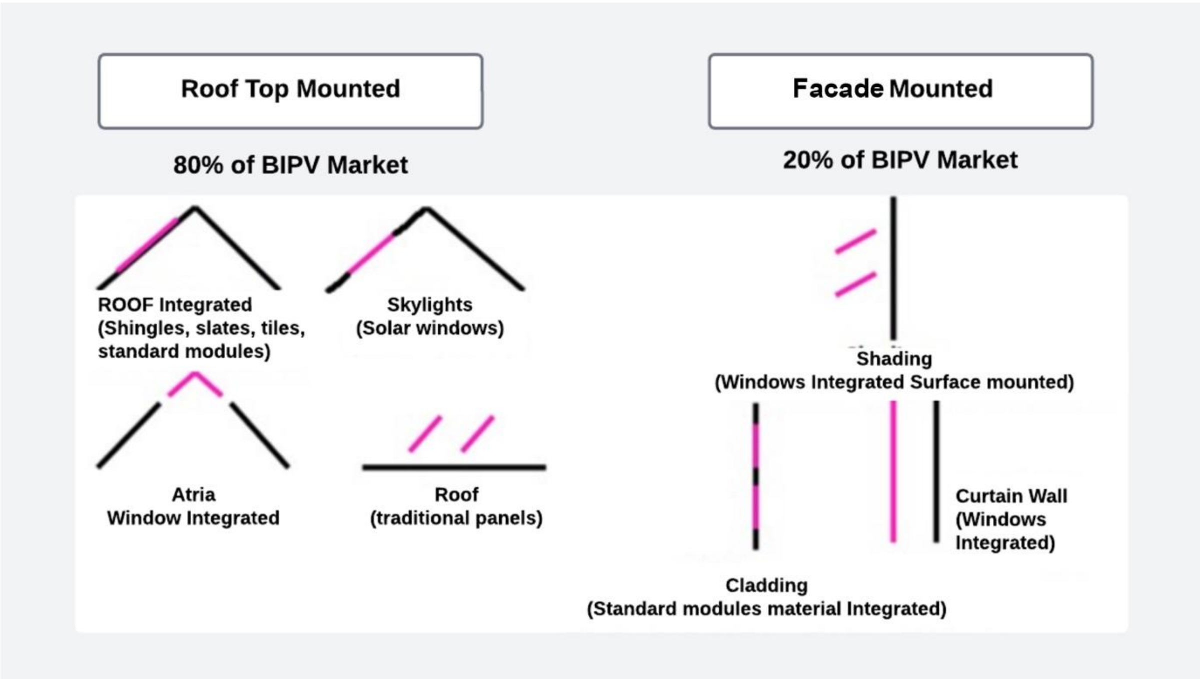

Figure 16. BIPV market segmentation (Shukla et al., 2017)

These days, BIPV technology has become comparatively cheaper, thanks to advanced technological research and increased production capacities of solar PV (Shukla et al., 2017). As awareness of climate change and the "desire to go green" increases, photovoltaics have become an easy option to consider due to their modest nature (Hassanien et al., 2018). Manufacturers are keen on meeting the taste of the market, therefore, there has been a significant improvement when it comes to appearance, cell technology, colour and make of PVs for BIPV purposes (Cibi and Manikandan, 2021). The next sub-section will shed more light on cell technology and types of BIPV.

2.3.3 Solar cell technology for BIPV

Polycrystalline and monocrystalline are the most popular and widely used silicon photovoltaic modules on the market. This is due to its reliability and the vicinity of the raw components required for production. Experts say that monocrystalline PVs are more expensive than polycrystalline, and the most efficient. These module types are popularly used for BAPV applications due to their rigid aluminium frame and simplistic nature. Advancements in technology have brought about much more flexible PV materials most suitable for BIPV applications called thin films. As the name implies, they are much thinner and more flexible, however, less efficient compared to their counterpart's mono and polycrystalline. Classical examples of modern thin-film cells which are believed to be more efficient include perovskite, tandem and dye-sensitized cells. These third-generation solar cells have become the backbone of the BIPV industry and have won the attention of many manufacturers (Shukla et al., 2016).

Various PV panels are used for different things depending on their category. For BIPV applications, panels are usually used to replace building components such as roofs, windows, façades, sunshades, and skylights. Sometimes, panels are flexible, translucent, colourful, or transparent depending on the user and the expected outcome (Reddy et al., 2020). Figure 17 shows different PVs used in the BIPV application. Naturally, many end users may prefer to design their facades with BIPV next to the roof partly since it has a large surface area thereby allowing more light into the building. Panels that are semi-transparent and coloured have gradually become popular within the BIPV space due to their attractiveness, although some proponents opine that they are less efficient (Cibi and Manikandan, 2021).

Figure 17. BIPV application with different cell materials (Reddy et al., 2020)

In BIPV applications, PVs ought to appear in varied materials rather than regular rigid plastic-framed shapes. Advancement in BIPV technology has therefore brought about divergent materials and products that can easily mimic and replace conventional building materials. Figure 18 shows a classification of BIPV products. The next subsection sheds more light on some specific BIPV products.

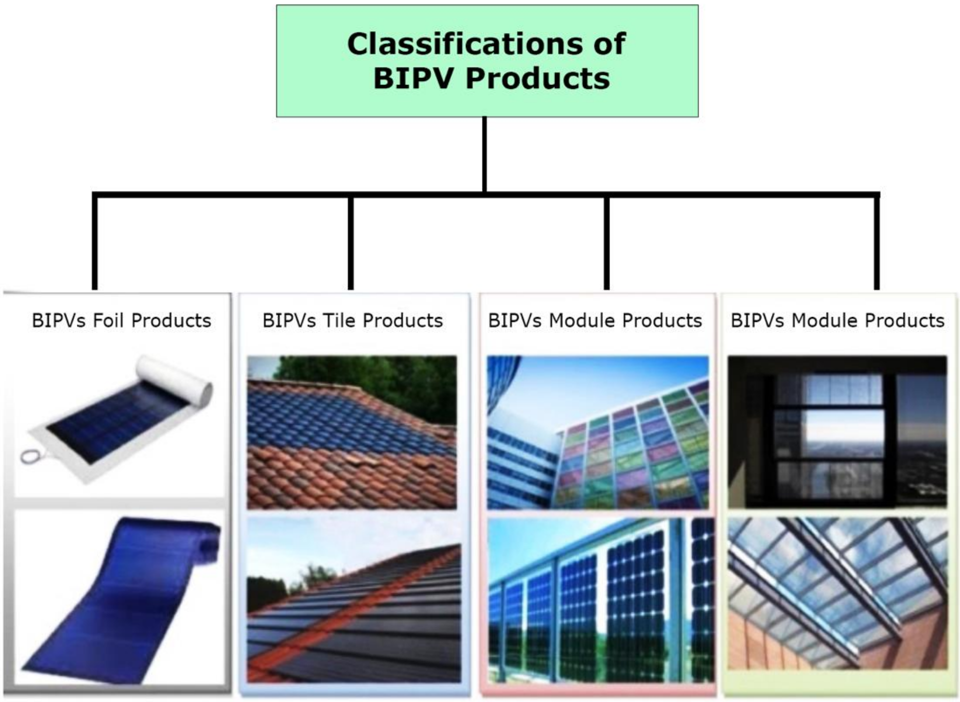

Figure 18. Classification of BIPV products (Shukla et al., 2016)

2.3.4 Categorisation of BIPV Products

A. BIPV roofing tile products: As the name implies, BIPV roofing tile products have the characteristics of conventional tiles used for roofing buildings. Understandably, they may cover the entire roof or just a selected portion depending on the expected generation outcome. Traditional roofing tiles come either flat or curved, and so do BIPV tiles. Figure 19 shows some BIPV roofing tiles.

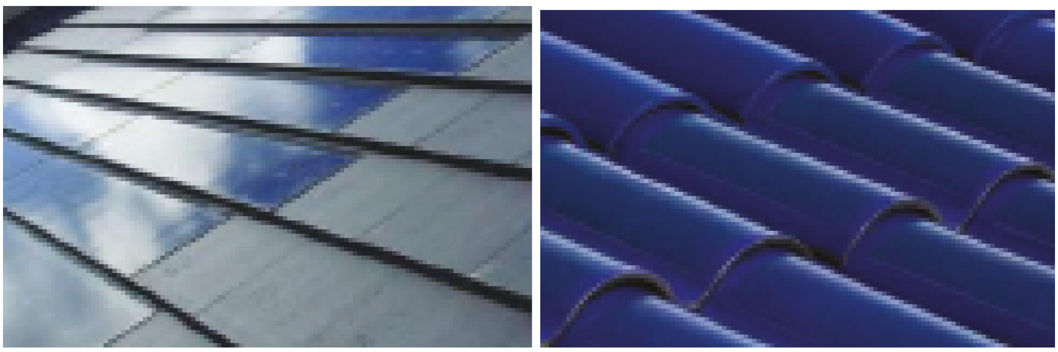

Figure 19. Examples of BIPV roofing tiles (Jelle and Breivik, 2012)

B. BIPV Foils

Just like everyday foils, BIPV foils are flexible and imponderous and have the advantage of portability, and easy installation. Traditionally, foil cells are made of micro-thick photon-drawing components laid over a malleable surface. As seen in Figure 18 above, foil products can be rolled to take the shape of any substrate, thereby making it a feasible option for contoured surfaces and a great addition for aesthetical considerations in architecture (Shukla et al., 2016).

C. Module Products

Although BIPV module products mimic conventional panels, they are made with materials that can comparatively withstand the weather. They can successfully replace conventional roofing materials without difficulty. The ability of the BIPV solar module to successfully function as "weather skin" to harsh temperatures is very essential as it replaces conventional building materials and is not an add-on (Shukla et al., 2016). Therefore, a compromise in the quality of the material will potentially render it unrealistic and inappropriate to replace building materials.

D. Solar cell Glazing

Solar cell glazing is a striking technology that combines glass and solar photovoltaic. Here, two panels of specialised glazing are used to cover the solar PV. Energy is then produced from a resultant glass laminate that is created. This can potentially produce energy and shade concurrently. Solar cell glazing can be employed especially in contemporary architecture, where glazing or cladding is essential and is therefore given a lot of credence, especially in multi-storey complexes with limited roof space. This technology is ideal for skylights, canopies, curtain walls and facades (Niclas, 2021) . Aesthetics is a key advantage of this technology as the possible outcomes are varied and can be easily designed to suit architectural preferences (Shukla et al., 2016).

Solar cells are fundamental to achieving solar electrification. Growth in technology and advancement in climate change awareness have given cause to solar adoption, especially in the built environment. These days, solar cells have become cheaper due to a boost in production capacity and favourable policies. As solar adoption increases, cell types increase as well, especially for the purposes of BIPV.

The idea of BIPV is to integrate solar PV into buildings so that they end up replacing conventional building materials and form part of the building envelope. Here, solar PV serves dual purposes; as a building material and energy source (Peng et al., 2011) . Technically, the cost of conventional building material is bypassed, and although the cost of BIPV is much higher, the energy advantage still makes up for the difference. This makes considering BIPV advantageous over separate add-on PV systems (BAPV). Since this study focuses on the adoption of BIPV in Ghana, fundamental applicable theories of product adoption shall be reviewed.

2.4 Theories of product adoption and Diffusion in new markets

Marketing and economic principles have laid down solid theories that surround the adoption of new products. Key amongst them are the Theory of Reasoned Action (TRA), Uses and Gratification Theory (U&G), Social Cognitive Theory (SCT), Diffusion of Innovation Theory (DOI), Unified Theory of Acceptance and use of Technology (UTAUT), Technology Acceptance Model (TAM) and Aesthetic Theory (AT) as shown in Figure 20.

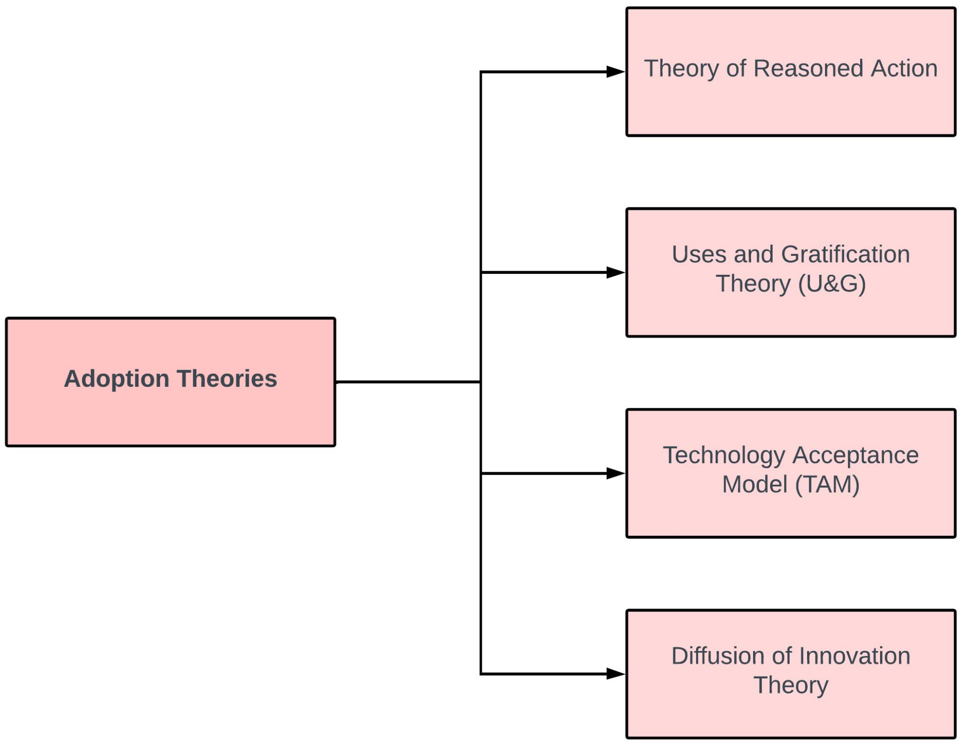

Figure 20. Product adoption Theories – Authors construct, curled from (Taherdoost, 2018)

Key among the theories is the Diffusion of Innovation (DOI). DOI refers to the circulation of an idea, product, or technology amongst a populace over a period (Dearing, 2009). The idea of diffusion moves in tandem with adoption. Adoption has to do with the decision an individual makes to either accept or reject a product or technology (Straub, 2017). This implies that for DOI to thrive, the process of adoption or rejection must occur. Therefore, in this research, DOI shall form the epistemological basis considering the novelty of BIPV in Ghana. This theory shall be extensively discussed in relation to the adoption of BIPV in Ghana.

2.4.1 Definition of Innovation

To create a solid understanding of how a product or technology can be adopted, rejected, or diffused amongst consumers, it is imperative to establish the clear meaning of the term innovation. To innovate in essence means to create anew. Other scholars extend the meaning of innovation to; "the act of changing a basic idea into a practical solution that is helpful to an entity" (Skillicorn, 2021). These days, the term has been broadly adopted not just by individuals, but also in business circles and in the corporate world. Creativity is considered a skill that fuels innovation, hence the implementation of a fresh idea for the benefit of society. Although innovation can mean a futuristic or abstract idea, it can also describe a practical and existing technology or product. In this study, innovation shall point to BIPV as a "game changer" in the solar and architecture industry.

2.4.2 The Diffusion of Innovation Theory

Once innovation happens, practical measures are taken to ensure that it is proliferated among consumers. Hypothetically speaking, diffusion of innovation theory suggests the modalities that surround the dissemination of a new product or technology within a group of people or society at large (Orr, 2003). The theory highlights the rationale behind the adoption of a new technology. Popularly used within the marketing space to determine market shares, this theory gives credence to the discussions around innovation among consumers and how their subjective judgement goes a long way to affect the widespread of the product (Karjaluoto and Vaccaro, 2009).

Originally, the diffusion of innovation theory varies and cuts across diverse disciplines. A popular theorist linked to this theory is Everett Rogers, who universalised it in 1962. Roger’s theory mainly revolved around organisations and people. Five key steps are classified as essential for diffusion theory: innovation, communication medium, adopters, time, and social systems (Klingelhöfer, 2019). The term innovation was originally coined from the Latin word “Innovare” which means to renew. Innovation means creating something new, bringing a non-existing idea into reality or replacing an existing idea (Innolytics AG, 2023). Once innovation is done, a viable medium of communication must be considered to ensure the widespread of the innovation. Time is then allowed to guarantee the circulation of the idea among potential consumers. At this stage, the rate of adoption of the innovation is mostly said to be dependent on the social systems. The attitudes, beliefs, norms, and idiosyncrasies of potential consumers determine the rate of adoption or otherwise (Dearing, 2009). Understandably, all consumers are not the same and there are specific classes of adopters depending on how long it takes them to consider utilising the innovation. Some are early adopters, the early and late majority and the laggards as shown in Figure 21 below (Rogers, 2016). Innovators are naturally risk-takers and quick to adopt an idea, regardless of the risks involved. They form a smaller percentage compared to all others. Most adopters fall within the scope of “early majority and late majority”, which is assumed to be a safe mode (Klingelhöfer, 2019).

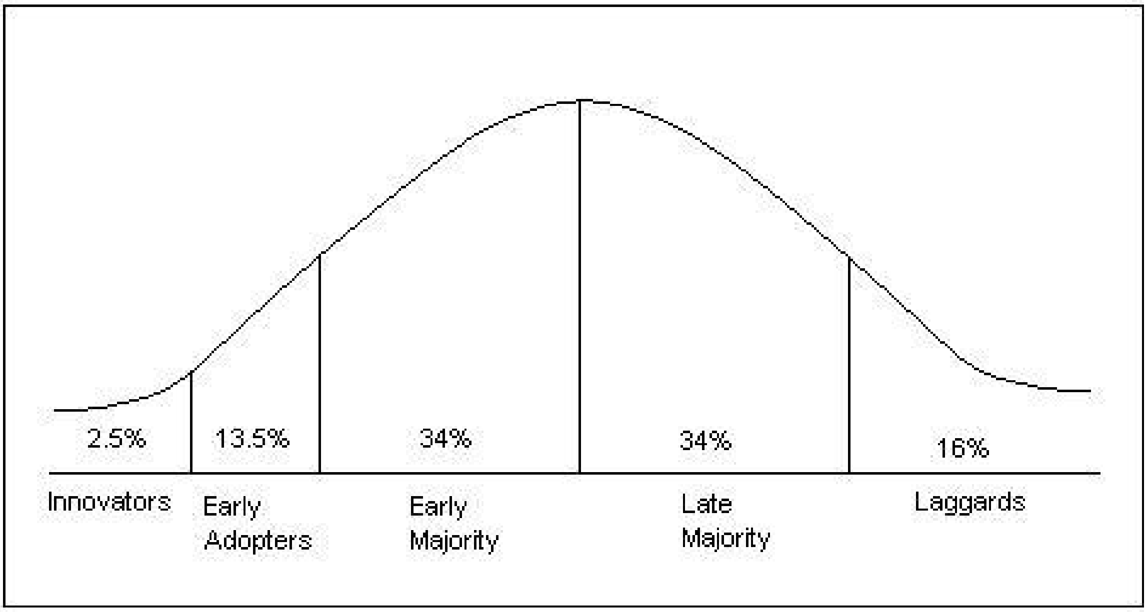

Figure 21. Categorisation of adopters based (Rogers, 2016)

2.4.3 Adopter Categorisation

According to Rogers (2016), various adopters have strong drivers that encourage or discourage them to adopt an innovation.

A. Innovators

The innovators of the idea are the daring ones who are eager to try new things regardless of the consequences. This category of persons is mostly obsessed and tends to stray out of their small circle, with the hope of exploring new things and encountering new people. Innovators are mostly smart and can pull resources together for a set purpose. Just as setbacks are bound to occur, innovators have enough zeal and temperance to overcome hurdles until they reach their destination.

B. Early adopters

Next to innovators, early adopters tend to have the desire to try new things and are mostly educated. This category of adopters is more social-oriented than inventors. Many leaders and advisory bodies fall under this category as they tend to access and advise other adopters. They serve as influencing agents in the diffusion process as other adopters usually look up to them.

C. Early Majority

At this stage, a sizable group of people become eager to adopt a proposed innovation. The early majority are reliant partly on the experience and enthusiasm of early adopters and innovators to satisfy their doubts. When the rate of acceptance of innovation reaches up to 34% of the targeted populace, it can be classified as the early majority. Understandably, this category of adopters is reluctant and usually not technologically friendly but somewhat willing to consider based on the testimony of others. They form the link between innovators and late adopters.

D. Late Majority

This category of adopters usually looks up to the early majority before deciding (Rosen, 2009) . The late majority appear to be relatively unconcerned about modern trends, technology, and innovations in general. They are used to very basic ways of doing things. Unlike innovators, early adopters, and the early majority who are mostly youthful, daring and technologically friendly, consumers within the late majority category tend to be among the older generation, less educated and relatively poor. This category will naturally not rush to spend on new technology but rather wait for testimonies and discounted sales. Factors such as product safety, cost and reliability are essential considerations for this category of adopters (Chen, 2021).

E. Laggards

This category of adopters is very traditional-minded and the last group to consider adopting an innovation. They are either risk-averse or lack a full understanding of the need for change. Laggards are not eager to change but sometimes may have no choice due to modernity and social transformation (Frank et al., 2021).

Diffusion of innovation is a key marketing tool as it gives direction to investors on the potential failure or success of new products introduced on the market at a particular period (Robertson, 1967) . The number of products introduced on the market must be in sync with the rate of diffusion and acceptance to avoid losses. For the successful diffusion of a new product on the market, there is the need for consumers to alleviate any personal ambivalence when introduced to a new product; there must be room for consumers to hear feedback and testimonies from early users of the product and, there must be a built-up pressure to switch to use the new technology. When consumers are doubtful of innovation, yet they find it useful, there is the natural drive to ask questions and find answers from innovators, trusted sources, and earlier adopters to be able to make informed decisions. For most consumers and adopters of innovation, the decision is based on the assurance and testimonies of other users (Gigerenzer and Selten, 2002).

2.4.4 Adoption Rate

The adoption rate refers to the comparable speed with which a group or society accepts and adopts an innovation. The adoption rate is practically measurable by the amount of time required for a specific percentage of consumers to finally decide to consider innovation. There is a stage popularly known as critical mass or tipping point on the innovation curve. Here, the rate of adoption among consumers reaches a self-sustaining stage, and the innovation is widely accepted. Attaining this stage is the expectation of many innovators and marketers as it marks the exponential adoption of technology. Figure 22 demonstrates the tipping point on the diffusion of the innovation curve. The society within which an innovation is being introduced is important as it determines the rate of adoption. For instance, the adoption of many new products is usually slow, especially in areas where most of the population are not technology enthusiasts, partly due to low educational levels or their age category.

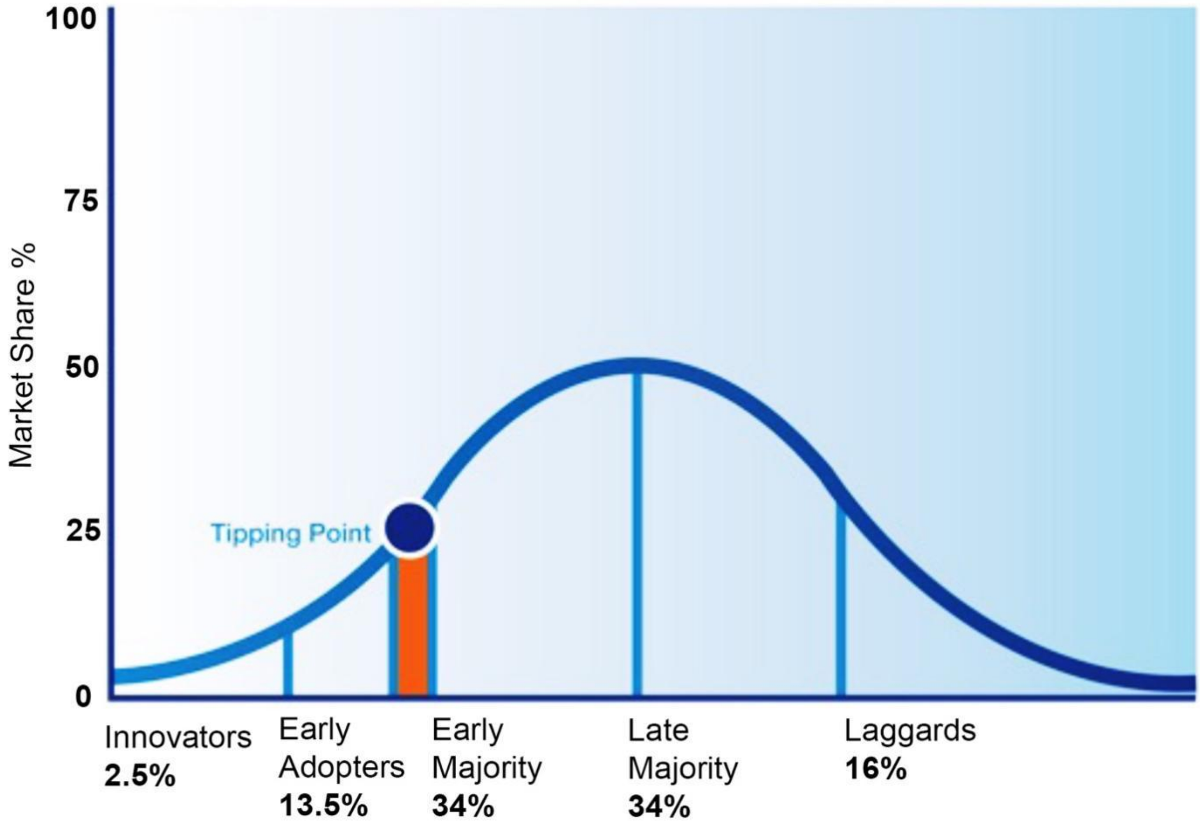

Figure 22. Demonstration of tipping point on the diffusion of innovation curve (Learneo, 2021)

2.4.5 Characteristics of the Diffusion Process

Rogers identified five core characteristics of DOI among adopters. These are known as the triggers of adoption, in other words, the determinants of the adoption of innovation. These are the comparative advantage, complexity of the innovation, trialability, observability and compatibility (Ferster, 2017; Yocco, 2015).

A. Comparative advantage

Comparative advantage deals with the measure of efficiency, improvement, social advantages, ergonomics, economics, and other advantages the innovation may have above other substitutes. Adopters must see a difference to consider prioritising one product above the other. Comparative advantage is one of the greatest determinants of adoption rate as it highlights the need for innovation. The clearer the comparative advantage, the easier and more convincing it is for adopters to jump unto an innovation.

B. Complexity or simplicity of the innovation

Adopters are mostly keen on using simple innovations. The complexity or simplicity of innovation measures the extent to which an innovation is difficult or vice-versa for adopters to use. Naturally, potential adopters will easily shun a complex innovation. Innovators are therefore expected to consider basic and simple product design approaches to make it easier for adopters to consider.

C. Trialability

Adopters are curious about the efficiency and meritoriousness of innovation and, hence will hesitate to jump on to it. Trialability measures the facileness with which an innovation can be explored by adopters. Once an innovation has been tried and tested, adopters become convinced about the goodness or otherwise of the innovation, hence making it easier to decide. Similar to developing a prototype, demo, or trial size, trialability puts the real user experience into perspective for potential adopters.

D. Observability

The ability to see an innovation physically, monitor how it works and weigh the benefits before deciding can be a great influencer for adopters. Observability allows other adopters to monitor an innovation to be able to access its merits to decide. It can be a silent motivator as it gives evidence and testimony rather than mere words.

E. Compatibility

Compatibility measures the extent to which the innovation fits into the daily livelihoods of the adopters. An innovation must naturally find its place of relevance to be considered by a potential adopter. Adopters of innovations are easily attracted to innovations that do not require an extreme change in lifestyle or attitude, hence if an innovation clearly differs from the lifestyle of adopters, there is a high tendency of reluctance in adoption. In cases where an innovation falls under a "cluster of technology" (innovation that falls under the umbrella of a larger group of the same technology), it is easy for adopters to judge the innovation within the ambit of the known larger group rather than individually. The user's ability to effortlessly blend an innovation into their livelihood or be regarded as an improvement of an existing product makes it easy to adopt.

2.4.6 Stages of the Adoption of an Innovation

Apart from the major elements of DOI: innovation, communication channels, social factors, time, and the rate of adoption, five key factors underpin the diffusion process (Sirk, 2020). These five factors are Awareness, Persuasion, Decision, Implementation and Continuation. The next paragraphs shall expound on them.

A. 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 his stage.

B. 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.

C. Decision

This is the point where the potential adopter makes a clear resolve to embrace the innovation or reject it. Here, critical analysis such as Strengths Weakness Opportunity and Threats (SWOT analysis) of the product is made to ascertain its viability.

D. Implementation

At the implementation stage, the innovation is finally accepted, and adopted. Adopters may not have a full understanding of the innovation yet but would have gone for it with high hopes and expectations.

E. 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 usage or otherwise.

2.4.7 Diffusion of Innovation; the Future of BIPV in Ghana

The adoption of BIPV in Ghana is expected soon, considering modern energy trends, climate change issues, increasing demand for electricity, especially in the built environment and the call for green buildings. Most Ghanaians have had their share of power instability and the payment of increasing recurring electric bills, hence a move to BIPV is much anticipated within the built environment, considering the numerous advantages it has over other energy sources.

The rate of elitism and increasing desire for sustainable housing amongst a larger portion of Ghana's population indicates that most adopters could potentially fall between the early majority and the late majority on the diffusion of innovation curve. Hypothetically, this implies that BIPV has great potential in Ghana, given the underlying conditions. Another critical perspective to consider is the interest of the government in promoting GBTs and electrification, especially in rural areas. The government could act as an early adopter should there be a full understanding of the benefits and relative advantages BIPV have over other options. In this case, the adoption rate could be perceived as relatively higher considering the numerous governmental projects across various sectors of the economy. For instance, the technology could be adopted for government buildings, schools, hospitals, rural community centres and other amenities.

2.4.8 Challenges related to the adoption and diffusion of BIPV

Apart from BIPV's ability to produce energy, they are developed to replace conventional building materials, hence the ability to mimic these building materials in terms of durability, aesthetics, functionality, and cost is paramount in its successful adaptation. The general perception that retards the adoption of BIPV in many places has been the issue of cost, technical limitations, and lack of general awareness of the technology among potential adopters. The idea of a "sophisticated" energy option for buildings sounds complex in the minds of potential adopters and considering the lack of awareness of the comparative advantages, consumers are reluctant to embrace BIPVs even in advanced countries where the technology seems popular.

Key challenges that have been identified in the literature on BIPV are technical barriers, the issue of efficiency, design and aesthetics, public perception, awareness and education, economic limitations, and limited demo projects (Attoye et al., 2017; Imenes, 2016; Shukla et al., 2017 ; Shukla et al., 2018 ; Jelle et al, 2012) . The focus of this thesis is on awareness, willingness to adopt and aesthetics of BIPV, as there is a general lack of extensive literature hence practical attempts have been made to fill in the gap. The next topic shall provide a comprehensive review of product awareness and aesthetics.

2.5 Product Awareness

One of the fundamental goals of marketing a product is to create and sustain brand awareness (Huang and Sarigöllü, 2014). 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 (Hoyer and Brown, 1990; Olanipekun and Adelekan, 2022).

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 (Im et al., 2003; Mallo et al., 2015) . 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., 2021) 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., (2020) 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., (2022) on strategies to eliminate barriers to renewable energy adoption in Ghana suggests education as 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 (Guta, 2018; Labay and Kinnear, 1981; Mohandes et al., 2019; Malik and Ayop, 2020) . Existing research on consumer behaviour tend to focus on branding, costing and attitude (Haghpour et al., 2022; Macdonald and Sharp, 2000; Zhang, 2015). Interestingly, a fundamental marketing study conducted in 1984 by Hoyer (Hoyer, 1984) 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 and cost differentials 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.

2.5.1 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 (Hummon, 1988). 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 19^{th} century, post-World War II, and current times (McDonald and Scott, 2007) . 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 allows the producer to showcase their product (Terkan, 2014). Beyond the consumer and producer affair, adverts can benefit society as they convey critical information to the public.

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 (Sharifi et al., 2019).

Advertising has a role to play in the promulgation of sustainable building materials such as BIPVs. For instance, a study conducted by Alamsyah et al. (2020) indicates that advertising tends to promote the adoption of green building technologies (GBTs) among Indonesians (Alamsyah et al., 2020). A conscious effort to advertise BIPV products can therefore go a long way to increase awareness among consumers.

2.6 Aesthetics: The Art of Beauty

Aesthetics, coined from the Greek word "aesthesis" which is originally linked to "sensory perception" is a hoary philosophical concept that examines the art of beauty and taste. Aesthetics have been further concocted to mean various things by art Philosophers, for instance, Baumgarten gave a new meaning which implied satisfaction of senses or sybaritic fulfilment (Hekkert and Leder, 2008). The idea is to substantiate the fact that artworks are produced for satisfaction, fulfilment, and self-gratification. Based on these divergent perspectives, aesthetics has been applicative in the art field and has served as the yardstick for judgement, evaluation, understanding and emotions (Hekkert, 2006). Aesthetics is originally intertwined with design and art, but has recently been used to imply different things in different disciplines, however, it remains a basic principle in assessing nature, people, and art.

As technology advances, industrialisation increases, and humanity explores better ways of solving problems, aesthetics has gradually become a bedrock underlining these developments. The quest for beauty in products and nature has increased compared to the olden days when functionality was the core of everything. In the same manner with which good looks earn people a 'beauty premium', a beautiful product outlook earns a product a natural consideration in the minds of many consumers. Although functionality, cost, brand, ergonomics, and hedonics are core in product choice, aesthetics play an equally crucial role (Townsend and Sood, 2012).

The first impression tends to ward off or invite potential consumers, especially in the choice of a product. Assuming two products with similar content are presented in different packages, one with a low aesthetic value and vice versa, there is a high tendency for consumers to rush for the "beautiful" product irrespective of prior knowledge of the content. This is what some researchers have coined as the "amelioration effect of visual design and aesthetics on content credibility", giving justification to the ligature between credibility and aesthetics (Robins and Holmes, 2008).

Consumers mostly liken beauty to quality. Until people take time to try a product out, or based on the testimony of other consumers, aesthetics and a beautiful outlook mostly serve as the criteria for selection. The appeal is as important as functionality in the world of architecture. Aesthetics can be for commercial, comfort, positive brain stimulation and pleasure, although they may require consumers to pay more. Compromising aesthetics can be related to shooting oneself in the foot. Eventually, consumers will look out for aesthetically pleasant products once they have options.

Various researchers have highlighted the importance of aesthetics in BIPV adoption. For instance, Zomer et al. (2013) investigated the balance between aesthetics and efficiency in BIPVs in Tropical areas. A live study was conducted on a BIPV building in Singapore for one year to ascertain the influence of aesthetics on efficiency. The author's findings demonstrated that efficiency should not be compromised should BIPV aesthetics be explored to full capacity. In fact, the losses determined were relatively minor and it was advised that prominence be given to the aesthetics of BIPV. A paper by Peng, et al. (2011) sheds light on BIPV within the architectural world in China. The findings of the paper reveal that aesthetics, cost, technology, and function are fundamental in BIPV applications apart from focusing solely on integration. It also proposed a maintenance culture for PV cells rather than focusing on prolonging the life span of PV. Therefore, the authors developed a PV structure that makes maintenance easy without compromising the aesthetical value of the building. Kryszak and Wang (2020) also evaluated the aesthetical value of BIPV for roofing. The paper offered an estimate of the cost of aesthetics and established the fact that although BIPV is costly, compared to other options, consumers are willing to purchase them because of their visual appeal. A case study was used to assess the investment cost and the economic benefit of aesthetics. It was realised that manufacturers tend to focus more on functionality, installation complexities, and exorbitant maintenance thereby giving less attention to aesthetics. This intends to hinder acceptance by consumers. Zomer et al. (2014) again analysed two Brazilian airports and accessed the performance of BAPV and BIPV respectively. The rationale was to establish the aesthetic impact of BIPV over its counterpart BAPV when it comes to efficiency and performance. It was realised in both cases that the installed peak power was 100% and 87% respectively. It was concluded that it is worth compromising slightly on efficiency to meet the aesthetic requirements of PV application and to make it attractive to various stakeholders within the built environment. Finally, Shukla et al. (2017) consider the opportunities and challenges of BIPVs in Southeast Asian countries. The study identified that aesthetics among other factors have impeded the acceptance and growth of BIPV acceptance.

It is evident that most of the previous studies conducted on the aesthetics of BIPVs do not tackle the basic approach to improving aesthetics itself in BIPV application, but rather focus on highlighting the mere relevance of aesthetics in BIPV application. The difference here is that this study offers exceptional knowledge from a design perspective by exploring the impact of traditional design symbols on BIPV adoption. Considering the importance of aesthetics in BIPV application, designers and artists must add their voices to the discourse to maximise its beauty and push BIPVs to an enviable design standard that can duly replace modern building materials without struggle.

In the application of BIPVs, the idea of aesthetics cannot be overlooked, else there would have been no need for its development. Since BIPV offers a perfect envelope and merge-off PVs into the building by replacing conventional materials, emphasis is placed on the final outlook of the building. Regular application of solar PVs (BAPVs) could have served its main purpose of electrification but as development and industrialisation increases, there has been a pressing demand to modify PV application to suit modernity. Architectural aesthetics, innovation, creativity, and face-lift have become a priority in the 21st century compared to centuries ago when functionality was the core aim (Forte and Girard, 2009).

Although not much difference, aesthetics has a direct bearing on other factors that influence the adoption of BIPVs such as efficiency and cost (Kryszak and Wang 2020). Just like in product enhancement and packaging, the extra finesse attracts extra cost and in certain cases compromises efficiency (Awuku et al., 2021). With the aim of introducing PVs to replace conventional building materials such that they form part of the building envelope, BIPV consumers must be prepared to make up for the aesthetic additions. However, several studies have revealed that the difference in cost and efficiency because of the aesthetics trade-off is minimal (Corti et al., 2020; Reidel et al., 2021; Kryszak and Wang 2020; Zomer et al., 2014).

2.6.1 General Rules of Aesthetics and Design (Visual Aesthetics)

Aesthetics cuts across various areas and cannot be restricted only to the arts, although art forms a critical part of the philosophy of aesthetics. In the Western world of art, visual art has gained massive attention compared to other forms, thereby making it very easy to associate it with aesthetics. However, it is worth noting that, aesthetics goes beyond visual art, as it captures the sense of pleasantness in general. For example, landscapes, humans, the sun, and the moon can strike beauty, therefore equally qualify to be tagged as aesthetically pleasant (Hekkert, 2006).

Naturally, consumers prefer shiny and beauteous things and therefore may sometimes desire them even above functionality. Aesthetics gives pleasure when perceived and vision gives substance to aesthetics. However, there is more to aesthetic design than what is merely perceived. To evaluate the role of aesthetics in BIPV adoption, aesthetics shall be limited to visuals and landscapes. In visual aesthetics, various elements, and principles trigger beauty. In other words, for one to appreciate beauty, there are some underlining elements and principles that formulate beauty. The build-up of a design for visual impact usually goes through various stages of consideration and development. This gives credence to the elements and principles of design, which are the foundation and building blocks of every design. This section shall discuss three of these elements, namely colour, shape, and texture. Design principles such as variety, balance, rhythm, emphasis, contrast, and proportion shall also be discussed. Gaining some substantial understanding of the elements and principles of design will serve as the building blocks for appreciating aesthetics in the contest of BIPV application.

2.6.1.1 Elements of Design

A. Colour

Colour forms a basic visual base in product design and consumer choice. Colour is what the eye perceives when light falls on an object. It is estimated that there are over ten million colours, making it difficult to determine specific shades of a colour (Evans, 2010) . Colour comes up basically in design, architectural finishing, nature and almost all aspects of life. Theoretically, colour can be grouped into many systems. From a graphical perspective, colour has been grouped fundamentally into primary, secondary, and tertiary. The primary colours are red, blue, and yellow and the secondary colours are orange, green and violet. Tertiary colours on the other hand are the mixtures of primary and secondary colours (Cassidy, 2017). Colour forms a fundamental aspect of product beauty and helps artwork or products to gain their full glory and appeal.

In PVs, it is possible to explore various colours to meet aesthetic requirements, especially in the architectural world. (Soman and Antony, 2019) explores Selectively Modulated Aesthetic Reflectors Technology (SMART), which is useful in producing variations in cell colours. Figure 23 below shows a variety of colours for solar cells.

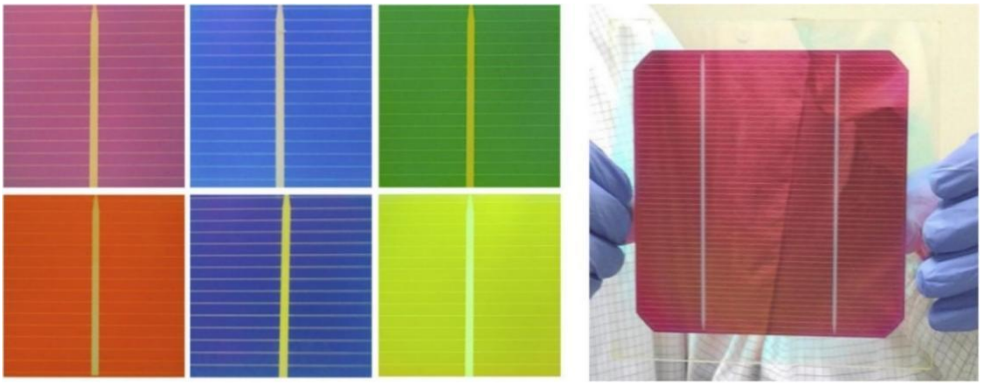

Figure 23. Visual representation of coloured cell coating (Soman and Antony, 2019)

B. Shape

Shape is important in design as it serves as the fundamental element and building block for developing an artwork. Shape basically refers to an enclosed space that is defined by a perimeter. Every single element of design exists in the form of shape. Basic shapes include squares, rectangles, and triangles. On a broader scale, shapes can be categorised into geometric, organic, and abstract (Rothbart and Lewis, 1988) . Determining the most appropriate shape fit for purpose is key in the successful execution of an artwork, as well as full acceptance by the set target audience. In a study conducted by (Dimitrokali, 2015) , it is evident that solar PVs can be explored in various shapes, for instance moulding somewhat complex shapes such as trees as seen in Figure 24. Shapes in PV applications can be basic, carved into creative pieces or sophisticated designs.

Figure 24. Shapes of PVs (Black, 2017; Barber, 2018; Cameron, 2015)

C. Texture

Texture is the general feel of a substrate. In other words, the roughness or smoothness of a surface. Texture comes in two forms: visual and tactile. Visual texture refers to the impression of texture created either through lines, shapes or colour on a substrate or screen, whereas tactile refers to the actual texture that can be felt, for instance, smooth or rough (Benard, 2016). Texture brings life and realism to an object. In product design, the tactile texture is important as it serves as the final feel of an object. In PVs, texture can be achieved by plasma etching, laser texturing and metal-assisted texturing (Abbott and Cotter, 2006) . In PV design, various textures have been explored to improve its efficiency. For instance, (Schmager et al., 2017) use the texture of the viola flower to enhance the effectiveness of photovoltaics. Figure 25 shows textures curled from the viola flower for PV development.

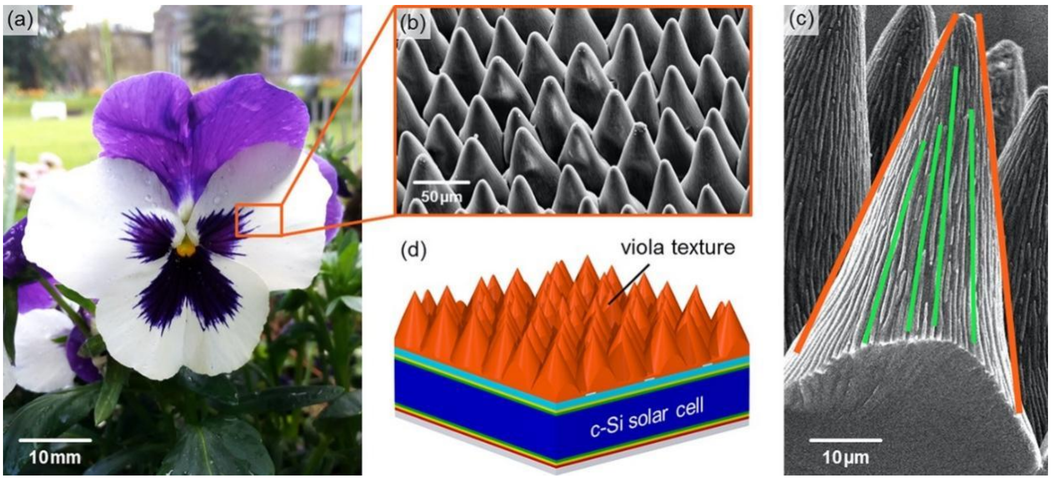

Figure 25. Microscopic Textured image of PV texture curled from viola flower (Schmager et al., 2017)

However, the choice and application of colour shape and texture as elements of design in BIPV application are partly dependent on external or environmental factors. The surroundings, nature of the building, culture, ethos of the people as well as taste may inform the application of these elements.

2.6.1.2 Principles of Design

A. Variety

This usually refers to the ability to match varied elements that have very little or nothing in common to achieve a holistic composition. Variety brings a different touch, unique from the same element in a composition. It is easy to break monotony through variety, to excite and spark the interest of consumers. Variety can come through texture, shape, and colour among other elements of design (Hurst, 2018) . Variety is usually introduced to reinforce the aesthetic magnitude of other elements of design in composition to enhance user experience. In PV applications, variety can be demonstrated through the juxtaposition of different colours, shapes, and textures among others.

B. Balance

The idea of visual weight and pictorial balance is of true essence in the world of art. Perhaps not to sideline other principles of design, but it happens to be the easiest the eye can pick (Niekamp, 1981). Balance in design simply put is the even arrangement of elements in an artwork. It constitutes the apportionment of visual weight, such that one side of the design does not appear smaller than the other. Balance usually comes in either symmetrical or asymmetrical forms. Symmetrical balance ensures that the components on the left equally match those on the right and vice-versa while in asymmetrical balance elements on one side differ but can still give an illusion of balance. Usually, symmetrical balance is regarded as more appealing and beautiful compared to other forms of balance. This is evident in humans, and patterns as depicted in the works of (Perrett et al., 1999; Jacobsen and Höfel, 2003). Visual balance makes compositions interesting and can hold a viewer's attention since it is aesthetically pleasing (Kandemir et al., 2017). To achieve aesthetics in product display, balance is a crucial principle that cannot be compromised. In the BIPV application, the ability to balance the various PVs in each space, such that harmony is achieved is key. For instance, balance can be achieved by evenly distributing shapes or colours of PVs during application to make it aesthetically appealing.

C. Rhythm

Rhythm is the repetition of specific or several components of a design to intentionally create movement. The phenomenology of rhythm coordinates the idea of repetition to how viewers perceive them. In real life, rhythm ends up creating balance and stability in a work of art. In the world of design, rhythm may be reflected in the repetition of structures, function, movement, growth, and process (Chan, 2012). The idea of rhythm mimics duplication or re-creation. Once an element is repeated, with the overall aim of creating a pattern that is pleasant for visualization, then the rhythm is created. Rhythm demonstrates consistency and dominance in practicality. In the BIPV application, various panels can be arranged to create an illusion of repetition that is intended to rhyme when perceived. This makes it seem attractive to onlookers. A classic example is Figure 26 below, where panels have been vertically mounted on the façade to depict rhythm.

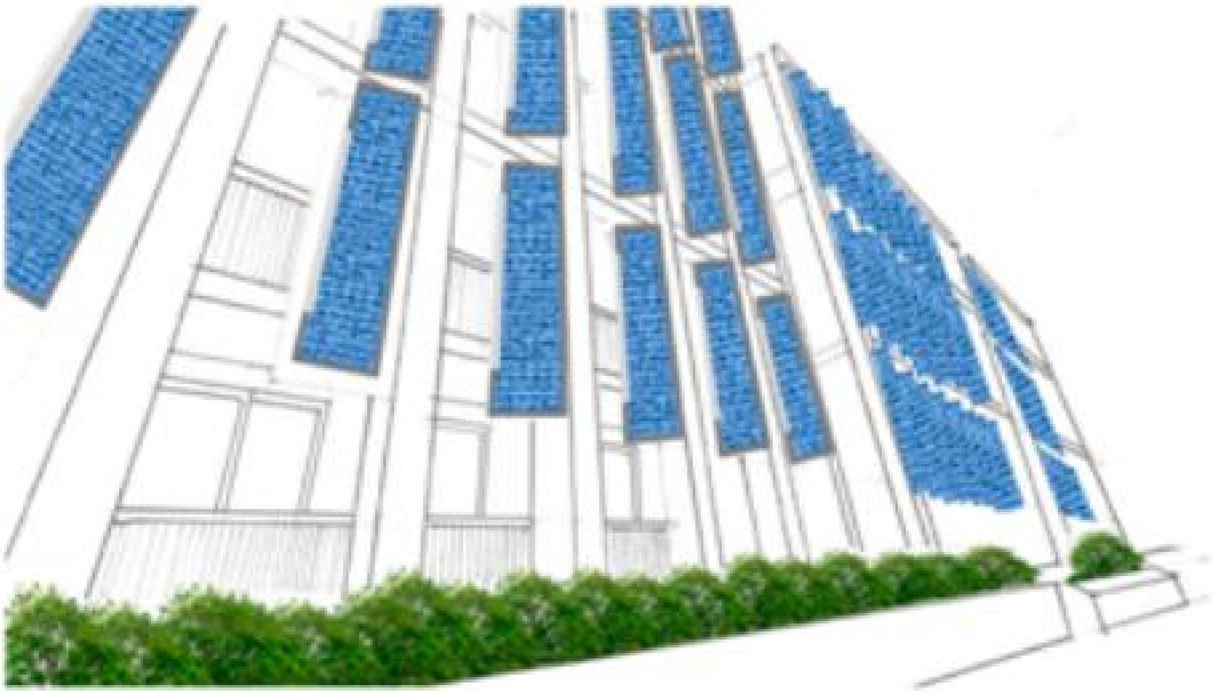

Figure 26. PV mounted on the façade to depict rhythm (Attoye et al., 2017)

D. Contrast

Contrast means being different. The idea that different elements can be peacefully composed into a substrate to give a homogenous effect and a sense of agreement is not new in design. However, achieving contrast requires considerable skill and conscious aesthetic effort. The contrast could be in colour, text, shape, style, and texture among others. The most important thing to look out for is the combination of different elements for a holistic outcome (Black, 2015). Contrast introduces an emphasis on a particular point of interest.

E. Proportion

This is a fundamental principle of design which highlights the relationship between the sizes of elements in a composition. Proportion somehow highlights the most essential elements in a work. For instance, bigger elements are given prominence and vice-versa. A perfect playout of proportion in a composition emphasises harmony. There is a high tendency for all elements of design not to be on the same scale in a composition. However, prominence or emphasis may be given to specific elements depending on their relevance. A perfect balance of the scale of the elements in surface design helps achieve a perfect proportional application (Cohen, 2014). Opening up to aesthetics in BIPV application is essential for its complete adoption in the architectural landscape as it replaces conventional building materials.

2.6.2 Cultural Relevance of Traditional "Adinkra" Symbols in Ghana

Culture is intrinsic among most Ghanaians, shaping their identity, values, and social interactions (Darley and Blankson, 2020). From one generation to the other, cultural practices such as symbolism, craft, music, dance, and festivals portray the diverse ethnic heritage of Ghana. Culture has great influence on every facet of life, Symbols like Adinkra and practices such as communal living foster unity, respect, and a sense of belonging. Culture influences every aspect of life, from language and rituals to moral values, guiding social norms and providing a shared sense of history and continuity, thus preserving Ghanaian identity and pride.

Symbolism forms a significant part of indigenous Ghanaian culture, and it is used to express the beliefs, values, and background of a particular group of people. Usually, there is a clear linkage between specific words, sayings or proverbs and these symbols. This gives meaning and tangibility to traditional symbols although sometimes they can be subjected to personal opinions (Kuwornu-Adjaottor et al., 2016). In Ghana, Adinkra has emerged as the most popular symbol that is widely used for various purposes. For instance, they are printed on cloths, used as emblems, adopted by various ethnic groups and clans as totems (Asare et al., 2014), used for industrial and commercial purposes such as company logos and have even been featured in intercultural communication games (Müller and Muijen, 2021).

According to history, Adinkra was named after a famous Ghanaian King (Nana Kofi Adinkra) who became popular in the Asante empire in the 19th century after the then-Asante's defeated and captured him after a war in their capital, Kumasi. The craftsmen among the captives started using these Adinkra symbols as stamped patterns. Adinkra which means "Goodbye" in the famous Ghanaian language (Akan) was later fully adopted and replicated as patterns on textiles by the Asantes (Aboagyewaa-Ntiri et al., 2018). The complexity of saying goodbye to a loved one spurs mixed feelings, sometimes of pain and happiness. The former is usually associated with death, and considering the dreadful nature of death among humans, the artisans demonstrated these emotions through philosophies, messages, and abstract symbols. Meanings were given to each of these symbols and replicated through dyes on various substrates including fabric, wood, metal, and pottery for both commercial and personal use (Kquofi et al., 2018). Since then, Adinkra has grown to become one of the most popular African symbols and it is acknowledged globally (Prempeh, 2020).

Ghanaians uphold Adinkra with pride and dignity. Presidents, Chiefs, and well-acknowledged leaders wear popular "Kente cloth", mostly made with patterns of Adinkra to various ceremonial gatherings. This goes a long way towards promoting the high stakes of Adinkra in Ghana. Adinkra has also been adopted for various architectural purposes. Many traditional-minded people and millennials with a taste of antiquity have adopted Adinkra symbols for cladding, decorations, and facades in buildings. Also, national monumental buildings, churches and other religious temples have been adorned with Adinkra symbols as some proponents believe that there is a relationship between these adinkras and spirituality (Ossom-Batsa and Apaah, 2018).

2.6.2.1 Some Popular Adinkra Symbols in Ghana and Their Meaning

Various Adinkra symbols have names, meanings, and philosophical underpinnings as seen in Appendix 1. This research highlights five popular Adinkra symbols and their meanings as seen in Figure 27.

Figure 27. Popular Adinkra symbols (Adinkra Symbol & Meanings, 2024)

Over the past years, some specific symbols have become very popular among Ghanaians. They are widely adopted as emblems, logos, themes for fabric design and other artefacts. Classical ones and their meanings as shown in Figure 27 are as follows:

The Akofena symbol (Sword of War) showcases a crisscrossed sword. In Ghana, the sword signifies heroism, strength, bravery, and fearlessness. Many traditional powerful chiefs and leaders have adopted this symbol as a motif due to its significance. Apart from all the meanings, the crisscrossed sword signifies the authority of the state. The Akoma just like in everyday life, the symbol of the heart signifies patience, love, tolerance, and containment. This symbol is adopted by many Ghanaians, especially as a sign of peace and love. The Gye Nyame (Only God) is valued by Ghanaians as it portrays their relationship with the supreme being (God), hence giving credence to Him in every instance. The 'Gye Nyame' symbolises the sovereignty and pre-eminence of God. Many Ghanaians adore this symbol and place a lot of premium on it. This symbol is known to be the most popular of all Adinkra symbols to be adopted for various purposes. It further highlights the deep connection many Ghanaians have with religion and the belief in God.

Adinkrahene (King of all Adinkra) is tagged as superior to all Adinkra since most of the symbols were developed following inspiration from this symbol. It goes on to signify the immense role of leadership and direction. Osram ne Nsromma (The Moon and the Star) tells a story of the love, loyalty, and understanding that exists between a man and a woman. It highlights the myth of the "sky's relationship with the moon". This symbol has been adopted for textile printing and on various substrates for commercial and religious purposes.

2.6.3 Traditional Adinkra Symbols and BIPV Applications

The idea of replacing conventional building materials such as roofs, windows and façades makes it incumbent to consider the taste of consumers especially when it comes to aesthetics. Although issues such as cost and efficiency are greatly considered, aesthetics cannot be underrated when it comes to buildings, especially in this modern day. Buildings go beyond the "safe space" to contain people. Value is placed on the overall beauty of building materials hence if solar PVs are to replace conventional building materials, the aesthetic premium cannot be underrated. BIPV can be largely tagged as aesthetically appealing and attractive as compared to other variants of PV applications used directly on buildings. However, to promote the adoption of BIPV in specific countries, it is important to explore specific epitomes of beauty that appeal to the people. The literature on BIPVs in Ghana and Africa at large appears scanty. In a desktop search, a handful of studies were traceable hence giving credence to this study. The next topic elaborates on the top contact of solar PV cells and printing procedures.

2.7 Top Contact of Solar Photovoltaic Cell and Printing Procedures

Since the inception of solar PV cell technology, its top contact has played a crucial role in the collating and transfer of electrical energy from the sun. A direct optimisation of the top contact is therefore essential as it improves conductivity, reduces shading, and improves overall cell performance. An improvement in top contact goes beyond lowering electrical losses, minimising shading, and ensuring cell efficiency (Handy, 1967). Now, aesthetic optimisation and the beauty of cells have become imperative due to modernity and the quest for nicety (Awuku et al., 2021; Sánchez-Pantoja et al., 2018) . The top contact design of a solar cell critically considers the patterns, fingers, reliability, and adhesion dynamics (Handy, 1967). Top pattern designs can be produced economically through screen-printing and laser scribbling. These aesthetic methods can help create more precise and customised patterns on solar cells (Ojeda et al., 2020).

2.7.1 Solar PV Cells Printing Materials

A wide variety of printing materials have been explored for top contact printing of solar PVs. Key considerations are the overall cost, stability, availability, electrical conductivity, and compatibility with other components. Famous among these materials are Silver, copper, and aluminium pastes.

Silver conductive paste tends to create thin, smooth, and flexible patterns with high electrical conductivity. They can be used on a wide variety of substrates including wood, plastic, glass, ceramic, metals, and fabric. A silver paste can be applied on a selected substrate by spraying, dipping, and brushing and has the possibility of drying on its own at room temperature (AntsLAB, 2023; Xiao and Chung, 2005). However, for optimal electrical conductivity, it is recommended to cure between 15-20 hours at room temperature or 125-150^{o}C for 30 minutes (Science Services, 2023). Table 2 shows detailed advantages and characteristics of conductive silver paste (AntsLAB, 2023).

Table 2. Characteristics of Conductive Silver Paste - Authors construct, curled from: (AntsLAB, 2023)

• Extremely resistant to fracture
• Very high bond strength
• Suitable for joining materials with dissimilar thermal coefficients of expansion
• Used at room temperature
• Excellent aging resistance
• Wide operating temperature range – retains resistance and conductivity at extreme temperatures
• Stable – low bond (set) of resistance through cycling temperature
• Compatible with most common substrates – do not tarnish
• Excellent adherence to a wide range of materials
• Hard and wear-resistant after proper drying
• Compatible with a wide range of materials
• Suitable for substrates that cannot be welded
• High electrical conductivity

Copper on the other hand has several advantages as well, however its conductivity is not comparable to silver. Other advantages include less expensiveness and availability. Copper is known to have a high curing temperature and time, compatibility issues, and reliability. Several studies have investigated mechanisms to improve copper paste's efficacy in solar PV cell printing (Ebong et al., 2021; Hee Lee and Hong Lee, 2019; Musztyfaga-Staszuk et al., 2018) with the hope that copper can be widely adopted due to its affordability and availability.

Finally, aluminium is another high-conductive material adopted in the solar industry. It is less expensive, compared to silver, and has good electrical conductivity. However, aluminium is often used as a back contact material in solar cell production (Kamp et al., 2014).

2.7.2 Top Contact Printing Procedures

In basic terms, to print means to transfer colour onto a substrate to develop a body of text or image. The history of Printing can be tied to an integral part of civilisation. As far as the end of the second-century common era, printing had been discovered in parts of China. By then, they had access to paper, ink and surface-oriented texts which had further developed into reliefs. Over the years, printing evolved into three major techniques (i). letterpress (ii). Offset Printing and (iii). Gravure Printing. These days, other types including screen-printing, lino printing, flexography, digital printing, 3D printing, and Monography have been explored.

When it comes to the printing of solar cell top contact, both traditional and modern techniques are applicable. Famous traditional techniques include screen printing and thermal evaporation. Some modern printing methods also include electroplating, chemical vapour deposition and sputtering. It is important to note that the thickness or size of the top contact and electrical characterisation determines the selection of the print method.

2.7.2.1 Screen-Printing

Screen-printing is a traditional process which involves the use of force to push ink usually through an organdie mesh onto a substrate to create a pattern, text, or illustration. The idea is to create a stencil with the notion of making the negative image area impervious to ink. Ink is only allowed through the positive area, which registers on the substrate.

The process involves tightly stretching the organdie fine mesh onto a wooden or metal frame, after which a stencil is created. Stencils can be created from a wide range of approaches and materials. These include fabric, stencil paper and greasy paint. Stencils can be applied on a screen in diverse ways. For instance, they can be placed directly under the screen for printing or transfer the design onto the screen by using a photo-sensitive paint. Once the design has been transferred, the squeegee can be used to force the ink through the mesh onto the substrate (The Metropolitan Museum of Art, 2023). The elements of screen printing are shown in Figure 28.

Figure 28. Elements of Screen-Printing (The Metropolitan Museum of Art, 2023)

2.8 Empirical Review on BIPV in Ghana and Africa / Previous Study and Literature Gap

The literature that exists mainly revolves around basic solar energy (stand-alone, mini-grid and off-grid systems) and it's widespread. It is prevalent that there is very little literature on Building Integrated Photovoltaics in Ghana, hence the need to conduct extensive research on BIPV adoption in Ghana. The few existing pieces of literature on BIPVs are mainly on cost advantage analysis (Gyimah, 2014) and the option of BIPV triple-junction amorphous silicon (3a-Si) roof shingles for Ghanaian homes (Essah, 2010) . It is also evident that, even beyond Ghana, there is still very little literature on BIPVs in Africa. Searching an existing academic database such as Scorpus, google-scholar, zlibrary, and university library among others, a few papers were identified on BIPV in Ghana and Africa. For instance, Gyimah (2014) conducted a study on the cost analysis and advantages that come with adopting BIPV roofing in Ghana. A quantitative approach was adopted to explore the prices of roofing sheets and PV materials for roofing. It was established that on average, it costs $2,160.00 to roof an area of

24m^2 and $9,600.00 to use BIPV roofing for the same space. The BIPV advantage; offsetting the cost of building materials was applied hence bringing the cost of BIPV to $7,044.00. The estimated amount of energy generated from the installed PV was 16,512 kWh. The researcher then converted the generated amount of energy to a monetary value of $3,302.00 per annum. Considering this amount, the payback period for adopting BIPV is stipulated as two and half years, therefore BIPV is considered a viable option for roofing in Ghana (Gyimah, 2014).

Essah et al. (2010) conducted a study into the opportunity of producing electricity from BIPV shingles. The study mainly focused on BIPV roof shingles from "triple-junction amorphous silicon (3a-Si) being used to replace conventional roofing materials in Ghana. The efficiency of the triple-junction amorphous roof was measured against conventional roofing tiles. Disparities in room temperature, tilt angles, and the impact of temperature on the materials were observed. The findings showed that 3a-Si performed well in Ghana and had a high possibility of replacing conventional building roofs in Ghana and could withstand salt spray, especially in buildings around the coastal belts. A shortfall such as an increase in room temperature by 1-2°C was identified (Essah, 2010).

Ziuku et al., (2013) accessed the possibility of BIPV in South African residential housing considering the suitable environmental conditions. The paper aimed at creating awareness of BIPV among policymakers and stakeholders. It was established through a BIPV energy-efficient building simulation that room temperature can be significantly affected by BIPV adoption (Ziuku and Meyer, 2013).

Akata et al. (2017) explored the possibility of BIPV in tropical regions of Cameroon. The paper presents a substantial case for BIPV adoption in Cameroon by analysing a selected BIPV building (roof integration) of 3 kW/day. Simulation and modelling techniques are employed to determine the "indoor air temperature and humidity" (IATH). The study showed that BIPV had the advantage of reducing the primary energy consumption annually from 79.58 kWh/m^2 to about 13.64 kWh/m^2 apart from offsetting the cost of conventional building materials (Akata et al., 2017).

The scanty nature of literature on BIPV in Ghana and Africa at large gives credence to this study which seeks to investigate the opportunity of BIPV in Ghana. Also, considering the above studies on BIPVs in Africa, it is evident that none of them have highlighted the relevance of aesthetics or the potential policies that can expedite the acceptance and adoption of BIPVs in Ghana and other African countries.

2.9 Chapter Summary

This chapter has presented an extensive literature review on the prospects and quagmire surrounding BIPV adoption in Ghana. Pertinent topics on energy problems in Ghana, solar energy, BIPV, aesthetics and the Ghanaian Adinkra symbol have been covered. An empirical review of existing literature on BIPV in Africa has been highlighted. The growth in solar adoption in Ghana promises to make room for BIPV especially as it offers a more sophisticated and architecturally friendly solar application. Very few studies have been conducted on BIPV adoption in Africa hence making this study unique and promising to contribute extensively to the knowledge gap in the area. This study sets out to (a), determine the effectiveness of Architectural visualisation and Design on BIPV awareness in Ghana; (b), establish the nexus between Adinkra symbols and BIPV adoption in Ghana; (c), use screen-printing technique to transfer traditional Ghanaian Adrinka symbols on solar cells and examine their characterisation and (d), identify and propose favourable policies to improve BIPV adoption in Ghana. The next chapter highlights the methodology adopted for the study.

CHAPTER 3: METHODOLOGY

3.0 Introduction

This chapter contextualizes the research design and related methods adopted for the study. The research paradigms, strategic processes, tools, and methods used to specifically address the various objectives of this study are outlined in this chapter.

3.1 Research Paradigm

Thomas Kuhn popularized the word 'Paradigm' within the academic community in the 1960s as a philosophical way of thinking (Mertens, 2012) . Originally, the Greek aetiology 'paradeigma' means pattern. In scientific studies, the paradigm can be said to be the bedrock on which the methodology is framed and how the researcher perceives the study (Mackenzie and Knipe, 2006). In basic terms, it comprises the school of thought that underpins a study. Fundamental philosophical terminologies such as ontology, epistemology, methodology and axiology (Killam, 2013) have become popular in educational research. In one way or another, every research is upheld by these identified fundamental paradigms. It is therefore imperative to contextualize this by discussing the paradigm adopted for this study. These days paradigms have evolved. Proponents such as Creswell, (2013) simply put paradigm as "worldview". He categorizes paradigms into pragmatism, positivism, constructivism and participatory. Figure 29 below identifies the fundamental elements that underpin each worldview as propounded by Creswell.

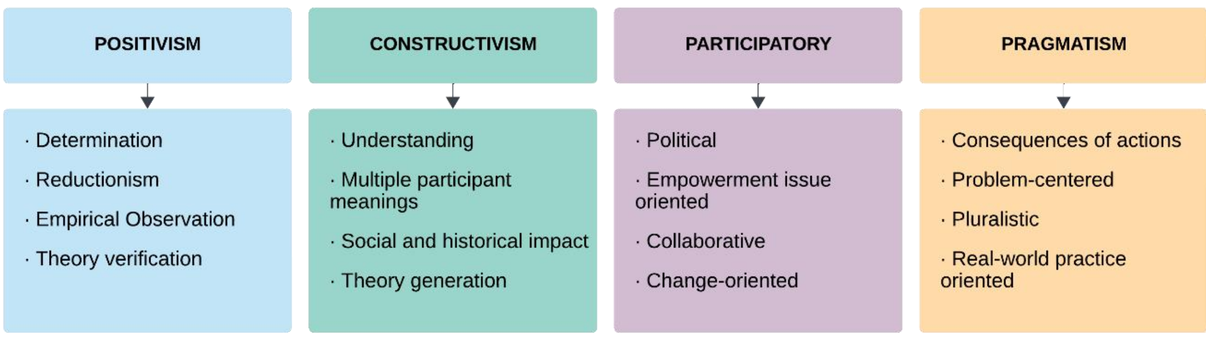

Figure 29. Four worldviews (Creswell, 2013)

This study can be categorized under positivism since it ticks all the identified attributes. Positivism was first introduced by French philosopher; Auguste Comte in 1856. This worldview holds that a study is validated through scientific means, for instance, experiments and observation. Ideally, a positivist paradigm is based on deductive logic, assumptions/hypotheses, scientific method, discussions of findings and drawing meaningful conclusions (Kivunja and Kuyini, 2017) . Here, outcomes are measurable and definite since verifiable empirical data is utilized. Due to the assumptive nature of the positivist paradigm, the quantitative method is adopted to ensure precision in explaining the retrieved dataset.

On the other hand, Saunders et al. (2009) suggested two specific paradigms that can be adopted as a guide to executing research: positivism and interpretivism. Several studies have reiterated and reviewed these paradigms as acceptable standards in any scientific research (Alharahsheh and Pius, 2020 ; Clarke, 2009; Ryan, 2018). The next topic shall briefly touch on positivism and interpretivism as relevant paradigms for this study.

3.1.1 Positivism versus Interpretivism

Positivism stems from the philosophical viewpoint of observing the reality that surrounds us in society. The positivist researcher adopts an observable and measurable objective to test various variables stemming from raised questions as usually seen in quantitative studies (Creswell, 2013) . Positivists view research through an objective inference from a sampled population, assessing the variables involved, and validating set hypotheses based on findings. Many scientific studies that deal with positivism are devoid of human biases since there is direct numerical evidence (Saunders et al., 2009).

Interpretivism on the other hand emerged from the reassessment of the defects of positivism, mainly subjectivity of perspective (Alharahsheh and Pius, 2020) . It rather focuses on direct interaction and response from the subject being understudied. This paradigm adds depth and regards humans as superior to mere objects being studied. In other words, there is a difference between research that involves humans and physical phenomena. Interpretivism usually explores qualitative data (Saunders et., 2009) and relies on empirical evidence rather than mere quantities. Just as the deductive research approach is employed for quantitative studies, the inductive approach is adopted for qualitative studies. Interpretivism can be said to add more details to a study compared to positivism.

This current study, therefore, leverages the positivist paradigm as it seeks to gather the opinions of Ghanaians on the prospects of BIPV. In line with positivism, a solid framework was developed through an extensive review of related literature. This led to the formulation of research questions. The survey questionnaire approach was adopted to solicit data from 412 respondents and the retrieved data was tested and validated using a statistical analytical software called SPSS.

3.1.2 Deductive and Inductive

The human mind has a unique way of manipulating and processing a given information to arrive at a substantial conclusion. The reasoning process is usually categorized into two perspectives: inductive and deductive (Azungah, 2018) . Inductive reasoning starts with critical observation, followed by the quest to establish a logical conclusion about the phenomena understudied (Hyde, 2000) . Usually, studies that involve inductive reasoning are not theory testing and dwell on limited data, mostly categorised as qualitative in nature (Saunders et al., 2009).

Deductive on the other hand is based on a verifiable theory and starts with the original intention to study phenomena against the backdrop of validating an existing theory (Hyde, 2000) . The deductive research approach starts with identifying an existing theory that best fits the phenomena being studied; developing related hypotheses considering the identified theory, gathering data, scientifically testing the hypothesis, and finally analysing the result to create a meaningful discussion. Studies under the deductive approach are mostly quantitative since they involve a numerical measure to answer specific questions (Azungah, 2018; Hyde, 2000; Saunders et al., 2009). This study, therefore, relies on the deductive approach since it seeks to validate a set theory through specific "smart" questions with quantifiable data that is scientifically validated.

3.2 Quantitative, Qualitative, Experimental and Mixed Methods

A. Quantitative as the name implies deals with numbers. This approach is usually adopted when collating and analysing data objectively from closed-ended questions that involve statistical analysis. The final data outcomes are presented as graphs, charts, and tables (Bryman et al., 2008). As discussed above, the retrieved data is used to answer a set of research questions to further confirm an underlying theory. The quantitative research approach is usually associated with positivism and deductive reasoning approaches (Saunders et al., 2009) and involves a high number of participants. In some instances, a quantitative study can create room for qualitative data to further validate its findings (Mackenzie and Knipe, 2006). The quantitative study further establishes the correlation between independent and dependent variables to help build a more robust understanding of the relationship between subjects.

B. Qualitative study on the other hand relies on in-depth data acquired through detailed interviews, observations, and open-ended questionnaires to understand a phenomenon. Here, the sample size is usually smaller compared to the quantitative and is analysed through the subjective interpretation of findings (Mackenzie and Knipe, 2006). A qualitative approach is said to be adopted if the researcher seeks an in-depth understanding of a phenomenon rather than mere numerical evaluation.

C. Experimental design/ Design of experiment on the other hand involves a systemised approach with guided principles leading to a verifiable, replicable, and specific conclusion. Experiments are usually based on the overarching intention of verifying an existing hypothesis or probing into the characteristics and functionality of a system. This approach usually marries existing theoretical underpinnings of experimental design and adequate knowledge of the specific topic to be investigated. The selection of a specific experimental design usually depends on the specific object under investigation. Nonetheless, an initial mind-map planning is essential (McIntosh and Pontius, 2017). Figure 30 shows a schematic representation of an experimental planning process.

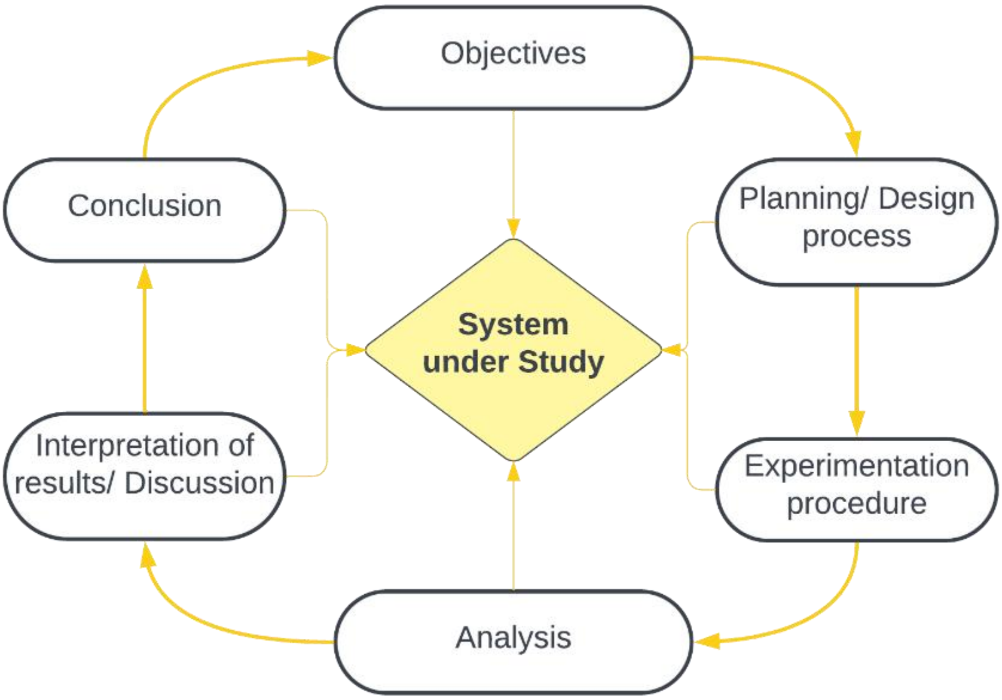

Figure 30 Schematic diagram of Experimental Planning Process (Authors construct, culled from (McIntosh and Pontius, 2017)

D. Finally, the mixed method is a blend of both quantitative and qualitative or other approaches to better understand a phenomenon. It demonstrates a purposeful blend of both methods in collecting data, analysing, interpreting, and drawing meaningful conclusions. Mixed methods emerged to solve the perceived biases and deficiencies in both quantitative and qualitative methods (Shorten and Smith, 2017) . Some quantitative studies make room for qualitative inputs from respondents (Mackenzie and Knipe, 2006). Ideally, mixed methods may have the same level of quantitative or qualitative data input or qualitative being the dominant and vice versa (Johnson et al., 2007). Similarly, other approaches such as experimental design can be blended for a purposeful outcome as seen in Figure 31. This study is therefore considered as a mixed method since it blends quantitative and experimental design.

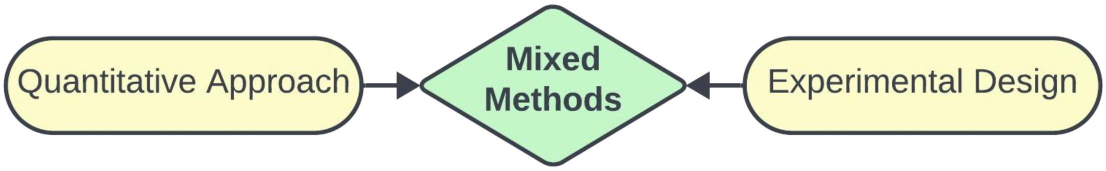

Figure 31. Research Method (Authors construct)

3.3 Background of the Research Design

The idea to turn an assumption into a tangible outcome can be fiddly hence a scientifically rigorous procedure must be followed to clear any doubt and confusion. The validity of any research work can be attributed to the research design. In other words, a failed research design automatically annuls the outcome of the study. Research design in basic terms applies to the collective name for the procedure adopted in gathering, presenting, and analysing data such that the purpose of the research is achieved scientifically (Akhtar, 2016) . Although the specific research questions and objectives determine the design approach to be adopted, there is no one route to research design (Robson, 1993).

Some proponents argue that there are three main approaches to research design: case studies, experiments, and surveys (Robson, 1993) . However, (Saunders et al., 2009) opine that, eight approaches exist: grounded theory, experiments, case study, archival research, action, ethnography, narrative enquiry, and surveys. Most importantly, all these approaches lead to a scientifically sound conclusion and are valid for research purposes. A scientific research design enhances the replicability of the study for future works. Empirical evidence points to the fact that a quantitative research approach is usually adopted for investigating new product/technology adoption (Crabbe et al., 2009; Liu et al., 2009; Shaikh and Karjaluoto, 2015) . This study, therefore, takes clues from similar studies and mainly adopts a quantitative survey approach, and experimental design.

3.3.1 Sources of Data for the Study

Traditionally, data sourcing approaches, known as research instruments, have been categorized into two, namely, Primary and Secondary. As the name implies, primary data is collected from the researchers 'first-hand', whereas secondary data may be sourced from the works of other researchers. This may include books, journals, published or unpublished research papers from verifiable sources and web pages (Rabianski, 2003). These second-hand data are used by other researchers apart from the primary collector. To answer the research questions and set objectives, this study relied on primary data collected from the survey and experimental design. Details of specific approaches shall be outlined in the subsequent sections. To enable a consistent outline of methodical components for the study, this chapter is grouped into five main sections in line with the stages used in the approaches and design process (Creswell and Creswell, 2018).

The sections are (a) the Research approach – which outlines the data collection styles (b) the Research Strategy – which outlines the plan of action for the study, (c) Research techniques – which define the operational procedures for data collection and analysis (d) Research Timelines – which defines time horizons of the project and (e) Ethical considerations – which outlines the ethical principles underpinning the research work. The details under the various stages are sequentially presented below.

3.3.2 Research Approach

This research aims to generate insight into the prospect of BIPVs in Ghana's built environment while carefully considering aesthetics and Policy. Therefore, a robust research approach and method are essential to guarantee its validity, replicability, and reliability. The research approach describes the data collection and analysis pathway paradigms of a study (Baxter et al., 2008; Hunter, 2009; Creswell, 2013).

Fundamentally, several recognized approaches and methodologies such as surveys, case studies, observations, experiments, and interviews have been explored in studies that involve product adoption. Considering the research aim and objectives, the positivist paradigm was adopted for this study with a mixed-method approach

(Quantitative - Experimental). After gathering quantitative data from 412 respondents, an open-ended space was created for respondents to make input to serve as auxiliary qualitative data to back the main findings.

Creswell (2013) describes three types of mixed method designs for a given study where the order of qualitative and quantitative data is outlined (Creswell, 2013). These are (a) exploratory sequential design where qualitative data is analysed before quantitative, (b) explanatory sequential design where quantitative data is analysed before qualitative and (c) convergent where qualitative and quantitative are analysed at the same time. In this instance, quantitative and experimental designs are analysed concurrently as shown in Figure 32.

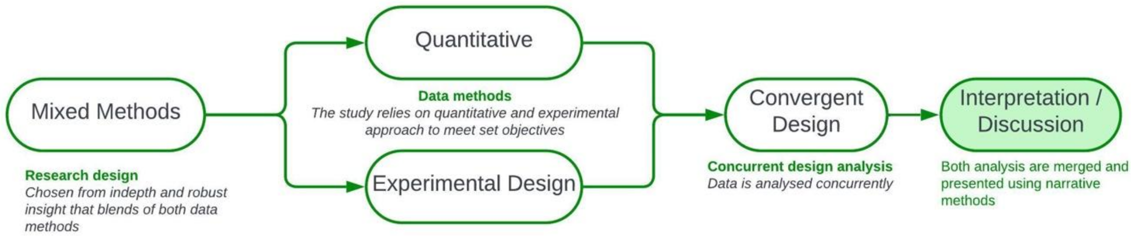

Figure 32. Research Design flow for the study, adapted from (Creswell, 2013)

This current study leverages the convergent research design. The convergent design provides a comprehensive analysis of a data set without any restrictions to sequence or order of analysis using quantitative or qualitative data (Razali et al., 2019;Edmonds and Kennedy, 2017). Each data type, in this instance (quantitative and experimental design) carries equal weight and the results of both are merged to provide an in-depth interpretation of results in a process called convergence. The approach adopted makes room for respondents to share their opinions through a letter box provided in the survey. This offers qualitative information to support the answers provided in the survey.

The choice of positivism and quantitative deductive research approach stems from the review of existing literature on technology acceptance. In line with Creswell (2013), this study identifies existing theories, develops questionnaires, collects, and verifies if the data supports and validates the hypothesis made using IBM SPSS (Creswell, 2013). The researcher was also informed by several studies that adopted a quantitative approach to determine the acceptance of similar solar products (Bisaga, 2019; Cheam et al., 2021; Dzokoto, 2017 ; Delaportas, 2016; Sommerfeld and Mengersen, 2016)

3.3.3 Research Strategy

The systematic plan of action for achieving the research objectives is outlined in this section. Commonly employed research strategies for understanding and investigating customer choices are surveys, experiments, archival research, and case studies. To comprehensively achieve the research aim, the main research strategies used are survey and experimental design.

Surveys are widely used for gathering large data, especially within the marketing and academic world. The main survey approach utilized in the study is a market research technique known as Conjoint Analysis. Conjoint analysis is a survey technique that is used to statistically measure the perceptive attributes (or features) survey and experimental design that influence respondent choice when presented with a product or service (Alaraji and Jusan, 2014). Respondents make choices based on hypothetical scenarios or options presented to them. The resultant stated preference of the respondents then forms the basis of analysis to uncover what would drive BIPV adoption decisions in Ghana. The stated preference approach is used over the revealed preference in the study because there is limited variation observed in sustainable building choices in Ghana. Besides, there is very little evidence of BIPV in Ghana's solar sector hence, limiting the availability of observing revealed customer behaviours in making real-time decisions on BIPV adoption (Mansour and Radford, 2016).

A choice-based-conjoint (CBC) approach is utilized in modelling the attributes that influence the respondent decision-making process. The CBC is preferred for this current study as it outperforms other main conjoint approaches (ranking-based conjoint and rating-based conjoint analysis approaches) in the simulation of real-world performance in housing and architectural research applications (Alalouch et al., 2015). In line with the objectives of this study to ascertain the key drivers that would influence the adoption of BIPVs in Ghana, the CBC enables a clearly defined way to gauge user preferences between presented options.

The key steps utilized for the CBC are (a) determining the attributes to be tested, (b) designing the survey that hosts the tasks (c) Collecting responses (d) Analysing the results and (e) reporting the findings. The procedure for these processes is detailed in the next section.

3.4 Research Design, Techniques, Procedures and Data

This section details the operational design, and techniques used to collect, extract, and analyse data for this study. This includes targeting, sampling, data collection and analysis procedures.

3.4.1 Research Design

A gap between the conception of a research problem and finding relevant outcomes vastly depends on the modalities that surround the fundamentals of the research activities, identifying the appropriate data collection approach and efficient analysis. The research design technically serves as the ligature between extant theory and empirical data obtained. The researcher went through three stages to design the study as shown in Figure 33.

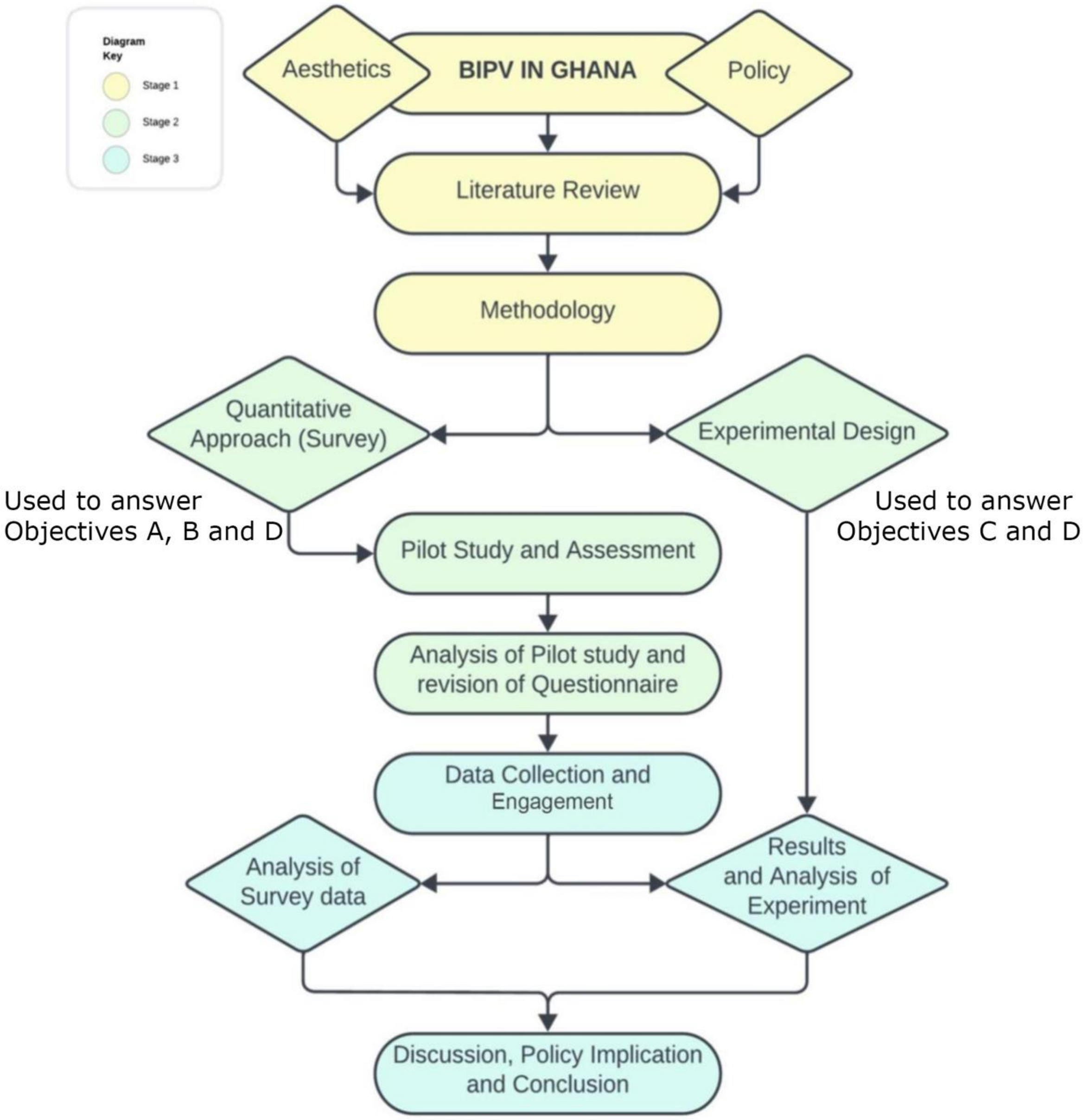

Figure 33. Stages of Research Design (Authors Construct)

The first stage involved an in-depth exploration of existing literature on BIPV in Ghana and related topics on product adoption. There, underlining assumptions, and questions were developed by relying on grounded theories in product adoption such as the Diffusion of Innovation, and Technology Acceptance Model.

The next stage involved the development of a well-informed questionnaire from existing literature and opinions of industry experts as well as academics. The questionnaire went through a rigorous assessment by the supervisory team to ensure all aspects of the study were covered and they were fit for purpose. Ethical consideration was made at this stage. The pilot questionnaire was then distributed to selected people in various regions across Ghana. In all, 102 participants were involved. The retrieved data was then analysed using SPSS and presented for assessment as part of the university's criteria for PhD progression.

At stage three, there was a detailed assessment and revision of the survey questions to eliminate ambiguity. Feedback received from the pilot study was carefully considered for the final design. The revised survey questions were administered upon approval by the supervisory team to all 16 regions of Ghana between December 2021 to May 2022. The retrieved data was analysed by using IBM SPSS. Descriptive analysis was conducted from supporting data from the survey questionnaires. The models were then tested to ensure validity and reliability. The retrieved results have been presented and published at several conferences and journals (as indicated in J1, J2, J7, C3, C4, C5).

The identified stages above shaped the thesis to meet the set objectives and overall aim. The next topic explains the process undertaken during the development and design of the survey questionnaire.

3.4.2 Survey Questionnaire Design

After a critical assessment of the various questions, complex words were deliberately demystified to ensure easy comprehension by the target group. Again, the researcher adopted illustrations and visual aids to improve understanding of the questionnaire as seen in Figure 34.

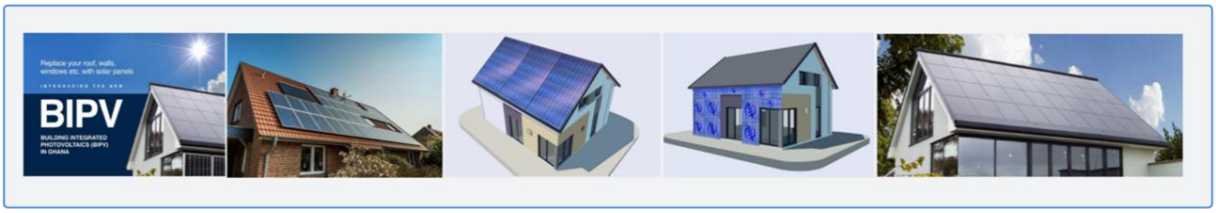

Figure 34. Illustrations adapted for survey questionnaire (Authors construct)

The questionnaire was developed with a graphical visual aid to help explain the questions to the target group since it is relatively new in Ghana. The first page basically introduced the name of the University where the researcher studied and the topic. The participants were also informed about the voluntary nature of their involvement as well as confidentiality and anonymity. The estimated time duration and contact details of the researcher were also provided.

The questionnaire was categorized into seven major sections. Section one captured basic demographic information about respondents. Section two was on the interviewee's status and awareness of solar energy in general. Section three touches on BIPV awareness and willingness to adopt. Section four discussed the value of aesthetics in BIPV application. Section five accessed interviewees' interest in adopting BIPVs for retrofitting. Section six asked questions pertaining to the prospects of adinkra symbols on BIPVs and their influence on adoption. The final section highlights some policies relevant to BIPV adoption. The complete questionnaire is provided in Appendix 2. Figure 35 shows a thematic summary of the research questionnaire.

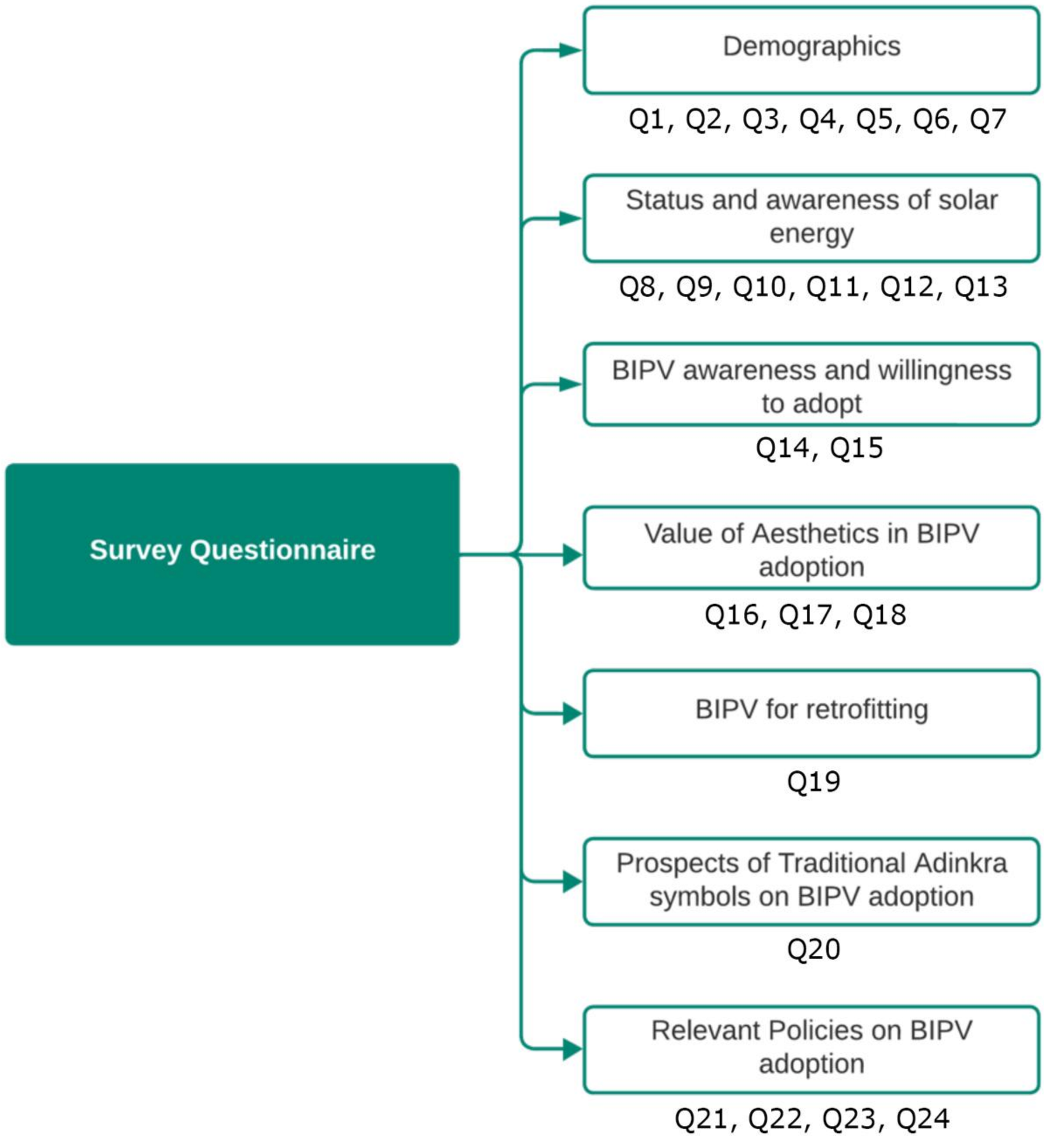

Figure 35. Thematic Summary of Research Questionnaire (Authors construct)

Extra letter boxes were provided for respondents to express their opinions to generate qualitative data to support the answers provided. BIPV was explained on the first page, and a poster was provided to explain the concept further so that respondents could familiarize themselves before attempting to answer the questions. The strategy was adopted because of concerns raised in the pilot study. The respondents also had the researcher's email address which was provided on the last page in case they needed further clarification. Table 3 below details the empirical basis and relatable studies that adopted a similar line of questions to investigate product adoption.

Table 3. Empirical basis for survey questions

Variables	Questions	References
Demographics	i. What is your age range? ii. What is your gender? iii. What is your occupation? iv. Where do you live? v. What is your income range? vi. What is your family size? Vii. What is your level of education?	(Axinn et al., 2011; Beel et al., 2013; Kang et al., 2014; Labay and Kinnear; 1981)
Status and awareness of Solar energy as well as willingness to adopt	i. Are you a homeowner? What type of house do you live in? ii. Do you have an alternative source of electricity? iii. Do you know about solar energy? iv. Are you likely to adopt solar energy for your home should you have the money for it? v. Are you likely to adopt solar energy for your home should there be a flexible loan facility that allows you to pay about GH¢150 monthly over a period of 6 years and	(Adjakloe et al., 2020; Sardianou and Genoudi, 2013; Qazi et al., 2021; Ayodele et al., 2021; Mosly and Makki, 2018; Gyimah, 2014)

	enjoy free electricity for up to 25 years? (Depending on your home size and energy consumption vi. Are you likely to adopt solar panels for your home should there be a government policy that reduces their overall cost?	
BIPV awareness	i. Have you heard of Building Integrated Photovoltaics (BIPV)? ii. Looking at the following images (A) and (B), which are you likely to adopt for your home? (The main difference is the way the solar panels have been arranged)	(Albattah and Attoye, 2021; Curtius, 2018; Macdonald and Sharp, 2003; Macdonald and Sharp, 2000; Malik and Ayop, 2020; Eves and Kippes, 2010)
The Value of Aesthetics	i. Do you think Aesthetics (beauty) matter when it comes to solar application for your home? ii. Are you likely to adopt Building Integrated Photovoltaics (BIPV) for your home if there are variety of colours and shapes to replace wall	(Pelle et al., 2020; Kryszak and Wang; 2020; Zomer et al., 2014; Mumcu and Kimzan, 2015; Mowen, Fang and Scott 2010; Yamamoto and Lambert, 1994; Awuku et al., 2021; Blount and Brookins, 2021)

	tiles, roofing materials and windows? iii. Are you likely to adopt Building Integrated Photovoltaics (BIPV) because of Aesthetics (Beauty)?	
Willingness to adopt BIPV for retrofitting	i. Are you likely to adopt Building Integrated Photovoltaics (BIPV) should you decide to renovate your old house?	(Asaee et al., 2017; Saretta et al., 2019; Scognamiglio, 2017; Martín-Chivelet et al., 2018)
Willingness to adopt BIPV after introduction of Adinkra symbols	i. Do you think adding symbols such as Adinkra to solar design can influence your decision to adopt Building Integrated Photovoltaics (BIPV) as seen in the Figure?	(Attoye et al., 2017;, Deng and Nanor 2021; Inkum et al., 2021; Ampadu et al., 2022)
Policy	i. Do you believe that an enabling environment by the government will help promote BIPV as an alternative energy source? ii. Would you agree that subsidies and grants from the government could promote BIPV adoption in Ghana?	(Ampadu et al., 2022; (Awuku et al., 2021; Gyimah, 2014)

	iii. Would you agree that advertising has a major role to play in BIPV adoption in Ghana? iv. Do you believe that having more technicians, after sale services, and experts could influence your decision to adopt BIPV?	

3.5 Target Population and Sampling Technique

3.5.1 Target Population

To find more evidence-based answers for the project, respondents were chosen from all sixteen regions of Ghana. In Ghana, evidence points to isolated deployments of solar projects across the country, mainly for roof-based, street-lighting or off-grid electrification projects (International Trade Administration, 2020; Kuada and Mensah, 2020; Adam et al., 2021). However, empirical research points to limited integration of green principles in building projects, and these buildings are only found in the major cities of the country (Budds, 2017; Darko et al., 2020) . To ensure a fair representation, the survey targeted people from all regions of the country. The study's main units of observation and analysis are solar energy, BIPV, aesthetics, and policy.

3.5.2 Sampling

According to (Bock, 2019) and other scholarly studies on conjoint analysis, sample size determination in a conjoint approach is dependent on the study goals as well as other study factors (Johnson and Orme, 2003; Rose and Bliemer, 2009; de Bekker-Grob et al., 2015) . These factors include (a) the number of choice alternatives to be presented (higher number of choices [lower samples], lower number of choices [larger samples]); (b) the number of attributes and utility levels to be used in the research (higher number of attributes differences [lower samples], lower number of attribute differences [larger samples]); and (c) the research questions the study intends to solve (identifying key drivers [lower samples] vs precise predictions between two options [larger samples]).

In summary, the efficiency of the design process influences the sample size determination (Rose and Bliemer, 2009) . To resolve this complexity, Siddiqui (2013) suggests a heuristic for sample sizes for conjoint studies. He suggests a range between 150 to 1,200 respondents, with 300 respondents being a useful range for robust analysis in a non-comparative study (for instance this current study), and 200 respondents for each group in a study that compares different groups of respondents (Siddiqui, 2013). Also, based on identified factors, Orme-Johnson, and Walton, (1998) (Orme-Johnson and Walton, 1998) provided a rule of thumb for the Bayesian calculation of sample sizes which was revised by (Tang et al., 2006) as follows:

$$n \geq H\frac{p(1-d)}{MT}$$

where M is the number of attributes, n is the total number of respondents, d is the percentage of cases where respondents choose a nonalternative, H is an index representing the heterogeneity of the sample, and p is the number of choices or parameters to be estimated per respondent. However, according to Vilikus (2012), this heuristic does not account for a given study's research questions and goals (Vilikus, 2012) . Hence, comparing results of simulations of different conjoint sampling scenarios based on the rule of thumb with weights added for research question importance, he concludes that a "sample size over 400" respondents 'hardly improves our results' and 'sufficient accuracy' can be obtained with 'relatively small sample'. In line with heuristic recommendations by Vilikus (2012), [400 respondents] and Siddiqui (2013) (Siddiqui, 2013) [300 respondents], the research aimed to collect questionnaire data from at least 400+/- respondents. However, the survey exceeded its target by 12, reaching up to 412 respondents.

3.5.3 Data Type and Collection

The study relied on two main sources of data: Quantitative and Experimental design. These are collected from survey questionnaire results and the solar cell design experiment conducted to determine the viability of using screen-printing approach to transfer traditional Adinkra symbols on solar cells and the energy efficiency afterwards. The Surveys conducted through questionnaires were created and distributed digitally (using an online survey service provided by the Joint Information Systems Committee(JISC): https://robertgordonuniversity.onlinesurveys.ac.uk/questionnaire-on-the-opportunities-of-building-integrated-3. Effort was made to fairly distribute the questionnaire to all 16 regions of Ghana. Although the targets were prospective homeowners/homeowners, and workers within the construction sector, respondents outside this category were not prevented from participating. Provisions were made for respondents who did not have access to electronic devices and the Internet. The survey was distributed over a period of four months. In all, 22 entries were recorded as incomplete and hence were not added for analysis. Descriptive statistics, chi-square test, and multiple regression analysis were performed on the results to determine the impact of selected variables on the subject being understudied.

3.5.3.1 The Pilot Study

To ensure a reliable study outcome, the survey was piloted between January to March 2022. One hundred and two participants were selected for the pilot study. The targets were Ghanaian homeowners or prospective homeowners and people within the construction sector. The pilot study was initially launched to Ghanaians based in the UK who were either students or in the working class. It was later distributed among respondents in Ghana through the snowballing approach.

The results showed that about 70% of the respondents were males while the remaining 30% were females. Most of the respondents were from Greater Accra and Ashanti regions, which indicated an uneven distribution of the questionnaire among all 16 regions of Ghana as targeted. A more significant percentage of the respondents had challenges understanding the technical terminologies used in the questionnaire. They had very little understanding of the subject and hence were not keen on completing the questionnaire. About 38 of the respondents did not complete the questionnaire fully out of the 140 participants. The findings indicated very little knowledge of BIPV in Ghana and an utmost desire to adopt BIPV should they have the means for it. The survey was restructured while considering the feedback from respondents of the pilot study. Table 4 shows the revisions made.

Table 4. Challenges of Pilot Study and Refinements Made (Authors construct)

Challenge	Refinement
The survey was too worded and marred with terminologies which were challenging to understand by respondents	Complex terms were demystified to ensure easy comprehension.
Some of the Respondents could not relate the concept of BIPV and were not interested in participating.	Images and advertising posters were introduced to educate the respondents ahead of the survey
Respondents in rural areas could not take part because they either did not have access to the internet or computer/phone.	Printed copies were distributed to participants who had challenges accessing the internet or computer/phone. The filled-out copies were later computed using the link provided.

3.5.4 Data Analysis

In analysing data, the methodology follows three steps in deriving findings for the study. That is (A) data reduction – a data abstraction process that is transformed from and organized into sizeable appropriate patterns and themes. The study relied on software tools including IBM SPSS Statistics and Microsoft Excel; (B) data display – at this stage, data is communicated using appropriate visualisations – figures, graphs, tables, and text; and (C) Drawing conclusions – analytical explanations of the findings are conducted in this stage. For consistency, a framework by Carney (1990) that provides a sequential approach to data analysis is utilised (Carney, 1990). The steps are (A) Noting patterns – where different themes and patterns noted in data are identified; (B) Clustering – where similar data is grouped into similar themes; and (C) Comparisons – where primary and secondary data patterns are compared, as well as inferences and possible explanations are drawn based results of data themes.

3.6 Online Survey Questions Techniques and Limitations

Survey questions have been adopted for scientific studies in recent times (Nie et al., 2008). A questionnaire outlines a set of questions in an orderly manner following various themes or set objectives. It presents a set of standards, and well-structured questions in a particular pattern to solicit data for a project (Lavrakas, 2008). Understandably, it comes with rubrics to guide respondents. These days, computer-aided applications have made survey questionnaires relatively easier compared to complex coding and scripting. With little understanding and knowledge, one can practically develop a survey questionnaire for research work. Bearing in mind all ethical considerations, fundamental requirements such as a statement of anonymity and confidentiality are displayed where needed.

The craft of designing a questionnaire is essential for a valid scientific outcome. A questionnaire must be appropriate, incontrovertible, fair, codable, and ethically sound. Stone (1993) identifies ten practical steps to achieve a rigorous online survey. These are (a). Decision on specific time frame (b). Select the required items to be included (c). Develop the individual questions according to the aim/objectives (d). Recompose the words (e). Layout design and presentation (f).

Coding (g). Dummy preparation (h). Pilot test (i). Overall evaluation and (j). Distribution of the survey (Stone, 1993).

In line with the proposed structure for conducting a successful survey by Stone (Stone, 1993) , this study adopted and followed all the suggested stages sequentially to ensure a viable outcome. The advantages of using surveys are numerous compared to other traditional data collection approaches. Some known advantages include Participants in rural/remote settings can be easily reached, it is much more convenient to collate and analyse retrieved data, saving money and time, it is a visually engaging way of sourcing data, flexibility, and access to large sample size (Mahmutovic, 2021).

On the flip side, online survey questionnaires have their own limitations. Key amongst them include (a). sampling issues – very little information may be known about the respondents online apart from their demographics, (b). Distribution challenges – difficult to reach people with no access to the internet, smartphones, and computers (Kevin, 2005) , (c). The complexities that surround data validity and issues around design, implementation, overall evaluation, and limitations that come with close-ended questions (Mahmutovic, 2021).

3.7 Chosen Approach for Various Objectives

The study adopts the SMART objective technique to set measurable objectives which leads ultimately to the research aim. Four main objectives have been identified: (a). To determine the effectiveness of architectural visualisation and advertising on BIPV awareness in Ghana (b). To establish the nexus between Adinkra symbols and BIPV adoption in Ghana (c). Use a screen-printing technique to transfer traditional Ghanaian Adinkra symbols on solar cells and determine their energy efficiency afterwards and (d). Identify and propose favourable policies to promote BIPV adoption in Ghana. The approach to examining each objective and its commensurate analytical response is outlined in the subsequent sub-sections.

A. To determine the effectiveness of architectural visualisation and advertising on BIPV awareness in Ghana, the study relied on data from the survey questionnaire. An essential aspect was the adoption of an architectural visualisation approach to render selected buildings in Ghana with BIPV application and to design a sensitisation poster to educate respondents on BIPV adoption. Due to the novelty of this study in Ghana, the pilot study indicated that most of the respondents had no idea about BIPV and hence could not make any meaningful contribution or declined to take part. This approach was therefore adopted to provide a visual reference and an awareness material for BIPVs and how they integrate into existing architectural structures in Ghana and to show how traditional aesthetic features (in the case of Ghana; Adinkra symbols) can be incorporated into building structures. Also, the sensitisation poster was to educate respondents on the basic meaning of BIPV. Several illustrations of selected buildings in Ghana were provided to give respondents a local visual impression of BIPV.

The architectural visualisation (AV) approach was adopted to develop the illustrations of BIPV buildings. AV is a process for presenting a model's new structure in a way that can be easily digested visually (in 2-dimensional or 3-dimensional space) through hand-made or Computer-Aided Design (Bafna, 2008). AV is applied in this study as it is an effective approach for achieving the research objective without requiring advanced architectural expertise (Gueorguiev and Georgieva, 2008).

A three-stage process is utilized for architectural visualization development. These are shown in Figure 36 and Table 5 below.

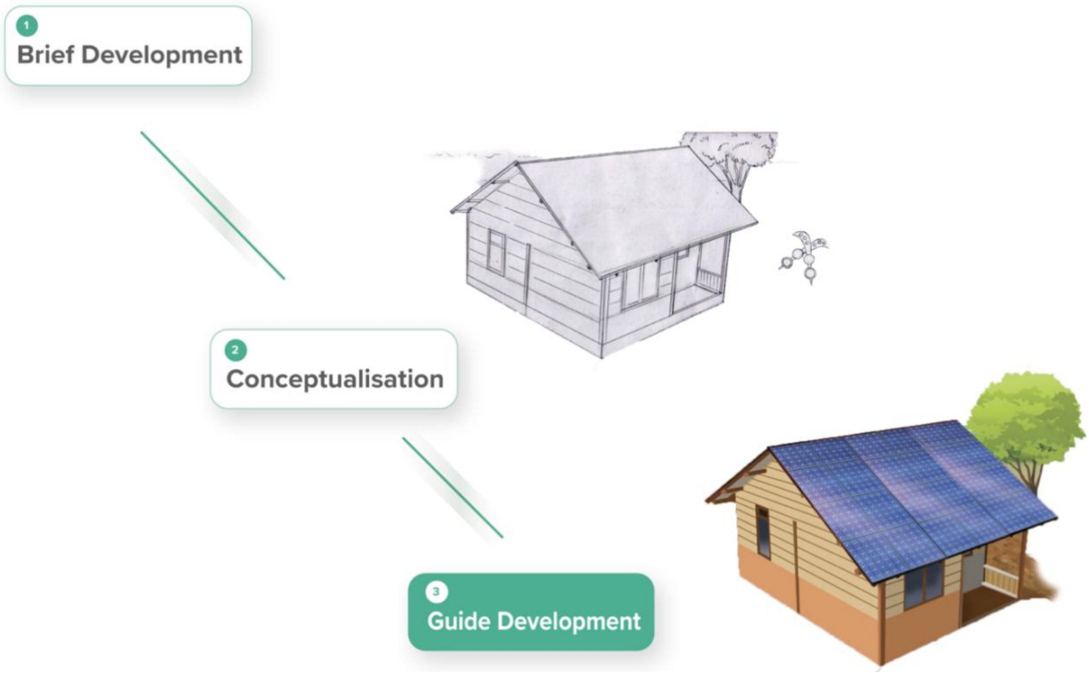

Figure 36. Architectural Guide Development Flow (Authors Construct (2021)

Table 5. Architectural Guide Development Process (Authors Construct)

	Brief Development	Conceptualization	Guide Development
Core task	- Research into traditional aesthetic symbols and Adinkra (Danzy, 2009) - Review of building design patterns in Ghana.	- Development of visual concepts. - Designing hand-drawn sketches.	Rendering of 3D sketches in computer graphic software.
Tools used	Literature review	Paper drawings	Adobe Illustrator and Photoshop
Outcome	Design Brief	Sketches	Architectural Guide

B. To establish the nexus between Adinkra symbols and BIPV adoption in Ghana, the study relies on the data from the survey questionnaire. The respondents' quest to adopt BIPV was measured using survey data, after producing illustrations of BIPV buildings with Adinkra patterns by using AV.

C. To use a screen-printing technique to transfer traditional Ghanaian Adinkra symbols on solar cells and determine their energy efficiency afterwards, the study adopts an experimental approach. A traditional screen-printing approach is adopted to transfer three Adinkra symbols onto solar cells. The cells are optically and electrically characterised to test the efficiency. Figure 37 shows the systematic procedure used for the experiment.

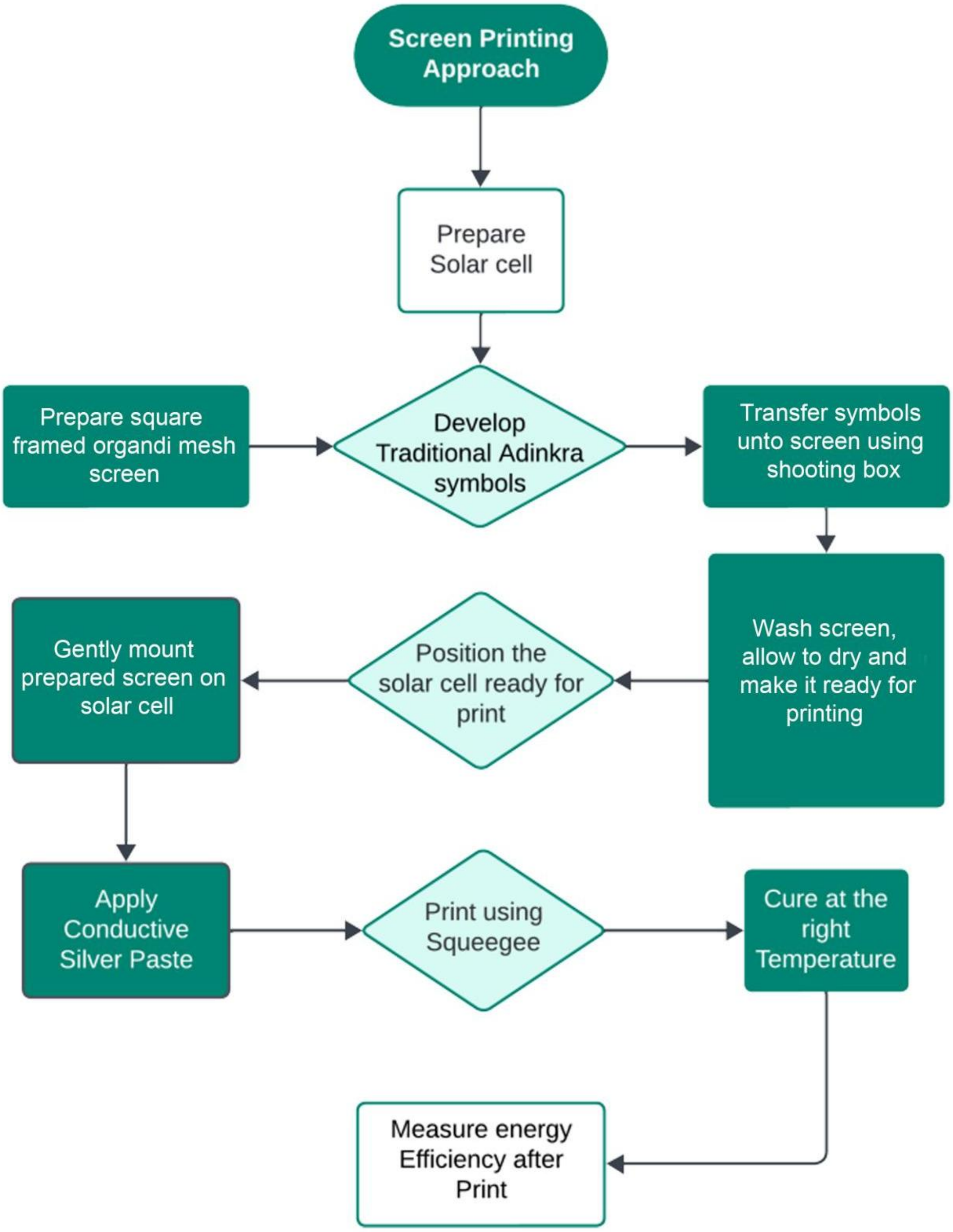

Figure 37. Screen-Printing (Authors construct)

D. To make recommendations on BIPV adoption in Ghana, a framework for assessing value preferences and decisions called the Evidence to Decision framework (EtD) (Li et al., 2018; Quilodrán et al., 2021) is adopted. The EtD is a "transparent and structured system for formulating recommendations" used as a guiding framework for deploying new interventions and technologies mainly in health sectors (Moberg et al., 2018) . Key components (variables) of the framework are borrowed for this study as they are useful for developing a consistent structure for new systems. The variables for assessment to develop the recommendations for BIPV aesthetic considerations are preferences/acceptability, feasibility, and costs.

The process for developing EtD-based considerations follows (a) gathering evidence based on survey results, experiments, and existing information; (b) quantitively assessing the results from study evidence against set variables; and (c) making recommendations as shown in Figure 38 (Moberg et al., 2018).

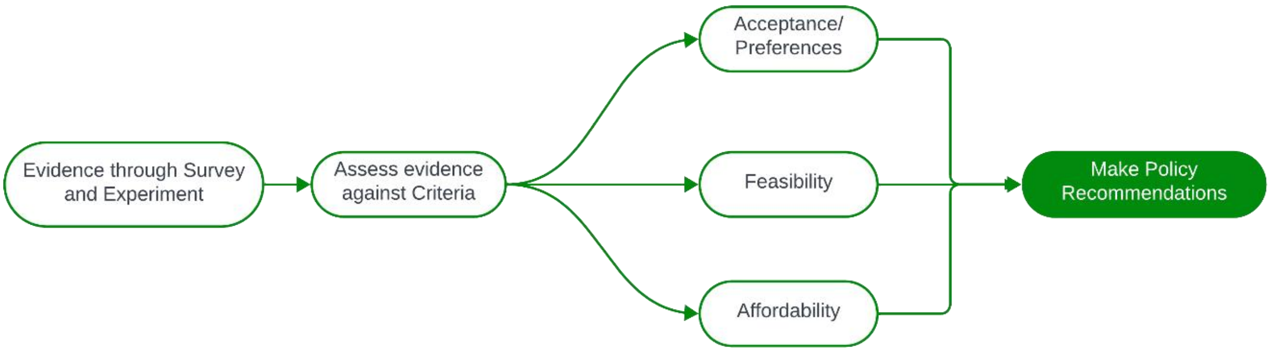

Figure 38. Framework for Developing BIPV Adoption Policy (Authors Construct, adapted from (Quilodrán et al., 2021))

Apart from the EtD approach, a systematic review of existing literature and policy documents is used to give clear insights into the current state of Ghana's solar energy sector and the challenges that cripple it. Based on the identified trends and themes, the review results are merged with data from the questionnaire. The thematic analysis provides a way to measure patterns in the data and it is useful in identifying qualitative/quantitative issues in empirical settings (Nowell et al., 2017; Vaismoradi et al., 2013) . Based on comparing analysis of result findings from the survey questions, existing literature and policy documents, specific recommendations are made for policymakers and lead implementers of renewable systems to follow.

3.8 Ethical Consideration

Ethical consideration is fundamental in any research activity that deals with individuals in the real world. As research in various disciplines increases, the idea of ethics is to help promote trust, protect various contributors, and save the environment. With the overall aim of making the world a better place and promoting a structured research environment, ethics ensure that potential long-term harm to the various individuals, society and ecosystem is circumvented (Isreal and Hay, 2006). The ethical procedure has a direct bearing with common sense and respect. In other words, courtesy, respect, privacy, and a sense of responsibility are pivotal in any research activity.

3.8.1 Principles

The basic principles guiding the study's ethics follow the Robert Gordon University (RGU) guidelines on conducting good research. The dual central principles are strictly applied in this research. They are (a) beneficence: the principle of 'doing good' which is a requirement to promote the interests and well-being of others and (b) non-maleficence: the principle of 'not doing harm'. In addition, the study also adopts the guidelines, and responsible research principles of integrity, accountability, and openness adopted by the RGU (Robert Gordon University, 2016).

3.8.2 Informed Consent and Privacy

Standard practices are followed throughout all stages of data collection for the thesis. Documentary data is properly cited and where permission is required for incorporation, it is duly sought using defined processes. Collection of informed consent before the questionnaire and interview administration at each phase is done in line with the university's ethical requirements as well as prevailing legislation.

Before each data collection exercise is conducted, informed consent is strictly required. A two-pronged approach is employed for the study. These are (a) a written and/or oral description and disclaimer given to the respondent on the reason behind the collection of the data and the responsible use of the information collected. For employees of institutions, where necessary, (b) a formal consent letter is sent to the organization to seek permission for its workers to participate in the questionnaire.

The requisite data protection, privacy and intellectual property requirements follow the stipulated legal frameworks for managing data in the United Kingdom (UK) and Ghana. Legislatively, the study follows the principles of two main regulatory Enactments. That is, (a) the UK General Data Protection Regulation (UK GDPR) which extends the UK Data Protection Act 2018 and (b) Ghana's Data Protection Act 2012, (Act 843) (Government of Ghana, 2012) . This is to ensure proper privacy and protection of data measures are adhered to. In line with the ethical requirements of the university; currently, no ethical issues are identified based on the research questions, hence ethical clearance has been given.

3.9 Chapter Summary

This chapter has discussed the various methods adopted for the study. Positivism was identified as the most appropriate research paradigm for this study. The chapter further highlights that a mixture of quantitative and experimental designs was adopted. Valid limitations of online survey questionnaires such as sampling issues, distribution challenges, and complexities of data validity have been highlighted. Further, ethical approval was sought and granted by the Robert Gordon University ethics committee. The next chapter reveals the outcome of the data. It adopts graphs, charts, and tables to display the findings of the study according to the various objectives.

CHAPTER 4: SURVEY CHARACTERISTICS, ARCHITECTURAL VISUALISATION AND EXPERIMENTAL DESIGN

4.0 Introduction

This chapter presents the outcome of the survey conducted in all 16 regions of Ghana and the Architectural visualisation (AV) of BIPV. The survey questions were mainly developed to measure the effectiveness of AV on Ghanaians' willingness to adopt (WTA) BIPVs, aesthetic preferences, possibility of merging Adinkra symbols for cultural relevance and policy perspectives. AV on the other hand was designed with the core aim of serving as a visual reference and awareness material for BIPVs in the Ghanaian context. The retrieved data is evaluated by conducting descriptive statistics of the respondents' demographics, testing the reliability and validity of the data using techniques such as Cronbach's alpha and Pearson correlation coefficient. A Chi-square test of independence was also done to ascertain the relationship between the categorical variables. A multiple regression approach was employed to test the hypothesis of the study to demonstrate the impact between selected variables. This approach was considered because of its flexibility and appropriateness when examining relationships between variables (Berger 2004).

4.1 highlights the descriptive statistics, which have been categorised into themes. These are a. Demographics b. Solar Energy Adoption (SEA) c. Policy (POL), d. Aesthetics of BIPV (AESTH.) and e. Adoption of BIPV (ADPT_BIPV). 4.2 explores the applicable reliability and validity tests. 4.3 highlights the Chi-square test estimates and 4.4 presents the results of the multiple regression analysis aiming to establish the influence of selected dependent variables. The chapter ends with an architectural visualisation of BIPV in Ghana with Adinkra symbols embedded in them. The survey questions were distributed between January to May 2022. A total of 412 respondents contributed from all 16 regions of the country, although a larger percentage were from Greater Accra and Ashanti regions. The survey took approximately 15 minutes to answer.

4.1 Descriptive Statistics

4.1.1 Sample Profile

A. Gender

As highlighted by Roger's Diffusion of Innovation (DOI) theory, variables such as age, income and education may have a direct bearing on the adoption of an innovation (Rogers, 1962). These factors may determine whether an innovation will be adopted early or not. Figure 39 demonstrates that out of a total sample size of 412 (N=412) across all 16 regions of Ghana, 59% (243) were males while 39.3% (162) were females. (4) representing 1.0% preferred not to disclose their gender, whereas 0.7% (3) are categorised under 'other'. The results reflect a black African society where males are expected to put up buildings to house their families (Lesejane, 2006).

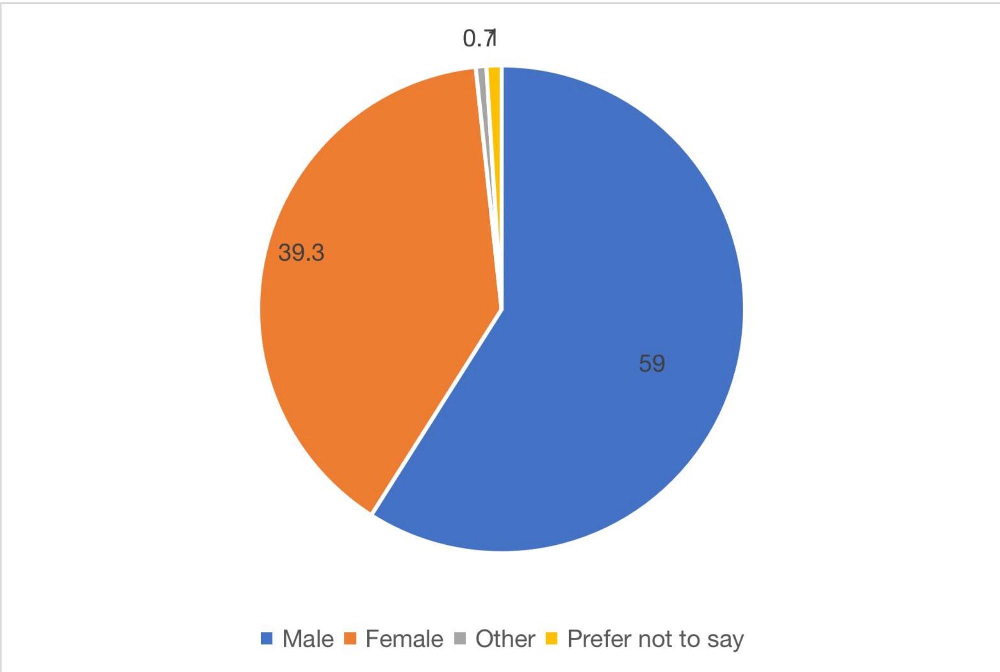

Figure 39. Gender of Respondents

B. Age Range

Figure 40 below shows that out of the total sample size of 412, 17.6% were between ages 20-29, 24.6% were between 30-39, 25.9% were between 40-49, 15.4% were between 50-59, 10.7% were between 60-69 whereas 5.9% were 70 and above. This confirms a youthful sample size with the majority between ages 30 – 49 years.

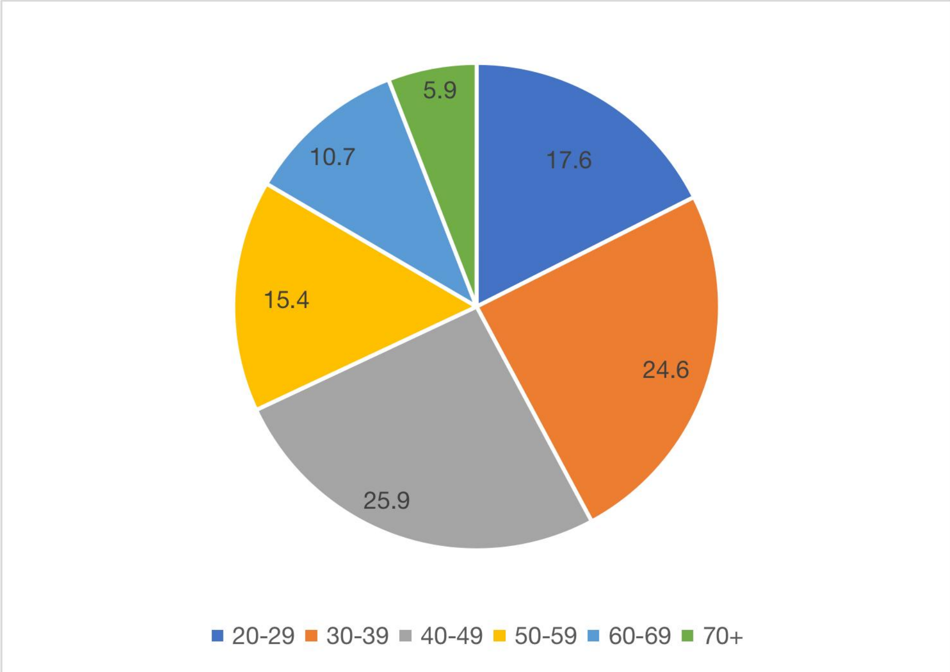

Figure 40. Age Range of Respondents

C. Occupation

Table 6 below shows the occupations of the various respondents. A total of five (5) representing 1.2% were students, Sixty-four (64) representing 15.6% were in the Agricultural sector, seventy-five (75) representing 18.3% were in the industrial sector, One hundred and eighteen (118) representing 28.8% were in the service sector, One hundred and nine (109) representing 26.6% were in the private sector, twenty-one (21) representing 5.1% preferred not to disclose their profession, twelve (12) representing 2.9% were mid-level professionals and six (6) representing 1.5% were upper-level professionals. The table indicates that most of the respondents work within the services industry.

Table 6. Descriptive data on Respondents' Occupation

Profession	Frequency	Percentage	Cumulative Percentage
Student	5	1.21	1.21
Agriculture	64	15.53	16.74
Industry	75	18.20	34.94

Services	118	28.64	63.58
Private Sector	109	26.5	90.04
Prefer not to say	21	5.1	95.14
Mid-level professional (e.g., teacher, nurse, mid-level government officer)	12	2.91	98.05
Upper-level professional (e.g., banker/finance, doctor, accountant)	6	1.5	100.0
Total	412	100.0	

Again, the mean occupational value of the respondents sampled for the study was 3.04 with a standard deviation of (SD=1.33) (Table 7). The results suggest that respondents may be able to adopt BIPV and solar energy should they be offered the required support.

Table 7. Occupation of Respondents

Item	N	Minimum	Maximum	Mean	Std. Deviation
Occupation	412	1	8	3.04	1.335
Valid N (listwise)	412				

D. Income Range

Figure 41 indicates that the income ranges of Ghanaian workers are sparsely distributed, with some respondents earning below the average minimum wage (GH¢14.88/day). According to Figure 43, 9.5% of the respondents receive less than GH¢ 10,000 per annum, 9.5% receive between GH¢ 10,000 and GH¢ 20,000, 15.4% receive between GH¢ 20,000-30,000, 16.6% receive GH¢ 30,000-40,000, 13.7% receive GH¢ 40,000-50,000, 10.5% receive 60,000-80,000, 8.8% receive GH¢ 80,000-120,000, 9.8% receive GH¢ 120,000 and above per annum respectively. However, 6.3% preferred not to disclose their income. Figure 40 shows that most of the respondents earned between GH 30,000 – and GH 40,000 (About 3000 - 4000 USD).

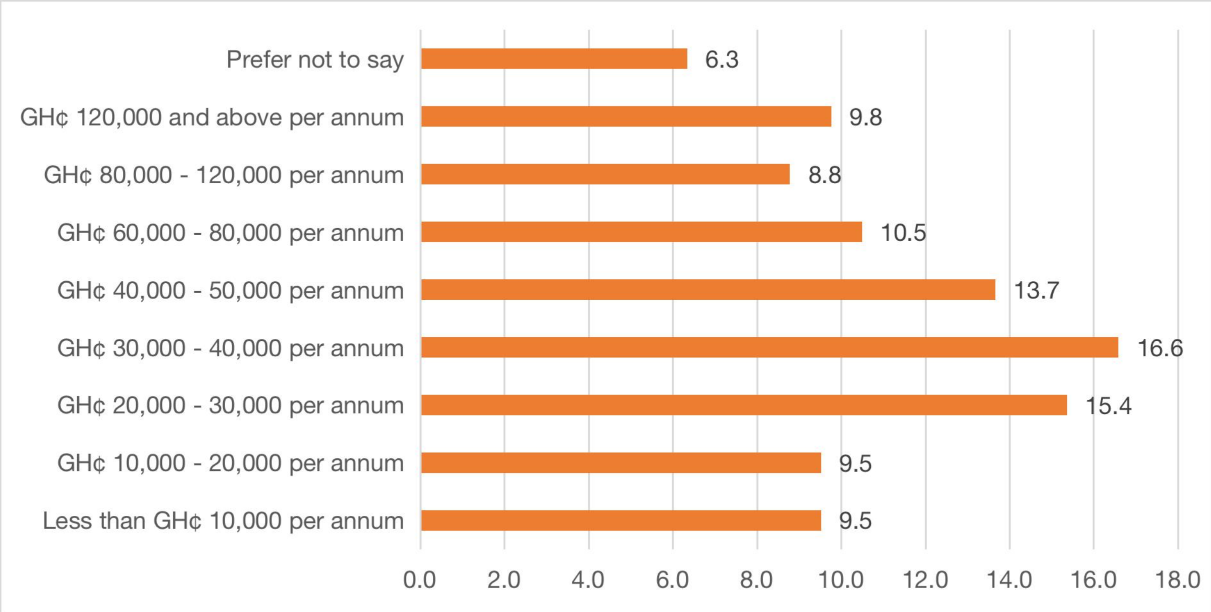

Figure 41. Income range of Respondents

The average income value of the respondents as shown in Table 8 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. Most of the respondents belong to an annual income bracket of GH¢30,000-GH¢40,000.

Table 8. Income range of Respondents

Item	N	Minimum	Maximum	Mean	Std. Deviation
Income range	412	1	9	4.69	2.324
Valid N (listwise)	412				

E. Family Size

Family size is key when it comes to household energy consumption. 17% (70) of the respondents live alone. 54.6% (225) are between 2-4, 23.5% (97) are between 5-8, 3.6% (15) are between 9-12. 1.2% (5) are above 12 in their households as shown in Table 9. Again, Table 10 indicates that the mean number of the family size of respondents sampled for the study was 2.20 with a standard deviation of (SD=.824). The results suggest a family size of more than 2-4 forms the majority.

Table 9. Descriptive Data on Respondents' Family Size

	Frequency	Percentage	Cumulative Percentage
1	70	17	17
2-4	225	54.6	71.6
5-8	97	23.5	95.1
9-12	15	3.6	98.8
Above 12	5	1.2	100.0
Total	410	100.0	

Table 10. Respondents' Family Size

Item	N	Minimum	Maximum	Mean	Std. Deviation
Family size.	412	1	5	2.20	0.824
Valid N (listwise)	412				

F. Level of Education

Table 11 highlights the educational levels of the various respondents. It can be observed that twelve (12) representing 2.9% had basic school education, sixty-three (63) representing 15.3% had Senior high school education, one hundred and eighty-six (186) representing 45.2% had a bachelor's degree, one hundred and twelve (112) representing 27.2% had master's degree, thirty-five (35) representing 8.5% had PhDs and the remaining four (4) representing 0.9% preferred not to say. This clearly shows that most of the respondents had at least a high school education.

Table 11. Descriptive Data on Respondents' Educational Level

	Frequency	Percentage	Cumulative Percentage
Basic School	12	2.9	2.9
Senior High School	63	15.3	18.2
Bachelor's Degree	186	45.2	63.4
Master's Degree	112	27.2	90.6
PhD	35	8.5	99.1
Prefer not to say	4	0.9	100.0
Total	412	100.0	

Also, the mean educational level of respondents sampled for the study was 3.32 with a standard deviation of (SD =.950). Most of the respondents representing more than 80% had a bachelor's degree and above. The results show that most of the respondents were knowledgeable enough to learn about BIPV and solar energy and possibly adopt them as alternative energy for their homes (see Table 12).

Table 12. Respondents' Educational Level

	N	Minimum	Maximum	Mean	Std. Deviation
Level of education.	412	1	6	3.26	0.950
Valid N (listwise)	412				

G. Location of Respondents

Ghana has 16 regions; therefore, an attempt was made to reach out to respondents from all regions. However, the major regions (Accra and Kumasi) had the largest number of respondents compared to the others. The breakdown of the respondents according to regions is as follows: Western North region had 1.9% (8), the Western region had 3.9% (16), Volta 4.1% (17), Greater Accra 20.1% (83), Eastern 9.0% (37), Ashanti 11.7% (48), Central 6.3% (26), Northern 4.4% (18), Upper East 3.9% (16), Upper West 3.7% (15), Oti 5.1 (21), Bono East 4.9%

(20), Ahafo 4.4% (18), Bono 4.6 (19), North East 7.2 (30) and Savannah 4.9 (20). Figure 42 indicates that most of the respondents were residents of Greater Accra, Ashanti, Eastern, Central and Northeast Regions. The results show respondents in these five (5) regions represent more than half of the sample population.

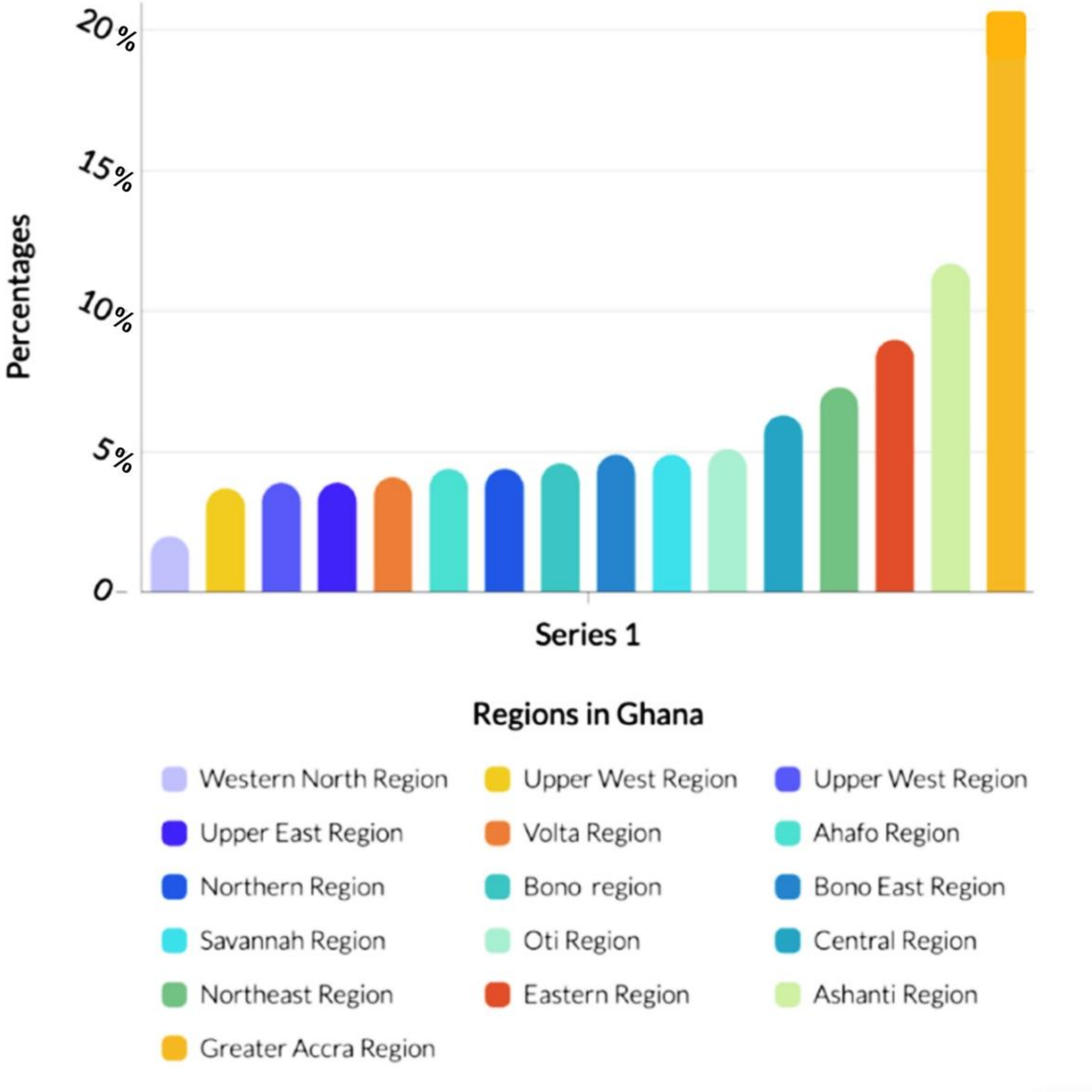

Figure 42. Graphical representation of Respondent location

4.1.2 Solar Energy Adoption (SEA) Construct

The Solar Energy Adoption (SEA) category has five major questions. (A). Homeownership status (B). Type of house (C). An alternative source of electricity (D). Awareness of solar energy (E). The likelihood of adopting solar energy should funding be available. A summary of the SEA construct is displayed in Figure 43. The data shows that most of the respondents (64%) owned houses of which 60.6% were self-contained. 97.1% were aware of solar energy and 94% were likely to adopt it if funding was made available. Also, 57% of the respondents had an alternative source of electricity, mainly diesel generators.

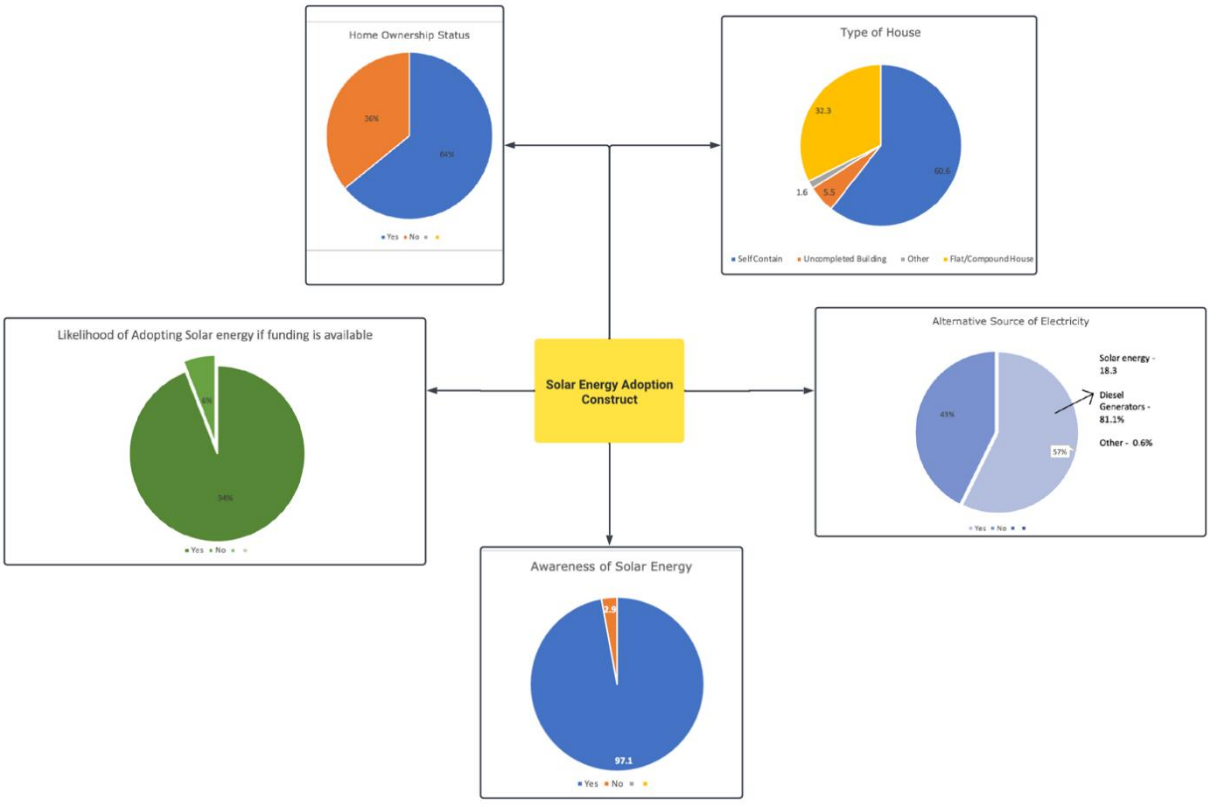

Figure 43. Summary of Solar Energy Construct (Authors Construct)

The descriptive statistics for Solar energy adoption reveal an overall mean score of 1.4501 with a standard deviation of (SD=.342). This shows a positive perception of SEA amongst the respondents. SEA4 had the highest mean value of 1.96 indicating that the respondents knew about solar energy and may consider adopting it as an alternative source of energy for their homes (see Table 13 below).

Table 13. Solar Energy Adoption (SEA) Construct

	N	Minimum	Maximum	Mean	Std. Deviation
Homeownership Status (SEA1)	412	1	2	1.38	0.485
What type of house do you live in (SEA2)	412	1	4	1.64	0.667
Alternative source of electricity (SEA3)	412	1	2	1.57	0.495
Awareness of solar energy (SEA4)	412	1	2	1.03	0.161
If Yes	412	1	3	1.96	0.497
Likely adoption of solar energy for home should you have money for it (SEA5)	412	1	2	1.05	0.220
If Yes	412	1	4	1.52	0.806
SEA	412	1	2.71	1.45	0.342

Valid N (listwise)	412				

On the other hand, the respondents provided some qualitative answers on their rationale for not adopting any other source of energy as tabulated in Table 14

Table 14. Rationale for Not Adopting Alternative Energy

R1	I am unable to adopt any other source of energy such as solar because I currently rent an apartment and the property owner will not agree to any alteration in the building
R2	I am still building my house, but my only limitation is the upfront high cost of solar energy. However, I will be happy to adopt solar in the future if it is made affordable
R3	I have not thought about investing in any other source of energy apart from electricity from the national grid because electricity has been stable these days
R4	Although I do not like the noise and high fuel cost of diesel generators, I think solar is still expensive so cannot afford it
R5	The best energy alternative is solar, but it is costly and there are limited technicians to fix them when there is a problem
R6	I have always resorted to torch lights and lanterns during power cuts
R7	I have not considered it
R8	I have not explored the options on the market yet because I currently cannot afford it
R9	I am not ready to invest in alternative source of energy because of the initial financial requirements
R10	When a cheaper energy option comes up, I will gladly adopt it
R11	I am not financially ready to invest in an alternative source of energy
R12	I am renting an apartment, and the owner has no alternative source of

	electricity. Maybe if there were portable solar applications on the market, I could have considered that
R13	It is not economically viable based on my current electricity cost
	The government has not provided any incentive to support the adoption of solar energy, so it remains very expensive. Only the rich can afford it

4.1.3 Policy (POL) construct

Four policy themes were adopted under the Policy construct. These are i. Likelihood to adopt solar energy should there be a flexible loan facility ii. Likelihood to adopt solar panels should there be a government policy to reduce the overall cost iii. An enabling environment could promote BIPV as an alternative source of energy iv. Subsidies and grants would promote BIPV in Ghana. The descriptive statistics for policy-related issues in the study reveal an overall mean score of 1.0837 with a standard deviation of (SD=0.24). This shows a positive perception towards alternative energy solutions should there be a motivation for it amongst the respondents (homeowner or prospective homeowners). POL1 had the highest mean value indicating that if a flexible loan is available respondents are more likely to adopt solar energy for their homes (see Table 15 below).

Table 15. Policy (POL) Issues construct

	N	Min	Max	Mean	Std. Deviation
(POL1) Likely adoption of solar energy for your home should there be a flexible loan facility that allows you to pay about 250 monthly for a period of 10 years	412	1	2	1.13	0.341
(POL2) Likely adoption of solar panels for your home should there	412	1	2	1.04	0.188

be a government policy to reduce their overall cost.					
(POL3) Do you believe that an enabling environment by government will help promote BIPV as an alternative source of energy.	412	1	2	1.10	0.306
(POL4) Would you agree that subsidies and grants from government could promote BIPV adoption in Ghana?	412	1	2	1.06	0.239
POLICY	412	1.00	2.00	1.0837	0.236
Valid N (listwise)	412				

4.1.4 Aesthetics of BIPV (AESTH) construct

Under the Aesthetics of BIPV (AESTH) construct, three key questions were asked: A. Knowledge of BIPV B. Likelihood to adopt BIPV or BAPV and C. Value of aesthetics in solar applications. The descriptive statistics 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 WTA. IMG5 (An image of a building illustration with Ghanaian Adinkra symbols merged with BIPV) had the highest mean value indicating respondents' affinity towards cultural images (see Table 16). Eight Respondents also provided qualitative feedback on the rationale for aesthetic consideration when it comes to BIPV as seen in Table 17.

Table 16. Aesthetics of BIPV (AESTH) Construct

	N	Minimum	Maximum	Mean	Std. Deviation
Knowledge of Building Integrated Photovoltaics (BIPV) (IMG1)	412	1	2	1.20	0.403
Likely adoption of images BIPV (A) or BAPV (B) for your home. (IMG2)	412	1	2	1.12	0.321
If A	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	412	1	3	1.45	0.536
AESTH	412	1.00	2.40	1.2403	0.353
Valid N (listwise)	412				

Table 17. Qualitative Data – Rationale for Aesthetic Consideration when it Comes to BIPV Adoption

R1	Aesthetics provides me with variety of dark and bright colours as well as shapes that will fit the design of my building
R2	I prefer aesthetic solar panels because I can have variety of colours, shapes, and texture to choose from. This makes it easier to showcase my consciousness and support for climate change

R3	Depending on the nature of the house design, I can choose the right colours and shapes which suit me.
R4	The design needs to flow into the building to give a unit appeal and feel. Once BIPV offers flexibility in design, varied colours and shapes can be available for modern buildings
R5	If all colours whether dark or bright are available, consumers will have alternatives to choose from. Depending on the design I will prefer both (dark and bright) so far as it's appropriate
R6	Aesthetics provides a variety of panels to blend with the entire house design, thereby making my house more appealing. This can intend increase the market value and attract more tenants
R7	Aesthetics in BIPV is very important because they can beautify the environment. Variety of colours and shapes can enhance the architectural appeal of buildings, thereby creating a pleasant visual effect on the environment.
R8	Aesthetic is important because I can have the opportunity to replace major building components with solar PV without distorting the original design of my building.

4.1.5 Adoption of Building Integrated Photovoltaics (ADPT_BIPV)

ABPT_BIPV has six main areas: (A). Likelihood to adopt BIPV if there are variety of colours and shapes (B). Likely adoption of BIPV because of aesthetics (C). Likely adoption of BIPV should you decide to renovate your old house iv. Influence of Adinkra symbols on BIPV adoption (D). Role of advertising in BIPV adoption and (E). Influence of after-sale services and experts on BIPV adoption. The descriptive statistics for the adoption of BIPV in the study reveal an overall mean score of 1.2797 with a standard deviation of (SD=0.3566). This shows a positive perception of respondents' willingness to adopt BIPV for their homes. ADPT_BIPV4 had the highest mean value indicating respondents' leanings towards cultural images when adopting BIPV for their homes (see Table 18). Table 19 and

20 also show the qualitative rationales for adopting and not adopting traditional Ghanaian Adinkra symbols in BIPV design in Ghana.

Table 18. Adoption of BIPV

	N	Minimum	Maximum	Mean	Std. Deviation
Likely adoption of BIPV for your home if there are variety of colours and shapes to replace the wall tiles, roofing materials and windows. (ADPT_BIPV1)	412	1	2	1.06	0.235
Likely adoption of BIPV because of aesthetics (Beauty). (ADPT_BIPV2)	412	1	2	1.11	0.315
Likely adoption of BIPV should you decide to renovate your old house. (ADPT_BIPV3)	412	1	2	1.08	0.272
Can adding symbols such as adinkra influence your decision to adopt BIPV as seen in the figure. (ADPT_BIPV4)	412	1	2	1.21	0.409
Would you agree that advertising has a major role to play in BIPV adoption?	412	1	2	1.05	0.220

(ADPT_BIPV5)					
Do you believe that having more technicians and after sale services and experts could influence your decision to adopt BIPV (ADPT_BIPV6)	412	1	2	1.09	0.286
ADPT_BIPV	412	1.00	2.50	1.2797	0.356
Valid N (listwise)	412				

Table 19. Qualitative Data – Rationale for adopting Adinkra symbols for BIPV in Ghana

R1	Adinkra symbols have a historical meaning to Ghanaians. It preserves our heritage and blending it with modern solar wall tiles can boost our culture. I will go for it
R2	I am very Patriotic and will therefore go for any design that represents Ghana
R3	Customizing the designs with local/traditional symbols will give an added feel. Yet my take is that customization must be at the buyer specific requirements and not necessarily traditional symbols. This calls for greater flexibility in the design aspect of BIPVs
R4	It can be used for advertising also. If the company logo can run on the side of a high-rise solar building, it helps with brand enhancement and recognition
R5	I see it to be more appropriate for the palace instead of other buildings

	I own. I will rather prefer other creative designs for my home
R6	It is innovative and promotes our culture
R7	It is more Ghanaian because recently, foreign goods have dominated the Ghanaian architectural market, hence all our buildings look foreign. It is important we promote our culture in our buildings
R8	I think that Ghana will be able to export to other countries to adopt it should we have the expertise. This can increase revenue generation for the country
R9	Adinkra symbols in BIPV design will increase the adoption of Solar energy in Ghana and help the country meet its renewable energy target
R10	This will give buildings a traditional and local look, which is very good for the promotion of our culture

Table 20. Qualitative Data – Rationale for not adopting Adinkra symbols for BIPV

R1	Because I personally do not like patterns on buildings
R2	Because it doesn't matter whether it has or not, the cost of solar remains high
R3	Because of their traditional meaning, it is against my religious faith
R4	I personally don't like traditional symbols because it's normally associated with the palaces and Chieftaincy in Ghana. Most of the things they do are against my religion
R5	I would prefer other designs, or it must be flexible such that the customer can determine design preference
R6	I am only interested in the energy and not symbols per say
R7	It means nothing if it is not reliable and affordable
R8	My religion prohibits the use of symbols related to ancestral tradition

R9	Not everyone may like the Adinkra symbol, and people will want to have their building designs in a particular style. A universal blueprint will be good. However traditional designs can be attached upon requests from clients.
R10	I think the design must be the choice of the consumer. This will give the consumer alternatives and as well reduce the chances of seeing the Adinkra symbol on almost everyone's building. There should be a variety

4.2. Reliability and Validity of the study

4.2 1 Reliability

Reliability and validity are very closely related to each other; however, their meanings are different. There are instances where a measurement can be reliable without being valid. In most cases, if a measurement is valid, it is usually also reliable. The reliability of the questionnaire is expressed as a reliability coefficient (index) which can assume values from 0 (indicating no reliability) to 1 (indicating perfect reliability).

Reliability measures the internal consistency of constructs in a study. A construct may be deemed reliable if its Alpha (α) value is greater than 0.70 (Hair et al 2013). The construct reliability in this study was assessed using Cronbach's Alpha (α). The results revealed that the demographic (DG) characteristics scale with seven (7) items ($\alpha = 0.899$), adoption of images and aesthetics (IMG) scale with five (5) items ($\alpha = 0.878$), solar energy knowledge and adoption (SEA) scale with seven (7) items ($\alpha = 0.781$), and adoption of BIPV scale with six (6) items ($\alpha = 0.924$) were found reliable. Likewise, the policy encouragement (POL) scale with four (4) items was also found reliable ($\alpha = 0.883$). The general rule of thumb for Cronbach's Alpha reliability test is .70+ = Good, .80+ = Better and .90+ Best (Cortina, 1993). Reliability results are summarised in Table 21 below.

Table 21. Reliability Test Results

Construct	No of Items	Alpha
DG Variables	7	0.899
SEA	7	0.781
AESTH	5	0.878
ADPT_BIPV	6	0.924
POL	4	0.883

4.2.2 Validity

Validity measures the extent to which an instrument or a survey estimates what it is supposed to estimate (Taherdoost, 2016). It is also an assessment of accuracy to which a survey instrument is measured, that is the extent to which the results of a study really measure what they are supposed to measure. For instance, research with high validity means it produces outcomes that correspond to real properties, characteristics, and variations in the physical or social world. There are two types of validity which are construct and content validity, however, this study focuses on construct validity which looks at the adherence of a measure to existing theory and knowledge of the concept being measured (O'Leary-Kelly and Vokurka, 1998).

Construct validity assesses how well a research team has measured or manipulated variable(s) in a study. Assessments of construct validity can range from a subjective judgment about whether questions look like they measure what they are supposed to measure to a mathematical assessment of how well different questions or measures are related to each other (O'Leary-Kelly and Vokurka, 1998). A survey construct may be deemed valid if its Pearson correlation coefficient is significant or its expected value is greater than the critical value on the Pearson correlation coefficient table. The construct validity was assessed using the Pearson correlation coefficient significance values. The obtained values in the validity estimates (total for all variables) of the study were compared to the critical value of 412 (Degree of Freedom (DF)) (0.05) =0.097 in the Pearson correlation coefficient table and the obtained values were all greater than the critical value which indicates high significance of all questions (See Appendix 3).

4.3. Chi-Square test

The Chi-Square test is a statistical procedure used by researchers to look at the differences between categorical variables in the study. It is also a test of independence used to test the hypothesis that two categorical variables are independent of each other. A lesser chi-square statistic indicates that the null hypothesis is correct and that the two variables are independent of each other whereas the reverse is the case.

The procedure involves comparing the observed cell frequencies with the expected cell frequencies. Observed cell frequencies are the actual number of cases falling in different cells of the contingency table and the expected frequencies are the number of cases that should fall in each cell if there is no relationship between the two categorical variables. To establish the differences or otherwise of the categorical variables in the study, six hypotheses were developed.

Hypothesis 1

To establish whether there is an association between the level of education and knowledge/awareness of solar energy, the following hypotheses were formulated:

H_0: There is no significant association between the level of education and knowledge/awareness of solar energy of the respondents.

H_1: There is a significant association between the level of education and knowledge/awareness of solar energy.

The Chi-square statistic was used to examine the association between the variable's level of education and knowledge/awareness of solar energy. The results reveal that there is an association of 5% significance between education and knowledge/awareness of solar energy among the respondents. (X^2 =196.501, DF=5, p=0.000). Therefore, the null hypothesis is rejected while the alternative hypothesis is accepted. This indicates that awareness and knowledge of solar energy are not independent of the level of education of the respondents sampled for the study. In other words, the awareness and knowledge of solar energy is more likely to influence the level of education of the respondents. Refer to Tables 22 and 23 below.

Table 22. Chi-Square Test

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	196.501[a]	5	.000
Likelihood Ratio	66.384	5	.000
Linear-by-Linear Association	55.390	1	.000
N of Valid Cases	412		
a. 7 cells (58.3%) have expected count less than 5. The minimum expected count is .11			

Table 23. Cross tabulation

Educational Level		Knowledge/awareness of solar energy	
		Yes	No
Basic Level	Count	12	0
	Expected Count	11.7	3
Senior High School Level	Count	63	0
	Expected Count	61.3	1.7
Bachelors degree Level	Count	186	0
	Expected Count	181.0	5.0
Masters Level	Count	112	0

		Expected Count	109.0	3.0
	PhD Level	Count	28	7
		Expected Count	34.1	.9
	Prefer not to say	Count	0	4
		Expected Count	3.9	0.1
Total		Count	401	11
		Expected Count	401.0	11.0

Hypothesis 2

To establish whether there is an association between the level of education and the adoption of solar energy, the following hypotheses were formulated:

H_0: There is no significant association between the level of education and the adoption of solar energy.

H_1: There is a significant association between the level of education and the adoption of solar energy.

The Chi-square statistic was used to test the association between the variable's educational level and adoption of solar energy. The results indicate an association of 5% significance level between educational level and adoption of solar energy of respondents in the study. This indicates that the adoption of solar energy is dependent on the level of education of the respondents (X^2 =231.261, DF =5, p=0.000). Hence, H_1: is supported (See Tables 24 & 25 below).

Table 24. Chi-Square Tests

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	231.261[a]	5	.000
Likelihood Ratio	117.432	5	.000

Linear-by-Linear Association	91.331	1	.000
N of Valid Cases	412		
a. 5 cells (41.7%) have expected count less than 5. The minimum expected count is .20.			

Table 25. Cross-tabulation

			Likely adoption of solar energy for home should you have money for it		Total
			Yes	No	
Level of education.	Basic Level	Count	12	0	12
		Expected Count	11.4	0.6	12.0
	Senior High School Level	Count	63	0	63
		Expected Count	59.8	3.2	63.0
	Bachelor's degree Level	Count	186	0	186
		Expected Count	176.5	9.5	186.0
	Masters Level	Count	112	0	112
		Expected Count	106.3	5.7	112.0
	PhD Level	Count	18	17	35
		Expected Count	33.2	1.8	35.0

	Prefer not to say	Count	0	4	4
		Expected Count	3.8	0.2	4.0
Total		Count	391	21	412
		Expected Count	391.0	21.0	412.0

Hypothesis 3

To establish whether there is an association between educational level and the adoption of solar energy because of the availability of a flexible loan scheme, the following hypothesis were formulated:

H_0: There is no significant association between educational level and adoption of solar energy because of the availability of a flexible loan.

H_1: There is a significant association between educational level and adoption of solar energy because of the availability of a flexible loan.

Chi-square statistics were used to examine the association between the variable's educational level and adoption of solar energy because of the availability of a flexible loan scheme. The results show an association of 5% significance level between educational level and adoption of solar energy because of a flexible loan scheme available (X^2 =293.440, DF=5, p=0.00). Therefore, the alternate hypothesis (H_1) is supported (See Tables 26 and 27) while the null (H_0) hypothesis is rejected. This suggests that education has a direct impact on adopting solar energy even if a flexible loan is provided.

Table 26. Chi-Square Tests

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	293.440[a]	5	.000
Likelihood Ratio	231.947	5	.000
Linear-by-Linear Association	162.819	1	.000

N of Valid Cases	412		
a. 4 cells (33.3%) have expected count less than 5. The minimum expected count is .53.			

Table 27. Cross-tabulation

Educational Level			Adoption of SE (Loan)		Total
			Yes	No	
Level of education	Basic Level	Count	12	0	12
		Expected Count	10.4	1.6	12.0
	Senior High School Level	Count	63	0	63
		Expected Count	54.6	8.4	63.0
	Bachelors degree Level	Count	186	0	186
		Expected Count	161.2	24.8	186.0
	Masters Level	Count	96	16	112
		Expected Count	97.0	15.0	112.0
	PhD Level	Count	0	35	35
		Expected Count	30.3	4.7	35.0
	Prefer not to say	Count	0	4	4
		Expected Count	3.5	0.5	4.0

Total	Count	357	55	412
	Expected Count	357.0	55.0	412.0

Hypothesis 4

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 level 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 there is a significant likelihood that the awareness of BIPV is dependent on the respondent’s level of education (See Tables 28 and 29).

Table 28. Chi-Square Tests

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	246.152[a]	5	.000
Likelihood Ratio	265.814	5	.000
Linear-by-Linear Association	183.176	1	.000
N of Valid Cases	412		
a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is .82.			

Table 29. Cross tabulation

Item			Awareness of BIPV		Total
			Yes	No	
Level of education.	Basic Level	Count	12	0	12
		Expected Count	9.6	2.4	12.0
	Senior High School Level	Count	63	0	63
		Expected Count	50.2	12.8	63.0
	Bachelors degree Level	Count	186	0	186
		Expected Count	148.1	37.9	186.0
	Masters Level	Count	67	45	112
		Expected Count	89.2	22.8	112.0
	PhD Level	Count	0	35	35
		Expected Count	27.9	7.1	35.0
	Prefer not to say	Count	0	4	4
		Expected Count	3.2	0.8	4.0
Total		Count	328	84	412
		Expected Count	328.0	84.0	412.0

Hypothesis 5

To establish whether there is an association between educational level and the willingness to adopt BIPV, the following hypotheses were formulated:

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

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

Chi-square statistics were used to examine the association between the variable's educational level and adoption of building integrated photovoltaics (BIPV). The results reveal an association of 5% significance level between educational level and adoption of building integrated photovoltaics (BIPV) by respondents. (X^2 =255.756, DF=5, p=0.000). Therefore, the alternative hypothesis (H_1) is accepted while the null hypothesis (H_0) is rejected. This means that the adoption of BIPV is not independent of respondents' level of education (Refer to Table 30 and 31 below)

Table 30. Chi-Square Tests

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	255.756[a]	5	.000
Likelihood Ratio	135.233	5	.000
Linear-by-Linear Association	102.608	1	.000
N of Valid Cases	412		
a. 5 cells (41.7%) have an expected count less than 5. The minimum expected count is .23			

Table 31. Cross-tabulation

Item			adoption of BIPV		Total
			Yes	No	
Q7. Level of education.	Basic Level	Count	12	0	12
		Expected Count	11.3	0.7	12.0
	Senior High School Level	Count	63	0	63
		Expected Count	59.3	3.7	63.0
	Bachelor's degree Level	Count	186	0	186
		Expected Count	175.2	10.8	186.0
	Masters Level	Count	112	0	112
		Expected Count	105.5	6.5	112.0
	PhD Level	Count	15	20	35
		Expected Count	33.0	2.0	35.0
	Prefer not to say	Count	0	4	4
		Expected Count	3.8	0.2	4.0
Total		Count	388	24	412
		Expected Count	388.0	24.0	412.0

Hypothesis 6

To establish whether there is an association between educational level and the adoption of BIPV because of aesthetics, the following hypotheses were formulated:

H_0: There is no significant association between educational level and adoption of BIPV because of aesthetics.

H_1: There is a significant association between educational level and adoption of BIPV because of aesthetics.

Chi-square statistics were used to examine the association between the variable's educational level and adoption of BIPV because of aesthetics. The results point to an association of 5% significance level between educational level and adoption of BIPV because of aesthetics, (X^2 =345.836, DF=5, p=0.00). Therefore, H_1 is supported whereas the Null hypothesis (H_0) is rejected. This suggests that respondents' adoption of BIPV because of aesthetics is likely to be dependent on respondents' level of education (Refer to Table 32 and 33).

Table 32. Chi-Square Tests

	Value	DF	Asymp. Sig. (2-sided)
Pearson Chi-Square	345.836[a]	5	.000
Likelihood Ratio	235.991	5	.000
Linear-by-Linear Association	160.865	1	.000
N of Valid Cases	412		

a. 4 cells (33.3%) have an expected count less than 5. The minimum expected count is .45.

Table 33 Cross-tabulation

Item			Adoption of BIPV because of aesthetics (Beauty)		Total
			Yes	No	
Level of education	Basic Level	Count	12	0	12
		Expected Count	10.7	1.3	12.0
	Senior High School Level	Count	63	0	63
		Expected Count	56.0	7.0	63.0
	Bachelor's degree Level	Count	186	0	186
		Expected Count	165.2	20.8	186.0
	Masters Level	Count	105	7	112
		Expected Count	99.5	12.5	112.0
	PhD Level	Count	0	35	35
		Expected Count	31.1	3.9	35.0
	Prefer not to say	Count	0	4	4
		Expected Count	3.6	0.4	4.0
Total		Count	366	46	412
		Expected Count	366.0	46.0	412.0

4.4 Results of Multiple Regression Analyses

Multiple regression is a statistical technique that shows interest in the estimation of the values of X based on known values of variable Y. In other words, based on the results obtained from the sample, researchers can predict patterns of performance, impact, influence and or behaviour of a population with a specified degree of certainty (Ethington et al. 2002; Pedhazur, 1982). Regression analysis allows researchers to generalise their findings from the sample to the whole population. In this study a multiple regression method is used to test the influence policy and aesthetics could have on BIPV in Ghana. The study uses respondents' educational level as a measure of BIPV awareness and adoption since studies indicate that peoples' WTA or pay for renewable energy is largely influenced by their level of education (Sestino, 2018).

The government of Ghana recognises the benefits of solar energy and views it as an essential contributor to the attainment of the country's overall RE targets. Therefore, it is necessary to ascertain the influence of governmental policies as well as the impact of aesthetics on BIPV awareness and adoption in Ghana. Energy industry players have shown commitment by expanding portfolios, initiating new projects, and developing technological capabilities to support solar energy usage. However, due to the novelty of BIPV in Ghana, its uptake requires a fresh market investigation and related policies to augment existing policies. This section analyses the influence of policy-related issues and aesthetics of BIPV in Ghana. The following hypotheses are tested.

Objective One (Related)

To test whether aesthetics influence 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 hypothesis H_1. The independent variable (aesthetics) significantly influenced BIPV adoption in Ghana, F (136. 652), $P < 0.05$, which indicated that colours, patterns, scale, shapes, and visual weights influence the adoption of BIPV and solar energy usage in Ghana. The results point to a direct positive influence of aesthetics on BIPV adoption. Moreover, the R^2 depicts that the model explains 40.1% of the variance in BIPV awareness and adoption. Table 34 shows a summary of the findings.

Table 34. 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 AEST, Aesthetics, BIPV, Building Integrated Photovoltaics.

Objective Two (Related)

To test whether advertising (ADVRT) could influence 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 (117.140), $P < 0.05$, which indicates that advertising 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 many and sustained advertising campaigns to increase BIPV awareness and adoption in Ghana. Moreover, the R^2 depicts that the model explains 22.2% of the variance in BIPV awareness. Table 35 shows a summary of the findings.

Table 35. 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, Advertising, BIPV, Building Integrated Photovoltaics.

Objective Three (Related)

To investigate the link between adinkra symbols (IMG) and BIPV and to establish whether adinkra symbols influence the adoption of BIPV in Ghana

H_1: There is a significant connection between adinkra symbols (IMG) and BIPV and adinkra symbols influence the adoption of BIPV in Ghana.

The hypothesis tests whether there is a link between adinkra symbols and BIPV and whether adinkra symbols influence BIPV adoption in Ghana. The dependent variable BIPV measured by level of education was regressed on predicting variable adinkra symbols (IMG) to test the hypotheses. IMG has a significant connection with BIPV, and they influence BIPV adoption in Ghana, F (203.959), $P < 0.05$, which indicated that adinkra symbols influence the adoption of building integrated photovoltaics and solar energy usage in Ghana. The results suggest a direct positive influence of adinkra symbols on BIPV adoption. Moreover, the R^2 depicts that the model explains 49.9% of the variance in BIPV adoption. Table 36 shows a summary of the findings.

Table 36. Link Between Adinkra symbol and BIPV

Hypothesis	Regression weights	Beta Coefficient	R^2	F	t-value	p-value	Hypothesis supported
H_1.	IMG→BIPV	1.071	0.499	203.959	9.373	0.000	Yes
	IMG→BIPV	0.896			6.165	0.000	Yes

Note. $P < 0.05$ IMG, Adinkra Symbols, BIPV, Building Integrated Photovoltaics.

Objective Four (Related)

To investigate whether governmental policies could influence the adoption of BIPV in Ghana

H_1: There is a significant influence of policy-related issues on the adoption of BIPV in Ghana.

The hypothesis tests whether governmental policies (POL) such as grants, subsidies, flexible loan facilities and reduction in overall cost could influence the adoption of BIPV in Ghana. The dependent variable BIPV measured by level of education was regressed on predicting variables to test the hypotheses. Some of the POL variables significantly influenced BIPV adoption in Ghana, F (75.729), $P < 0.05$, which indicated that government policies influence the adoption of BIPV and solar energy usage in Ghana whereas others do not influence BIPV adoption in Ghana. The results indicate a direct positive influence of policy-related issues like the government creating an enabling environment and ensuring easy access to loans or flexible loan facilities for alternative power usage. Table 37 shows a summary of the findings.

Table 37. Government Policies and BIPV adoption in Ghana

	Regression weights	Beta Coefficient	R^2	F	t-value	p-value	Hypothesis supported
H_1	POL→BIPV	0.975	0.427	75.729	4.593	.000	Yes (flexible Loan facility)
	POL→BIPV	0.267			0.903	0.367	No (Reduce Overall Cost)
	POL→BIPV	0.778			2.886	0.004	Yes (Enabling Environment)
	POL→BIPV	0.222			0.779	0.436	No (Grants and subsidies from gov't)

Note. $P < 0.05$ POL, Policy issues, BIPV, Building Integrated Photovoltaic

4.5 Architectural Visualisation of BIPV in Ghana

BIPV remains a relatively new concept within the Ghanaian context, hence a practical attempt has been made to develop illustrations of selected buildings in Ghana with BIPV design on either their roof or façade. The buildings are categorised under rural, industrial, modern, and small urban apartments. These illustrations contextualise BIPV within the current Ghanaian architectural space. The illustrations also display Ghanaian Adinkra symbols in BIPV design and application as shown in Figure 44 - 53.

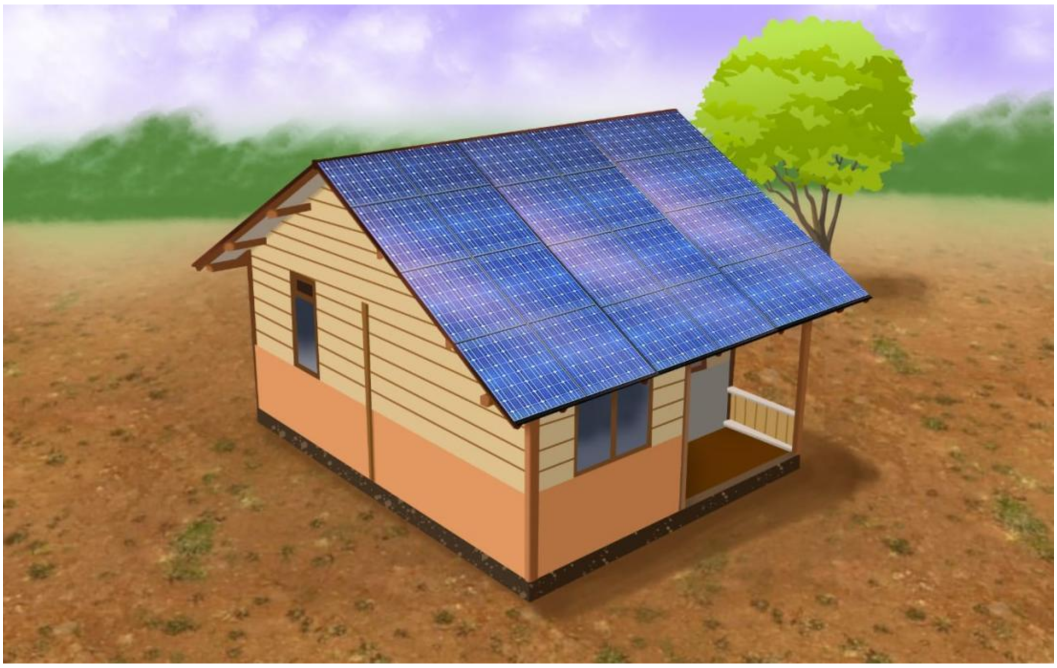

Figure 44. Rural house in Ghana with BIPV roof

Figure 45. Building with BIPV cladding

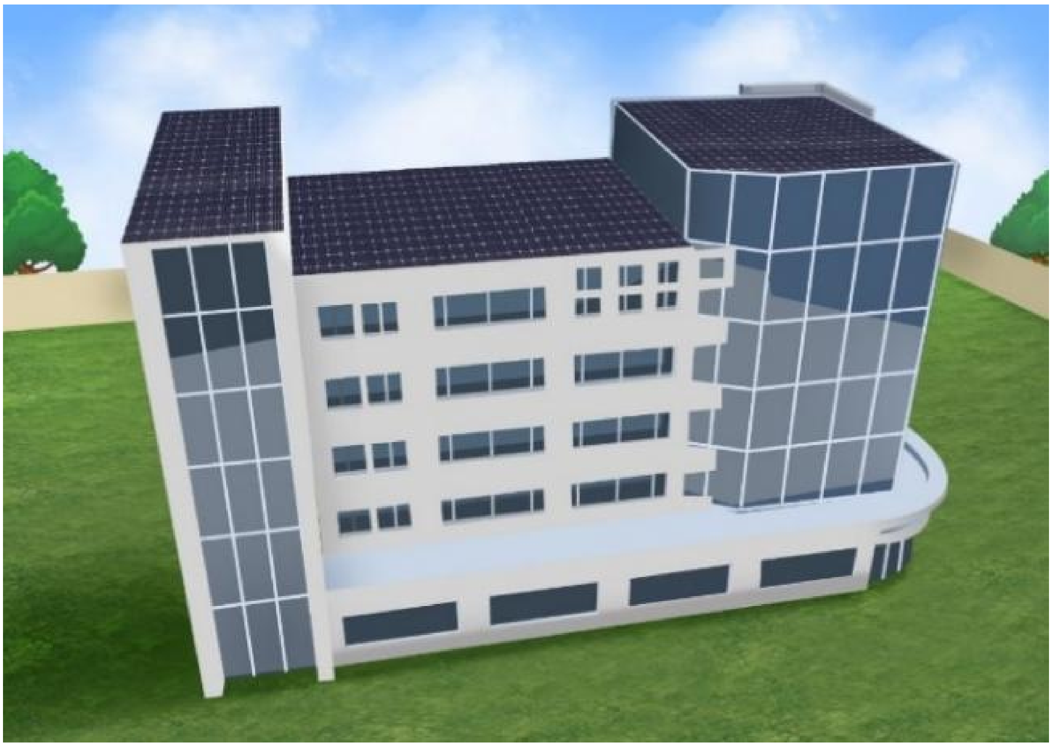

Figure 46. Industrial Building with BIPV roof

Figure 47. Industrial Building with BIPV cladding and Adinkra symbols, Akoma (Heart) – Symbolises consistency, endurance, patience, love, and goodwill

Figure 48. Modern house with BIPV cladding

Figure 49. Modern house with BIPV Roof

Figure 50. Modern house with BIPV cladding and Adinkra symbols, Adinkrahene (King of all Adinkra symbols) – Symbolises authority, leadership, and charisma

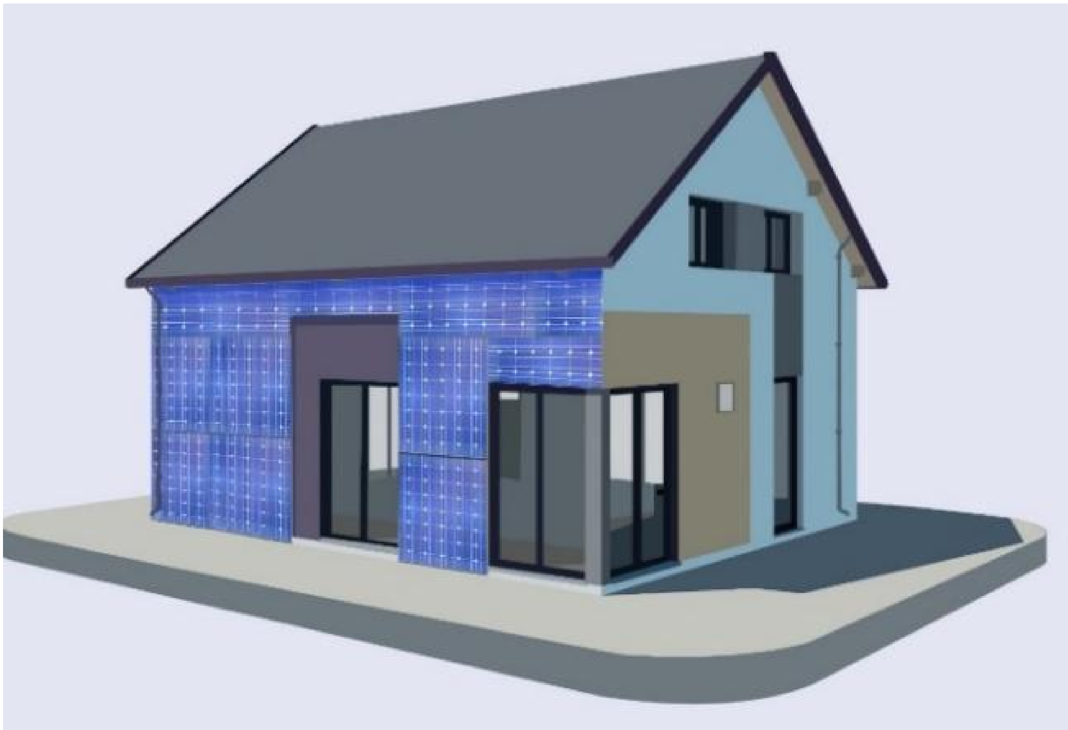

Figure 51. Simple urban house with cladding

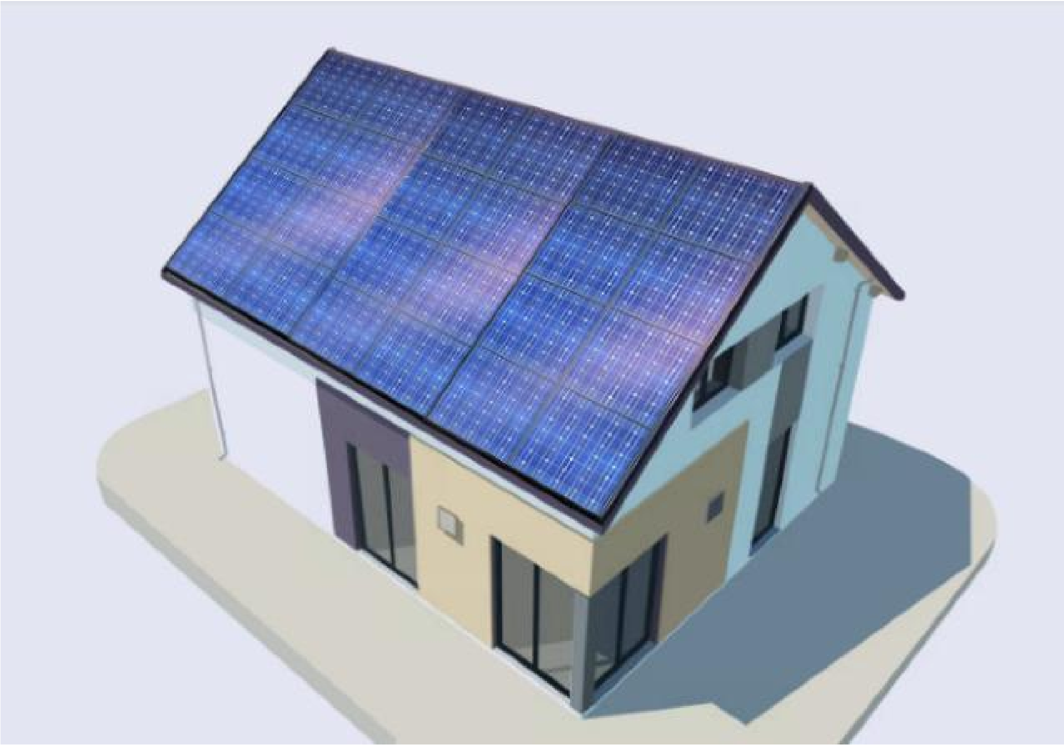

Figure 52. Simple urban house with BIPV

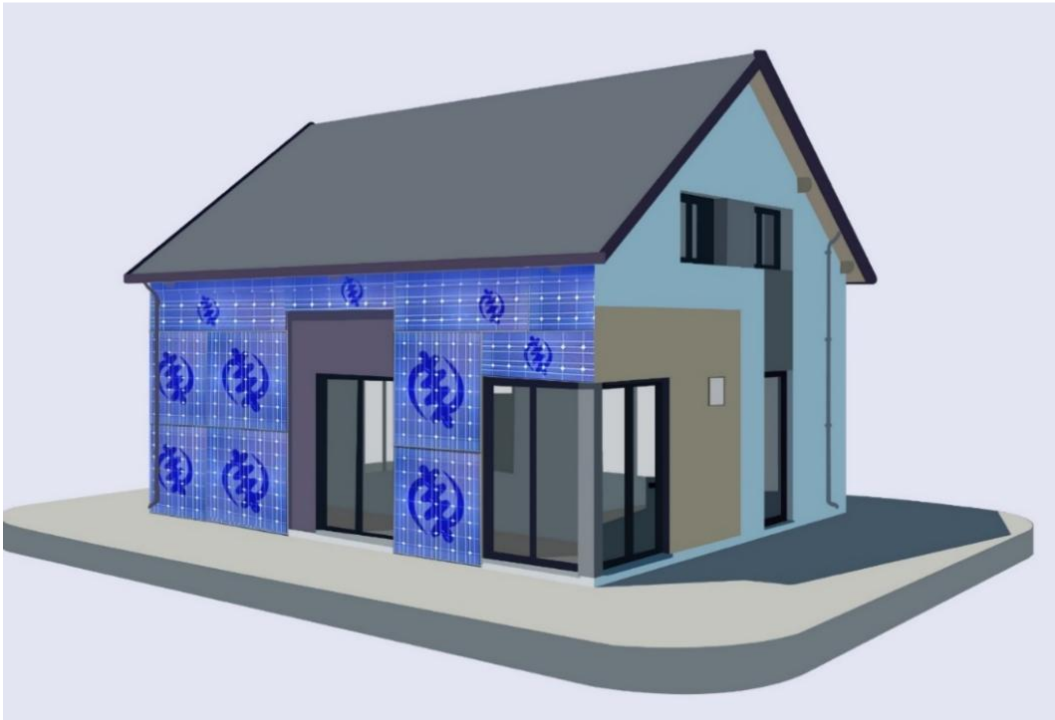

Figure 53. Simple urban house with BIPV cladding and Adinkra symbols, Gye Nyame (Except God) – This symbol represents the supremacy of God (Adinkra Symbol & Meanings, 2024)

4.6 Experimental Design

This chapter aims to use the screen-printing technique for transferring traditional adinkra symbols on solar cells for BIPV design. This experiment serves as a preliminary study on the feasibility of custom-printed top contact of solar cells. It does not offer a detailed investigation into the full characterisation and technicalities; however, it serves as a solid premise for future studies. Key stages include the organisation of general materials, pattern creation, conductive paste preparation, substrate preparation, curing, and cell characterisation.

4.6.1 Organisation of General Materials

4.6.1.1 Ink and Substrate Preparation

The conductive silver paste was used for printing. It was stored in an air-tight container at room temperature and stirred to ensure a uniform mixture before printing. The substrates (RESERV 626) were processed through acid texturization to ensure they had an isotropic textured surface. Cells were tested for mechanical discrepancies, however same cannot be said for electrical performance. Key cell characteristics are shown in Table 38.

Table 38. Characteristics of Substrate

Product	Mono Crystalline Silicon Solar Cell
Substrate	P-Type Multi Crystalline Silicon Wafer
Device structure	n+ / p / p+
Dimensions	Size: 156.75mm x 156.75mm ± 0.25mm Average Thickness: 200 ± 20μm
Front	Blue An-Reflective Coating (Silicon Nitride) Acid textured surface Full-surface Aluminium BSF 0.15 ± 0.1 mm 0.6 ± 0.1 mm silver bus bars, Negative Pole (-)
Back	Full-surface Aluminium BSF 0.15 ± 0.1 mm silver bus bars Posi e pole (+)

4.7 Patterns Creation

The top contact design of PV cells has great advertising and cultural relevance. For instance, they can be used to project a company's brand, culture, and tradition of a group of people. This study adopts modified traditional Adinkra symbols from Ghana. Adinkra symbols have deep proverbial meanings and hence are valued by Ghanaians for both traditional and commercial purposes (Deng and Nanor, 2021).

This study adopts different types of top contact patterns which are created by the Adobe Photoshop and Illustrator software. In all, three traditional symbols were selected and modified using design principles for the experiment. The symbols were mainly selected based on their layout and replicability. The original symbols as shown in Figure 53 adopted for the experiment were "Nea Onnim no sua" (He who does not know learns), "Dwennimmen" (humility and strength and "Gye Nyame" (Except God). Some areas of the patterns were made to connect and overlap to improve the flow of current through the cell as shown in Figure 54. Design techniques such as half drop, side by side and repetition were adopted for designing the patterns. The positive and negative ratios of the images were between approximately 21% to 29%.

Figure 54. Patterns Used for Screen Printing

The designed patterns were transferred onto a screen. The screen was made of a square wooden frame with 110 organdie mesh tightly stretched to fit all four edges. The screen was then coated with a thin layer of light-sensitive photo emulsion. A dark room was required for this activity due to the light sensitivity of the chemical. The screen was allowed to dry and placed on the shooting box with the design ready for transfer. The screen was exposed to light and rinsed as seen in Figure 55.

Figure 55. Final Screens ready for Printing

4.8 Thermal curing

A crucial phase in the creation of solar cells is its curing. The curing process involves heating the printed solar cell to a specific temperature for a certain amount of time to ensure that the ink is fully cured and adheres to the substrate. The kind of conductive ink, substrate material, desired electrical qualities, and equipment accessibility play a role in determining the curing temperature. It is essential to review the manufacturer's suggestions for the conductive ink being used because they frequently offer ideal curing temperature and time recommendations. Here, an external oven was used for curing. In this study, the printed cells were cured at 200 ℃ for 30 minutes to ensure compatibility and solid bonding.

4.9 Screen-Printing

The following steps were followed to ensure a successful setup for the screen- printing. Figure 56 shows a diagrammatic illustration of the printing process.

A. Organising needed materials: designed screen, squeegee, ink, printing glass, flat surface, and paper.
B. Preparing the screen frame, ink, and solar cell.
C. Placing the solar cell on a flat glass prism and holding it in position.
D. Attaching the designed screen to the solar cell gently.
E. Forcing the ink through the mesh onto the solar cell.
F. Gently detaching the screen from the printed cell.
G. Curing to a temperature of 200℃ 30 minutes to ensure combustion of gases and stronger bonding.

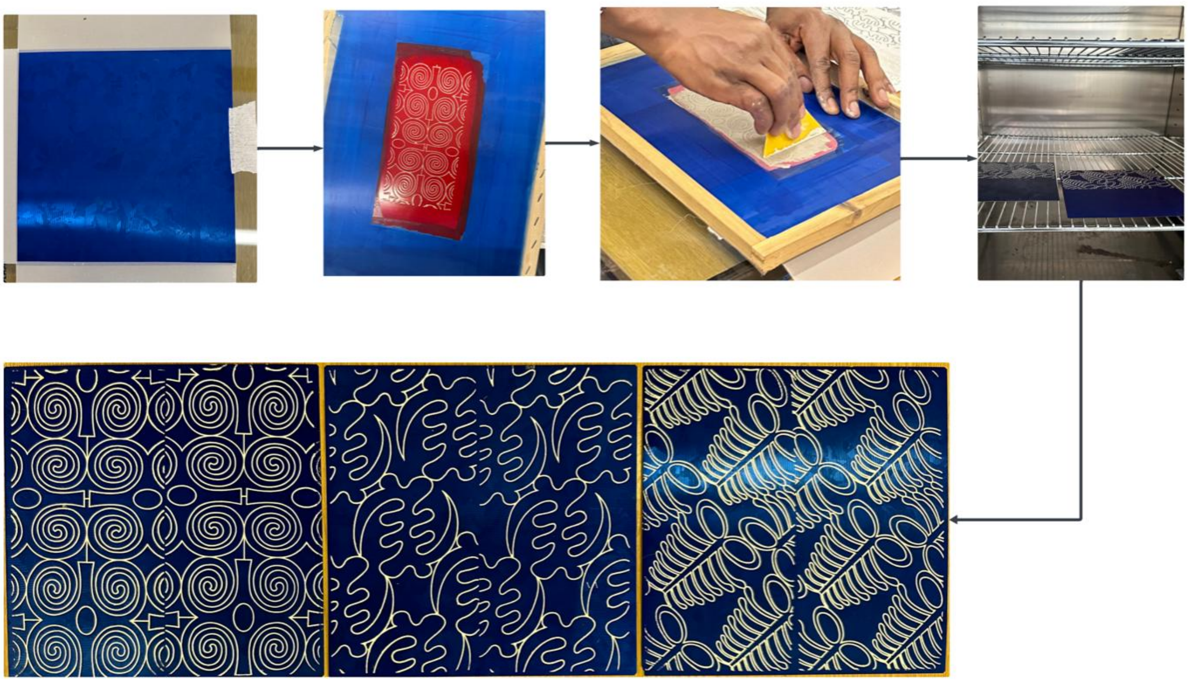

Figure 56. Diagrammatic illustration of the Screen-printing process

4.10 Characterization of Solar Cell

4.10.1 Optical Characterization by Scanning Electron Microscopy (SEM)

Evaluation of the microscopic scanning of the printed solar cell is a crucial step in the production and study of solar cells. Its primary objective is to evaluate the printed top contact for consistency, quality, printing flaws, and efficiency (Krause et al., 2020; Li et al., 2022). Scientists and engineers may also use the data from picture evaluation to explore novel materials, improve printing techniques, and create cutting-edge solar cell technologies. These findings can lead to cost reduction, higher acceptance, and improvements in solar technology by continually refining the top contact printing process. Figures 57, 58 and 59 show line widths of 50μm, 100μm and 200μm respectively, showing consistent print and perfectly bonded ink. The microscope used was the Leica Wild M3Z.

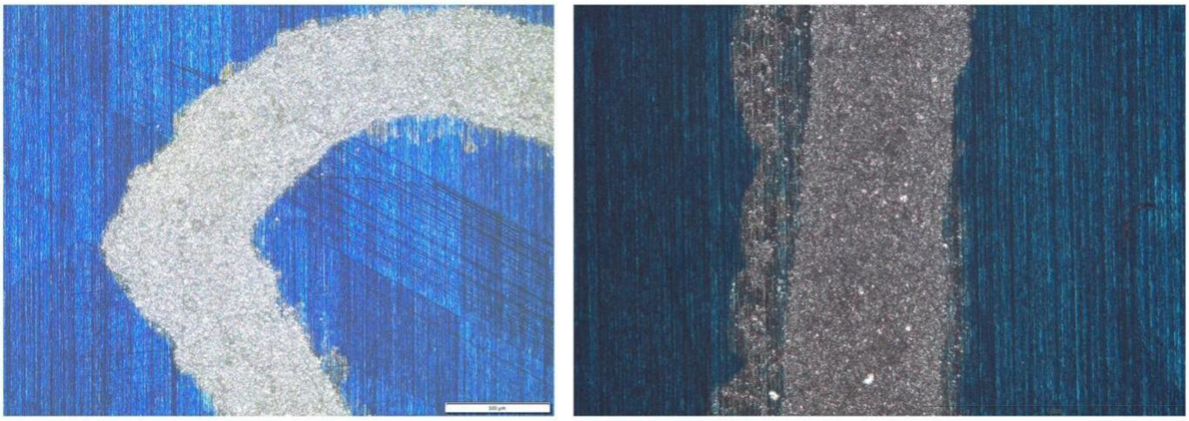

Figure 57. Leica wild M3Z Microscopic image of Printed Solar cell - 50μm

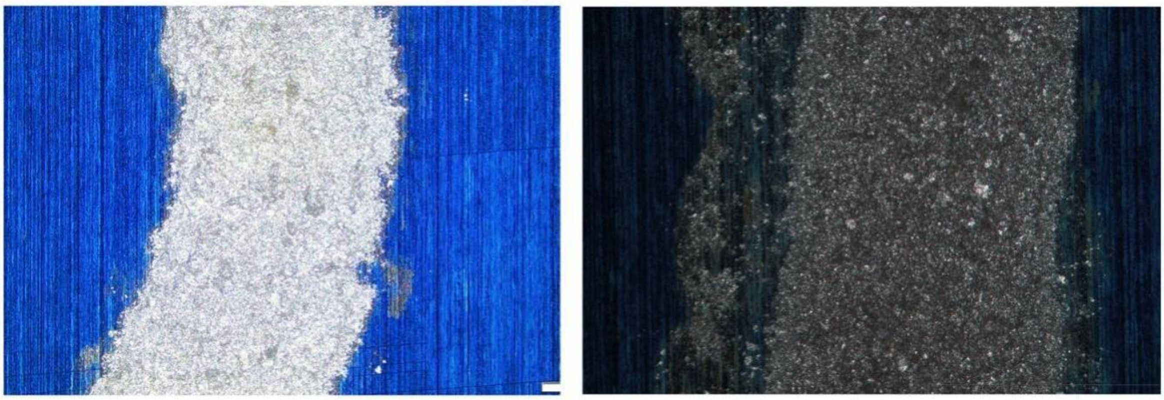

Figure 58. Leica wild M3Z Microscopic image of Printed Solar cell - 100μm

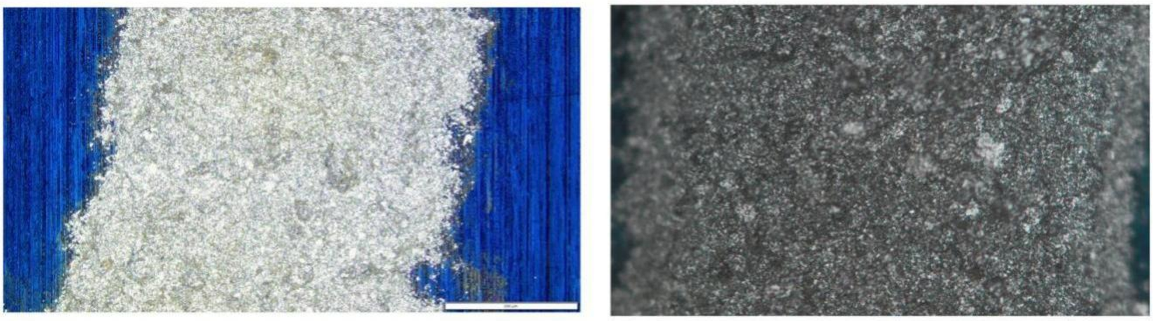

Figure 59. Leica wild M3Z Microscopic image of Printed Solar cell - 200μm

The print quality as shown above appears to have continuity and bonding, which are essential for cell efficiency. A clear difference though is the fact that they do not appear as smooth and even as the original cell. Figures 60, 61 and 62 show line widths of 50μm, 100μm and 200μm respectively of the original reference solar cell. This comparison indicates the quality of print achieved in the study.

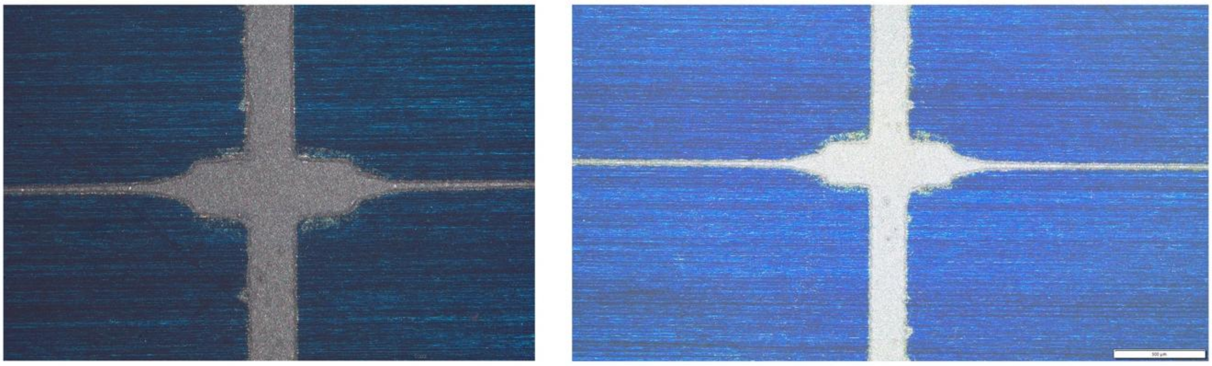

Figure 60. Microscopic image of Printed Solar cell - 50μm

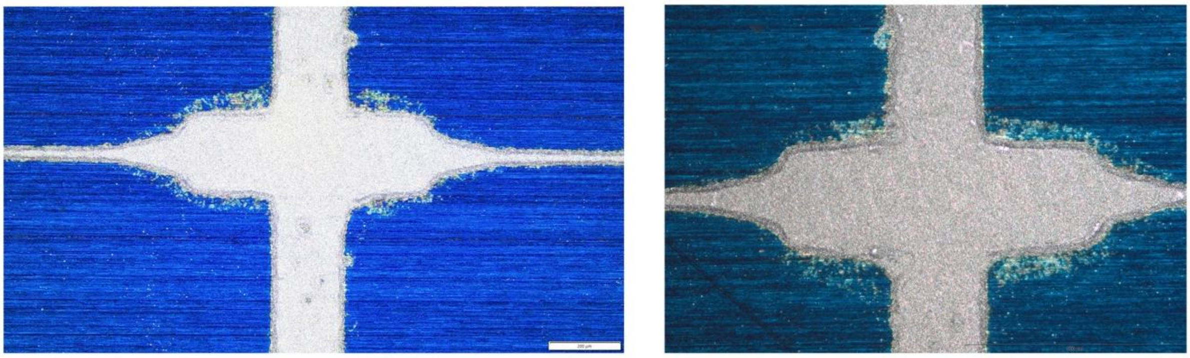

Figure 61. Microscopic image of Printed Solar cell - 100μm

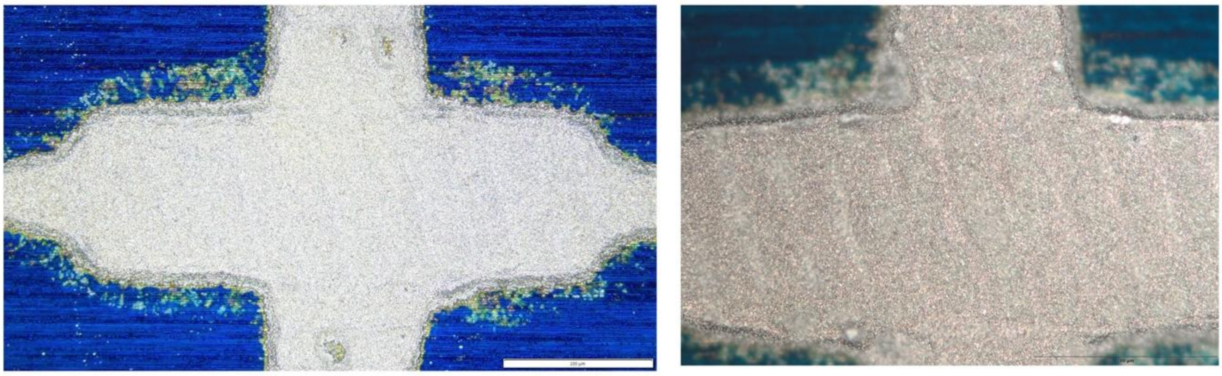

Figure 62. Microscopic Scan of Printed Solar cell - 200μm

The outlook of these images indicates that metal particles are perfectly and uniformly bonded, hence a greater chance of good conductivity on the top contact of the cell.

4.10.2 Electrical Characterization of Printed Solar Cell

Electrical characterisation of the printed cell is critical to understanding its performance and efficiency. This preliminary study sets the premise for future research into optimizing custom-printed top-contact solar cells. Here, various parameters are analysed to determine the behaviour and conductivity of the cell after printing. The solar simulator was used to test the efficiency. The negative and positive cable connectors on the simulator were mounted on the solar cell. An artificial light was used to simulate sunlight. Figure 63 shows the printed solar cell mounted on the simulator prop.

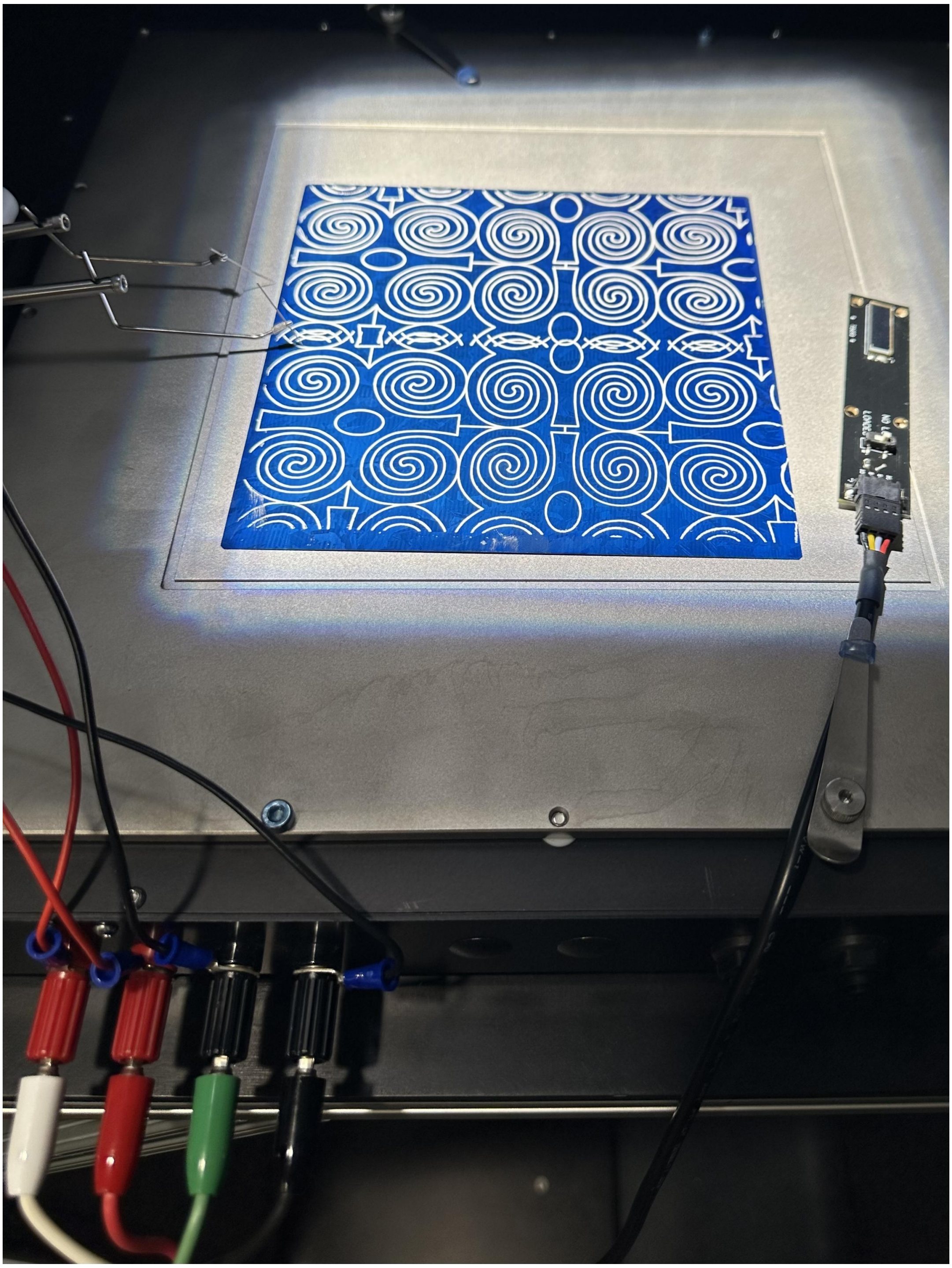

Figure 63. Printed Solar cell mounted on Simulator Prop

An essential aspect of electrical characterisation in solar cells involves measuring the current-voltage (I-V) to determine the performance behaviour under different operational situations. This typically involves introducing different voltage levels and measuring the resulting current flow. The open-circuit voltage, short -circuit current (Isc), maximum power point (MPP), fill factor (FF) and overall efficiency of the solar cell can be determined by plotting the values on the I-V curve.

Most commercial monocrystalline solar cells have an efficiency of between 15%-25% (Sawle and Thirunavukkarasu, 2021). However, in this study, the newly developed top contact pattern testing generated open circuit voltage (Voc) and short circuit current (Isc) measurements of 0.487 volts and 70 microamperes, respectively. The cell's fill factor was 30%, and efficiency was 0.018%, This indicates more room for improvement in cell performance through optimization techniques. The thicker top contact width caused by printing limitations and curing temperature resulted in shading losses and decreased efficiency compared to conventional designs. Scanning electron microscopy (SEM) evaluation revealed imperfect bonding of the metal ink paste which affected conductive path resistance resulting in a reduction in efficiency.

From the cell characterisation, it is known that the customised top contact patterned solar cell has less efficiency compared to the conventional solar cell. This could be due to shading loss created by the thicker top contact pattern, inappropriate curing temperature, and silver paste used.

The custom-printed version shows lower bonding with contact material paste and isolated spread of metal ink across some areas. The bonding of particles in the metal ink paste used also had an impact on the overall performance. A weaker bonding created series resistance in the cell and reduced the flow of current. Non-uniformities and gaps on the contact surface also resulted in inefficient bonding or adhesion. As a result, the contact area for current collection decreased, resulting in localised current losses and poor efficiency. However, the conventional (reference solar cell) shows better bonding between the solar cell and top contact.

4.11 Chapter Summary

This chapter has covered the sample profile of respondents. The age, gender, occupation, location, income range, family size and level of education have been explored. Four key findings are evident from the main themes in the study. In terms of solar energy adoption (SEA), there was a positive perception among respondents, with proven knowledge and interest in adoption. On the Policy (POL) side, the findings reveal that a flexible loan is likely to boost solar adoption. Regarding BIPV Aesthetics, respondents showed a high awareness of BIPV and an affinity towards cultural images. Architectural visualisation was used to render BIPV buildings in Ghana under rural, industrial, modern, and small urban apartments. This aided in the understanding of BIPV by the respondents and aimed at serving as an architectural guide depicting BIPV with traditional Adinkra symbols.

Next, three Adinkra symbols were printed on monocrystalline solar cells and cured at 200^0 C. The outcome was aesthetically appealing, however, there were issues such as imperfect bonding of ink, curing temperature, and type of conductive silver paste used which affected the overall performance of the solar cell. The next chapter focuses on discussing the outcome of both the survey and experiment as well as its policy implications.

CHAPTER 5: DISCUSSION AND CONCLUSIONS

5.0 Introduction

This chapter critically discusses the results obtained from the survey questionnaires displayed in Chapter 4 and the outcome of the experiment. The discussion is categorised according to the objectives (effectiveness of architectural visualisation on BIPV awareness in Ghana, the acceptance rate of BIPV in Ghana before and after merging traditional Ghanaian Adinkra symbols, Aesthetics of BIPV and prospects after merging Adinkra symbols and policies for BIPV adoption in Ghana). The discussion aims to compare, evaluate, and synthesize the findings of the study with existing literature to demonstrate the novelty of this study.

This dissertation has highlighted the prospects of BIPVs in Ghana focusing on the aesthetics and potential policies that could boost adoption. BIPV was specifically selected based on its adaptability, aesthetic values, environmental impact, and ability to integrate into buildings seamlessly. A developing nation such as Ghana has more room for industrialisation, infrastructural growth, and development, hence BIPV sits well within the future scope of a sustainable built environment. Despite the enormous benefits of BIPV, its adoption has remained sluggish globally, thus this research establishes its prospects in developing countries and explores ways to promote adoption. This was reliably done using a blend of quantitative and experimental design approaches. This chapter concludes the entire thesis by summarising the major findings, limitations encountered, overall contribution to the body of knowledge and recommendations for future studies.

5.1 Effectiveness of Architectural Visualisation and Advertising on BIPV Awareness in Ghana

Solar energy has been part of Ghana's energy portfolio since at least 1992 (Kemausuor et al., 2011). It is important to prevent the foreseeable limitations of BIPV adoption in Ghana. Some respondents indicated a negative perception when it comes to the adoption of BIPV and solar energy in general. The issues of cost, efficiency and public perception have been identified as limitations. It can be argued that even if the cost of BIPVs becomes very competitive, hurdles such as awareness and perception must be crossed. Therefore, awareness of BIPV in Ghana is a big deal; to overcome this, a sequential marketing strategy may be helpful.

Understandably, BIPV remains a relatively new technology in Ghana, hence a deliberate intervention to sensitise the respondents was made. When it comes to awareness of BIPV, advertising plays a crucial role in reaching a wider audience and educating them about the benefits and potential of this innovative technology. However, this study has pointed out that, the effectiveness of advertising on BIPV awareness depends on two key factors: target audience and advertising channel.

The target audience must be identified and understood. BIPV is a niche market and likely to primarily appeal to architects, builders, developers, and environmentally conscious individuals. Therefore, advertising efforts should be directed towards these specific groups to maximize their impact. In this study, the target group was extended to all Ghanaians to avoid biases. The choice of advertising channels is crucial. Traditional mediums such as television, radio, print media, and billboards can still be effective in reaching a broad audience. However, digital platforms have become increasingly important in recent years due to their ability to target specific demographics and track engagement metrics.

The pilot study suggested that most of the respondents had no idea about BIPV despite the preliminary explanation given in the introductory section of the survey. This indicates that most of the respondents did not practically understand the mere words while others complained that it was somewhat complex. In history, images were used to convey messages, even amongst prehistoric men. As early as 30,000 BC, images were drawn on tombs and walls for communication purposes (Novin, 2016). This proves that images tend to improve understanding. As propounded by (Smiciklas, 2012) , images are fundamental for conveying complex messages to the target audience. This research therefore heavily relied on posters and illustrations of selected buildings in Ghana to ensure a better understanding of the meaning and functions of BIPVs. The aim was to assess the effectiveness of these designs on BIPV awareness in Ghana. Figure 64 is a classical poster that was designed to match the introduction of the survey.

Figure 64. Poster for BIPV survey in Ghana – Authors Design

After the respondents were offered infographics and architectural drawings for sensitisation through the survey, there was a positive impact on awareness. The findings indicated that a clear majority of respondents 79.5% knew about BIPV after the introduction of infographics, as compared to the pilot study, where only 18% knew about BIPVs. An overall mean score of 1.24 with a standard deviation of (SD=0.354) suggests a positive perception of awareness of BIPV and aesthetics among respondents. This finding is in line with other studies which have highlighted the role of infographics in stimulating and promoting awareness (Provvidenza et al., 2019; Prandi et al., 2021).

Apart from infographics, architectural visualisation (AV) was also adopted to depict BIPV in the Ghanaian context using selected buildings (ranging from traditional to modern) across the country. Illustrations were carefully simulated by Graphic design software such as Adobe Photoshop and Illustrator. These illustrations were used to back the explanations offered in the survey to make it comprehensible to the target group. In the field of architecture and Engineering, AV has been used to enhance presentation, reduce/cut the cost of producing prototypes and explain concepts to the public (Designblendz Team, 2018). In this case, AV ensured that most of the respondents had at least some level of visual understanding of the concept to make informed choices.

A solid sensitisation mechanism is crucial for the promotion of especially new products. In Ghana, several studies indicate that the public reacts positively to product sensitisation mechanisms such as the use of Graphic aids, and media adverts (radio and TV) among others (Amoako et al., 2012; Okyere, et al., 2011). This study therefore adopted a similar trend by using visual aids to help sensitise its target audience ahead of answering the questionnaires. Clearly, there was a positive impact of AV and advertising on awareness as most respondents were able to understand the BIPV concept compared to the pilot study.

An important factor revealed in this study is the significant association between educational level and awareness of solar energy and BIPV. The Chi-square analysis revealed a 5% significance respectively. This implies that education has a great bearing on BIPV awareness and potential adoption. In other words, the more educated an individual is, the more likely they are to know or adopt BIPVs. Also, the outcome of the multiple regression from the survey highlights that advertising has a positive influence on awareness.

Public awareness through adverts is essential for the successful diffusion of BIPV in Ghana. Although this study adopts illustrations to educate the respondents, several other means can be used to promote awareness of BIPV in Ghana. For instance, by implementing practical demonstrations, such as adopting a Pilot BIPV building in a public space, where the public can witness first-hand functionality and benefits. These demo projects could serve as information hubs, where trained personnel could educate the public on the technology. The media could also have a strong voice in campaigning about technologies such as BIPVs and their benefits. On average, 91% and 92% of Ghanaians listen to the radio and watch TV daily (The Media Online, 2023). This implies that TV and radio could be great mediums for awareness creation. This knowledge can empower individuals to make informed decisions about their energy consumption habits and encourage them to adopt sustainable renewable energy in the bid for environmental preservation. It is only reasonable that stakeholders and the right regulatory policies will follow once public awareness and demand for BIPV grow. Figure 65 shows an awareness diffusion model for solar and BIPV in Ghana.

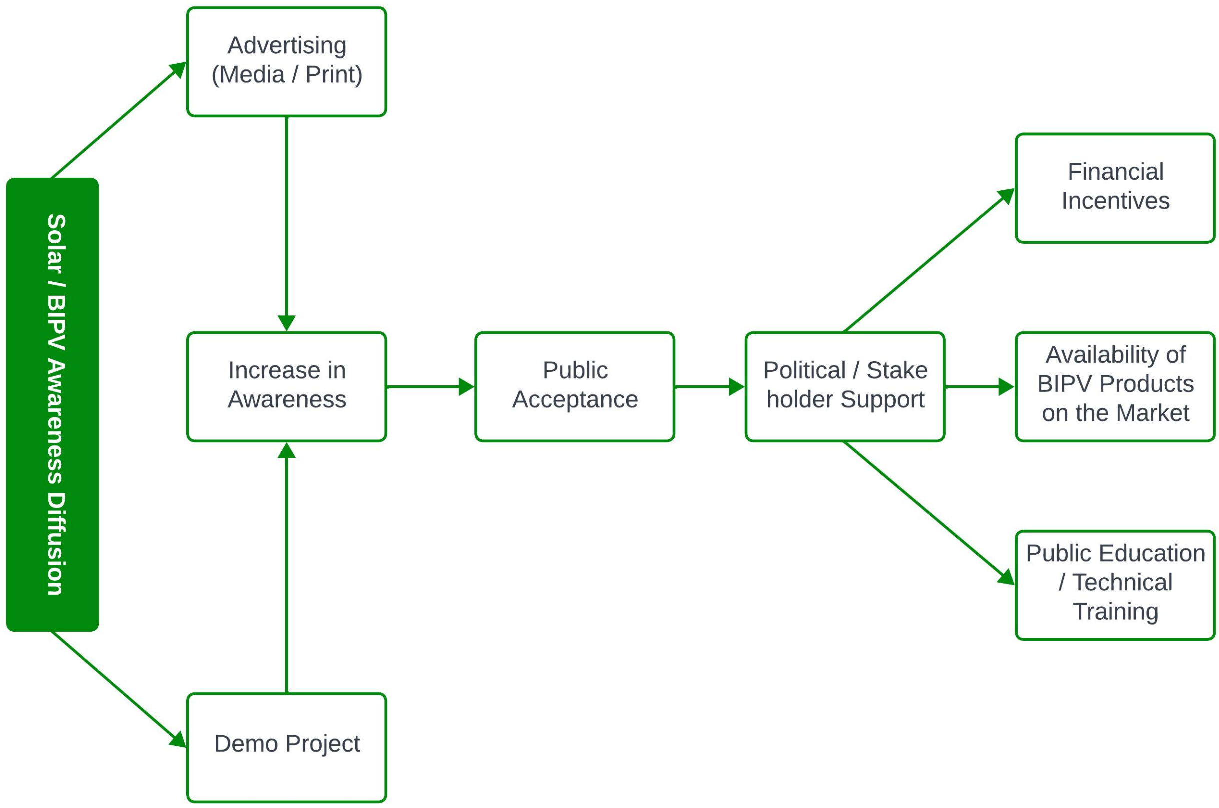

Figure 65. Awareness Diffusion Model for Solar and BIPV in Ghana (Authors Construct)

In summary, the outcome of the survey confirms that AV and advertising have a great impact on the awareness of BIPV in Ghana. Adverts in both print and media can have a direct impact by increasing overall awareness of BIPV and promoting public acceptance. The acceptance of the public naturally calls for political and stakeholder intervention in the form of providing financial incentives, making products available on the market, public education, and training of experts.

5.2 The Nexus Between Adinkra Symbols and BIPV Adoption in Ghana

Culture plays a vital role in BIPV adoption in Ghana by shaping aesthetic preferences and public acceptance. Incorporating traditional symbols like Adinkra into BIPV designs resonates with local values, making the technology more relatable. The importance of traditional symbols in BIPV lies in their ability to bridge the gap between modern technology and cultural heritage. Traditional symbols hold significant cultural, historical, and emotional value for communities. They often represent a collective identity, values, beliefs, and aspirations. Incorporating these symbols into BIPV installations creates a harmonious blend of modern renewable energy technology with traditional cultural expressions. One of the core objectives of this study is to determine the acceptance rate of BIPV in Ghana before and after merging traditional Ghanaian Adinkra symbols because of the premium placed on culture. Ghanaians are a cultural people; hence they are likely to uphold their traditions, beliefs, and culture in all spheres of life (Inkum et al., 2021).

Adinkra symbols have been adopted for various purposes in Ghana partly because of their deep proverbial meaning. It remains one of the most popular symbols in Ghana after it was replicated on fabrics in the early 19^{th} century (Danzy, 2009). One crucial aspect is the preservation of cultural heritage. These symbols have been passed down through generations and are integral to a community's identity. By integrating these symbols into BIPV systems, we ensure that they are not lost or forgotten but rather celebrated and showcased in a contemporary context. They provide an opportunity to educate people about the significance of these symbols, their historical and cultural importance, and the stories behind them. This integration of traditional symbols on BIPV systems creates a unique blend of art, technology, and heritage, fostering a deeper appreciation for the community's roots.

The introduction of Adinkra symbols in buildings is not a new concept. Many historic buildings have been designed with Adinkra symbols in Ghana and beyond (Awuku et al., 2022) . Most Ghanaians have a strong attachment towards these symbols and hold them in high esteem. They have been adopted for decorating various State houses, commercial as well as private houses. Replicating this idea in BIPV applications in Ghana could be a potential booster for its marketability.
Most of the respondents preferred BIPVs to BAPVs because of their aesthetics and the fact that they can offset the cost of conventional building materials. Although BIPV remains a relatively new technology in Ghana, this survey indicates that if awareness and full understanding are given, there will be a high rate of acceptance.

The survey indicates that most of the respondents were willing to adopt BIPVs with Adinkra symbols mainly because they represent the culture, tradition, and heritage of the people. This is in line with several studies conducted on the impact of Adinkra symbols on product adoption (Osei-Tutu and Jenewa, 2017; Aboagyewaa-Ntiri et al., 2016; Zhe and Bawuah, 2019). In a follow-up qualitative response, some respondents thought BIPV with Adinkra symbols was more appropriate for palaces of traditional leaders, community centres and State houses while other raised concerns about potential distortion of the original designs of buildings.

However, some respondents also indicated that adopting innovative designs will introduce more flexibility and offer room to display company logos on BIPV for advertising purposes. This is highly achievable because Adinkra symbols have been adopted or modified as logos for several companies in Ghana. Adopting BIPV with Adinkra symbols will therefore offer the opportunity to display the company brand identity while generating energy. A few respondents raised concern that "traditional symbols must not be used on modern buildings". This indicates that a smaller portion of Ghanaians will likely oppose the integration of antiquity, culture, and tradition in modern architecture.

According to the survey, the adoption of BIPV after the introduction of Adinkra symbols remains very high. Although major building materials are being replaced with BIPV (with Adinkra designs), most respondents still prefer it. The meanings of these symbols touch on the core values, character and ethos upheld by individuals and societies. This puts Adinkra at the heart of many people in Ghana, hence the likelihood to prefer BIPV with Adinkra symbols for their buildings. The inclusion of Adinkra symbols in BIPV design will go a long way to promote its adoption in Ghana, considering the strong affinity most Ghanaians have towards these symbols and their deep meanings.

On the other hand, the DOI theory has significant underpinnings when it comes to the widespread adoption of BIPV embedded with Adrinkra symbols in Ghana. Typically, early innovators such as architects, engineers and sustainability advocates are more likely to welcome the idea of adopting traditional Adinkra symbols embedded in BIPV design first. The highlight of Ghanaian culture on BIPV design can promote its appeal and relevance, reducing resistance to adoption. Early adopters, such as the government, cultural leaders, and eco-conscious businesses, may promote the adoption of this product by emphasizing its aesthetic appeal and environmental benefits. Their endorsement builds social proof, encouraging broader acceptance. As the early majority realises the practical benefits of BIPV in improving energy efficiency and reducing costs, combined with the cultural resonance of Adinkra symbols, they are more likely to adopt the technology, recognising its value to both the economy and national identity. The late majority and laggards, who are typically more resistant to change, are likely to adopt BIPV as it becomes normalized, seeing it as both a sustainable solution and a reflection of Ghanaian tradition.

In summary, sustainable practices and renewable energy adoption may be encouraged while maintaining cultural heritage by adding traditional Adinkra symbols into BIPV systems. This combination not only demonstrates the community's dedication to environmental awareness but also shows how tradition and innovation may coexist. The presence of traditional symbols on BIPV systems can pique interest and intrigue observers in many cultures around the world, encouraging them to learn more about the community's rich cultural heritage. It acts as a reminder that customs are not set in stone but can change and adapt to the needs of the modern world, inspiring pride, and a sense of connection to one's ancestry. In general, the incorporation of conventional symbols on BIPV systems ensures their preservation and gives them a new life, allowing posterity to appreciate and value the significance of these symbols in the contemporary world.

5.3 Using Screen-printing to Transfer Ghanaian Adinkra Symbols on Solar Cells and Their Characterisation

This section of the study aimed to explore screen-printing techniques to develop traditional adinkra symbols on solar cells. As expressed theoretically, it is possible to print customised shapes and patterns on solar cells. The focus here was to i. Explore the possibility of printing adinkra symbols on solar cells using screen-printing techniques, ii. Characterisation of the printed solar cells to establish printing efficiency and cell performance. Although the idea of using different methods for solar cell printing is not new (Gupta et al., 2016; Välimäki et al., 2017; Verma et al., 2020) , this is one of the fundamental studies to explore the printing of traditional symbols on solar cells. Some of our previous studies highlighted the prospects of incorporating traditional symbols on solar cells (Awuku et al., 2021; Awuku et al., 2022). This study crowns them by producing selected traditional symbols on solar cells and further investigating their characterisation.

Printing traditional Adinkra symbols on solar cells could have a lot of significant benefits. Table 39 shows a summary of three key benefits of blending traditional symbols on solar cells. The academic and industrial community has embraced the novelty of this new venture within the BIPV space at various conferences attended by the researcher. The experiment proves that it is highly possible to print customised patterns such as Adinkra symbols on solar cells.

Table 39. Benefits of Printing Traditional Symbols on Solar Cells (Authors Construct, curled from (Attoye, et al., 2017; Awuku et al., 2021; Awuku et al., 2022; Custom Solar Panels, 2023)

Benefit 1	Printing traditional symbols on solar cells for cultural purposes can serve as a powerful way to blend technology with heritage. Incorporating traditional symbols onto solar cells can bridge the gap between the past and the future and pay homage to cultural roots while embracing modern advancement.
Benefit 2	Symbols hold deep meanings within different cultures, representing their values, beliefs, and stories. Integrating these symbols onto solar panels creates a visual representation of cultural heritage that can be seen by many. This not only helps in preserving traditions but also educates others about our rich history.
Benefit 3	Incorporating traditional symbols on solar cells can foster a sense of pride and connection within communities. When people see their cultural symbols displayed prominently on renewable energy sources like solar panels, it instils a sense of ownership and belonging.

It is imperative to consider fundamental limitations to optimise top contact design and print for BIPV. Three key areas have been identified in this experiment which need improvement:

A. Optimisation of top contact design: The first step would involve redesigning the top contact pattern to minimize shading loss. This could include reducing the width or thickness of the top contact lines, altering their arrangement, or exploring alternative materials. By carefully optimizing the design, it may be possible to reduce shading and improve overall efficiency. For instance, a study by Gupta et al. (2016) explored the optimisation of free-form solar cells. The topology optimisation (TO) approach was adopted, and the results indicated a strong possibility of optimising solar cells even with free-form designs (Gupka et al., 2016).

B. Explore other conductive printing inks: Printing ink is pivotal in cell conductivity, therefore a highly conductive ink with high bonding properties must be used. The viscosity of ink also affects flow behaviour. If the ink viscosity is too high, it may result in poor ink spreading and incomplete coverage of the cell surface. On the flip side, the low viscosity of ink will also result in excessive spreading and merging of adjacent printed lines, which may lead to short circuits between contacts. A study conducted by Pourjafari et al. (2023) highlights the significance of ink formulation and its impact on solar cell efficiency (Pourjafari et al, 2023).

C. Refine printing parameters: It is essential to consider parameters such as printing speed and pressure and the uniform deposition of top contact materials. A study conducted by Ojeda et al. (2020) indicates that refining printing parameters through geometric optimisation tends to boost cell efficiency (Ojeda et al., 2020). Zarabina et al., (2022) also explored refined printing parameters for perovskite solar cells and realised an improvement by 82% (Zarabina et al., 2022).

It is imperative to note that, a preliminary laboratory study does not in itself conclusively represent a promising technology. To be convincing, critical limitations such as production methods, cost and efficiency need to be addressed.

5.4 Identify and Propose Favourable Policies to Promote BIPV Adoption and Aesthetics

Identifying and implementing favourable policies is crucial for BIPVs to thrive, especially in developing countries such as Ghana. A core objective of this thesis is to identify unique policies to promote the adoption of BIPVs. It is likely to assume that policies that apply to regular PV applications (BAPV) could apply to BIPVs. However, the unique and niche nature of BIPV requires more pragmatic and definite targeted policies to enhance its market shares. Key policy themes identified in this research are A. Enabling environment B. Aesthetics, C. Incentives and Subsidies D. Traditional symbols and BIPV adoption E. Availability of Technicians/Experts F. BIPV for retrofitting G. Advertising. Figure 66 shows a thematic illustration of key policy directions identified in this research. These policy directions were developed from both literature and empirical data.

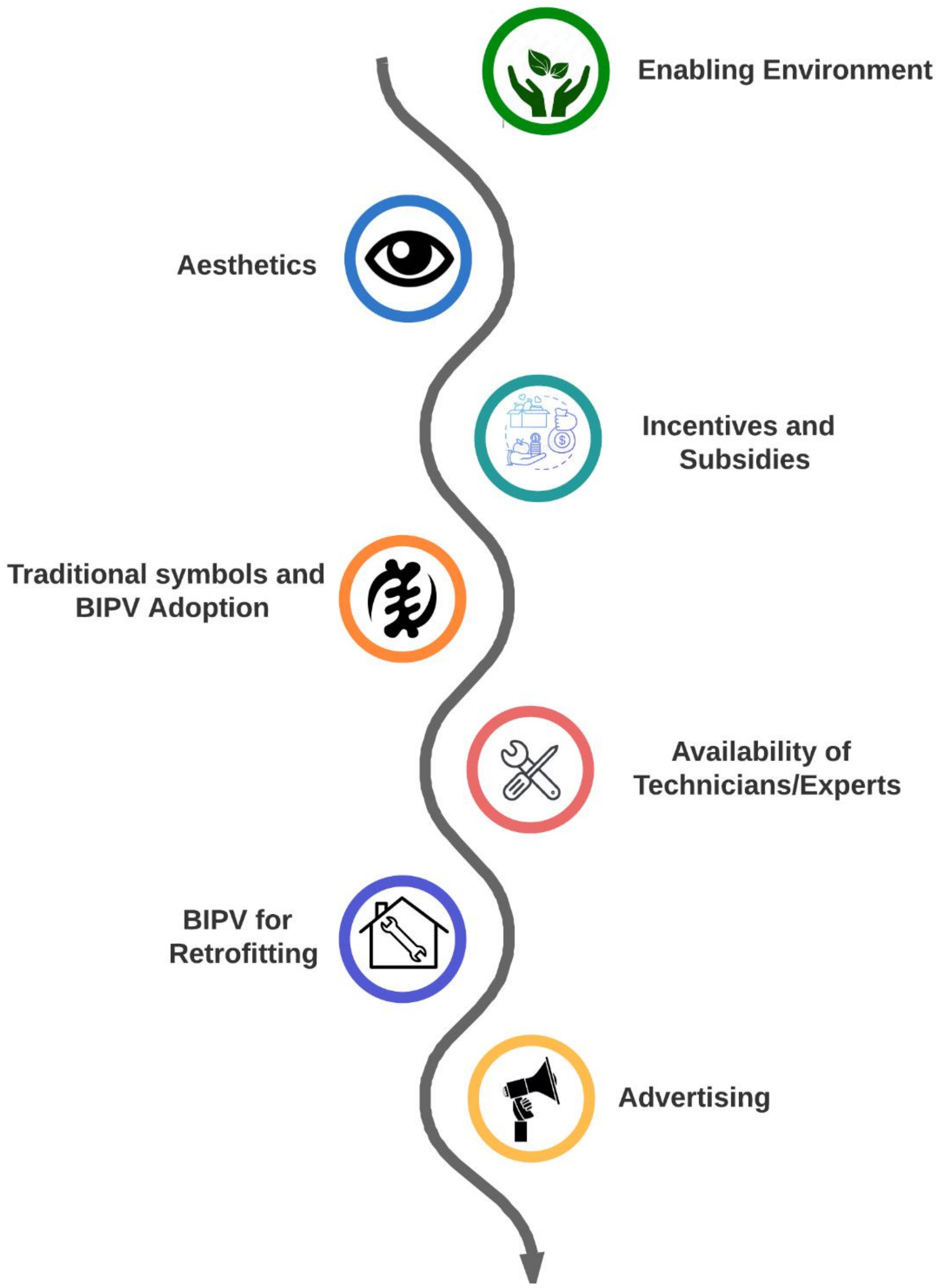

Figure 66. Policy Tree for BIPV Adoption (Authors Construct)

A. Creating an Enabling Environment

An enabling environment for BIPV adoption in Ghana requires a comprehensive approach with overarching solutions across various aspects such as political climate, policy, financing, capacity building, advertising and all the core pillars essential for the technology to thrive. Fostering and maintaining a functional enabling environment calls for an unambiguous regulatory framework with actors from both private and public sectors. It is imperative to ensure that the institution in charge is autonomous, has vested authority to deliver its mandates and is accountable. The employed framework must be explicit when it comes to fundamental issues such as performance standards, technical maintenance, building specifications, feed-in-tariffs, environmental impact assessments, offtake arrangements and pricing. Ensuring an enabling environment can tend to boost investor confidence while ensuring the widespread adoption of BIPV. This recommendation is in line with the conclusions of studies by Curtius (2018); Boesigner and Bacher (2018) and Kosorić et al. (2021) which highlights the significance of creating an enabling environment for the facilitation of BIPV (Boesigner and Bacher, 2018; Curtius, 2018; Kosorić et al., 2021).

B. Aesthetic considerations

Aesthetics is a core aspect of BIPV, hence remains crucial for its full uptake into architectural designs. As far as BIPV is concerned, it is essential that stakeholders uphold the elements and principles of design such as colour, shape, variety, texture balance, rhythm, and contrast to ensure the overall value of BIPV is attained as cited earlier in the literature. For instance, in the qualitative data provided in Table 19, some respondents indicated a high enthusiasm about the variety of colours BIPV offers. Beyond their interest in colours, some respondents also highlighted the overall aesthetic impact on the environment. Expanding the aesthetic net of BIPV means offering architects and designers endless possibilities to create visually stunning sustainable buildings with a positive impact on the environment. BIPV Stakeholders, government and other regulatory agencies must establish collaboration with urban planners, architects, artists, and other industry experts to project a statutory design guideline for acceptable BIPV installation. The focus should be on ensuring BIPVs are integrated into building designs seamlessly without distorting environmental aesthetics. A qualitative study conducted by Curtius (2018) on the facilitator and barriers to the adoption of BIPV indicates that aesthetics is the main driver behind its adoption. About 80% of the interviewed stakeholders across the BIPV supply chain indicated that the nicety of BIPV is fundamental to its adoption (Curtius, 2018).

C. Incentives and subsidies

The overall cost of solar energy systems has been an inhibitive factor for its widespread adoption. Incentives and subsidies by the government can go a long way to eliminate or reduce the cost burden on consumers, thereby making BIPVs financially attractive for individuals, businesses, and organizations. These incentives could come in the form of tax credits, feed-in-tariffs (FITs), grants, and subsidies. The empirical data provided in this study can serve as a guide to further understanding the affordability and consumers' willingness to adopt. Dijkgraaf et al. (2018) investigated the effectiveness of FITs on solar adoption and concluded that a well-designed FIT structure with consistency and continuity can positively influence the adoption of solar energy (Dijkgraaf et al., 2018). Also, a study by Sukki et al. (2014) on FITS in Malaysia indicated that solar PV adoption increased significantly after a year of introducing FITS (Sukki, 2014).

D. Introduction of Traditional Symbols in BIPV Design

Inculcating traditional symbolism in BIPV applications tends to bridge the gap between modern sustainable technology and cultural heritage. Traditional symbols have deep proverbial meanings with great significance for communities, as they represent their history, values, and identity. For instance, in the qualitative data retrieved, some respondents indicated their affinity towards adinkra symbols merely because of tradition and patriotism and believed it would boost BIPV adoption, especially in households. On the other hand, some respondents also indicated that Adinkra symbols were only appropriate in palaces and other traditional buildings and not for homes. Overall, integrating these symbols can tend to foster a sense of ownership, pride, and acceptance among the local consumers. This modification may also offer an alternative solution to the disruption of traditional architecture caused by modern building technologies.

E. Training of technicians/ experts

Having trained technicians available is critical for BIPV adoption. To boost the confidence of potential adopters, it is imperative to ensure that technical support is readily available in case they face challenges. Experts in areas such as BIPV installation, maintenance, and troubleshooting are important to ensure the holistic functionality and longevity of the installations. A study by Lucas et al. (2018) indicates that the lack of qualified human resources is one of the biggest limitations to the adoption of solar PV especially in developing countries (Lucas, 2018).

F. BIPV for retrofitting

The ability to integrate BIPV into existing structures is essential as it transforms passive structures into active energy generators. The conventional retrofitting approach is to add solar panels as an afterthought, which mostly appears unappealing. However, BIPV tends to offer the opportunity to replace conventional building components, which can improve the general aesthetics of the building. BIPV therefore offers a truly unique opportunity for retrofitters, architects, and other stakeholders to give a facelift to otherwise old buildings. Farghaly and Hassan (2019) quantitatively explored types of BIPVs for retrofitting purposes. It was concluded that BIPV has great retrofitting prospects in Egypt, especially the BISOL Premium BXO 365 Wp monocrystalline, which proved to be more efficient (Farghaly and Hassan 2019).

G. Investment in Advertising and Awareness Creation

The focus has often been on investing massively in various renewable energy products without the necessary sensitization. The study is evidence that media (print, web, and digital) 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. A study conducted by Boesiger and Bacher (2018) indicated that lack of knowledge was a major limitation to the adoption of BIPV even in advanced countries like Switzerland (Boesiger and Bacher, 2018). Awareness creation is therefore a necessary mechanism for the boost in BIPV uptake.

H. Demo Projects

An existing demo 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.

I. Increase BIPV investment in Africa

Considering the rate of industrialization and economic growth, stakeholders must 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 will not only help meet the energy needs of communities but also reduce reliance on fossil fuels and contribute to mitigating climate change.

5.5 Main Findings

This thesis identified four significant outcomes that highlight the culmination of the investigation conducted based on the quantitative analysis and experimental design. The outcomes are in line with the overarching objectives set in this research, which are: A). Effectiveness of Architectural Visualisation and Advertising on BIPV Awareness in Ghana, B). The Nexus Between Adinkra Symbols and BIPV Adoption in Ghana, C). The use of a screen-printing approach to transfer traditional Ghanaian Adinkra symbols on solar cells and their characterisation and D). Identifying and Proposing Favourable Policies to Promote BIPV Adoption.

A. Effectiveness of Architectural Visualisation (AV) and Advertising on BIPV Awareness in Ghana:

The research indicated that a very small fraction of the respondents had prior knowledge and understanding of BIPV technology and its importance. It was revealed that AV and Advertising greatly impact the awareness of BIPV in Ghana. Further analysis also showed that education has a bearing on the awareness rate of the respondents. In other words, the more educated an individual is, the more likely they are to know or adopt BIPVs. It was also revealed that public awareness through advertising mediums (print/media) is essential for the successful diffusion of BIPV in Ghana. This is a key policy driver for the overall increase in BIPV adoption globally.

B. The Nexus Between Adinkra Symbols and BIPV Adoption in Ghana:

The outcome of the quantitative analysis revealed that Adinkra symbols are likely to boost the adoption of BIPV in Ghana. Ghanaians proved to be a cultural people, hence demonstrated a strong affinity towards traditional Adinkra symbols, and were willing to adopt them for their buildings. This combination indicated that tradition and innovation may coexist. This finding is particularly strategic for policy developers and planners to accelerate the uptake of BIPV especially in culturally conscious regions.

C. Use the Screen-printing Approach to transfer Traditional Ghanaian Adinkra Symbols onto Solar Cells and their Characterisation:

Screen-printing approach was adopted to test the feasibility of printing Adinkra symbols on solar cells. The outcome reveals that screen-printing is viable for transferring custom top contact designs onto solar cells. However, the characterisation revealed a reduction in cell efficiency. This could be attributed to cell handling defects, inappropriate curing temperature or issues with the conductive silver paste adopted for the experiments. In essence, it points out a viable direction for further studies.

D. Identify and Propose Favourable Policies to Promote BIPV Adoption and Aesthetics:

The reviewed literature and empirical evidence provided in this thesis have led to applicable policies to promote the adoption of BIPV in Ghana and other developing countries. Key policies identified are enabling environment, aesthetics, demo projects, advertising/awareness creation, trained personnel, providing incentives and subsidies, providing demo projects, and increasing BIPV investment in Ghana and Africa at large.

5.6 Research Limitations

The conclusions of the thesis were the outcome of a comprehensive research design with some restrictions on scope, data collection, and research methodology and experiment used to address the set goals. The choice to accept any new product may, in terms of the overall scope of this study, simply be based on a customer's personal preference or taste, as opposed to any external factor. Stakeholder opinions about this research may be subjective or ephemeral.

In general, acquiring an understanding of viewpoints and opinions was the main goal of the quantitative data collection. Therefore, unlike with qualitative data, the results are more specific and tailored. Just like many quantitative studies, this study overlooks subjective aspects such as emotions, motivations, and personal perspectives that cannot be easily quantified. This is partly because BIPV is a new concept in Ghana, hence most of the respondents had very limited knowledge, and therefore could not make detailed contributions apart from the directed responses.

Additionally, using a quantitative research approach tends to prioritise generalizability and statistical significance over detailed comprehension. The focus on gathering a large sample size and creating detailed statistical patterns tends to take attention off the nuance and unique characterisation of various responses and contexts. This can mostly lead to generalisation or oversimplification of outcomes which may not accurately represent the diversity of the respondents.

The study setting was Ghana, where the local language was Akan and other tribal languages. Although most of the respondents could speak English, there were a few isolated cases where respondents were unwilling to take part because they could not fully understand English. An attempt was made to explain the questionnaire, however only a few (9 respondents) were willing to take part. This tailored the distribution of the questionnaire towards educated respondents who could easily read and understand English.

Also, BIPV is a niche area, and this study is among one of the first few to be conducted in Ghana and Africa. Hence it was difficult to find a substantial number of existing literature and reference materials. The researcher therefore had to broaden the scope and search terms to gather relevant information applicable and transferrable within the context.

Finally, several factors affected the validity, reliability and generalizability of the outcome obtained from the experiment. The characterisation of printed solar cells revealed an uneven distribution of ink, thicker printed patterns, splotches of ink, and curing temperature issues which resulted in the underperformance of the customised solar cell. Hence, this experiment can only serve as a preliminary study and a solid base for future studies.

5.7 Recommendations for Future Studies

Future studies may focus on exploring other printing techniques such as nano printing and address the challenges encountered by the screen-printing approach to make them cheaper and affordable on a commercial scale. These include line width, innovative curing approaches, and enhanced ink bonding mechanisms. It is necessary to overcome these challenges to improve efficiency and performance in custom-made top-contact solar cells. This research shows that the customised top contact has a huge potential to develop in future. Custom top contact design when explored to its most efficient state can serve as a strong link between advertising and energy performance especially in commercial buildings. This innovative approach combines the power of renewable energy with the effectiveness of targeted marketing, opening new opportunities in the business world for brand promotion while contributing to a sustainable future. By combining renewable energy technology with innovative design concepts, this approach can lead to visually captivating and environmentally conscious advertising solutions.

Also, future studies can consider more detailed research methods such as the qualitative approach to establish the viability of BIPV in developing countries. The qualitative approach may offer a deeper appreciation, emotions, and insight into the complexities of BIPV adoption and surrounding issues.

Another interesting area for future studies will be to conduct further investigation into the environmental impact of BIPV. The focus could be the Life Cycle Assessment (LCA) for BIPV systems, Material Selection, and Integration into the

Circular Economy Frameworks to help deepen understanding and inform sustainable decision-making.

Finally, future studies can consider further exploring aesthetic enhancement techniques in BIPV manufacturing. The more appealing and versatile BIPV becomes, the better its chances of competing with existing building materials on the market. The Aesthetic impact of BIPV on the environment may also be qualitatively explored to help build a holistic understanding of its importance.

5.8 Impact and Novelty

This study contributes immensely to the body of literature related to product adoption, awareness of BIPV, traditionalism and sustainable buildings, and innovation. Additionally, it succinctly encourages the adoption of GBT in Ghana and other countries. This work is unique as it highlights novel approaches to the diffusion of BIPV. Its outcome improves on existing measures to boost BIPV adoption globally by developing more robust and tailored marketing approaches. Several significant impacts can be drawn from this research, some of which are described in subsequent paragraphs.

A. Confirmation of Innovation Theories

Roger's diffusion of innovation (DOI) theory highlights awareness as an integral aspect of the adoption process. Specifically, regarding factors that could potentially affect the diffusion of BIPV, the findings in this study emphasise the fact that awareness has a great bearing on the adoption. A key characteristic of the DOI theory is the comparative advantage a product offers above others. The findings of this thesis also further confirm that respondents were keen on adopting BIPV over BAPV because of the relative advantages it presented. In addition, this thesis offers a clear image of the complex relationship between significant facts which influence the diffusion of an innovation. It provides a solid canvas for defining and implementing practical and realistic approaches to the uptake of BIPV.

B. Offers a unique blend of Art and Innovation Technology

A truly unique aspect of this thesis is the blend of Art and Innovation technology. This study is identified as the first to blend traditional symbols in BIPVs for cultural and advertising purposes. A unique approach to capturing the attention of people through advertising is to create memorable experiences. By adopting culturally significant symbols, we buy into how people connect emotionally with their heritage while fostering a stronger bond between consumers and brands. A classical revelation in this study is the simulation of BIPV buildings adorned in intricate patterns inspired by indigenous traditional Adinkra symbols. These buildings do not just promote sustainability but truly serve as the epitome of culture and tradition.

C. Introduces a Pathway for BIPV Adoption

This thesis offers a research-based pathway to promote BIPV adoption in Ghana. The identified policies recommended provide a truly practical approach to the widespread of BIPV in Ghana. To facilitate BIPV adoption, it is imperative to establish supportive policies and regulations that incentivize the holistic integration of BIPV systems.

D. Contribution to existing Literature on BIPV

The elaborate literature on BIPV shown in this thesis is of immense significance to the academic community. It presents novel findings on pertinent topics such as the aesthetics of BIPV, the characterisation of printed solar cells, advertising opportunities for BIPV, and a robust approach to BIPV adoption in developing countries. These findings serve as a premise for future studies especially on maximising cell efficiency after custom printing as well as the impact of BIPV adoption on environmental aesthetics. Also, several publications have been made in both journal and conference proceedings as seen in the LIST OF PUBLICATIONS.

5.8.1 Significance and Impact on Stakeholders

The findings of this study have significant implications for various stakeholders, including architects, policymakers, engineers, culturally sensitive communities, and investors. It underscores the role of advertising through web, digital, and digital platforms in raising public sensitisation about BIPV in Ghana. High awareness rate is crucial for creating the bedrock upon which stakeholders can implement crucial policies to promote the adoption of BIPV. In terms of Policymaking, this research underscores the need for demo projects, financial incentives, and training programs to support BIPV deployment. For Designers and Architects, the findings of the study are a clear indication that incorporating traditional symbols into BIPV design enhances public acceptance as well as promotes cultural preservation. This approach ensures a smooth transition into a sustainable built environment while upholding local culture, traditions, and values. This research highlights the potential BIPV market growth driven by increased awareness, offering an investment opportunity. Moreover, the findings contribute to the global discourse on integrating culture into GBTs, offering a replicable model for other countries looking to balance modernisation with cultural heritage preservation. Ultimately, this research provides a foundation for future studies on aesthetics, advertising, social acceptance, and policy in the context of sustainable energy solutions.

5.9 Chapter Summary

This chapter has discussed the outcome of the survey, the experimental design, and some policy implications. BIPV uptake is likely to increase when public awareness is prioritised. This will intend set the right premise for stakeholders to intervene with critical policies to increase its uptake. The chapter also shows that traditional Adinkra symbols have a great bearing on BIPV adoption. Incorporating traditional symbols in BIPV design ensures the preservation of culture, tradition and ethos of a society while transitioning into a green built environment. Regardless of the limitations highlighted in this research, substantive contributions have been made to the body of knowledge in understanding the prospects of BIPV application in Ghana. This novelty indicates that Advertising has a great impact on BIPV awareness and inculcating traditional visual symbols has the potential to boost BIPV adoption. Also, the preliminary printing experiment indicates the possibility of custom solar cells for cultural and advertising purposes. This research sets the premise for studies in aesthetics, advertising, marketing, social acceptance, and the often-overlooked mechanisms for boosting GBTs such as BIPVs. The findings of this research have the tendency to boost BIPV adoption not just in Ghana, but across various countries, especially in areas with the hope of preserving culture in the built environment while adopting GBTs.

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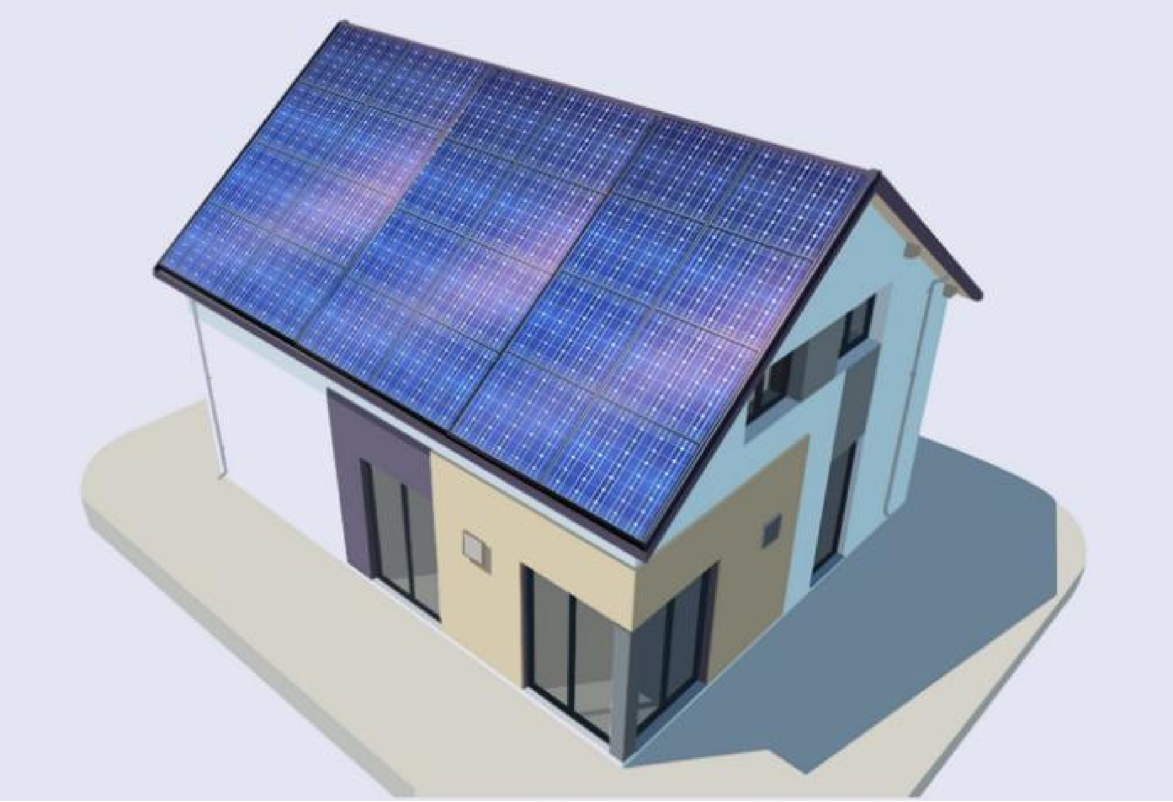
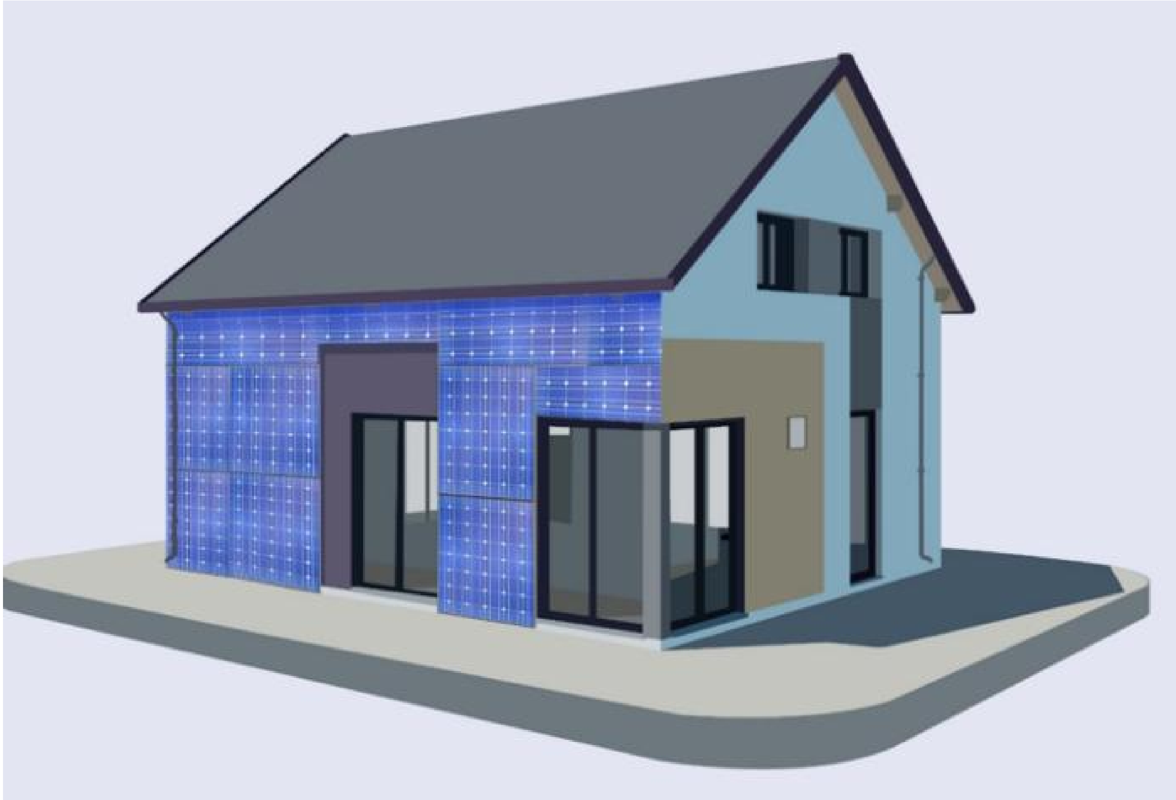
Appendix 1: Traditional Ghanaian Adinkra Symbols

Appendix 2: Research Questionnaire

Building Integrated Photovoltaics (BIPV) in Ghana

Building Integrated Photovoltaics (BIPV for short) refers to the use of solar panels to replace building materials such as roof, window, and walls such that they form part of the building. Examples are seen in the images below:





Demographics

1. What is your age Range?

- 20-29 years
- 30-39 years
- 40-49 years
- 50-59 years
- 60-69 years
- 70 years and above

2. What is your gender?

- Male
- Female
- Other
- Prefer not to say

If you selected Other, please specify:

3. What is your occupation?

- Agriculture
- Industry
- Services
- Private Sector
- Prefer not to say
- Other

If you selected Other, please specify:

4. Where do you live?

- Western North Region
- Western Region
- Volta Region
- Greater Accra Region
- Eastern Region
- Ashanti Region
- Central Region
- Northern Region

- Upper East Region
- Upper West Region
- Oti Region
- Bono East Region
- Ahafo Region
- Bono Region
- Northeast Region
- Savannah Region

5. What is your Income Range?

- Less than GH¢ 10,000 per annum
- GH¢ 10,000 - 20,000 per annum
- GH¢ 20,000 - 30,000 per annum
- GH¢ 30,000 - 40,000 per annum
- GH¢ 40,000 - 50,000 per annum
- GH¢ 60,000 - 80,000 per annum
- GH¢ 80,000 - 120,000 per annum
- GH¢ 120,000 and above per annum
- Prefer not to say

6. What is your family size?

- 1
- 2-4
- 5-8
- 9-12
- Above 12

7. What is your level of education?

- Basic School
- Senior High School
- Bachelor's Degree
- Masters Degree
- PhD.
- Prefer not to say

Interviewee Status and Awareness of Solar Energy

8. Are you a homeowner?

- Yes
- No

9. Do you have an alternative source of electricity?

- Yes
- No

If yes, what other energy source do you have?

- Solar Energy
- Diesel Generator
- Other

If you selected Other, please specify.

If No

- Because I don't know any alternative source of electricity
- Because I cannot afford it
- Because I am not interested
- Other

If you selected Other, please specify:

10. Do you know about solar energy?

If yes,

- I know about solar because I work in the energy/solar sector
- I heard about it in the media (news, radio, outdoor adverts etc.)
- Other

11. Are you likely to adopt solar energy for your home should you have the money for it?

- Yes
- No

If yes,

- Because it is a reliable source of energy
- Because it saves money
- Because it is environmentally friendly

- Other

If you selected Other, please specify:

If No,

- Because it is not beautiful
- Because it is not reliable
- Because there are not enough technicians in case of breakdown
- Other

12. Are you likely to adopt solar energy for your home should there be a flexible loan facility that allows you to pay GH¢150 monthly over a period of 6 years and enjoy free electricity of up to 25years? (Depending on your home size and energy consumption)

- Yes
- No

If yes,

- Because solar PVs are beautiful
- Because I can offset my electricity bills
- Because I can have uninterrupted electricity supply
- Other

If No,

- Because solar PVs are not beautiful
- Because solar PVs are too expensive
- Because solar PVs are not reliable
- Other

13. Are you likely to adopt solar panels for your home should there be a government policy that reduces their overall cost?

- Yes
- No

Public Awareness of Building Integrated Photovoltaics (BIPV)

14. Have you heard of Building Integrated Photovoltaics (BIPV)?

- Yes
- No

15. 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)

A

B

If A,

- Because it looks beautiful and well-organised
- Because it replaces the entire roof so no need to buy roofing sheet

- Other

If you selected Other, please specify:

If B,

- Because I like the way it is scattered
- It does not matter, once it generates electricity, that's all that matters
- Other

If you selected Other, please specify:

The Value of Aesthetics (Beauty)

16. Do you think Aesthetics (beauty) matter when it comes to solar application for your home?

- Yes
- No

If Yes

- Because I am very particular about the materials I choose for my home
- Because I like specific colours and shapes for my home
- Other

If you selected Other, please specify:

If No

- Because I don't care about the outlook of my home
- Because colours and shapes don't matter to me
- Other

If you selected Other, please specify:

17. 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?

- Yes
- No

18. Are you likely to adopt Building Integrated Photovoltaics (BIPV) because of Aesthetics (Beauty)?

- Yes
- No

If Yes

- I prefer bright colours for my building
- I prefer dark colours for my building
- I prefer BIPV to be in shapes such as triangle, circles, and squares
- Other

If you selected Other, please specify:

Interest of interviewee in adopting Building Integrated Photovoltaics (BIPV) for their old buildings (retrofitting)

19. Are you likely to adopt Building Integrated Photovoltaics (BIPV) should you decide to renovate your old house?

- Yes
- No

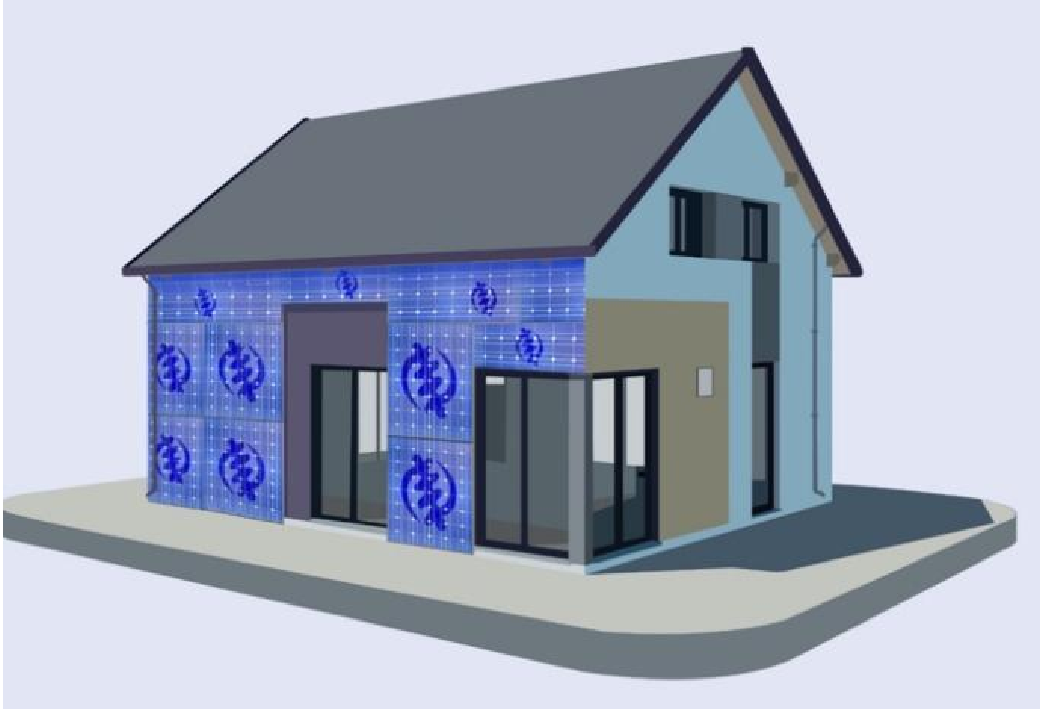
If yes,

- Because it can give my old building a modern look
- Because it will reduce the cost of electricity
- Because I will enjoy reduction in the cost of building materials
- Other

If No,

- Because I prefer to use a diesel/petrol generator
- Because I think BIPV is not durable enough to replace building materials such as roof and windows
- Because it will be relatively expensive, therefore I cannot afford it
- Other

20. Do you think adding symbols such as Adinkra to solar design can influence your decision to adopt Building Integrated Photovoltaics (BIPV) as seen in the figures?



- Yes
- No

If yes,

- Because they represent our tradition, culture and heritage
- Because they are a form of decoration
- Because of their meaning

- Other

If No,

- Because traditional symbols must not be used on modern buildings
- Because they are not nice
- Because they will distort the design of the building
- Other

If you selected Other, please specify.

Policy Perspective

21. Do you believe that an enabling environment by the government will help promote BIPV as an alternative source of energy?

- Yes
- No

22. Would you agree that subsidies and grants from the government could promote BIPV adoption in Ghana?

- Yes
- No

23. Would you agree that advertising has advertising has a major role to play in BIPV adoption in Ghana?

- Yes
- No

24. Do you believe that having more technicians and after sale services and experts could influence your decision to adopt BIPV?

- Yes
- No

Any further comment?

Thank you for taking part of this survey. If you are happy to talk to the researchers, make any input or discuss further, kindly get in touch via email; s.awuku@rgu.ac.uk/nanaawuku021@gmail.com.

Appendix 3: Outcome of Validity Test

Items	Q1.	Q2.	Q3.	Q4.	Q5.	Q6.	Q7.	Q8.	Q9.	Q10.	Q11.	Q12.	Q13.	Q14.	Q15.	Q16.	Q17.	Q18.	Q19.	Q20.	Q21.	Q22.	Q23.	Q24.	Total
Q1 PeasonCorr																									
Sig.(2tailed	1																								
N																									
	412																								
Q2.PeasonCorr																									
Sig.(2tailed	.798**	1																							
N	.000																								
	412	412																							
Q3.																									
PeasonCorr	.948**	.795**	1																						
Sig.(2tailed	.000	.000																							
N	412	412	412																						
Q4.																									
PeasonCorr	.960**	.c861**	.930**	1																					
Sig.(2tailed	.000	.000	.000																						
N	412	412	412	412																					
Q5																									
PeasonCorr	.971**	.814**	.959**	.977**	1																				
Sig.(2tailed	.000	.000	.000	/000																					
N.	412	412	412	412	412																				
Q6.																									
PeasonCorr	.921**	.775**	.904**	.880**	.900**	1																			
Sig.(2tailed	.000	.000	.000	.000	.000																				
N	412	412	412	412	412	412																			
Q7																									
PeasonCorr	.918**	.803**	.939**	.911**	.930**	.908**	1																		
Sig.(2tailed	.000	.000	.000	.000	.000	.000																			
N.	412	412	412	412	412	412	412																		
Q8																									
PeasonCorr	.810**	.872**	.807**	.894**	.837**	.733**	.812**	1																	
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000																		
N.	412	412	412	412	412	412	412	412																	
Q9.																									
PeasonCorr	.808**	.668**	.778**	.785**	.803**	.620**	.686**	.671**	1																
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000																	
N	412	412	412	412	412	412	412	412	412																
Q10.																									
PeasonCorr	.354**	.458**	.368**	.309**	.307**	.490**	.367**	.213**	.143**	1															
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000																
N	412	412	412	412	412	412	412	412	412	412															
Q11																									
PeasonCorr	.495**	.446**	.514**	.430**	.430**	.600	.471**	.298**	.200**	.715**	1														
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000															
N.	412	412	412	412	412	412	412	412	412	412	412														
Q12																									
PeasonCorr	.683**	.530**	.641**	.667**	.639**	.649**	.629**	.505**	.339**	.422**	.590**	1													
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000														
N.	412	412	412	412	412	412	412	412	412	412	412	412													
Q13.																									
PeasonCorr	.415**	.446**	.431**	.363**	.361**	.535**	.411**	.250**	.168**	.852**	.839**	.495**	1												
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000													
N	412	412	412	412	412	412	412	412	412	412	412	412	412												
Q14																									
PeasonCorr	.760**	.622**	.667**	.788**	.742**	.717**	.668**	.652**	.437**	.327**	.458**	.776**	.384**	1											
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000												
N.	412	412	412	412	412	412	412	412	412	412	412	412	412	412											
Q15.																									
PeasonCorr	.648**	.510**	.641**	.629**	.602**	.636**	.626**	.468**	.314**	.456**	.638**	.925**	.535**	.718**	1										

Sig.(2tailed	.000	.000	/000	.000	.000	.000	.000	.000	.000	.000	.000	.000	,000	.000											
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412										
Q16.																									
PeasonCorr	/559**	.461**	.573**	.502**	.504**	.623**	.553**	.361**	.242**	.591**	.827**	.714**	.694**	.554**	.772**	1									
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000										
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412									
Q17.	.	.																							
PeasonCorr	531**	450**	.544**	.455**	.462**	.631**	.500**	.320**	.215**	.666**	.932**	.634**	.782**	.491**	.885**	.887**	1								
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1								
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412								
Q18.																									
PeasonCorr	.638**	.504**	.642**	.616**	.592**	.633**	.626**	.456**	.306**	.467**	.654**	.903**	.548**	.701**	.976**	.790**	.702**	1							
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000								
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412							
Q19.																									
PeasonCorr	.574**	.468**	.588**	.524**	.521**	.622**	.579**	.380**	.255**	.561**	.785**	.752**	.659**	.583**	.813**	.950**	.843**	.832**	1						
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000							
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412						
Q20.																									
PeasonCorr	.764**	.632**	.671**	.799**	.750**	.725**	.673**	.666**	.447**	.320**	.448**	.759**	.376**	.978**	.702**	.542**	.481**	.685**	.570**	1					
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000						
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412					
Q21.																									
PeasonCorr	.623**	.495**	.638**	.596**	.575**	.629**	.626**	.440**	.295**	.485**	.679**	.870**	.569**	.675**	.940**	.821**	.729**	.963**	.864**	.660**	1				
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000					
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412				
Q22.																									
PeasonCorr	.535**	.452**	.549**	.463**	.472**	.629**	.509**	.327**	.219**	.652**	.912**	.648**	.765**	.502**	.700**	.907**	.979**	.717**	.861**	.491**	.745**	1			
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000				
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412			
Q23.																									
PeasonCorr	.495**	.446**	.514**	.430**	.430**	.600**	.471**	.298**	.200**	.715**	1.000**	.590**	.839**	.458**	.638**	.827**	.932**	.654**	.785**	.448**	.679**	.912**	1		
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000			
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412		
Q24.																									
PeasonCorr	.593**	.479**	.608**	.553**	.543**	.624**	.612**	.404**	.271**	.527**	.738**	.800**	.619**	.621**	.865**	.892	.792**	.886**	.939**	.607**	.920**	.809**	.783**	1	
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	
Total																									
PeasonCorr	.975**	.853**	.955**	.973**	.970**	.935**	.935**	.836**	.739**	.449**	.577**	.750**	.570**	.804**	.730**	.644**	.605**	.723**	.661**	.808**	.721**	.612**	.577**	.683**	1
Sig.(2tailed	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
N	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412

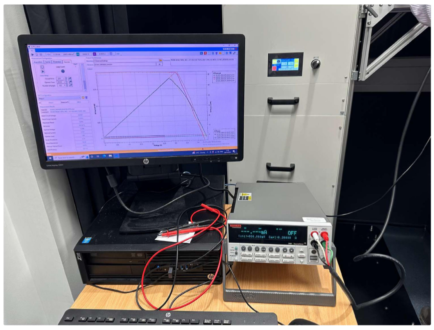
Appendix 4: Further comments

Adoption of building photovoltaics will save Ghana from energy crises in the future.
BIPV is a step in the right direction.
BIPVs if well done would help offset energy and building costs. This two-pronged benefit is useful to offset cost in construction and daily use.
Brilliant questionnaire! Great project!
Cost will play important role in adopting this technology.
Durability and longevity matter if BIPVs are adopted. Other factors such as cost of reinstalling should also be considered.
Good innovation in Ghana
I am used to the normal way of generating energy and I don't think it will ever change. Besides I think BIPV's will be expensive comparatively. Also, I am not sure how good it is health-wise.
I do not know the health implications of solar radiation for buildings so once I know the effects it may influence me to adopt it.
If government will subsidise these materials and they won't be expensive as what we are currently experiencing in the building industry, then most people will patronise, taking into consideration the quality of materials.
If the prices of BIPV materials are affordable, people will be able to patronize it and will reduce over dependency on the national grid which is even not the best.
It is time Ghanaians are more productive and start with something of their own for export. Customised BIPV can be exported to other countries to demonstrate the unique culture of various communities
Other designs can be considered since traditional symbols are outdated

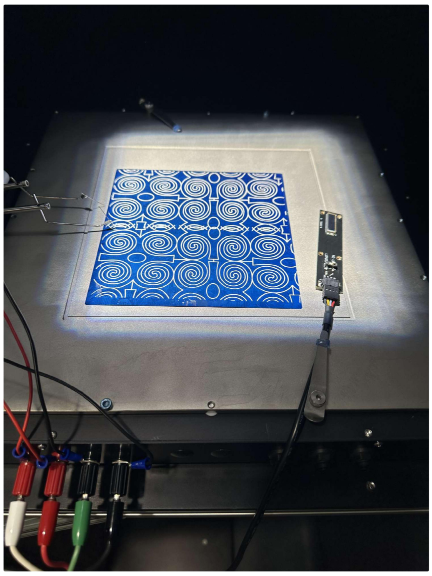
Prices of building materials are currently high, if BIPV prices are reasonable people will patronize for the added advantage.
Solar energy is the best alternative. I will choose this energy source every day because it is cost efficient and environmentally friendly.
Solar is cost effective compared to electricity from the national grid
Solar is the best but expensive for most Ghanaians.
The beauty of a building adds to its value.
The predominant factor in solar adaptation is the cost of the PVs
There’s not a lot of information on how to maintain the BIPV, so it affected my selection at the A or B part. I believe I need much education on how it will affect my painting inside the building and how I can perform maintenance cleaning for sustainability.
This research is very useful in this modern era. Green Building technology is fundamental to achieve Climate change mitigation. BIPV can control potential environmental mess. Very good survey!

Appendix 5: Images from Experiment Lab work at Edinburgh Napier University

Student during
Printing Process

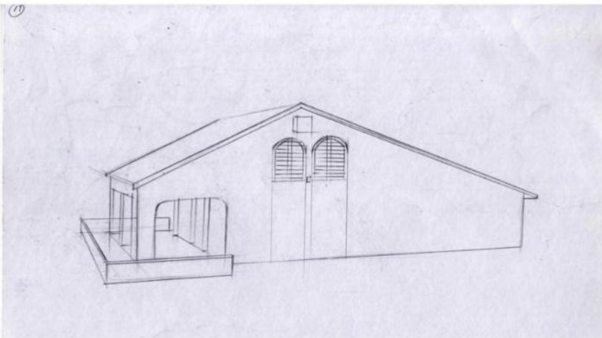


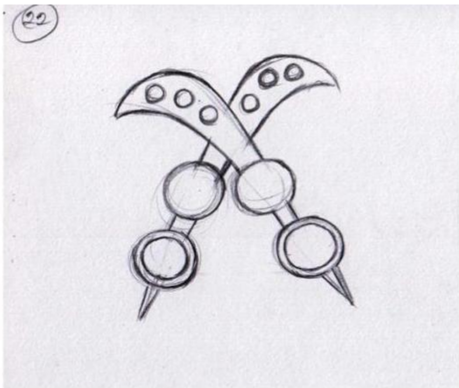
Cell Efficiency Characterisation System

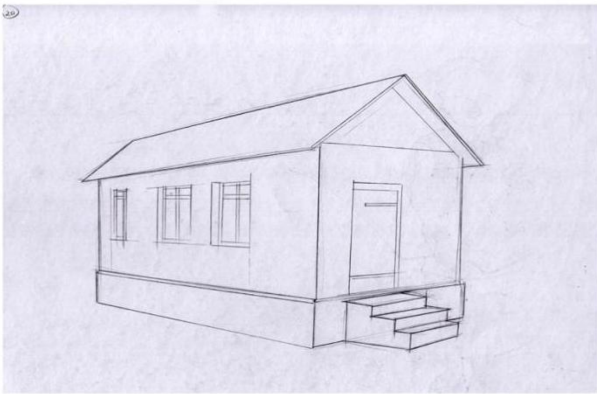


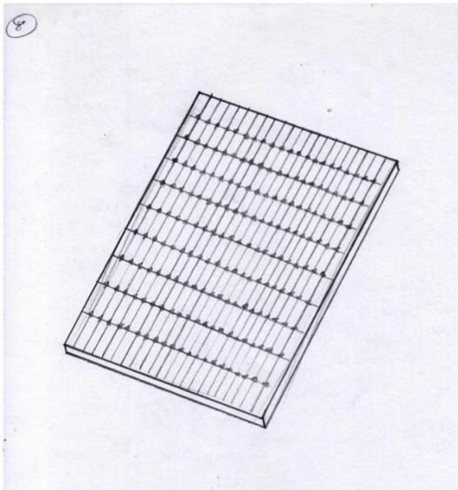
Printed Solar cell on Props ready for
Efficiency test

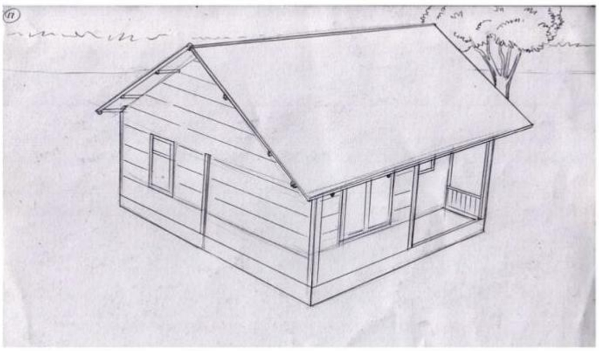
Appendix 6: Thumbnail Sketches/ Design Process for AV

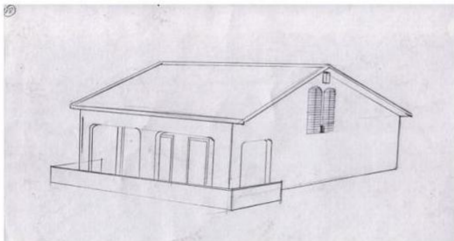


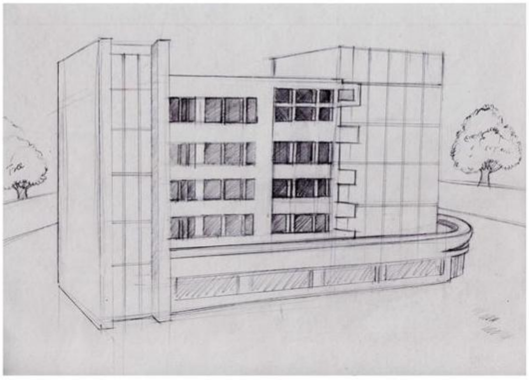


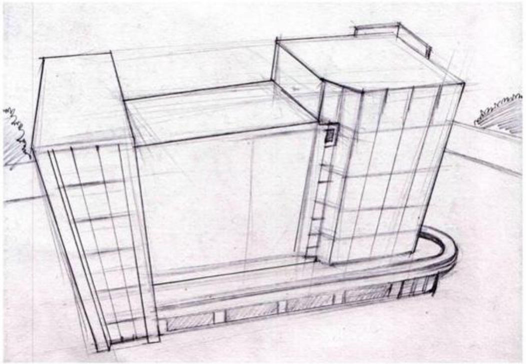
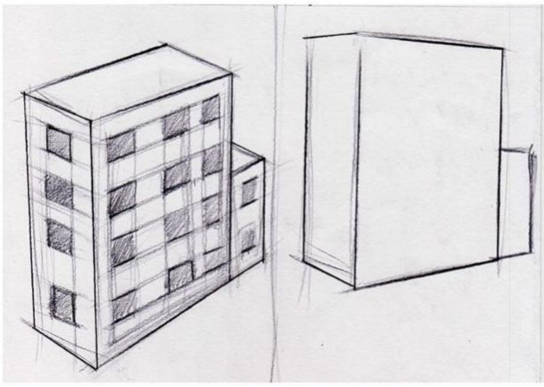
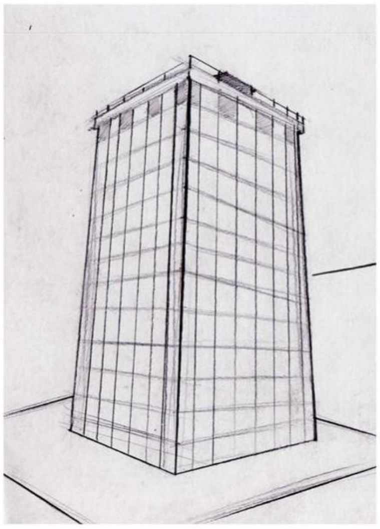
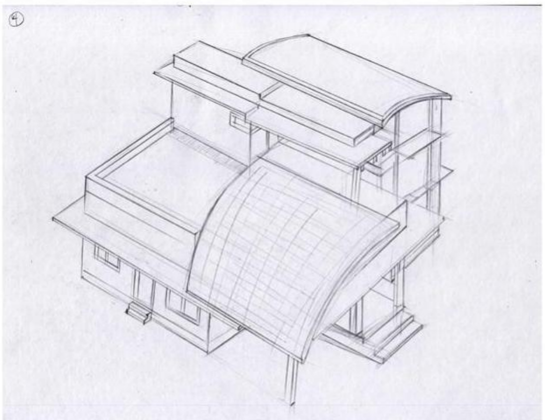
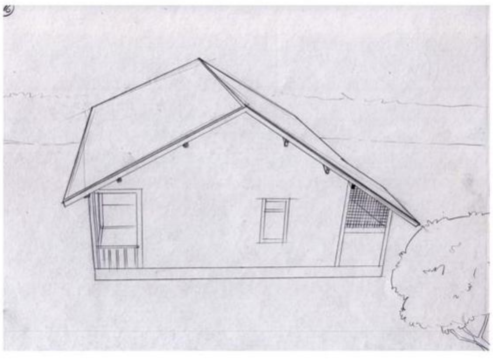
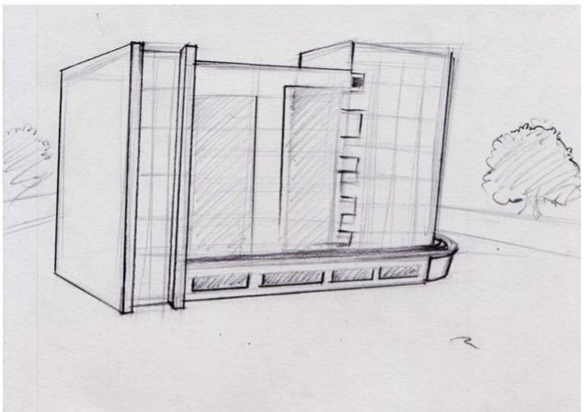


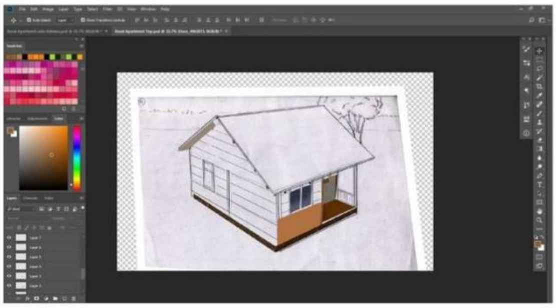


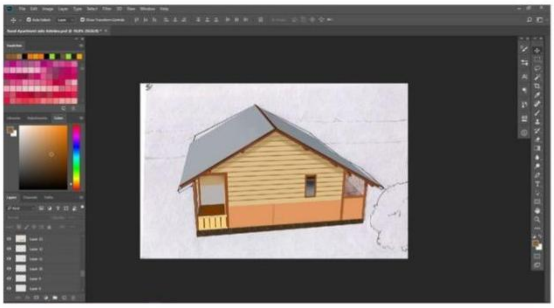


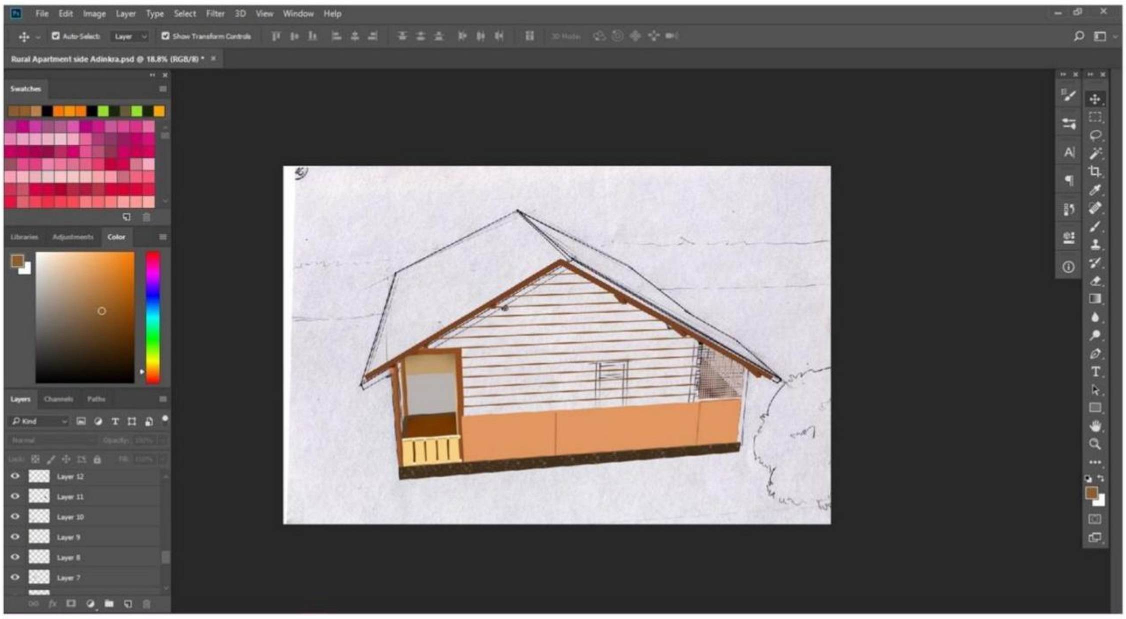






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Auto-Select: Layer
Show Transform Controls
Rural Apartment side Adinkra.psd @ 18.8% (RGB/8) *
Swatches
Libraries Adjustments Color
Layers Channels Paths
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Layer 12
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