Photovoltaic Energy Technology: The Perceptions of Architects in the Ghanaian Building Industry

Naa Adjeley Ashiboe-Mensah[1*] Frank D. K. Fugar[2] Fred Akuffo[3]

1. Department of Building Technology, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana
2. Department of Building Technology, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana
3. Department of Mechanical Engineering, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana

* E-mail of the corresponding author: naaadjeleyashiboe@yahoo.co.uk

Abstract

Photovoltaic energy conversion is widely considered one of the promising renewable energy technologies with the potential to contribute significantly to a sustainable energy supply and which may help to mitigate green house emissions. However, a number of factors including how the technology and its attributes are perceived by potential adopters influence the adoption decision. This study therefore investigates the perceptions of photovoltaic by architects in the Ghanaian building industry. It involved a survey of architects within the Ghana Institute of Architects. Results of the study showed a generally positive perception regarding photovoltaic except with a number of items such as initial cost of the technology. The few negative perceptions may however account for the low levels of actual photovoltaic adoption in the Ghanaian building industry.

Keywords: photovoltaic, innovation diffusion, adoption, Ghanaian building industry

1. Introduction

According to (Alsema & Nieulaar 2000), "photovoltaic (PV) energy conversion is widely considered one of the promising renewable energy technologies which has the potential to contribute significantly to a sustainable energy supply and may help to mitigate green house emissions" (Jackson & Oliver 2000; Johansson *et al*. 2004).

Ghana experiences an annual solar radiation of 16 – 29MJ/m2 and a daily solar irradiation of 4 – 6kWh/m2 (Edjekumhene & Brew-Hammond 2001) and in Ghana where there is a need to decrease demand on the national grid and also increase the renewable component of the nation's energy mix, photovoltaic seem like a plausible means of achieving both goals simultaneously especially by incorporating them in new buildings in urban areas.

In spite of the physical potential and technical knowledge available to exploit photovoltaics, literature relating to Ghana and the world, shows that there is a significant difference in the actual levels of investment in photovoltaic energy technology and the possible levels of investment (Bawakyillennuo 2007). This problem of adoption and use of photovoltaic have been attributed to a number of barriers including misplaced incentives, distortionary fiscal and regulatory policies, unpriced cost such as air pollution, unpriced goods such as education, training and technological advances, and insufficient and imperfect information (Brown 2001) (Golove & Eto 1996) (Painuly & Fenhann 2002). Consequently, the aim and traditional approach to the management of this problem has been to identify these barriers and eliminate them in order to promote adoption. Thus related research work and investigations have been aligned in a like manner.

However, although photovoltaic adoption and diffusion have widespread interest owing to their environmental, national security and macroeconomic repercussions; they are essentially like other products and services which also face obstacles that hinder their adoption. As such, they can be investigated using the vast array of concepts and theories; grouped under the umbrella of innovation diffusion; specially established to study how and why new products, practices and ideas spread.

This paper is therefore part of a larger research to investigate the factors that may influence photovoltaic adoption in the Ghanaian building industry by focusing on how the theoretical understanding of innovation diffusion as presented by Rogers (2003) and Hartmann *et al*. (2006) can be used to evaluate the factors that influence PV adoption and diffusion in the Ghanaian building industry.

The study is a cross-sectional survey that evaluates the factors that relate to perceived innovation attributes as these have been noted to account for 49-87 percent of variance in the rate of adoption of innovations (Rogers 2003; Ostlund 1974; Dearing 2007). Five standard attributes have been defined by Rogers (2003) which include:

- The relative advantage of the innovation
- Its compatibility with the potential adopters' current way of doing things and with social norms
- The complexity of the innovation
- Trialability, the ease with which the innovation can be tested by potential adopter
- Observability, the ease with which the innovation can be evaluated after trial

The perceptions of architects with regard to the above attributes about photovoltaic technology are investigated in the study.

The study contributes to the need for rigorous systematic investigations to inform the photovoltaic adoption policy-making processes as well as promotional efforts in the Ghanaian building industry. Such investigations in Ghana are few and those that relate to the Ghanaian building industry are absent.

2. Research Design and Method

The study employed a survey method of research to fit the research aim outlined above. The choice of the survey method in this research was informed by the methods used in related research on innovation diffusion and adoption as well the aim of this study. The survey was a cross-sectional one with data collected at one point in time rather than over time and involved the use of a structured self administered questionnaire. The attributes identified by Rogers (2003) formed the basis of the items that were rated in the questionnaire.

The population of the study comprised architects within the Ghanaian building industry with the sample frame of the architects selected based on the list of members of good standing as at February, 2010 as provided by Ghana Institute of Architects. The list was made up of 586 architects out of whom 314 had valid email addresses

2.1 Questionnaire Design

The design of the research questionnaire was carried out in four steps: informal interviews, literature review, informal and formal questionnaire pre-tests. The initial step conducted in the research and which informed the questionnaire design was the informal interview of building professionals and researchers, employees at the Ghana Energy Foundation and Energy Commission. These interviews brought to light the issues surrounding energy generation and use in Ghana and hence helped identify the research problem investigated and the major issue the questionnaire was to tackle. Clearly identifying the research problem guided and focused the literature review. The interviews also made sure that the problem identified was directly relevant to the Ghanaian context.

A review of literature of other related surveys and interviews was then conducted so as to determine the format of the survey instrument and how questions were paraphrased and generated. The literature review also provided the theoretical framework of the research and most of the relevant variables included in the instrument. Supporting the empirical inquiry with a theoretical framework as was done provided a majority of the factors to be evaluated. Also it made it easier to identify new information that may extend the boundaries of the selected framework. Furthermore, the framework also presented the methodological options available for the study and provided a reference point around which the discussion of the results and findings are centred.

A draft of the questionnaire was then developed and an informal pre-test conducted to determine whether the questions were easily and consistently understood by asking the individuals to say in their own words what they thought the questions meant. Finally, a final formal pre-test involving ten individuals working as professionals and researchers in the building industry and clients was done. Although respondents included only architects, the pre-test had respondents drawn from a range of individuals within the Ghanaian building industry in addition to architects in order to obtain comprehensive comments and input. This culminated in the final questionnaire used in data collection.

2.2 Sample Size

Sample size was calculated using the following formulae:

$$n = \frac{(z_{0.05})^2 p(1-p)}{E^2} = \frac{(1.96)^2 0.5(1-0.5)}{0.1^2} = 96 \text{ (Israel 1992)} \qquad (1)$$

n = sample size

Z = the z-score from a normal distribution table at 95% confidence interval (1.96)

p = the proportion of the population that expresses the same opinion. 0.05 is selected since this value of 'p' gives the highest sample size

E = standard error which is assumed to be 0.1 for the study

Table 1. Sample Size Allocation to Strata

Strata	Target Population	Disproportionate Sample Size*
Architects	329	39(40.5%)
Building services engineers	18	18(19%)
Clients	75	39(40.5%)
Total	422	96

This sample size of 96 was however allocated to the different building industry participants using disproportionate sample size allocation as shown in Table 1.

Although only 39 architects were required to respond, 314 architects (all those with valid email addresses on the Ghana Institute of Architects' list) were contacted with the questionnaires to cater for low response rates.

2.3 Data Collection

Actual data collection was carried out using dual methods. The initial distribution of the questionnaires was done via email and then a second phase involved the distribution of hard copies of the questionnaire. Respondents were first sent an introductory email informing them of the impending survey and explaining the purpose of the survey. Subsequently, a second email containing a hyperlink to access the survey was sent followed by two reminder emails a week apart. Respondents who failed to respond to the questionnaire were then contacted by telephone with a final reminder. Some respondents expressed a preference for hard copies of the questionnaire and were therefore furnished with them.

3. Findings

The findings reported in this paper are based on sixty-five responses obtained from the survey out of the total of 314 questionnaires sent out.

3.1 Awareness of PV

The first question sought to find out how many architects knew about photovoltaic. Out of the 65 responses obtained 51(78%) knew about PV and 14(22%) did not. The study then went on to investigate if the awareness of the technology is associated with the level of education, in other words whether the awareness of the technology depended on the level of education of architects. Results of a Fishers' Exact Test to test the null hypothesis that the two variables are independent indicated a two-tailed significance level of 0.940. Since this significance level was greater than 0.05, the evidence did not adequately support the existence of a relationship between the architects' awareness and their level of education. Only respondents that knew about photovoltaic (51) went on to answer the follow up-questions.

3.2 Communication Channels

Table 2. Source of Information on Photovoltaic

COMMUNICATION CHANNEL	FREQUENCY	PERCENTAGE
University/research institute	11	21
Worldwide web/internet	7	13.5
Peers/friends	7	13.5
Don't remember	4	8
Trade show/building exhibition	4	8
Manufacturer's brochure	3	6
Consultants and fellow building participants	2	4
Journal/technical publication	6	12
Secondary school	1	2
Client	1	2
Sales and supplier representatives	2	4
Seminar/conference	1	2
Advertisement (television, newspapers, radio etc.)	2	4
Total	51	100

In this question respondents were asked to indicate where they first heard about photovoltaic [Table 2]. The results show that respondents first learnt about PV from a wide variety of channels but a good number of the respondents were first introduced to PV technology through a University/research institute level.

3.3 Level of Adoption

Table 1 Photovoltaic adoption by architects

TYPE OF ADOPTION DECISION	RESPONSES	PERCENTAGE
Been part of a project in which photovoltaic was adopted (adoption)	9	18
Currently on a project in which photovoltaic is to be installed (adoption)	4	8
Been part of a project in which photovoltaic was proposed but not installed (rejection)	17	33
Never been part of a project in which photovoltaic has been adopted (non-adoption)	19	37
Been part of a project in which photovoltaic was adopted but later discontinued (discontinuance)	2	4
Total	51	100

This question investigated the number of architects who had actually adopted the technology. In spite of the high level of knowledge on photovoltaics (78%), the level of adoption [Table 3] is not commensurate with the level of PV knowledge. Approximately twenty-six percent of the respondents had adopted PV.

3.4 Decision-making

Table 2 Innovation-decision making unit

BUILDING PARTICIPANT	HAD AN INFLUENCE		HAD NO INFLUENCE		TOTAL	NON APPLICABLE	NON RESPONSE	MADE THE FINAL DECISION	
Client	26	87%	4	13%	30	33	2	17	56.7%
Project manager	6	40%	9	60%	15	43	7	0	0.0%
Architect	24	89%	3	11%	27	33	5	11	36.7%
Quantity surveyor	5	28%	13	72%	18	39	8	0	0.0%
Structural engineer	1	6%	16	94%	17	39	9	0	0.0%
Contractor	3	14%	19	86%	22	35	8	0	0.0%
Lenders, insurers and bankers	1	6%	15	94%	16	41	8	0	0.0%
Electrical engineer	19	73%	7	27%	26	34	5	1	3.3%
Mechanical engineer	11	48%	12	52%	23	35	7	1	3.3%
					Total responses			30	100%
					Non-applicable			33	
					Non-response			2	

This aspect of the questionnaire had two questions that found out about building participants involved in the decision to adopt photovoltaic and building participants that made the final decision. According to the results [Table 4], Clients, Architects and Project managers seem to influence the decisions to adopt PV than the other building participants – eight-six percent (86%), eighty-nine percent (89%) and seventy-three percent (73%) of respondents indicated that clients, architects and electrical engineers respectively had an influence on the decision to adopt PV. However, the final decision to adopt the technology was often made by clients - approximately fifty-seven percent (56.7%) of the time.

3.5 Perceived Innovation Attributes

This question sought to investigate the perceptions of architects on the attributes of photovoltaic by rating a number of items listed in Table 5. A summary of statistics of the results is presented in tables 6 and 7.

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Table 5 Item codes for attributes and definition[1]

ITEM ID	ATTRIBUTES
1	Impact of photovoltaics on profitability
2	Certainty of its future performance
3	Labour savings derived from the use of photovoltaics
4	Waste reduction potential of photovoltaics
5	Ability to recover the cost of photovoltaics
6	Reduction in build time
7	Compatibility with preferred construction practices
8	Ease of continuing use of photovoltaics
9	Impact of photovoltaics on image/status
10	Initial cost of the photovoltaics
11	Ease in first use of photovoltaics
12	The risk of failure associated with using photovoltaics
13	Continuing cost of photovoltaics (Cost-in-use/running cost)
14	Quality compared with alternatives (diesel generators, electricity from the grid i.e. Electricity Company of Ghana Limited etc.)
15	Compatibility with construction codes and standards
16	Greenhouse gases/CO2 reduction potential of photovoltaics
17	Ability to see the photovoltaics in use in other projects
18	Noise reduction potential of photovoltaics
19	Cost savings derived from the use of photovoltaics
20	Visual/aesthetic impact of photovoltaics
21	Ability to try the photovoltaics prior to actual adoption
22	Material savings derived from the use of photovoltaics
23	Impact of photovoltaics on safety

[1] Table 5 is to be used with Table 6 and 7 to define the meaning of the Row headings 1-23 and the attributes they represent

Table 6 Architects' Perceptions of Photovoltaic Energy Technology[2]

ANALYTIC STATISTICS	ATTRIBUTES											
	1	2	3	4	5	6	7	8	9	10	11	12
Mode[3]	3	3	3	3	4	2	3	3	4	1	3	3
Mode frequency	10	12	9	8	8	9	9	10	8	10	9	6
Rating < good (frequency)	5	3	7	2	4	10	7	4	4	16	7	9
Rating > good (frequency)	7	9	3	11	15	5	8	10	11	4	4	5
Rating ≥ good (frequency)	17	21	12	19	20	12	17	20	18	7	13	11
Total response	64	64	65	65	65	65	65	65	65	65	65	65
Total response with opinions	22	24	19	21	24	22	24	24	22	23	20	20
Non-response	1	1	0	0	0	0	0	0	0	0	0	0
% Mode	45	50	47	38	33	41	38	42	36	43	45	30
% Rating < good (frequency)	23	13	37	10	17	45	29	17	18	70	35	45
% Rating > good (frequency)	32	38	16	52	63	23	33	42	50	17	20	25
% Rating ≥ good (frequency)	77	88	63	90	83	55	71	83	82	30	65	55
Interpretation of mode	Good	Good	Good	Good	Very good	Fair	Good	Good	Very Good	Poor	Good	Good

Table 7 Architects' Perceptions of Photovoltaic Energy Technology[4]

ANALYTIC STATISTICS	ATTRIBUTES										
	13	14	15	16	17	18	19	20	21	22	23
Mode[5]	5	4	3	5	2	5	5	3	3	2/3	3
Mode frequency	9	8	9	14	8	13	9	10	9	7	8
Rating < good (frequency)	4	5	5	3	8	2	4	8	8	11	6
Rating > good (frequency)	14	13	10	20	9	18	15	6	4	4	8
Rating ≥ good (frequency)	22	20	19	23	15	22	21	16	13	11	16
Total response	65	65	65	64	65	65	65	64	65	65	65
Total response with opinions	26	25	24	26	23	24	25	24	21	22	22
Non-response	0	0	0	1	0	0	0	1	0	0	0
% Mode	35	32	38	54	35	54	36	42	43	32	36
% Rating < good (frequency)	15	20	21	12	35	8	16	33	38	50	27
% Rating > good (frequency)	54	52	42	77	39	75	60	25	19	18	36
% Rating ≥ good (frequency)	85	80	79	88	65	92	84	67	62	50	73
Interpretation of mode	Excellent	Very Good	Good	Excellent	Fair	Excellent	Excellent	Good	Good	Fair/ good	Good

[2] Note that all percentage calculation use total response with opinions
[3] 5 = Excellent 4= Very good 3= Good 2= Fair 1= Poor
[4] Note that all percentage calculation use total response with opinions
[5] 5 = Excellent 4= Very good 3= Good 2= Fair 1= Poor

4. Discussions

Prior to making a decision to adopt or reject an innovation such as photovoltaic, there must be the knowledge of the existence of the innovations (Rogers 2003). Data collected reveals a majority of the architects have been exposed to the existence of photovoltaic, however the question does not explore the extent of knowledge they have.

The results show that respondents first learnt about PV from a wide variety of channels but a good number of the respondents were first introduced to PV technology through a University/research institute [Table 2]. A majority of respondents are also aware of PV technology giving the indication that efforts at knowledge creation should shift from awareness creation to focus more on provision of how-to knowledge. This type of knowledge deals with the information necessary to use an innovation properly and is what is required if individuals need to make informed decisions about PV technology.

In spite of the high level of knowledge on photovoltaic (78%), the level of adoption [Table 3] is not commensurate with the level of PV knowledge. Approximately eighteen percent (18%) of those aware of PV technology had adopted PV [Table 3] (that is 14% of total respondents). This is consistent with Rogers' (2003) theory in that the knowledge of an innovation does not guarantee adoption; rather the attitude towards an innovation frequently intervenes between knowledge and the decision functions in the innovation decision process.

The perceptions of architects were then evaluated to determine respondents' assessments of PV technology with regard to certain attributes. Table 6 and Table 7 show a generally favourable attitude (i.e. over 50% of the respondents rated the attributes as good or better) towards photovoltaic but the initial cost show a very unfavourable attitude. This subjective assessment by participants generally coincides with objective assessments of PV as an environmentally friendly technology with an expensive initial cost.

This goes to show that respondents have a well-informed perception of the technology. The extremely low assessment of the initial cost also provides some explanation for the low adoption of photovoltaic by building participants especially since building construction is an already expensive venture even without the added cost of photovoltaic incorporation.

The study also investigated the building participants involved in decision to adopt photovoltaic. Clients and architect were detected to wield a greater influence in the innovation decision than other building participants. [Table 4]

5. Conclusion

The use of the theory of diffusion of innovation in investigating the adoption of photovoltaic is limited and those that pertain to the Ghanaian building industry are absent. This paper therefore is part of a larger study which extends the use of the theory applying it to a new context.

The theory of diffusion of innovation is extensive in its propositions and concepts hence fitting it within a single research study presents a challenge. This study focuses on just a portion and so there remains need for further research in this area within the context of the Ghanaian building industry. The current study only investigates the perceptions of architects but the perceptions of other building project participants, for example the building client, are relevant hence more studies are needed in this regard.

In spite of these limitations, the current study has practical implications for PV adoption in the Ghanaian building industry. The study identified the architect as the building participant with the most influence and hence he/she may be appropriate as a change agent in the Ghanaian building industry. Given his/her expertise in technical matters, as change agents, the architect could play a distinctive role in the innovation-decision process if they concentrated on how-to knowledge which is essential to an individual's decision to adopt or reject an PV technology.

Although the study shows a high level of knowledge and generally positive perceptions regarding photovoltaic, a number of attributes reveal negative perceptions and actual adoption of the technology is low (9 respondents have been part of projects in which they have been adopted [Table 3]). Consequently if the preferred end of policy makers to increase adoption is to be realised, perceptions must be positively influenced. Efforts should be aimed at improving the technology and introducing policies that minimise negative effects of adoption, for example, policies that minimise initial cost.

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