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Exploration of Architect perception on energy -efficient design decisions for Ghanaian building industry.

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***Abstract**: Advocates of sustainable energy had made several attempts to educate the professionals and ordinary people towards the energy development, efficiency, consumption and conservations for future energy sustainability. The aim of this study, is the exploration of Architect perception on energy –efficient design decisions for Ghanaian building industry. The study employed quantitative survey approach. Questionnaire was the main data collection tool. The questionnaires were distributed to a randomly selected sample of one hundred and thirty-five (135) registered architects out of the total population of 162 with Architects Registration Council of Ghana. The data was analysed using descriptive and inferential statistics such as factor analysis, and Pearson product moment correlation coefficient. The study revealed that the energy efficient design decisions made by the Architect on building envelope/orientation and site condition are passive solar technique, provision of natural ventilation, day lighting technique, and temperature of the building site and site shading strategy decision respectively. The findings of the study shows that, energy efficient design decisions performance is to reduced energy consumption, less energy cost and improves the comfort of occupants. The study recommend government to enforce the EED framework designs as an appropriate strategy to improve the energy performance of public buildings.*

***Keywords**: Energy efficient designs, public buildings, Architect, energy performance*

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I. INTRODUCTION

Buildings form the confines of work and leisure, eating and sleeping, passion and boredom [1]. Thus, the design of buildings is important, functionally as well as aesthetically [1]. Besides, buildings are durable; most structures are used for long time, some even for several hundred years [2]. Therefore, building decisions have long-term consequences, particularly for environment and the consumption of energy. According to [3], significant portion of the energy is consumed by today’s buildings in both developed and developing countries. [4]also found that buildings account for 40 percent of the world’s total primary energy consumption. The sector’s contribution to current world CO_2 emission according to [5] is estimated at 25 to 35 percent. [6]found that CO_2 emissions from buildings have doubled from 4 gigotonnes (Gt) per year in 1971 to 8 Gt per year in 2004. It is also expected to reach up to 14 Gt per year in 2030 as a result of increasing energy consumption from developing countries. Buildings are expected to achieve energy efficiency because the huge energy consumption for cooling and lighting buildings not only demands valuable fossil fuel resources, but also emits a huge amount of CO_2 and other pollutants into the atmosphere [7]. Moreover, in Ghana according to the energy commission, the total energy consumption for the year 2012 was 8,552 (Gwh), with this statistics, building sector consumed about 30-40 percent of the total consumption [8]. It is therefore necessary to assess the perceptions of Architect on energy efficient decision required for Ghanaian building industry. This study is part of the larger studies that assesses the effects of energy-efficient decisions on energy performance of public buildings: the perspectives of architects. The objective of the study is to identify energy efficient design decisions and their performance in Ghanaian building industry.

1.1 Statement of the Problem

US environmental protection agency (EPA) (2008) emphasized that the aspirations of developing countries for higher living standards can only be satisfied through sustainable use of energy. According to [3], significant portion of the energy is consumed by today's buildings in both developed and developing countries. In recent years, energy has become a major concern in Africa of which Ghana is no exception ([9]; [10]). Though, the Ghana Building Regulations [11] (Li 1630) provides regulations and practices in buildings, no section(s) in the act strictly spell out the enforcement of energy efficiency in housings. As a result, there is no legal enforcement of energy efficient regulations of buildings in Ghana. While there have been considerable studies focusing on behavioral change in inefficient utilization of energy [10] Hence the study to assess the perceptions of Architect on energy efficient decision required for Ghanaian building industry.

1.2 Aim of the Study

The main aim of this study is to assess the perceptions of Architect on energy efficient design decisions for Ghanaian building industry.

II. LITERATURE REVIEW

2.1 Sustainable Energy Consumption

Back to US congress [12] towards assessment of building energy efficiency, there have been attempts to educate the professionals and ordinary people towards the energy development, efficiency, consumption and conservations for future. Energy is essential to economic and social development and improved quality of life [7]. Much of the world's energy, however, is currently produced and consumed in a way that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially [13]. [14] argued that the need to control atmospheric emissions of greenhouse and other gases need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems. However, sustainable energy consumption is an umbrella term that aims at how sound energy systems, particularly new and renewable energy systems could be used in an economically efficient manner taking into account the use of technologies that minimize adverse impacts on the environment [4]. Essentially, the purpose of sustainable energy consumption is to avoid environmental and social meltdown of energy supply, thus sustaining the existence of not only modern society, but the future of the humans [15]. [16], also added that all energy sources need to be used in a way that respects the atmosphere, human health and the environment as a whole.

2.2 The Global Energy Situation on Building

Significant efforts have been made on how best to improve energy efficiency of buildings and to reduce energy consumption, as well as gas emission. [17]found that the concept of energy-efficient buildings is related to the energy supply needed to achieve desirable environmental conditions that minimize energy consumption. To design energy-efficient building, design variables and construction parameters must be optimized [18]. The best time to integrate energy efficiency in buildings is the conceptual design phase. [19]also found that building design based on energy-saving criteria reduces cost throughout the useful life of the buildings because of its lower energy consumption. [20]also added that significant part of energy consumption can be reduced during the architectural design since this has a direct impact on choosing and sizing the mechanical system of the building which in turn affects the energy consumption of the building during its life time. Therefore, identifying the energy- efficient building components is critical from the standpoint of building designers. Properly designed buildings can not only reduce energy consumption but also reduce greenhouse gas emission. Buildings are major consumers of energy throughout their life cycle [14]. Generation of energy depends on conventional source which is the basic cause of environmental pollution. To improve energy efficiency of public buildings, it is essential to involve all parameters which control their energy efficiency. Construction of public building is energy intensive process right from site clearance up to operation and through its life cycle. Energy efficiency of a building can be improved by designing and implementing either active or passive energy-efficient strategies. Improvement of components such as walls, fenestration, roof, foundation, thermal insulation, thermal mass, shading devices etc. is known as passive energy efficient strategies. Passive strategies are also known as building envelope. [21]found that energy savings of 31.4% - 36.8% were recorded for high – rise apartments in the hot and humid climate of Hong Kong by implementing passive energy efficient strategies.

2.3 Energy Supply in Ghana

The primary sources of energy in Ghana consist of electricity, fossil fuels, and biomass. Locally, energy production is mainly derived from hydroelectric dams, thermal electric plants and biomass sources [22]. In order to meet the country's energy demand, electricity, fossil fuel and crude oil are imported to supplement the primary indigenous energy production. The installed grid electricity generation capacity as of December 2013 was about 2936 megawatt (MW) (see Table 1).

Table 1: Installed Electricity Generation Capacity as of December, 2013

Generation Plant		Fuel Type	Installed Capacity (MW)		Share %
Hydro Power Plants					
Akosombo		Hydro	1,020		
Kpong		Hydro	400		
Bui		Hydro	160		
Sub – Total			**1,580**		**53.8**
Thermal Power Plants					
Takoradi Power Company (TAPCO)		LCO/NG/Diesel	330		
Takoradi Inter-Nation Company (TICO)		LCO/NG/Diesel	220		
Sunon-Asongli Power (SAPP)		NG	200		
Tema Thermal Plant 1 (TTP 1)		LCO/NG/Diesel	126		
Tema Thermal Plant 2		NG	49.5		
CEL IT Energy Ltd. (CEL)		LCO/NG	126		
Takoradi (T3)		NG	132		
Mines Reserve Plant (MRP)		Diesel/NG	40		
Osagyefo Power Barge		NG	125		
Sub-Total				1,348.5	**45.9**
Renewable	**VRA Solar**	Solar	2.5		
Sub-Total			**2.5**		**0.1**
Embedded generation		LPG	5		
Genser Power					
Sub-Total			**5**		**0.2**
Total			**2936**		

Source: (Energy Commission, 2014)

Hydropower and imported fossil fuel are the main energy sources used to generate electricity[23]. In the year 2013 the amount of electricity generated amounted to 2,936 megawatt (MW), hydro-electricity accounted for 1,580, megawatt (MW), thermal electricity 1,348.5 megawatt (MW), Renewable accounted for 2.5 megawatt (MW) and amended generation also accounted for 5 megawatt (MW) (Energy Commission of Ghana, 2013).

The Volta River Authority (VRA) is the company responsible for the generation of electricity and operates all power plants in Ghana. Electricity Company of Ghana (ECG), and the Northern Electricity Department (NED) – a subsidiary of VRA are in charge of the distribution of electricity, whereas, Ghana Grid Company (GRIDCO) is the body responsible for the transmission system of electricity. The electricity supply system in Ghana is divided into bulk electricity (transmission level) and final electricity (distribution level).

2.4 Energy Efficiency Defined

Energy efficiency refers to the state or condition of having reduced energy consumption [24]. [20]also found that energy efficiency is the ratio between the input and output of energy conversion. U.S department of energy (DOE), [25] also added to the definition of energy efficiency as using less energy to provide the same service. Energy efficiency is not energy conservation. Better still; energy efficiency can also be defined as a ratio between an output of performance, service, goods or energy and the input of energy [26].

2.5 Zero – Energy Building

[27]found that zero-energy building also known as a zero net energy (ZNE) building or net zero building is a building with zero net energy consumption. They further added that the total amount of energy used by the zero energy building on an annual basis is roughly equal to the amount of renewable energy created on site. With zero-energy building, energy is usually harvested on site through a combination of energy producing technologies like solar and wind, while reducing the overall use of energy with highly efficient HVAC and lighting technologies [28]. Successful zero energy building designers typically combine time tested passive solar or artificial conditioning principles that work with the onsite assets.

2.6 An Energy-Efficient Building

The concept of energy efficient buildings has implications on regulations, economic energy demand and the environment [29]. Energy Efficient Buildings are buildings which use design practice to take advantage of natural resources and minimize energy waste. [30]proposed three (3) criteria for an energy efficient building. These are;

- the building must be equipped with efficient equipment and material appropriate for the location and conditions;
- the building must be provided with amenities or services appropriate to the buildings intended use; and
- the building must be operated in such a manner as to have a low energy use compared to other similar buildings.

Notably, the definition of an energy-efficient building is related to the specific design approach comprising exactly defined parameters which influence the efficient building design to take advantage of many renewable energy sources combined with low-energy technology as possible. [31] opined that low-energy building is a building with annual energy consumption less than 30Kwh/m^2.

2.6Integrating Energy Efficient Concepts into Design Process

Buildings can be designed to meet occupants need for thermal and visual comfort at reduced levels of energy and resources consumption. Energy efficiency in new constructions can be influenced by adopting an integrated approach to buildings design. [19]Found that the highest energy saving potentials can be realized during the design stage of the building. [27]Also added that the energy efficiency of a building is significantly influenced by architectural design. They further added that by following a careful design process, it is possible to produce buildings that use substantially less energy without compromising occupant comfort or the building's functionality

2.7 Features of an Energy-Efficient Building Design and Construction

Energy-efficient building design is not just the result of applying one or more isolated technologies [27]. Rather, it is an integrated whole-building process that requires advocacy and action on the part of the design team, throughout the entire project development process. Moreover, energy-efficient design does not necessarily have to result in increased construction cost [27]. Indeed, one of the indispensable approaches to energy-efficient design is to invest in the building's form and enclose (eg, windows, walls) so that cooling and lighting loads are reduced, and in turn, smaller, less costly heating, ventilation, and air conditioning system are needed. It is important to appreciate that the underlying purpose of the building is neither to save nor use energy [19]. Rather, the building is there to serve the occupants and their activities. Indeed, elements of an energy-efficient building design include, but not limited to, Passive solar features, efficient electric lighting, High-Performance Glazing, Displacement Ventilation, Evaporation Cooling System, Landscaping, Building Automation system, Building Integrated Photovoltaics, and Shading System [19] ; [27]. In general, highly energy-efficient buildings use less energy, cost less to operate, use less in the way of natural resources, and produce less environmental impact than conventional buildings [31]. [2]Also claimed that the process of designing, constructing or renovating a high-performance energy efficient building is different from traditional design build-methods. [32], again added that, the capacity of mechanical and electrical systems can be minimized by incorporating passive solar technologies, to help meet indoor space-conditioning requirement and lighting loads. According to [7], most methods currently used for improving building energy efficiency are focused on minimizing unwanted solar heat gain, maximizing usable natural light and heat, and minimizing building heat loss through air leaks around windows and ductwork. In designing energy-efficient building, [21] added that passive solar technique is one of the key elements of energy-efficient building designs. Passive solar techniques are those that take advantages of solar heat and light to offset the need for air conditioning and lighting. It includes South-facing building orientations that absorb and store solar heat during the winter and deflect solar heat during the summer, and day lighting or maximizing the use of windows and full-glass exterior walls, often covered in a heat-deflecting glaze, to allow natural lighting into the building's interior work spaces, which minimize the heat gain that might normally result.

2.8 Window Geometry

Windows should be shaped and located in a manner that minimizes glare and unwanted solar gain and maximizes useful daylight and desirable solar heating [33]. [34]Further argued that, it is important to avoid incorporating more window area than is beneficial to the building occupants or that is needed to enhance energy efficiency performance. Again [34] also supported that window decisions should be based on occupant activities and energy efficiency rather than simply for aesthetic purposes.

III. METHODOLOGY

3.1 Research Design

According to [35], research designs are plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis. This study employed quantitative research approach using survey questionnaires developed and administered to the targeted respondents. Walker and Green [36] also found that quantitative research design enables the researcher to decide what to study; ask specific, narrow questions; collect quantifiable data from participants; analysed these numbers using statistics; and conduct the inquiry in an unbiased, objective manner.

3.2 Population

The population of the study comprised registered architects and architectural firms in the Greater Accra, Ashanti and Western regions of Ghana. These regions were selected because they are the major regions in Ghana where construction activities are highly concentrated [37]. Sampling frame is an objective list of the population from which the researcher can make his or her selection [38]. The study sampling frame consisted of all one hundred and sixty-two (162) architects and architectural firms registered with Ghana Institute of Architects and Architects Registration Council of Ghana as of January, 2014 located in the Greater Accra, Ashanti and Western Regions of Ghana. The sample size was determined using the formula [39]

$$n = \frac{n^1}{1 + \left(\frac{n^1}{N}\right)}$$

Where n = sample size

$n^1 = \frac{S^2}{V^2}$, $S^2 = p(1 - p)$

N = total population = 162

S = maximum standard deviation in the population element

P = proportion to the population elements that belong to the defined category

i.e. p = 0.5 (95%) confidence level

V = standard error of the sampling distribution i.e. V = 0.05

Hence solving for n^1

$S^2 = p(1 - p) = 0.5(0.5) = 0.25$

$V^2 = 0.05^2 = 0.0025$

$n^1 = \frac{S^2}{V^2}$, $n^1 = \frac{0.25}{0.0025} = 100$

$$n = \frac{n^1}{1 + \frac{n^1}{N}}$$

n = 100/ (1 + 100 / 162)

= 62 Architects

This formula provides the minimum number of survey participants to be obtained. Although only 62 architects were required to participate in the survey, similarresearch conducted in Ghana have indicated non response rates ranging from 38% to 87% [40]. Based on the non-response rates recorded in the aforementioned studies and taking into consideration the study setting, 135 architects (all those with valid email addresses on the ARCG list in the three regions) were contacted with the questionnaires to cater for low response rates. Purposive sampling technique were used to select the respondents because architect are knowledgeable in their field and also because the distributions of Architects in Ghana are largely based towards these major city capitals [40]; [41].

3.3 Administration of the Questionnaires

The questionnaires were delivered to the respondents personally and via email. Out of 135 questionnaires administered; 75 responses were received and out of this, 72 were acceptable, representing a usable response rate of 53 percent. This response rate is considered adequate as, according to [42], [43] a response rate of 30 percent is good enough in construction studies. T-Test was used to find out about the problem of non- response bias, no major differences were found between early and late respondents suggesting that non-response bias may not be a problem [43]

3.4 Method of Data Analysis

Completed questionnaires from the field were edited and coded appropriately to make effective meaning out of the data. The data was analyzed and interpreted by using Statistical Package for Social Science (SPSS) version 16

3.5 Validity

According to [44] validity is the extent to which the instrument measures what it purports to measure. To ensure face or content validity, items can be generated from a number of sources including consultation with experts in the field [45]. Hence the validity was checked using “face validity” by the experts in the design profession. The identified design decisions were scrutinized and verified through a series of face-to-face interviews with four selected senior Architects possessing sufficient experience in public construction projects, in Kumasi (the second largest city in Ghana).

3.6 Pilot Study

The researcher conducted a pilot study to ensure the reliability of the questionnaire and to identify items that should be revised. The pilot study was done in the Kumasi Metropolis and it involved the administration of the questionnaire to a sample of eight (8) randomly selected Architects from the population. Because no major adverse comments were received from the respondents, the pilot study questionnaire after slight modifications was taken as the final empirical questionnaire for the investigation.

IV. RESULTS AND DISCUSSION.

4.1 Respondents' Working Experience

Table 2 indicates that majority of the respondents, thus, sixty six (66) accounting for 92 percent have more than 5years working experience. Impliedly, the respondents have vast experience in public building design; hence, their contributions are presumed to be very useful in achieving the objective of the study.

Table 2: Respondents' Working Experience

Experience	**Frequency**	**Percentage**
Under 5years	6	8%
5 – 10 years	18	25%
Above 10 less than15 years	26	36%
15 – 20 years	14	20%
Above 20 years	8	11%
Total	**72**	**100%**

4.2 Integration of Energy Efficiency Decisions (EED) of the Respondents

The first part of the study related to how the respondents 'integrate the identified EEDs in the design of public buildings. Table (3) shows that the overall mean of the site condition related decisions was 4.55 while that of building envelope /orientation related decisions was 4.32. Considering the site condition related decisions, the results revealed that temperature of the building site item had the highest mean 4.64, while humidity & site water bodies' item had the lowest mean 4.50. Regarding building envelope/orientation related decisions, passive solar technique had the highest mean 4.58, while Integration of roof monitors item had the lowest mean 3.36. The results further indicated that the means of the items of the site condition related decisions and that of building envelope /orientation decisions all exceeded the scale mid-point (3); this suggests that the respondents (Architects) attach importance to all the EED aspects assessed. The standard deviation lies between (0.50 - 0.66); this indicates a homogenous data and a reasonable dispersion of central tendency.

Table 3: Energy Efficient Decisions of the Respondents Designs

Item	**Mean**	**SD**	**Rank**
Site Condition Related Decisions	**4.55**	0.56	
Temperature of the building site	4.64	0.52	1
Site shading	4.55	0.50	2
Building site topography	4.54	0.58	3
Wind velocity of the building site	4.52	0.58	4
Humidity & site water bodies	4.50	0.64	5
Building Envelope/Orientation Related Decisions	**4.32**	0.57	
Passive solar technique	4.58	0.50	1
Adequate natural ventilation	4.56	0.56	2
Day lighting	4.53	0.54	3
Thermal storage	4.53	0.56	4
Provision of adequate heat insulation	4.46	0.54	5
Air tightness	4.42	0.56	6
Incorporation of differential facade	4.08	0.66	7
Integration of roof monitors	3.36	0.64	8

4.3 Energy Efficient Decisions by respondents.

The study further explore Factor analysis to ascertain which energy efficient decision did the respondents adopted in their designs. The principal components analysis were used for items pertaining to energy efficient decisions and site conditions that inform the choice of EED elements. The identification and labelling of the two extracted factors is discussed below. Table 4 presents the principal components analysis of energy efficient decisions for public buildings. The overall energy efficiency decisions had a KMO value of 0.714 and the Bartlett test of sphericity shows overall significance of the correlation matrix at the 0.000 level. The factor analysis of the items led to the extraction of two main factors which cumulatively explain 73.613 percent of the variance. The first factor loads very heavily onto a vector generating an eigenvalue of 8.350.

Given that these items appear to gauge the extent to which Architects' energy efficiency decisions affect the building envelope/orientation, the solution is accepted and ascribed the label building envelope/orientation related decisions. The second factor solution loads five items onto a vector generating an eigenvalue of 1.219 and accounting for 9.20 percent of total variance. The five items appear to gauge the degree to which Architects' energy efficiency decisions integrate the site conditions. Consequently the solution is accepted and the factor labelled as site conditions related decisions. Each of the 13 decisions has a loading above 0.50. Since all the loadings exceeded the threshold of 0.50 the loadings can be considered as statistically significant [45].

Table 4: Principal Component Analysis of Energy Efficient Decisions

Item	Factor loadings 1	2
I integrate passive solar technique in my designs	**0.832**	
I integrate natural ventilation in my designs such as provision of adequate windows, circulation and atrium spaces and heat pumps	**0.815**	
I incorporate heat control techniques such as the use of non-absorbing /light Coloured reflecting roofing coverage and covering of full glass-exterior walls with a heating deflecting glaze and appropriate shading	**0.808**	
I ensure that the orientation of windows and glass areas suit the different amount of light entering/approaching the building	**0.797**	
I incorporate high performance insulation materials in my designs	**0.767**	
I ensure that air leaks around doors, windows, ducts, cracks, vent pipes and electrical outlet are properly sealed	**0.733**	
I create variations in my facade design in response to change in orientation	**0.695**	
I integrate roof monitors in my design	**0.641**	
I take advantage of the temperature of the building site in my design	0.241	**0.923**
I take advantage of the site shading by vegetation	0.196	**0.858**
I take advantage of the topography of the site in my design	0.428	**0.576**
I take advantage of the wind velocity at the building site in my design	0.576	**0.597**
I take advantage of the humidity and the presence of water bodies at the site	0.492	**0.539**
KMO = 0.714, **Bartlett's Test** = 1.195E3**, Sig.** 0.000	**8.350**	**1.219**
Eigen values	**73.613**	
Cumulative % Variance		

Principal Components Analysis with Varimax Rotation Converging in 3 iterations (all loadings less than 0.5 suppressed)

*****Question wording was "Please to what extent do you incorporate the following energy efficiency decision in the design of public buildings by ticking the appropriate point. Likert –type scale respectively anchored by (1) Very little extent and (5) Very large extent.

4.4 The performance of energy efficient designs.

Further exploration was than by the study, to ascertain the performance of energy efficient design in building construction project. Energy performance (EP) construct consisting of five variables were used. The results of the factor analysis for the EP construct are shown in Table 5. Factor loadings of the five variables are all higher than the suggested value of 0.50 on a single construct. The total variance explained was 80.524 percent. Meanwhile, the KMO value was 0.792; and the Bartlett test of sphericity shows overall significance of the correlation matrix at the 0.000 level.

Table 5: Principal Component Analysis of Energy Performance

Item	Factor loadings
Reduced energy consumption	0.945
Less energy cost	0.936
Improves the comfort of occupants	0.922
Improves health and safety of occupants	0.880
Improves the productivity of occupants	0.818
KMO = 0.792, **Bartlett's Test** = 389.781, **Sig.** 0.000	
Eigen values	4.026
Cumulative % Variance	80.524

Principal Components Analysis (all loadings less than 0.5 suppressed)

*****Question wording was "Please indicate the extent to which the energy efficient decisions indicated contribute to the following energy efficiency performance of public buildings by ticking the appropriate point. Likert –type scale respectively anchored by (1) Very little extent and (5) Very large extent

V. CONCLUSION

In conclusion, Architects in Ghana should be more concerned with passive solar technique, provision of natural ventilation, and day lighting technique of building envelope/orientation related decisions as well as temperature of the building site, and site shading strategies of site condition related decisions. The performance of energy efficient designs are reduced energy consumption, less energy cost, Improves the comfort of occupants, Improves health and safety of occupants and Improves the productivity of occupants when designing public buildings.

VI. RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made towards improving the adoption of Energy-efficient building design and construction practices in Ghana. These recommendations could form the basis for interventions designed to overcome or reduce the energy challenges in Ghana.

- There should be policy by government to enforce the EED framework designed as an appropriate strategy to improve the energy performance of public buildings.
- Architects should be more concerned with passive solar technique, provision of natural ventilation, and day lighting technique of building envelope/ orientation related decisions as well as temperature of the building site, and site shading strategies of site condition related decisions when designing public buildings as these considerations have greater impact on energy-efficiency of buildings.
- Private individuals should be encouraged to adopt energy efficient building concept.

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