UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ASSESSING THE KNOWLEDGE AND UTILIZATION OF ENERGY EFFICIENCY ASSESSMENT TOOLS FOR OFFICE BUILDINGS IN GHANA: A CASE STUDY OF THE KUMASI METROPOLIS

BY

JOSEPH APPIAH

SEPTEMBER, 2021

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ASSESSING THE KNOWLEDGE AND UTILIZATION OF ENERGY EFFICIENCY ASSESSMENT TOOLS FOR OFFICE BUILDINGS IN GHANA: A CASE STUDY OF THE KUMASI METROPOLIS

BY

JOSEPH APPIAH

(190012974)

A DISSERTATION PRESENTED TO THE DEPARTMENT OF CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, FACULTY OF TECHNICAL EDUCATION, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE REWARD OF A MASTER OF TECHNOLOGY DEGREE IN CONSTRUCTION TECHNOLOGY

SEPTEMBER, 2021

DECLARATION

CANDIDATES DECLARATION

I, **JOSEPH APPIAH** hereby declare that this Dissertation is the result of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the university except where due acknowledgement has been made in the text.

Signature: ……………………………… **Date:** ………………………………

SUPERVISOR'S DECLARATION

I am satisfied that this work is the result of the student's own effort and therefore declare that, the preparation and presentation of this Dissertation was supervised in accordance with the guidelines on supervision of Dissertation laid down by the university of education, Winneba-Kumasi.

NAME: ING. DR. EMMANUEL APPIAH-KUBI

Signature: ……………………………... **Date:** …………………………………

ACKNOWLEDGEMENT

I am most grateful to the Almighty God for His guidance and protection during the time I undertook my research work. I also give bigger thanks to my supervisor, Ing. Dr. Emmanuel Appiah-Kubi for his effort in supervising this dissertation. I also want to thank Mr. Thomas Asiedu, Chief Fire Commander, Ghana National Fire Service Manso Nkwanta, Mr. Agorsor Francis, former headmaster Jacobu Senior High Technical School. Finally, to all my friends who in diverse ways encouraged me to come out successfully with this dissertation. To all, I say God richly bless you.

DEDICATION

I dedicate this dissertation to my Mother Ernestina Adjoa Pinamang, my Wife Juliana Afoakwa, my Children Antoinette Appiah Pinamang, Hans Appiah Joseph, Phanuel Wise Osei Appiah, Miguel Appiah Poku my Brothers Appiah Hans Joseph, John Osei Baffour and my Uncle, Kwame Afriyie Appiah Joseph. I owe this lovely family of mine a debt of gratitude for the love, motivation, support and encouragement they gave to me while I carried out my dissertation.

TABLE OF CONTENT

CONTENTS **PAGES**

LIST OF TABLES

TABLES **PAGES**

LIST OF FIGURES

FIGURES **PAGES**

ABSTRACT

Conducting an energy efficiency assessment helps construction firms and management team understand how and where energy is used, where to improve usage and equipment, and how to reduce costs. This dissertation was conducted with the main aim of assessing the level of knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana. The study adopted descriptive survey as the research design with a population of owners and tenants of office buildings as well as construction managers, electrical engineers, mechanical engineers, quantity surveyors, civil engineers, architects who worked in some public office buildings in the Kumasi Metropolis. The study used simple random sampling technique to select twenty (20) building owners and tenants and purposive sampling technique was used to select seventy (70) building professionals. In all, ninety (90) respondents were used for data collection through questionnaires. Statistical Package for the Social Sciences (SPSS) and Microsoft Excel (MS Excel) were used to analyze the data and the results were presented in charts and tables showing their frequencies and percentages. The study found that, the Pearl Rating System (ESTIDAMA), the Green Building Assessment (GBA), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) among others are the major energy efficiency assessment tools that building professionals in Kumasi metropolis are aware of. The study concluded that, even though building professionals are aware of energy efficiency assessment tools, its cost was identified as a barrier to the adoption and application to improve energy consumption in office buildings. The study also concluded that, inculcating energy efficiency factors in both new and existing office building stock can substantially reduce energy consumption and most of the environmental impacts. The study recommended that, building professionals must make it a point to abreast themselves with more sustainable energy efficiency assessment tools that are less costly to encourage client's acceptance and adoption in their designs.

.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The rise in demand for building services and higher comfort levels together with the increased time spent inside buildings have led to increased global consumption of energy and resources in the building sector (Pérez-Lombard *et al.,* 2008). In particular, buildings alone contribute to 40 % of global energy consumption and it is projected that commercial building energy use will grow worldwide (Urge-Vorstaz *et al.,* 2015). Promotion of energy efficiency, adopting new technologies for energy sufficiency and raising awareness about rational use of energy resources are recommended to support progress towards a more sustainable future (Lucon & Urge-Vorstaz, 2014). Recent economic development has propelled increase in building energy consumption in most developing countries, African countries not being excluded. Hui (2000) averred that, developing countries are experiencing an increase in construction of buildings; however, the uptake of efficient technologies is low due to the energy prices and market. One major challenge and critical developmental goal of most growing economies is the need to increase the energy capacity to meet its rising energy consumption base. Nonetheless, in Ghana, it is projected that consumption of electricity is increasing by 10% per annum due to the surging population's demand for energy (Essah, 2011). This is as a result of several factors including population and related economic expansion. Obviously, the rapid increase in population all over the world has attracted the attention of nations and major actors in the construction industry.

Crossette and Kollodge (2011) posited that, the global population reached 7 billion during 2011 and it is expected that by the year 2025, the world population will be more than 7.2 billion and projected to increase by another 1 billion (1,000 million) people by 2037 (UNFPA, 2012). This population growth leads to increasing demand for services which provides significant investment opportunities and contributes to economic growth (DeSA, 2013). However, the rapid rate of population growth, coupled with economic development and expected growth, is likely to affect living standards through the expansion of infrastructure and low capacity of energy to use due to the higher consumption of energy in the built environment. Recently, the demand for reducing energy cost in existing buildings has increased, and this has led to greater interest in energy performance improvements for buildings (Wang *et al*., 2012; McKinsey, 2009). Consequently, many countries have developed and introduced energy performance assessment methods to support retrofit decision-making for enhancing building energy efficiency (Fabrizio & Monetti, 2015; Touloupaki & Theodosiou, 2017).

In this context, the Energy Performance of Buildings Directive of the European Union (European Parliament and the Council of the European Union, 2002) has set the pace in improving the energy efficiency of constructions during their use phase, specifically in lowering their heating demand. In parallel, optional building energy efficiency certifications have emerged. For example, passive houses, first developed in Germany can reach extremely low annual heating demands (Feist, 2007). This trend towards improving the energy efficiency of buildings has also been enforced in other countries through different policies e.g., the 6-Star Standard in Australia (Australian Building Codes Board, 2010). Rising energy consumption has had severe environmental impacts including increasing energy demand, global warming, air pollution and acid rain (Hongkong University, 2016). Across the globe, solving such issues has seen the uptake and use of building energy efficiency standards. The energy consumed in a building or within a building system such as an air conditioning or heating can be addressed using energy regulation (Birner & Martinot, 2002). Frequently used for ensuring energy efficiency in most buildings is the building energy standard or energy regulation (OECD, 2003). Studies however, show that the uptake of these building energy standards is quite low in developing countries and with some still not having any standard in place (Iwaro & Mwasha, 2010; Janda, 2008). The limited information about developing countries reflects an information gap surrounding the development, use and effectiveness of building energy regulations for building energy conservation. In Ghana, power rationing coupled with erratic electricity supply has ensued due to the inability to find a balance between reducing demand and increasing supply (Ackah *et al*., 2014). The increasing demand for energy is among other factors, caused by the numerous newly constructed air-conditioned commercial buildings, especially in the metropolitan areas of Accra and Kumasi.

The incessant blackouts and lack of reliable energy supply has had a negative effect on the economy resulting in job cuts and lower productivity (Doe & Asamoah, 2014). Despite efforts made in the demand side management of energy including the introduction of an appliance rating system, the lack of building energy standard represents a significant drawback in building energy efficiency in Ghana. Therefore, this study seeks to address the main questions raised on the level of knowledge and utilization of energy efficiency assessment tools for office buildings in Kumasi metropolis.

1.2 Statement of the Problem

It is becoming increasingly evident that human activities have an impact on the environmental balance of our planet. The release of greenhouse gases into the atmosphere is likely to be one of the major driving forces behind climate change (IPCC, 2007). Carbon dioxide (CO_2) emissions, which are the main driver of the greenhouse effect, are closely related to the generation of energy. In 2009, CO_2 represented 83% of global energy-related emissions (IEA, 2010). Hence, energy use is currently one of the main factors contributing to climate change. The situation of global energy-related emissions is not excluded from the building sector since it accounts for 40% of the final energy use in most developed economies (IEA, 2010). This has been the basis for increasing the energy efficiency of buildings during their use phase, notably in terms of space heating and cooling, in order to reduce their energy use.

With regards to the above-mentioned factors, remarkable researches and standards or policies have been done with most focusing on ways to reduce energy use in buildings and tools to assess building energy efficiency. A research done by Wong *et al*. (2005) identified several assessment methods for building performance with energy efficient characteristic, but these methods are not comprehensive enough to most of the developing countries especially Africa. Another research done by Ma and Wang (2009) focused on technical methods and a comprehensive assessment method was also mentioned to have been predominantly utilized by most of the developed countries whereas the knowledge is not known to some of the developing countries. Furthermore, United Nations Environment Programme (2009) report shows that in the year 2000, building energy standards implemented in the United States have contributed to 16% of energy reduction. However, standards and policies made to regulate building energy efficiency mostly focus on the building energy efficiency during the use phase which often fail to take a more holistic approach.

Iwaro and Mwasha (2010) showed that Ghana is among the developing countries lacking an energy standard. The lack of a building energy assessment tool remains a critical challenge to energy security in Ghana (Addy, 2016). As a result, there is a huge demand for diesel or renewable energy-based backup/stand-by power generation from end-users, high cost of bills showing higher energy consumption, high rate of power fluctuations showing inefficient energy use and many more. Growing power and energy requirements in buildings have the consequential effect of increasing capital outlay required, and the running costs of these stand-by systems (Addy, 2016). In fact, from the account of the 2014 – 2016 frequent power on and off in Ghana indicates that efficient use of energy in most Ghanaian homes have been downplayed.

In view of the above, it is evident that, energy-efficient buildings performance do not only depends on its energy-efficient design but the interaction between building users and its energy-efficient design play a major role to determine the building performance as well (Huat & Akasah, 2011). Considering all facts and current experiences there is therefore the need to conduct a study that assesses the knowledge and utilization of energy efficiency assessment tools for office buildings to control and enhance the efficient use of energy in Ghana.

1.3 Purpose of the Study

The purpose of this study was to assess the knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana.

1.4 Objectives of the Study

1. To determine the awareness of building professionals on energy efficiency assessment tools in their office building designs at Kumasi Metropolis.
2. To determine the factors that building professionals consider in their design to ensure efficiency in the usage of energy in Kumasi Metropolis.
3. To evaluate practices that improves energy efficiency in office buildings in Kumasi Metropolis.

1.5 Research Questions

1. What is the awareness of building professionals on energy efficiency assessment tools in their office building designs at Kumasi Metropolis?
2. What are the factors building professionals consider in their design to ensure efficiency in the usage of energy at Kumasi Metropolis?
3. What are practices that improves energy efficiency in office buildings in Kumasi Metropolis?

1.6 Significance of the Study

The research seeks to address the knowledge gap found in energy efficiency in building research by assessing the level of knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana. The knowledge on the utilization of energy efficiency assessment tools would enable the reduction in the degree of energy expended while sustaining or bettering the quality of services delivered in the buildings. A reduction in energy demand has the consequential effect of lowering energy costs. In view of the several prospects to significantly cutback buildings’ energy needs, the possible savings from energy efficiency in the building sector will make momentous contributions to lessening of energy utilization within an entire society. The research would help office or business owners and users to know the efficient use of office buildings to save energy and money for the business. To the other players in the construction industry such as the contractors, subcontractors, architects etc., it will provide them with the requisite ideas with regards to knowledge in building design and construction to appropriate energy efficiency. Finally, the study will also assist lecturers, students and individuals from different works of life as a basis for further research into the subject area of energy efficiency in buildings.

1.7 Scope of the Study

The study is centered on office buildings within the Kumasi Metropolis since Kumasi is the capital town of Ashanti Region of Ghana and the hub of most business activities and consequently has a lot of office buildings located in its suburbs. The research largely focused on construction managers, electrical engineers, mechanical engineers, architects. The study is tasked to find out awareness of building professionals on energy efficiency assessment tools in their office building designs, the knowledge of building professionals on the usage of energy efficiency assessment tools in their office building designs and energy assessment recommendations that primary improves energy efficiency in office buildings at Kumasi Metropolis.

1.8 Organization of the Study

This study is divided into five main chapters following from chapter one to chapter five. The Chapter One presents the background to the study, statement of the problem, aim and objectives of the study, research questions, significance of the study, the scope of the study, and organization of the study. The succeeding chapter gives an assessment of pertinent literature on the concept of energy efficiency assessment tools for buildings particularly office buildings. Various energy performance assessment methods are also examined and presented. The chapter three presents the philosophical dimensions and research approach used in investigating and collecting data for the study. The following chapter, presents the results from the primary data collection, analysis and the discussions of analyzed data. Finally, the concluding chapter, Chapter five, provides a succinct presentation on the summary of findings, conclusions, recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature related to the topic at hand. It considered energy consumption in Ghana, building energy efficiency in Ghana, energy performance assessment energy efficiency indicators, management of energy efficiency indicators, energy efficiency labels and standards, products covered by energy efficiency standards, energy efficiency targets, benefit of energy efficiency, barriers to energy efficiency and energy efficiency assessment tools.

2.1 Energy Consumption in Ghana

Ghana's population over the years has been on the increase with strides in economic growth; however, the same cannot be said of the energy situation (Essah, 2011). Statistics show that marginal increase has been seen in energy supply as compared to the burgeoning population growth (Essah, 2011). Currently it is estimated that 55% of Ghana's capacity to generate electricity is presently attributed to hydro-based sources; Akosombo (1,020 MW), Kpong (160 MW) and Bui (400MW) (Energy Commission Ghana, 2015). The remaining percentage of the energy supply is derived from thermal based plants in which the operation is based on using fuel sources such as natural gas and oil and converts energy stored in them into electrical energy (Energy Commission Ghana, 2015). The Navrongo Solar Farm a renewable source provides only 2.5 MW to the total supply (Energy Commission Ghana, 2015). It is reported that the total demand for electricity far exceeds the current available generation capacity. As at the year 2015, the current peak demand was about 2400MW, however only 1600MW of capacity was available at peak and 1400 MW at off-peak leaving a huge deficit of 800MW at peak (Energy Commission Ghana, 2015).

Key in energy supply increase is the addition of thermal sources to the nation-wide capacity to generate electricity. This comes with associated environmental hazards as this is linked with carbon emissions to the atmosphere. The Energy Commission Ghana (2007) has estimated that Ghana would require over 7 times its 2007 electrical power capacity by 2020 if it is to be successful in advancing its economy to a middle-income status. Rapidly advancing, particularly in developing countries, the building sector provides the biggest, most economical prospects for energy efficiency and also provides the greatest co-benefits. The marginal cost of causing an upsurge in the energy efficiency of a building is minimum in the period of construction. Empirical data points to the fact that particular building elements and the appropriate management and control of such elements provides for considerable savings in energy (Fall, 2010). In a broad sense, building energy can be divided into embodied energy and operation energy. Embodied energy makes reference to the energy used in the manufacturing and conveyance of building supplies in the erection of building, whilst operation energy makes reference to the energy requisite for retaining cozy conditions within buildings, water usage as well as powering. The focus of this study is on the operation energy and the section that follows will centre on this aspect.

2.2 Building Energy Efficiency in Ghana

The practice of energy efficiency within Ghana is not an entirely new concept. Records show that the first noticeable attempts came in 1975 after the first world oil price shock and in 1979 after supply disruptions occurred due to political activities taking place in

Ghana then (Energy Commission, 2007). These attempts included policies that allowed consumers to produce more with less energy emphasizing more on industrial electrical energy and fuel. The Energy Commission (2007) provides that the early attempts were discontinued as a result of the normalization of the supply situation. Despite this, initial study results showed a lot of potential for energy saving in Ghana, especially in the industrial sector. Various reasons were advanced for the decline of energy efficiency methods. Notable amongst them were the lack of enforcement; lack of expertise for the failure and non-availability of energy saving technologies on the local market (Energy Commission, 2007). Individual projects and case studies all confirm the huge potential existing in the demand side management. Some of the case studies include the various survey conducted on institutional buildings in Ghana to identify the level of electrical consumption and end-user patterns. However, this was not a critical issue then, due to low energy prices in the 1990's. This was particularly made evident by the donor agencies when GOG approached them for funding to increase the nation's power generation capacity (Energy Commission-Ghana, 2007).

The donor agencies proposed the option of demand side management rather than concentrating on the supply-side (Energy Commission Ghana, 2007). Focus on demand side management within the Ghanaian environment has pivoted on the appliance efficiency, particularly looking at the practices by Energy Foundation (Essah, 2011). This has resulted in the move to use Compact Fluorescent Lamps (CFL) and replacement of old refrigerators. The introduction of the Energy Efficiency Standards and Labelling Regulations, 2005 (LI1815) requires that a label is displayed which informs on the energy efficiency rating of the product (Energy Commission Ghana, 2016). The label is based on the star labelling principle or the energy star, with a maximum of five stars that can be awarded, thus the more the stars the higher the efficiency (Energy Commission Ghana, 2016). Currently, in Ghana importers and vendors of both air conditioners and CFL have been mandated by the Appliance Standards and Labelling regime to deal in products that meet the performance and efficiency requirements as postulated by the Ghana Standard Authoritys (Energy Commission Ghana, 2016). It is also reported that import duties and VAT on Compact Fluorescent Lamps were removed by the Government in April 2003 (Energy Commission Ghana, 2016). This directive was to ensure this popularly known energy saving lamps were more accessible and affordable to the average Ghanaian in a move to ensure energy efficiency and reduce electricity cost. The Energy Foundation, the Energy Commission and the Ghana Standard Authority have also introduced a Performance and Efficiency Standard for Compact Fluorescent Lamps (CFL) in a bid to protect consumers from substandard and fake CFL which have penetrated into the Ghanaian market (Energy Commission Ghana, 2016). Clearly, results emanating from such activities have had some impact on energy efficiency practices. Unfortunately, studies hardly exist in the assessment of the impact and the growing energy demands show more drive to look at the total energy consumption.

2.3 Energy Performance Assessment

Energy performance is a phrase used to specify the quantity of energy utilized in actuality or projected to satisfy the differing demands connected to a homogenous usage of the buildings (Poel *et al.,* 2007). This amount is mirrored in one or more numeric indicators referred to as Energy performance indicators (EPI). Most frequently used in many buildings and globally, is energy use intensities, i.e. kWh/m2. The energy performance of a building is largely decided by six main variables: climate, building envelope, building services and energy systems, building operation and maintenance, occupants' activities and behaviour and indoor environmental quality provided, as placed in International Energy Agency (IEA) Annex 53 project (IEA, 2000). In the building sector, energy performance evaluation approaches can be placed in a two-fold categorization: performance-based and feature-specific approaches. These two approaches adopt different methods of assessing building energy. The performance-based approach looks at comparing performance indicators (e.g., Energy Use Intensities or carbon dioxide emission) against yardsticks to inform on energy efficiency level. With the feature specific approach, examination is done to check whether certain specific features are met for credits to be awarded. The energy efficiency level is then determined by the total awarded credits (Lee & Burnett, 2008). These two have their advantages and their disadvantages. Wang *et al.,* (2012) argues that the performance-based approach is preferable as computations are easily quantifiable based on performance indicators. However, they averred that such an approach is cumbersome to develop as it includes firstly, the establishing of a suitable method of quantification and its associated criteria.

2.4 Energy Efficiency Indicators

Analyses of energy efficiency usually include taking several placements of systems indicators and later grouping and evaluating them together. However, their effectiveness is always subject to the stipulation, particularly regarding, data quality and reliability, as well as availability (Bosseboeuf *et al*., 1997). Placement of indicators shows that there are 4 groups of energy efficiency indicators.

i. Thermodynamic: This group of indicators relies on the measurement of data by thermodynamic science applications while simple ratios and more complicated measures are used to measure the actual energy usage of an ideal process.

ii. Physical-thermodynamic: A much-improved version of thermodynamic units. However, the output is measured as a physical quantity. The purpose of using a physical approach is to measure severing parameters in terms of passenger miles or tones of product.

iii. Economic-thermodynamic: Another hybrid version of energy efficiency indicator where the input is still being measured in terms of thermodynamic units. The output meanwhile is measured according to market prices.

iv. Economic: A measure of this indicator defines changes in energy efficiency by the market values. Both input and output are in terms of the market prices. Specific energy consumption (SEC) reduction is defined as the improvement of energy efficiency (EE) by industrial players.

SEC is one of the EE indicators as it gives a ratio of energy consumption to the beneficial output (physical) of a process. SEC also can serve as an energy intensity indicator, especially for single processes that generate one single product. The fifth group with addition to Patterson’s definition is environmental EE indicators. They are special for measuring energy related specific emission which is direct to environmental issues. However, these indicators only allow for the comparison of the efficiency of processes which require the same end use service. It is a very evident that the energy quality problem is a fundamental problem across all energy efficiency indicators when trying to compare process with different quality inputs and outputs (Oikonomou *et al*., 2009).

2.5 Management of Energy Efficiency Indicators

Energy efficiency indicators, while functioning to provide information about EE consumption and its end results, also function to compare and provide benchmarks for present and future technologies. Benchmarking is quite a tedious process, where external influences that affect economic, financial and other non-includable parameters have to be excluded from the judgment (Yunchang, 2008). The influence of external factors tends to dynamically increase which can easily frustrate assessments (Bosseboeuf *et al*., 1997). According to Oikonomou *et al*., (2009) the main problems with EE indicators are.

i. Inhomogeneous data,

ii. Geographical differences that make the ratios and indicators vary continuously, and

iii. Interpretations of ratios that diverge accordingly

The evaluation of EE indicators heavily depends on the transparency of the data collected and calculation of indicators. In order to reach these 3 targets are identified as follows IEA International Energy Agency (1997).

i. Progressive harmonization of data and regularity of updated database for data management.

ii. Defining the status of common technology for EE assessment. This can also be applied on the consequences on Carbon dioxide (CO_2) emissions and the related ratios.

iii. Acquiring necessary mechanisms in order to regularize the findings to the real time experiences. Harmonization of interpretations is a necessity to ensure the reliability of indicators produced from common database.

2.6 Energy Efficiency Labels and Standards

Energy efficiency standards and labels usually come together. Standards are technical settings of energy efficiency, while labels provide guidelines to consumers to select more efficient appliances when they make a purchase (Konstantinos *et al*., 2008).

2.6.1 Labels

Energy efficiency labels are educational labels that are affixed to explain the energy performance of manufactured products, and to give the consumer the necessary data for making knowledgeable purchases (Konstantinos *et al*., 2008). According to Mahlia (2004) there are three kinds of labels.

i. Endorsement Labels: Fundamentally given according to products that meet specified criteria.
ii. Comparative labels: Allows a customer to evaluate product performance against similar products using discrete categories of performance or a continuous scale.
iii. Information-only labels: Provides data on a product's presentation.

Energy labels can stand alone or balance energy standards (Bertoldi, 2000). They provide information that allows consumers to select efficient products. The effectiveness of energy labels is very dependent on how they present information to the consumer. The sample of European label is shown in Figure 2.1a where it will tell you about the energy efficiency of electrical appliances. Grade A++ is now the most efficient, and Grade G is the least efficient. While Figure 2.1b shows energy, label used in Malaysia where the number of stars reflect the most efficient.

(a) (b)

Figure 2. 1: Energy Efficiency label (a) European Energy Level and (b) Malaysia energy level

2.6.2 Standards

There are several definitions of energy efficiency standards. According to Greg *et al.,* (2006) an energy standard is defined as a minimal requirement for efficiency, or the measured energy consumption for the household appliance. Duffy (1996) stated that the energy efficiency standards are government mandated standards that define minimum levels of efficiency or maximum levels of energy consumption and that must be met by all products sold in the particular authority. However, definition given by McMahon and Turiel (1997) which points out the energy efficiency standard as the prescribed energy performance of a manufactured product, sometimes keeping out the manufacture of products with less energy efficiency than the minimum standards. There are three types of energy-efficiency standards.

i. Prescriptive standards: Requiring that a particular feature or device be installed (e.g., insulation) or not installed (e.g., pilot lights) in all new products;

ii. Minimum energy-performance standards (MEPS): Prescribing minimum efficiencies (or maximum energy consumption usually as a function of size or capacity) that manufacturers must achieve in each and every product, specifying the energy

iii. performance but not the technology or design details of the product; and

iv. Class-average standards: Specifying the average efficiency of a manufactured product, allowing each manufacturer to select the level of efficiency for each model so that the overall average is achieved.

2.7 Products Covered by Energy Efficiency Standards

Products covered under National Commission on Energy Policy (NCEP) as shown in Table 2.1. In normal condition heating and cooling consumed more energy utilization compare to others and in some case; it contributed to nearly 80% of energy bill (Rosenquist *et al.,* 2004). The standard which was implemented includes those set by the legislation as well as standard adopted by DOE through rulemaking. The impact cover primary energy savings and water saving, net present value of customer benefits and estimated reduction in CO_2 (Meyers *et al*., 2011).

Table 2. 1: Products covered by energy efficiency standards

Heating and Cooling	Residential Central Air Conditioners and Heat Pumps Room Air Conditioners Commercial Unitary Air Conditioners and Heat Pumps Direct Heating Equipment Residential Furnaces, Boilers Mobile Home Furnaces Swimming Pool Heaters
Cleaning & Water	Clothes Washers Clothes Dryers, Dishwashers Water Heaters Faucets, Showerheads

	Toilets/Water Closets, Urinals
Lighting	Fluorescent Lamps and Ballasts Incandescent Reflector Lamps High-Intensity Discharge Lamps
Food Preservation and Cooking	Refrigerator Freezers Kitchen Ranges and Ovens
Other Products	Distribution Transformers Small Electric Motors Televisions

Source: (Meyers *et al*., 2011)

2.8 Energy Efficiency Targets

Energy efficiency practices could the solution to ensure energy is available to satisfy all demands, to ensure energy is used and supplied with minimal cost/ environmental impact and to ensure energy is not wasted. The challenge of achieving these targets is the driving force for the development of computer-based energy management tools that enable users to understand how energy is consumed within their properties and how they can improve the use of energy resources for effective task processing (Anwar *et al*., 2007). The Energy Efficiency Initiative, a report published by the IEA, Danish Energy Agency and the Energy Charter 1999, identified four most essential elements of a normal framework for effective energy policies;

i. Focus market interest on energy efficiency Actions include: Fostering voluntary agreements, establishing and enforcing building codes, minimum energy performance standards, integrating energy efficiency in procurement practices and using government purchasing to stimulate the market for advanced technology.

ii. Ensure access to good technology Actions include: Encouraging the development, adaptation and diffusion of energy efficient technology, improving district heating systems and expanding the use of combined heat and power.

iii. Develop and maintain a supportive institutional framework: Actions include: Integrating energy efficiency in sectoral policies and ensuring the availability of impartial expertise.

iv. Act to ensure continuity: Actions include: Establishing policy clarity, demonstrating leadership, implementing effective evaluation, monitoring techniques and strengthening international collaboration

Other outcomes of the implementation of energy efficiency in industries can be given as (Jan, 2008).

a. Industries became aware of the actual and rational energy utilization performance, as well as Energy Efficiency and Energy Conservation measures that can be applied to improve energy utilization efficiency through the establishment of energy use norms for industrial sub-sectors and processes.

b. Industries comply with regulations / guidelines designed to encourage the use of energy efficient equipment and practices.

c. Awareness about, and attitude towards, energy efficiency and environmental improvement by industries widespread.

d. Industries are using and benefiting the local energy support services Energy Service Companies (ESCOs) in the implementation of their energy efficiency projects.

e. Industries are implementing proven and cost-effective energy efficiency technology projects.

f. Industries utilize locally manufactured equipment with comparable efficiencies to imported quality industrial equipment.
g. The energy authorities is able to increase its capacity and capability in providing energy advisory services to the public and the private sectors

A proposal by Escriva to impose seven actions of the base improvement in energy efficiency in commercial building had shown a considerable financial saving is being made. These actions include an accurate operational data measurement, a proper schedule, automatically monitored of the consumption of electricity, individual responsibility for energy use in each building, proactive action to increase energy efficiency, facilities modification to enable easier energy management and an excellent communication between user and the building managers. Even many national governments and international organization have developed new regulations, what is lacking today is the universal energy efficiency index for building. In order to address this issue Gonzalez *et al*., (2011) had proposed an energy efficiency index for buildings that relates the energy consumption within a building to reference consumption. The proposed energy index can be obtained in a simple manner by combination standard measurement, simulation and public data base; furthermore, the index is upgradable whenever new data are available. It will be reflected as a price raise for the end product and in turn make the firm less competitive on the market (Sardianou, 2008). Other economic barriers are the internal rivalry between the different profitable investments the firm can choose from (Groot *et al.*, 2001) and the bureaucratic procedures to get financial support for EEIs (Sardianou, 2008). Some investments are never realized simply because there are other investments that are more important (Groot *et al.*, 2001).

2.9 Energy Efficiency Assessment Tools

Based on research performed by Hastings and Wall (2007), systems for environmental evaluation for buildings, processes and products range from a single aspect to the multi-aspects evaluation. The authors have defined three main approaches for sustainability evaluation of building performance; cumulative energy demand (CED) systems: It evaluates the energy consumption, life cycle analysis (LCA) systems: It considers the environmental aspects only, and total quality assessment (TQA) systems, which evaluate ecological, economic and social aspects; it is also known as Sustainability rating systems such as LEED and BREEAM.

CED and LCA have the quantitative approach of measurement, whereas TQA could have both the qualitative and quantitative evaluation approach (Hastings and Wall 2007). Globally, there have been many studies in the field of green building in both developing and developed countries. Zuo and Zhao (2014) suggest that among most of the green building rating systems studied, there are mutual attentions and emphases through allocating consideration to two main aspects (a) process (method for process fulfillment) (b) outcome (method for process assessment).

There are over forty 'total building energy efficiency assessment systems' which are commonly called green building rating systems; such as LEED in United States, BREEAM in UK, CASBEE in Japan, Minergie in Switzerland, HK Beam in Hong Kong, the Pearl Rating System for ESTIDAMA in Abu Dhabi, United Arab Emirates, and Green Pyramid Rating System (GPRS) in Egypt.

2.9.1 Building Research Establishment Environmental Assessment Methodology (BREEAM)

Building Research Establishment Environmental Assessment Methodology (BREEAM) is the pioneer assessment system, established in 1990. Its introduction and control were through the Building Research Establishment (BRE) in the United Kingdom (BREEAM, 2015). The launch of the first version of BREEAM for offices was in 1993. In 1998, the second version was released covering a wide range of building types. Furthermore, the year 2014 witnessed the release of the latest version of BREEAM UK New Construction (Non-Domestic). Based on statistics performed in 2014, over 534,056 buildings are BREEAM certified whereas the number of registered projects for assessment are around two million (BREEAM, 2015). Furthermore, BREEAM is applicable in 72 countries (BREEAM, 2015). BREEAM has four assessment tools that can be used at different stages of a building's life cycle. BREEAM Design and Procurement (D&P) can be used during the design stage of a building renovation for a new build or extension project. The Post Construction Review (PCR) is carried out once the construction is complete to verify the D&P assessment. The Fit Out assessment is employed during major renovations of existing buildings and a Management and Operation (M&O) assessment evaluates the performance of a building during its operation (Saunders, 2008).

BREEAM works by awarding credits in 10 categories for meeting a series of performance criteria that, if complied with, would reduce the building's negative environmental impact and increase its environmental benefits. The total number of credits awarded in each category is multiplied by an environmental weighting factor, which takes into account the relative importance of that category. The category scores are then added together to produce a single overall score on a scale of Pass, Good, Very Good, Excellent and Outstanding. A star rating from 1 to 5 also is provided. BREEAM International certification levels/schemes also use star rating systems: 1 Star – pass: 30%; 2 Stars: - good: 45%; 3 Stars: - 55%; 4 Stars: excellent: 70%; 5 Stars – outstanding: 85% (Saunders, 2008). The strengths of BREEAM are as follows: it allows comparison and benchmarking of different buildings, can be independently assessed, is adjusted to European and U.K. legislation and U.K. culture, and can assess any building with the BREEAM bespoke version. However, the weaknesses of BREEAM are that it requires very exact requirements, the weighing system is complex, a market profile is required and has a high cost of compliance.

2.9.2 Leadership in Energy and Environmental Design (LEED)

LEED stands for Leadership in Energy and Environmental Design, a green building rating system originally developed in 1998 by the U.S. Green Building Council (USGBC) to offer a well-known standard for the construction industry to evaluate the environmental sustainability levels of building designs (USGBC, 2014). The announcement of the latest version of LEED was on November 20th, 2013; however, projects can still register and work with the older version of LEED until October 2016. For a project to receive LEED certification, it has to satisfy prerequisites and earn points to achieve different levels of certification. Prerequisites and credits differ for each rating system, and teams choose from among them according to their project type and stage. There are five different schemes of LEED rating system, which are as follows:

1. Building Design and Construction
2. Interior Design and Construction
3. Building Operation and Maintenance

4. Neighborhood Development
5. Homes (USGBC 2014).

The LEED Assessment relies on evaluating eight main categories which are; (1) Location and Transportation, (2) Sustainable Sites, (3) Water Efficiency, (4) Energy and Atmosphere, (5) Materials and Resources, (6) Indoor Environmental Quality, (7) Innovation, and (8) Regional priority; see Appendix G. Projects applying for LEED certification should consider these categories and their specific prerequisites. The project must then pursue a set of credits in order to earn points. Additionally, some of the requirements under selected categories are obligatory and required in order to receive LEED certification. The number of points the project earns determines its level of LEED certification. A project that earns 40-49 points from the different categories would be ‘Certified’, whereas a project that earns 50-59 points is ‘Silver’, a project with 60-79 points is ‘Gold’ and a project with more than 80-110 points would be ‘Platinum’ (USGBC, 2014).

2.9.3 Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)

With the establishment of the international agreement ‘Kyoto protocol’, that commits its members to adhere to Greenhouse Gas (GHG) emission reduction targets, CASBEE ‘Comprehensive Assessment System for Building Environmental Efficiency’ was established. The establishment of this rating system was through a joint collaboration between industrial, academic, and governmental entities with the support of the Housing bureau, a branch of the Ministry of Land, Infrastructure, Transport, and Tourism (MLITT) (IBEC, 2014). CASBEE’s mission is to evaluate and assess the environmental performance of buildings. The quality of the building, interior comfort, materials usage, energy efficiency, and internal power loads are all included in CASBEE assessment. There are five possible grades in the CASBEE rating: Superior (S); very good (A); Good (B+); slightly poor (B-) and Poor (C). Furthermore, CASBEE has several tools, which are known as CASBEE family. These tools can work according to the different project scales: construction such as residential and non-residential, and urban and district in the range of town and city development (IBEC, 2014).

The first assessment tool of CASBEE family was CASBEE for Office, completed in 2002. In July 2003, CASBEE for New Construction was established and one year later, CASBEE for Existing Buildings was created. The last tool in the CASBEE family was CASBEE for Renovation, launched in July 2005. The following three principles represent the basis for the CASBEE assessment tools: 1) Comprehensive assessment throughout the life cycle of the building, 2) Assessment of the "Building Environmental Quality (Q)" and "Building Environmental Load (L)" and 3) Assessment based on the newly developed Building Environmental Efficiency (BEE) indicator (IBEC, 2014). Furthermore, CASBEE employs the value of Building Environment Efficiency (BEE) in the evaluation of the sustainability of a building (Wong et al. 2014). The approach employed in CASBEE evaluation is through the concept of Building Environment Efficiency (BEE) with weighting coefficients; see Appendix I for a list of CASBEE New Construction 2014 scoring criteria. BEE is the core of CASBEE by plotting results on a graph to determine the building final score. The uniqueness of CASBEE relies on assessing multi aspects and deriving the final score from the relation between those aspects (Alyami and Rezgui, 2012). Similarly, Gu *et al.*, (2001) consider CASBEE as the most advanced assessment system covering almost all issues during building construction stage.

2.9.4. The Pearl Rating System - ESTIDAMA

Sustainability is ‘Estidama’ in Arabic. Abu Dhabi, the capital of United Arab Emirates, has initiated the ‘Estidama’ with the aim of transforming this emirate into an icon of sustainability (UPC, 2010). The Pearl Rating System (PRS) is the green building assessment system developed by Abu Dhabi Urban Planning Council in 2007 (UPC, 2010). The aim of this system is to employ the basic concepts of green architecture through highlighting the need for balanced use of land, materials, energy, and water (UPC, 2010). The mission and vision of PRS are to create a sense of equilibrium between Estidama’s four aspects: (1) environmental, (2) economic, (3) cultural, and (4) social by creating more sustainable communities, cities and global enterprises (UPC, 2010). The Pearl rating system is divided into seven categories which are: (1) Integrated Development Process, (2) Natural Systems, (3) Livable Buildings, (4) Precious Water, (5) Resourceful Energy, (6) Materials, (7) Innovating Practice. This rating system divides sections in mandatory and optional credits. The achievement of the mandatory credits is a prerequisite in order to receive the minimum pearl level ‘1 pearl’. A higher pearl rating is achievable by meeting all mandatory levels along with further credits as shown in Table 2-4 (UPC, 2010). It is obligatory that buildings in Abu Dhabi achieve a minimum of ‘1 pearl’ rating, whereas buildings financed by the government have to achieve a minimum of ‘2 pearls’ rating.

2.9.5 Global Sustainability Assessment System (GSAS)

Global Sustainability Assessment System (GSAS), which was formerly known as QSAS, was developed by Qatari Diar Real Estate Investment Company with the purpose of promoting environmentally responsible building practices in Qatar and the whole Middle East region (GSAS, 2013). The main objective of GSAS is the creation of a sustainable built environment that reduces the impact of buildings on the environment through maintaining and considering the regional requirements and needs (GSAS, 2013). The approach that was followed in the creation of this system was through initially considering and reviewing more than 140 green building rating systems, tools and guidelines around the world and then reassessing the most relevant and comprehensive schemes (GSAS, 2013). There are three types of GSAS certification; (1) design and build certification, (2) construction management certification, and (3) operations certification. Furthermore, there are various schemes and publications of GSAS assessment, which are: (1) District and Infrastructure, (2) Commercial, (3) Mosques, (4) Neighborhood, (4) Parks, (5) Residential/Group residential, (6) Education, (7) Hotels, (8) Light Industry, (9) Sports, (9) Railways, (10) Healthcare, (11) Workers' accommodation, (12) Existing buildings, and (13) bespoke.

There are eight categories in GSAS system, with direct emphasis on mitigation approaches, outlined as follows (GSAS, 2013):

1. [UC] Urban Connectivity: Urban considerations during building planning phase.
2. [S] Site: Existing site conditions control during the building's development.
3. [E] Energy: Over the building's service life, control its depletion of fossil energy.
4. [W] Water: Control the overall water resource and the impact of buildings on it.

5. [M] Materials: Control the impact of the buildings use of materials on the environment.
6. [IE] Indoor Environment: Control the building's indoor environment.
7. [CE] Cultural and Economic value: Maintain and enhance the building's cultural and economic value.
8. [MO] Management and Operation: Define the building’s management and operations plan. Moreover, there are various aspects under each of the categories in Figure 2.3. The scoring mechanism in GSAS is measured on the scale of -1 -2 3 [-1, 0, 1, 2, 3]. Only for the scoring in the ‘Urban Connectivity and Management’ category, it must be either 0 or 3 (GSAS, 2013). A negative scoring makes an emphasis on the criteria that has a harmful impact on the environment; thus, promote trading-off of that impact and thoroughly considering the building performance in remaining criteria.

2.9.6 Excellence in Design for Greater Efficiencies (EDGE)

Excellence in Design for Greater Efficiency (EDGE) was a voluntary program developed by the International Finance Corporation (IFC), a member in the World Bank Group, demands reduction of 20% as an improvement. In July 2013, the launch of EDGE rating system was during an event called 'Transforming the Built Environment in Emerging Markets'. During the event, a partnership between The World Bank and IFC was established aiming at promoting and pushing the construction of green buildings in emerging markets (IFC, 2015). The main mission of the EDGE tool is to ‘encourage resource-efficient building growth by proving the business case for building green’ (IFC, 2015). Cost savings and greenhouse gas reductions, which are demonstrated in the EDGE tool, are achievable through the different choices that are offered by the software such as using buildings materials with lower environmental impact, efficient Heating, Ventilation, and Air Conditioning (HVAC) systems, natural ventilation, and water-saving plumbing (IFC, 2015). Through the several case studies that are available on the EDGE-IFC website, it is clear that monthly heating, electricity, and water bills; the amount of the materials used in the construction were minimized which would essentially have an effect in reducing the building impact on the environment (IFC, 2015). The newest version of EDGE (version 1.1) was available on May 15th, 2015. Accordingly, the employment of Edge software in the building design phase can determine the potential attainable cost savings by designing an EDGE building. The target of the EDGE green building program is to transform the traditional thinking about the building construction into a sustainable way of thinking; making building designers and users believe and understand that efficient buildings are 'practical and necessary' and not a luxury (IFC, 2015).

The EDGE online software provides default settings for projects based on each building type, function and use (IFC, 2015). Through the reduction of at least 20% in energy, water, and materials and according to the different scenarios provided by Edge, lower costs are achievable than conventional buildings. Among the factors that support in minimizing the resource consumption are: (a) reduced window to wall ratio, (b) energy-efficient lighting, and (c) superior HVAC systems (IFC, 2015).

2.9.7 Green Pyramid Rating System (GPRS)

The Green Pyramid rating system was introduced according to the initiative that was taken by the Housing and Building National Research Center to establish the Green Building Council in 2009 (GPRS, 2011). The objective of GPRS is to provide green credentials for the assessment of buildings in Egypt through raising awareness of the necessity of green buildings according to the Egyptian context and conditions (GPRS, 2011). Its target is to allow innovative solutions and designs in the building sector in Egypt (GPRS, 2011). The focal intention of this rating system is the assessment of new buildings at their design stage and post construction stage. The methodology employed in the GPRS scoring system of GPRS is, a point weighting system divided under seven categories. There are three levels of green building certification in GPRS: (1) Silver Pyramid, (2) Golden Pyramid, and (3) Green Pyramid. A minimum of 40-49 points is required for any new construction building to receive 'GPRS certified'. Accordingly, the award of certifications to projects relies on their total points; for example, for a project with 50-59 points, it will receive a silver certification whereas a project with 60-79 points will receive the Gold pyramid. The highest level of certification is 80 points and more awarding the project 'Green Pyramid' certification (GPRS, 2011).

2.9.8 Sustainable Building Tool (SBTool)

The International Initiative for a Sustainable Built Environment is the entity that developed SBTool rating system. This assessment system allows evaluation in four distinct stages, which are; (1) Pre-design; (2) Design; (3) Construction; (4) Operations. The scope of the SBTool is adjustable allowing it to have criteria's ranging from 120 down to 6 according to the size and requirement of buildings (IISBE, 2015). This assessment system covers issues related to sustainable building rather than aspects related to green building only (IISBE, 2015). Furthermore, SBTool considers regional and site-specific conditions allowing the systems users to adapt according to regional priorities and requirements (Sev, 2011).

2.9.9 Green Star

Green Star is a voluntary building rating system that evaluates the environmental design and construction of all Australian buildings. The Green Building Council of Australia (GBCA), a national, non-profit, member-based organization that is committed to developing a sustainable property industry for Australia, launched Green Star in 2002. Members represent a broad spectrum of both the building industry and governments across Australia. The GBCA objective in creating Green Star is to encourage the Australian building industry to embrace sustainable building by promoting green building programs, technologies, design practices and operations. New Zealand and South Africa have adapted Green Star to rate and certify sustainable buildings in those countries (GBCA, 2009; NZGBC, 2009). Technical manuals, which have been developed for the rating tools, are a key element of the Green Star rating system. These manuals provide detailed descriptions for each credit, including aim or objective, credit criteria, compliance requirements, additional guidance, background information and references for further information (GBCA, 2009). Although Green Star rating tools are available for self-assessment, a design, project or building cannot publicly claim or promote a Green Star rating or use the Green Star rating logo unless the GBCA has validated the project's achievement through a formal assessment (GBCA, 2009).

During the formal assessment process, Green Star offers applicants two opportunities to receive a rating. The first step is for the project team to select which rating tool is most appropriate and demonstrate that the project meets all four of the rating tool's eligibility requirements (GBCA, 2009). The four-rating tool's eligibility requirements are space use, spatial differentiation, conditional requirements and timing of certification. The Assessment Panel may award a rating of one to six stars. Projects that are awarded one to three stars may not be certified, but those awarded with four or more stars may be certified and are recognized as follows: 4 Star Green Star Certified Rating (score of 54 to 59) – Best Practice; 5 Star Green Star Certified Rating (score of 60 to 74) –Australian Excellence; 6 Star Green Star Certified Rating (score of 75 to 100) – World Leadership (GBCA, 2009). The strengths of Green Star are as follows: there are mandatory requirements, external benchmarks and can be customized, however the weaknesses of Green Star are that there are no baseline models and no recertification.

2.9.10 Indian Green Building Council (IGBC) Green Homes Rating System

Indian Green Building Council (IGBC) Green Homes is the first rating programme developed in India, exclusively for the residential sector. It is based on accepted energy and environmental principles and strikes a balance between known established practices and emerging concepts. The system is designed to be comprehensive in scope, yet simple in operation (www.igbc.org; www.igbc.in). Measurement is in five areas: sustainability site development; water savings; energy efficiency; materials selection and indoor environment quality. The strength of Green Homes Rating System is that it has a strong social component; however, the weakness of Green Homes Rating System is that that there is an increase in cost of construction.

2.9.11 Hong Kong Building Environmental Assessment Method

Hong Kong Building Environmental Assessment Method (HK-BEAM) developed in 1996 by the BEAM Society. HK-BEAM rewards buildings that are built operated and maintained using sustainable building practices throughout the buildings' lifecycles. But because Hong Kong is a subtropical, high-density and high-rise community, HK-BEAM emphasizes indoor environmental quality (IEQ) more than other green building rating systems. To that end, HK-BEAM embraces (in order of priority) safety, health, comfort, function and efficiency while protecting local, regional and global ecosystems throughout a building's life cycle (BEAM Society, 2003). These standards apply to residential, commercial, industrial and institutional buildings (HK-BEAM Society, 2004). An interim update of the HK-BEAM standards is underway to place more emphasis on reducing greenhouse gas emissions. A new standard, HK-BEAM Commercial Interiors, also is in the works. In addition, online assessment tools are under development that will allow applicants to obtain a preliminarily score and BEAM rating of the new / existing building projects. These tools are user-friendly self-assessments that will automatically screen out the non-applicable credits (BEAM Society, 2003). The strength of HK-BEAM is that it focuses on environmental and economic issues; however, the weakness of HK-BEAM is that it does not have a socio-cultural category.

2.10 Factors Building Professionals Consider in their Design to Ensure Efficiency in the Usage of Energy

To promote the utilization of energy efficiency tools in design practice, the necessary inputs and whether those necessary inputs can be easily acquired or not must be considered. Some examples of these necessary inputs are presented in Table 2.2. However, the use of the thermal load as the objective function is focused on in this study. Thus, only the inputs related to the thermal load are listed for these tools. The collected necessary inputs are divided into three large categories: weather data, building geometry data and building properties (BP) data. BP data are defined as the non-geometrical inputs required by energy models (Cerezo *et al.*, 2014). Both simple analysis programs and Building Information Modelling (BIM) relevant programs use some approaches based on the hourly climate data to represent the standardized annual climate. Thus, users need to know only the location of their project. Regarding geometry data, a simple method with the capacity of converting 2-dimensional (2D) building models to the representative "shoebox" thermal models has been described (Dogan & Reinhart, 2013). In addition, the "simulation domain model" is able to exchange data between the 3-dimensional (3D) BIM software and the simulation domain and makes it possible to directly acquire building information to reduce the efforts required to handle geometry inputs (Donnell *et al.,* 2012). The huge progress of typical meteorological years and the BIM technique extensively simplify the setup of weather and geometry inputs. Hence, an effective solution to set up BP data is urgently required. BP data can be further divided into general data, construction data, internal load data and conditioning data. General data represent the building application and site information, including terrain and surrounding building. A majority of construction data are used to describe the building material properties, which are specified as the properties of opaque envelope and glazing. The rest of the construction data are used to describe the dimensions of the openings. The dimensions of the openings are expressed as the window-to-wall ratio (WWR). Internal load data are composed of the internal heat gain density and their corresponding schedules. Conditioning data are composed of two groups. One group comprises the indoor environment controlling data to maintain the comfortable level of occupants. The other group comprises the passive design strategies, such as ventilation and shading devices. General data can be completely obtained from the client demand, even during the very early design stages. Besides general data, a part of internal load data and indoor environment controlling data within the conditioning data also depend on the client demand. The establishment of remnant BP data can be greatly simplified by BP templates (Cerezo *et al.*, 2014).

The BP templates proposed for BPS are defined as a comprehensive database of the thermal zone attribution data. The utilization of BP templates can greatly reduce the time consumption and the risk of error. The predefined data in BP templates mainly originate from the reference design guideline and experience. Building material properties data in construction data and the remnant indoor environment controlling data in conditioning data can be precisely obtained through the BP templates. It is explained that such data in BP templates are from the design guideline. All of the BP data mentioned above can be acquired from reliable sources, as shown in Figure 2.2.

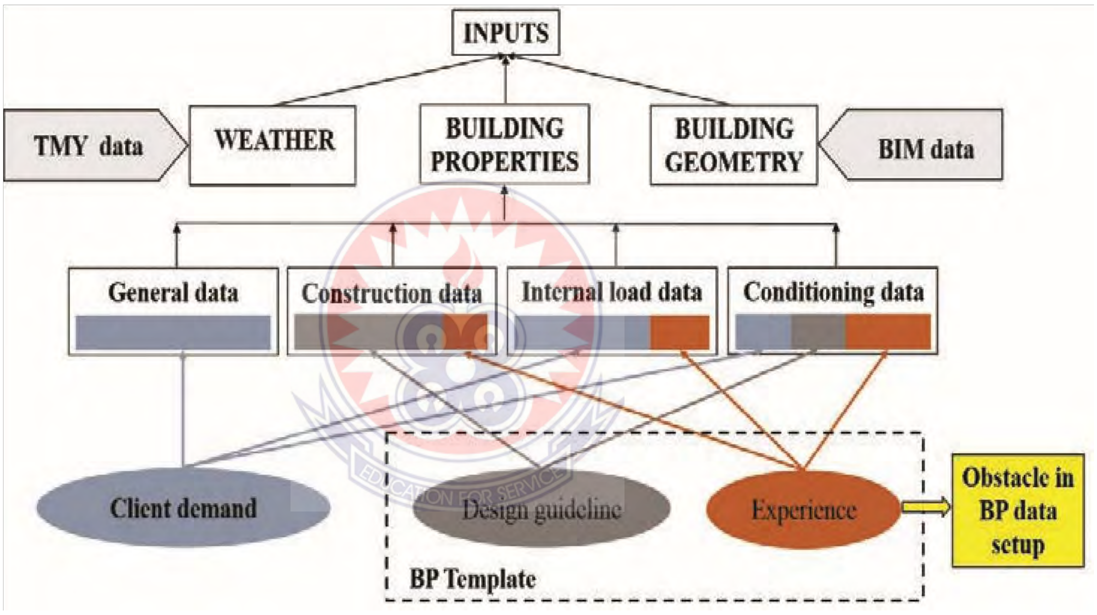

Figure 2. 2: Reliable sources of building properties data

However, some data without reliable sources also exists. Those data are generally determined by experiences, such as WWR, belonging to construction data, and shading device and ventilation strategies, belonging to conditioning data. The lack of measure to efficiently and rapidly establish those data is recognized as the obstacle in the process of BP data setup. The target percentage glazing, shade depth, target percentage skylight and conceptual construction mass glazing was reported to be very sensitive to the predicted results and should be carefully given in the early design stages. Such parameters are called energy setting parameters (Lin & Gerber, 2014). Energy setting parameters cannot be solely determined by uniform standards or design guidelines. The issues involved with energy setting parameters are highlighted by the example of setting up the WWR. However, the analysis results of case studies indicated that the optimal WWR was greatly influenced by the building design conditions, such as the building scale, location, and operation mode (daylighting and natural ventilation). For a building with a relatively large floor area and space depth, the largest WWR was found to be the best solution (Hiyama, 2015). As a consequence, an effective measure must be developed to determine energy setting parameters that cannot be determined by a regular standard. One feasible method is to reuse the BIM data of past well-designed projects to generate optimal default values during the early design stages (Hiyama *et al.,* 2014). It is critical to find the link between a new project and past projects for such data inherit. This link refers to not only the building configuration but also the operation mode. Therefore, the exploration of design conditions sensitive to energy setting parameters is necessary to generate robust default values. The authors plan to perform relevant studies regarding this issue in the future.

Table 2. 2: Necessary inputs/factors for energy efficiency assessment tools

SN	General Input	Factors
1	Weather data	Location
		Outdoor temperature
		Wind Speed
		Wind direction
		Solar radiation
2	Building geometry data	Orientation
		Volume
		Number of floors
		Floor dimension
		Interior wall length
		Floor areas
		Exterior wall areas
		Internal wall areas

			Roof areas
			Ground floor areas
			Window areas
			Atrium dimensions
3	Building properties data	General data	Application
			Terrain information
			Surrounding building
		Construction data	Exterior wall properties
			Roof properties
			Floor properties
			Interior wall properties
			Thermal capacity of construction
			Glazing properties
			Frame properties
			Exterior wall/roof color
4	Internal load data		Occupation density
			Occupation schedule
			Equipment density
			Equipment schedule
			Lighting density
			Lighting schedule
			Total internal load
5	Building properties data Conditioning data		Heating set points
			Cooling set points
			Heating season
			Cooling season
			Over temperature limit
			Initial building temperature
			Blind
			Artificial lighting type
			Ventilation type
			Window opening setting temp.
			Window opening parameters
			Mechanical ventilation rates
			Natural ventilation rates
			Infiltration rate
			Shading device

2.11 Energy Assessment Recommendations that Primary Improves Energy Efficiency in Office Buildings

Several energy saving features presented in Table 2.3 were identified as feasible options based on ease of installation and applicability to most building types. Other features were included in this study to provide a “measure of opportunity” for additional energy savings (Raustad *et al.*, 2008). Selected features cover a range of categories: building envelope, lighting, Heating, Ventilation, and Air Conditioning (HVAC), equipment, indoor air quality, and solar. Each of the features are described below in further detail. Advanced energy design guides (AEDG) recommendations for building materials and equipment were used as a basis for energy saving feature selection (ASHRAE, 2007).

Table 2. 3: Energy Saving Features Selected for Study

Feature	Property	Option Description
Roof	Reflectance Emittance	Roof Only
Wall	Reflectance	Wall Only
Window	U-value Overhang	Window Only
Lighting	90% Power Density	Lighting Only
	75% Power Density	75% Lighting
HVAC	System Efficiency	AEDG HVAC
	Fan Efficiency	HiEff Fan
Equipment	90% Power Density	90% Equipment
Outside Air	85% Outside Air	85% Outside Air
Solar Hot Water	HW Heating Energy	Solar Hot Water only

Source: (Raustad *et al.*, 2008)

2.11.1 Sustainable Building Envelopes

Sustainable building envelopes are technologies designed to control heat loss and gains in buildings. Buildings are insulated to resist the forces of the weather which have a constant impact energy performance of buildings. Envelope technologies are grouped under three main headings: wall, fenestration and roof structures. The walls include passive solar walls, lightweight concrete walls, ventilated walls and walls with latent heat storage. Passive solar walls include Trombe wall and composite Trombe walls

(Saadatian *et al.,* 2012), and are able to improve energy efficiency and savings when insulated (Stazi *et al.*, 2012). The lightweight walls are designed to address the challenges facing thermal heat losses, usually for hot climatic regions (Friess *et al.,* 2012) and improve efficiency with insulation materials (Al–Sanea & Zedan, 2011). The double skin walls have two categories: those that are made of brick or concrete, and those built with glass. Brick walls often have cavities which serve as barriers against heat transfer (Bergman, 2011). Glazing of the external façade has been a major source of concern. The glazed areas of buildings contribute close to 60% of heat transfer in buildings (Cuce & Riffat, 2015).

Thus, new technologies are developed on a regular basis to manage the impact. Innovative technologies include multilayer glazing, suspended films, vacuum glazing, low–emittance coatings and smart glazing. Others include photovoltaic, aerogel, gas filled and self–cleaning glazing, solar absorbing, switchable reflective glazing, suspended particle devices (SPD) film and holographic optical elements. These technologies have high energy saving potential (Carmody, 2007) because of improved thermal conductivity (U–value) (Moss, 2015). Similarly, the multiple layers, smart glazing, double skin façade and the low–emittance coatings contribute to energy savings. For instance, the multiple layers consist of double skin glazing for walls and windows. These types of technologies also rely on the effectiveness of U–values in resisting heat transfer in buildings (Petter Jelle, 2013). There are multiple layers of glazing with air or filled by argon or krypton gas, and the number of layers is effective and ensure resistant against heat transfer (Cuce & Riffat, 2015). Other types are multiple film structure of high/low /high Titanium dioxide or Silicon Dioxide (TiO_2, SiO_2/TiO_2) multiple layer film, the TiO_2 (Belliot, 2011), Vanadium dioxide (VO_2

based) double layers of film (Chen *et al.,* 2011) and oxide electrochromic (Granqvist, 2012). The energy performance of triple glazing is also known to support sustainable construction, where high energy performance has been recorded through adoption and application (Gasparella *et al.,* 2011). The energy performance of double glazing is also consistent with that of triple glazing (Chan *et al.,* 2009; Gasparella *et al.,* 2011).

In addition, low–emittance technologies such as coating of oxides, either metallic or non–metallic, allow only the required amount of visible light in the solar spectrum to be transferred thus resisting or preventing an equally high amount of wavelength responsible for high amount of heat transfer (Liu, 2012). Thus, they are more transparent with high infra reflection and capable of restricting high heat transfer (Liu, 2012) which translates into improved energy performance. The low–emittance glazing has high energy saving potential (Gasparella *et al.,* 2011). Smart façades, unlike low–emittance glazing, are able to change visible and thermal transmittance features to aid expected levels of indoor lighting and heat transfer (Baetens *et al.*, 2010). They include chromic materials, liquid crystals and suspended particles (Cuce & Riffat, 2015) and have been applied to improve energy efficiency in existing buildings (Loonen *et al.,* 2010) as well as thermal and indoor comfort (Ajaji & André, 2015). The double skin façade involves the main façade which is often referred to as the building envelope and another external façade thus creating a gap between the two elements. The gap is a means for heat circulation thus limiting the amount of heat lost in buildings and contributing to energy savings. The double skin façade system with single clear glazing as the inner pane and double reflective glazing as the outer pane can provide an annual saving of around 26% in building cooling energy, compared to a conventional single skin façade with single absorptive glazing (Barbosa & Ip, 2014). There are various types such as the ventilated double skin façade (Zhou & Chen, 2010). The roof is also a major contributor to heat transfer in buildings, influenced by the choice of materials used as covering. Of the many types of materials, the major materials are concrete, lightweight materials, ventilated and micro–ventilated, with various shapes such as vaulted and doomed solar–reflective (Shen *et al.*, 2011) or green, photovoltaic roofs (Castleton *et al.,* 2010). These discussions provide details on the energy savings potential of sustainable technologies and support the demand for increased adoption and use to improve environmental sustainability of existing stock especially office and commercial buildings.

2.11.2 Lighting Technologies

There are generally two main types of lighting systems: the conventional and energy efficient bulbs or lamps. The conventional types include incandescent lamps, generally regarded as the oldest, with undesirable energy consumption (Laughton & Say, 2013). They are considered the least efficient and have the shortest lifespan thus affecting cost of energy consumption. There are various types of energy efficient bulbs including the compact fluorescent lamp and light-emitting diode (LED) bulb. The compact fluorescent lamps were designed purposely to replace incandescent lamps, in tandem with the drive towards sustainable construction as they last longer than incandescent lamps, consume less energy and reduce the cost of energy consumption. There are generally two types of the compact fluorescent lamps: the lamp and the ballast. These two components can combine to enable compact fluorescent lamps to last longer, usually more than 60,000 hours (Kitsinelis, 2016). These hours translate into energy and hence cost savings. Fluorescent lamps, like compact fluorescent lamps, are considered energy efficient, with the main differences between the two being the design and how they are built (Kitsinelis & Kitsinelis, 2015). Fluorescent lamps are durable and more compact with design flexibilities resulting in varying shapes and sizes. A typical example is the development of the T8 or T5 lamps with electronic ballasts manufactured to replace the conventional or old T12 lamp, which relies on a magnetic ballast to operate (Kreith & Goswami, 2007). Fluorescent lamps share similar characteristics with high–intensity discharge lamps, named for their high energy emittance thus generating much lighter, heat and pressure within the arc tube than fluorescent lamps (Kitsinelis & Kitsinelis, 2015). The main similarity is the means of producing light, where both technologies emit light by discharging an electric arc through a tube filled with gases. Although high–intensity discharge lamps are a replacement for incandescent lamps, they share similar size characteristics and similarities. They are small, relying on reflectors, refractors and light pipes that are capable of directing the light (Flesch, 2006). They have hours and duration similar to fluorescent lamps ranging from 5,000 to over 24,000 hours, making them highly efficient. This results in energy savings and associated cost as well as cost of maintenance. There are different types of high–intensity discharge lamps including mercury vapour, metal halide and high-pressure sodium (Laughton & Say, 2013).

2.11.3 Heating, Ventilation and Air Conditioning (HVAC) Systems

2.11.3.1 Underfloor Air Distribution

Heating, ventilation and air conditioning (HVAC) systems have two basic types: radiant and air–forced systems (Kubba, 2012). In line with the aim of this study, the underfloor air distribution systems (UFAD), chilled beams, energy efficient chillers, cooling towers, energy efficient pumps and motors were the main technologies considered because of their high energy reduction potential. Although energy savings of the UFAD systems are well noted and reported, the focus has been on improving new buildings as in studies by Qi *et al.*, (2012). However, Syed (2012) observed that the main function of underfloor air distribution is to improve indoor thermal comfort and general well–being of occupants. The three main functions of the UFAD system as identified by Kim *et al.* (2013) are energy savings, comfort and air quality. The potential of the UFAD system is generally acknowledged, however lack of comparative studies makes some of the arguments in support of energy savings unrealistic. However, Alajmi and El–Amer (2010) provided evidence to support the energy savings capabilities of underfloor air distribution over the conventional overhead system. Comparing simulated underfloor air distribution and overhead systems under similar conditions showed the underfloor air distribution system reduced energy compared to an overhead system by about 37% to 39% during the peak months and 51% during non–peak periods in Kuwait (Alajmi *et al.*, 2013). Similarly, the underfloor air distribution reduced energy by 21% to 22% over the conventional system during peak periods, and a further 31% reduction in peak hourly electricity consumption however, when compared to the underfloor air distribution system, energy saving of 24% was achieved (Raftery *et al.,* 2012). The studies confirm high energy savings using underfloor air distribution compared to overhead conventional systems, thus underfloor air distribution was adopted in the later stages of this study.

2.11.3.2 Chilled Beams

Chilled beams provide a means of transporting conditioned air to specific locations where it is required. The system uses chilled water tubes in modular units mounted to the ceiling and relies on convention as a means of heat transfer. There are basically two types: active and passive (Dieckmann & Zogg, 2007). Active beams are also referred to as induction diffusers, with a complex design structure (Rumsey & Weale, 2007).

They are designed using finned cooling coils and an integral air supply designed to meet minimum outdoor air requirements (Dieckmann & Zogg, 2007). Unlike active beams, passive chilled beams consist of a cooling coil with fins and encasement housing fixed to a suspended ceiling. The operation involves transport of water through coils at varying temperatures, typically between 13°C to 17°C (Dieckmann & Zogg 2007). The process of cooling the air around the coils leads to the formation of cool air which moves from the ceiling level to the floor level (Lowell, 2012). However, energy consumption in both beam systems is similar because the design is almost the same, thus they are all referred to as beams (Lowell, 2012). The benefits of using chilled beams are energy savings, better comfort and lower noise, space savings, a flexible system for high churn rate and low maintenance with no moving parts (Syed, 2012). Due to the reduction in pipe work the heat flow through the coils is direct and uses less energy than the radiation system (Rhee *et al*., 2015).

2.11.3.3 Energy Efficient HVAC Systems

These systems include chillers, cooling towers, motors and pumps which together consume close to 50% of the total energy use in buildings (Saidur *et al.,* 2011). The structure of a pump includes is a pump unit, suction reservoir, delivery reservoir, pipe arrangements, water or other fluid. The pump unit consists of alternative current supply, transformer, variable frequency drive and the motor (Viholainen, 2014). The efficiency of the pump is between 85% to 90% (Kaya *et al.,* 2008), energy efficient motors more than 90% (Lu, 2016) and the variable frequency drive 95% to 98% (Saidur *et al.,* 2012). The energy efficiency of pumps is driven by the variable frequency drive which controls the speed, torque and stator current (Arun Shankar *et al.,* 2016). The use of the variable frequency drive can lead to energy savings of between 12% and 32% (Ma & Wang

2009). Similarly, variable frequency drive mode can reduce water consumption by around 13% compared to the conventional dual speed mode. Energy for chillers and cooling tower fans can be reduced by 5.8% in the variable frequency drive mode for the same amount of cooling (Al–Bassam & Alasseri, 2013). Energy efficiency in the pumping system is controlled by the efficiency of the motors adopted. The energy efficiency of the motors is classified into an international efficiency class (IEC) defined in the range of standard (IEC 60034-30-1), high efficiency (IE class-1) and super premium efficiency (IE class-3) (Saidur, 2010). The conventional motors are built to function at a constant speed and provide a constant output, however the energy efficient motors operate at varying speeds. A typical example of an energy efficient motor is the variable speed drive.

The variable speed drive is machine which controls the speed and rotational force, or output torque of mechanical equipment. Variable speed drives on electrical motor applications also improve the efficiency of the systems and save a substantial amount of energy due to their low starting current demand, thereby reducing the thermal and mechanical loads on motors and belts (Saidur *et al.,* 2012). The energy saving potential of the variable speed drive is enormous. A variable speed drive can save 50% or more of the energy in applications that use pumps and fans (Tolvanen, 2008). Once the motors are efficient, the chillers and cooling towers tend to save energy as well. Thus, available projections show that close to 8,368 MWh annual energy can be saved by using efficient chillers at different loadings (Saidur *et al.,* 2011b) and about 23,532 MWh annual energy can be saved for chilled water supply pumps, condenser pumps and cooling tower fan motors by matching required speeds using variable speed drives for 60% of speed reduction (Saidur *et al.,* 2011b). The energy, economic and environmental benefits of chillers have been addressed (Saidur, 2010), thus adoption and implementation of the Pre-cooling and economizer system could save 115 kW/m2/month and 72 kW/m2/month total cooling energy and 26 kW/m2/month and 42 kW/m2/month chiller energy (Chowdhury *et al.*, 2009).

2.11.4 Renewable Energy Technologies

Renewable energy systems include solar PV panels and solar hot water systems. These are useful because the energy production processes of the PV panels are clean with minimal impact on the environment (Santamouris, 2013). The efficiency of the panels has been increased through two approaches based on outliers. Mallor *et al.* (2017) developed a method using two approaches based on outlier detection methods and functional principal component analysis, similar to earlier studies that focused on improving energy savings using effective battery systems (Hill *et al.,* 2012). However, there are challenges with the cost of production (Rehman *et al.,* 2007) that tend to have a negative effect on savings (Nemet *et al.,* 2017). This has contributed to the development of hybrid systems, where solar systems are merged with other building elements such as the wall and roof to reduce energy consumption (Zhou *et al.,* 2017). The hybrid system works with façade systems to improve energy efficiency such as the Trombe wall (Jovanovic *et al.,* 2017). Panels have powered air conditioners thus enabling comparative analysis of energy savings (Greenaway & Kohlenbach, 2017) and can be applied as façades. A comparison between a Photovoltaic double skin façade (PV–DSF) and a Photovoltaic insulating glass unit (PV–IGU) has shown that the average energy saving potential of the PV–DSF is 28.4% and for the PV–IGU is 30% (Wang *et al.,* 2017). In addition, the use of photovoltaic-thermal hybrid collectors as co–generation components to convert solar energy into both electricity and heat is an efficient way to use solar energy in hot water systems supporting the drive towards environmental sustainability.

The adoption and application of the photovoltaic-thermal collectors in the building envelope can be more advantageous than standard PV and solar thermal components, due to the high energy savings (Dupeyrat *et al.*, 2014). Also, some new and energy efficient solar hot water systems have promising environmental and economic benefits (Hang *et al.*, 2012). The design of a single glazed flat plate photovoltaic-thermal (PV–T) solar collector also has the potential to save energy but related electrical efficiency is lower than the efficiency of a standard PV panel using the same technology (Dupeyrat *et al.,* 2011). Unfortunately, most of these studies are based on only experiments. However, technologies adopted in existing commercial buildings were found to be reliable with consistent energy savings, thereby supporting the drive towards environmental sustainability of existing buildings.

2.11.4 Miscellaneous Electric Load

Equipment loads prove to be an ever-increasing drain on the electrical energy consumption of buildings. Although manufacturers strive to make equipment as efficient as possible, several equipment models draw a significant amount of electricity even when in stand-by mode (Raustad *et al.*, 2008). In addition, equipment typically used is often on solely as a convenience instead of on an as-needed basis. For these reasons, the equipment loads were modified to reflect a reduction of 10% over the maximum equipment loads specified by ASHRAE Standard 90.1 (ASHRAE, 2007). These reductions are assumed possible through application of power strips to non-essential equipment that can be turned off when not needed. An alternate method would be to connect non-essential equipment to a dedicated electrical circuit which is controlled manually or scheduled through building automation systems. By this means that Raustad *et al.*, (2008) recommended the use of energy star appliances, installation of smart power strips to turn off phantom power from unplugged gadgets at nights and unplug any electrical gadget from sockets when not in use.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter deals with methods and procedures used in gathering information for the study with particular focus on; research design, population, sample and sampling techniques as well as data collection instruments and later considers validity of the study, data collection procedures and data analysis techniques employed to summarize the results obtained.

3.1 Research Design

According to Burns (2002), research design is a planned and structured investigation used to obtain answers to research questions. A research design constitutes the blueprint for collection, measurement and analysis of data. There are three main types of research designs and they are; the exploratory, explanatory and descriptive research design. This study adopted the descriptive research design. According to Burns (2002), descriptive design involves describing, recording, analyzing and interpreting conditions that exist. The descriptive survey allows one to have a detailed analysis of responses collected from respondents in the organization (Burns, 2002).

3.2 Population of the Study

A research population can be defined as the totality of well-defined collection of individuals or objects that have a common characteristics or traits (Polit & Hungler, 1993). Burns (2002) also added that a population is defined as all elements (individuals, objects and events) that meet the sample criteria for inclusion in a study. The study had as its population, owners and tenants of office buildings as well as construction managers, electrical engineers, mechanical engineers, quantity surveyors, civil engineers, architects who worked on some office buildings in the metropolis.

3.3 Sample and Sampling Techniques

With regards to sampling techniques, according to Alhassan (2006), the objective of a research work decides the sample number. A sample is a smaller group of individuals which must represent the target population, so that the data from the sample would accurately represent what is happening in the target population (Cassim, 2014). Bryman (2004) defines sampling technique as the process to select a unit or an entity from a sample frame or population that its attribute will reflect. Because of yearning for generalizability of the findings of this study, sampling of the population was based on critical sampling technique requiring that all targeted respondents with effective knowledge in utilization of energy efficiency assessment tool for office buildings be represented. At this stage of data collection, two sampling techniques were used for reaching out to the research participants. To prevent potential bias in the study, random sampling technique was used as the main mode of recruiting participants for the study (Gravetter & Wallnau, 2013). In a simple random sampling technique, every data source in the population has an equal chance of being included in the sample (Leedy & Ormrod, 2014). The units comprising a population are allotted numbers, and a set of random numbers is generated, and the units having those numbers are included in the sample (Babbie, 2010). The study randomly selected 40 owners and tenants public office buildings, 30 construction managers, 35 electrical engineers, 37 mechanical engineers, 28 architects who have worked on the planning, designing and construction stages of public office buildings.

Alhassan (2006) further explained that, for a sample to reflect the purpose of an investigation a purposive sampling technique must be employed to select the sample. Purposive sampling technique was used to select the construction managers, electrical engineers, mechanical engineers and architects. The choice of purposive sampling technique was influenced by the statement made by Palys (2008), which states that, 'to say one will engage in purposive sampling signifies that, one sees sampling as a series of strategic choices about with whom, where, and how one does one's research'. The statement implies that the way that researcher sample must be tied to their research objectives. The researcher presented written questions to the randomly selected respondents personally, through google link and via mail, and those who answered the questions most appropriately were chosen to represent the final sample. The research had 90 respondents including 10 construction managers, 25 electrical engineers, 10 mechanical engineers, 15 architects, 5 civil engineers, 5 quantity surveyors, and 20 office owners and tenants as the sample for the study.

3.4 Data Collection Instruments

The research instrument used for the study was a questionnaire with a mixed composition of close ended and the five (5) point Likert scale questions. Cohen *et al.,* (2000), described questionnaires 'as a widely and useful instrument for collecting survey information, providing structured and often numerical data, being able to be administered without the presence of the researcher and often straight forward to analyze. Questionnaires were preferred because it's simple to administer, allows high proportion of usable answers to be collected from a large sample, it's comprehensive and simpler to analyze since they provide direct observations.

3.5 Data Collection Procedure

The researcher sought permission from the respondents before going to administer the questionnaires and used five days to collect the data. The researcher went back to distribute the questionnaires personally to the various respondents in order to explain some technical terms to them. In all, ninety (90) questionnaires were administered and the respondents were asked to respond to the questionnaires and return them same way.

3.6 Validity of the Study

The validity and reliability of a data collection mostly depends on the construction, content validity, wording, and format and question flow. According to Delamont (1992), Validity and reliability of a data collection instrument is regarded as an important concept in research work because the validity and reliability of a test (survey) determines the degree to which it is capable of achieving the aim for which it is conducted. In order to authenticate the validity and of the research outcome, the information were presented as they were, such that, responses from both questionnaires and interview were not uttered or manipulated.

3.7 Data Analysis

Analyzing the data is an important step in any research, and must be done according to the aims of the study. Walliman (2005), states that; data is analyzed in order to measure, make comparisons, examine relationships, forecast, test hypothesis, construct concepts and theories, explore, control and explain. Gall, Gall and Borg (2007), argued that the results of quantitative studies should be presented in numerical form. The data was analysed using the Statistical Packages for the Social Sciences (SPSS) data analysis tool, in conjunction with Microsoft Excel (MS Excel) where required. A descriptive form of analysis was adopted and data was presented in charts and tables showing their frequencies, percentages, means and ranks.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter deals with the presentation, analysis and interpretation of data generated by the researcher through the questionnaires administered to building professionals and public office users in Kumasi metropolis. The results of the questionnaire are presented in tables and charts. A total of 100 questionnaires were administered to get the views of the building professionals in the built environment. Out of which 70 were returned and 30 were not returned. Another 30 questionnaires were administered to the owners and the users of public office buildings. Twenty (20) were returned and 10 were not returned. In all, ninety (90) questionnaires were used.

4.2 Demographic Characteristics of Respondents

Table 4.1 presents the demographic characteristics of the building professionals selected for the study.

Table 4. 1: Demographic characteristics of respondents

Demographic characteristics of respondents	Frequency	Percentage%
Area of specialization		
Electrical Engineering	21	30%
Mechanical Engineering	9	12.9%
Architecture/Architectural Engineering	16	22.8%
Quantity Surveying	8	11.3%
Civil Engineering	6	8.8%
Construction Management	10	14.2%
Total	70	100%
Experience		
Less than 5 years	21	30.0%
6 – 10 years	30	42.9%

11 – 15 years	15	21.4%
16 – 20 years	3	4.3%
21 years and above	1	1.4%
Total	70	100%
Level of education		
HND	17	24.3%
1st Degree	45	64.3%
Post graduate	8	11.4%
Others	0	-
Total	70	100%

Source: Data from field survey, 2021

From Table 4.1, the respondents were asked to indicate their area of specialization, the results indicate that, out of 70 respondents 21 representing 30% are electrical engineers, 9 representing 12.9% were mechanical engineers, 16 representing 22.8% are architects, 8 representing 11.3% are quantity surveyors, 6 representing 8.8% are civil engineers and 10 representing 14.2% are construction managers. This implies almost all building professionals relevant to the topic at hand were sampled thus diverse ideas were solicited to enhance the results of the study.

From Table 4.1, 18 respondents representing 25.7% have had between 11 – 15 years' experience, another 18 representing 25.7% had 16 – 20 years' experience, 15 representing 21.4% had 6 – 10 years' experience. Twelve (12) respondents representing 17.1% had 21 years and above and only 7 representing 10.0% had less than 5 years' experience. This implies that, majority of the respondents have practiced or executed projects for more than five years.

As shown in Table 4.1, 31 out of 70 respondents representing 44.3% had obtained 1st Degree, 22 representing 31.4% had completed their post graduate programmes and 17 representing 24.3% had Higher National Diploma (HND) certificates. Majority of the respondents representing 75.7% holds at least BSc degree as their highest academic qualification.

4.3 General Knowledge on Energy Efficiency Assessment

Table 4.2 presents the results of general knowledge on energy efficiency assessment of building professionals selected for the study.

Table 4. 2: General Knowledge on Energy Efficiency Assessment

General Knowledge on Energy Efficiency Assessment	**Frequency**	**Percentage%**
Building energy efficiency Assessment definition		
Significant reduction of the energy needed for lighting, heating and cooling in building	27	38.6%
Reduction in the building electricity demand	22	31.4%
Reduction in annual CO_2 emission in buildings	12	17.1%
Reduction in annual energy cost	9	12.9%
Total	70	100%
Description of building energy efficiency assessment tools		
Tools that audit the annual energy cost in buildings	28	40%
Tools that identify and analyses the potential savings and cost effectiveness of energy in buildings	26	37.1%
Tools that analyses the energy performance of buildings	16	22.9%
Total	70	100%
Form of training		
Basic energy management information	21	30%
Comprehensive operational training	17	24.3%
Comprehensive technical training	17	24.3%
No training	15	21.4%
Total	70	100%

Organizational commitment to improving energy efficiency		
Policy for energy reduction clearly stated and published	21	30%
Targets set for whole organization for only energy consumption reduction	19	27.1%
Targets set by the organization for carbon and energy consumption reduction	17	24.3%
No policy	13	18.6%
Total	70	100%
Energy Efficiency Indicators		
Bioclimatic architecture (shape and orientation of the building)	26	37.1%
High performance-controlled ventilation (wider corridors, and significant number and size of windows and doors)	18	25.7%
High performing building envelope (use of glazing doors and windows, air-sealed construction)	17	24.3%
Provision of skylight to allow daylighting through the roofs	5	7.1%
Advanced sensor and control systems to provide ventilation only where and when its needed	4	5.7%
Glazing materials with tunable optical properties (transmissivity and emissivity adjustable by wavelength)	-	-
Total	70	100%

Source: Data form field survey, 2021

From Table 4.2, 27 out of 70 respondents representing 38.6% had knowledge in Significant reduction of the energy for lighting, heating and cooling in building, 22 representing 31.4% selected Reduction in the building electricity demand, 12 representing 17.1% were also aware of the Reduction in annual CO_2 emissions in buildings and 9 respondents representing 12.9% opined that they have heard that Reduction in annual energy cost best describes building energy efficiency.

Again, from Table 4.2, out of the 70 respondents, 28 representing 40% knew of tools that audit the annual energy cost in buildings, 26 representing 37.1% were able to describe tools that analyses the energy performance of buildings and the remaining 16 representing 22.9% said that tools that identify and analyze the potential savings and cost effectiveness of energy in buildings best describe building energy efficiency assessment tools before and after construction.

From Table 4.2, 21 representing 30% indicated basic energy management information as a form of training that their organisation has adopted training them, seventeen (17) representing 24.3% said comprehensive operational training is what they use, and 17 representing 24.3% also indicated comprehensive technical training. Meanwhile, the remaining 15 representing 21.4% said their organizations do not offer any training on energy management at all. It can be seen from Table 4.2 that, 30% of them said policy for energy reduction clearly stated and published, another 27.1% said targets set by the organization for carbon and energy consumption reduction, 24.3% went for the targets set for whole organization for only energy consumption reduction and the remaining 18.6% declared that there are no policy.

From this Table 4.2, one realizes that, 26 representing 37.1% declared that bioclimatic architecture (Shape and orientation of the building) is the way their organisation use to ensure that office buildings are designed and constructed to become energy efficient, 18 representing 25.7% asserted that High performance-controlled ventilation (Wider corridors, and significant number and size of windows and doors) is the method use, 17 representing 24.3% were of the view that High performing building envelope (use of glazing doors and windows, air-sealed construction) is their best method, Five (5) representing 7.1% accepted provision of skylight to allow daylighting through the roof as their best option and the rest being 4 representing 5.7% know of advanced sensor and control systems to provide ventilation only where and when its needed.

4.4 Level of Awareness of Building Professionals on Energy Efficiency Assessment Tools for Office Building Designs

Table 4.3 presents the results on the level of awareness of building professionals on energy efficiency assessment tools.

Table 4. 3: Level of Awareness of Building Professionals on Energy Efficiency Assessment Tools

Level of Awareness of Energy Efficiency Assessment Tools	Not aware 1	Modera-tely aware 2	Not sure 3	Aware 4	Highly aware 5	Frequ-ency (N=70)	Mean	Rank
The Green Building Assessment (GBA)	2 (2.9%)	18 (25.7%)	12 (17.1%)	28 (40%)	10 (14.3%)	70	3.37	1
The Pearl Rating System (ESTIDAMA)	8 (11.4%)	12 (17.1%)	14 (20%)	20 (28.6%)	16 (22.9%)	70	3.34	2
Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)	6 (8.6%)	12 (17.1%)	18 (25.7%)	21 (30%)	13 (18.6%)	70	3.33	3
Leadership in Energy and Environmental Design (LEED)	8 (11.4%)	17 (24.3%)	12 (17.2%)	19 (27.1%)	14 (20%)	70	3.20	4
Global Sustainability Assessment System (GSAS)	6 (8.6%)	19 (27.1%)	18 (25.7%)	19 (27.1%)	8 (11.4%)	70	3.05	5
Building Environmental Performance Assessment Criteria (BEPAC)	16 (22.9%)	15 (21.4%)	8 (11.4%)	15 (21.4%)	16 (22.9%)	70	3.00	6
Excellence in Design for Greater Efficiencies (EDGE)	8 (11.4%)	18 (25.7%)	20 (28.6%)	15 (21.4%)	9 (12.9%)	70	2.99	7

Green Pyramid Rating System (GPRS)	14 (20%)	19 (27.1%)	13 (18.6%)	12 (17.1%)	12 (17.1%)	70	2.84	8
Sustainable Building Tools (SB Tools)	13 (18.6%)	21 (30%)	9 (12.9%)	20 (28.6%)	7 (10%)	70	2.81	9
Green Star	12 (17.1%)	17 (24.3%)	23 (32.9%)	10 (14.3%)	8 (11.4%)	70	2.79	10
Hong Kong Building Environmental Assessment Method (HK-BEAM	13 (18.6%)	20 (28.6%)	16 (22.9%)	11 (15.7%)	10 (14.3%)	70	2.79	11
IGBC Green Homes Rating System	11 (15.7%)	22 (31.4%)	16 (22.9%)	15 (21.4%)	6 (8.6%)	70	2.76	12
Building Research Establishment's Environmental Assessment Method (BREEAM)	27 (38.6%)	8 (11.4%)	8 (11.4%)	10 (14.3%)	17 (24.3%)	70	2.74	13

Source: Data form field survey, 2021

According to Table 4.3, The Green Building Assessment (GBA) recorded the highest mean value of (3.37) having 38 representing 54.3% who are aware of the assessment tool with The Pearl Rating System (ESTIDAMA) recording the next highest mean value of (3.34). This implies that, the green building assessment and the pearl rating system are among the major energy efficiency assessment tools that can help ensure energy efficiency in office buildings at the Kumasi Metropolis. The result may be due to the fact that building professionals are very much aware of these assessment tools and not only that but also implements them in their various designs when it comes to office buildings. This agrees with the literature as the Pearl Rating System (PRS) is the green building assessment system developed by Abu Dhabi Urban Planning Council in 2007 (UPC, 2010) and the aim of this system is to employ the basic concepts of green architecture through highlighting the need for balanced use of land, materials, energy, and water (UPC, 2010).

From Table 4.3, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) (3.33) and Leadership in Energy and Environmental Design (LEED) (3.20) were also found to be among the major energy assessment tools for office building designs at the Kumasi metropolis. This indicates that, it is highly possibly to do a comprehensive assessment of office buildings in respect to energy efficiency by the use of the CASBEE. This is in agreement with Gu *et al., (*2001) as he considers CASBEE as the most advanced assessment system covering almost all issues during building construction stage. In addition, Leadership in Energy and Environmental Design (LEED) was developed to offer a well-known standard for the construction industry to evaluate the environmental sustainability levels of building designs (USGBC, 2014).

With reference to Table 4.3, Building Research Establishment's Environmental Assessment Method (BREEAM) (2.74) recorded the least mean value even though it formed part of the energy efficiency assessment tools that are used in office buildings at Kumasi metropolis. This indicates that, the building professionals at the Kumasi Metropolis are not much aware of the Building Research Establishment's Environmental Assessment Method (BREEAM) even though it is the pioneer assessment system, established in 1990. Another factor could be the weaknesses of BREEAM. That is, it requires very exact requirements, the weighting system is complex, and a market profile is required and has a high cost of compliance.

4.5 Level of Knowledge on the Factors that Building Professionals Consider in their Designs to Ensure Efficiency in the Usage of Energy

Table 4.4 presents the results on the level of knowledge on the factors that building professionals consider in their designs to ensure efficiency in the usage of energy.

Table 4. 4: Level of Knowledge on the Factors Considered in Building Designs to Ensure Energy Efficiency in the Usage of Energy

Level of Knowledge on Energy Efficiency Factors in Buildings	**Strongly disagree 1**	**Disagree 2**	**Not sure 3**	**Agree 4**	**Strongly agree 5**	**Frequency (N=70)**	**Mean**	**Rank**
Surrounding buildings	–	–	14 (20%)	24 (34.3%)	32 (45.7%)	70	4.26	1
Glazing properties	–	10 (14.3%)	8 (11.4%)	30 (42.9%)	22 (31.4%)	70	3.91	2
Appropriate floor dimensions	4 (5.7%)	6 (8.6%)	12 (17.1%)	25 (35.7%)	23 (32.9%)	70	3.81	3
Mechanical ventilation rates	6 (8.6%)	8 (11.4%)	12 (17.1%)	21 (30%)	23 (32.9%)	70	3.67	4
Building Location	3 (4.3%)	11 (15.7%)	13 (18.6%)	23 (32.9%)	20 (28.6%)	70	3.66	5
Natural ventilation rates	–	13 (18.6%)	14 (20%)	28 (40%)	15 (21.4%)	70	3.64	6
Interior wall length	6 (8.6%)	10 (14.3%)	14 (20%)	24 (34.3%)	16 (22.9%)	70	3.49	7
Exterior wall areas	15 (21.4%)	–	13 (18.6%)	23 (32.9%)	19 (27.1%)	70	3.44	8
Direction of wind	9 (12.9%)	13 (18.6%)	13 (18.6%)	19 (27.1%)	16 (22.9%)	70	3.29	9
Exterior wall properties	11 (15.7%)	18 (25.7%)	10 (14.3%)	8 (11.4%)	23 (32.9%)	70	3.20	10
Window areas	16 (22.9%)	15 (21.4%)	-	24 (34.3%)	15 (21.4%)	70	3.10	11
Orientation of building	8 (11.4%)	18 (25.7%)	15 (21.4%)	20 (34.3%)	9 (12.9%)	70	3.06	12
Roof areas	13 (18.6%)	16 (22.9%)	11 (15.7%)	16 (22.8%)	14 (20.0%)	70	3.03	13
Number of floors	11 (15.9%)	17 (24.3%)	13 (18.6%)	20 (28.6%)	9 (12.9%)	70	2.99	14
Outdoor Temperature	8 (11.4%)	19 (27.1%)	19 (27.1%)	14 (20%)	10 (14.3%)	70	2.99	15
Artificial lighting types	11 (15.7%)	16 (22.9%)	11 (15.7%)	32 (45.7%)	–	70	2.91	16

Source: Data from field survey, 2021.

The results according to Table 4.4 indicates that Surrounding buildings recorded the highest rank as the major factor considered in building designs to ensure energy efficiency in the usage of energy with none of the respondents disagreeing to the statement, 14 representing 20% were not sure with the statement with as many as 56 representing 80% agreeing and strongly agreeing to the statement. This implies that, building professionals at Kumasi metropolis really consider surrounding buildings around a site to be developed to make pertinent decisions relating to building energy. This maybe as a result of the fact that, surrounding buildings around a site tends to block ventilation to a new building if there were no proper energy decisions carefully considered.

From Table 4.4 the results show that glazing properties (2nd ranked), appropriate floor dimensions (3rd ranked), mechanical ventilation (4th ranked) and building location (5th ranked) with as many as 74.3%, 68.6%, 62.9%, and 61.5% of respondents strongly agreeing and agreeing to the statements respectively. There are also some major factors considered in building designs to ensure energy efficiency in the usage of energy in the Kumasi metropolis. The result is so crucial as the addition of more glazing properties to an office building is an excellent way to enhance energy efficiency. Again, floor dimension for office buildings should be kept at standard to keep the office as spacious as it should be to enhance the free flow of natural ventilation.

According to Table 4.4, artificial lighting types ranked last having 11 representing 15.7% strongly disagreeing to the statement, 16 representing 22.9% disagreeing to the statement, 11 representing 15.7% not sure of the statement with 32 representing 45.7% agreeing to the statement. The result indicates that, too many artificial lighting types into an office building will only decrease the energy efficiency of the building. This may be due to the fact that, office buildings at Kumasi metropolis that have little of natural lighting entering into their premises records higher electricity bills than office buildings that are energy efficient.

4.6 Energy Assessment Recommendations that Primary Improves Energy Efficiency in Office Buildings

Table 4.5 presents the results on the energy assessment recommendations that primary improves energy efficiency in office buildings.

Table 4. 5: Energy Assessment Recommendations that Primary Improves Energy Efficiency

Energy Assessment Recommendations to Improve Energy Efficiency	Strongly disagree 1	Disagree 2	Not sure 3	Agree 4	Strongly agree 5	Frequ -ency (N=70)	Mean	Rank
The use of advanced building design and construction technique that makes building energy efficient	–	–	–	25 (35.7%)	45 (64.3%)	70	4.64	1
Adopting to a proper office building shape to allow natural lighting and ventilation	–	–	–	33 (47.1%)	37 (52.9%)	70	4.53	2
Use of solar shading devices to reduce the need for artificial lighting and heating	–	–	10 (14.3%)	32 (45.7%)	28 (40%)	70	4.26	3
Installation of smart power strips to turn off phantom power from unplugged gadgets at nights	–	–	16 (22.9%)	21 (30%)	33 (47.1%)	70	4.24	4

Conscious improvement of glazing ratio to solid walls	–	–	18 (25.7%)	28 (40%)	24 (34.3%)	70	4.09	5
Use of local renewable energy sources in office building	–	–	17 (24.3%)	37 (52.9%)	16 (22.9%)	70	3.99	6
Proper orientation of office buildings to adequate source of sunlight	–	14 (20%)	11 (15.7%)	27 (38.6%)	18 (25.7%)	70	3.70	7
Replace High-intensity discharge (HID) lighting with more efficient lighting like Tubular 8 (T8) or Tubular 5 (T5) lighting or CFLs	4 (5.7%)	11 (15.7%)	13 (18.6%)	28 (40%)	14 (20%)	70	3.53	8
The use of LED Lighting	3 (4.3%)	13 (18.6%)	19 (27.1%)	19 (27.1%)	16 (22.9%)	70	3.46	9
The use of energy star appliances	10 (14.3%)	8 (11.4%)	13 (18.6%)	20 (28.6%)	19 (27.1%)	70	3.43	10
Unplug any electrical gadget from sockets when not in use	2 (2.9%)	29 (41.4%)	2 (2.9%)	18 (25.7%)	19 (27.1%)	70	3.33	11
Installing a variable-frequency drive (VFD) fan in a fan system is a possible energy-saving AR	8 (11.4%)	13 (18.6%)	13 (18.6%)	23 (32.9%)	13 (18.6%)	70	3.29	12
Ensure proper airtightness of office building to avoid energy wastage	6 (8.6%)	9 (12.9%)	31 (44.3%)	14 (20.0%)	10 (14.3%)	70	3.19	13

Source: Data from field survey, 2021

The results according to Table 4.5 indicates that the use of advanced building design and construction technique that makes building energy efficient recorded the highest rank as the major energy assessment recommendation to improve energy efficiency with none of the respondents disagreeing to the statement, 25 representing 35.7% agreeing to the statement and as many as 45 representing 64.3% strongly agreeing to the statement. This implies that, building professionals at Kumasi metropolis ensures that advanced building designs and construction technique that makes building energy efficient are adopted to construct office buildings. This agrees with Carmody (2007) that these advanced building technologies have high energy saving potential because of improved thermal conductivity (U–value).

From Table 4.5 the results show that adopting to a proper office building shape to allow natural lighting and ventilation (2nd ranked), use of solar shading devices to reduce the need for artificial lighting and heating (3rd ranked) and installation of smart power strips to turn off phantom power from unplugged gadgets at nights (4th ranked) which recorded as many as 100%, 85.7%, and 77.1% respondents agreeing and strongly agreeing to the respective statements are also major energy assessment recommendations to improve energy efficiency of office buildings at Kumasi metropolis. This may be due to the fact that, some electrical equipment still consumes a lot of energy even when it is on but not using it. The result supports the statement that, although manufacturers strive to make equipment as efficient as possible, several equipment models draw a significant amount of electricity even when in stand-by mode (Raustad *et al.*, 2008). By this means that Raustad *et al.*, (2008) recommended the use of energy star appliances, installation of smart power strips to turn off phantom power from unplugged gadgets at nights and unplug any electrical gadget from sockets when not in use.

According to Table 4.5, to ensure proper airtightness of office building to avoid energy wastage ranked last with 15 representing 21.5% disagreeing to the statement, 31 representing 44.3% not sure of the statement and as many as 24 representing 34.3% agreeing and strongly agreeing to the statement. The result indicates that, building professionals at the Kumasi metropolis see the proper airtightness of office building to avoid energy wastage as the least way of improving energy efficiency in office building even though it helps to save energy.

4.7 Demographic Characteristics of Owners and Tenants

Figure 4.1, Figure 4.2, Figure 4.3, Figure 4.4, and Figure 4.5 presents the results on demographic characteristics of building owners and tenants selected for the study.

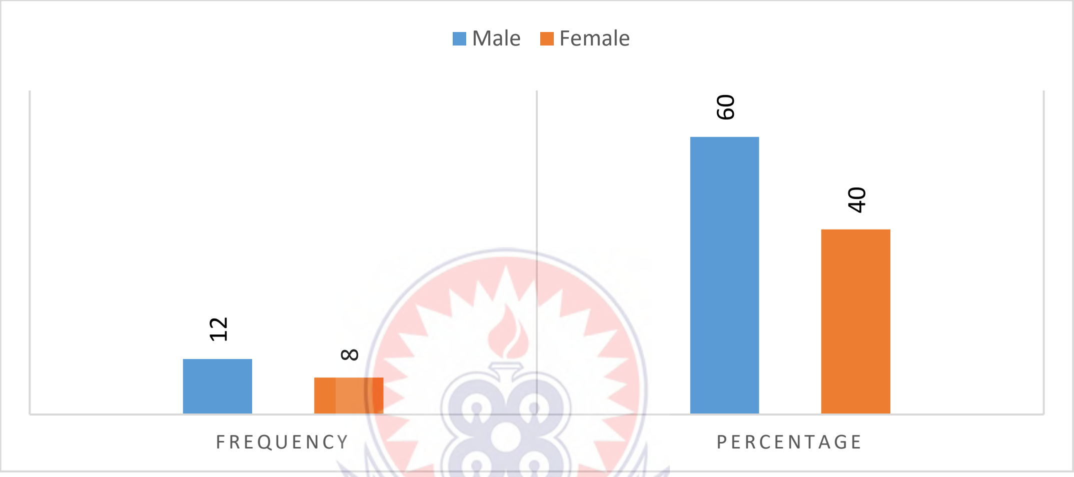

Figure 4. 1: Gender of respondents (Source: Field data, 2021)

The results presented in Figure 4.1 were based on the data collected from the questionnaires issued to 20 building owners and tenants in the Kumasi metropolis during the time of the study. The results showed that 12 out of 20 representing 60% were males whereas 8 respondents representing 40% were females. The results indicate that more males participated in the survey than females in the time of study.

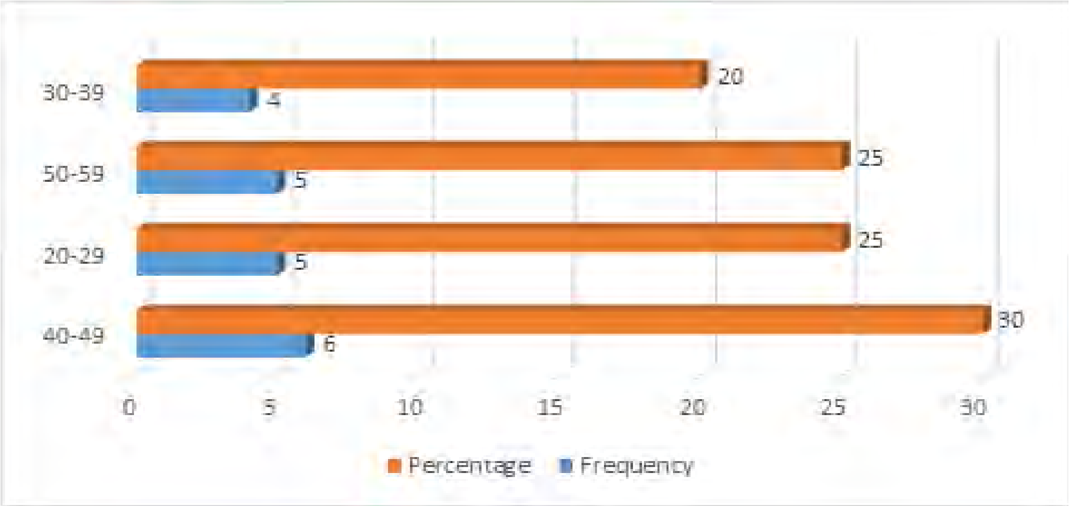

Figure 4. 2: Age of respondents (Source: Field data, 2021)

The results presented in Figure 4.2 showed that 6 respondents representing 30.0% of the respondents were in the ages of 40-49 years, whereas 5 respondents representing 25.0% were in the ages of 20-29 years. Another 5 or 25% were in the ages of 50-59 years. While the remaining 4 respondents representing 20% were in the ages of 30 – 39 years.

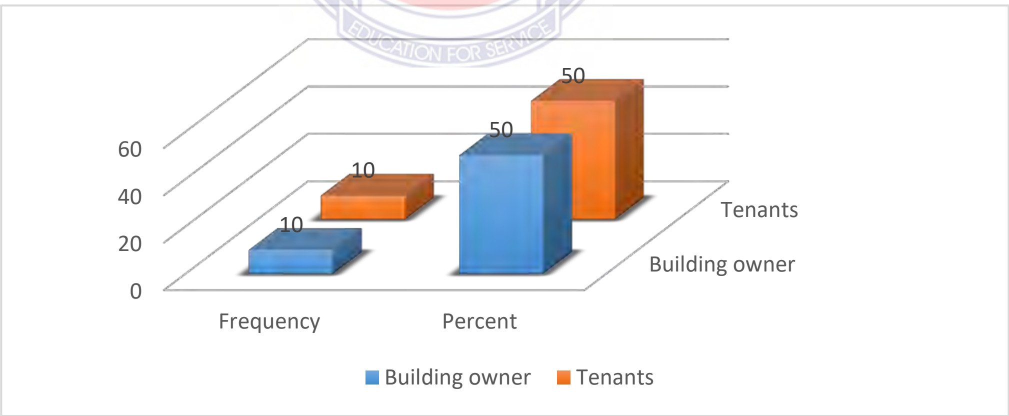

Figure 4. 3: Please indicate that which best describes your status (Source: Field data, 2021)

The result in figure 4.3 indicates that half of the respondents which is 10 representing 50% were building owners whereas the remaining 10 or 50% served as tenants.

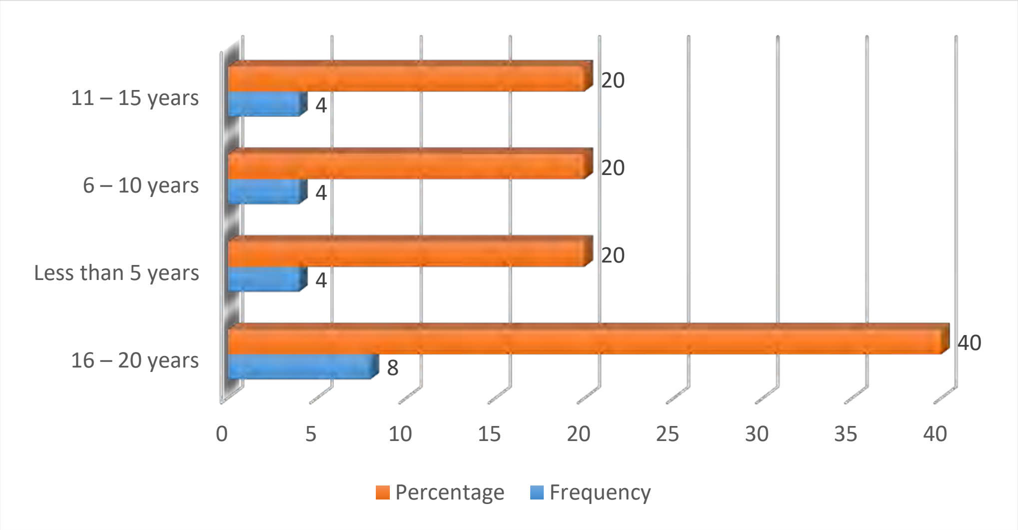

Figure 4. 4: How long have you own an office building or rented the office building (Source: Field data, 2021)

Regarding the number of years respondents have stayed the building, 8 out of 20 respondents representing 40.0% had 16-20 years of working experience in their building, followed by 4 respondents representing 20.0% less than 5 years, 6-10 years and 11-15 years all had 4 respondents each representing 20%.

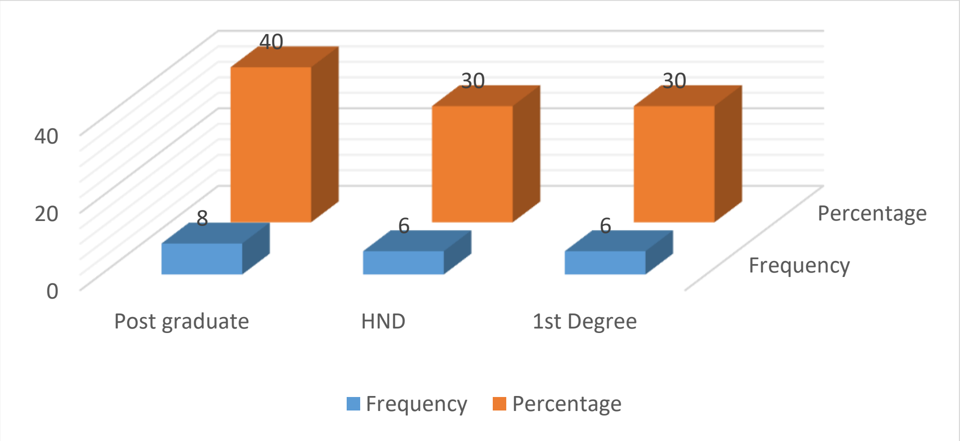

Figure 4. 5: Please indicate that which best describes your status (Source: Field data, 2021)

Respondents from the Kumasi Metropolis that is building owners and tenants were asked to indicate their highest academic qualification and the results are indicated in Figure 5. Regarding this question, 8 out of 20 respondents representing 40.0% selected post graduate, 6 respondents representing 30.0% selected HND and the remaining 6 respondents also representing 30.0% selected 1st degree. It is clear from the findings that majority of the respondents representing 40.0% holds at least a BSc degree as their highest academic qualification.

4.8 Energy Assessment Recommendations that Improves Energy Efficiency in Office Buildings

Table 4.6 presents the results on the energy assessment recommendations that primary improves energy efficiency in office buildings.

Table 4. 6: Energy Assessment Recommendations to that Improves Energy Efficiency

Energy Assessment Recommendations to Improve Energy Efficiency	Strongly disagree 1	Disagree 2	Not sure 3	Agree 4	Strongly agree 5	Frequ -ency (N=20)	Mean	Rank
Unplug any electrical gadget from sockets when not in use	–	–	–	7 (35%)	13 (65%)	20	4.65	1
Installation of smart power strips to turn off phantom power from unplugged gadgets at nights	–	–	–	8 (40%)	12 (60%)	20	4.60	2
Use of local renewable energy sources in office building	–	–	2 (10%)	8 (40%)	10 (50%)	20	4.40	3
Installing a VFD fan in a fan system is a possible energy-saving AR	–	–	4 (20%)	5 (25%)	11 (55%)	20	4.35	4

Use of solar shading devices to reduce the need for artificial lighting and heating	–	–	3 (15%)	8 (40%)	9 (45%)	20	4.30	5
The use of energy star appliances	–	–	5 (25%)	10 (50%)	5 (25%)	20	4.00	6
The use of advanced building design and construction technique that makes building energy efficient	–	–	5 (35%)	10 (50%)	5 (25%)	20	4.00	7
The use of LED Lighting	–	–	5 (25%)	10 (50%)	5 (25%)	20	4.00	8
Replace HID lighting with more efficient lighting like T8 or T5 lighting or CFLs	–	–	6 (30%)	9 (45%)	5 (25%)	20	3.95	9
Adopting to a proper office building shape to allow natural lighting and ventilation	–	6 (30%)	–	7 (35%)	7 (35%)	20	3.75	10
Proper orientation of office buildings to adequate source of sunlight	–	6 (30%)	–	8 (40%)	6 (30%)	20	3.70	11
Ensure proper airtightness of office building to avoid energy wastage	–	7 (35%)	–	6 (30%)	7 (35%)	20	3.65	12
Conscious improvement of glazing ratio to solid walls	–	5 (25%)	7 (35%)	8 (40%)	–	20	3.15	13

Source: Data from field survey, 2021

In respect to table 4.6, the first ranked statement “Unplug any electrical gadget from sockets when not in use”, out of 20 respondents, none of them disagreed with the statement that unplug any electrical gadget from sockets when not in use is a major factor to adopt in order to ensure energy efficiency, 7 respondents representing 35.0% agreed and as many as 13 respondents representing 65.0% out of the total respondent strongly agreed. This implies that, all of the respondents, thus 100% agreed and strongly agreed that; unplug any electrical gadget from sockets when not in use is a major recommended factor that helps to improve energy efficiency in the Metropolis.

Table 4.6 again shows the level of agreement regarding Installation of smart power strips to turn off phantom power from unplugged gadgets at nights is a factor to consider by building professionals to ensure efficiency of energy, the result indicates that none of the respondents disagreed with the statement, 8 respondents representing 40.0% agreed with the statement and 12 respondents representing 60.0% strongly agreed with the statement. These results also suggest that, all of the respondents were of the view that Installation of smart power strips to turn off phantom power from unplugged gadgets at nights is an important energy efficiency factor to be considered by building professionals at the Metropolis to ensure energy efficiency.

Furthermore, in table 4.6, the statement “Use of local renewable energy sources in office building” had 20 respondents, out of which none of the respondents strongly disagreed with the statement, only 2 respondents representing 10.0% were not sure with the statement, 8 respondents representing 40.0% were in agreement with the statement and 10 respondents strongly agreed with statement given a percentage of 50.0%. The respondents’ agreement to the statement was very positive as majority of the building owners and tenants believe that use of local renewable energy sources in office building is an integral factor to take note of when it comes to energy efficiency in buildings in the Municipality.

Also from table 4.6, the statement “Installing a VFD fan in a fan system is a possible energy-saving AR”, the study sought to find out whether Installing a VFD fan in a fan system is a possible energy-saving AR is an accepted energy efficiency assessment factor by building owners and tenants, it was found that, out of none of the respondents strongly disagreed with the statement, 4 respondents representing 20.0% were not sure with the statement, 5 respondents representing 25.0% were in agreement with the statement and 11 respondents representing 55.0% strongly agreed with the statement. The results showed that majority of the respondents, thus 80.0% agreed and strongly agreed that, installing a VFD fan in a fan system is a possible energy-saving AR is a necessary energy efficiency assessment factor that if used by building professionals will help improve energy efficiency in the Metropolis.

Regarding the fifth ranked statement “Use of solar shading devices to reduce the need for artificial lighting and heating” that seeks to find out whether the aforementioned recommended energy efficiency assessment tool is necessary to adopt. Table 4.6 reveals that none of the respondents strongly disagreed with the statement while 3 respondents representing 15.0% were not sure, 8 respondents representing 40.0% agreed with the statement and 9 respondents representing 45.0% have strongly agreed with the statement. Therefore, the respondents believed that use of solar shading devices to reduce the need for artificial lighting and heating is a valuable energy efficiency assessment factor that should be employed by building professionals to ensure energy efficiency.

Also from table 4.6, the responses to the sixth ranked statement “The use of energy star appliances” the study sought to find out whether The use of energy star appliances is an energy assessment factor that can be incorporated by building professionals in respect to energy efficiency, it was found that, none of the respondents out of 20 strongly disagreed with the statement, 5 representing 25.0% were not sure with the statement, 10 representing 50.0% were in agreement with the statement and 5 respondents representing 25.0% strongly agreed with the statement. The results showed that majority of the respondents, thus 75.0% agreed and strongly agreed that, the use of energy star appliances is a favourable energy efficiency method that is can be used by building professionals in the Kumasi Metropolis.

Additionally with regards to the seventh ranked statement "The use of advanced building design and construction technique that makes building energy efficient", the study sought to find out whether the use of advanced building design and construction technique that makes building energy efficient can be implemented by building professionals to ensure energy efficiency in buildings, it was found that, out of 20 respondents none of the respondents disagreed with the statement, 5 representing 25.0% were not sure with the statement, 10 respondents representing 50.0% were in agreement with the statement and 5 respondents representing 25.0% strongly agreed with the statement. The results showed that majority of the respondents, thus 75.0% agreed and strongly agreed that, the use of advanced building design and construction technique that makes building energy efficient is a positive energy efficiency assessment tool that is necessary to consider by building professionals in their building designs.

With regards to the eighth ranked statement "The use of LED Lighting" which records mean value of 4.00, out of 20 respondents none of the respondents strongly disagreed with the statement that The use of LED Lighting is an energy assessment factor, 5 of them representing 25% were not sure with the statement, 10 respondents representing 50.0% agreed with the statement and 5 respondents representing 25.0% strongly agreed with statement. This implies that, the use of LED Lighting is an effective energy efficiency assessment method that will be expedient to practise by building professionals in the Metropolis.

Other recommended energy efficiency assessment methods like, Replace HID lighting with more efficient lighting like T8 or T5 lighting or CFLs, Adopting to a proper office building shape to allow natural lighting and ventilation, Proper orientation of office buildings to adequate source of sunlight, Ensure proper airtightness of office building to avoid energy wastage and Conscious improvement of glazing ratio to solid walls, despite their low mean values, they still need to be considered as energy efficiency assessment methods that can be utilized by building professionals to reduce energy usage in office buildings in the Kumasi Metropolis.

The study concludes that, building professionals operating in the Metropolis should liaise together with building owners and tenants to implement the various energy efficiency assessment methods like Unplug any electrical gadget from sockets when not in use, Installation of smart power strips to turn off phantom power from unplugged gadgets at nights, Use of local renewable energy sources in office building, Installing a VFD fan in a fan system is a possible energy-saving AR, Use of solar shading devices to reduce the need for artificial lighting and heating, The use of energy star appliances, etc. in order to ensure energy efficiency in office buildings at Kumasi Metropolis.

4.9 Discussion of Results

In this section of the study, discussions of the results were done by putting them against results of previous studies. This section was divided according to the various research questions in the study.

4.9.1 General Knowledge on Energy Efficiency Assessment

From Table 4.2, it is unsurprising that majority of the respondents had knowledge in the statement “Significant reduction of the energy for lighting, heating and cooling in building”. It is evident that the major areas of energy consumption in buildings are heating, ventilation, and air conditioning; lighting, major appliances (water heating, refrigerators and freezers, dryers); and a significant fraction remaining in miscellaneous areas including electronics. Therefore, it can be deduced that building professionals are always engaged in installing these systems in buildings, hence, they are familiar with engineering concepts and rules that are applied to lighting, heating and cooling in building and the built environment. This finding is well-supported by the study of Jovanovic, Sun, Stevovic and Chen (2017) on energy-efficiency gain by low-energy building design, who found that most building services in India are well-informed in the significant reduction of the energy needed for lighting, heating and cooling in building. The researchers further concluded that as buildings are key to Asia’s future, building heating and cooling are the most energy-intensive activities, followed by electricity use for lighting and appliances. This implies that India being in a temperate climate, demand for cooling is more intensive than heating, and this can be said of the study area.

One of the key tasks in energy auditing is the collection of all energy related data required to apportion the total facility energy consumption into various energy end-uses. From the results, it can be mentioned that building professionals in the study area had an idea of how to identify where, when and how much energy was being used in the business and how to reduce the cost of energy for the business. This implies that building professionals knew the building energy efficiency assessment tools and their functions which are to reduce the energy consumption without compromising comfort and quality of the building. This has been reinforced by Anwar, Soib and Salah (2007), who studied the energy policy and energy demand for Malaysian development energy efficiency. They found that building service contractors knew of tools that are used to collect data for auditing the annual energy cost in buildings. They further mentioned that the collected data is used to build a reliable picture of where and how much energy is being consumed and the cost of energy being used at the building. The researchers concluded that data collection is one of the most laborious tasks in energy auditing and inability to collect the required data will lead to less reliable energy audit results.

With regards to the form of training given by organizations toward energy management, the results indicated that majority (78.6%) of the respondents have been trained by their respective organizations towards energy management. This means that training of building professionals is one of the best means main contractors demonstrate their obligation to building energy efficiency. However, critical analysis and observation suggest that, training has been limited to general induction and health and safety. Training on the utilization of energy efficiency assessment tool issues are dealt with to some extent but the amount and frequency of training cannot be considered to match the level of training advocated under energy management in building. These outcomes are in consonance with the view of Addy (2016) that training must not be a one-off incident, energy efficiency training should be a constant effort to help strengthen best quality management practices among construction firms.

Also, this results shows that commitment to improving energy efficiency in the various organizations was high as 81.4% respondents agreed that there were policies that stipulates the quality vision and provides strategies to achieve this vision. It can be said that in order to develop energy efficiency program, it is essential that there be strong management commitment and strong worker participation in the effort to cease and maintain the energy efficiency assessment of buildings. From the view point of Fall (2010), energy assessment performance of an organization is the responsibility of top management, though an important role is played by workers and team members in order to achieve the overall objectives of the company. This results is backed by Huat and Akasah (2011) that management is responsible for most of the energy efficiency issues within buildings because they control the assignment of resources, establish and implement the methods of work as well as develop the policies. From the presentation of this data, it can be mentioned that the sampled organizations ensure that office buildings are designed and constructed to become energy efficient by the use of bioclimatic architecture, high performance-controlled ventilation and high performing building envelope. It can therefore be concluded from the study that; the building professionals have adequate knowledge on energy efficiency and tool for assessing energy efficiency in office buildings.

4.9.2 The Awareness of Building Professionals on Energy Efficiency Assessment Tools for Office Building Designs

The results from the study (Table 4.3) indicate that respondents perceived a high level of awareness of Green Building Assessment (GBA) as an energy efficiency assessment tools. The use of Green Building Assessment (GBA) materials could be considered as the primary tool for measuring quality, hence, the implementation of effective and efficient energy management. It is evident that green building has become the guiding paradigm for physical development in the construction industry. The green buildings have been marketed as economical and as alternatives to convectional buildings (Issa, Mohammed, & Christian, 2011), and the total number of commercial green building commissioned has hit the 10,000th mark (World Architecture News, 2011). This could mean that the building professionals in the Kumasi Metropolis are aware of Green Building Assessment (GBA) and readily adopting it as an energy efficiency assessment tool. This finding gives a further support to Agyekum et al. (2019) who found that most building professionals in Ghana were aware of Green Building Assessment (GBA), this notwithstanding, the number of green buildings in Ghana is still low as compared to other countries. They further concluded that the promotion of green building technology and its adoption in various regions can contribute to the success of implementing green building, and thus achieving more sustainable building developments in Ghana. The Pearl Rating System (ESTIDAMA) scored the next highest mean value which was considerably above average. This implies that, the pearl rating system is among the major energy efficiency assessment tools that can help ensure energy efficiency in office buildings at the Kumasi Metropolis. These results show that Pearl Rating System is a popular assessment tool in Ghana. It could be reasoned that the prevalence of ‘Estidama’ is due to Abu Dhabi, the capital of United Arab Emirates, who has initiated the ‘Estidama’ with the aim of transforming the entire Emirates into an icon of sustainability (UPC, 2010). The result may be due to the fact that building professionals are very much aware of these assessment tools and not only that but also implements them in their various designs when it comes to office buildings. This agrees with the literature as the Pearl Rating System (PRS) is the green building assessment system developed by Abu Dhabi Urban Planning Council in 2007 (UPC, 2010) and the aim of this system is to employ the basic concepts of green architecture through highlighting the need for balanced use of land, materials, energy, and water (UPC, 2010).

This was followed by the tools "Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)" and "Leadership in Energy and Environmental Design (LEED)". These tools had mean scores of 3.33 and 3.20 respectively which were above the average mean score and had responses pointing that there were clear disparities and divergence in the opinions. The tools were also ranked third and fourth respectively, showing that these tools formed part of the significant energy efficiency assessment tools that are used in office buildings at Kumasi Metropolis. This means that since building professionals are aware of the existence of Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), it can be gathered that they would know it significance and influence as an energy efficiency assessment tool for office buildings in Ghana. This implies that, it is highly possibly to do a comprehensive assessment of office buildings in respect to energy efficiency by the use of the CASBEE. This is in agreement with Gu et al. (2001) as they consider CASBEE as the most advanced assessment system covering almost all issues during building construction stage. In addition, Leadership in Energy and Environmental Design (LEED) was developed to offer a well-known standard for the construction industry to evaluate the environmental sustainability levels of building designs (USGBC, 2014). This is in line with the findings of Wiafe (2017) that following the gradual success, the LEED certification system was also adopted and used to certify the Ridge Hospital and United Nations Building. As confirmed by Agyekum et al. (2019) that, though the World Bank Building was not certified with LEED, green building approaches underpinned in LEED were used. With the successes obtained in the adoption and usage of these certification systems, it is evident that the path for the adoption of energy efficiency within Ghana is clear.

With reference to Table 4.3, Green Pyramid Rating System (GPRS), Sustainable Building Tools (SB Tools), Green Star, Hong Kong Building Environmental Assessment Method (HK-BEAM), IGBC Green Homes Rating System and Building Research Establishment's Environmental Assessment Method (BREEAM) recorded the lowest mean values even though they formed part of the energy efficiency assessment tools. The level of awareness of these energy efficiency assessment tools for office building designs among building professionals in Kumasi Metropolis was low. This implies that, the building professionals at the Kumasi Metropolis are not much familiar with these tools especially, the Building Research Establishment's Environmental Assessment Method (BREEAM), even though it is the pioneer assessment system, established in 1990. Another factor could be the weaknesses of BREEAM. That is, it requires very exact requirements, the weighting system is complex, and a market profile is required and has a high cost of compliance. This is consistent with the finding of Alyami, Saleh and Yacine (2012) who established that building professionals do not pay attention to Green Star, Hong Kong Building Environmental Assessment Method (HK-BEAM), IGBC Green Homes Rating System and Building Research Establishment's Environmental Assessment Method (BREEAM) because of the additional project delivery requirements, such as energy modelling, more design iterations, advanced simulation and analysis, higher construction standards and additional site precautions are needed. In addition, many multidisciplinary project participants, often with added competencies, are required to work together in a non-sequential, iterative and interconnected manner (Iwaro & Mwasha, 2010). The study concludes that, even though building professionals are aware of energy efficiency assessment tools, its cost was identified as a barrier to the adoption and application to improve energy consumption in both new and existing office buildings at Kumasi metropolis. It is recommended that, building professionals must make it a point to abreast themselves with more sustainable energy efficiency assessment tools that are less costive to encourage client's acceptance and adoption in their designs.

4.9.3 Knowledge on the Factors that Building Professionals Consider in their Designs to Ensure Efficiency in the Usage of Energy

The results according to Table 4.4 indicates that Surrounding buildings recorded the highest rank as the major factor considered in building designs to ensure energy efficiency in the usage of energy with none of the respondents disagreeing to the statement. This means that surrounding buildings is a major significant factor that building professionals consider in their designs to ensure efficiency in the usage of energy. To predict the performance of a naturally ventilated building, estimates of the wind-induced surface pressure distribution are needed. This implies that the arrangement of adjacent buildings is a key point in the energy consumption of a building, particularly their number of floors and the width of streets. This finding corroborate a study by Gobakis et al. (2017) that building professionals always consider surrounding buildings in their building designs to ensure energy efficiency. Their results show that when the height of the surrounding buildings was more than base building, energy consumption was significantly compromised. Moreover, when the adjacent buildings had the same number of floors as the base building and the width of the street in the south of the building was 14.5 meters, the optimal result was achieved and energy consumption was reduced by 14.13% compared to the initial state. It can be mentioned from this result that respondents are knowledgeable on the effect of surrounding buildings' height and the width of the street on a building's energy consumption.

As reported in Table 4.4, the results portray a high level of knowledge on glazing properties that building professionals consider in their designs to ensure efficiency in the usage of energy. The great incidence that glazing has in a building energy conservation makes it one of the most important parameters to be taken into account especially in commercial buildings, where the surface occupied by glazing materials areas is very important. Therefore, it could be deduced that different shapes of glass areas, traditional wall and curtain-wall and their influence in the energy consumption of a commercial building are considered by these building professionals in the Kumasi Metropolis. It is clear that unlike any other material, glazing materials can transmit, absorb or refract light. As a result, it can be both translucent and transparent. Such characteristics add extraordinary beauty to your building. This finding is in agreement with the study by Wong et al. (2005) that glazing window design is a very important parameter of the building envelope since it controls the penetration of the solar radiation to the building. Also, a large portion of heat is transferred through the window because of the high U-Value.

The results of the study showed that, appropriate floor dimensions, mechanical ventilation, building location and natural ventilation rates existed among major significant factors that building professionals consider in their designs to ensure efficiency in the usage of energy. It will be unprofessional on the part of building contractors if they fail to consider buildings usable floor area by the site or land parcel which it sits in their designs. Again, floor dimensions for office buildings should be kept at standard to keep the office as spacious as it should be to enhance the free flow of natural ventilation. To predict the performance of a naturally ventilated building, estimates of the wind-induced surface pressure distribution are needed. In urban environments like Kumasi Metropolis, where buildings are grouped closely together, these surface pressures will be strongly influenced by the surrounding structures. Therefore, it can be mentioned that, the sheltering effect of the building location can make it more difficult to obtain large enough pressure differences across a building necessary to produce adequate natural ventilation airflow rates.

The study concludes that, inculcating energy efficiency factors in both new and existing office building stock can substantially reduce energy consumption and most of the environmental impacts especially for impact categories affected by operational energy use. The study therefore recommended that, the application of energy efficiency factors on building designs should be promoted across the construction and conservation of not only office buildings but domestic, industrial and other public buildings as well.

4.9.4 Energy Assessment Recommendations that Primary Improves Energy Efficiency in Office Buildings

In order to improve energy efficiency in office buildings in Kumasi Metropolis in the Ashanti Region, the possible recommendations needed to be in place were also assessed. In achieving this, certain possible energy assessment recommendations were identified from the review of existing literature. From Table 4.5, it is evident that all the assessed recommendations have a mean value of above average of 3.0. This implies that the respondents believe that if put in place these identified energy assessment recommendations can help significantly improve energy efficiency in office buildings in the study area. The key significant recommendation identified is the use of advanced building design and construction technique that makes building energy efficient. This implies that a good construction professional should ensure that advanced building designs and construction technique that make building energy efficient are adopted to construct office buildings. This would certainly help alleviate many of the problems encountered at the back end of the project as most of the building services contractors refuse to rework when their works fall below required standard of quality. This agrees with Carmody (2007) that building professionals should adopt advanced building designs and construction technique that make building energy efficient. The researcher further mentioned that these advanced building technologies have high energy saving potential because of improved thermal conductivity (U–value).

The results of the study showed that the respondents agreed to the adopting to a proper office building shape to allow natural lighting and ventilation, use of solar shading devices to reduce the need for artificial lighting and heating and installation of smart power strips to turn off phantom power from unplugged gadgets at nights as energy assessment recommendations that primary improve energy efficiency in office buildings. In most tropical countries, achieving thermal comfort without the use of air conditioning is becoming difficult due to poor building designs and global warming may make the issue worse. The thermal comfort of a poorly designed naturally ventilated building is difficult to control unlike in air-conditioned buildings, where thermal comfort can be achieved with the compensation of higher energy consumption. These outcomes are in consonance with the view of Galvin, Sunikka-Blank (2013) that for low-income commercial buildings, thermal renovation is difficult due to poor economic conditions. Hence, considering the proper design aspects at the initial building design would avoid such costs and both thermal comfort and lower electricity requirement would be met. In the study by Gobakis and Kolokotsa (2017), it was recognized that for naturally ventilated buildings, wind direction plays an important role in achieving the required thermal comfort. This finding is consistent with that of Caruso and Kämpf, (2015) who conducted simulations for four locations including

Rome, Tunis, Cairo and Gabes. The results indicated a strong interdependency between the annual building energy use and various basic building features such as building shape, window size and glazing type.

With regards to installation of smart power strips to turn off phantom power from unplugged gadgets at nights as energy assessment recommendation that primary improve energy efficiency in office buildings, it can be deduced that traditional power strips are an affordable way to expand the number of electrical outlets. But their convenience can encourage a user to leave electronics plugged in all the time -- and many devices keep drawing power even when not in used. Electronic devices such as printers, computers and plasma televisions are all examples of products with standby modes that make them convenient to use but suck significant power on the sly. This phantom power drain costs money, wastes electricity and ups the carbon output to boot. The result supports the finding by Raustad et al. (2008) that, although manufacturers strive to make equipment as efficient as possible, several equipment models draw a significant amount of electricity even when in stand-by mode. The researchers recommended the use of energy star appliances, installation of smart power strips to turn off phantom power from unplugged gadgets at nights and unplug any electrical gadget from sockets when not in use.

The study concludes that, energy efficient features of building is not the only critical element for good energy performance but best management practices and operational procedures are the best compliments to energy efficiency in office buildings. The study therefore recommended that, construction firms, district assemblies and ECG personnel should make a conscious effort to annually educate clients and tenants of office buildings on current sustainable operational practices that improves energy efficiency in buildings.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents the summary of findings, conclusion and recommendations, of the study that sought to assess the knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana.

5.1 Summary of Findings

The findings of the study are summarized according to the set objectives of the study. The study set out to achieve the following objectives:

1. To find out the level of awareness of building professionals on energy efficiency assessment tools in their office building designs at Kumasi Metropolis.
2. To discover the level of knowledge on the factors building professionals consider in their design to ensure efficiency in the usage of energy at Kumasi Metropolis.
3. To evaluate energy assessment recommendations that primary improves energy efficiency in office buildings at Kumasi Metropolis

5.1.1 The awareness of building professionals on energy efficiency assessment tools in their office building designs

With reference to the first objective, the study found that, the Pearl Rating System (ESTIDAMA), the Green Building Assessment (GBA), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) among others are the major energy efficiency assessment tools that building professionals in Kumasi metropolis are aware of.

5.1.2 To determine the factors that building professionals consider in their design to ensure efficiency in the usage of energy

The second objective sought to determine the factors that building professionals consider in their design to ensure efficiency in the usage of energy in Kumasi Metropolis, the study found that, surrounding buildings, glazing properties, appropriate floor dimensions, mechanical ventilation rates and building location are the major factors that building professionals consider in their designs to ensure efficiency in energy usage.

5.1.3 To evaluate energy assessment recommendations that primary improves energy efficiency in office buildings

The last objective which sought after evaluating the energy assessment recommendations that primary improves energy efficiency, revealed that, the use of advanced building design and construction technique, adopting to a proper office building shape to allow natural lighting and ventilation, use of solar shading devices to reduce the need for artificial lighting and heating among others are the major energy assessment recommendations that primary improves energy efficiency.

5.2 Conclusion of the Study

Based on the findings identified from the study, the following conclusions were made;

1. Even though building professionals are aware of energy efficiency assessment tools, its cost was identified as a barrier to the adoption and application to improve energy consumption in both new and existing office buildings.

2. Inculcating energy efficiency factors in both new and existing office building stock can substantially reduce energy consumption and most of the environmental impacts especially for impact categories affected by operational energy use.
3. Energy efficient features of building is not the only critical element for good energy performance but best management practices and operational procedures are the best compliments to energy efficiency in office buildings.

5.3 Recommendations

Based on the findings identified from the study, the following recommendations were made;

1. It is recommended that, building professionals must make it a point to abreast themselves with more sustainable energy efficiency assessment tools that are less costive to encourage client's acceptance and adoption in their designs.
2. The application of energy efficiency factors on building designs should be promoted across the construction and conservation of not only office buildings but domestic, industrial and other public buildings as well.
3. Construction firms, district assemblies and ECG personnel should make a conscious effort to annually educate clients and tenants of office buildings on current sustainable operational practices that improves energy efficiency in buildings.

5.4 Suggestions for Future Research Work

In order to strengthen the results and conclusions in this study, and also give a broader view about the subject, further research can be done. Suggestions for further research are:

1. The current study has focused solely on office buildings within the Ghanaian context. It is recommended that further studies should explore other type of buildings including the different types of residential buildings and industrial buildings.
2. The focus of the study centered primarily on buildings at the design stage. Further studies looking at already built buildings and how to measure the energy efficiency would be very interesting.

REFERENCES

Ackah, I., Adu, F., & Takyi, R. (2014). On the Demand Dynamics of Electricity in Ghana: Do Exogenous Non-Economic Variables Count? *International Journal of Energy Economics and Policy*.

Addy, M. N. (2016). Development of A Building Energy Efficiency Assessment Tool for Office Buildings in Ghana; A Thesis submitted to the Department of Building Technology, College of Art and Built Environment, Kwame Nkrumah University of Science and Technology.

Ajaji, Y., & André, P. (2015). 'Thermal comfort and visual comfort in an office building equipped with smart electrochromic glazing: an experimental study', *Energy Procedia* (vol. 78, pp. 2464-9).

Alajmi, A.F., Abou-Ziyan, H.Z., & El-Amer, W. (2013). 'Energy analysis of under-floor air distribution (UFAD) system: An office building case study', *Energy Conversion and Management* (vol. 73, pp. 78-85).

Al-Bassam, E., & Alasseri, R. (2013). 'Measurable energy savings of installing variable frequency drives for cooling towers' fans, compared to dual speed motors', *Energy and Buildings* (vol. 67, pp. 261-6).

Alhassan, S. (2006). *Modern approaches in educational administration for research students. Amakom*, Kumasi: Payless Publications Ltd.

Alyami, Saleh, H., & Yacine, R. (2012). Sustainable Building Assessment Tool Development Approach. *Sustainable Cities and Society* 5 (0) (12): 52-62 (accessed 2/3/2015 8:06:02 AM).

Anwar, A., Soib, T., & Salah, W. (2007). Energy Policy and Energy Demand for Malaysian Development Energy Efficiency: Proceeding of Power Engineering and Optimization Conference Shah Alam, Malaysia.

Australian Building Codes Board (2010) *Energy efficiency provisions for BCA 2010 volume two - information handbook.* Vol. 2. Canberra: Australian Building Codes Board.

Available: http://www.gbca.org.au. Green Building Council of Australia. Sydney, Australia (2009).

Babbie, E. (2010). *The Practice of Social Research.* Twelfth edition. Chapman University, US: WARDSWORTH CENGAGE learning.

Baetens, R., Jelle, B.P. & Gustavsen, A. (2010). 'Properties, requirements and possibilities of smart windows for dynamic daylight and solar energy control in buildings: A state-of-the-art review', *Solar Energy Materials and Solar Cells* (vol. 94, no. 2, pp. 87-105).

Barbosa, S. & Ip, K. (2014). 'Perspectives of double skin façades for naturally ventilated buildings: A review', *Renewable and Sustainable Energy Reviews* (vol. 40, pp. 1019-29).

Belliot, S. (2011). 'Glazing provided with a stack of thin films acting on the sunlight', Google Patents.

Bertoldi P. (2000). European Union Efforts to Promote More Efficient Equipment, European Commission, Directorate General for Energy, Brussels, Belgium.

Birner, S. & Martinot, E. (2002). The GEF energy-efficient product portfolio: emerging experience and lessons. Washington, DC: Global Environmental Facility.

Bosseboeuf, D., Chateau, B., & Lapillonne B. (1997). Cross-country comparison on energy efficiency indicators: The on-going European effort towards a common methodology: Energy Policy (25) 673-82

BREEAM. 2015. http://www.breeam.com/

Bryman A., (2004). The Disneyization of society, pp.1-21.

Burns, R. (2002). *Introduction to Research Methods*. London: Sage.

Caruso, G., Kämpf, J.H. (2015). Building shape optimisation to reduce air-conditioning needs using constrained evolutionary algorithms. Solar Energy 118, 186–196

Carmody, J. (2007). 'High performance windows and facades', *Centre for Sustainable Building Research (CSBR), University of Minnesota*.

Cassim, L. (2014). "Postgraduate Capacitation Workshop." Workshop, Nelson Mandela Metropolitan University, South Africa, Port Elizabeth, 1-92.

Castleton, H.F., Stovin, V., Beck, S.B., & Davison, J.B. (2010a) 'Green roofs; building energy savings and the potential for retrofit', *Energy and buildings* (vol. 42, no. 10, pp. 1582-91).

Chan, A.L.S., Chow, T.T., Fong, K.F., & Lin, Z. (2009b). 'Investigation on energy performance of double skin façade in Hong Kong', *Energy and Buildings* (vol. 41, no. 11, pp. 1135-42).

Chen, Z., Gao, Y., Kang, L., Du, J., Zhang, Z., Luo, H., Miao, H. & Tan, G. (2011). 'VO 2-based double-layered films for smart windows: optical design, all solution preparation and improved properties', *Solar Energy Materials and Solar Cells* (vol. 95, no. 9, pp. 2677-84).

Chowdhury, A.A., Rasul, M.G., & Khan, M.M.K. (2009). 'Modelling and analysis of air-cooled reciprocating chiller and demand energy savings using passive cooling', *Applied Thermal Engineering* (vol. 29, no. 8, pp. 1825-30).

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education*. London. Routledge Falmer.

Crossette, B., & Kollodge, R. (2011). 'State of world population 2011-People and possibilities in a world of 7 billion. New York (2011). Published by UNFPA.(www. unfpa. org/public/home/news/pid/8769).

Cuce, E., & Riffat, S.B. (2015). 'A state-of-the-art review on innovative glazing technologies', *Renewable and sustainable energy reviews* (vol. 41, pp. 695 714).

DeSA, U. (2013). 'World population prospects: the 2012 revision', *Population division of the department of economic and social affairs of the United Nations Secretariat, New York*.

Dieckmann, J., & Zogg, R. (2007). 'Chilled beam cooling', *Ashrae journal* (vol. 49, no. 9, p. 84).

Doe F., and Asamoah E. (2014). The effect of electric power fluctuations on the profitability and competitiveness of SMEs: A study of SMEs within the Accra Business District of Ghana. *Journal of Competitiveness*.

Duffy J. (1996). Energy Labeling, Standards and Building Codes: A Global Survey and Assessment for Developing Countries. International Institute for Energy Conservation, Washington.

Dupeyrat, P., Ménézo, C., & Fortuin, S. (2014). 'Study of the thermal and electrical performances of PVT solar hot water system', *Energy and Buildings* (vol. 68, pp. 751-5).

Energy Commission Ghana (2007). *Strategic National Energy Plan.* Accra: Energy Commission Ghana.

Energy Commission Ghana (2015). National Energy Statistics – 2015. Accra: Energy Commission Ghana.

Energy Commission Ghana (2016). Ghana Appliance Energy Efficiency Standards and labelling programme. Available at: http://www.energycom.gov.gh/index.php/standards-and-labelling. [Accessed on January, 2016].

Essah, EA. Energy Generation and Consumption in Ghana. *In Proceedings of the West Africa Built Environment Research Conference 2011*; Accra. (2011).

European Parliament and the Council of the European Union (2002). Directive 2002/91/EC of the European parliament and the of the council of 16 December 2002 on the energy performance of buildings. Brussels: Official Journal of the European Communities.

Fabrizio, E., and Monetti, B. (2015). Methodologies and Advancements in the Calibration of Building. Energies (2015). 8, 2548–2574.

Fall, L., (2010). *Achieving Energy Efficiency in Africa: What are the Priorities, the best Practices and the Policy Measures*. XXIst. Montreal, Canada.

Feist, W. (2007). What is a Passive House? *Passivhaus Institute*, http://www.passiv.de/07 eng/PHI/Flyer_quality_assurance.pdf.

Flesch, P. (2006). *Light and light Sources*, Springer.

Friess, W.A., Rakhshan, K., Hendawi, T.A. & Tajerzadeh, S. (2012). Wall insulation measures for residential villas in Dubai: A case study in energy efficiency, *Energy and Buildings* (vol. 44, pp. 26-32).

Galvin, R., Sunikka-Blank, M. (2013). Economic viability in thermal retrofit policies: learning from ten years of experience in Germany. *Energy Policy* 54, 343–351

Gasparella, A., Pernigotto, G., Cappelletti, F., Romagnoni, P. & Baggio, P. (2011). Analysis and modelling of window and glazing systems energy performance for a well-insulated residential building, *Energy and Buildings* (vol. 43, no. 4, pp. 1030-7).

Gobakis, K., Kolokotsa, D. (2017). Coupling building energy simulation software with microclimatic simulation for the evaluation of the impact of urban outdoor conditions on the energy consumption and indoor environmental quality. *Energy Build*. 157, 101–115

Gonzalez A., B., R., Diaz J., J., V., Caamano A., J., & Wilby, M., R. (2011). Towards a universal energy efficiency index for buildings: Energy and Building (43) 980-87

GPRS. (2011). Green Pyramid Rating System for Public Review. Egypt Green Building Council. Housing and Building National Research Center-Egypt.

Granqvist, C., G. (2012). Oxide electrochromics: An introduction to devices and materials, *Solar Energy Materials and Solar Cells* (vol. 99, pp. 1-13).

Green Building Council of Australia (GBCA) (2009a), "Green Star Overview, Certification". [Online].

Green Building Council" (2009). Auckland, New Zealand. [Online] Available: http://www.nzgbc.org.nz/main/greenstar. (August 6, 2012).

Greenaway, T., & Kohlenbach, P. (2017). Assessment of Potential Energy and Greenhouse Gas Savings in the Commercial Building Sector by Using Solar.

Greg R., Michael M., Maithili I., Stephen M., & James M. (2006). Energy efficiency standards for equipment: Additional opportunities in the residential and commercial sectors: Energy Policy (34) 3257–67.

Groot, H. L., Verhoef, E. T., & Nijkamp, P. (2001). Energy saving by firms: decision-making barriers and policies. *Energy Economics,* 717-740.

GSAS. (2013).Global Sustainability Assessment System. Gulf Organization for Research and Development (GORD). *a. Building Typologies (v2.0-2013. B). "Technical Guide" Issue 2: 1–76.*

Gu, Zhenhong, Getachew Assefa, Ronald Wennersten, Industrial ecology (flyttat 2013-06-30), KTH, and Skolan for Industrial Teknik och management (ITM). (2006).

Analysis of the most widely used building environmental assessment methods. *Journal of Environmental Sciences (China) 3, (3): 175).*

Hang, Y., Qu, M., & Zhao, F. (2012) Economic and environmental life cycle analysis of solar hot water systems in the United States, *Energy and Buildings* (vol. 45, pp. 181-8).

Hastings, R., and Wall M. (2007). Sustainable Solar Housing, vol. 1 – Strategies and Solutions. London.

Hill, C.A., Such, M.C., Chen, D., Gonzalez, J. & Grady, W.M. (2012). Battery energy storage for enabling integration of distributed solar power generation, *IEEE Transactions on smart grid* (vol. 3, no. 2, pp. 850-7).

Hongkong University, (2016). *Building Energy Standards and Codes (BESC)*. Available from: http://www.arch.hku/research/BEER/besc.htm.

Huat, B. N. & Akasah, Z. A. (2011). Building Performance Analysis Model Using Post Occupancy Evaluation for Energy-Efficient Building in Malaysia: A Review.

Hui, SCM. Building energy efficiency standards in Hong Kong and mainland China. *In: Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings*, *20–25 August 2000*, Pacific Grove, California. 2000.

IBEC. Comprehensive Assessment System for Built Environment Efficiency (CASBEE) New Construction Technical Manual (2014 Edition) http://www.ibec.or.jp/CASBEE/english/

IEA (2000) ECBCS Annex 53, Annex 53 Total Energy Use in Buildings: Analysis & Evaluation Methods (available at: www.ecbcsa53.org). [Accessed on 15 January 2015].

IEA International Energy Agency (1997). Energy efficiency initiative. Energy policy analysis 1997: (1) p.193-99.

IEA (2010). *Energy policies of IEA countries- New Zealand*. Retrieved from https://www.iea.org/countries/membercountries/newzealand/

IFC (2015). International Finance Corporation. World Bank. *a. Climate Business, Green Buildings. World Bank Group. http://www.ifc.org/wps/wcm/connect/topics_ ext_content/ifc-external_corporate_site/cb_home/sectors/green_buildings b. User Guide for Homes Version 1.1 Last modified 15.5.2015 http://www.ifc.org/ wps/wcm/connect/f2a2cb8044fe4791814c8dc66d9c728b/150515-00101-Homes+ User+Guide-Version+1+1.pdf?MOD=AJPERES*

IISBE (2015). International Initiative for a Sustainable Built Environment. SB Method and SBTool.

IPCC, W. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. United Kingdom and New York, NY, USA. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf

Iwaro J., & Mwasha A. (2010). A review of building energy regulation and policy for energy conservation in developing countries. *Energy Policy*.

Donnell, J.O., See, R., Rose, C., Maile, T., Bazjanac, V., & Haves, P. SIMMODEL: A DOMAIN DATA MODEL FOR WHOLE BUILDING ENERGY SIMULATION, Proceedings of Building Simulation (2011). 12th Conference of International Building Performance Simulation Association (2012), pp.382-389.

Jan V. D. A. (2008). Malaysian Industrial Energy Efficiency Improvement Project.

Janda, K. (2008). Worldwide status of energy standards for buildings. In: Proceedings of the Fifth Annual IEECB, April 9-10, 2008. Frankfurt Germany.

Jovanovic, J., Sun, X., Stevovic, S., & Chen, J. (2017). Energy-efficiency gain by combination of PV modules and Trombe wall in the low-energy building design, *Energy and Buildings* (vol. 152, pp. 568-76).

K. Hiyama, Assigning Robust Default Values in Building Performance Simulation Software for Improved Decision-Making in the Initial Stages of Building Design, The Scientific World Journal, Volume 2015 (2015) 1-11.

K. Hiyama, S. Kato, M. Kubota, J. Zhang, A new method for reusing building information models of past projects to optimize the default configuration for performance simulations, Energy and Buildings 73 (2014) 83-91.

Kaya, D., Yagmur, E.A., Yigit, K.S., Kilic, F.C., Eren, A.S., & Celik, C. (2008), 'Energy efficiency in pumps', *Energy Conversion and Management* (vol. 49, no. 6, pp. 1662-73).

Kim, G., Schaefer, L., Lim, T.S., & Kim, J.T. (2013), Thermal comfort prediction of an underfloor air distribution system in a large indoor environment, *Energy and Buildings* (vol. 64, pp. 323-31).

Kitsinelis, S., & Kitsinelis, S. (2015). *Light Sources: Basics of Lighting Technologies and Applications*, CRC Press.

Kitsinelis, S. (2016) *Light sources: technologies and applications*, CRC Press.

Konstantinos P., Haris D., Argyris K., & John P. (2008). Sustainable energy policy indicators: Review and recommendations: Renewable Energy (33) 966–73.

Kreith, F., & Goswami, D.Y. 2007, *Energy management and conservation handbook*, CRC Press.

Kubba, S. (2012) *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*, Butterworth-Heinemann.

Laughton, M. A., & Say, M. G. (2013). *Electrical engineer's reference book*, Elsevier.

Lee, W. L., & Burnett, J. (2008). Benchmarking energy use assessment of HK-BEAM, BREEAM and LEED. *Building and Environment 43*, 1882–1891.

Leedy, P. D., and Ormrod, J. E. (2014). *Practical Research Planning and Design.* Tenth Edition. Edited by Pearson new international Edition. Edinburgh Gate, England: Pearson Education Limited.

Loonen, R., Trcka, M., Cóstola, D., Hensen, J., In Lemort, V., André, P. & Bertagnolio, S. (2010). 'Performance simulation of climate adaptive building shells-Smart Energy Glass as a case study', *Proceedings of SSB*, pp. 1-19.

Lowell, C. (2012), Don't turn active beams into expensive diffusers', *ASHRAE journal* (vol. 54, no. 4, p. 52).

Lu, S. M. (2016) A review of high-efficiency motors: Specification, policy, and technology, *Renewable and Sustainable Energy Reviews*, (vol. 59, pp. 1-12).

Lucon, O., & Ürge-Vorsatz, D. (2014). *Intergovernmental Panel for Climate Change Mitigation-Buildings Chapter 9*. Intergovernmental Panel for Climate Change. Retrieved from http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-forpolicymakers_approved.pdf

Ma, Z. & Wang, S. (2009). Building energy research in Hong Kong: A review, Renewable and Sustainable Energy Reviews 13 (2009) 1870-1883.

Ma, Z., & Wang, S. (2009). 'Energy efficient control of variable speed pumps in complex building central air-conditioning systems', *Energy and Buildings*, (vol.41, no. 2, pp. 197-205).

Mahlia, T.M.I. (2004). Methodology for predicting market transformation due to implementation of energy efficiency standards and labels: Energy Conversion and Management (45) 1785–93.

Mallor, F., León, T., De Boeck, L., Van Gulck, S., Meulders, M. & Van der Meerssche, B. (2017) A method for detecting malfunctions in PV solar panels based on electricity production monitoring, *Solar Energy*, (vol. 153, pp. 51-63).

McKinsey, C. (2009). Unlocking Energy Efficiency in the U.S. Economy; McKinsey & Co.: New York, NY, USA.

McMahon J., & Turiel I. (1997). Introduction to special issue devoted to appliance and lighting standards: Energy and Buildings (26) 1–4.

Meyers S., Williams A., & Chan P. (2011). Energy and Economic Impacts of US Federal Energy and Water Conservation Standards Adopted From 1987 Through 2010, Lawrence Berkeley National Laboratory (2011).

Moss, K.J. (2015). *Heat and mass transfer in buildings*, Routledge.

Nemet, G.F., O'Shaughnessy, E., Wiser, R., Darghouth, N.R., Barbose, G., Gillingham, K., & Rai, V. (2017). What factors affect the prices of low-priced U.S. solar PV systems?, *Renewable Energy*.

New Zealand Green Building Council (NZGBC). (2009), "Green Star New Zealand Website. New Zealand.

OECD (2003). Cool appliances: Policy strategies for energy efficient homes, Energy Efficiency Policy Profiles, Paris Cedex, France.

Oikonomou V., Becchis F Stegc L., Russolillo D. (2009). Energy saving and energy efficiency concepts for policy making: Energy Policy (37) 4787–96.

Palys, T. (2008). *Purposive sampling*. In L.M. Given (Ed). The Sage Encyclopedia of Qualitative Research Methods. (vol. 2). Los Ageles: Sage. Pp.69-78.

Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. *Energy and Buildings, 40*(3), 394-398. doi: http://dx.doi.org/10.1016/jenbuild .2007.03.007

Petter J. B. (2013). Fenestration of Today and Tomorrow: A State-of-the-Art Review and Future Research Opportunities, *Solar Energy Materials & Solar Cells, 96, 1-28, 2012.*

Poel, B., Cruchten, G., van & Balaras, C. A. (2007). Energy performance assessment of existing dwellings. *Energy and Buildings 39* (4), 393–403.

Polit, D. F., & Hungler, B. P. (1993). *Essentials of Nursing Research: Methods, Appraisals and Utilization*, 3rd ed. Philadelphia, Lippincott-Raven Publisher.

Qi, R., Lu, L., & Yang, H. (2012). Investigation on air-conditioning load profile and energy consumption of desiccant cooling system for commercial buildings in Hong Kong, *Energy and Buildings*, (vol. 49, pp. 509-18).

Raftery, P., Lee, K.H., Webster, T. & Bauman, F. (2012). 'Performance analysis of an integrated UFAD and radiant hydronic slab system', *Applied energy*, (vol. 90, no. 1, pp. 250-7).

Rehman, S., Bader, M.A. & Al-Moallem, S.A. (2007). 'Cost of solar energy generated using PV panels', *Renewable and Sustainable Energy Reviews*, (vol. 11, no. 8, pp. 1843-57).

Rhee, K.-N., Shin, M.-S., & Choi, S.-H. (2015). 'Thermal uniformity in an open plan room with an active chilled beam system and conventional air distribution systems', *Energy and Buildings*, (vol. 93, pp. 236-48).

Rosenquist, G., McNeil, M., Iyer, M., Meyers, S., & McMahon, J. (2004). Energy efficiency standards for residential and commercial equipment: Additional opportunities: International Conference on Energy Efficiency in Domestic Appliances and Lighting, LBNL

S.-H.E., Lin, D.J. Gerber, Designing-in performance: A framework for evolutionary energy performance feedback in early-stage design. Automation in Construction 38 (2014) 59-73.

Saadatian, O., Sopian, K., Lim, C.H., Asim, N., & Sulaiman, M.Y. (2012). 'Trombe walls: A review of opportunities and challenges in research and development', *Renewable and Sustainable Energy Reviews*, (vol. 16, no. 8, pp. 6340-51).

Saidur, R., Hasanuzzaman, M., Mahlia, T., Rahim, N., & Mohammed, H. (2011a), 'Chillers energy consumption, energy savings and emission analysis in an institutional building', *Energy*, (vol. 36, no. 8, pp. 5233-8).

Saidur, R., Mekhilef, S., Ali, M., Safari, A., & Mohammed, H. (2012). 'Applications of variable speed drive (VSD) in electrical motors energy savings', *Renewable and Sustainable Energy Reviews*, (vol. 16, no. 1, pp. 543-50).

Santamouris, M. (2013). *Energy and climate in the urban built environment*, Routledge.

Sardianou, E. (2008). Barriers to industrial energy efficiency investments in Greece. *Journal of Cleaner Production,* 1416-1423.

Saunders, T. (2008), "A Discussion Document Comparing International Environmental Assessment Methods for Buildings", BRE Global. Watford, United Kingdom. (March 2008).

Sev, A. (2011). A comparative analysis of building environmental assessment tools and suggestions for regional adaptations. Civil Engineering and Environmental Systems 28, (3): 231-15.

Shen, H., Tan, H., & Tzempelikos, A. (2011). The effect of reflective coatings on building surface temperatures, indoor environment and energy consumption-An experimental study, *Energy and Buildings*, (vol. 43, no. 2, pp. 573-80).

Stazi, F., Mastrucci, A., & di Perna, C. (2012). 'The behaviour of solar walls in residential buildings with different insulation levels: an experimental and numerical study', *Energy and Buildings*, (vol. 47, pp. 217-29).

Syed, A. (2012). *Advanced building technologies for sustainability*, (vol. 3, John Wiley & Sons).

Togan, D., AUTOMATED CONVERSION OF ARCHITECTURAL MASSING MODELS INTO THERMAL "SHOEBOX" MODELS, Proceeding of BS2013: 13th Conference of International Building Performance Simulation Association, pp.3745-3752.

Tolvanen, J. (2008). 'Saving energy with variable speed drives', *World Pumps*, vol. 2008, no. 501, pp. 32-3.

Touloupaki, E., & Theodosiou, T. (2017). Performance Simulation Integrated in Parametric 3D Modeling as a Method for Early Stage Design Optimization-A Review. Energies **2017**, 10, 637.

UNEP, (2009). *Buildings and Climate Change*. Paris: UNEP Sustainable Consumption and Production Branch. Retrieved from http://www.unep.org/sbci/pdfs/SBCIBCC

UNFPA (2012). 'Trends in global population'.

UPC. 2010. Urban Planning Council. ESTIDAMA. The Pearl Rating System. http://estidama.upc.gov.ae/template/estidama/docs/PBRS%20Version%201.0.

Urge-Vorstaz, D., Cabeza, L. F., Serrano, S., Barreneche, C., & Petrichenko, K. (2015). Heating and Cooling energy trends and drivers in buildings. *Renewable and Sustainable Energy Reviews, 41*, 85-98.

USGBC. (2013). U.S. Green Building Council. LEED Reference Guide for Building Design and Construction version 4. 2013 Edition.

USGBC. (2014). *History. US Green Building Council.* Accessed November 6, 2014. http://www.usgbc.org/about/history.

Viholainen, J. (2014), 'Energy-efficient control strategies for variable speed driven parallel pumping systems based on pump operation point monitoring with frequency converters', *Acta Universitatis Lappeenrantaensis*.

Wang, M., Peng, J., Li, N., Yang, H., Wang, C., Li, X., & Lu, T. (2017). 'Comparison of energy performance between PV double skin facades and PV insulating glass units', *Applied Energy*, (vol. 194, pp. 148-60).

Wang, S., Yan, C., & Xiao, F. (2012). Quantitative energy performance assessment methods for existing buildings. *Energy and Buildings* 55, 873-888.

Wen, L., & Hiyama, K. (2015). A review: simple tools for evaluating the energy performance in early design stages. 8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015.

Wong, J.K.W, Li, H., & Wang, S.W. (2005). Intelligent building research: a review, Automation in Construction 14 (2005) 143–159.

Yunchang J.B. (2008). Consistent multi-level energy efficiency indicators and their policy implications: Energy Economics (30) 2401-19.

Zhou, J., & Chen, Y. (2010) 'A review on applying ventilated double-skin facade to buildings in hot-summer and cold-winter zone in China', *Renewable and Sustainable Energy Reviews*, (vol. 14, no. 4, pp. 1321-8).

Zuo, J., & Zhao, Z.-Y. (2014). "Green Building Research–current Status and Future Agenda: A Review." *Renewable and Sustainable Energy Reviews* 30 (0): 271-281. doi: http://dx.doi.org/10.1016/j.rser.2013.10.021.

APPENDIX

UNIVERSITY OF EDUCATION, WINNEBA-KUMASI CAMPUS

QUESTIONNAIRE FOR BUILDING PERSONNEL AT KUMASI METROPOLIS

Introduction

This questionnaire forms part of a master's research project which aims to assess the knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana. I will like to solicit your views on the topic. The study is purely for academic purpose and your response will be treated with confidentiality.

Instruction for completing the questionnaires: Please kindly tick (√) inside the box provided to indicate your choice of a response and also write where necessary the appropriate response in the space provided.

SECTION A: DEMOGRAPHIC DATA

1. What best describes your area of specialisation?

a) Electrical Engineering [ ]
b) Mechanical Engineering [ ]
c) Architecture/Architectural Engineering [ ]
d) Quantity Surveying [ ]
e) Civil Engineering [ ]
f) Construction Management [ ]
g) Others Please specify ……………………………………………………

2. How long have you been working in this sector?

a) Less than 5 years [ ] b) 6 – 10 years [ ] c) 11 – 15 years [ ]
d) 16 – 20 years [ ] e) 21 years and above [ ]

3. What is your highest level of education?

a) HND [ ] b) 1st Degree [ ] c) Post graduate [ ]

d) Others (specify),……………………………………………………...

SECTION B: GENERAL ENERGY EFFICIENCY ASSESSMENT KNOWLEDGE

1. Which of the following best describes building energy efficiency?

a) Significant reduction of the energy needed for lighting, heating and cooling in building [ ] b) Reduction in the building electricity demand [ ]

c) Reduction in annual energy cost [ ]

d) Reduction in annual Co2 emissions in buildings [ ]

2. Which of the following best describes building energy efficiency assessment tools? a) Tools that analyses the energy performance of buildings [ ]

b) Tools that audits the annual energy cost in buildings [ ]

c) Tools that identify and analyze the potential savings and cost effectiveness of energy in buildings before and after construction [ ]

3. What form of training does your organization give towards energy management?

a) Comprehensive operational training

b) Comprehensive technical training

c) Provided basic energy management information

d) No training

4. Which of the following best describes your organization’s commitment to improving energy efficiency in buildings?

a) Targets set by the organization for carbon and energy consumption reduction [ ]

b) Targets set for whole organization for only energy consumption reduction

c) Policy for energy reduction clearly stated
and published

d) Invest in power-saving technologies

e) Buy certified equipment

f) No policy

5. How does your organisation ensures that office buildings are designed and constructed to become energy efficient?

a) Bioclimatic architecture (Shape and orientation of the building) [ ]

b) High performing building envelope (use of glazing doors and windows, air-sealed construction) [ ]

c) High performance controlled ventilation (Wider corridors, and significant number and size of windows and doors) [}

d) Provision of skylight to allow daylighting through the roofs [ ]

e) Advanced sensor and control systems provide ventilation only where and when it's needed

f) Glazing materials with tunable optical properties (transmissivity and emissivity adjustable

by wavelength)

SECTION B: LEVEL OF AWARENESS OF BUILDING PROFESSIONALS ON ENERGY EFFICIENCY ASSESSMENT TOOLS FOR OFFICE BUILDING DESIGNS

With your experience, please answer the following questions to the best of your ability by indicating the level of awareness of building professionals on energy efficiency assessment tools for office building designs by ticking (√) the appropriate boxes below:

1 = NOT AWARE, 2=MODERATELY AWARE, 3= NOT SURE, 4=AWARE 5=HIGHLY AWARE

S/N	**Level of Awareness of Energy Efficiency Assessment Tools**	1	2	3	4	5
1	Building Research Establishment's Environmental Assessment Method					
2	Building Environmental Performance Assessment Criteria (BEPAC)					
3	Leadership in Energy and Environmental Design (LEED)					
4	The Green Building Assessment (GBA)					
5	Comprehensive Assessment System for Building Environmental					
6	The Pearl Rating System (ESTIDAMA)					
7	Global Sustainability Assessment System (GSAS)					
8	Excellence in Design for Greater Efficiencies (EDGE)					
9	Green Pyramid Rating System (GPRS)					
10	Sustainable Building Tool (SBTool^{PT})					
11	Hong Kong Building Environmental Assessment Method (HK-BEAM)					
12	IGBC Green Homes Rating System					
13	Green Star					

Other please specify……………………………………………………………………

……………………………………………………………………………………………
……

……………………………………………………………………………………………

……

SECTION C: LEVEL OF KNOWLEDGE ON THE FACTORS THAT BUILDING PROFESSIONALS CONSIDER IN THEIR DESIGNS TO ENSURE EFFICIENCY IN THE USAGE OF ENERGY.

With your experience, please answer the following questions to the best of your ability by indicating the level of agreement of each determinant on the level of knowledge of the factors building professionals consider in their design to ensure efficiency in the usage of energy by ticking (√) the appropriate boxes below:

1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = NOT SURE, 4 = AGREE, 5 = STRONGLY AGREE

S/N	**Level of Knowledge on the Factors Considered in Building Designs to Ensure Efficiency in the**	**1**	**2**	**3**	**4**	**5**
1	Building Location					
2	Orientation of building					
3	Outdoor Temperature					
4	Direction of wind					
5	Number of floors					
6	Appropriate floor dimensions					
7	Interior wall length					
8	Exterior wall areas					
9	Roof areas					
10	Exterior wall properties					
11	Window areas					
12	Natural ventilation rates					
13	Artificial lighting types					
14	Glazing properties					
15	Surrounding buildings					
16	Mechanical ventilation rates					

Other please specify…………………………………………………….……….................

………………………………………………………………………………………

………… ....

SECTION D:

ENERGY ASSESSMENT RECOMMENDATIONS THAT PRIMARY IMPROVES ENERGY EFFICIENCY IN OFFICE BUILDINGS

With your experience, please answer the following questions to the best of your ability by indicating the level of agreement of each determinant on energy assessment recommendations that primary improves energy efficiency in office buildings by ticking (√) the appropriate boxes below:

1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = NOT SURE, 4 = AGREE, 5 =

STRONGLY AGREE

S/N	**Energy Assessment Recommendations to Improve Energy Efficiency**	**1**	**2**	**3**	**4**	**5**
1	Replace HID lighting with more efficient lighting like T8 or T5 lighting or CFLs					
2	Use of local renewable energy sources in office building					
3	Installing a VFD fan in a fan system is a possible energy-saving AR					
4	Ensure proper airtightness of office building to avoid energy wastage					
5	Use of solar shading devices to reduce the need for artificial lighting and heating					
6	Adopting to a proper office building shape to allow natural lighting and ventilation					
7	The use of LED Lighting					
8	The use of energy star appliances					
9	Installation of smart power strips to turn off phantom power from unplugged gadgets at nights					
10	Unplug any electrical gadget from sockets when not in use					
11	The use of advanced building design and construction technique that makes building energy efficient					
12	Conscious improvement of glazing ratio to solid walls					
13	Proper orientation of office buildings to adequate source of sunlight					
14	Switch off your air-conditioner during short absence from the office					
15	Installing thermostat (air-conditioning regulators) in public offices					

Other please specify……………………………………………………….............

UNIVERSITY OF EDUCATION, WINNEBA-KUMASI CAMPUS
QUESTIONNAIRE FOR BUILDING OWNERS AND TENANTS AT KUMASI METROPOLIS

Introduction

This questionnaire forms part of a master's research project which aims to assess the knowledge and utilization of energy efficiency assessment tool for office buildings in Ghana. I will like to solicit your views on the topic. The study is purely for academic purpose and your response will be treated with confidentiality.

Instruction for completing the questionnaires: Please kindly tick (√) inside the box provided to indicate your choice of a response and also write where necessary the appropriate response in the space provided.

SECTION A: DEMOGRAPHIC DATA

1. Please state your gender

a. Male
[ ]

b. Female
[ ]

2. Age

a. 20-29 [ ]

b. 30-39 [ ]

c. 40-49 [ ]

d. 50-59 [ ]

e. 60 and above [ ]

3. Please indicate that which best describes your area of work

a. Building owner [ ]

b. Tenants [ ]

4. How long have you own an office building or rented the office building?

a) Less than 5 years [ ]

b) 6 – 10 years [ ]

c) 11 – 15 years [ ]

d) 16 – 20 years [ ]

e) 21 years and above [ ]

5. What is your highest level of education?

b) HND [ ]
b) 1st Degree [ ]
c) Post graduate [ ]

d) Others (specify),………………………………………………………

SECTION B:

ENERGY ASSESSMENT RECOMMENDATIONS THAT PRIMARY IMPROVES ENERGY EFFICIENCY IN OFFICE BUILDINGS

With your experience, please answer the following questions to the best of your ability by indicating the level of agreement of each determinant on energy assessment recommendations that primary improves energy efficiency in office buildings by ticking (√) the appropriate boxes below:

1 = STRONGLY DISAGREE, 2 = DISAGREE, 3 = NOT SURE, 4 = AGREE, 5 =

STRONGLY AGREE

S/N	**Energy Assessment Recommendations to Improve Energy Efficiency**	**1**	**2**	**3**	**4**	**5**
1	Replace HID lighting with more efficient lighting like T8 or T5 lighting or CFLs					
2	Use of local renewable energy sources in office building					
3	Installing a VFD fan in a fan system is a possible energy-saving AR					
4	Ensure proper airtightness of office building to avoid energy wastage					
5	Use of solar shading devices to reduce the need for artificial lighting and heating					
6	Adopting to a proper office building shape to allow natural lighting and ventilation					
7	The use of LED Lighting					
8	The use of energy star appliances					
9	Installation of smart power strips to turn off phantom power from unplugged gadgets at nights					
10	Unplug any electrical gadget from sockets when not in use					
11	The use of advanced building design and construction technique that makes building energy efficient					
12	Conscious improvement of glazing ratio to solid walls					
13	Proper orientation of office buildings to adequate source of sunlight					

Other please specify………………………………………………………………