KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

THE DEVELOPMENT OF A FRAMEWORK FOR THE UPTAKE OF NET ZERO ENERGY BUILDINGS IN GHANA

By

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MASTER OF SCIENCE

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

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ABSTRACT

For decades Ghana's economy has been fuelled by the abundant inexpensive hydropower. As a developing economy, Ghana's electricity demand has been relatively low, though rising in recent times due to increasing economic growth, urbanisation and industrial activities. However, the rapid demand growth, as well as periodic hydrological changes leaves the country increasingly reliant on expensive oil and gas-based generation power plants, with a resultant drain on the national economy. The main electricity generation company, the Volta River Authority, is not able to generate enough electricity for all the demand sectors. The electricity supply-demand margins - the difference between peak demand and available supply - of the country fall short of the recommended engineering practice and thus presents a high supply security risk. The country has been experiencing an increase in the frequency of power cuts over the last ten years. It is clear that Ghana will have to expand and diversify its generation capacity in order to improve supply security. This study aims to assess the availability of renewable energy resources, examine the economic and environmental benefits of a promising renewable energy concept i.e. net zero energy buildings to ensure the efficient production and use of the Ghana's renewable energy resources, and develop a framework for the uptake of net zero energy. This was done by collecting data on the current energy system and its effect on people in Kumasi. It was found out that the current energy system causes huge losses in productivity and profit for a lot of people in Ghana. Through literature it was found out that the current high dependence on thermal sources of energy poses a lot of harmful effects to the environment. In order to solve these issues it was recommended that the country looks at developing its renewable energy resources through the concept of net zero energy buildings

Keywords: energy balance, net zero energy

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ABBREVIATIONS

BP	British Petroleum
IPCC	Intergovernmental Panel on Climate Change
CO_2	Carbon dioxide
ISSER	Institute of Statistical, Social and Economic Research
GDP	Gross Domestic Product
PV	Photovoltaic
NZEB	Net Zero Energy Building
GHG	Green House Gas
SDG	Sustainable Development Goals
VALCO	Volta Aluminium Company
ZEB	Zero Energy Building
CH_4	Methane
N_2O	Nitrous Oxide
WAGP	West African Gas Pipeline
VRA	Volta River Authority
SLT	Special Load Tariff
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
EPA	Environmental Protection Agency

EIA	Environmental Impact Assessment
GGBL	Guinness Ghana Brewery Limited
KMA	Kumasi Metropolitan Assembly
PHC	Population and Housing Census
CBD	Central Business District
SPSS	Statistical Package for Social Sciences
ECG	Electricity Company of Ghana
PURC	Public Utility Regulatory Commission
GridCo	Ghana Grid Company
MOE	Ministry of Energy

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First, I would like to thank my parents and family for all the support they have given me. My parents taught me that education is the first and foremost aspect of my life. I would also like to thank my supervisor Dr Daniel Duah. Finally, I would like to thank all my friends and colleagues throughout the years who have influenced and shaped me in one way or another into the person I am today.

DEDICATION

I will like to dedicate this work to my parent's Dr Anthony Kwame Danso and Mrs Cynthia Danso, all Construction Management lecturers and to all 2017/2018 Construction Management students.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

The economic prosperity of every nation depends heavily on energy. It plays a significant role in doing day-to-day activities from running plants in the manufacturing sector to heating, cooling, lighting, cooking, etc. Energy is again vital for good education, effective communication, efficient transportation, mineral exploration, quality healthcare delivery and many more. It also serves as the building block on which every sector of a nation's economy thrives. This emphasizes how crucial and indispensable energy is for human existence in the 21st century (Kumi, 2017).

Renewable energy also called alternative energy or sustainable energy is a type of energy derived from naturally occurring phenomenon. For example, geothermal, solar, hydropower, wind, tidal, wave, and bio power. The reason why they are deemed sustainable is because they are environmentally friendly and their usage now will have no consequence on future generations (Gorjian, 2017). The rising concerns over fossil fuel depletion around the world, rising energy prices and the dangers of climate change have triggered engineers and scientists to search for innovative methods to reduce the usage and consumption of non-renewable energy sources particularly fossil fuels. Statistical data by the BP statistical review of world energy June 2017 showed that, there is high dependence on the use of non- renewable energy in the share of the worldwide total primary energy supply than any other energy resource (See Figure 1.1) (British Petroleum, 2017).

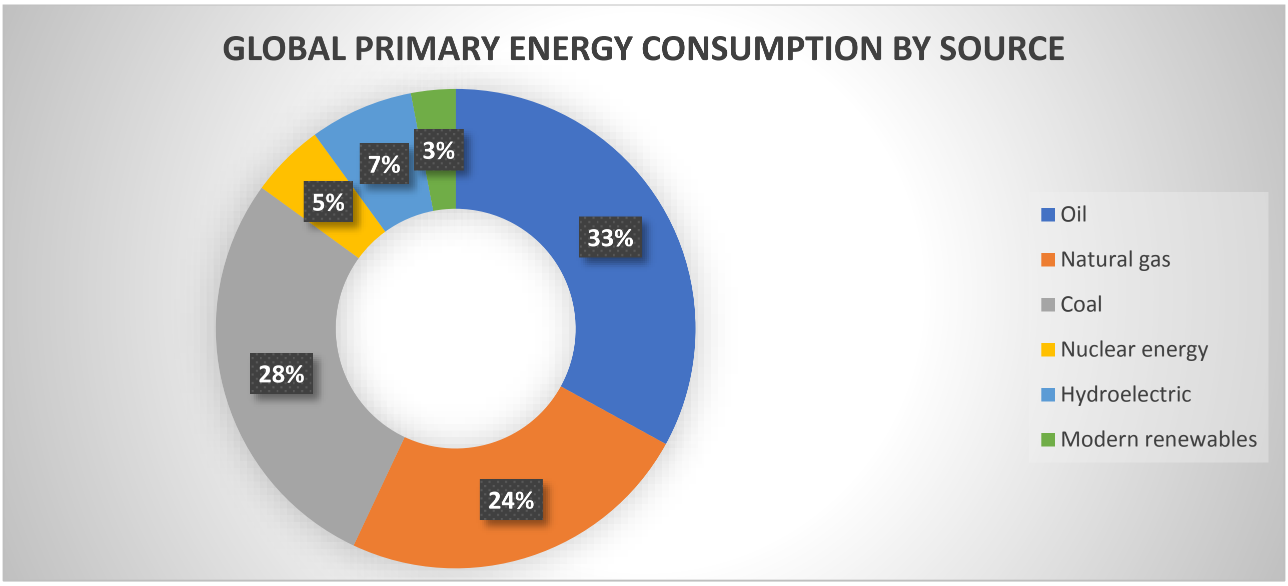

Figure 5.1: Fuel shares of total primary energy source Source:(British Petroleum, 2017)

In the power-generating sector, coal dominates the total share of fuel for generating electricity than any other fuel source with a share of about 40 percent in the year 2010. Apart from hydropower generation, electricity generation from other renewable energy sources has been very insignificant, a total of about 6.5 percent, which includes solar, wind, geothermal and biofuels (Figure 1.2) (Noris et al., 2014)

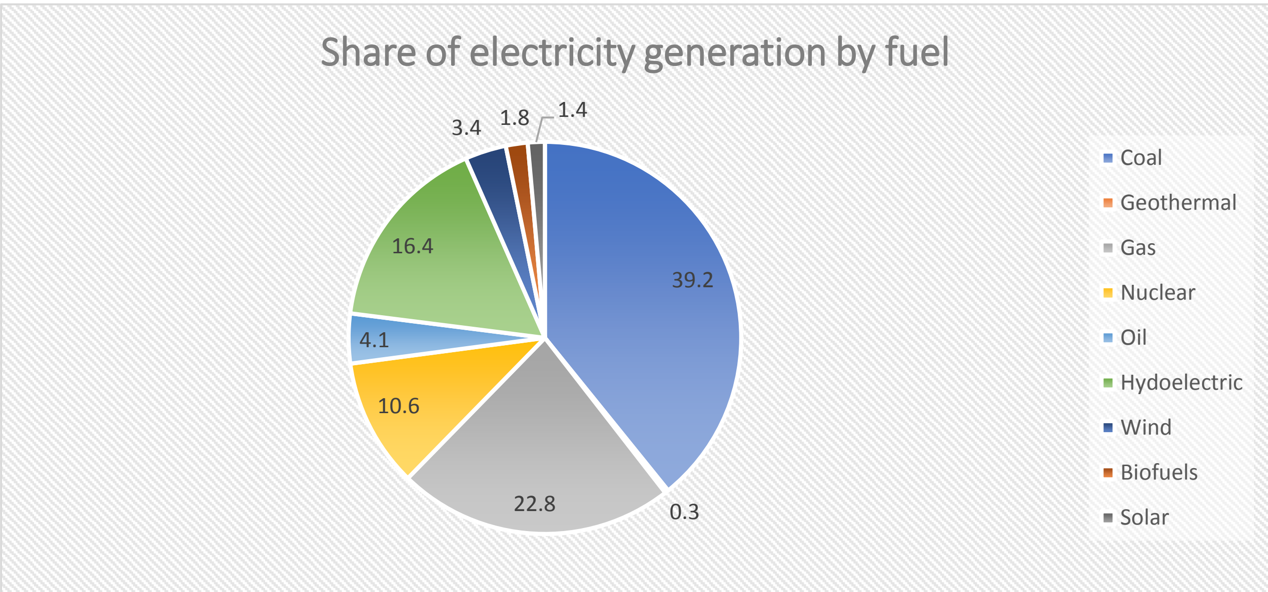

Figure 1.6: Fuel share of electricity generation.

The over dependence on non-renewable energy resources especially fossil fuels comes with very hard challenges, a classical example is global warming, which is instigated by the emissions of greenhouse gasses (carbon dioxide and methane gas) from the burning of fossil fuels. Coal, which is largely used for producing power, is the highest emitter of carbon dioxide among the fossil fuels. Figure 1.3 shows fuel share of carbon dioxide emission from 1971 to 2013 (Together, 2015).

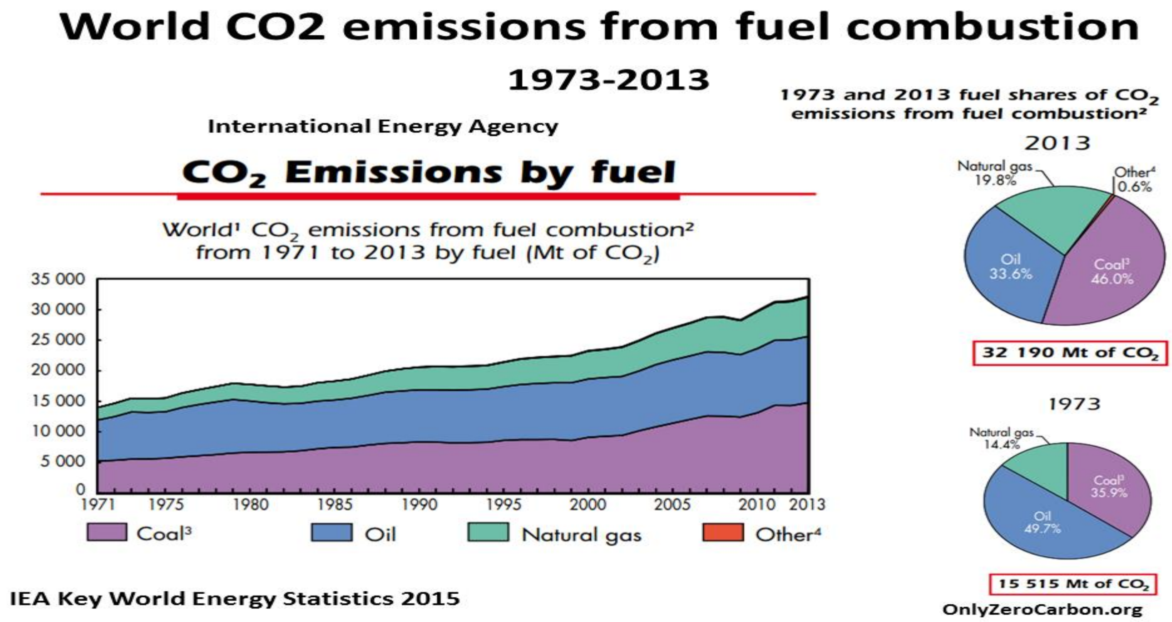

Figure 1.7 World carbon emissions by fuel

There is an intensifying natural climate change owing to the emission of carbon dioxides. In 2007, the Intergovernmental Panel on Climate Change (IPCC) forecasted global temperature rise in Figure 1.4 (Panel et al., 2007).

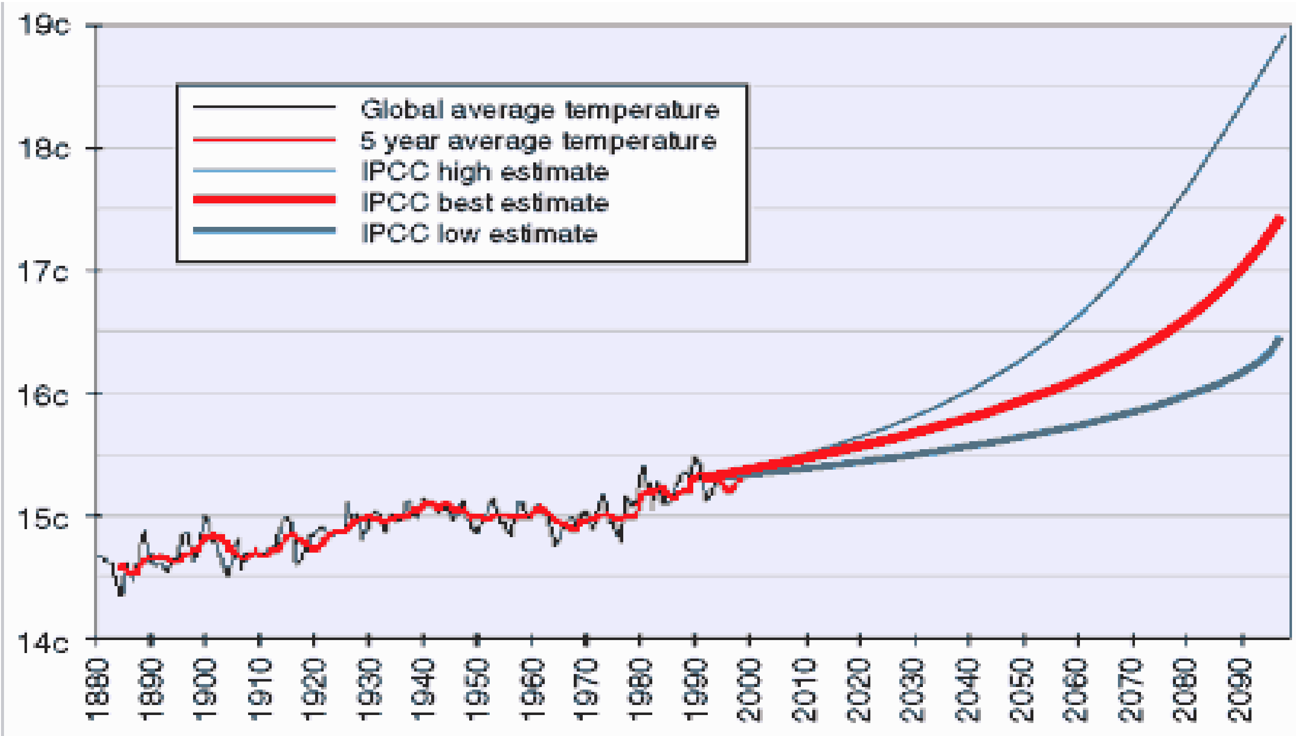

Figure 1.8: Global temperature rise

The conclusion that can be drawn from the prediction is that in the few decades to come if the measures to reduce carbon dioxides emissions are not well strengthened, a more dangerous climatic change is feared to happen. The call therefore to shift our energy preferences to a more sustainable and environmentally friendly sources especially in the energy generation sector is cannot be over emphasized (Panel et al., 2007).

All over the globe alternative energy sources are now being considered especially in the energy generation sector. Among the renewable energy sources (solar, wind, geothermal and biofuel), solar and wind energy are found to be attractive and are rapidly growing in terms of power generation (Kylili & Fokaides, 2015).

Energy is an important resource needed for economic development. It is vital to be readily accessible uninterruptedly and in adequate quantities. It is required to be environmentally friendly and clean. It is a big task ensuring this, yet necessary to ensure that economies are run in a sustainable way. Sustainable energy development is not a new idea, or a new concern.

Nevertheless, as a result of new problems, innovative solutions and a broader approach is required. Both the consumption (demand) and generation (supply) should be taken into consideration by this approach, as well as take into consideration energy shortage situations and excess opportunities. Also, it should give way for both private (individual) and public (government) initiatives. Sustainable energy development is defined, in this context, as the achievement of social, economic and environmental benefits for the present and future generations through the provision of sufficient, affordable and environmentally sustainable energy services (Buildings & One, 2017).

The rising need for a sustainable built environment calls for the need to look at our energy needs and sources. About 40% of energy produced is consumed by buildings with a large amount of this energy coming from the burning of fossil fuels. Fossil fuel is a limited resource and the burning of these fuels produces gases and toxins that affect the environment negatively. There is the need therefore to find sustainable ways of providing energy for our buildings. This can be done by the use of renewable energy resources in the production of energy for buildings (Alirezaei et al, 2016). In the built environment the balance between the energy produced by renewable energy systems and the energy used by a building is used to describe net energy. The idea of net zero energy means that the systems installed in, on or near a building can convert energy from renewable sources to produce at least as much energy as the building needs in a year (Hernandez & Kenny, 2010).

A net zero energy building whose total annual energy consumption is equal to or less than the quantity of renewable energy (energy created by sources that are naturally replenished, such as rain, solar, or wind) created on-site. A net zero energy building is normally connected to the electric grid and can sell surplus energy, as well as buy extra energy during periods of high energy demand. Nevertheless, over the course of an whole year, this building will be net zero because it cleanly produces as much energy as it consumes (Bourrelle et al, 2013).

1.2 PROBLEM STATEMENT

The problem statement identifies and species in clear terms, the problem that the study will address by explaining its nature, causes and symptoms. Thus, the problem statement indicates the motivation for the study, that is, whatever the purpose of research, its significance rest in the way it is likely to contribute to theory, policy, practice and social action.

1.2.1 The Unsustainability of the Current Energy System

Energy systems to generate and supply electricity and heat to consumers in the developing world have been designed around the use of non-renewable fuels. In the 20th century, most communities in the developing world became reliant on energy that was generated from non-renewable fuels in large, centralized facilities far from the users (Blum & Legey, 2012).

In developing nations like Ghana, the supply of power is a vital factor required for development. The decreasing availability of fossil fuel sources of energy has caused conflicts to arise amongst competing countries and regions. The release of greenhouse gasses from fossil energy sources contributes to the pollution of the environment making it unsustainable. Many of the downsides of fossil fuels can be removed through the use of renewable energy sources because the energy will be readily accessible for all with no cost or negative environmental effects. The need for us to build sustainably has increased in recent years. One of the main areas that has to be looked at in building sustainably is energy. Energy production and usage has to be done in a more sustainable manner. Over 40% of energy is used by buildings. The idea of net zero energy buildings seeks to produce energy from renewable resources in a sustainable way (Alirezaei et al., 2016).

Table 2.1: Energy generation sources in Ghana

Plant	Installed Capacity (MW)	Dependable Capacity (MW)	% of Installed Capacity
Hydro			
Akosombo	1,020	1,000	
Bui	400	360	41.6%
Kpong	160	148	
Sub-Total	1,580	1,508	
Thermal			
Takoradi Power Company (TAPCO)	330	300	
Takoradi International Company (TICO)	340	320	
Sunon Asogli Power (Ghana) Limited (SAPP) - IPP	200	180	
Sunon Asogli Power (Ghana) Limited (SAPP2) - IPP	180	170	
Cenit Energy Ltd (CEL) - IPP	126	100	
Tema Thermal 1 Power Plant (TT1PP)	126	110	57.8%
Tema Thermal 2 Power Plant (TT2PP)	50	45	
Mines Reserve Plant (MRP)	80	70	
Kpone Thermal Power Plant (KTPP)	220	200	
Karpowership	235	220	
Ameri Plant	250	240	
Trojan	25	22	
Genser	30	18	
Sub-Total	2,192	1,995	
Renewables			
Safisana Biogas	0.1	0.1	
VRA Solar	2.5	2	0.6%
BXC Solar	20	20	
Sub-Total	22.6	22.1	
Total	**3,795**	**3,525**	**100.0%**

In Ghana, 57.8% of our electricity is generated from thermal sources which is unsustainable due to the depletion of the limited fossil fuels and the pollution it causes to the environment (Kumi, 2017).

1.2.2 Environmental Implications of the Current Energy System

A large amount of energy produced in Ghana (about 60%) is from the burning of fossil fuels. This has a huge negative impact on our environment and has to be checked. The need to decrease fossil fuels usage and greenhouse emissions shows the need for this topic. About 80% of carbon emissions in Ghana comes from urban centres. Transportation, buildings and industries are the main elements that contribute greatly to the increase pollution in the Ghana. Buildings require extremely intricate energy systems because it interacts in a lot of ways with its surroundings. Over the years, carbon dioxide emission has increased due to the increase in fuel consumption for electricity production from thermal sources (Asante & Amuakwa-mensah, 2015).

The undoubted importance of the use of renewable energy for environmental reasons as an answer to problems of finite fuel resources and potentially irreversible effects of atmospheric pollution makes it doubly necessary to understand how renewable energy itself is constrained by environmental impact. It is crucial for the successful implementation of renewable energy to understand the underlying structure and patterns of its environmental effects (Asante, 2014). This thesis sought to identify ways of developing renewable resources to produce energy for our buildings.

1.2.3 Effects of The Current Energy System on The Economy

The unavailability of sufficient reliable energy for our buildings has hugely affected and impeded productivity in our industries in Ghana. The rampant power outages have led to the folding up of a lot of businesses in the country. This raises the need to find additional sources of energy to supplement the traditional sources available in the country (Krarti & Ihm, 2016). Once the fossil fuels are depleted, apart from nuclear sources of energy, only the renewable sources will be available to humanity. Long before that time, fossil fuels will rise in price as demand exceeds supply (David & Bphil, 2012). The increase in the prices of fossil fuels on the global market will put a huge stress on our limited financial resources.

Ghana’s power sector has, over the past decade, been plagued with power supply challenges resulting in considerable effect on the economy of the country. Electricity was ranked as the second most important limiting factor by the World Bank to economic activities in Ghana and it was estimated that about 1.8% of the country’s gross domestic product was lost during the power crisis in 2007 (Mathrani & Viehland, 2013). Also, in a 2014 study by the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana, it was estimated that in Ghana an average of 2.1 million US dollars’ worth of production was lost per day or US $55.8 million per month as a result of the energy crisis alone (ISSER, 2015). This shows that in 2014 as a result of the energy crisis Ghana lost about US$680 million which is 2 percent of the nation’s gross domestic product (Kumi, 2017).

1.3 JUSTIFICATION OF STUDY

The concept of net zero energy building is a very viable one if we want to move towards sustainable energy development in Ghana. The nation’s current power generation systems are not able to meet the energy demands of the population. This has led to huge stress on industry and infrastructure leading to the need to find alternative sources of energy. Many businesses and industries have folded up in the country due to inadequate and unreliable power supply increasing unemployment in the country. About 50 percent of Ghana's electricity is generated by thermal power plants which run on fossil fuels (Energy Commission of Ghana, 2014). The generation of half of our electricity from fossil fuels poses a huge environmental threat to the nation. This study seeks to throw light on the economic and environmental benefits of generating energy in a sustainable way through the concept of net zero energy buildings.

1.4 AIM OF STUDY

The aim of this study is to encourage the use of sustainable energy through the development of a framework for the uptake of the net zero energy building concept in help Ghana.

1.5 RESEARCH QUESTIONS

1. Are the current energy systems in Ghana sustainable?
2. What are the environmental implications of the current energy systems?
3. What are the economic implications of the current energy systems?
4. What measures can be put in place to develop a framework for the development of net zero energy buildings?

1.6 OBJECTIVES OF STUDY

The main objective of this thesis is to analyse the economic and environmental implications of net zero energy buildings. The specific objectives are

1. To know the opinion of people about the sustainability of the current energy system.

2. To determine the environmental impacts of the current energy system.
3. To evaluate the economic impacts of the current energy system.
4. To make recommendations for the uptake of net zero energy buildings.

1.7 RESEARCH METHODOLOGY

Research methodology deals with the methods employed in the collection and analysis of the data required for the study. The quantitative and qualitative research method was employed in this research. This method used mathematical and statistical techniques to identify facts and casual relationships. It followed the practices and norms of the natural scientific model. Sampling was done by choosing research units from a target population. Data was collected through interviews and the use of questionnaires.

1.8 SCOPE OF STUDY

This study covered sustainable energy development in Ghana through the concept of net zero energy buildings. The research was conducted in Kumasi the second largest city in Ghana. This study sought to bring forth the economic and environmental benefits of net zero energy buildings if it is considered as a way of meeting our sustainable energy development goals.

1.9 ORGANISATION OF STUDY

The report consists of five (5) chapters. The first chapter introduces the report and comprises the background of study, problem statement, aim, objectives, research questions, scope of study, research methodology, organisation of study and the chapter summary. The second chapter reviews existing literature on net zero energy buildings and the economic and environmental implications of the technology. The third chapter discusses the methodology used for the study i.e. in the collection and analysis of data. The fourth chapter analysis the data collected, highlights the results and discusses the findings. Lastly, the fifth chapter concludes the findings of the study and makes recommendations regarding the study.

1.10 CHAPTER SUMMARY

This chapter introduced the concept of net zero energy building as a way of sustainable energy development. The research problems were also discussed in this chapter. It showed the challenges we face as a result of our current energy systems both economically and environmentally. The objectives and aims for this research were also derived from the problem statement in this chapter. Questions which have to be answered by the thesis were also asked. Justification for the research was made known. The procedure for the research was discussed in this chapter. Lastly, the scope and the organisation of the study was looked at.

CHAPTER 2: REVIEW OF LITERATURE

2.1 INTRODUCTION

Energy poverty issues, climate change and energy consumption are some of the significant challenges the building sector is experiencing. In addition, the developing market for renewable energy has being caused by the long-standing trend of increasing energy prices and has led to decreasing costs of renewable energy technologies such as wind systems and solar photovoltaics. The boundaries for new development in the built environment have been pushed by this. The achievement of net zero energy building status or energy neutrality through the retrofitting of the existing buildings and the design of more sustainable commercial and residential buildings is one of such developments. A sustainable building can be well-defined as a structure that considers the health, safety, comfort of users and maintains structural integrity including efficiency measures and takes into consideration environmental impacts. In other words, it provides efficiency, maximum energy gains and reduces losses. In Ghana net zero energy buildings are still rare which is likely due to the lack of education on the concept to an ordinary Ghanaian however there are many examples of both commercial and residential buildings with zero energy status around the world (Wells, Rismanchi, & Aye, 2018).

Zero energy buildings provide substantial prospects to minimise GHG emissions and to decrease energy usage because about one-third of GHG emissions can be attributed to buildings and given that buildings are estimated to account for about 40% of energy use worldwide. There are quite a number of genuine net zero energy building projects around the world, with the recent rapid development of NZEB projects driven by the improved accessibility to renewable energy and energy-efficient technologies. People interested in NZEBs tend to be from research, design background, individuals or institutions (such as Burger King and

Walmart) wanting to reduce their energy costs, expand their image or give their institution a competitive edge.

NZEBs are most predominantly concentrated around North America and Europe even though examples of NZEBs exists worldwide perhaps as a result of factors such as more advanced research, better accessibility to technologies, availability of funding for investment and high energy costs (predominantly heating costs) due to extreme climates (Wells et al., 2018).

2.2 DEFINITION OF KEY CONCEPTS

The main terminologies used in this study are explained in this section.

2.2.1 Sustainable Development

Sustainable development can be defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The UN General Assembly in 2015 accepted the 2030 Sustainable Development Agenda and its Sustainable Development Goals (SDGs), which consist of a devoted and stand-alone goal on energy, SDG 7, calling for the assembly to “ensure access to affordable, reliable, sustainable and modern energy for all" (Fonseca et al., 2018).

Energy lies at the heart of the 2030 Agenda for Sustainable Development. Making sure there is access to sustainable, affordable, dependable, and modern energy for all will create a lot of opportunities for many people by empowering women, children and the youth, providing new economic opportunities and jobs, better education and health, more inclusive, sustainable and equitable communities, and greater protections from climate change (Matthew & Leardini, 2017).

Sustainability is built on a principle (USEPA, 2014). Everything humans need for well-being and survival depends directly or indirectly on our natural environment. Sustainability creates and maintains conditions for humans and nature to exist in productive harmony to:

- Achieve social, economic, and environmental gains for current and upcoming generations
- Make sure we continue to have the materials, water, and resources to protect the health of humans and the natural environment

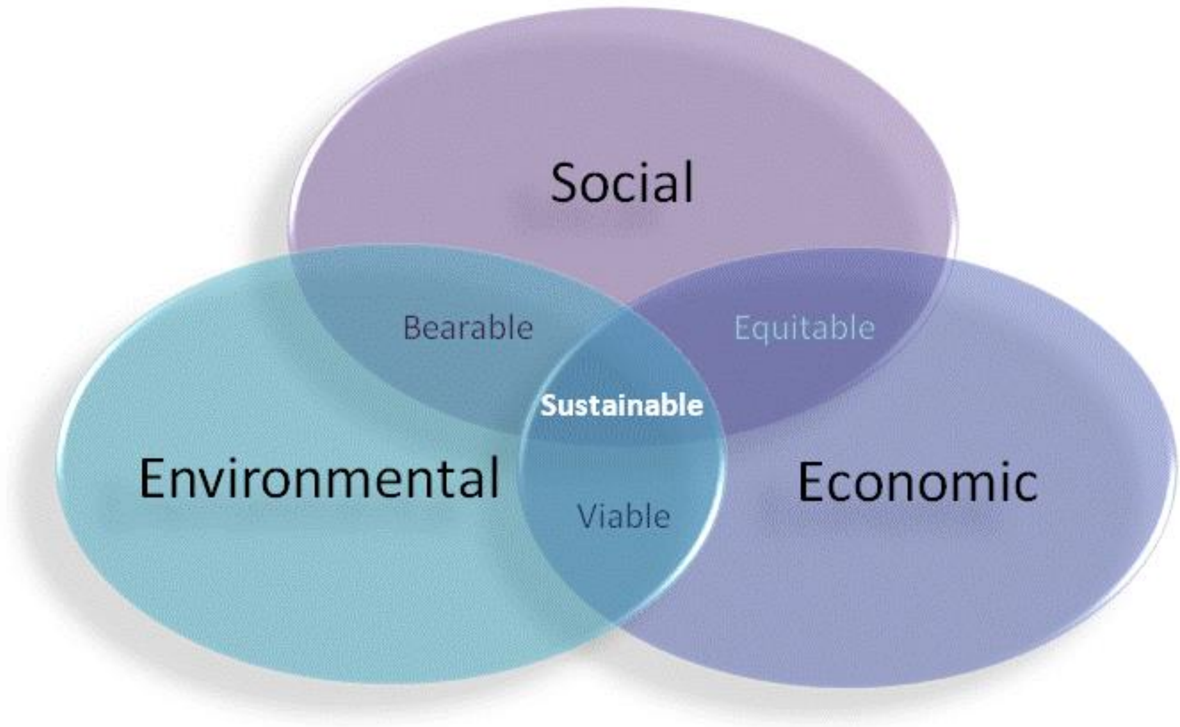

Figure 2.1: Dimensions of sustainability   Source: USEPA, 2014

Dimensions of sustainability are not independent of one another. The dimensions of sustainability are intertwined in the inherent trade-offs in any engineering decision. Interrelationships among dimensions creates inherent complexity in sustainable engineering design and decision making. Perfect sustainability for the earth system is (theoretically) possible. Humans must consume less energy than supplied by natural renewable sources as long as available (USEPA, 2014).

2.2.2 Renewable Energy

Renewable energy can be defined as energy produced from naturally existing resources such as rain, wind, geothermal heat, tides and sunlight which are renewable. Renewable resources are unlimited natural resources that can be replenished in a no of time. For example, wind, solar energy, biomass, hydroelectricity, ocean energy, geothermal, etc. Renewable energy technologies are important contributors to sustainable energy as they generally contribute to world energy security, lowering dependence on fossil fuel resources, and providing opportunities for mitigating greenhouse gases (Gyamfi et al, 2015).

2.2.3 Net Zero Energy

The use of energy conservation, on-site renewable generation and energy efficiency to account for all of a particular building's or community's energy usage can be said to be net zero energy. A net zero energy building can be conceptualized in the context of a building like a home or office. The production of as much or more energy than required by a building would mean that it is a net zero energy building (Sartori et al., 2012).

2.3 Net Zero Energy Buildings

Currently, there is no nationally or globally fixed description of what it means for a building to be zero-energy. Nevertheless, this major impediment has been recognized and effort is being put forth to define the parameters and standards of what a zero-energy building will look like and to establish a consistent framework for all zero energy buildings (Szalay & Zöld, 2014). A zero-energy building could be achieved by taking a conventional building and adding a very large solar array, or any renewable energy source, that would offset the building's energy use through its renewable energy generation. For example, if the goal were only to achieve net zero energy, and an installed photovoltaic system delivers more energy than a building uses, then the building is potentially a net zero energy building under a very loose standard. Thus, the purpose behind building a net zero energy building or the goals of a net zero energy building must be considered before a given definition can be settled upon. So, in many cases, the definition or type of zero-energy building will be largely dependent on the individual project and its objectives. It is with this understanding that we can define several different types of zero-energy buildings (Jerzak, 2017).

With no prior understanding of the potentials of zero-energy buildings, one might envision a compact minimalist hut set remotely off the grid. Several solar panels and a few golf cart batteries, to store the excess energy, would be tucked away to provide this self-sustaining building with some of the little energy it would need. Although these types of buildings are definitely zero energy, they should really be considered as the jumping off point for the modern day zero-energy building. That is to say, they were simply an intermediate step on the path towards the true potential of zero-energy that can be achieved through net metering. In simple terms, net metering uses the power grid like a massive battery. All the excess energy that the building produces through its renewable energy generation is exported to the grid to be used by others, since it must be used as it is being generated. This output is accounted for like money in a bank account, to be used at a later time. For example, at night and during the dark winter months when PV (photovoltaic) generation is lacking or non-existent, a building can hypothetically import the energy it produced back, thus resulting in a net-balance. It is with this technology that we are beginning to see the potential of zero-energy buildings unleashed. Beforehand, all excess energy must have been stored in batteries or used as it was being generated. That was until 1983, when Minnesota enacted the first net-metering law in the world. So, if you wanted to put a PV system on your building, economically it would not have been feasible given the immense amount of batteries needed. Unless your goal was to be off the grid, in which case you probably do not require much energy to begin with. Although off-grid zero-energy buildings are truly zero-energy, they are not practical for the purposes of this thesis. If we are to work towards zero-energy buildings on a massive scale, it is necessary that they be connected to the grid and able to utilize net metering (Shen & Lior, 2016).

Thus, from now on, all zero-energy buildings referred to in this thesis as "ZEB" will refer to any net zero-energy building thus will be considered nearly net zero energy buildings. These latter are buildings on the path towards net zero, not to be confused with buildings that have achieved a net zero standing. Separately, "ZEB" will be used to denote any zero-energy building (i.e., not just residential buildings), although the focus of this thesis is on zero-energy buildings. Lastly, photovoltaic (PV) is consistently referred to in this thesis as the primary source of renewable energy generation for ZEBs. This is because of its general acceptance as the most cost-effective form of renewable energy, its widespread implementation and compatibility with net metering (Shen & Lior, 2016).

With this in mind, the heart of defining zero-energy buildings comes down to the different methods of calculating the "zero" balance that is, "a condition that is fulfilled when total supply meets or exceeds total demand over a period of time, normally a year" (Sartori et al. 2012). This balance is influenced by a variety of measures and each must be considered when defining the net zero building. For example, one might select CO_2 emissions, end-use energy, energy or cost of energy as the metric of balance. An on-site ZEB provides at least the minimum amount of energy required by the building in a year, when accounted for on the site. A building which produces as least as much power as it uses in a year when accounted for at the source is a source ZEB. The primary energy used to produce and bring the energy to the site is known as source energy. In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year (Miller et al, 2018).

A net zero-emissions building produces GHG (greenhouse gas) emissions-free energy in an amount that is at least as much as it uses from emissions-producing energy sources. Each one has its own unique advantages and disadvantages. What they all share, however, is the idea that energy efficiency is the first priority and once that is achieved, the addition of renewable energy sources can be added to reach the zero balance. Each of the definitions assumes that they will use the grid for net metering. The site ZEB produces as much energy as it consumes when accounted for at the site. Like the others, it can generate energy through a variety of renewables suitable to the given location. This could be roof-mounted PV, a small-scale wind turbine, low-impact hydroelectricity etc (Torcellini et al., 2006).

Regardless of type of renewable, the first option is always to reduce the site energy through low-energy building technologies. This is usually a given but can be easily overlooked. After this, the best option is to use renewable energy sources available within the building's footprint e.g., using PV, solar hot water, and wind located on the building. Ideally, this is the best option after all efficiency measures have been met. This is primarily due to the renewables not requiring additional resources, but instead taking advantage of available space, such as the roof, in cases of PV and wind generation. Next is the use of renewables from energy sources at the site. These could be PV, solar hot water, low-impact Hydro, and wind that are on site but not on the building. While still a stellar option, there may be additional environmental impacts when dealing with sources away from the building. The last two options are to utilize renewable energy from off-site sources. For example, one could bring in biomass, ethanol, and biodiesel from another site or waste stream and process it on site to generate electricity. Lastly, one could purchase off-site renewables, for example, by buying utility-based wind, PV, emissions credits, or even hydroelectric energy. However, in the last two cases, one could potentially purchase all power from hydroelectric or biomass and declare their building “zero energy,” which is not quite what a ZEB is attempting to reach. Rather it would be best practice to utilize as much of the first options as possible and only consider the offsite renewables as a last resort, to reach Zero Energy (Berry & Davidson, 2015).

2.4 ENERGY SYSTEM IN GHANA

Ghana’s electricity sector dates back to the Gold Coast era where electricity supply was mainly from diesel generators owned by industrial establishments including factories and mines as well as other institutions such as hospitals and schools. The sector was revolutionised with the completion of the Akosombo Hydroelectric Power Station which also saw the export of electricity to neighbouring countries including Togo, Burkina Faso and Benin. Electricity demand has since grown significantly to the point where supply is not enough to meet the demand, resulting in severe power crises over the last decade. In a bid to solve the crisis, a power sector reform was implemented in the late 1990s to open up the electricity market for private sector participation to help deal with the power crises (Adom-Opare, 2012).

Demand for electricity in Ghana has increased by about 52 percent over the last decade (2006-2016) whiles installed generation capacity has more than doubled over the same period. In spite of this, the country still suffers from persistent power supply challenges. This situation can be attributed to the fact that most of the installed generation facilities are not available for generation due to fuel supply challenges (Kumi, 2017).

In 1972, the commencement of use of the Akosombo Dam on the Volta River made available an overall installed capacity of 912 MW for electricity generation. Though the primary aim of the dam was to provide electricity for the Volta Aluminium Company, it also made it possible for most of the major electricity used to be switched from thermal sources to hydroelectricity. The Kpong Hydroelectric Power Station was commissioned in 1982, adding to the installed generation capacity by 160 MW. Ghana, experienced its first electricity crisis in 1984 in spite of the increase in generation capacity. This was a result of a severe drought that happened between 1982 and 1984, during which the total inflow into the Akosombo Dam was less than 15 percent of the long term expected amount. This crisis led to the introduction of Thermal Power Plants into Ghana's generation mix. The first of these thermal plants was a 550 MW facility (Tapco and Tico) at the Takoradi Thermal Plant managed by VRA. The total installed capacity of thermal power plants in Ghana has increased to 2,053 MW as at the end of 2015 (Energy Commission of Ghana, 2016).

Electricity crisis has become a household phenomenon in Ghana leading to the adoption of the local word "Dumsor" to describe the situation. In December 2013, the 400 MW Bui Hydroelectric Power Station was commissioned to provide electricity to support the peak load of the country, which has been on an ever-increasing trajectory (Energy Commission of Ghana, 2012).

Ghana's electricity sector has been heavily dependent on the Akosombo Dam which has seen water levels drop consistently below acceptable operational levels. In recent times however, significant amounts of thermal generation sources running on mostly natural gas have been introduced into the sector. The problem with these sources is that supply of natural gas by the West African Gas Pipeline (WAGP) has been very unreliable (Gyamfi et al., 2015).

Other challenges plaguing the sector include high levels of transportation losses, lack of revenue due to the non-payment of bills and also poor tariff structure, which makes it tough for the power utilities to make significant investments to improve the sector due to financial constraints. Opportunities, however, remain in the sector for the introduction of renewable energy sources into the generation mix, seeing that the country has potential for solar power generation and other renewable energy sources. In light of this, the necessary regulatory frameworks have been provided notable among these is the passage of the Renewable Energy Act in 2011 (Quartey, 2014).

2.4.1 Energy Consumption in Ghana

Electricity consumers in Ghana are grouped into street lighting, non-residential, residential and industrial by the Energy Commission of Ghana. Industrial, sometimes referred to as Special Load Tariff (SLT), consumers are those who use electricity for industrial purposes including VALCO, the mining companies and other production and manufacturing facilities. Residential consumers refer to homes in both rural and urban sectors of the country whereas non-residential consumers are mostly commercial facilities. The electricity consumed by street lights across the country is captured under the street lighting class. The electricity consumption trend shown in Figure 3 indicates that, the past decade has seen the industrial sector, the residential sector, and non-residential sector emerge as the three top consumers of the electricity in the country. Export and street lighting account for the least in terms of electricity consumption. It is interesting to note that the amount of electricity lost in transmission and distribution (including commercial losses) was higher than the consumption for the non-residential sector. On average, transmission and distribution losses account for 21.9 percent of total electricity consumption annually (Barnor & Ahunu, 2017).

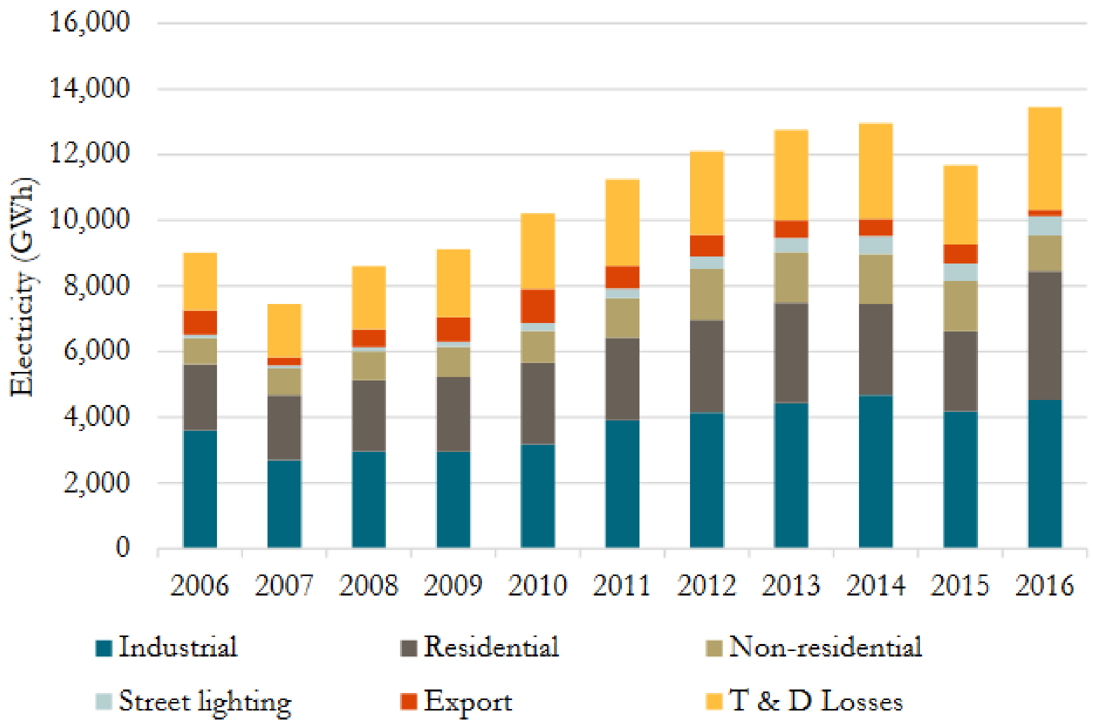

Figure 2.2: Electricity consumption pattern for Ghana from 2006 to 2016

Source: Energy Commission of Ghana, 2016a; Energy Commission of Ghana, 2017)

2.4.2 The Electricity Generation Mix

Hydro and thermal sources have been the main electricity generation mix in Ghana, with the country taking steps to introduce substantial amounts of renewable energy to diversify the mix. At the end of 2016, the generation mix was made up of approximately 57.21 percent of thermal energy against 42.79 percent of hydropower sources as shown in Figure 2.3. Renewable energy has not played any main role in Ghana's generation mix, contributing only 0.2 percent to the generation mix in 2016. Prior to 2016, the only renewable facility feeding directly into the national grid being the 2.5 MW solar photovoltaic plant owned by the Volta River Authority in Navrongo. A 20 MW solar plant owned by BXC Ghana was completed in 2016 to boost the amount of renewable energy sources in the generation mix. Also, a 100kW biogas electricity generation facility was connected to the national grid in 2016. The Energy Commission of Ghana reports a total of 500 kW of installed solar PV systems (both grids connected and with battery backup) owned by individuals and institutions (EADTF, 2014). Figure 2.3 shows a clear drift from heavy dependence on hydro sources to thermal sources. Over the last decade energy generation from thermal sources in Ghana have overtaken hydro generation sources and it keeps on increasing. In the year 2015 thermal generation sources overtook hydro generation sources in Ghana to become the main source of power.

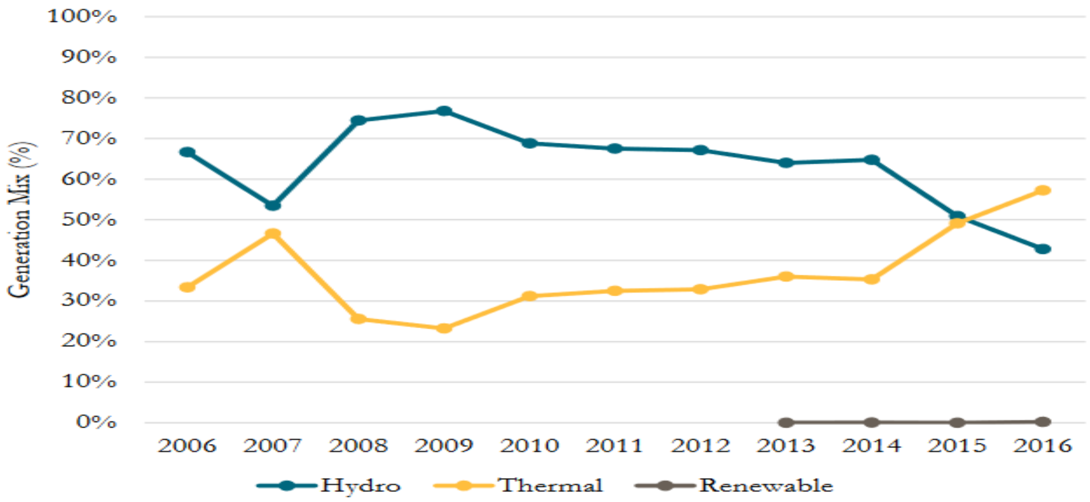

Figure 2.3: Historic electricity generation mix from 2006 to 2016

2.5 THE UNSUSTAINABILITY OF THE CURRENT ENERGY SYSTEM

The need for a sustainable energy system is of a very high importance to a lot of countries around the world and Ghana is no exception.

2.5.1 Unsustainable Energy Sources in Ghana

Ghana's energy sector depends mainly on hydro and thermal sources for the generation of electricity. These sources are not sustainable as a result of the problems the country faces in their use. The main hydro power sources in the country are the Bui and Akosombo dam. The water level in the dam's changes over the year and at certain levels some of the turbines are shut down leading to the reduction in the power generated by them and can therefore not be relied on. The thermal plants in the country also have high running costs and pollute the environment making it unsustainable (Kylili & Fokaides, 2015).

The problem of energy shortage has affected the country for decades. Shocks in energy supply from existing traditional sources such as oil and hydroelectricity have pushed the designated authorities to adopt power-rationing strategies. The unsustainability and inconsistency in energy supply has led to the "dumsor" syndrome. In order to increase productivity, supply from sustainable sources is key (Anane, 2015).

2.5.2 Potential Sustainable Energy Sources in Ghana

By virtue of its location, Ghana is endowed with abundant sunlight, the primary input for solar energy. It is estimated that one hour of radiation from the sun provides more energy than the entire human populace uses in a year. With high solar irradiation in Ghana (e.g. average ground radiation of 4.6kWh/m^2/day in Kumasi, 5.5kWh/m^2/day in Navrongo, 5.4kWh/m^2/day in Yendi, 5.1kWh/m^2/day in Ho, 5.5kWh/m^2/day in Wa, 5.1kWh/m^2/day, etc.) and with more cities on and near the prime meridian and between the equator and Tropic of Cancer, solar power alone can clear all Ghanaian energy consumption hurdles (Agyepong, 2018). Renewable resources such as sunlight are in abundant supply and probably will never deplete or run out.

Thus, renewable energy can serve Ghana as its sustainable and consistent source of energy and save it from the problem of shortages which routinely affect the nation.

2.6 ENVIRONMENTAL IMPACT OF THE CURRENT ENERGY SYSTEM

Global environmental issues are getting more attention due to the rising threat of global warming and climate change. The inter-governmental panel on climate change (IPCC) reports a 1.1 to 6.4°C increase of global temperatures and a rise in sea level of about 16.5 to 53.8 cm by 2100. Bearing global warming and climate change in mind, the issue of environmental pollutants is on a progressive trend in Ghana as more energy consumption is required for higher economic development (Al-mimar, 2016). Subsequently, Ghana has many environmental issues due to recent surges in fossil fuel consumption. The main effect of fossil fuel-energy use is related to changes in the composition of ambient air, called air-pollution, and some of its side-effects. The rapid increase of CO_2 emissions is mainly the result of human activities due to development and industrialisation in Ghana over the last decades. It is evident that Ghana's fossil fuel consumption has overtaken that of renewables. This implies that carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) etc. are being emitted into the environment and further endangering human life.(Asante & Amuakwa-Mensah, 2015)

The use of fossils fuels for energy emits greenhouse gases through combustion, and causes a number of health problems for humans, food, and the general environment. Studies by various scholars, based on their results, all conclude that renewable sources of energy are environmentally friendly. Relative to fossil fuels, renewable sources of energy have low or zero carbon and greenhouse gas emissions. Key inputs for renewable sources of energy including biomass, sunlight, water and wind generate zero harmful pollutants in the environment (Barnor & Ahunu, 2017), (Asante & Amuakwa-mensah, 2015), (Together, 2015).

The waste and harmful by-products from using existing fossil fuel-sources would be completely eradicated if Ghana gradually switched to renewables. Reports from extant literature show that a solar-hydrogen system produces zero carbon dioxide (CO_2), zero carbon monoxide (CO), zero sulphur dioxide (SO_2), zero oxides of nitrogen (NOx), zero hydrocarbons (HC) and no particulate matter (PM). Thus, environmental-related issues such as premature death of humans, loss of livestock and wildlife, reduction in crop yield due to acid-rain, loss of fish population, air pollution and sea level rise would be minimised massively should the country switch to hundred percent renewables.

From Figure 2.4, it can be seen that Ghana's trend of CO_2 emission from electricity and heat generation far exceeds Occupational Safety and Health Administration (OSHA)'s permissible exposure limit (PEL) of 5,000 ppm. It is worrying that from 1998 to 2013, Ghana has not recorded CO_2 emissions below 111,000ppm. From this trend, it is not surprising that the country recorded about 17,524 air pollution deaths in 2013 alone. This implies that the country's air quality has fatal health implications for Ghanaians. The lack of CO_2 standards for power plants by the EPA is a contributing factor to this. In the absence of stringent regulations on air pollutants specific to power plants, the trend of air pollution is likely to continue thereby resulting in more air pollution deaths across the country (Barnor & Ahunu, 2017).

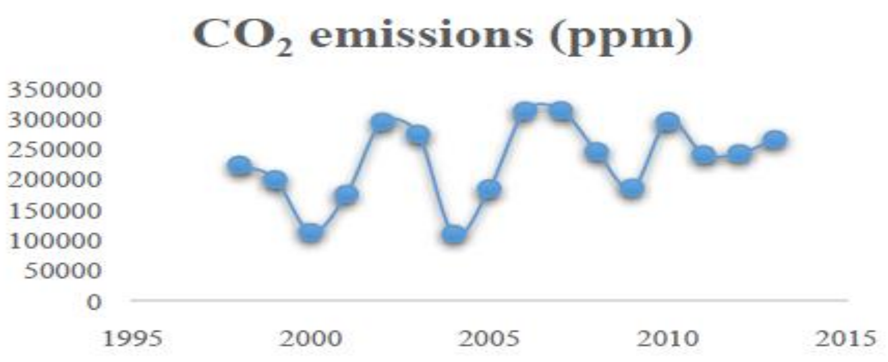

Figure 2.4: Trend of Ghana's CO2 emission from electricity and heat generation

Environmental management in Ghana is mainly the mandate of the Environmental Protection Agency (EPA). The EPA is mandated under the Environmental Protection Act, 1994 to formulate an environmental policy and set standards and guidelines for the protection of the environment. The EPA is responsible for ensuring compliance with environmental impact assessment (EIA) procedures in the design and implementation of any project likely to have potential adverse effects on the environment. Ghana is confronted with several environmental challenges, key among which is waste management, air pollution, and land and water degradation. The EPA has set environmental quality standards for Ghana's manufacturing industry including industries which use thermal energy. However, the standards are silent on air pollutants especially CO_2 emissions and particulate matter for power plants. This has implications for public health in Ghana as the country is predisposed to high rates of air pollution deaths. In 2013, Ghana recorded about 17,524 deaths from air pollution alone. Ghana needs strengthening of its environmental management systems to improve air quality in the country and the EPA has a crucial role to play in this (Barnor & Ahunu, 2017).

2.7 ECONOMIC IMPACT OF THE CURRENT ENERGY SYSTEM

The need for reliable, high quality electricity access is on the rise due to the growing economy of Ghana. The reliability and quality of electricity is also important due to the major role of electricity in our day-to-day activities. During long periods without power, consumers experience inconveniences which can be very costly (Stritih et al., 2018).

There are two types of power disturbances consumers suffer from. These are power quality and power outage. Power outage is a complete loss of power or zero voltage. The duration of a power outage is from one second to several hours. Usually, supply shortages, equipment failures, or faults on the transmission or distribution system are the main causes of power outages. The quality of voltage power and current is called power quality. Voltage fluctuations are the main causes of poor power quality whereas a constant and steady voltage indicates good power quality. Regarding the cost of power outages to an economy, the frequency and duration of interruptions to electricity supplies are instrumental to assessing the cost (Anane, 2015).

The effect of power cuts on cost-competitiveness, investment decisions and productivity cannot be underestimated. Unreliable power supply tends to undesirably affect the productivity of manufacturing small and medium scale enterprises and the duration of the outages seems to have a bigger impact on productivity than the number of days outages are experienced. Consequently, the negative impact on firm's productivity due to power outages depends more on the duration of the power outages than the frequency of outages (Scott et al., 2014).

On cost-competitiveness, SMEs experiencing power outages do not have higher unit costs of production than other SMEs and so are not competitively disadvantaged. This is because, electricity cost makes up only a minor share of the entire cost of manufacturing SMEs. Finally, on investment decision by SMEs, the location of investments by SMEs is dependents on the reliability of existing electricity. Hence, there is limited investments in the energy-intensive sectors of countries with electricity insecurities. Evidence from Ghanaian manufacturing firms show that high electricity cost leads firms to decrease their electricity usage and move to industries with a reduced amount of electricity-intensive production processes which is a limiting factor to productivity (Abeberese, 2013).

Probing into the impacts of power outages in Ghanaian manufacturing firms, it was estimated that revenue losses due to power outages is significantly higher compared to productivity losses because production inputs can be stored through outage periods. Also, power outages have diverse effects across firms with and without generators and firms with high and low electric intensity. The study additionally revealed that because small firms are less likely to own generators, outages have much stronger negative effects on small firms than medium and large firms (Anane, 2015).

The effect of outages on the productivity of firm's productivity in the industrial sector in Ghana shows that there is a negative effect on productivity due to power outage variables (measured in hours per day without power and percentage of output lost owing to power interruptions). It was also revealed that the negative impact of power outages on smaller companies was higher than on larger firms due to huge monetary restraints (Moyo, 2012). Nevertheless, it was revealed by Oseni and Pollitt (2013) that big companies suffer higher total power outage costs than smaller companies regardless of having a higher tendency of providing their own power.

The impact of power outages is not totally negative as pointed out by empirical evidence but the effect will hinge on external and internal factors in the organisation (Cissokho and Seck, 2013). The research by Cissokho and Seck (2013) on power outages and productivity of SMEs in Senegal found out that in spite of the negative effects of power outages on the SMEs there was an encouraging and substantial impact on SMEs in Senegal as a result of good management practices adopted by the SMEs to alleviate adverse impact of power cuts. Therefore, in determining revenue and productivity losses due to power outages, the duration of power cuts is very critical. This shows that if the length of power outage is long, unexpected and spontaneous, productive inputs such as labour during outage periods become idle which leads to huge losses in both revenue and productivity. Business productivity decreases as a result of long power outages. Since power outages are erratic and the accuracy of their occurrence cannot be predicted by the businesses it makes them unable to meet deadlines and profit from new market opportunities (Cissokho and Seck, 2013).

Numerous factors such as fossil fuel production and trade, deployment of renewable energy etc. influences GDP growth. A large share of GDP growth is driven by the increased investments needed to deploy the high capital needs of renewables. Compared with most investment options, the use of renewable energy technologies triggers GDP growth though they are capital intensive. There is a massive capital investment at the early stages when considering a renewable energy plant against the expenditure on fossil fuels throughout the lifecycle of a thermal plant. Surges in energy demand correspond to comparable investments in energy infrastructure. To ensure free-flow of sustainable energy systems and to realise potential benefits on investments, energy sector investments need to be directed toward renewable energy systems. There has to be a substantial increase in investments in renewable energy across all sectors of the economy (Asante, 2014).

2.8 ENVIRONMENTAL IMPLICATIONS OF NET ZERO ENERGY BUILDINGS

Sustainable energy concepts such as net zero energy buildings are gaining widespread demand as a result of the increasing demand to mitigate the environmental effects fossil fuels. The final energy consumption in Europe in the year 2010 showed that buildings were the largest consumers of energy accounting for 41% of the total energy trailed by transportation (32 %) and industry (25%). Difficulties in supply, exhaustion of energy resources and heavy environmental effects such as ozone layer depletion, global warming, climate change, etc have grown as a result of the high increase in the consumption of energy by a lot of sectors. This has resulted in various actions taken by governments to decrease the use of energy and its impact on the environment by creating new energy laws. The incorporation of renewable energy resources into a nation's energy generation mix to supply energy will contribute immensely in the reduction of the environmental effects energy consumption by buildings have on the environment (Doroudchi et al., 2018).

2.8.1 Positive Environmental Effects of Net Zero Energy Buildings

Quite a lot of of our environmental concerns such as the depletion of fossil fuel resources and climate change can be solved by the concept of net zero energy buildings. It is a radical agenda for eliminating the use of combustion fuels for energy production within the built environment (Marszal et al., 2011). The use of energy by buildings is one of the largest sole contributors to our carbon footprint contributing about 40 percent depending on the estimate. The leading contributor to global warming is the burning of fossil fuel particularly oil and coal. The use of coal by China is one of the main reasons why they have overtaken the U.S as the leading producer of the GHG carbon dioxide. The amount per pound of carbon dioxide that the burning of coal emits into the atmosphere is 25% more than that of oil. The carbon footprint by man on the earth would be reduced by 40% if all existing buildings are retrofitted to be net zero energy buildings and all new buildings are built to the standard of a net zero energy building. Retrofitting existing building to meet net zero energy standards would be a good exercise that would benefit all. It is a moral imperative to protect the humans mostly affected by the emission of greenhouse gases (Deng et al., 2018).

The extraction of oil, coal reserves, and natural gas at a rate higher than the rate at which they are naturally replenished causes the depletion of fossil fuels. The anaerobic decay of the dead organisms such as plants and animals cause fossil fuels to be formed deep down in the crust of the earth. A lot of time that is, millions of years is required to form fossil fuels such as natural gas, coal and petroleum in the crust of the earth. There is increasing fear for the extinction of fossil fuels due to rapid urbanization in developing and underdeveloped countries. The hope of humans for a better future has been shaken by the reckless usage of energy by people. The natural resources available to humans now are now dying and decreasing miserably(Greenius et al., 2010).

The adoption of the concept of net zero energy buildings will help solve the problems we are facing such as fossil fuel depletion, climate change, global warming and the increasing amount of carbon in the atmosphere.

2.8.2 Negative Environmental Effects of Net Zero Energy Buildings

A persistent criticism of renewable energy's practicality by nuclear and fossil fuel industries has been that the land use, that is, area required, is too great; that is renewable sources are too wide spread. One of the most evident relationships between power flux density (energy generated per square metre) and environmental impact may be the issue of the area required by any renewable energy source, per unit of energy produced, or on a larger scale the use of land or space required. Land use is the term usually applied to the type of land use by humans. Here it is applied to the amount of land used by each source and technology per kW of power (Walker 1995).

For solar, the power flux density, or intensity can be fairly easily related to the area of collector required, and also to general notions of land use. Since power flux density is here defined as the watts per square metre (Wm^{-2}), of an imaginary collector perpendicular to the ambient energy flow, it is apparent how the density is related to collector area; a greater power flux density will require less collector area per energy unit. If the flow is horizontal to the earth's surface, then the collector angle will be perpendicular, i.e. vertical, and the area it occupies will be in a vertical plane. Hence land use will tend to be less. Where the renewable energy flow's angle relative to the earth's surface, is greater than zero degrees, i.e. tilted, the collector angle will occupy space in a horizontal plane in addition to a vertical one (Wells et al., 2018).

Solar and geothermal flows are generally from a vertical (though varying in the case of solar) direction, or perpendicular to the earth's surface, while water flows, and air flows are generally horizontal or parallel to the earth's surface. So, it would follow that direct solar, biomass and geothermal collectors occupy horizontal areas i.e. using land area; and wind, hydro, wave and tidal collectors in occupying space in a vertical plane, may not relatively speaking, occupy very much land area. Of course, the associated ancillary conversion and energy storage facilities e.g. reservoirs, may well occupy considerable land area. Do typically quoted land use values for each renewable tend to bear out the relationship with the power flux density? Those cited by Gagnon et al (2002a), shown in Figure 2.5, only do so to an extent, in that biomass plantations require the largest land areas and have the lowest power flux density, and the hydro run of river requires the lowest land area, and has a relatively high-power flux density, as might be expected (Gyamfi et al., 2015).

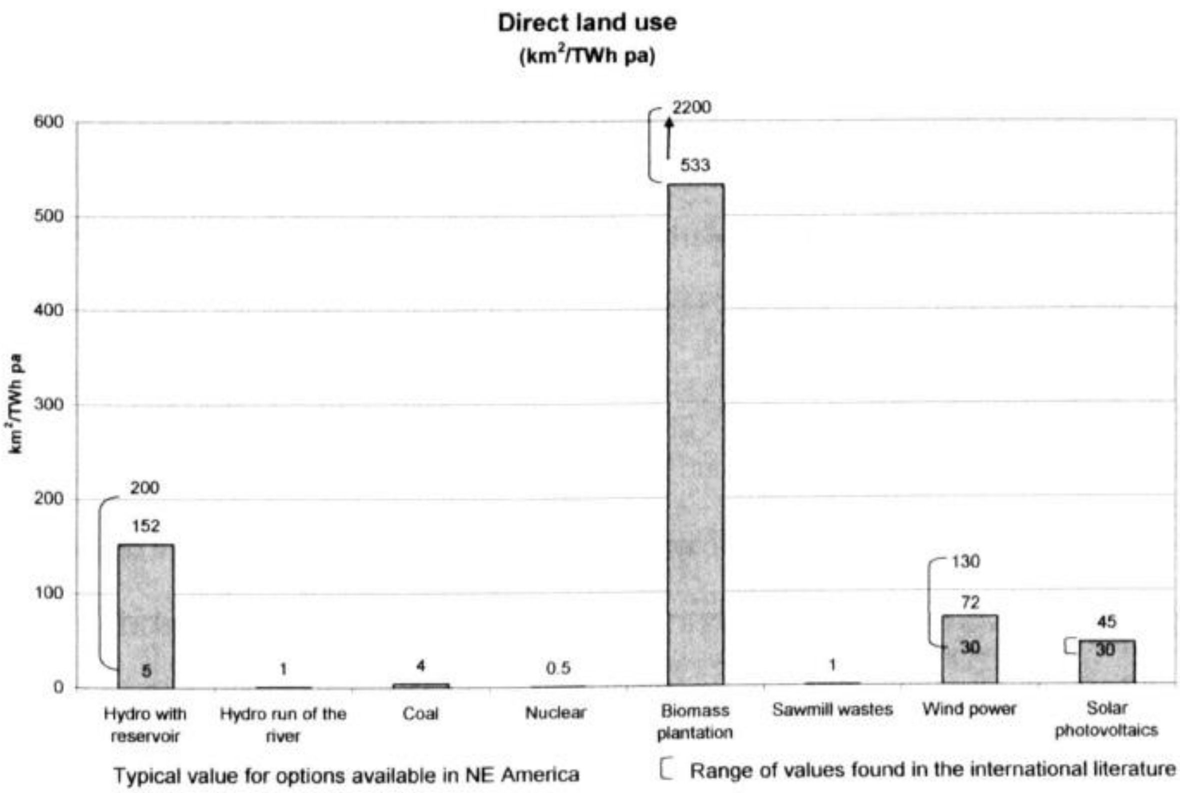

Figure 2.5: Land use of renewable and conventional energy sources data from international literature (Gagnon et al 2002a).

The figures for hydro with reservoir, range from 5-200 km^2 / TWh, a surprisingly large figure considering that wind power is allocated a 30 - 130 km^2 / TWh range, and again surprisingly and questionably, this is higher than the figure for Solar PV -30 - 45 km^2 /TWh. Some of these results would contradict the hypothesis here, being inverted in relation to power flux density at the converter and may be averaged over total land areas (Satori et al., 2012).

Unfortunately, due to the lack of references and lack of explanation of methods used to generate this data, only suggestions can be made for the difference in results. The authors do however caution against simple interpretation of the data, as "it does not consider the intensity of impact nor the degree of compatibility of generation options with other land use. "

Table 3.1: Average overall power per unit of area of total resource. (MacKay 2008)

Energy Source	Power Flux Density (W/m^2)
Wind	2
Offshore wind	3
Tidal Pools	3
Tidal stream	6
Solar PV panels	5-20
Plants	0.5
Rainwater (highlands)	0.24
Hydroelectric facility	11
Solar chimney	0.1
Ocean thermal	5
Concentrating solar power (desert)	15

2.9 ECONOMIC IMPLICATIONS OF NET ZERO ENERGY BUILDINGS

There has been an average daily production loss of 2.1 million U.S dollars during the past decade in Ghana due to challenges faced in the supply of electricity. Over this period more generation plants have been installed to more than double the generation capacity of Ghana by adding 2065 MW to the already existing 1730 MW to provide 3795 MW between 2006 and 2016. There was a 50% increase from 1393 MW in 2006 to 2087 MW in 2016 in the peak electricity demand of Ghana over the same period. Poor revenue collection by the ECG from consumers and the archaic distribution systems in use the country are the main causes of these challenges in the supply of electricity. The bad tariff structure making it difficult for ECG to recuperate the cost incurred in the production of electricity and the high dependence on hydro and thermal sources of power generation are other factors causing supply challenges (Adom-Opare, 2012).

The massive potential in the growth of hydro power and renewable energy resources such as solar and wind in Ghana which would diversify the generation mix, educating people on energy efficiency, providing proper tariff structures to enable the utility providers to recuperate the cost in the generation, putting all public and private individuals on the prepaid metering system are some of the measures that can help to solve Ghana's electricity challenges (Gyamfi et al., 2015).

On the 14th of August, 2003 there was a power outage in parts of the United States and Canada that lasted for up to four days in some areas. Businesses suffered a lot from this outage with an estimated cost of 6 billion U.S dollars. In the case of Chrysler motors, a car manufacturer there was a loss in production at 14 of their 31 plants causing them to scrap 10000 vehicles because they did not have power to dry the cars at their painting shops (LaCommare and Eto, 2006).

The rise in energy prices over the last ten years, led by the rise in oil prices from $ 10 to a peak of almost $150 per barrel by July 2008, falling thereafter to $40 as a result of recession and then rising once more, has renewed the urgency for government policies to plan for a post-oil and post-fossil fuel age. Since net zero energy buildings do not depend on oil products for energy generation the increase of oil prices will not affect users economically. The initial cost of net zero energy buildings is very high and therefore only a few can afford it. But the savings that can be made over the life of the building is massive. It provides a source of reliable uninterrupted power over the course of the buildings life. This concept will enable us provide energy for ourselves in a sustainable and help increase productivity (Morales et al., 2017).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This section introduces the overall research approach. It represents the databases used to gather the relevant data. The keywords that have been used to find the suitable literature, the steps of analysing the data and the criteria of analysis through which the researcher reach to the conclusion. The chapter explains the research design, the population of the study, the sample for the study and the sampling techniques used for the study. This section also explains the methods and instruments that will be used to collect data from respondents.

3.2 RESEARCH APPROACH

Quantitative research is a structured way of collecting and analysing data obtained from different sources. Quantitative research involves the use of computational, statistical, and mathematical tools to derive results. It is conclusive in its purpose as it tries to quantify the problem and understand how prevalent it is by looking for projectable results to a larger population.

Data collection is one of the most important aspects of the quantitative research process. Data collection involves having the researcher to prepare and obtain the required information from the target audience. Data preparation includes determining the objective of data collection, methods of obtaining information, and the sequence of data collection activities. One of the most important aspect in this process is selecting the right sample for data collection. The data is then carefully collected from only those people who are most relevant to the objectives of the study. Known as a target segment, this sample is a group of people who are similar across a variety of variables. The data collection tools for a quantitative research are surveys and experiments. Experiments can provide specific results regarding the cause-and-effect relationship of several independent or interdependent factors related to a particular problem.

The most common approach to doing quantitative market research is a survey or questionnaire. Surveys can include interviews, which can be carried out using several different methodologies including face-to-face, telephone, online or computer assisted interviews. After data collection, another step is the data analysis process. The analysis of statistical data requires systematic tools and processes to be conducted. Many analytical tools exist such as independent sample t-tests, correlated t-tests, variance calculations, and regression analysis that can be used to derive results from the data.

3.3 POPULATION

A population is any set of persons or objects that possesses at least one common characteristic." The term 'population' should not be taken in its normal sense when sampling rather it represents the full set of cases from which the sample is chosen (Saunders and Lewis, 2012). Thus, the population from which sample for the study were chosen are residents and business operators in the Kumasi Metropolis.

3.4 SAMPLE SIZE AND SAMPLING TECHNIQUES

This is the part that explains the procedures or methods by which respondents (sample) for the study are selected from the population. It is most fundamental to the conduct of the research and interpretation of the research results. In order to best answer the research questions and achieve objectives, the researcher randomly selected residents and business owners in the Kumasi Metropolis from Deduako residential area and the Kumasi Central Business District

(CBD). Residents and business owners were selected because of their heavy dependence on electricity in order to operate efficiently and effectively. The two areas (Deduako and CBD) were chosen because of the high concentration of residential dwellers and business owners within the metropolis. The residential dwellers were selected from Deduako residential area while the rest of the business owners were selected from the CBD.

The researcher selected 100 respondents who were the residents and business owners as the sample size. The method used to determine the sample size was adopted because the selected businesses were from the non-formal sector and so was difficult to determine the actual population size. A total of 66 residents and 34 business owners were selected for the study. Though the one hundred sample size may not be true representation of the population, they have been selected as prototype of residents and business owners in the Metropolis to achieve objectives of the study.

In addition, the snowball sampling method was used to locate respondents for the study. The snowball sampling method was deemed appropriate because the total members of the desired sample were difficult to identify. Thus, through random sampling the first respondent was located and then asked to locate other similar respondents till the sample size for the study was achieved.

3.5 DATA COLLECTION PROCEDURE

For the purpose of this study, secondary and primary sources were used in the collection of data for the study. Secondary sources refer to published and unpublished works of others in the form of books, reports, organisational and academic surveys, statistics, journals and newspapers, and online information from the internet, all of which relates to the topic of the study. Primary sources are first-hand recordings of data or the actual data themselves. Primary source of data involved the data obtained from the field, from selected respondents for the study. The primary source enabled the researcher to provide answers to the questions posed by the study. Concerning the method used to gather primary data, questionnaires consisting of open and close-ended questions were administered to the respondents (selected residents and business operators). The questionnaires were administered to the respondents in the form of an interview and terms such as thermal energy, hydroelectricity and net zero energy were explained to respondents who did not understand. In addition to the administered questionnaires, semi-structured interviews alongside notes taking were also used on the field to gather data. A total of 100 questionnaires were self-administered to obtain primary data of the study (Saunders et al., 2012).

3.6 MODE OF ANALYSIS

Quantitative means of analysis was used as the mode of analysis after collecting primary data. The Statistical Package for Social Sciences (SPSS Version 25) was also used in presenting the findings in quantitative terms and after comprehensive study of statistics presented by SPSS, the implications of the findings were descriptively analysed.

3.7 PROFILE OF KUMASI METROPOLITAN AREA

Kumasi Metropolis is located about 270km north of the capital of Ghana, Accra and is in the transitional forest zone of the Ashanti Region of the country, the second largest city in Ghana with a population of 2,035,064 and an annual growth rate of 4.8%. The land area of the

Metropolis covers an area of about 254 square kilometres and an approximate radius of ten (10) kilometres as shown in figure 3.1a in appendix 1.

The growth in urbanization has led to an increase in population size of the metropolis. Even though the metropolis is known to be the second largest city, it is now the largest city in the country due to its population size which accounts for 8% of national population while Accra Metropolitan Assembly (AMA) accounts for 7% according to the 2010 population census. The population of the Metropolis increased at annual growth rate of 5.63% between 1984 and 2000, and 5.69% between 2000 and 2010 as depicted in Table 3.1 below. Though KMA is known to be the largest city but it is not entirely urban. The Metropolis consists of an estimated 48%, 46% and 6% urban, peri-urban and rural areas respectively (KMA, 2014). The population of Kumasi has been increasing rapidly at an annual growth rate of 5.13% between 1984 and 2000 and 4.62% between 2000 and 2010 (indicated by table 3.1), a growth rate much larger than that of Ashanti region and national population growth rate (2.5%) recorded during the 2010 Population and Housing Census (PHC) (Ghana Statistical Service, 2010).

Table 3.1 Population of KMA (1984-2010)

Area	1984	2000	Growth rate1984-2000	2010	Growth rate 2000-2010
KMA	487,504	1,170,270	5.63	2,035,064	5.69
Kumasi	790,374	1,758,741	5.13	2,764,091	4.62
Ashanti Region	2,090,100	3,612,950	3.48	4,780,380	2.84

The city of Kumasi has been serving as the centre of commerce, probably the reason for its large population size. Due to its strategic location coupled with its status as a commercial hub, the city attracts many people from neighbouring regions who come to trade. Kumasi is in the intersection of routes which connects the north and south of the country making the city a commercial hub for neighbouring regions. Thus, Kumasi Metropolis has become home for several micro and small-scale enterprises sustained by the large population size.

According to KMA (2014), about 86% of the active population are employed in the service, industry and agriculture sectors. The service sector employs majority (72%) of the active labour force and so serves as the backbone of the local economy and a complementing factor for the city's status as a commercial hub. Economic activities carried out in the service sector include wholesale and retail activities of all kinds of commodities such as foodstuffs, clothing, building materials, office and educational stationeries, herbal and orthodox medicines. These commercial activities are coupled with ancillary services offered by sectors such as banking, insurance, transport, telecommunication, health care and tourism.

The industrial sector in Kumasi employs 23% of the active labour force (KMA, 2014). The industrial sector of Kumasi can be categorized into three major cluster based on industrial activities. The categorizations are mechanical garages, wood processing and food and beverages. There are two mechanical garages in the metropolis offering employment to the active labour force namely Suame Magazine and Asafo mechanical garages however notable and larger of the two is Suame Magazine industrial enclave which is also the biggest mechanical garage in West Africa. Suame Magazine industrial enclave is mostly made up of informal micro and small mechanical workshops offering services such as vehicle repairs and maintenance, sale of spare parts, metal workings and manufacturing to local customers and customers from West African countries. The second industrial enclave contributing to revenue generation and employment is wood processing. Medium and large-scale companies engaged in timber processing and plywood manufacturing are located at the Asokwa-Ahinsan-Kaase stretch. The semi-finished products of these companies are exported to the international market and some sold to domestic furniture workers. Another wood working area worth mentioning is the Sokoban Wood Village formerly located at the Anloga junction.

The third industrial cluster is the food and beverages, related companies are also located at the Asokwa-Ahinsan-Kaase stretch. These beverage processing industries are a mixture of micro, small, medium and large-scale enterprises producing products such as fruit juice, yoghurt and other assorted drinkables. Notable companies in the industry are Guinness Ghana Brewery Limited (GGBL) and Coca Cola Bottling Company.

Due to the urbanization pressures in the Metropolis, its contribution to the agriculture sector has been minimal. The foodstuffs (including maize, plantain, cocoyam, cassava, tomatoes, pepper, carrots, cabbage etc.) produced in the metropolis are from its peri-urban areas and others from adjoining districts and other regions of the country. Thus, agriculture in Kumasi is largely on small-scale basis and does not only involve farming but also aquaculture, animal rearing and horticulture (KMA, 2014).

3.8 BRIEF DESCRIPTION OF KUMASI CENTRAL BUSINESS DISTRICT (CBD)

According to the (Richards, 2013) , CBDs are “areas of intense economic and social interactions and zones for pedestrian activities”. Kumasi CBD lies at the centre of the city and has a total land area of about 294.5 acres. Due to the central location of the area within the Metropolis, Kumasi CBD is the commercial capital of the metropolis where major traders converge to trade assorted products and services. Kumasi CBD covers Adum, Central Post Office area, Asafo Market, Kejetia Lorry terminal and Central Market (Amoako et al., 2013).

CHAPTER 4: DATA ANALYSIS AND DISCUSSION

4.1 INTRODUCTION

This section presents an analysis and discussion of the results of the primary data gathered from the field of the study. It is obvious from literature that the current energy system in Ghana is not sustainable, environmentally friendly and retards economic growth. Thus, purpose of the study is to assess the sustainability and effects of the current energy system in Ghana on the economy and environment and also to develop a framework for the uptake of net zero energy buildings.

4.2 CHARACTERISTICS OF RESPONDENTS

The questionnaire was administered to 38 homeowners representing 38% of respondents, 34 business owners representing 34% of respondents and 28 tenants representing 28% of the total respondents. The questionnaires were administered to this group of people because they rely heavily on electricity for their daily activities.

Table 4.1: Type of respondent

Respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Homeowner	38	38.0	38.0	38.0
	Tenant	28	28.0	28.0	66.0
	Business Owner	34	34.0	34.0	100.0
	Total	100	100.0	100.0	

The analysis revealed that 94.7% of homeowners, 64.3% of tenants and 82.4% of business owners representing 82% of the respondents were paying for electricity whilst 5.3% of homeowners, 35.7% of tenants and 17.6% of business owners representing 18% of the respondents were not paying for the electricity they were using. This showed that most tenants and business owners are not paying for the electricity they are using. Most of them had used illegal connections to gain access to the national grid.

From the analysis 100% of homeowners, tenants and 35.3% of business owners representing 78% of the respondents were using residential meters whereas no tenant, homeowners and 64.7% of the business owners were using commercial meters. This was because some of the residential buildings were being used for commercial purposes and still had the residential meters even though the use of the buildings had been changed.

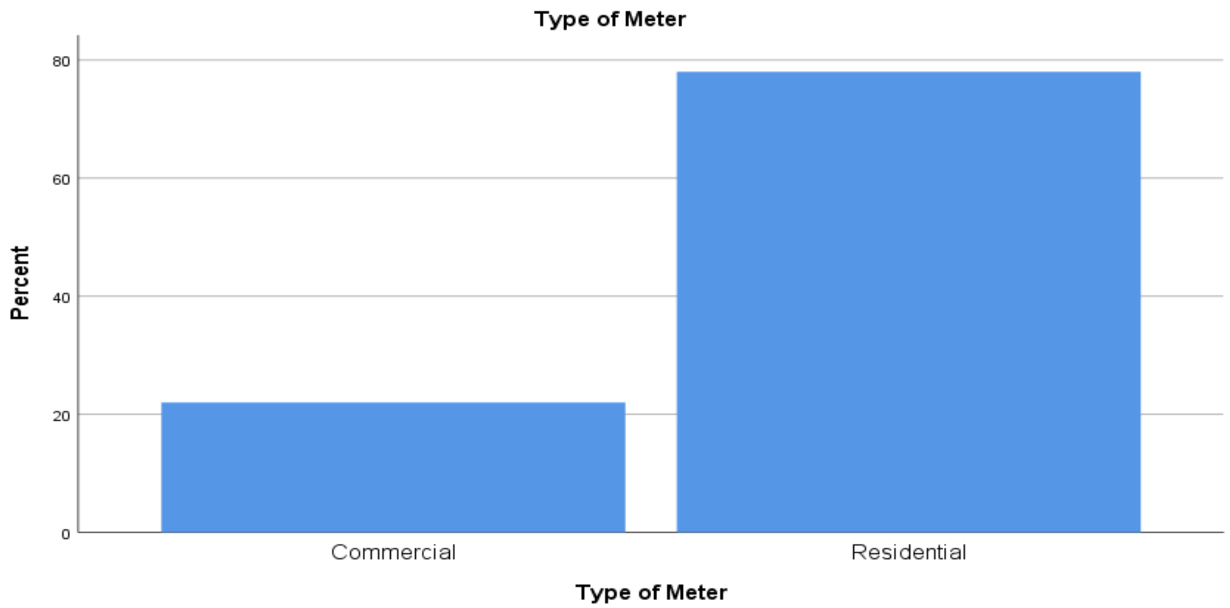

Figure 4.1: The type of meter used by respondents

4.3 ELECTRICITY USE OF RESPONDENT

The study sought to identify what respondents mainly used electricity for. A total of 54% of respondents used electricity for providing light for their homes and businesses, 27% were using electricity for cooling their homes and 19% of the respondents were using electricity to operate other electrical appliances.

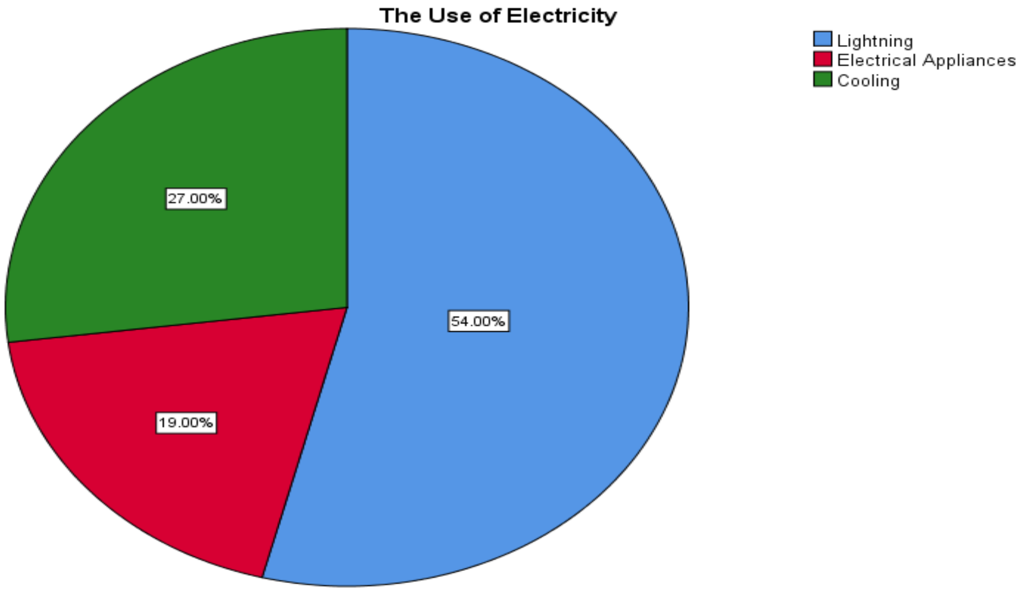

Figure 4.2: Usage of electricity

The study sort to find out the average amount of money respondents paid in a month for electricity. The analysis shows that 25 of the respondents paid less than an average amount of GH₵100 in a month, 27 of the respondents paid an average amount of GH₵100-GH₵300 in a month, 19 respondents paid between GH₵300-GH₵500 and 29 respondents paid above GH₵500 in a month.

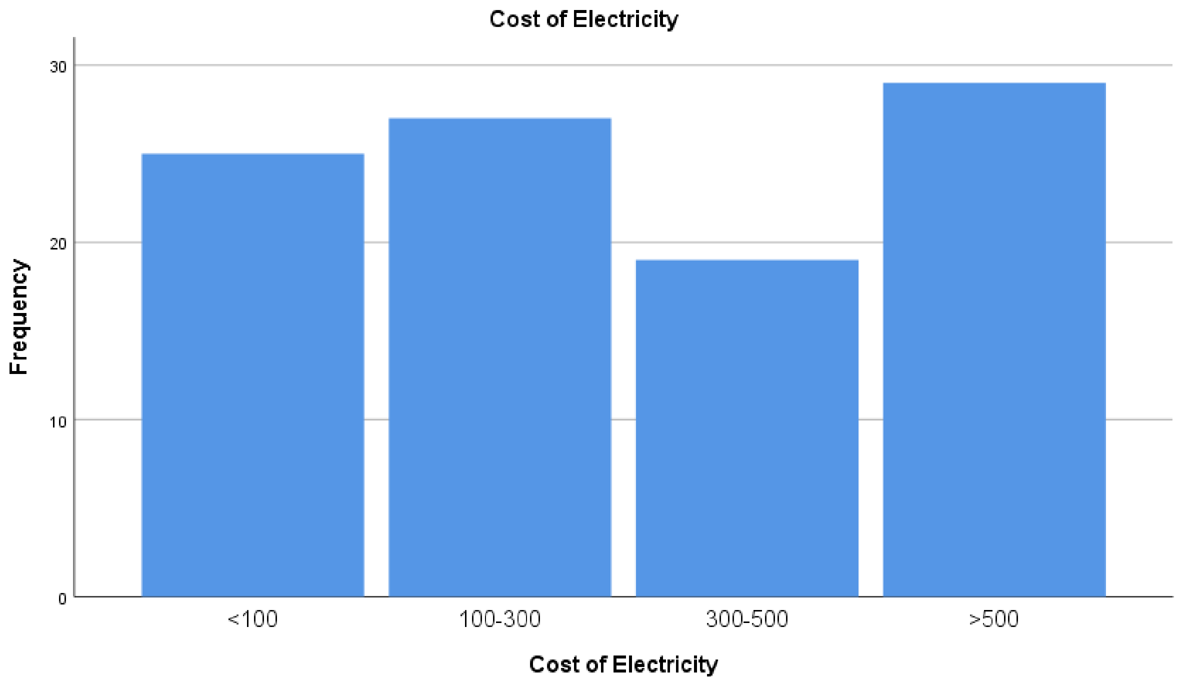

Figure 4.3: Average expenditure on electricity

4.4 CHARACTERISTICS OF POWER OUTAGES

The study identified that all the respondents relied on electricity provided by the VRA through ECG for their operations. The study identified that 98% of respondent's experience power outages and 2% of respondents do not experience power outages. The analysis revealed almost all respondents had experienced a power outage in the year.

Based on the energy requirements of the respondents, the study investigated the frequency at which the power outages occur among the tenant's homeowners and business owners. The study revealed an obvious occurrence that the respondents experienced power outages on either a weekly or monthly basis. From interview with the respondents, the power outages occur consistently for some days or weeks and at other times they enjoy electricity without any interruptions. According to the tenants, business owners and homeowners sometimes they get the required amount of electricity for a week or two for their operations but rarely do they for a whole month without an interruption. From the analysis, 35.7% of tenants, 50% of homeowners and 38.2% of business owners representing 42% of the respondents were experiencing power outages weekly, 42.9% of tenants, 39.5% of homeowners and 35.3% of business owners representing 39% of the respondents were experiencing power outages monthly, 21.4% of tenants, 10.5% of homeowners and 26.5% of business owners representing 19% of the total respondents were experiencing power outages rarely.

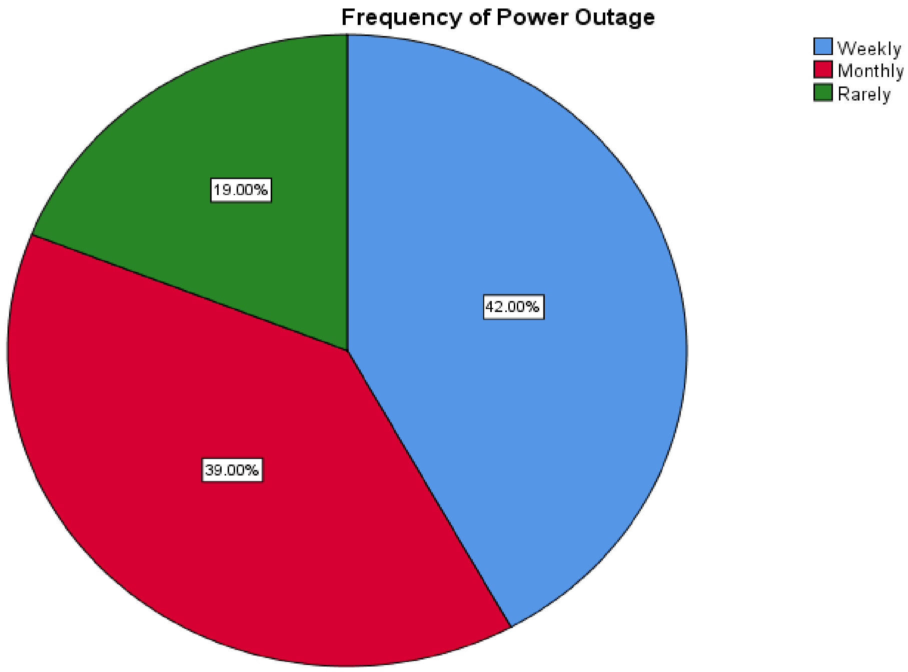

Figure 4.4: The frequency of power outages

Due to the power outages, the tenants, homeowners and businessowners go off electricity supply for a period of time and as such are unable to assess the required electricity for effective operations. From the analysis, 64.7%, 26.5% and 8.8% of business owners experience an average of less than 1 hour, 1 – 6 hours and 6 – 24 hours of power outage respectively. In addition, 42.9%, 46.4%, 7.1% and 3.6% of tenants experience an average of less than 1 hour, 1 – 6 hours, 6 – 24 hours and more than 24 hours of power outage respectively. Lastly, the study revealed that 42.1%, 36.8%, 7.9% and 2.6 of homeowners experience an average of less than 1 hour, 1 – 6 hours and 6 – 24 hours and more than 24 hours of power outage respectively.

Again, from the analysis as depicted in figure 4.7 below 50% of respondents experience an average power outage duration less than an hour, 36% of respondents experience an average power outage duration between 1 – 6 hours, 12% of respondents experience an average power outage duration between 6 – 24 hours and 2% of respondents experience an average power outage duration greater than 24 hours.

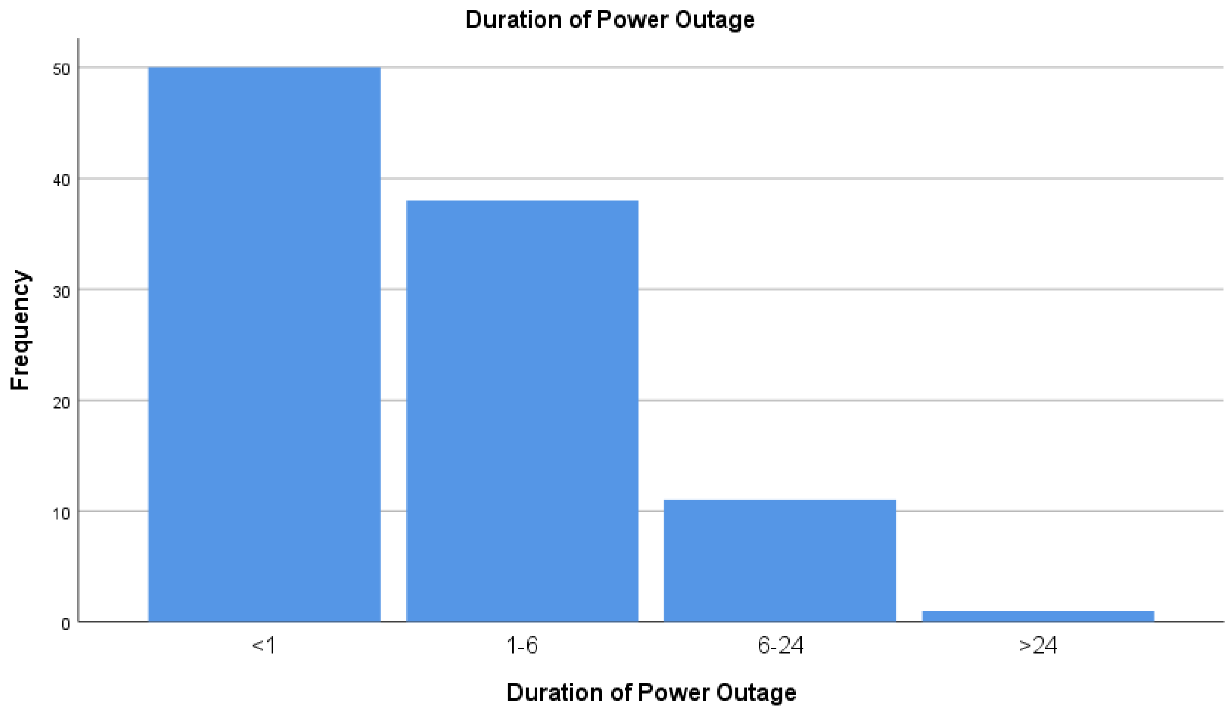

Figure 4.5: The average duration of power outages

4.5 EFFECTS OF POWER OUTAGES

The study to know if the power outages decreased the productivity of the respondents. 18% of the respondents said the power outages did not decrease their productivity, 8% were indifferent of the decrease in productivity due to power outages and 74% of the respondents agreed that there was a decrease in their productivity due to the power outages.

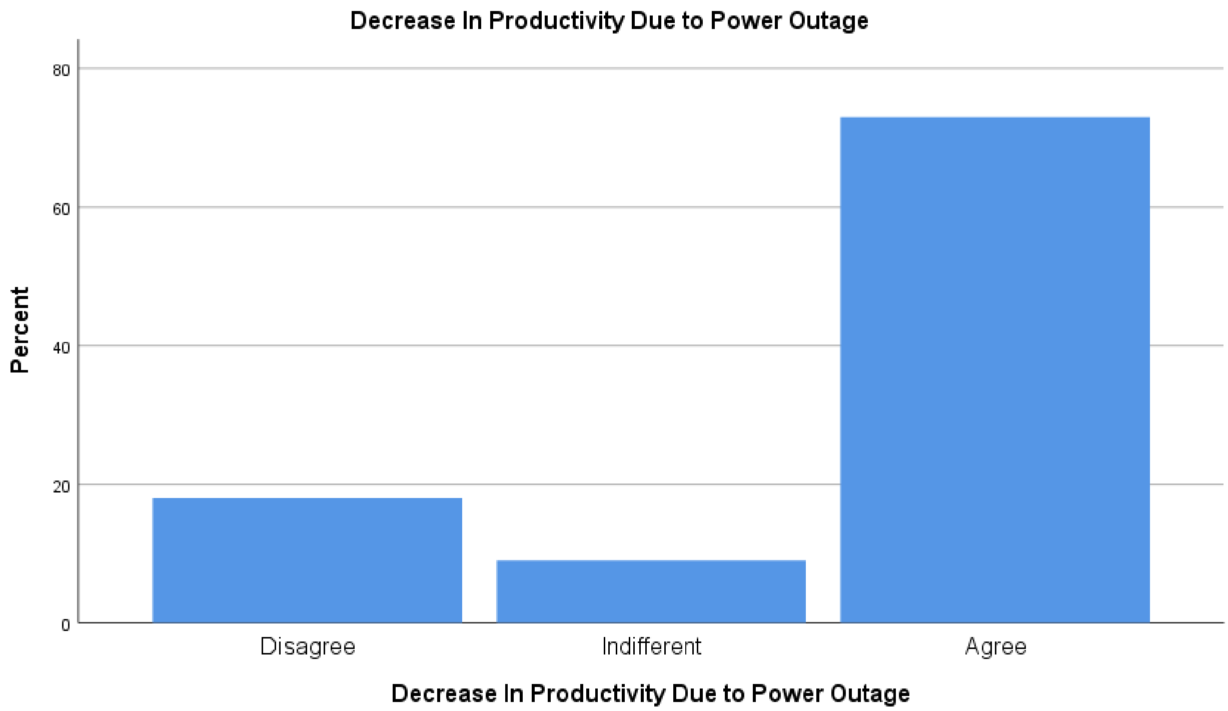

Figure 4.6: The decrease in the productivity of the respondents due to power outages

The study identified that there was an increase in the operation cost of some of the respondents due to the use of alternative sources of power during the power outages. 24% of the respondents said there was an increase in their operation cost due to the use of power from an alternative source, 2% of the respondents said the use of the alternative source of power did not increase their operation cost and it was not applicable to 74% of the respondents because they were not using an alternative source of energy.

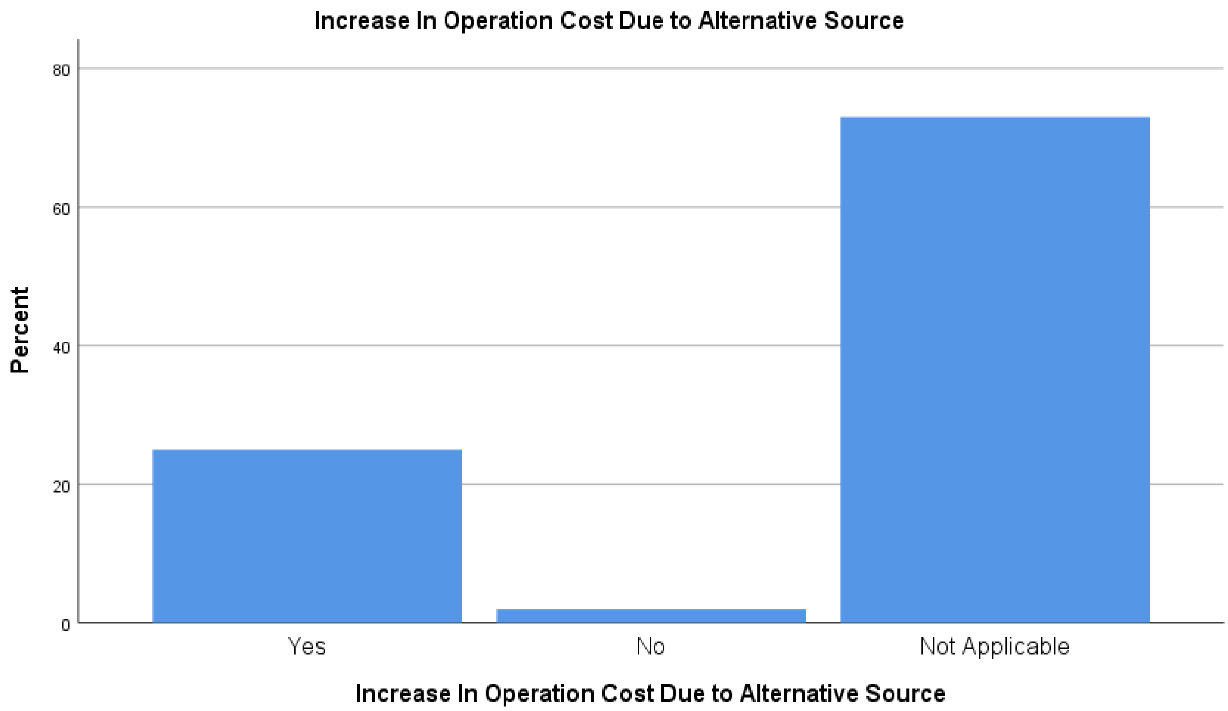

Figure 4.7: The increase in operation cost due to the use of an alternative source of energy

Profit for the purpose of the study is defined as the difference between the amount earned and the amount spent on buying, operating or producing something. Thus, profit refers to the gains of a business that has engaged in providing goods or services (Anane, 2015).

As part of the study's objective, the impact of Ghana's power outages on the profit of business owners was researched. Without very little exception the business owners agreed that the load shedding has caused a gradual decline in their output level and consequently their profit. The analysis revealed that the profit of business owners declined due to the power outages as shown in Figure 4.8. The power outages which has caused the output of the business owners to decline also translates into reduction in the profit of business owners basically because they rely on electricity to operate effectively and efficiently. 85.3% of business owners representing 29% of respondents said power outages lead to a decline in their profit and 14.7% of business owners representing 5% of respondents said power outages did not cause a decline in their profit.

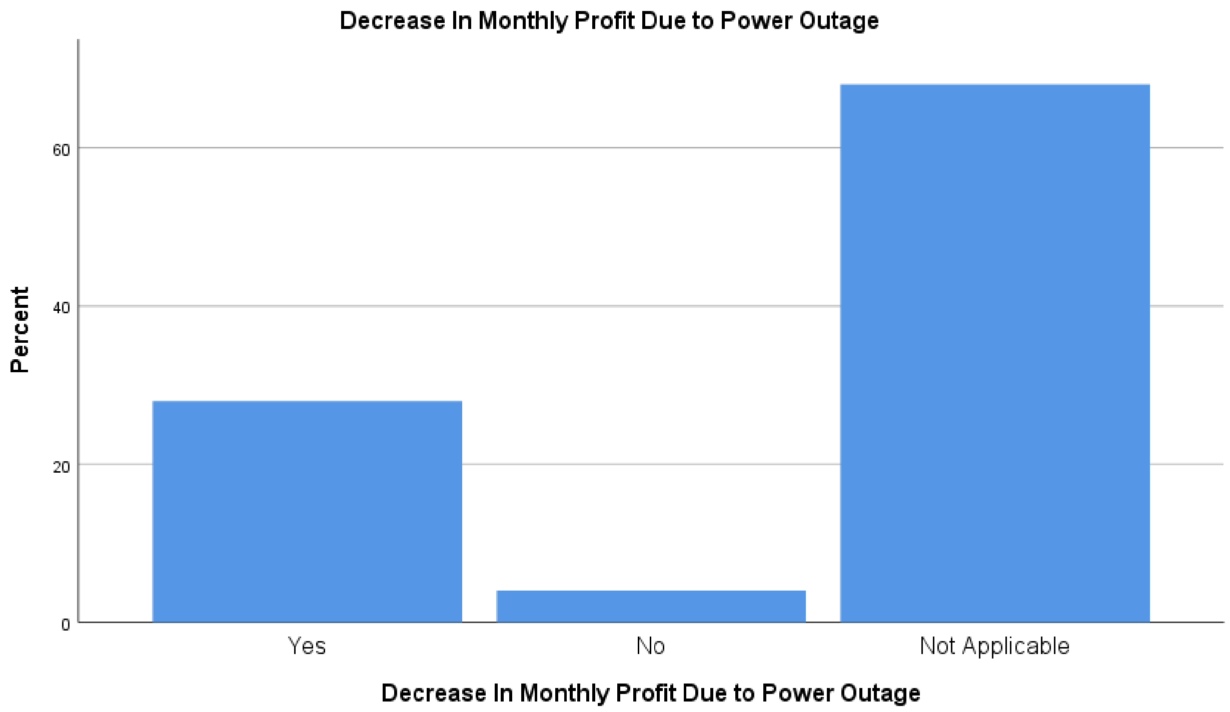

Figure 4.8: The decline in profit of business owners due to power outages

4.6 MEASURES TO REDUCE EFFECTS OF POWER OUTAGES

Due to the deleterious effects of the power outages, some of the respondents have been forced to seek out alternative power sources in order to operate efficiently. The study investigated the alternative measures adopted by the respondents to reduce the brunt of the unfortunate load shedding exercise carried out by the utility service provider (ECG) since all the respondents obtained electricity power from the company. Alternative measures adopted by the respondents are depicted in Figure 4.9 below.

The study identified that the alternative power facilities used by respondents are generators and solar systems. The respondents interviewed revealed that they had to acquire these machines to supplement their energy shortfall. Solar energy was used only by homeowners to supplement their energy needs.

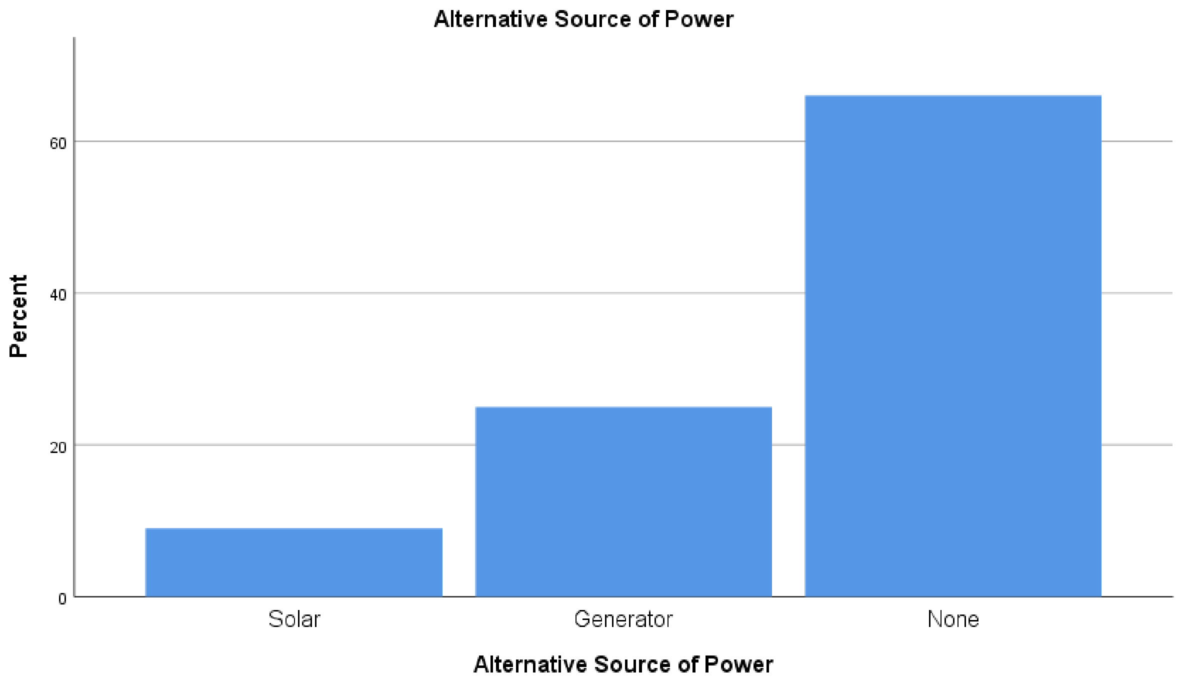

Figure 4.9: The alternative sources of energy used by respondents

The business owners were asked of the measures they put in place to minimize the decline in their profit or gains. The purpose was to establish whether an increase in operations cost caused by the usage of alternative power is likely to affect prices of the output of businesses.

Analysis from the data revealed that due to the power outages, the operation cost of businesses using alternative power has increased and as a result, some business owners have devised measures to minimize the reduction in their profit. The measures adopted by enterprise owners were either to ‘increase price’, ‘work overtime’ or ‘cut down the number of workers’ as indicated in Figure 4.10 below.

From the analysis, 55% of business owners increase the price of their products or services during power outages, 18% of business owners cut down on the number of their workers and 27% of business owners work overtime during power outages to make up shortfall in profit.

Figure 4.10: The measures to prevent a decline in profit

4.7 COST OF ALTERNATIVE MEASURES TO REDUCE THE EFFECTS OF POWER OUTAGES

As the study has revealed, some of the business owners, tenants and homeowners have adopted alternative power sources to supplement the shortfall in their energy needs and these alternative power sources are employed at an additional cost which increases the total energy cost as well as operations cost of these individuals. All respondents with alternative power interviewed for the study disclosed that, their operations costs have increased due to operation and maintenance cost incurred on alternative power sources. The additional costs incurred on the generators included repairs, replacement, fuel/diesel and technician costs. The analysis revealed that 20% of respondents incurred an average monthly cost of GH₵100-GH₵300 on their alternative source of power, 5% of the respondents incurred an average monthly cost of GH₵300-GH₵500 and 7% of the respondents incurred an average monthly cost greater than GH₵500

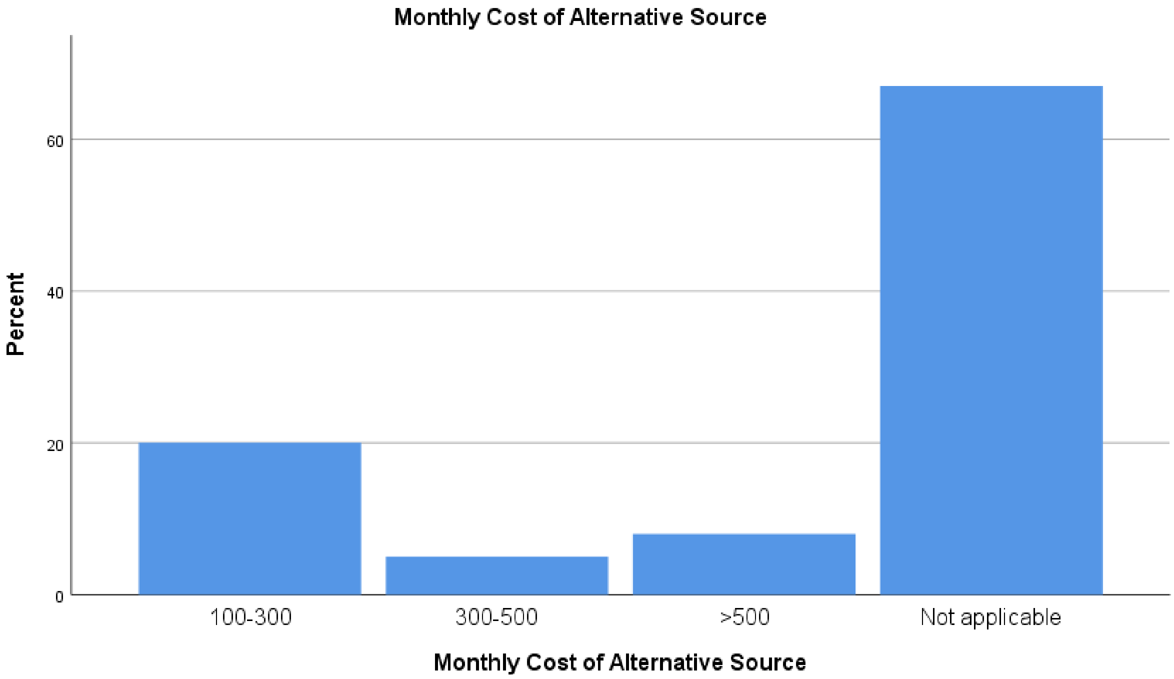

Figure 4.11: The average monthly cost of alternate source of power

In addition to ascertaining cost incurred on alternative power source, the study also investigated the comparative perception of respondents about the cost of the alternative source and their electricity tariffs.

The study revealed that 32% of respondents consider the additional energy cost from generators more expensive than electricity tariff, 4% of respondents consider the additional energy cost from generators and solar as cheaper than electricity tariff and 5% of respondents were indifferent about the relative cost of alternative energy to the electricity tariffs. Lastly, it was not applicable to 59% of the respondents.

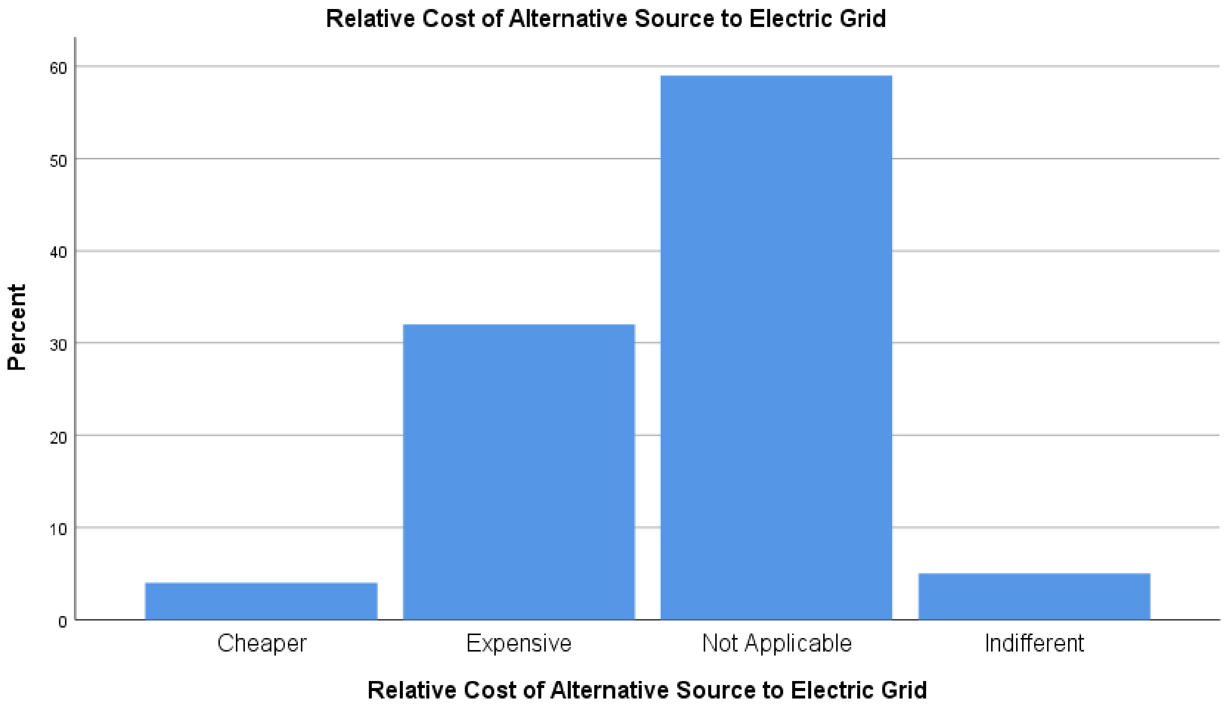

Figure 4.12: The relative cost of the alternative source to the national grid

4.8 SUSTAINABILITY OF HYDROELECTRIC, THERMAL AND NET ZERO ENERGY IN GHANA

There were also questions on the sustainability of hydroelectric, thermal and net zero energy in Ghana. A total of 77% of the respondents said hydroelectricity was sustainable, 19% of the respondents said thermal energy was sustainable and 91% of respondents said net zero energy was sustainable.

Table 4.2 The sustainability of hydroelectricity in Ghana

Sustainability of Hydroelectricity

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	77	77.0	77.0	77.0
No	23	23.0	23.0	100.0
Total	100	100.0	100.0	

Table 4.3 The sustainability of thermal energy in Ghana

Sustainability of Thermal Energy

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	19	19.0	19.0	19.0
No	81	81.0	81.0	100.0
Total	100	100.0	100.0	

Table 4.4 The sustainability of net zero energy in Ghana

Sustainability of Net Zero Energy

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	91	91.0	91.0	91.0
No	9	9.0	9.0	100.0
Total	100	100.0	100.0	

4.9 ENVIRONMENTAL FRIENDILINESS OF HYDROELECTRIC, THERMAL AND NET ZERO ENERGY IN GHANA

The study sought to identify if hydroelectricity, thermal energy and net zero energy are environmentally friendly. 99% of respondents said net zero energy was environmentally friendly whereas 1% of respondents said net zero energy was not environmentally friendly. 90% of respondents said hydroelectricity in Ghana was environmentally friendly whereas 10% of respondents said hydroelectricity was not environmentally friendly. Lastly, 2% of respondents said thermal energy was environmentally friendly whereas 98% of the respondents said it was not environmentally friendly.

Table 4.5 The environmental friendliness of hydroelectricity in Ghana

Environmental Friendliness of Hydroelectricity

	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	90	90.0	90.0	90.0
No	10	10.0	10.0	100.0
Total	100	100.0	100.0	

Table 4.6 The environmental friendliness of thermal energy in Ghana

Environmental Friendliness of Thermal Energy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	2.0	2.0	2.0
	No	98	98.0	98.0	100.0
	Total	100	100.0	100.0	

Table 4.7 The environmental friendliness of net zero energy in Ghana

Environmental Friendliness of Net Zero Energy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	99	99.0	99.0	99.0
	No	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

4.10 CHARACTERISTICS OF NET ZERO ENERGY IN GHANA

The study sought to find out if the respondents could afford to provide net zero energy for their homes and businesses. 22% of the respondents said they could afford to provide net zero energy for themselves whereas 78% of respondents could not afford to provide it for themselves.

The respondents were asked if there was enough education on net zero energy in Ghana. 19% of the respondents said there was enough education on net zero energy in Ghana and 81% of the respondents said there was no little or no education on net zero energy in Ghana.

4.11 POLICIES ON NET ZERO ENERGY IN GHANA

The study investigated the need for policies to be formulated on the the concept of net zero energy to help encourage its uptake in Ghana. It was identified that 98% of the respondents wanted policies to be formulated on the concept of net zero energy in Ghana whereas 2% of the respondents did not see the need for the formulation of policies on net zero energy in Ghana. The respondents were asked if the government were implementing existing policies on renewable energy in Ghana. 12% of the respondents said the existing policies on renewable energy in Ghana were being implemented whereas 88% of the respondents said the existing policies on renewable energy in Ghana were not being implemented.

The study investigated whether there were enough policies on renewable energy in Ghana. 22% of respondents said the policies on renewable energy were enough and 78% of the respondents said that the policies on renewable energy in Ghana were not enough.

4.12 Framework for the uptake of net zero energy buildings

The need for sustainable energy policies in Ghana is of immense importance and it comes from different angles therefore requiring the cooperation of all stakeholders. The Ministry of Energy (MOE) should deliberate issues with the Energy Commission (EC) and after that issue to the Volta River Authority (VRA) a general course to take as in policies with respect to net zero energy buildings. The policy statement should include these vital elements:

- The electricity sector of Ghana should be developed in a way to lower the cost of electricity to the greatest extent possible by encouraging the use of renewable energy and energy efficiency.
- The Volta River Authority should be tasked by the government to investigate the wide range of renewable energy resources and energy options available in Ghana and prepare a plan to develop them to enable electricity delivery at all times and at a cheaper cost to consumers.
- Government should ensure that when other institutions or individuals other than Volta River Authority using net zero energy produce extra energy from renewable or energy efficient sources at lower cost than the Volta River Authority is able to, and to do so reliably, the Volta River Authority should buy the energy and transfer the cost reduction to consumers.

- The efficient distribution of energy generated and energy efficiency ought to be stimulated through a move toward a more disaggregated, cost-reflective tariff, together with appropriate social safety nets.
- The safety, technical operation, power quality and reliability of the grid should be the responsibility of GridCo, and to this effect ought to be allowed to establish technical, reasonable and interconnection standards for third party power generators and distributed generation, through promulgation of a grid code.

This policy statement would enable the Ministry of Energy to make efficient renewable generation, distributed generation and utility upscale, an explicit part of its regulatory approach, in a way that is consistent with other aspects of government policy.

The decrease in the price of small-scale solar systems and wind generation technologies will make it attractive for Ghanaians to fix these systems on their buildings. he savings on their power bills will, under current tariffs, provide a reasonable return on their investment. Other small-scale distributed generation opportunities may become financially viable in time.

When Ghanaians invest in renewable energy resources, their consumption of the energy the Volta River Authority generates with fossil fuels will decline. Nevertheless, since the generated renewable energy is sporadic and will sometimes not be able to fully meet the demands of consumers there will be a continual demand for electricity by consumers from the Electricity Company of Ghana (ECG). Customers will also at times generate power in excess of their own needs. This power can be made available to the grid, and customers will expect to be paid for it. The review of literature in this report has shown that greater use of renewable energy would increase sustainability and lower the cost of electricity service.

The government through MOE should make sure VRA produces plans for the development of renewable energy resources in Ghana. The government should also make funds available for the development of the renewable energy resources. VRA has to then make the energy produced available to GridCo for distribution. GridCo has to ensure reliable and quality power is distributed. The PURC should ensure tarrifs are affordable to enable customers enjoy the energy produced. The customers should then give a feedback of the service they are receiving to the government through the MOE.

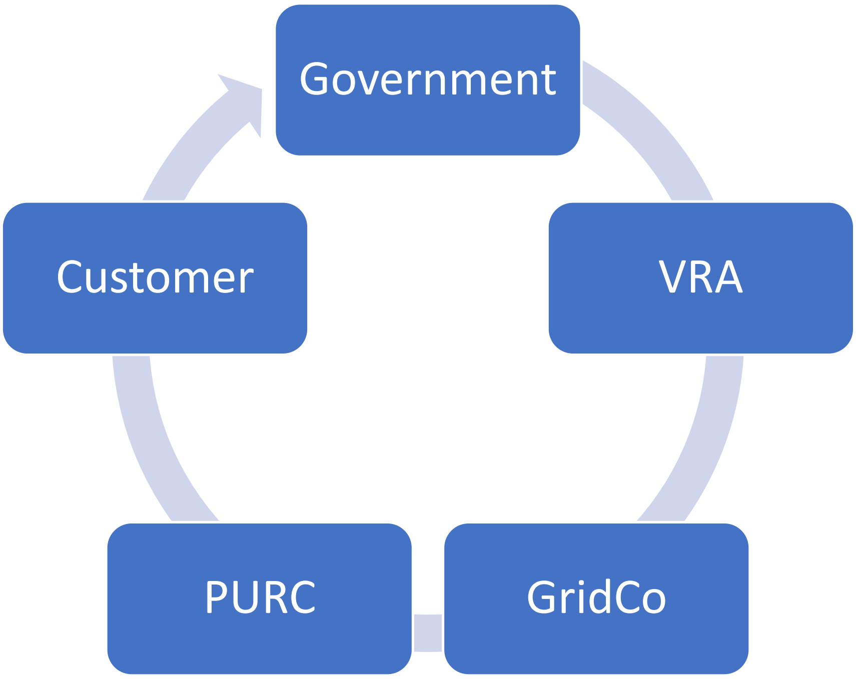

Figure 4.13: Framework for NZEBs

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The chapter presents a summary of findings analysed from the data gathered through the use of questionnaires and interviews in chapter 4 and focuses on the specific objectives of the study. The chapter also provides conclusion based on findings of the study and makes available possible recommendations that can help to encourage the uptake of net zero energy buildings in Ghana.

5.2 CONCLUSION

Based on the findings of the study, it can be concluded that the current energy system is harming the operations businesses and residents in the Kumasi Metropolis. The erratic power outages sometimes caused by the deficit in supply due to excess demand has led to disruptions in the operations of businesses and residents. From Figure 4.8 it was clearly revealed that the operational performance and efficiency of many businesses have dwindled which has led to lower output.

In order to mitigate the adverse effects of the erratic power outages, business owners and residents are compelled to acquire and use alternative power sources such as generators, inverters and solar. These alternative power sources lead to an increase in the operations cost of businesses.

In addition to the increase in operations costs, the power outages have led to a decline in the productivity and profit of residents and business owners in the metropolis. It was established in the study that the current energy system in Ghana is not sustainable and environmentally friendly since a large amount of our energy comes from the burning of fossil fuels. It was also established in the study that net zero energy is a new way Ghana can look in trying to provide energy in a sustainable and environmentally friendly way so as to protect life and the environment.

5.2.1 Sustainability of the Current Energy System

It was found out through literature and the analysis of data that the energy in Ghana was from main thermal and hydro power sources. The change in water level throughout the year makes hydro power unreliable and not sustainable since the maximum energy the dams are capable of producing will not be available throughout the year. Also, since fossil fuels which are used for generating energy from thermal plants is a non-renewable resource it will finish with time and cannot be relied on. This is because non-renewable resources do not replenish themselves and can therefore be exhausted. Based on the above-mentioned findings of the study it can be concluded that the current energy system in Ghana is not sustainable.

5.2.2 Environmental Implications of the Current Energy System

From the findings from the literature and the information gathered as shown in the data analysis (Chapter 4.9) on the study the use of fossil fuels for energy generation through thermal plants is not environmentally friendly since it produces a lot of carbon compounds that is released into the atmosphere and it causes climate change, global warming and other negative impacts on the environment.

5.2.3 Economic Implications of the Current Energy System

From the study and the results of the data analysis (Chapter 4.5) the current energy system was impeding productivity and businesses in the country. Business owners were making huge losses in profit and productivity due to the erratic power outages they encounter in their businesses.

5.2.4 Framework for the uptake of net zero energy buildings

From the findings of the research there is the need for Ghana to move towards net zero energy buildings. This can only happen if measures are put in place to make renewable energy sources easily accessible and affordable for people to patronise. This can be done by educating the public on the need to generate energy sustainably. Government can also scrap of taxes from renewable energy equipment's and materials imported into the country in order to make them more affordable.

5.3 RECOMMENDATIONS

The Public Utility Regulatory Commission (PURC) should ensure that customers do not pay more than is reasonably necessary for electricity, while also letting the Electricity Company of Ghana to recover its reasonable costs. To achieve this, I recommend that the Public Utility Regulatory Commission develop a regulatory regime with three core elements:

- Demanding the Volta River Authority to make sure that their plans are least cost for the expansion of their generation.
- Allowing Volta River Authority to securely recover the costs of investments in renewable generation and fuel efficiency
- Requiring Electricity Company of Ghana to purchase renewable and co-generated power from third party suppliers, where this is cheaper than providing power itself, and does not create risks to power quality or reliability.

The Public Utility Regulatory Commission should require Volta River Authority to demonstrate that its generation expansion plan is likely to result in the lowest cost of service, as a condition for allowing those costs to be passed on in tariffs. Specifically, Volta River Authority should be required to:

- Use globally accepted least-cost expansion planning optimization software to produce its expansion plan. The industry standard for many years for conducting utility power system studies has been either PSS/E (Siemens PTI product) or PSLF (GE Product). Other comparable packages (SKM Power Tools and ESA Easy Power) are unlikely to offer the same level of sophistication necessary for Ghana. Both software packages are very capable of handling the requirements of the Ghana system, considering its mix of potential generation types (PV, Wind, Diesel, Natural Gas), complexity, and the need to address fluctuating generation levels and overall system stability.
- Include in the planning process plausible renewable options agreed with the Ministry of Energy that can meet commercialization criteria
- Prepare the least cost expansion plan considering a range of future oil price scenarios.

The Volta River Authority should present its least cost expansion plan including renewable options to the Ministry of Energy for approval ex ante, that is before the Volta River Authority makes investments. The Ministry of Energy's approval should be given based on checking that Volta River Authority's assumptions are reasonable (in particular regarding oil price assumptions), and its analysis is accurate and correct. The Ministry of Energy should be involved in approving specific investment decisions of Volta River Authority and the role of the PURC should be one of control and not one of management.

Least cost expansion plans must be approved before investments are made, this will prevent mistakes from being made before they are corrected, and because the Volta River Authority will need a guarantee that the cost of their investments can be recuperated before investments are made.

The government should not tax renewable energy systems imported into the country to make them affordable and encourage people to patronise it. The government should make laws that will compel building owners who can afford renewable energy systems to provide energy for themselves.

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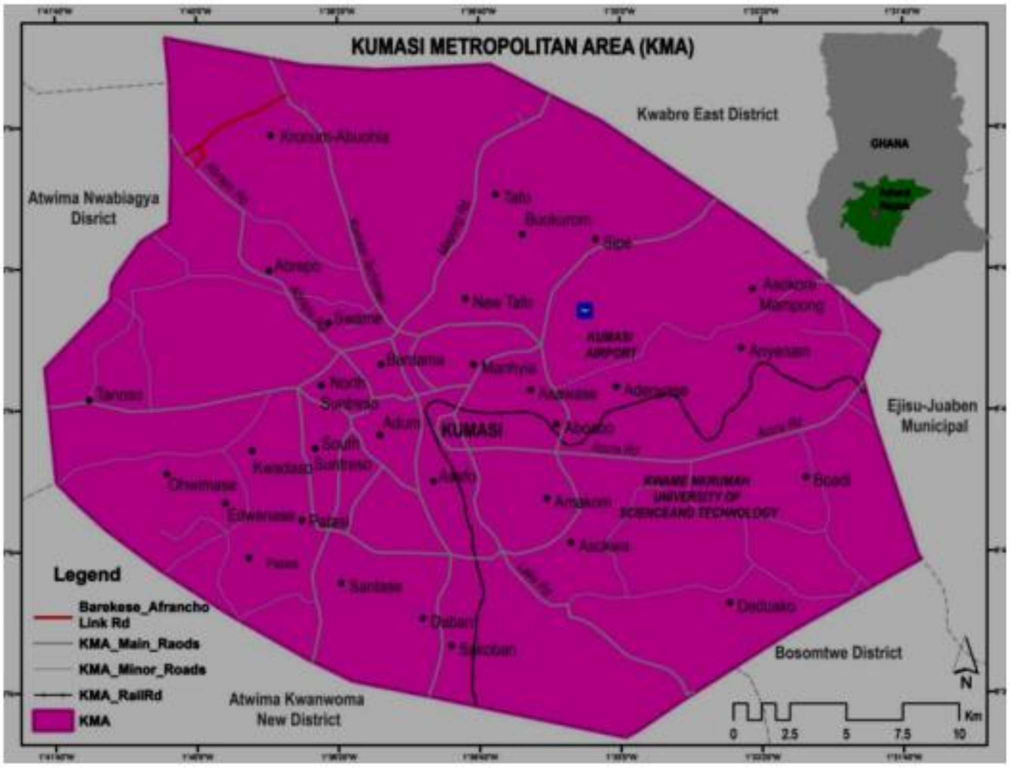
APPENDIX

Appendix 1. Figure 3.1a: Map of Kumasi Metropolitan Area



QUESTIONNAIRE

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Master's Thesis Research

Topic: Developing a framework for the uptake of net zero energy buildings in Ghana.

The information required will enable the researcher to develop a framework for the uptake of net zero energy buildings in Ghana. The author is a construction management student at KNUST. Please, be assured that any information provided shall be treated as confidential and for academic purposes only.

1. Which of the following are you?

   a. Homeowner b. Tenant c. Business Owner d. Other

2. Do you pay for electricity?

   a. Yes b. No

3. What do you use electricity for?

   a. Lightning b. Electrical Appliances c. Cooling d. Others, specify…………….

4. How much do you pay for electricity monthly?

   a. < 100 b. 100- 300 c. 300-500 d. > 500

5. What type of meter do you use?

   a. Commercial b. Residential

6. Do you experience power outages?

   a. Yes b. No

7. If YES, how often do you experience the power outage?

   a. Daily b. Weekly c. Monthly d. Rarely

8. What is the average duration of the power outages?

   a. < 1hr b. 1-6hrs c.6-24hrs d. >24hrs

9. What is your alternative source of power?

   a. Solar b. Generator c. None d. Other (specify) ……………

10. If you use a back-up power source (e.g. Generator), state the monthly cost for using the back-up power. ***(Note: respondent can give an estimate if not so sure about cost).***

    a. < 100 b. 100-300 c. 300-500 d. > 500

11. What is the cost of alternative measures in relation to electricity from the national grid taken to mitigate effects of the power outages?

a. Cheaper b. Expensive c. Not Applicable d. Indifferent

12. Does the alternative measure specified in question 10 above increase operations cost?

    a. Yes b. No c. Not Applicable

13. Do power outages cause a decline in productivity?

    a. Disagree b. Indifferent c. Agree d. Not Applicable

14. If you AGREE to question 13 above, do power outages lead to a decline in your monthly profit?

    a. Yes b. No

15. If your answer to question 15 above is YES, what measures do you take to prevent a decline in monthly profit?

    a. Increase price of products or service

    b. Cut down number of workers

    c. Work overtime during load shedding

    d. Other (specify)………………………….

16. Is hydroelectricity in Ghana sustainable?

    a. Yes b. No

17. Is thermal energy in Ghana sustainable?

    a. Yes b. No

18. Is renewable energy in Ghana sustainable?

    a. Yes b. No

19. Is hydroelectricity in Ghana environmentally friendly?

a. Yes b. No

20. Is thermal energy in Ghana environmentally friendly?

    a. Yes b. No

21. Are net zero energy buildings environmentally friendly?

    a. Yes   b. No

22. Can you afford to provide a net zero energy building for yourself?

    a. Yes   b. No

23. Is there enough education on net zero energy in Ghana?

    a. Yes   b. No

24. Are there enough government policies on renewable energy adoption?

    a. Yes   b. No

25. Are existing policies on renewable energy in Ghana been implemented?

    a. Yes   b. No

26. Is there a need for policies on net zero energy in Ghana?

    a. Yes   b. No

27. What policies can government implement to encourage the uptake of net zero energy buildings?

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

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

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

Thank you very much!!!