ENERGY SECURITY AND CLIMATE CHANGE ADAPTATION IN RURAL COMMUNITIES

BY

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DECLARATION

I hereby declare that this submission is my own work toward the M.Phil and that to the best of my knowledge, it contains neither materials previously published by another person or materials which have been accepted for the award of any other degree by this or any other university except where due acknowledgement has been made in the text.

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ABSTRACT

Energy of all kinds stimulates the quality of rural life and is an integral part of sustainable development. In most rural areas, and especially in Sub-Sahara Africa, the dominant energy used for cooking and other domestic energy needs is wood-based biomass. With the rise of the unprecedented effects of climate change, continual dependence on the wood-base energy sources become threatened since they are affected by a slight change in the climate.

The purpose of this study was to investigate into sustainable energy and climate change in rural communities. The study aimed at identifying the relationship between rural energy forms and climate change and finally, to find out a way in measuring sustainable energy amidst climate change.

Cross-sectional and prospective study designs with a combination of probability and non-probability sampling techniques were used. Ninety rural households were selected from the Nzema East Municipal Area in addition to 25 industries and 10 local energy suppliers for interviews and interactions.

Results from the study showed that, fuel wood and charcoal consumption was directly linked to family size with $r = 0.77$. Carbon emissions, calculated at a significant level of 0.05, show how rural energy was contributing to climate change. Again, current rural energy system was more likely not sustainable based on the use of the 'AAARE-ST'[1] models. As a result, it was recommended that wood lot plantations be increased and encouraged in the short-run in order to start off-setting increasing resource depletion and also a decentralized Ministry of Energy is recommended in the long-run as well as changing rural preference from wood-based biomass to modern ones.

The principal conclusion was that, though the study has revealed a number of key outcomes in sustainable rural energy and climate change, a number of research gaps still exist and the study was unable to use adequate test statistic to establish the nature of the relationship between rural energy forms and climate change.

[1] Affordability, Accessibility, Adaptive Capacity, Reliability, Equity, Space and Time models

DEDICATION

This thesis is dedicated to my late mother, who taught me that even the largest task can be accomplished if it is done one step at a time. It is also dedicated to my late father, who taught me that the best kind of knowledge to have is that which is learned for its own sake.

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LIST OF ACRONYMS

AFREA - Africa Renewable Energy Access Programme

BOST - Bulk Oil Storage and Transportation

CEB - Consumer Energy Burden

CLT - Central Limit Theorem

CO - Carbon monoxide

CO_2 - Carbon dioxide

DFID - Department for International Development

DPCU - District Planning Coordinating Unit

EC - Energy Commission

ECG - Electricity Company of Ghana

EJ - Exajoule

EPA - Environmental Protection Agency

ESMAP - Energy Sector Management Assistance Programme

FAO - Food and Agriculture Organization of the United Nations

FSD - Forestry Service Division

GHG - Greenhouse Gas

GHS - Ghana Cedi

GLSS - Ghana Living Standards Survey

GoG - Government of Ghana

GRIDCO - Ghana Grid Company

GSGDA - Ghana Shared Growth and Development Agenda

GTZ/GIZ - German Technical Cooperation

Hh - Household

IAEA - International Atomic Energy Agency

IEA - International Energy Agency

IPCC - Intergovernmental Panel on Climate Change

IPP - Independent Power Producer

IUNC - International Union for the Conservation of Nature

KG - Kilograms

KITE - Kumasi Institute of Technology, Energy and Environment

kWh - Kilowatt Per Hour

LGPRSP - Local Government and Poverty Reduction Support Programme

LPG - Liquefied Petroleum Gas

MA - Municipal Assembly

MCE - Municipal Chief Executive

MDG - Millennium Development Goal

MoEn - Ministry of Energy

MSD - Meteorological Survey Department

MTDP - Medium Term Development Plan

MUAT - Multi-Attribute Utility Theory

NEM - Nzema East Municipal

NEMA - Nzema East Municipal Assembly

NGO - Non-Governmental Organisation

OECD - Organization for Economic Co-operation and Development

p.a. - Per Annum

PUE - Productive Uses of Energy

r - Correlation Coefficient

$\mathbf{r^2}$ - Coefficient of Determination

REEEP - Renewable Energy and Efficiency Partnership

RETscreen - Renewable Energy Project Analysis Software

SD - Sustainable Development

SE - Sustainable Energy

SE4ALL - Sustainable Energy for All

SPSS - Statistical Package for the Social Sciences

SSA - Sub-Saharan Africa

tCO_2 - Tonnes of Carbon dioxide

TCPD - Town and Country Planning Department

TOR - Tema Oil Refinery

UN - United Nations

UNDP - United Nations Development Programme

UNESCO - United Nations Educational, Scientific and Cultural Organisation

VRA - Volta River Authority

WFY - Wood Fuel Yield

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Energy, of all kinds, very much stimulates the quality of rural life and consequently, its role in the process of rural development must be emphasized and improved. Having secured access to energy is key to increasing access to water, health care and electricity for businesses and agricultural growth. To appropriately explain the concept of energy security, perhaps, it is best understood when taken literally – 'to be secured in terms of energy supply' (Durante and Sneller, 2005). Several international bodies and energy scholars have wondered around the concept of energy security in a bid to find an appropriate explanation for it. Pandey (2008), defined it as a function of the ability of a nation to satisfy energy needs of current and future generations of all citizens in an affordable manner without adverse impact on the environment and sustainability. While most literature and actions towards sustainable energy, is mainly on the supply, the demand side is equally important; from this premise, the study is built and structured. For purposes of this study, the terms energy security and sustainable energy will mean the same and are used interchangeably; this is so because several literature assumes similarities between these terms.

The type of energy resource is very relevant in identifying and focusing on the form of security. Energy resources can be grouped into Fossil fuels, Renewable and Nuclear energy resources. Coal, petroleum, and natural gas could be classified under fossil fuels; solar, wind, hydroelectric, biomass, and geothermal power are considered under renewable energy resources; and fusion and fission are under nuclear power. Most developing countries especially those in Africa depend on renewable energy sources. These are mainly hydroelectricity and biomass energy resources (Wilbanks et. al., 2008); with virtually half of the world's population and 81 percent of Sub-Saharan African (SSA) households relying on wood-based biomass energy (fuel wood and charcoal) for cooking and other domestic activities (Africa Renewable Energy Access Programme[AFREA], 2011). However, the portion of total energy supply from renewable energy sources varies among countries. For example, biomass accounts for 5 percent of North African, 15 percent of South African, and 86 percent of SSA (minus South Africa) energy consumption (Thiam, 2009).

In the case of Ghana, wood base energy also dominates the total energy consumption with fuels such as fuel wood and charcoal providing the bulk (59 percent) of this energy needs (Energy Commission, 2010). Rural communities in Ghana presents a special case of interest in the sense that, majority (97 percent) depend on wood base fuels in the form of charcoal and fuel wood for their domestic needs (KITE, 2005; Energy Commission, 2010).

Stemming from these platforms, it is clear that, for the past decade, there has been rising concerns over rural energy needs in developing countries; described initially as a situation where biomass fuels were consumed at a rate faster than production and it led to deforestation (Brown et. al., 1988; 1992). Today, energy security has become more difficult as a result of climate change. Practically, rise in sea-levels can be expected to affect prospects of hydro-power generation either positively or negatively (Wilbanks et al., 2008) and the type and frequency of extreme phenomena (as a result of climate change); such as the increase in temperature, flood disasters and droughts can also affect natural forest cover; are expected to rise and have already been observed globally (Mosha, 2011). These impacts can be seen manifested in several ways across different geographic locations. The recent flooding in Accra and some parts of Kumasi in Ghana (August and October, 2011) and New Orleans flooding are palpable evidence. However, many indirect impacts are also probable (example, changes in the functions of coastal ecosystems and in the distribution of bottom sediments) and impacts will continue to be felt globally even if greenhouse gas (GHG) emissions are drastically reduced (UN, 2011). Some of these impacts are evident in rural areas in Ghana, example there is an increase in the rate of deforestation in most places and evidence of drastic changes in rainfall patterns has been recorded across rural areas in Ghana (Kpeli-Semabia, 2011).

Stepping from this background, the Intergovernmental Panel on Climate Change [IPCC] (2005) notes that climate change would impact energy supply and demand; for this case rural Ghana. Although renewable energy sources may be adaptable to new climate, larger percentages of renewables in Ghana’s rural energy supply makes it relatively more vulnerable to climate change. Biomass and hydropower generation are the energy sources that are most likely to be affected most due to its sensitive nature to the amount, timing, and geographical pattern of precipitation as well as temperature (Thiam, 2009). The heavy reliance on biomass is mostly likely to either remain at very high levels or even grow over the next few decades (AFREA, 2011); bearing climate change impacts on biomass energy in mind, this phenomenon then raises concerns and the question, how then can energy (especially wood-based ones; fuel wood and charcoal) be secured amidst climate change and already existing factors such population increase and economic challenges?

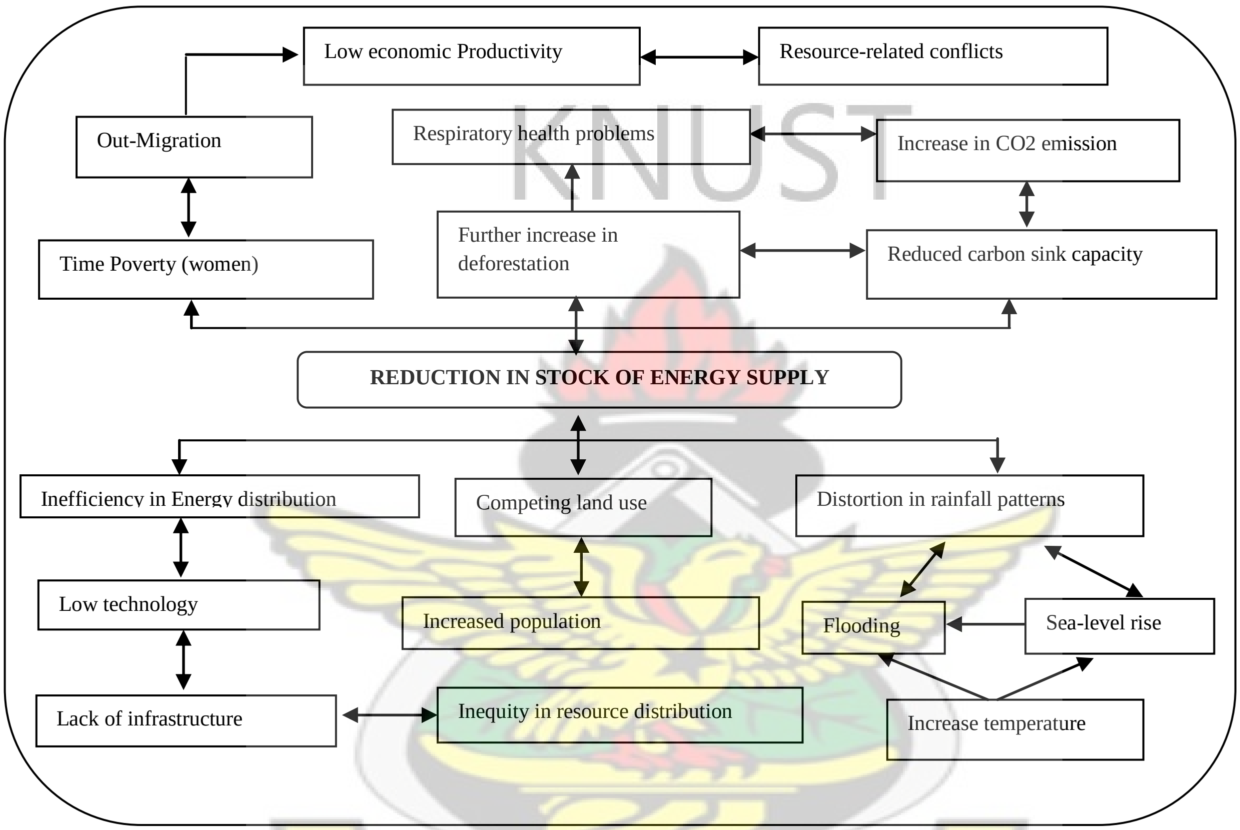
Adaption to climate change provides a good avenue to maintain a sustainable energy mechanism. A surge in interest in adaptation action is discernable since the beginning of the century (IPCC, 2005). Trying to define the scope of adaptation to operate in raises questions as to whether the process of adaptation is the development of technological changes that maintain current life styles, or implies the actual behavioral adjustments needed to adapt livelihoods to new climatic conditions (Smithers and Smit, 1997). Therefore defining terms is essential to a rational policy intervention. It is very important to mention here that, though adaptation is considered, it does not go without measures towards mitigation. Adaptation and mitigation are the two sides of the same coin and hence needs to be looked at together. However, for purposes of this study, adaption is looked at extensively.

Wood based energy is likely to continue to dominate as a prime energy source in rural Ghana (Energy Foundation, 2000; Energy Commission, 2012) whilst climate change impacts are feared to intensify with time (IPCC, 2009) and this phenomenon, has stimulated the interest and necessity to ensure sustainable energy in rural communities. The study therefore assesses policy-driven adaptation measures in rural areas as a solution to address energy insecurity in the current climate change dilemma.

1.2 Problem Statement (Development Issue)

It has become generally accepted that energy supply and demand is a vital component of development but has faced several challenges in supply meeting its demand over time. These challenges range from population growth to economic factors and today, the impacts of climate change. No state, not even one that is among the strongest, is capable of guaranteeing the complete mitigation of climate change impacts (Mosha, 2011). The situation becomes worse when the impact of climate change is difficult to forecast and the magnitude of uncertainty of the predictive capacity of nations, especially the developing ones, becomes blurring. The problem to be addressed in this study is the increasing rate of reduction of energy supply stock in Ghana's rural communities amidst the increasing threats of climate change (see figure 1.1 for the problem tree analysis).

Figure 1.1 Problem Tree



Source: Author's Construct, 2011

Rural communities are faced with unstable supply of energy and in most cases there is lack of access to modern energy services (Thiam, 2009). Development is hindered by lack of energy and must be overcome if the United Nations Millennium Development Goals (MDGs) are to be achieved. Lack of access to energy is thus, a very serious developmental issue that needs urgent intervention. In rural Ghana, this becomes very disturbing especially when the primary source of energy supply is traditional wood fuel (Energy Commission, 2008); affirmable to this is Thiam's (2009) study, revealing that 60 percent of SSA energy source is from biomass. This is alarming because the natural environment from which these energy sources are produced is gradually being damaged by the impacts of climate change. In rural Ghana, an annual deforestation rate of

3 percent (FAO, 2003) is estimated and this becomes a problem. Amoateng (2009) confirmed that, already 35 percent of Ghana's land mass, which is chiefly spatially located in rural areas, has been swallowed as a result of deforestation and drought.

Evidence of shortages in energy supply is seen in the imbalance between wood-based energy supply and demand in rural Ghana. According to Ghana's 2000-2030 energy outlook report, wood-based fuels yield (WFY) stood about 17million tones p.a. in 2000, while consumption was at about 19 million tones p.a. The phenomenon has been projected to worsen in 2016 and 2020, with WFY reducing considerably while consumptions increase exponentially. The projection figures showed that, for example in 2016 WFY will be about 12.5million tons p.a. and consumption will further rise to about 25million tons p.a.; also in 2020, it is projected that WFY will reduce again to about 10million tons p.a. while consumption will increase to about 27million tone p.a. (Energy Commission, 2012). These scenarios show that, the reduction in stock of rural energy supply poses a great challenge for rural development and hence needs urgent attention and action.

Knowing the increasing threats of climate change on the natural environment and the rate of natural environment self reconstruction, total dependence on biomass is questionable. This provides a case for energy security in the sense of depletion of the natural forest. A projection made by the Environmental Protection Agency indicates that, continual dependence on wood fuel will cause the natural forests in the managed and protected tropical forest reserves to decrease by 45,000 hectares. Total closed forests would decrease by 343,000 hectares, and natural savanna woodlands by about 600,000 hectares. The continual destruction of the forest reserves and closed forests raise concerns for sustainable energy supply. From figure 1.1 above, it becomes very clear that, further dependence on the natural forests for energy will lead to more forest destructions and thus will induce less capacity to serve as carbon sinks and the related respiratory health issues associated with use of wood base fuels in the homes.

In addition to the above, climate change also affects the available energy supply stock. Threats from the damaging effects of climate change have serious consequences on energy resources in rural areas since they rely heavily on the natural environment and are heavily susceptible to the devastating threats. Increased droughts are recorded to have increased around the equator and have affected the forest cover from which majority of rural communities obtain their energy source. Sea-level rise and increase in droughts have been recorded in Ghana and these have affected the rate of forest regeneration to reduce (FAO, 2003).

Sustaining energy amidst climate change cannot be overemphasized. Projections to 2050 indicate that world energy demand may increase dramatically, with the highest demand occurring in developing countries (REEEP, 2008). The growing of rural populations as well as increase in incomes will trigger high demand for energy (Ghalam, 2008; cited in Wilbanks et al. 2008). It is feared that not only are these levels of energy supply and use from current sources difficult to achieve but also unsustainable. Hence, sustaining energy for the present and future demand is paramount. However, this cannot be done without understanding the nature of the relationship between energy forms and climate change. It is therefore the purpose of this study to create the platform to understand sustainable energy through exploring the nature of relationship between energy forms and climate change and then finding ways in measuring sustainable energy.

1.3 Research Questions

The key research questions of the study are:

- What is the nature of the relationship between rural energy forms and climate change?
- To what extent is the rural energy forms affected and/or affects climate change?
- Is rural energy use sustainable amidst climate change?

1.4 Research Objectives

The study's aim is;

- Finding out the nature of the relationship between rural energy forms and climate change;
- Understanding the extent to which rural energy forms affect and/or is affected by climate change;
- Understanding the rural capacity to adapt to climate change; and
- Making policy contributions towards sustainable energy and adaptation to climate change in rural communities.

1.5 Justification

Securing energy in a climate change adaptive manner cannot be overemphasized, especially in a world where there is total dependence on wood-based fuels.

In Africa, energy security is central to empowering economic development and growth. Perhaps achieving the Millennium Development Goals (MDGs) is more or less dependent on energy. Without energy, growth will inevitably fail; how can there be good education when we have no energy for light for children to read and do their homework at night?

According to the EPA, about two-thirds of the total land area can be at risk as a consequence of the rise of the sea level in Ghana; a total of 1,110 km^2 of land area may be lost as a result of a one-meter rise in sea level. When this happens, a total population of 132,000 mostly living within the East Coast area would be affected (EPA, 2000). The displacement will cause migration to other areas and increase the demand for energy in such areas; which are most likely to be rural as migrants will settle in new places to start life over again.

Ghana has embarked on an action plan for sustainable energy for all by 2030. A plan geared toward ensuring universal access to electricity in rural communities and clean fuels and devises for cooking (Energy Commission, 2012). This action plan is also aimed at reducing GHG emissions as a result of the use of inefficient consumption of wood-based fuels. This agenda puts the study in the spotlight of sustainable energy at the time where sustainability has become paramount on the development agenda.

Rural poverty has become a disturbing phenomenon for successive governments in Ghana. The growth of urban population notwithstanding, Ghana has a significant number of rural communities averaging a rural population of 49.1 percent (GSS, 2012). Poverty is more prone in rural communities and thus the need for development. Energy is an important component of improving livelihoods in rural areas but these areas are almost characterized by lack of access to modern energy supply (Mosha, 2011).

1.6 Scope

The focus is on rural areas in Ghana as most of these areas are predominantly poor and subsistent in nature; and rely heavily on wood-based biomass. The Nzema East Municipal (NEM) was studied as it is predominantly rural and have experienced cases of heavy precipitation and some threats of sea-level rise (MTDP, 2008).

The study is limited to the demand (consumption) and supply of wood-based biomass and specifically fuel wood and charcoal biomass. This is because wood-based biomass constitutes the main source of energy in Ghana, about 60 percent (Energy Commission, 2012) and especially in rural areas; and because of its vulnerable nature to the threats of climate change. Adaption is favoured in this study to mitigation of climate change; that is the study will be restricted to climate change adaptation.

1.7 Limitations to the Study

The main limitation to the study was lack of data on wood-based fuel use in Ghana. There were virtually no studies on the quantification of fuel wood which could be reviewed in order to properly inform this study.

Again, it was difficult to obtain population data on the case area and the various communities selected. The population projections are only as good as the assumptions used. Although the assumptions used for the study are based on past and current demographic profile of Ghana, there is no certainty that such trends will continue.

Obtaining data on climate change parameters was very expensive. It costs GHS10.00 for a set of data, say rainfall patterns, per year; hence to obtain data for over 30 years, the researcher was suppose to pay as much as GHS 300.00 for only data on rainfall. Getting data for rainfall, temperature, sunshine and evaporation will cost GHS 1,200.00. This could not be afforded by the researcher.

1.8 Organization of Report

The report is grouped into six chapters. The first looked at the background and problem to the study; detailing the research questions, objectives and scope. The second chapter looked extensively at literatures on sustainable energy and climate change adaptation to reveal the framework within which the study was conducted. The third chapter detailed out the methodology followed in completing the study as well as the profile of the study area. The fourth chapter also presented the baseline data and established the nature of the relationship between energy forms and climate change. The fifth chapter discussed the sustainable energy framework in relation to the designed framework (discussed later in chapter 2). The sixth and final chapter considered the implications of the study to policy and summarized the major findings in relation to the research questions and made tangible and operative recommendations and conclusions.

CHAPTER TWO

SUSTAINABLE ENERGY MEASUREMENT AND CLIMATE CHANGE ADAPTATION; CONCEPTS AND APPLICATIONS

2.1 Introduction

The chapter commenced by looking at the understanding of sustainable development as a platform to build further analyses. It went on to discuss in detail rural development and rural energy in a global and Ghanaian context. The chapter also linked sustainable energy (SE) with the MDGs and also the GSGDA.

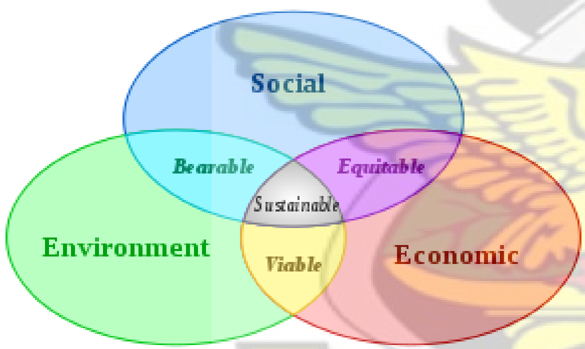
2.2 Sustainable Development

Sustainability and its corollary, sustainable development (SD), have become part of the development rhetoric over the past two decades, in part due to the publication of the Brundtland Commission report in 1987 - 'Our Common Future'. Before the Brundtland Commission, the concept of SD was coined explicitly to suggest that it was possible to achieve economic growth and industrialization without environmental damage and as early as the 1960s, SD was employed to mean a stable economy with basic ecological support systems (Stivers, 1976). This was however criticized by several ecologists who based their arguments on Meadows (1974) book, 'The Limits to Growth', and emphasized that the rapidly growing population on finite resource supplies is dreadful and thus SD defined by Stivers (1976) is not sustainable enough.

Hence in 1987 the concept was defined in the first report of the Brundtland Commission as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs' (Asefa, 2006). This definition has been widely used and applied in most development discussions but there are still several different ideas and ways of understanding and applying it.

Notwithstanding, there has generally been recognition of three aspects of sustainable development that is very clear and used more frequently; the economic, environmental and social aspects (Holmberg ed. 1992; Farinelli ed. 1999; Harris, 2000; OECD, 2001). Now there is the inclusion of institutional aspects (UN, 2001) and cultural issues (UNESCO, 2001), however the cultural aspects are looked at as part of social sustainability in most literature (Holmberg ed. 1992). In economic sustainability, the system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances which damage agricultural or industrial production. An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources (Adams, 2006). A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, gender equity, and political accountability and participation (Harris, 2000).

Figure 2.1 The Three Aspects of Sustainable Development



Source: Adams, 2006

The aspects expressed are multidimensional, raising the issue of how to balance objectives and how to arrive at SD in the middle. Figure 2.1 explains that in SD, tradeoffs can rarely be avoided, and as iterated by Neumayer (2003), only one objective at a time can be maximized. Surely if we could move closer to achieving this tripartite goal, the world would be a better place.

2.2.1 Measuring SD: Indicators for measurement

To achieve and maintain SD, decision-makers require information which demonstrates whether a system is generally becoming more or less sustainable, and specific information on which objectives need the most priority. Several forms of indicators have been designed and applied at different levels and places. The important thing that needs to be achieved is setting goals and objectives. In most of the applications of SD, a framework is first designed from which themes and/or sub themes are developed. In this sense figure 2.1 becomes the framework and its themes are the aspects – economic, environmental, social and institutional - discussed earlier. A summary of SD indicators gather from reviewed literature and widely used have been provided in table 2.1 below.

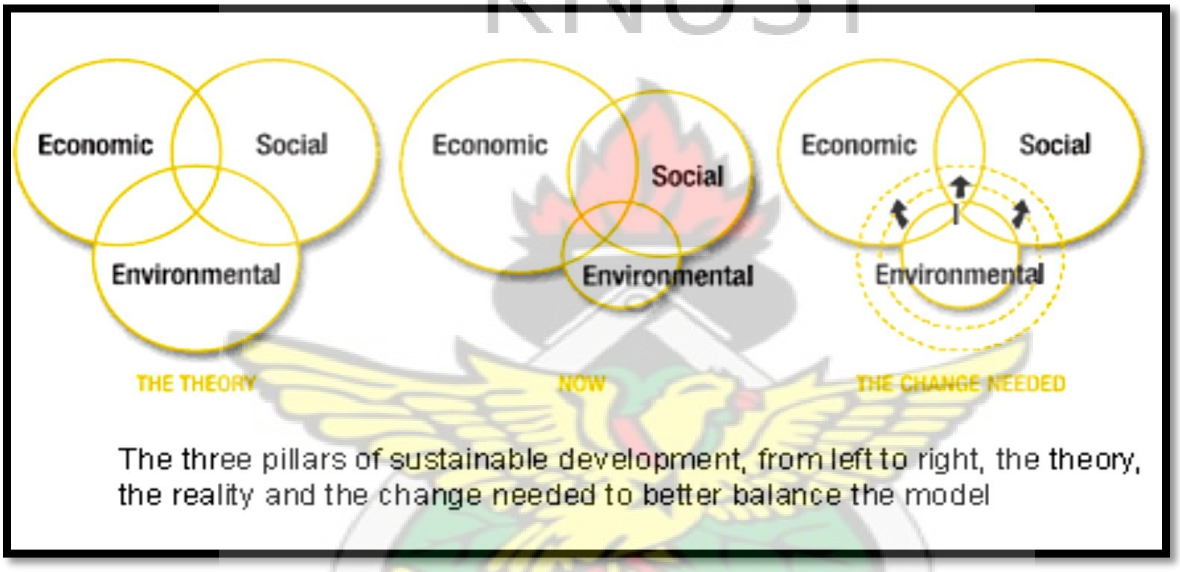
Table 2.1: Framework and Indicators for Measuring SD

Dimension	Theme	Sub-Theme	Indicator
Social	Equity	Poverty	Percentage of population living under poverty line
			Gini index of income inequality
			Unemployment rate
		Gender equity	Ratio of average female wage to male wage
	Education	Literacy	Adult literacy
		Educational level	Secondary/primary school completion rate
	Health	Mortality	Mortality rate under 5 years old
			Life expectancy at birth
		Sanitation	Percentage of population with access to primary health care facilities
Environmental	Atmosphere	Climate change	Emissions of greenhouse gases
		Ozone layer depletion	Consumption of ozone depleting substances
		Air quality	Ambient concentration of air pollution in urban areas
Economic	Economic structure	Economic performance	GDP per Capita
			Investment share in GDP
		Trade	Balance of trade in goods and services
	Consumption and production patterns	Energy use	Annual energy consumption per capita
			Share of consumption of renewable energy resources
			Intensity of energy use
		Transport	Distance travelled per capita by mode of transport
Institutional	Institutional framework	Strategic implementation of SD	National SD strategy
		International cooperation	Implementation of ratified global agreements
	Institutional capacity	Information access	Number of internet subscribers per 1000 inhabitants
		Science and technology	Expenditure on research and development as a percent of GDP
		Communication and infrastructure	Main telephone lines per 1000 inhabitants

Source: UN, 2001

It is true that finding the definite meaning of SD is very difficult. This literature has shown that SD is a process and an ongoing dialogue that needs diverse perspectives and contributions. Linking SD theory discussed above to the real world situation, it is very clear that there is still overemphasis on the economic aspect as compared to the remaining two aspects (Adams, 2006). The study adopts IUCN Programme, which used the interlocking circles model to demonstrate that the three objectives need to be better integrated, with action to redress the balance between dimensions of sustainability; this has been illustrated in figure 2.2 below.

Figure 2.2: Sustainable Development in the Real world context; The Change needed



Source: Adams, 2006; p.2

From this, the dialogue consensus should include a fair representation of all stakeholders in the three aspects especially social and environment. Hence for the purpose of this study, in essence, SD is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.

2.3 Energy

Energy is essential to economic and social development; from cars to cell phones, pharmaceuticals to plastics and air conditioning to water heating, energy is part of people's lives more than ever before. But energy's benefits extend far beyond what people use individually at home, at work and on the road. A range of essential activities – including agriculture, computing, manufacturing, construction, and health – depends on access to modern energy.

However, much of the world's energy is currently produced and used in ways that may not be sustainable in the long term (IAEA, 2002). But how can energy be sustained and how can this be measured? To begin to answer these questions, it is important to first understand energy and its various forms. Energy has its origin from the natural and physical sciences (physics to be precise) and the discussions preceding will lean a little towards that direction.

Energy in the sciences is the capacity to do work. From the physical sciences, White (2000) explains that it is often understood as the ability a physical system has to do work on other physical systems. Another dimension is seen as energy being a property of matter that can be converted into work, heat or radiation. Viewing these three statements, it can be said that in the natural science, energy is related to ability to work through conversion of some form of matter (Nolan, 1996). It is very much linked with Zimmerman's (1987); cited in Shaw (2004); assertion that 'resources are not they become' so that energy on its own is useless until it is converted into work, heat or radiation (Oxtoby and Nachtrieb, 1996). Physics has shown the various forms of energy as chemical, electric, thermal, nuclear, magnetic, sound, and mechanical energy among others; these are however outside the scope of the study. What is crucial in energy is its conversion for use. In this sense, scientists have agreed that the quantity of energy available is constant in the universe and cannot be created or destroyed, but only transformed from one form to the other; this forms the basis of the law of conservation of energy (Nolan, 1996).

Another way of energy categorization is the type of energy sources. The energy sources have been split into three categories: fossil fuels, renewable sources, and nuclear sources. The fossil fuels are coal, petroleum, and natural gas. The renewable energy sources are solar, wind, hydroelectric, biomass, and geothermal power. The nuclear-powered sources are fission and fusion (Energy Matters, 2000). This type of categorization becomes more useful and meaningful to social scientists as compared to the mechanical and magnetic categorization.

Fossil Fuels

Although there are many different types of fossil fuels, coal, petroleum, and natural gas are the most dominantly used. Fossil fuels have been a widely used source of energy every since the

Industrial Revolution just before the dawn of the 20th century. Fossil fuels are relatively easy to use and to generate energy because they only require a simple direct combustion. However, a problem with fossil fuels is their environmental impact. Not only does their excavation from the ground significantly alter the environment, but their combustion leads to a great deal of air pollution, releasing carbon dioxide (CO_2) and carbon monoxide (CO) and its resultant greenhouse emissions and climate change. Also recent studies have shown that, the continuous exploitation of fossil fuels today is going to have a negative impact on future demand and hence the call for alternative sources.

Nuclear

The diminishing availability of natural resources such as coal, petroleum, and crude oil has left scientists searching for an energy alternative. Fission research into lessening problems caused by reactors is of great concern to many, while fusion has risen to the forefront of future energy research. The benefits in fission energy production are shadowed by disturbing accounts of harm to the environment and dangerous nuclear waste by-products. Chernobyl, Hiroshima, and Nagasaki are frightening precedents in the field of fission development and are not to be ignored. For years now people have been turning to fusion as the energy of the future. Not only does fusion appear to be an extremely effective source of energy production, it is environmentally friendly and virtually inexhaustible. But continues research failures to make breakthroughs in obtaining energy have caused several countries to start abandoning the idea.

Renewables

Uncertainty about the future of fusion research has increased the importance of renewable energy sources. Among the most important of these sources are hydroelectric, solar, and wind. Renewable energy sources' main assets are their environmental cleanliness and their virtual inexhaustibility. Major drawbacks, however, are limited energy production (in most cases not suitable for large-scale power generation) as well as relative costliness to build and maintain. In light of diminishing fossil fuels, however, renewable energy may end up as the energy of choice for the 21st century and it is now gaining grounds in most energy debates as the key to future energy shortages and climate change.

These types of energy sources are much more relevant to this study and will be used in the subsequent sections. Energy, as used in this study, will invariably imply the types of energy sources explained in the previous paragraphs above but not to the natural and physical science view, postulated by Oxtoby and Nachtrieb (1996), Nolan (1996) and White (2000). It is also very important to draw a line between energy and power here since the two concepts are most often misinterpreted. In its technical sense, power is not at all the same as energy, but is the rate at which energy is converted. Example, a hydroelectric plant, by allowing the water above the dam to pass through turbines, converts the water's potential energy into kinetic energy and ultimately into electric energy, whereas the amount of electric energy that is generated per unit of time is the electric power generated.

Taking notes from the physical sciences, the entire problem of energy availability can be reduced to that of conversion of abundant but less convenient forms of energy into scarce and more convenient forms which our society needs most.

2.4 The Rural Concept and Energy

The intricacy in rural studies is that there is no international agreed definition on what a rural or urban area could mean that would be applicable to all countries. Though a complex concept, it is not as contentious as the concept of SD. For some, rural is a subjective state of mind while others see rural as an objective quantitative measure (John, 2008). Several other literatures also define rural by exclusion; that is any other scope under consideration which is not urban inclined is rural. This school of thought has not gained much currency and not used by most authorities and studies. These notwithstanding, the most agreed upon definition by authors are related to community variations in size and density of population (Dewey, 1960; John, 2008).

One major criticism was the demographic concept argued by Stewart (1952) cited in Dewey (1960). He postulates that defining rural or urban areas by demographics will render the idea behind distinguishing the two terms nullified since they apply the same rules of numbers to advanced and developing countries; so that in places where their population and land sizes are large their definition of what rural or urban is cannot be used in smaller places due to the difference in population densities. However, the definition of rural and urban communities has still been dominated by their demographics. For purposes of this study, the definition of the UN-Habitat and borrowing a little from John's (2008) 'what is rural?' is adopted; that is a rural community is identified by their populations and level of facilities available within the area.

About 59 percent of populations in developing countries (UN, 2004) are considered to be in rural areas. However, since 2004 it has been noted that rural populations are declining due to the general trend of migration to urban areas; example between 2004 and 2010, the world's rural population declined from 59 percent to 55.9 percent and in Sub-Sahara Africa, it reduced from 64.3 percent to 61 percent (UN, 2011). Though the populations in rural communities are declining, their energy problems are even now expected to have exacerbated. The increase in urban populations - which is estimated to increase from about 44 percent to 60 percent by 2030 (World Energy Council, 2004) - is very likely to reinforce policy-makers' preoccupation with urban issues, while increasing competition for rural energy supplies and as a result possible neglect of rural energy needs.

In developing countries, rural communities account for almost 40 percent of total energy consumption and their energy-use patterns center around wood-based biomass specifically fuel wood and charcoal (Bhagavan and Karekezi, 1992). At the beginning of the 21st century, rural populations are still heavily dependent on traditional biomass as their main source of energy (REEEP, 2008). This phenomenon is not wrong in itself but what makes it worrying is the manner in which they are being managed and used, which is not always at a sustainable rate (FAO, 2010). Rural energy is needed for mainly domestic activities (cooking and heating), agriculture, processing, small-scale industrial activities, transportation and social services. Table 2.2 shows the uses of some of these rural energy needs.

Rural energy provision is characterized by the rate of electrification and use of traditional fuels for cooking (UN, 2011). Though efforts have been put in providing modern energy to rural communities, there are still about 2 billion people who still rely on traditional biomass for cooking and another 1.7 billion people lack access to electrification (UN, 2011). It is feared that the large number of rural people might still lack modern energy in the short and long term perspectives. The reasons for this may include;

- High cost of grid extension due to long distances and scattered nature of most rural communities
- Low income levels in rural areas to afford modern energy sources
- Non-accessibility of most rural communities and high transport cost (KITE, 2008).

Table 2.2: Uses of Energy in Rural communities

ENERGY NEED	USES
Agriculture	Land preparation, planting, water pumping, harvesting, fertilizer production
Social needs	Medical treatment, lighting, education, entertainment
Transportation	Marketing, health services
Home	Cooking, ironing, lighting
Processing	Drying, grinding, cooking
Conservation	Cooling, drying

Source: Adopted from Bhagavan and Karekezi, 1992

2.5 Energy Demand

From the earlier discussions on energy as the ability to work, demand for energy in this context will be a derived demand since it is not demanded for itself but the services it can provide (DFID, 2002). There is a major difference between energy needs and demands. Energy needs are essential requirements relative to a given socio-economic conditions which can change with time. The demand on the other is basically an economic concept explaining what a person is willing and able to pay for (Bhagavan and Karekezi, 1992; Eyre et al., 2009). Demand for energy provides the main driving force in the whole energy system, influencing not only the total amount of energy consumed, but also the characteristics of both the fuel and the end use technology (Eyre et al., 2009).

To understand energy demand, it is important to know that it is an interdisciplinary approach which involves understanding the lifestyle and social drivers of the demand for energy services; the changing technologies at the point of energy use; the institutional and policy frameworks for decision making and the interactions between all of these (Eyre et al., 2009). Energy systems face increasing pressures from many directions, most notably for a rapid transition to a secure, low carbon energy system. Also, population and economic growth will drive demand higher (ExxonMobil, 2011). As economic output more than doubles and prosperity expands across a world whose population will grow from 7 billion to nearly 9 billion people in the next decade, ExxonMobil's projection indicates that, global energy demand will be about 30 percent higher in 2040 compared to 2010. Demand for energy can be seen here as ever increasing due to population increase and economic growth.

In a rural context, energy demand is mainly characterized by relatively few energy forms due to the poverty of rural areas (UN, 2011) and households consume the greatest amount primarily in the form of wood fuel for cooking (Bhagavan and Karekezi, 1992; KITE, 2008). Most of the energy consumed in these areas is non-commercial, obtained from rural dweller's production or forest and are rarely accounted for in national resources or energy balance sheet since it almost impossible to trace and add monetary value to it (Bhagavan and Karekezi, 1992; UN, 2011). This challenge has affected most developing countries in planning for energy needs and demand.

Factors Affecting Energy Demand

- The demand for energy in rural communities is affected by a number of factors which differ from one geographic area to the other. One major factor is the level of development. Agreeing to Ghalam (2008) cited in Wilbanks et al. 2008, that increase in income and in this case development, propels demand for energy, it is an appropriate conclusion to infer that the level of development affects demand for energy. Example, as living standards rise and agricultural productivity increase, the need for fertilizers and farm machinery becomes apparent.
- In addition, the price of energy is another factor affecting demand for energy. There is a positive relationship between energy demand and price of energy especially in rural areas; as prices increase the demand for energy are likely to decrease (Bhagavan and Karekezi, 1992).
- The climate of localities is another factor affecting energy demand. Where there is tremendous cold demand for energy for heating will be high as compared to the otherwise.
- In most rural communities, traditions are highly regarded and respected. In most areas there are taboos and fears associated with certain energy forms and hence their demand is affected by these taboos. Example, in a place where people see the sun to be a god, it is very possible that there will be resistance in introducing solar energy to the place.

2.6 Energy Supply

Energy planning in most countries assumes a supply-end approach mainly based on the theory that if energy resource were available demand will follow. Even in most sustainable energy concepts and approaches, a supply oriented approach is used. It is also very important to distinguish between energy resource and supply. Energy resource is simply the untapped and usable potential and energy supply is simply the resource that has been made available for consumption by consumers (Bhagavan and Karekezi, 1992; Sims et al., 2007).

Energy supply can be classified into commercial, traditional and renewable energy. Commercial energy supply sources involve oil, gas, coal, hydro-electric power; traditional sources involve fuelwood, charcoal, agro-waste, animal power and the renewables sources involve solar, wind, ocean and wave power, small-scale hydro among others (Bhagavan and Karekezi, 1992). Commercial energy supply is not very common in rural communities due to most notably cost and income levels in these areas (UN, 2011).

Traditional energy supply sources are the dominant energy source for rural areas and will continue to be so for the foreseeable future (Bhagavan and Karekezi, 1992; KITE, 2008; UN, 2011). It is the most readily available and abundant resource and as such most assessment of rural energy supply has often been focused on estimating biomass availability (KITE, 2008). One major feature of biomass is its dependence on land and its high labour intensity in extraction and conversion (Energy and Development, 2005). Land thus becomes an important factor in dealing with biomass studies. Natural forests are the only true natural biomass and are threatened by rural energy demand and other uses of wood and land. This has resulted in relatively fewer biomass sources in the Sahelian countries of Africa due to low rainfall and the result limited vegetation (Energy and Development, 2005). Crop and animal residue are used more in these countries as compared to more humid areas where vegetation and wood fuel are in abundance.

The renewable energy supply sources are more heterogeneous and depend on spatial concentration of such energy supply. Solar energy supply is quite abundant in the Sub-Sahara region as compared to an icier region of Eastern European region. However, factors such as latitude, atmospheric conditions and the time of the year influence the supply of solar for consumption (KITE, 2008). In terms of atmospheric and the time of the year, in the Sahelian countries, solar energy supply is high throughout the year but diminishes during the harmattan period due to dust storms and coastal areas also have reduced supply during the rainy season as a result concentrated cloud cover. Wind energy supply on the other hand is very site-specific (Energy and Development, 2005). This energy source is however not supplied regularly in most African countries due to wind speed of less than 5 meters per second (Bhagavan and Karekezi, 1992; Energy and Development, 2005).

Factors Affecting Energy Supply

- Urban growth affects the supply of energy in rural areas. As communities expand, energy supplies are outstretched. The migration to urban settings affects rural energy supply in the sense that urban areas direct the flow of energy in their communities since they have a more desirable marketing effort. Rural people are thus forced to switch to alternative energy sources and in this case traditional energy sources.
- Increase in demand automatically affects energy supply since a relative increase in demand will trigger a relative equal impetus for supply.
- Technological change also poses a great factor in affecting energy supply. High and advanced technology provides grounds for unknown energy sources to be supplied for consumption.
- Land tenure is another factor affecting energy supply. As discussed above, land is an important feature of energy supply. Land use play important role in rural energy supply. Putting land into, example, energy crops over food crops or vice versa is a way land tenure affects energy supply.

2.7 Energy Sources and Uses in Ghana

Energy usage in Ghana is not different from many developing countries. It is estimated that energy consumption in Ghana is 6.6 million tonnes of oil equivalent (Amissah-Arthur and Amonoo, 2004). The leading energy providers in Ghana include the Volta River Authority (VRA), Tema Oil Refinery (TOR), Bulk Oil Storage and Transportation Company Ltd. (BOST), Electricity Company of Ghana (ECG), Ghana Grid Company and Independent Power Producers

(IPPs). They have been tasked by the Energy Commission to effectively and efficiently create an enabling environment for excellence and fair competition in energy service delivery.

The majority of Ghana's energy use is from biomass in the form of firewood and charcoal. These two account for about 59 percent of the total energy consumption with petroleum products and electricity constituting 32 and 9 percent respectively (Energy Commission, 2011); an estimated total of 20 million tonnes of wood fuel and charcoal is consumed annually. The majority of Ghana's energy is consumed by households rather than in industry. There is no home heating requirement and energy use in the home is primarily for cooking and lighting (Amissah-Arthur and Amonoo, 2004).

Energy for cooking in Ghana is very important. In rural Ghana, it is estimated that about 84 percent of households use fuel wood for cooking and a further 13 percent depend on charcoal while the remaining 3 percent includes all other sources, such as electricity, kerosene and LPG (KITE, 2008). In the urban areas, the situation is a little different from the above premise. Charcoal contributes about 61 percent of energy for cooking and fuel wood accounts for 25 percent. LPG and other sources such as electricity, kerosene and crop residue accounts for 10 and 4 percent respectively (Amissah-Arthur and Amonoo, 2004). Compared to rural energy consumption for cooking, the urban areas are heavy consumers of charcoal which is mostly produced under primitive and unsustainable methods.

Energy for lighting is another important area that households consume a lot according to the Ghana Living Standards Survey 4. Both urban and rural areas use electricity and kerosene as their main source of energy for lighting (Amissah-Arthur and Amonoo, 2004). About 60 percent of all households use kerosene for lighting, while 39 percent of household use grid-connected electricity for lighting and only 1 percent of households use candles, generators and/or other sources. In the rural areas this premise is quite different. While about 82 percent of households use kerosene, candles and other traditional fuels as sources of light only 17.1 percent of rural households obtain their lighting from grid-connected electricity. Self-generators, dry-cell and automotive batteries together make up the remaining 0.9 percent.

Apart from the traditional biomass, electricity is the most used source of energy in Ghana. The main sources of electricity generation are hydropower and thermal which is powered by diesel.

The Energy Commission (2011) indicates that a share of 68.28 percent of total electricity was generated through hydropower, 30.73 percent through thermal power and 0.98 percent imported. However, over the periods between 2000 and 2010, the share of electricity generation by hydropower has decreased by 23 percent and the share of electricity generation by thermal power has also increased by 23 percent (Energy Commission, 2010). This indicates that the consumption of diesel or oil for thermal electricity has increased and any surge in the oil market will affect Ghana's electricity generation dramatically.

Apart from electricity generation, Ghana's energy source also covers petroleum (oil and natural gas). However, since this study is limited to electricity and traditional fuel, petroleum will not be reviewed in this chapter. It should be made clear here that traditional biomass were not discussed in depth as compared to electricity because there is inadequate information to make any serious and reliable forecasts and discussions (Energy Commission, 2010). This shortcoming could be minimized through this study if data is properly collected on the traditional fuels. See also Inkoom and Biney, 2010.

2.8 Energy and the MDGs and GSGDA; Linkages

Because of the concentration of poverty in rural areas, and the disproportionate effect it has on the venerable, improving the situation of rural people through better energy services will promote MDG 1 (reducing poverty and hunger). It is also relevant to MDG 2, (achieving universal primary education) because energy provides light for children to be able to learn even at night and also access ICT education. In a broader view, it helps in providing opportunities for girls to attain primary education since girls are often kept home from school to help their overburdened mothers with fuel collection and food processing. With respect to MDGs 4 and 5, which call for improvements in children's health and maternal mortality rates, cleaner and improved fuels would reduce the hazards associated with smoky indoor fires and carrying heavy loads of wood. Also in MDG 7 (ensuring sustainability) SE will play a key role in promoting SD.

Under Ghana's medium term development agenda (2010-2013), the Ghana Shared Growth and Development Agenda (GSGDA), the GoG seeks to, among several others, accelerate the achievement of the MDGs. The policy is anchored on, among others, oil and gas development and infrastructure, energy and human settlements development. The policy targets in energy supply to support industries and households and also increase in access to petroleum products.

2.9 Sustainable Energy

In Sub-Saharan Africa, sustaining energy has become key as a result of rising concerns of population growth, accelerated urbanization, economic development and relative price changes of other energy options (AFREA, 2011). These developments have offset important achievements made in the last decade in energy access, rural electrification, and the promotion of alternative energy sources (Thiam, 2009). A sustainable energy system is needed to speed the economic and social development process and in the long-run achieve sustainable development.

Sustainable energy (SE) just like SD, mean different things and depends on a lot of scenarios to be able to understand the concept (Ogunlade, 2001; Thiam, 2009). The drive towards SE have stemmed from a number of issues; ranging from shortages in energy supply to increase in GHG emissions and its resultant climate change impacts. All these rationale behind SE are very important impetus for SE. Some literature base their definition of the SE concept on these rationales, i.e. based on the school of thought one is associated with, the explanation of SE is also aligned. In recent times, the search of less carbon-intensive fuels has led some people to perceive SE as alternative renewable energy sources mainly solar, wind and mini-hydropower (Ogunlade, 2001). This way of viewing SE only defines the concept as using renewable energy sources and is highly advocated by most NGOs (Ogunlade, 2001). It is however not adequate enough to identify the indicators to use in measuring its sustainability and also fails to properly identify that not all societies have fully developed their renewable energy sources. Another way of understanding the concept is equating SE to energy-efficiency (Ogunlade, 2001). Here too, it is postulated that improving efficient use of energy can contribute to finding SE. Efficiency used in this view means avoiding energy wastage; of the total annual world energy of 400 EJ, 250 EJ is lost in the conversion to final energy (UNDP, 2000).

Others however combine efficient energy and renewable energy sources as SE and among them include Renewable Energy and Efficiency Partnership (REEEP) and the Jamaica Sustainable Development Network. Tester et al. (2009) also postulates that SE is achieved through finding new renewable energy sources and maintaining an efficient energy system where there is no or at least little waste through conversion. All these groups of perceptions have gain much currency over the past decade due to its popular use and application in most SE projects.

Again, SE can be defined depending on whether a country produces or imports oil (Thiam, 2009). However this classification is immensely useful in regions where oil is a major source of energy. It is postulated that in oil producing countries, SE or the use of energy security (in this case both are the same) as used in its original definition, means being able to maintain a position as an energy supplier for the long term, working with stable and low-risk clients and guaranteeing elevated petroleum prices. For those importing oil, SE means being economic and financially stable enough to continually be able to finance importation in the long-run (Thiam, 2009).

From the above premise and knowing the frequent oil crisis and the instability in the Middle East have shown that oil is not the most reliable energy source and that all countries should become less vulnerable to oil price fluctuations and diversify their energy sources or at least sources of supply. This has led to a bipolar perspective of SE that is secured supply and improved demand management (Bangaly et al., 1999). In this view also, increasing a secured supply is based on alternative energy sources and diversifying energy sources. That is avoiding dependence on one source of non-renewable energy (oil) but expanding the source base to cover other non-renewables and renewable sources. This will be preceded by awareness-raising actions to promote large scale use.

Though a secured supply side is very important, it is not enough to set up a SE framework; the demand management side will need to be included. It is estimated that in Sub-Sahara Africa dependence on biomass range between 70 and 80 percent and this trend will continue for the next 20 years (Thiam, 2009). This calls for action especially on the demand management side of biomass to develop best practices and consistent policies to maintain the biomass chain in a both environmentally sustainable and economically viable manner.

The International Energy Agency (IEA) and the Organization for Economic Co-operation and Development (OECD) also argues that energy security can be defined in terms of the physical availability of supplies to satisfy demand at a given price (OECD, 2001). This is rather an accrued way of defining SE since it only stands for physical availability and price. They linked the three pillars of SD with SE in ways that finds out how energy can create an economic, environmental and social sustainable development. Borrowing from the SD indicators, the OECD also used indicators in measuring their defined SE.

Table 2.3: Indicators in Energy Sector for Sustainable Development

Economic Indicators
Average subsidy per effective unit energy Average of the unit subsidy for each energy source weighted by its share in energy consumption
Consumption Per capita consumption of final energy
Energy Supply Indicators
Reliability Percentage of time that a particular energy source is available for use (with back up where available)
Import Dependency Oil import dependency from particular countries or regions
Energy Diversification The sum of the squares of the shares of different energy sources in effective energy consumption
Environmental Indicators
Greenhouse gases Per capita emissions of greenhouse gases expressed in CO_2 equivalent
Local emissions Deposits of SO_2 per square kilometer
Social Indicators
Affordability Ratio of a household's per capita effective energy consumption to a subsistence threshold
Education Hours of lighting available to schoolchildren
Health Proportion of population affected by energy-related health problems such as respiratory illness

Source: OECD, 2001

It is important to note that the context from which the parameter receives its meaning will change over time while the same parameter continues to be measured. Using indicators to measure SE is used extensively by the IEA and OECD in this context.

Like the criticisms surrounding SD, SE is also faced with several cases and all pointing to the fact that there is no universally agreed point where all definitions are met. However they all play important roles in the SE dialogue and contribute immensely to the body of knowledge in SE.

Notwithstanding these criticisms, there is a widely used approach which was adopted by the United Nations Development Programme. It describes SE in a more holistic manner and process as compared to the others who move more towards a crude and one side approach based on energy source. It sorts to define SE to cover factors such as the resource endowment, existing energy infrastructure and the development needs of the area in context (Ogunlade, 2001). Within this context, the UNDP (2000) defined SE as energy that will provide affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of the society while recognizing equitable distribution in meeting those needs. This definition has gained much attention and is used by most energy planners to identify indicators for planning.

For this reason, the study defines SE as energy that is <u>affordable</u>, <u>accessible</u>, <u>reliable</u> and <u>equitable</u> for current use without compromising future demand. Hence the variables to be used in this research will be affordability, accessibility, reliability and equitability; shortened as 'AARE'. The indicators used by the OECD explain what the indicators mean and how to apply them in measuring SE. This definition includes aspects of spatial and time considerations due to introducing equity to the original definition by the UNDP (2000).

2.9.1 Sustainable energy in Ghana: the SE4ALL framework

As part of UN action for Sustainable Energy for All (SE4ALL), Ghana has also embarked on an action plan to see to the fulfillment of SE4ALL goals and objectives. The objectives include ensuring universal access to modern energy services; doubling the rate of improvements in energy efficiency and doubling the share of renewable energy in the global energy mix (Energy Commission, 2012).

These objectives are global in nature and is expected to be localized in line with a country's plan of action. Within the Ghanaian context, an action plan has been drafted with focus on increase access to modern energy for cooking and productive uses of energy (PUE). Though progress has been made among the three broad goals of SE4ALL in Ghana, attention is specifically geared towards modern energy for cooking and PUE. Within this framework, SE in Ghana is defined; thus, SE for Ghana looks at moving towards more modern energy sources which are renewable in nature and reduces CO_2 emissions and also its consequences on the environment and climate change.

2.10 The Climate Change Phenomenon

In the past environmental changes have been attributed to natural causes. However, the term climate change is now generally used when referring to changes which have been identified since the early 1900s. These changes are thought to be mainly as a result of additional human behaviour rather than due to mainly natural changes in the atmosphere (Grubb, 2004). The greenhouse effect refers to the gases which keep the Earth warm; however, its excess release into the atmosphere through human industrial activities and modern lifestyles has contributed to global warming and climate change. Climate change is expected to have noticeable effects in all places the world over. A rise in average temperatures in most regions, changes in precipitation amounts and seasonal patterns in many regions, changes in the intensity and pattern of extreme weather events, and sea level rise are but a few experiences of Climate Change (IPCC, 2001 cited in Wilbanks et al., 2008). Some of these effects have clear implications for energy production and use.

Evidence of climate change has been immensely documented over the past decade. The following paragraphs will discuss a little on this. The Intergovernmental Panel on Climate Change (IPCC) projected in 2001 that climate could warm relative to 1990 by 0.4°C to 1.2°C by the year 2030 and by 1.4°C to 5.8°C by the end of the 21st century (Cubasch et al., 2001 and Ruosteenoja et al., 2003 cited in Wilbanks et al., 2008). The 1990's were the warmest decade of the last millennium with 1998 being the warmest year globally since records began in 1861. In addition, the total number of cold days has fallen from between 15 and 20 per year prior to the 20^{th} century, to around 10 per year in recent years. Average global sea levels have increased by between 0.1 and 0.2 meters over the last 100 years as a result of Arctic sea ice thinning (Grubb, 2004). High precipitation has increased from 0.5 to 1 percent per decade in many mid and high level areas of the northern hemisphere (Wilbanks et al., 2008). In Asia and Africa there has been an increased frequency and intensity of droughts in the last few decades.

The African continent is particularly vulnerable to the impacts of climate change because of factors such as widespread poverty, recurrent droughts, inequitable land distribution, and overdependence on rain fed agriculture (IPCC, 2001). However ironically, the impacts of climate change are expected to be severe, yet Africa’s contribution to climate change through emissions is minimal.

These notwithstanding, climate change also offer some opportunities. The processes of adapting to global climate change, including technology transfer and carbon sequestration, offer new development pathways that could take advantage of Africa’s resources and human potential. Regional cooperation in science, resource management, and development already are increasing, and access to international markets will diversify economies and increase food security (IPCC, 2009).

2.10.1 Impacts of Climate Change in Ghana

The impacts have been more evident in forest reserves, agriculture, water bodies, rainfall and temperature, migration and energy (IPCC, 2009 and Inkoom, 2011). The forest cover has depleted by 50 percent between 1970 and 1990 and further away from 1990 to 2009, it decreased by 86 percent [from 8.6 million hectares to 1.2 million hectares] (Inkoom, 2011). This phenomenon has been as a result of deforestation and the lack of rainfall to help forest reconstruct itself naturally from tree cutting (IPCC, 2009). What is more threatening is the rate at which the Sahel desert is advancing into the country; it is feared that as high as 20,000 hectares of land mass is affected by the desert per annum (Inkoom, 2011).

The increase in sea level which was recorded at 0.06m in 2010 (Inkoom, 2011) has caused frequent flooding and introducing more waterborne diseases into the country. Big cities are mostly vulnerable to flooding in Ghana due to poor waste management systems and uncontrolled development; Kumasi and Accra are recent cases of flooding. Increase in cholera cases in the year 2011 has been attributed to massive flooding and contamination of water sources as well as food sources.

In addition, the recorded droughts in 1983, 1994 and most recent 2001 caused the Akosombo and Kpong dams to generate low volumes of electricity demanded and Ghana was forced to share the little power supply (IPCC, 2009).

2.11 Climate Change Adaptation

The foregoing assessment highlights the high vulnerability of Africa and for that matter Ghana to climate change as a result of limited adaptive capacity constrained by numerous factors at the national level. Adaptation is recognized as a crucial response because even if current agreements to limit emissions are implemented, they will not stabilize atmospheric concentrations of GHG emissions and climate (Wigley, 1998 cited in IPCC, 2000). It is for this reason that adaptation is considered here more than mitigation – which is the crude reduction of GHG - as a key component of an integrated and balanced response to climate variability and change. Figure 2.3 shows how adaptation is featured in the climate change issue.

Adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (IPCC, 2000). It is thus relevant to the changes in the process, practices, structures or cultures to compensate potential damages or to take advantage of opportunities as a result of the changes in climate. In climate change adaptation will come about in two ways - the assessment of impacts and vulnerabilities and the assessment of response options (IPCC, 2000). In assessing the response options it is important to know what adaptive capacity is; it is the potential or ability of a system, region, or community to adapt to the impacts of climate change (Smit et al. 2000).

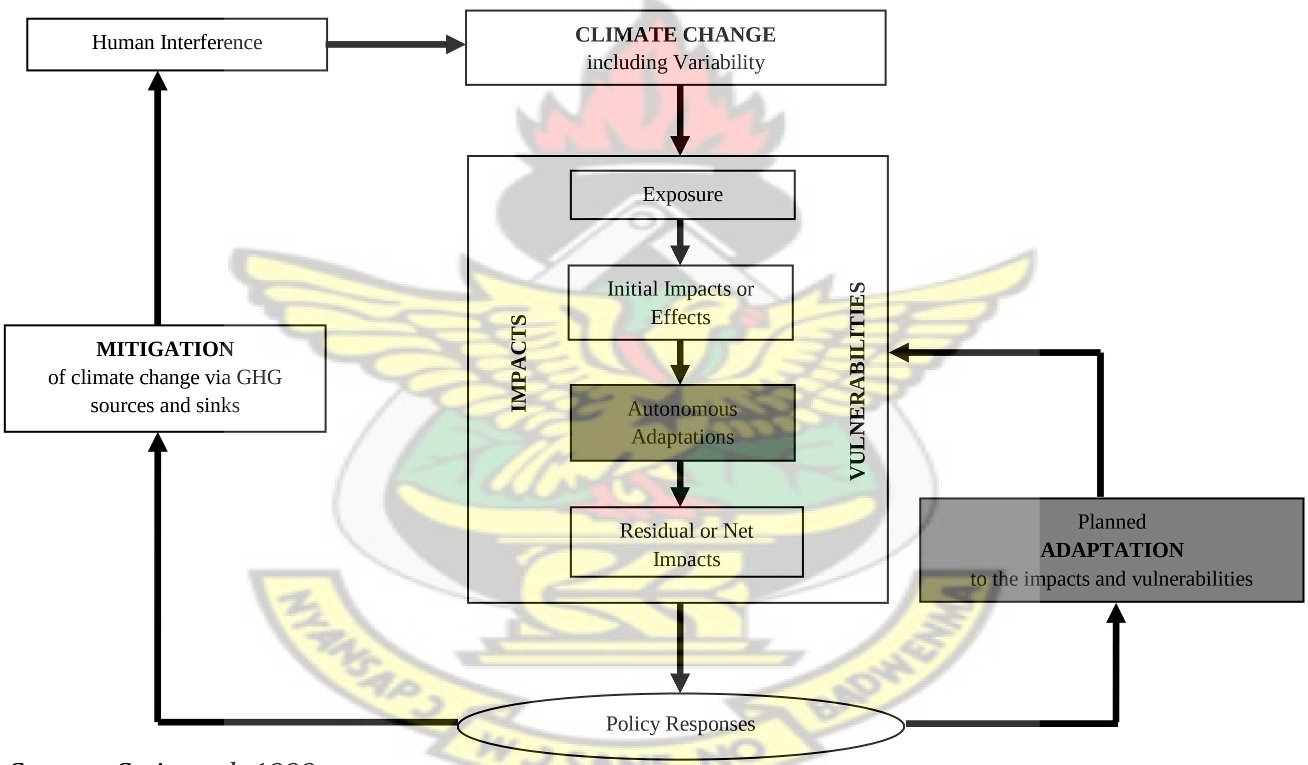
Adaptation in climate change can take two forms, either autonomous or planned (Smit et al. 2000). Autonomous adaptation occurs rather spontaneously without any well thought responses and it is important to consider and assess the level of autonomous adaptation possible to properly estimate the cost of impacts. Planned adaptation on the other is mainly policy driven and directed by a governing body.

Planned adaption is not as simple as perceived. It involves a number of options that need practical implementation since it is directive in nature. Some research has however been able to outline criteria to identify proper adaptation policies. Smith et al. (1996) and de Loë and Kreutzwiser (2000) cited in IPCC (2000) provided the following measures;

- The measure generates benefits to the economy, environment, or society under current conditions;

- The measure addresses high-priority adaptation issues such as irreversible impacts of climate change (example species extinction), long-term planning for adaptation and unfavorable trends like deforestation;
- The measure targets current areas of opportunity;
- The measure is feasible; that is, its adoption is not significantly constrained by institutional, social-cultural, financial, or technological barriers; and
- The measure is consistent with, or even complementary to, adaptation or mitigation efforts in other sectors.

Figure 2.3: Places of adaptation in the climate change issue



Source: Smit et al. 1999

Adaptation to climate change and risks takes place in a dynamic social, economic, technological, biophysical, and political context that varies over time, location, and sector. Being able to design policies for adaptation it is also as much important to understand the adaptive capacity of the system under consideration. This complex mix of conditions determines the capacity of systems to adapt. Literature has made it possible to identify the main features of communities or regions that seem to determine their adaptive capacity as economic wealth, technology, information and skills, infrastructure, institutions, and equity (Smit, 2001).

- *Economic Resources*: It is widely accepted that wealthy nations are better prepared to properly adapt to climate change impacts and risks than poorer nations (Goklany, 1995; Burton, 1996 cited in IPCC, 2000). Although poverty is not completely synonymous with vulnerability, it is "a rough indicator of the ability to cope" (Dow, 1992 cited in IPCC, 2000). A clear example is Hong Kong's financial strength which has contributed in the past to its ability to better manage environmental hazards through conservation and pollution control.
- *Technology*: Lack of technology has the potential to seriously impede a nation's ability to implement adaptation options by limiting the range of possible responses. Hence, a community's current level of technology and its ability to develop technologies are important determinants of adaptive capacity.
- *Infrastructure*: Adaptive capacity is likely to vary with social infrastructure. The availability of infrastructure has the ability to boost a system's capacity to cope and take advantage of climate change impacts (IPCC, 2000).
- *Institutions*: Institutions have been regarded as the system that holds society together (O'Riordan and Jordan, 1999 cited in IPCC, 2000). From this premise if institutions are weak it goes without saying and implying that, chaos and lack of coordination will result and these will affect the capacity to adapt. Again, there will poor adaptive policies to direct the flow of adaptation in planned adaptation.
- *Equity*: The allocation of power and access to resources within a community or nation shows that access to resources is not equitably distributed. But the extent to which nations or communities are allowed to draw on resources greatly influences their adaptive capacity and their ability to cope. Economic resources, technology endowment and infrastructure are inequitably distributed and hence places affected with little access to these are most vulnerable and not able to adapt.

These determinants of adaptive capacity are not independent of each other, nor are they mutually exclusive. Adaptive capacity is the outcome of a combination of determinants and varies widely between countries and groups, as well as over time.

The adaptive capacity of a system or nation is likely to be greater when the following requirements are met (adopted from IPCC, 2000):

- A stable and prosperous economy. Despite biophysical vulnerability to the impacts of climate change, wealthy nations are better prepared to bear the costs of adaptation compared to developing countries.
- Existing systems with high adaptive capacity are not compromised. For example, in the case of traditional or indigenous societies, pursuit of western-style development trajectories may reduce adaptive capacity by introducing greater technology dependence and higher density settlement and by devaluing traditional ecological knowledge and cultural values.
- High degree of access to technology at various levels and in all sectors.
- Systems in place for the dissemination of climate change and adaptation information, nationally and regionally, and forums for the discussion and innovation of adaptation strategies at various levels.
- Social institutions and arrangements governing the allocation of power and access to resources within a nation, region, or community assure that access to resources is equitably distributed because the presence of power differentials can contribute to reduced adaptive capacity.

2.12 Sustainable Energy and Climate Change Adaptation: Conceptual Framework

It is noted that climate change would impact energy supply and demand now and in the future (IPCC, 2000). Where reduced stream flows occur, they are expected to negatively impact hydropower production and greater stream flows, if they are timed correctly, might help hydroelectric production; this is also likely to affect wood-based biomass as they are mostly obtained from the natural forests which has become very vulnerable to climate change impacts (droughts, reduced rainfall patterns, rising temperatures, increased hours of sunshine and evaporation rates). Although it is not yet possible to provide reliable forecasts of shifts in flow regimes, what is known suggests more intense rainfall events and greater probability of drought (IPCC, 2000) will be felt now and in the near future.

Other energy sources are affected by the impacts of climate change. For example some advanced energy types are at risk; precisely the United States and Japan are trying to learn how to exploit the potential of methane hydrates. If global warming leads to warmer oceans or warms areas that currently are permafrost regions, these compounds are likely to become less stable, making it more problematic to attempt to recover methane from them (Kripowicz, 1998 cited in IPCC, 2000). Again, increased cloudiness can reduce solar energy production which has gained much currency in rural communities in Sub-Sahara Africa. Wind energy production would be reduced if wind speeds increase above or fall below the acceptable operating range of the technology. Climate change could worsen current trends in depletion of biomass energy stocks in Africa, which is expected to become drier. The impact on biomass elsewhere is less clear; it may include enhancement of growth because of higher rainfall. Also if a warmer climate is characterized by more extreme weather events such as windstorms, ice storms, floods, tornadoes, and hail, the transmission systems of electric utilities may experience a higher rate of failure, with attendant costs (IPCC, 2000).

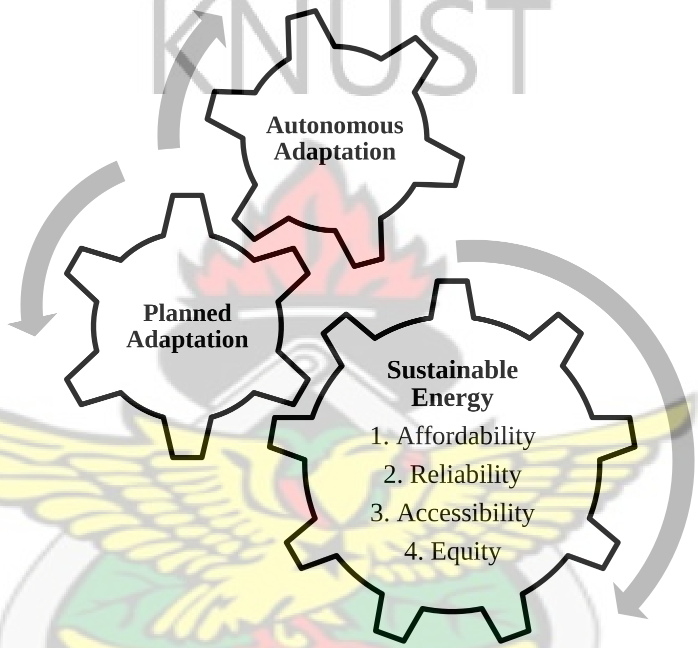
There is enough evidence to show that energy is affected by the impact of climate change now and in the unforeseen future. The above discussion though not conclusive, has provided adequate information to accept this premise – climate change affects energy.

Given the threatening effects of climate change on energy and also the drive for development trough energy supply, energy becomes a vital component for immediate attention and consideration. Aside the already existing stresses from population increase, economic turmoil and poverty, energy are now faced with a new and a more destructive stress in the form of climate change. The move toward sustainable development has warranted sustaining energy – which has been considered as the engine of growth.

From the previous sections, it is understood that sustainable energy (SE) is a very complex concept and difficult to attain or measure. Not only is it important to sustain energy but it should be achieved with adaptation to climate change since climate change is an important determinant of energy supply and demand. Both supply and demand is crucial in this definition; where the supply side looks at accessibility and equitability, the demand side covers reliability and affordability. Therefore, SE in this context looks at how affordable and equitable supply is and how demand can be satisfied with reliability and affordability with both the immediate and anticipated future impacts of climate change is coped with in adaptation (adaptive capacity).

It is important that in pursuing SE, adapting to climate change impacts in addition, becomes paramount. The manner in which this study assesses the various indicators for SE mentioned above as well as how to include adaptation in it are described in figure 2.4.

Figure 2.4: Sustainable Energy and Climate change Adaptation in consonance



Source: Author's Construct, 2011

It is clear how both SE and adaptation of climate change need to be engineered together. This forms the conceptual framework within which the study is anchored. The indicators as used in the framework are discussed in the following headings.

2.12.1 Affordability

This has been explained as the ratio of a household's per capita effective energy consumption to a subsistence threshold. To be able to scientifically measure the affordability in quantifiable terms, the Consumer Energy Burden (CEB) model as used by Power (2008) is adopted and applied. CEB measures the annual percentage of income, a household spends on energy utilities and all other residential fuels (Power, 2008). This percentage explains the burden on household well being with reference to how much income is required to pay for residential energy utility.

The model postulates that, the lower the income, the higher the burden for the same energy bill. That is, though a lower income earner's CEB could be lower than a high income earner's CEB, the burden on the lower income earner is heavier since though they will pay less in terms of percent, that percentage will require an even higher share of their very low incomes (Power, 2008).

2.12.2 Reliability

How reliable is demand and supply of energy? a question which requires thorough analysis and judgments. Up till now, the study has been able to identify and illustrate vulnerabilities inherent in energy supply as well as the costly impacts of disruptions by climate change. These vulnerabilities emphasize the need for a reliable energy system. In looking at reliability, it is very clear that, a number of elements affect its measurements; while some can be quantitative in nature, others are assessed qualitatively (McCarthy et. al., 2008). For a better analysis of this concept, all the elements need to be adequately balanced. The definition used here is adequacy and security; while adequacy looks to the ability of the energy system to supply customer requirements under normal operating conditions, security includes the dynamic response of the system to unexpected interruptions, and relates its ability to endure them. Together, adequacy and security describe the overall reliability and can be broadly described as the ability to supply (McCarthy et. al., 2008).

The framework for reliability is borrowed from the electricity sector, where Billiton and Allan (1984; 1996) cited in McCarthy et. al., (2008) described a formal framework often used to assess reliability. Reliability assessments here are probabilistic in nature and they attempt to quantify an energy system's inadequacy in relation to its likelihood, frequency, duration and severity (Billinton and Li, 1994). This is dependent on historical data and focus on quantifiable measures.

The model which is adopted is a multi-attribute utility theory (MAUT) model and used to calculate the composite scores of objectives based upon evaluation of lower-level attributes by an expert panel (McCarthy et. al., 2008). The MAUT model is used because it is able to capture the importance of large number of attributes form the perceptions of an expert panel - a feat most models, example pairwise ranking, fail to achieve. By incorporating expert opinion and MAUT into the framework used in the electricity sector, as used by Billinton and Li (1994), this concept is extended to include qualitative considerations and applies to other energy sectors and to new energy systems that lack historical performance data.

The selected indices and indicators under reliability are discussed below under adequacy and security;

Adequacy Concept and Metrics

1. Capacity: The ability of the system to provide sufficient throughput to supply final demand.

- *Utilization:* The degree to which the system is being utilized.
- *Intermittency:* The degree to which the system lacks constant levels of productivity.

2. Flexibility: The degree to which the system can adapt to changing conditions.

- *Response to demand fluctuations:* The extent to which the system is able to adapt to changes in quantity of energy demanded or location of demand.
- *Ability to expand facilities:* The degree to which the system can be easily and cost-effectively expanded.

Security Concepts and Metrics

1. Infrastructure vulnerability: The degree to which the system is susceptible to disruption.

- *Physical security:* The degree to which physical assets/natural wood land forests in the system are secure against threats.
- *Interdependencies:* The degree to which the system relies on other infrastructure for its reliable operation, and is vulnerable to their disruption.
- *Sector coordination:* The degree to which coordination between

stakeholders within the sector results in an effective exchange of information alerting stakeholders of emerging threats and mitigation strategies.

- *History:* The degree to which the system has been prone to disruption in the past.

2. Consequences of infrastructure disruption*:* The degree to which a disruption in the system could cause harm.

- *Economic impacts:* The degree to which a disruption in the system might feasibly cause economic damage to industry stakeholders, agriculture, the government, or the public/inhabitants.
- *Environmental impacts:* The degree to which a disruption in the system might feasibly cause environmental damage.
- *Human health impacts:* The degree to which a disruption in the system might feasibly harm the health of producers and/or the public.

3. Energy security: The degree to which the primary energy system is secure against threats to global supply infrastructure.

- *Import levels:* The degree to which *primary energy supply* relies on resources originating outside of the country.
- *World excess production capacity:* The degree to which excess production capacity exists in the global market and provides flexibility against demand fluctuations and supply outages.
- *Price volatility:* The degree of fluctuation in the average price of primary energy.

2.12.3 Equity

Finding measures and indices for equity has been a very difficult statistical activity. However, with sound and objective qualitative perceptions and observations, equity could be successfully analyzed. In line with this, the study seeks to define equity as the availability of energy source society/household is able to demand. Availability of energy society is able to pay for. It based on qualitative perceptions and observations that equity measurement will be achieved.

2.12.4 Accessibility

Surface accessibility is a term often used in transport and land-use planning, and is generally understood to mean ’ease of reaching'. It is a function of the mobility of the individual, of the spatial location of the opportunities relative to the starting point of the individual, of the times at which the individual is able to participate in the activity and of the times at which the activity is available. That is, the distance covered to reach energy source. Easy physical access to energy demanded.

Here, the surface distance to be covered is taken into consideration. The accessibility mapping model used by GTZ and Nkum and Associates (2003) in their programme for rural development is applied. The maximum time, travel speed and waiting time are used extensively in determining the minimum time to cover in order to have access to a particular energy system.

2.12.5 Adaptive capacity

All human settings have been characterised by adaptability in one way or the other, since human existence. But, what is particular about climate change adaptation within the energy context is the processes which considers impacts on energy and industry, agriculture and food security, terrestrial and freshwater ecosystems, coastal zones and marine ecosystems, human health, human settlements, among others (Adger et al., 2003 cited in Below et al., 2012).

It has been realised that, forecasting and trying to find out how a system can adapt to potential threats and changes, often become very uncertain and difficult to do at all. To reduce this uncertainty, using the current status of adaptive capacity of the social system have been identified as acceptable proxies for its capacity to adapt to future climate change (Cooper et al., 2008; Fussel and Klein, 2006; Challinor et al., 2009; cited in Below et al., 2012). As a result, certain features which have been identified as benchmarks for assessing the adaptive capacity have emerged over time. Yohe and Tol’s (2002) work builds on the Third Assessment Report of the IPCC which introduced the five features that determine the adaptive capacity of communities or regions: economic wealth, technology, information and skills, infrastructure, and institutions and equity (Smit et al., 2001); discussed earlier in section 2.10 above.

Yohe and Tol (2002) further extend this concept into the following eight major determinants of adaptive capacity: (1) the range of available technological options for adaptation; (2) the availability of resources and their distribution across the population; (3) the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed; (4) the stock of human capital, including education and personal security; (5) the stock of social capital, including the definition of property rights; (6) the system's access to risk-spreading processes; (7) the ability of decision makers to manage information, the processes by which these decision makers determine which information is credible, and the credibility of the decision-makers, themselves; and (8) the public's perceived attribution of the source of stress and the significance of exposure to its local manifestations. The eight determinants are also valid predictors of adaptation because they influence how adaptive capacity translates into adaptation (Burch and Robinson, 2007).

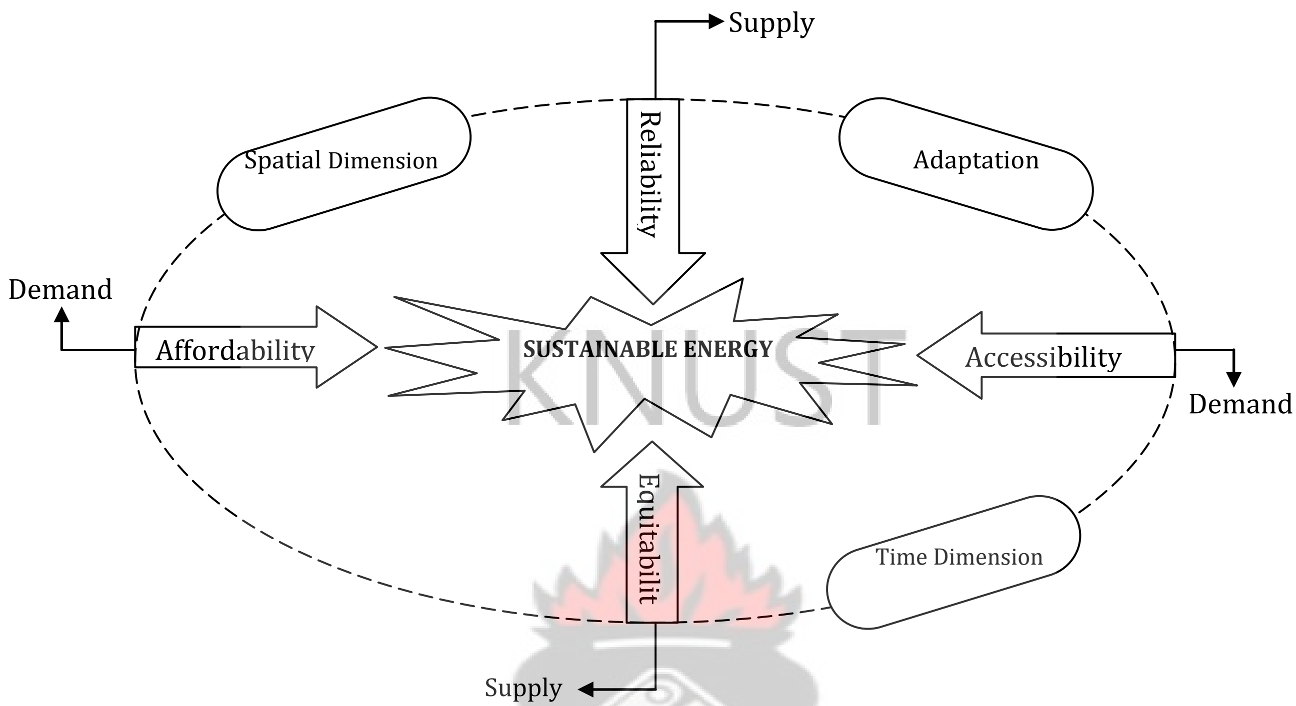
2.12.6 Space and Time

In SE, it is very important to understand that, sustainability can only be achieved if its spatial dimensions are taken into consideration. Space has a key influence over the different aspects of the energy demand, the resource availability and its use (Stoeglehner et al. 2011). Arrangement of natural resources across different ecological zones affects decisions of SE. Hence, the spatial dimension within this SE framework looks extensively at distribution of energy resources across different ecological zones and how they inter-relate.

Sustaining energy demand and supply will also take place within specific time frames, the short to long term spans. At each stage, it is very important to know how much energy can be supplied and how much is/will be demanded. This inequality equations are very relevant if the essence of sustainability for future generations, is to be achieved.

Putting all the discussed indicators into a workable framework, the reviewed literature on SE and adaptation to climate change have been conceptualized into figure 2.5.

Figure 2.5: Conceptual Framework



Source: Author's Construct, 2011

Given this framework, it is possible to define the best indicators that can be used in measuring SE in this study. Moving from framework to indicators, table 2.4 defines the indicators to use.

Table 2.4: Definition of Indicators to Measure SE

THEME	INDICATOR (S)
Affordability [A_1]	Ratio of a household's per capita effective energy consumption to a subsistence threshold
Accessibility [A_2]	Percentage of time that a particular energy source is available for use
	Less percentage of damage to the environment
Reliability [R]	Percentage of time that a particular energy source is available for use
	Percentage of damage to the environment
Equity [E]	Availability of energy source society/household is able to demand
	Availability of energy society is able to pay for
Autonomous Adaptation [A3]	Ratio of existing capacity per capita
Planned Adaptation [A3]	Willingness to adapt
	Availability of technology to direct adaptation
	Cultural willingness to adapt
Spatial Dimension [S]	Geographic location of area
	Presence of energy resources
Time Dimension [T]	Short, Medium and Long term demand and supply

Source: Author's Construct, 2011

The indicators that will guide the research could however be modified as circumstances on the ground may demand a change or modification of the definition. Notwithstanding, the objective of SE remains the same as well as the themes under which the framework was built.

2.13 Key Outcomes of the Literature Review: *Research Direction*

This review of literature has captured three important successive issues and has resulted in shaping the direction in which the study is focused. The first among the three was to understand SD. It has been understood here that a number of indicators can be used to measure SD but the most important is to properly define the goal of measurement and from there generate a conceptual framework within which themes and lastly the actual indicators could be defined. The section ended with a summary of defined indicators that have been widely applied in most cases.

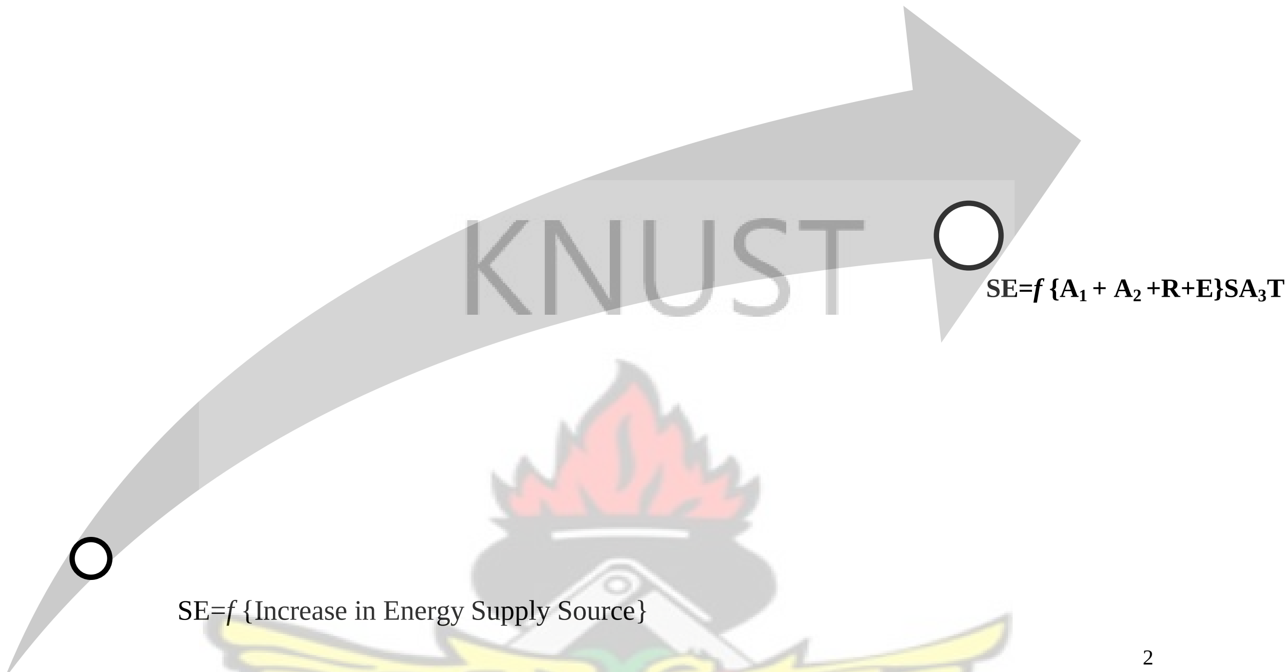
This understanding provided the platform to move to the main purpose of the study – sustainable energy and climate change adaptation. Literature on SE was reviewed separately from climate change adaptation. In viewing SE, it has been established that most literature and scholars view the concept as increasing energy sources for supply in order to achieve a sustained energy system. The idea here is emphasizing on increasing energy supply is synonymous to SE.

Under SE, one major conclusion was that, a four-tier thematic composition of affordability, availability, reliability and equity, shortened as AARE was identified as the foundation for SE – moving from the supply sided approach to demand and supply ends. Based on knowledge from SD earlier, spatial orientation of communities as well as time orientation – whether short or long term – were also included as a wheel to SE.

Again, autonomous and planned adaptations have been identified as the main areas of concern under climate change which is included in the SE framework. Notwithstanding, it is important to stress here that, though the study is limited to climate change adaptation, mitigation should also be talked as both paradigms are in consonance.

These outcomes have aided in showing this study the direction to follow from what has been done and practiced in the field of SE. Hence this study aims at helping in providing a way to move away from one-sided SE to a double view of SE; that is from supply sided approach to demand and supply approach to SE. Figure 2.6 summarizes the direction of the study mathematically.

Figure 2.6: Research Direction



Source: Author's Construct, 2011

2.14 Conclusion

Sustainable energy has become an important policy issue due to its irreplaceable part in attaining sustainable development. However, the ability to answer questions about climate change, vulnerability and adaptation on the basis of research evidence is very limited for human settlements, energy, and industry. Energy has been regarded mainly as a development issue in the 21st century, related more to causes and adaptation of climate change.

[2] $SE = f\{A_1 + A_2 + R+E\}SA_3T\}$, these variables have been defined in table 2.4

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

It is important to understand and know what data are required and how to obtain them in order to achieve the objectives of this study. After literature have been reviewed and analyzed to produce a framework within which to conduct the study, it is prudent explain the methodological process that is valid for this research. Also, a brief profile of the study area was discussed to further inform the methodology to adopt. These are the aims this chapter tries to achieve.

3.2 Understanding the Study Area

The Nzema East Municipal Assembly (NEMA) is the area the study was focus on. The issues that was discussed in this section are concerned with sustainable energy and climate change adaptation in the NEMA includes location and size, demographic issues, rural-urban issues, climate data, economic and available infrastructure.

NEMA was chosen for the study based on a number of factors. In the first place, it presents a case for rural studies as more than 90 percent of communities in the area are considered rural - when population and level of infrastructure is used (MTDP, 2010). Though other some districts in Northern Ghana also presents higher rural settings, NEMA's case is very interested as only the district capital Axim, has all the important levels of infrastructure and developments. Again, there has been an increasing trend in forests depletion according to the Municipal's forestry department. When compared to other rural districts like those in Northern and Volta parts where deforestation has already taken huge land masses, NEMA is now growing into a deforested area and hence the impetus to undertake this study help stop or minimize the spread. When climate change factors are taken into consideration, NEMA is experiencing negative trends of climate change impacts in the form of flooding and drastic changes in rainfall patterns and its nearness to the sea, has increased threats from sea level rise among others.

3.2.1 Location and Size

NEMA is located in the western region of Ghana on the southern end of the region between longitudes 20 05' and 20 35' west and latitudes 40 40' and 50 20 North. It is bordered to the west by Jomoro, north by Wassa Amenfi East, and the east by Wassa Amenfi West and Ahanta West District. On the south, it is bounded by the Gulf of Guinea with 70 kilometers stretch of sandy beaches (NEMA, 2006). It covers a land mass of 2,194 square kilometers, about 10 percent of the total western regional land mass.

Given its vastness and nearness to the sea, NEMA is sure to have effects of sea level rise with its subsequent impacts. Due to its large land mass, it is assumed that communities will be widely dispersed and so the study should take spatial coverage into consideration in its methodology. Calculating the minimum sample size will be required here after a pilot survey has been conducted as a result of the above premise.

3.2.2 Climate

The Municipal Assembly lies between the wet semi-equatorial climate zone of the West African Sub-region. Rainfall is experienced throughout the year with the highest monthly mean occurring around May and June each year. The average temperature in the District is about 29.4 ^{o}C with variation in mean monthly ranging between 4 to 5 ^{o}C throughout the year (NEMA, 2006).

Given the fact that it lies within relatively high rainfall zone, its vulnerability as a result of changes in sea level rise and rainfall pattern as a result of climate change is high and hence needs urgent interventions.

3.2.3 Demography

According to the 2000 population and housing census, the NEMA's (then the Nzema East District, including the Ellembele District) population was 142,959 (DMTP, 2006) made up of 50.1 percent males and 49.9 percent females. This figure represents both the Nzema East and Ellembele districts and as of the time of study, the 2010 PHC figures had not been realized; this was a major limitation in sampling for data collection.

These imply that, heavy demand for energy will be seen in the highly dense populated communities due to high economic activities and any surge in energy supply will have serious impacts in these areas. However with the relatively low population density across the entire municipal, forest reserves and other natural resources though currently under pressure according to the NEMA, could serve as a potential adaptive strength for unforeseen eventualities when properly utilized and managed.

3.2.4 Rural-Urban Split

NEMA is highly rural if the criterion that any settlement with population of 5,000 or more represents an urban area is used. The term rural used in this study also refers to population size and availability of infrastructure; thus it agrees with NEMA definition for their rural areas. Though only 26.6 percent urban areas were recorded during the 2000 population and housing census, it is believed the rate of urbanization is increasing rapidly (NEMA, 2006). The rural nature of the municipal presents a case for addressing rural energy in the NEMA.

Due to the seasonal fishing and farming activities in NEMA with an introduction of small-scale mining, there is a considerable increase in net-migration during such seasons. Increase in population is recorded mostly in the rural communities where these activities are profound (NEMA, 2006). Hence demand for energy will increase and any change in supply as a result of climate change impacts will be devastating.

3.2.5 Natural Resources

The vegetation of the Municipality is made up of the moist semi-deciduous rain forest mainly in the northern part and a secondary forest in the southern parts due to tree felling and farming (NEMA, 2006). The northern rainforest has three forest reserves - Shelter Forest Reserve, Draw River Forest Reserve (the largest) and Ndumfri Forest Reserve. These could be a potential source of energy amidst threats from climate change in the form of droughts and low precipitation to aid tree planting.

However due to land tenure problems and poor utilization practices, most of the forest resources from which fuel-wood are extracted are being deforested; especially the Gwira Banso Stool Land area (NEMA, 2006). Over 90 percent of the population in the NEMA depends on wood fuels and as a result an overwhelming majority of the population in all the major towns like Axim, Esiama, Aiyinase and Atuabo are under imminent threat of a fuel-wood crisis (NEMA, 2006).

3.2.6 Infrastructure Base

The municipality has a total of 154.1 kilometers of trunk roads with 63.9 kilometers tarred. A total of 253 kilometers feeder roads are also in the area especially in the southern parts where farming and fishing are predominant. However, only 59.3 percent of the feeder roads are motorable (NEMA, 2010). In assessing the adaptive capacity of the area it is important to understand the type and rate of infrastructure availability and these road figures shows especially that in the predominantly rural areas' (mostly southern parts) transportation are poor given that almost half of all feeder roads are not motorable.

From the above premise, the general surface accessibility situation in the municipal is much skewed towards the few urban towns - Axim, Aiyinase, Esiama, Asasetre, and Nkroful (NEMA, 2006).

3.2.7 Economy

The main economic activities in the area are fishing, farming and small-scale mining. The minerals mined include kaolin, silica and gold (NEMA, 2006). A number of energy tree species are also available for consumption – bamboo, timber and rattan which have been tested as a good source of fuel-wood. The most cultivated energy crop is coconut from which coconut oil is extracted for export. The potentials of these energy crops provide the area with high levels of alternative sources upon unseen eventualities and impacts of climate change.

3.3 Research Design

Multiple research designs were adopted in this study. Both the quantitative and qualitative approaches were used in a cross-sectional and prospective study designs (Burns, 2000); with a more quantitative data analysis and techniques. These two research designs have been chosen as they bring on board the capacity and ability to help achieve the study's objectives; the study seeks to understand current energy and climate change issues as well as consider issues of sustainability (which has a futuristic consideration). When compared with other designs like case study and experimental designs which are mainly for a particular case and also manipulates participates to create a desired change, cross-sectional and prospective designs are more able to provide current and future descriptions and relations between rural energy and climate change.

The cross-sectional study design was used to establish the prevalence of the rural energy mix by taking a cross-section of the population. This revealed the current demand and supply trends in the selected rural areas, as well as describing the current adaptive capacity of the communities to climate change impacts. Within the conceptual framework of this study, there is the spatial component which specifies the peculiar nature of the specific area under consideration. The cross-sectional design took the specific spatial dimensions into consideration.

Prospective study design on the other hand, predicted the likely trends of demand and supply as well as impacts of climate change. Since securing energy is about satisfying future needs as well, this research design aided in obtaining information for predicting possible outcomes of interventions and alternative technologies to be adopted and used. Again, within the conceptual framework, the time dimension which looks at the present and future (medium to long term sustainability issues) needs were also considered.

3.3.1 Sampling

A combination of both probability and non-probability sampling methods was used in the study. Under non-probability sample, purposive sampling, quota and chain referral sampling was adopted and with probability sampling, multi-stage sampling involving simple random sampling and stratified sampling were used.

Under the non-probability sampling, the study adopted purposive sampling because, it provided a selection of hand-pick units on the basis of their specific characteristics to the study; example, the selected institutions were selected by this method for their unique contributions to the study. Using other sampling techniques like random or stratified sampling, among others, will not provide the study with the specific uniqueness and accuracy of data required from the institutions. Quota sampling was adopted in sampling the industries since no prior knowledge was available on their existing number in the selected areas. Hence, quota sampling provided a grouped form of representation of these industries with appropriate characteristics ensuring the selection of adequate numbers of subjects within each grouping (quota).

Given the complex geographical distribution of the study area, multistage sampling techniques (simple random and stratified) under probability sampling was chosen. Again, since data on population size and sampling frame was unavailable at the time of design (as a result of delayed results presentation of Ghana's 2010 population and housing census figures), the study adopted to use the two-stage sampling approach to break the area into three strata and use simple random sampling to select the units of observations by the lottery approach. The stratified technique was used mainly because, it was the most convenient method given NEMA's geographic variations as well as the energy form utility variations across the zones. While in addition, the lottery system used under simple random sampling, was applied since the it gave each unit equal chance of being selected and hence its unbiased-nature in representation of population.

Quota sampling was used to select the small-scale industries and other businesses. Here the parameters that define the groups into which the quotas were formed are paramount. The small-scale industries and other businesses were grouped under quotas for which samples from within each quota was interviewed accidently using accidental sampling. The quotas were grouped according to the size of industry or businesses (in terms of number of employees) since larger industries will consume more energy as compared to smaller ones. And the individual business/industries interviewed were selected using the chain referral approach where interviewed respondents helps the interviewer to identify the next potential business owner. With purposive sampling, the energy supplying entities as well as the NEMA was selected purposively due to their relevance to the study. Purposive sampling was also used in obtaining institutional data from the institutions involved with energy and climate.

Under the multi-stage sampling approach, the following stages were followed. The study area was divided into three in terms of natural resources quantity and availability – the semi-deciduous forest (northern parts) which is endowed with lots of forest reserves, the secondary forest (central parts) and the coastal savannah (the coastal parts) characterized by advancing deforestation. Stratified sampling was used to stratify the area into three and the three strata was chosen because it presented the study with how each ecological zone within the area adapted to changing climate and their capacity for SE, since different places with access to energy sources will act different from those that do not have or have little access to alternative energy sources. The simple random sampling approach was only used in picking the communities to be selected, using the lottery system; this is explained further in the next sub-section.

3.3.1.1 Target population and selected communities

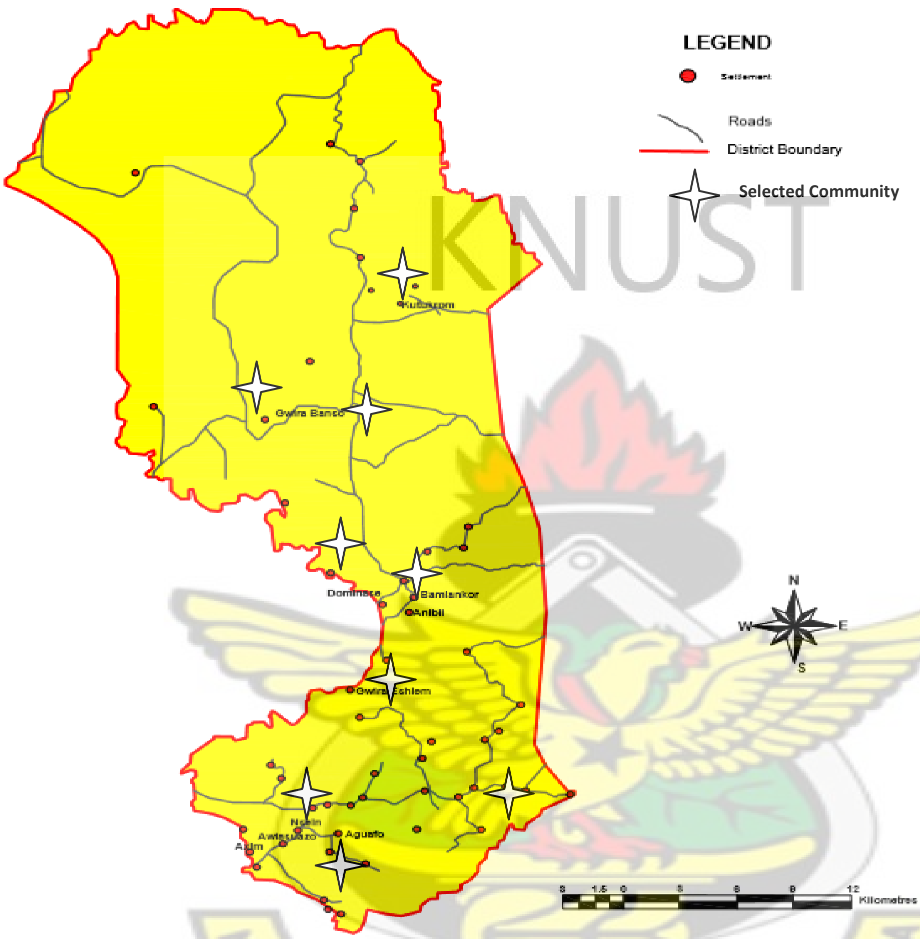
The total targeted population was 90 households, 25 industries/businesses and 10 local energy suppliers. The selection of the target business/industries and energy suppliers was done using the available targets at the time; this was because no data was available beforehand to calculate the sample required. However, the target population selection was able to provide the needed information which could be use for generalization.

Theoretical explanation for Sample size selection: The selection 90 households as the sample size was informed by literature and the Central Limit Theorem (CRT). Data on the sampling frame was not obtainable and hence based on the stratification of the area (stratified sampling), a sample size of 30 was assigned to each of the three strata, making 90 in all. The 30 was influenced by the fact that, NEMA's population has a normal uniform distribution (NEMA, 2006; NEMA, 2010), and according to the CLT, as argued by Smith and Wells (2006), that a sample size of 30 may be sufficient enough to invoke the CLT if the parent distribution is normal (bimodal parent distribution). Hence, the 30 sample size in each stratum was based on the arguments of CLT and the assumption that, the population distribution of NEMA will remain normally distributed through the study period.

Nine (9) communities were selected using the stratified sampling approach by stratifying the municipal assembly into three (3) zones and then selecting three communities from each stratum. The selection of the communities was done with the help of randomly using the lottery system. All the communities in the municipal assembly were obtained from the profile of the area (literature review) and numbered 1 to 300; since data on the communities were up to 300. The communities were then re-grouped under their respective zones (i.e. the stratified zones) and picked randomly without replacement in the lottery style system. The following were selected randomly as part of the study using the lottery system under simple random sampling;

Kutukrom, Gwira Banso, Gwira Eshiem, Bamiankor, Anibil, Dominase, Aguafo, Nsien and Edelesuazo. The figure below shows the spatial distributions of the selected communities.

Figure 3.1: Selected communities



Source: Author's construct, 2012

3.3.1.2 Sampling Errors

In choosing the sampling size a confidence level of 95 percent and 5 percent margin of error was allowed. This was so because the district is predominantly rural and thus the population most likely showed similar characteristics and so the study allowed 5 percent of significant errors and also 95 percent confident that data obtained represented the true reality on ground.

For sampling errors, a confidence interval (CI); as shown in the equation below; of ±5 was calculated and used to inform the confidence at which the study made conclusions and recommendations. Hence all conclusions and results obtained in chapters 4 and 5 was attributable to a ±5 confidence interval.

The test statistic for computing the sampling error was done by using;

$$\boldsymbol{CI} = \rho \pm e \bullet Z_{\alpha}$$

where ρ is the estimate from the sample, e is the estimate of the standard error, and Z_{α} is a constant that depends on the degree of certainty, α, we want the proportion of. However, for non-sampling errors, ample time was given to proper coding and editing of questionnaire as well as lengthy time used in training field enumerators.

3.4 Units of Enquiry

The basic units of enquiry were drawn from the knowledge gained from Ghana's Energy Commission's energy outlook report which categorizes energy consumption into three parts – residential, non-residential and industrial. However for the purposes of this study, the units interviewed were the households, energy supplying bodies, Municipal Assembly, Forestry Service Division, Meteorological Survey Department and small-scale industries owners. Other stakeholders were interviewed and they could not be put under a larger group. These units were mainly interviewed as only part of the model used in measuring some of the SE indicators; to be discussed later in this chapter.

3.4.1 Households

Within the households, the focus of the enquiry was the household head. Data on energy consumption and adaptive capacity to changes in energy supply and climate change was enquired and hence the head of the household was the point of contact for this information. However, there was also room for alteration given that the probability of meeting all household heads was not 1, and so the next of keen was interviewed.

Data required from this unit is mainly energy consumption levels and sources from which they obtain this energy. Their pattern of end-use consumption will be measured in relation to the already tested patterns of cooking, lighting and heating. Their adaptive capacity will also be accessed through indicators which are discussed later in this chapter.

3.4.2 Energy Supplying Bodies

The companies or individuals who supply energy to the rural communities are very important in undertaking this study. If SE is to be achieved there should be a reliable supply source as discussed in the previous chapter. The interviewed units were 10 fuel wood sellers/operators and 10 charcoal burners and/or sellers; making up a total of 20 interviewed local energy providers in all communities. The data obtained from this group was mainly consumer-coverage, that is the number of consumers they provide energy and the amount of energy they supply in measurable quantitative of kilograms for fuel wood and charcoal. Also their capacity to adapt to any change in either consumer demand or climate change induced alteration in supply was also obtained from these units.

3.4.3 Small-Scale Industries and Other Businesses

The main businesses and industries interviewed were 6 shops (included were grocery shops, cold stores, stationary shops), 2 alcohol distillers, 4 oil palm manufacturers, 3 dress makers, and 10 food vendors; making a total sample of 25 businesses in all communities. The key information obtained from these units included their consumption pattern and their adaptive capacity towards changes in supply and impacts resulting from climate change. The main interviewed cases here were the owners and in a few cases, especially among the food vendors, their assistants were interviewed due to the absence of the owner.

3.4.4 Municipal Assembly

The MA was a focal point of contact in obtaining most of the places to visit and also routes to take in order to reach the case communities. The main information obtained from the MA was a general snapshot of the way of life and energy sources and usage in the case communities. The DA also provided the study with the information and recommendation on the activities of the MoEn at the local level. A preliminary map of the municipal was also obtained and later digitized for further use. The main personnel interacted with included the all the members of the DPCU, with the exception of the MCE.

3.4.5 Forestry Service Division

The forestry service division was not located in the NEMA but in Tarkwa; it serves a zone within which NEMA is located that explained its location. The information obtained were basically on the size of forest cover, rate of forest depletion and the measures in place to control or reduce it. Arising issues from this interview included the causes of deforestation and rate of forest generation. Three staff were interviewed; the Director, Forest Management Coordinator and the Zonal Cartographer.

3.4.6 Meteorological Survey Department (MSD)

This unit provided all the current and past data on rainfall, temperature, sunshine and evaporation rates over a period of seven (7) years and also a snapshot of these variables over the past 30-40 years. Obtaining data from the MSD was very expensive and it explains why for climate data, only a 7-year period of data was gathered. However, a snapshot of the general outlook of these variables was obtained to support the 7-year data sheet.

3.5 Data Collection

Relevant data for the study was obtained from both primary and secondary sources. Questionnaires and interviews were the main tools used to gather data from the units of analysis identified.

3.5.1 Data Collected and Methods of Collection

The main data that were collected for this study are discussed in the following paragraphs. However it should be said here that, the data collected and mentioned here does not suffice as the survey revealed new areas of interest to the study that otherwise was not considered.

Rural energy consumption pattern

This was concerned with how energy is used in the communities; that is the end-use of energy sources. These were grouped into residential and industrial purpose and further into cooking, lighting, ironing, baking and/or other industrial activities.

Fuel wood and charcoal were measured in weight quantity (kg). The study used Ghana's average measurements for bag of charcoal and a bag of fuel wood as 50kg and 40kg respectively. It was found out that forms of measuring fuel wood was available but it could not be used in this study because of the complexities accompanying it. Since it not conventional to bag fuel wood for sale, the researcher inquire about the number of sticks used per day and collected as many that will fit into a bag weighing 40kg; this number of sticks was then used to calculate the kg of fuel wood used by that household. This methodology was used together with the households.

Data was also collected on the likely future consumption patterns of households with effects from anticipated change in supply sources due to climate change. Household and industrial questionnaires were used for data collection; see the annex for survey instruments.

Rural energy supply

Data on energy supply was mainly collected from the entities that provide energy to the rural communities; the quantities collected were obtained using the same methodology as explained above. Purposively, only energy supplying entities and individuals were sampled for data collection and interview guides were used in collecting data.

Rural climate change impacts

Climate change impacts were rather difficult to measure and collect; for this reason, mostly secondary data was used. The MSD and NEMA were the main sources of data on climate change impacts using institutional interview guides.

Sustainable energy framework

Under the SE framework, data was collected from a range of sources; i.e. household interviews, business/industry interviews and institutional (NEMA, MSD and FSD) interviews were used to collect data on affordability, reliability, accessibility, adaptive capacity, equity, spatial and time dimensions. The methodology that was chosen and used in measuring these indicators have been discussed in the analysis section below.

3.5.2 Levels of Measurement

The levels of measurements used for each of the variables discussed above included the following;

Energy consumption: a raw number of total quantities in their units (ratio level)

Energy supply: a raw number of total quantities in their units (ratio level)

Climate change impacts: four approximately equal categories based on perceptions of level of impacts in Low, Moderate, High and Very High (ordinal level)

Sustainable energy framework: four approximately equal categories based on perceptions on affordability, reliability, accessibility, equity, adaptive capacity, space and time in Very Low, Low, Moderate, High and Very High (ordinal level); and other nominal categorizations (nominal level).

3.5.3 Measurement error

Errors are common because the variables in social science are indirect and very subjective. It leads to unreliable conclusions and invalid inferences. It was based on this idea that the study considered measurement errors when the survey was being designed.

In this research most of the instruments used were questionnaires and much attention was given to the design of questionnaires by running pre-testing and review of content of the questionnaire with several other researchers and interviewees. The aim of this was to reduce possible error concerns of validity and reliability.

3.5.4 Equipment utilized

In carrying out the field survey, a number of tools and equipment were used. The following were the tools used;

- Structured and semi-structured questions (interview guides were also included)
- digital camera and video recorder (used mainly for pictorial analysis)
- voice recorder (used to capture instant events and occurrence)
- tape measure (used to measure length and width of fuel wood logs; this was used minimally due to the use of the weighing bag)
- mini-weighing kit (used to weigh the bags of fuel wood and quantity of charcoal consumed daily).

3.6 Data Analyses

In the analysis of data, a permutation of univariate descriptive, bivariate descriptive, inferential and narrative analyses were used. The univariate descriptive data analysis was used to reveal the characteristics of the socio-economic phenomenon and the bivariate descriptive data analysis was used establish the linkages among the characteristics of a social phenomenon and also the indicators in the SE framework (Blaikie, 2003). Inferential analysis was used mainly to estimate the characteristics of NEMA from the selected nine (9) communities. The study was only able to do this because since the cases were selected using probability selection procedures (Blaikie, 2003).

The univariate descriptive analysis helped the study to identify the characteristics of energy demand and supply from both the residential and industrial sectors and also the factors considered under climate change (rainfall, temperature, sunshine and evaporation). In the analysis of these, normal frequency counts and distributions were used to summarize data on energy demand and supply as well as the extent of climate change in the area. They were presented pictorially using histograms and line graphs since the level of measurements used at this level was continuous (Blaikie, 2003). In addition to the pictorial presentation of these variable characteristics, summary statistics in the form of central tendencies (mean and median) were used to further describe each of the variables. Standard deviations of the central tendencies were also calculated to identify how widely dispersed the calculated averages were, with reference to the mean and median.

Under bivariate descriptive analysis, the Pearson's product moment correlation coefficient was used in analyzing the correlation between energy forms and climate change; it was also used in determining some correlations between household size and quantity of energy consumed as well as household income and quantity of energy consumed. The analysis also used cross-tabulations in linking the energy forms variables and climate change variables. For further bivariate descriptive analyses where the prospective study was employed, the exponential projection statistical method was used to find the time dimension of energy demand and supply over a period of 20 years. It was also used to identify the probability of willingness of households and businesses to change from their current energy source to a more modern source over time. Triangulation analysis was in addition to the above used in data validation and for generalization.

The main inferences made included the average household size, average household monthly income, average daily consumption of fuel wood and charcoal for both households and businesses, the relationship between household size and average energy consumed among others. In making inferences, two main levels of confidence was used in univariate inferences; confidence level and the confidence interval. The confidence level was 95 percent and this was used to refer to the level of probability that the study was sure about the sample size interviewed. This explained that, with 95 percent of the selected sample, the study will be able make concrete inferences. In addition, the confidence interval, as discussed earlier (see section 3.3.2), was 5. This means that, the range of 5 around the sample was what the expected population characteristics will look like when inferences were made. Narratives from interviews were transcribed in short-hand and the key ideas were used in the data analysis.

3.6.1 Applicable statistical analyses for SE conceptual framework

A number of statistical models were used in measuring the indicators adopted under the SE framework. The indicators that were measured with these models included affordability, accessibility, reliability, time, adaptive capacity. The remaining indicators, spatial dimension and equity, were analyzed qualitatively using observations and perceptions from interviews. The following discussions show how the selected models were used under each indicator.

Affordability: here the Consumer Energy Burden (CEB) model was used. It represents how much "discretionary" income is needed to pay for residential energy year round; as used by Power (2008). This is, the percentage of household income required and spent on energy utilities. From each household, their CEB was calculated by dividing their income by the energy expenditure and finding the percentage of that household. All households percentages of CEB was averaged, using the mean.

Reliability: under this model, the attributes and objectives are discussed in earlier section 2.11.2 and hence, this part will only illustrate how it was used. A group of 25 experts were interviewed and their perceptions were used in this model; they included 7 household heads, 3 forestry service department staff, 4 staff from NEMA, 2 staff from the meteorological service department, 5 staff from 2 selected Health centres, 7 charcoal burners, 6 fuel wood operators and some 2 staff from KITE (an energy NGO).

The use of qualitative rating scales and criteria invariably allowed for some interpretation to the experts, by enabling them to apply their own perceptions of reliability and understanding of the systems. Although quantifiable criteria are often desirable, such flexibility is a meaningful and interesting aspect provided by expert opinion and revealed qualitative wisdom that other assessments might overlook. The multi-attribute utility theory (MUAT) model was used calculate composite scores for the general objectives based upon evaluation of the attributes by the expert panel; this is summarised below;

$$U = \sum_{i=1}^{n} w_i u_i$$

where w_i is the importance weight for attribute *i* and u_i is the utility of attribute *i*, scaled from 0 to 1 (McCarthy et. al., 2008). The criteria used in the model are defined as follows;

Table 3.1: Rating scale used to rate reliability and importance in terms of the attributes

	N/A	0	1	2	3	4	5
Importance ratings (w_i)	Unknown/does not apply	None	Low	Moderately low	Moderate	Moderately high	High
Reliability ratings (r_i)	Unknown/does not apply	Perfect	High	Moderately high	Moderate	Moderately low	Low

Source: Author's construct, 2012

Table 3.2: Criteria for reliability ratings

0	1	2	3	4	5
Indicates that under no circumstances will the component operate intermittently	Indicates that, given sufficient inputs, the component will operate with low levels of predictable intermittency	Please use your discretion	Indicates that, given sufficient inputs, the component will operate with relatively high levels of predictable intermittency	Please use your discretion	Indicates that, given sufficient inputs, the component will operate with high levels of unpredictable intermittency

Source: Author's construct, 2012

The experts used these criteria in answering the Likert scale and from that scale, the averages of their ratings was used for aggregating for total reliability under adequacy and security. Table 3.3 shows how the Likert scale was used by the expert panel to score values under the objective adequacy; see the annex for scores for adequacy and security objectives. For example, from table 3.3, the experts rated how energy is utilised under the three metrics, primary source of energy supply, its conversion and its transportation to final destination. This was done for all the attributes based on the definition of the attributes provided in section 2.11.2 and the criteria for rating in tables 3.1 and 3.2 above.

Table 3.3: Sample Likert scale for Adequacy objective

Attributes	**Metrics**		**Primary Source of supply**	**Energy conversion**	**Transport**
Capacity	Utilisation	r_i	0.4	0.4	0.1
		w_i	0.4	0.1	0.1
	Intermittency	r_i	0.5	0.2	0.9
		w_i	0.8	0.2	0.9
	Capacity	R	0.8	0.8	0.9
		W	0.8	0.5	0.9
Flexibility	Response to demand fluctuations	r_i	0.8	0.5	0.7
		w_i	0.8	0.5	0.7
	Ability to expand facilities	r_i	0.9	0.5	0.7
		w_i	0.2	0.5	0.2
	Flexibility	R	0.2	0.7	0.2
		W	0.2	0.4	0.4
ADEQUACY		$\boldsymbol{R}$	0.4		

Source: Author's construct, 2012

Accessibility: the surface accessibility mapping model/techniques was applied in this indicator. Using the maximum travel time, waiting time and maximum walking time, the access zones was calculated in order to determine those areas within high and low access zones to energy resources.

Adaptive capacity: using the various systems defined by Smit (2001) as the determinants of adaptive capacity, households and the other selected institutions were asked to rate these determinants using a scale of 1-5, with 1 being the least possible form to support adaptation and 5 being the best form of support to adaptation. Each of these rating sores was divided by 5 to get their ratios for a proper analysis.

Time dimension: the time dimensions used here were the short, medium and long terms. Microsoft excel spreadsheet was used in modeling a projection for the time periods. See the annex for snapshots of the excel model.

3.6.1.1 Carbon emission and Carbon capture calculations

In calculating the carbon emissions from fuel wood and charcoal, the model used by the Cambridge Climate Change research centre was used. The model as used and formulated is ad follows;

- Emissions factor for Fuel wood (wood logs) = 0.382 tCO_2/kWh
- Emissions factor for Charcoal = 0.018 tCO_2/kWh
- Carbon footprint calculations

  Emissions ($tCO_2/year$) = Per capita energy demand (kWh/person-year) x Population (persons) x Emissions Factor (tCO_2/kWh) ....(1)

In calculating the carbon capture/sequestration, the following methodology was used;

- Capture and Sequestration Sinks

  Rate of movement from air to vegetation (tCO_2/yr) = ∑Net Primary Productivity-NPP ($tCO_2/m^2/yr$ or $gC/m^2/yr$) × Area (m^2) ....(2)

Equations 1 and 2 were used in calculating the carbon footprints and sequestration respectively. The rates used in (2) are shown in the annex.

3.6.2 Applicable software used for analysis

The main software applications used were the SPSS (version 17.0) and Microsoft Excel spreadsheet. In the initial stages, RETscreen (version 4) was used in calculating the carbon emissions from fuel wood and charcoal; however, due to data requirement inadequacy in the application, this application was stopped.

3.7 Investigation timeframe

A total of 26 days was used for data collection and interviews with key informants. Table 3.4 summaries the activity time schedule.

Table 3.4: Investigation timeframe

Activity	Timeframe (days)
Household surveys	12
Institutional interviews and other stakeholders	7
Business/industry interviews	5
Energy suppliers interview	2

Source: Author's construct, 2012

CHAPTER FOUR

ENERGY FORMS AND CLIMATE CHANGE

4.1 Introduction

Following the framework that was designed in the previous chapter to guide data collection and analysis - this chapter pursued the initial discussions on energy forms and climate change in rural communities. Without doubt, energy is a key driver of socio-economic development both in the rural and urban contexts; so that without energy, whether sustainable or otherwise, development is beyond reach. But energy demand and supply is very central to both the problem and accruing advantages of climate change, especially in rural areas.

Literature explains potential and assumed relationships and effects between energy consumption and climate change, however without factual empirical evidence in tropical regions and rural communities; partly because climate change is not as severe in such areas, but this study tries to identify the empirical associations between these two variables. The forgoing sections will discuss the nature of the relationship between energy supply and demand and climate change impacts in rural communities in NEMA; with a description of the impacts of rural energy on gender issues. However, as a preface to the sections, the demographic and socio-economic settings of the selected communities will be presented to form the baseline for further analyses.

4.2 Demographic Characteristics (Baseline Data)

This section provides an overview of the people living in rural communities in NEMA. It presents what the rural NEMA population looks like in terms of household size, gender distribution and age structure.

However, the population figures for the municipal assembly were not accurately available as at the time of investigation and field preparation. This was because, the 2010 population and housing census figures for the area was not ready to be published by the Ghana Statistical Service (GSS). As a result, the researcher, chose sample of 90 households, spread to cover nine (9) communities (refer to figure 3.1), across the entire municipality.

4.2.1 Household Size

It was found out that, the average household size in rural communities in NEMA is higher at 6.21 when compared to the national rural household size average of 4.4 (GLSS 5, 2008). Table 4.1 shows the details of household sizes in all the selected communities and their averages.

Table 4.1: Average Household Size

Zones	Communities	Household size						Average C'ty Hh size	Average Zone Hh size	Average Hh size of entire study
		1-3	4-6	7-9	10-12	13-15	>15			
Moist deciduous forest	Kutukrom	20%	40%	40%	-	-	-	5.6	5.60	
	Gwira Banso	20%	40%	40%	-	-	-	6.0		
	Gwira Eshiem	30%	40%	10%	20%	-	-	5.6		
Secondary forest	Baimankor	-	70%	30%	-	-	-	5.7	6.13	6.21
	Anibil	-	30%	40%	30%	-	-	8.0		
	Dominase	30%	70%	-	-	-	-	4.7		
Coastal savannah	Aguafo	-	60%	30%	-	10%	-	6.8	6.90	
	Nsien	20%	40%	10%	20%	10%	-	7.1		
	Edelesuazo	20%	40%	30%	-	10%	-	6.8		

Source: Nzema East Municipal Field Survey, 2012

It can be realised that, households in Anibil had the highest household size of 8 while those in Dominase had the least of 4.7. However, both are located within the secondary forest part of the study area where it was identified to be experiencing a transition from a typical rural to some level of peri-urban status with new developments and access to certain facilities. Communities in the moist deciduous forest parts recorded the least average household size of 5.6 and it could be attributed to the fact that, lack of access to certain basic facilities coupled with out-migration is causing reductions in population sizes, compared to the coastal savannah part which had the highest average household size of 6.9 with about 30 percent of household sizes being more than 13; this zone was nearest to the capital Axim and thus had access to basic facilities.

The average household size of the area (6.21) further informs the analyses of the carbon emission calculations as well as the carbon sink calculation (to be discussed and applied in the next chapter). Comparing the study's household size of 6 to the national figure of 4.4 and the Western Region's size of 4.2, it shows that, NEMA has a large average household size. This has a bearing on high energy demand and consumption and pressure on available energy resources.

4.2.2 Gender

The gender ratio in rural NEMA, based on the sample survey was 1:0.95 for male: female. This means that, for every 109 males, there is an equivalent 100 females. However this average was different from the selected communities within the secondary forest (Bamiankor, Dominase and Anibil) which had a male-female ratio of 1:1.38. Table 4.2 shows the details of the various gender distributions across all the communities.

Table 4.2: Gender

Zones	Communities	Gender distribution of communities (%)		Gender distribution of zones (%)		Gender distribution of entire study area (%)	
		Male	Female	Male	Female	Male	Female
Moist deciduous forest	Kutukrom	61.9	38.1	64.0	36.0	51.0	49.0
	Gwira Banso	66.0	34.0				
	Gwira Eshiem	55.9	44.1				
Secondary forest	Baimankor	43.5	56.5	42.0	58.0		
	Anibil	40.9	59.1				
	Dominase	41.4	58.6				
Coastal savannah	Aguafo	48.8	51.2	50.0	50.0		
	Nsien	47.9	52.1				
	Edelesuazo	53.5	46.5				

Source: Nzema East Municipal Field Survey, 2012

Compared to the national gender ratio of 1:1.06 for male-female, the ratio recorded in all the communities is not consistent with the national average. With the exception of the secondary forest zone which has more females compared to males, all the other zones had more males compared to females.

From literature, it is clear that, rural women are mostly responsible for household energy gathering in the form of fuel wood and charcoal. Women are also at risk in terms of respiratory health issues from smoke from the fuel wood and charcoal burning (OECD, 2001). With women contributing almost half of the sample population (49 percent), it could be inferred here that, the increasing dependence on fuel wood and charcoal in rural homes will invariably increase the risks in acquiring respiratory diseases among women; this phenomenon will threaten their ability to collect wood for household needs and consequently, likely increase in continued energy poverty among rural households.

4.2.3 Age Distribution

The average age of the population, based on sample population, is 27.59 years. Extreme cases were seen in Bamiankor where the average age was 16.8 years while in Dominase it was 53.18 years. Generally, the trend in age distribution of the NEMA population is consistent with the national trend. The study showed that, majority (70.1 percent) of the population are within the active age cohort (15-60 years) compared to the national figure of 51.2 percent. Table 4.3 shows the details of the age distributions in all communities.

Table 4.3: Household Age distribution

Zones	**Communities**	**Age Cohort**							**Average Age of C'ty Hh members**	**Average Age of Zone Hh members**	**Average Age of entire study area Hh members**
		< 10 (%)	10-19 (%)	20-29 (%)	30-39 (%)	40-49 (%)	50-59 (%)	60+ (%)			
Moist deciduous forest	Kutukrom	9.5	19.0	38.2	14.3	9.5	9.5	-	24.72		
	Gwira Banso	15.1	18.9	37.8	9.4	7.5	7.5	3.8	23.35	24.80	
	Gwira Eshiem	7.5	19.0	43.2	12.3	9.5	8.5	-	26.32		
Secondary forest	Baimankor	15.2	50.0	10.9	17.4	6.5	-	-	16.8		27.59
	Anibil	31.8	22.7	-	13.6	11.5	6.8	13.6	27.66	32.55	
	Dominase	-	20.7	24.1	10.3	10.3	13.8	13.8	53.18		
Coastal savannah	Aguafo	14.6	19.5	26.8	9.8	14.6	12.3	2.4	22.58		
	Nsien	12.4	29.2	29.2	6.3	12.4	4.2	6.3	24.21	25.41	
	Edelesuazo	7.0	16.4	30.2	11.6	20.9	11.6	2.3	27.35		
Total distribution for entire Study Area		**12.6**	**23.9**	**27.5**	**11.7**	**11.4**	**8.2**	**4.7**			

Source: Nzema East Municipal Field Survey, 2012

From this set-up, with majority of people within the active age cohort, it could be inferred that, the demand for more energy and the ability to gather more fuel wood and obtain charcoal is much greater. The greater ability to gather fuel wood has the knack to affect the natural forests and its trickling contribution to climate change.

4.3 Socio-Economic Characteristics

This section looks at the socio-economic situation of people living in rural NEMA. Issues under employment, income and expenditure, education and facility availability will be covered under this section.

4.3.1 Employment

The active population age group of 15-60 years were part of the labour force and out of these, 65.8 percent were employed and 7.2 percent were unemployed. The remaining 27.8percent were currently in school or were apprentice of a trade. The study further showed that, more men (62.6 percent) than women were employed; this difference was consistent across age groups.

Based on the sample, majority (67 percent) of household members are engaged in agriculture, mainly cocoa farming, rubber plantation and other food crops. About 20 percent were engaged in mining, either galamsey or were employed by the mining companies in the district. This was especially found within the central secondary forest zone comprising Anibil, Dominase and Bamiankor. The remaining 13 percent were engaged in number of other occupations which included, teaching, nursing, petty trading among others.

With the majority of the employed, found in the agriculture sector, it could imply that, there is likely to be a continued use of fuel wood and charcoal for at least the next 2 to 3 decades as these sources are accessible in their farms and nearer their farms, as iterated by the Energy Commission (2012). It has however been identified that, this phenomenon is changing as farmers will have to travel further distances from their farms in search of fuel wood; as a result of deforestation and increased fuel wood and charcoal consumption.

4.3.2 Income Levels

Although income levels cannot be used as the only indicators of poverty, it provides probably the clearest picture of poverty levels and it is widely used. The average monthly income in rural households in NEMA is GHS 109.3. Spatial disparities were seen in Bamiankor where the least average monthly income of GHS 50.0 was realized while in Kutukrom, the largest average monthly income of GHS 155.0 was also recorded. Table 4.4 shows the details of the various income levels in the selected communities.

Table 4.4: Household Average Monthly Income Levels

Zones	Communities	Income (GHS)					Community Average monthly exp. (GHS)	Zone Average monthly exp. (GHS)	Entire Study Average monthly exp. (GHS)
		< 50	50-100	101-150	151-200	>200			
Moist deciduous forest	Kutukrom	-	-	60%	10%	30%	155.0	120.0	109.3
	Gwira Banso	-	30%	40%	10%	20%	150.0		
	Gwira Eshiem	-	20%	40%	-	40%	55.0		
Secondary forest	Baimankor	50%	50%	-	-	-	50.0	100.0	
	Anibil	-	100%	-	-	-	100.0		
	Dominase	-	10%	90%			150.0		
Coastal savannah	Aguafo	10%	-	70%	-	20%	140.0	108.3	
	Nsien	-	80%	20%	-	-	85.0		
	Edelesuazo	-	60%	20%	-	20%	100.0		

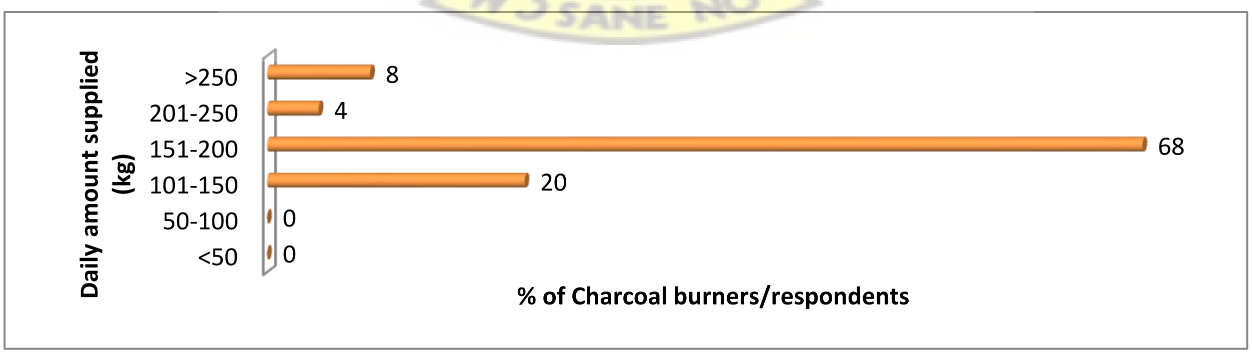
Source: Nzema East Municipal Field Survey, 2012

Comparing the monthly average of GHS 109.3 in the case communities to the national monthly average of GHS 101.4 for rural communities (GLSS 5, 2008), not much difference could be seen from the national perspective as well as from NEMA's point of view. Thus the study shows and confirms the monthly income levels in rural communities in Ghana.

4.3.3 Expenditure on Energy

From the income levels, the average of which was high compared to the national monthly incomes, it is expected that households in rural NEMA should spend more on their expenditure items; since it is more likely for higher income earners to spend more compared to lower income earners. The expenditure covered here is basically on the fuel wood and charcoal consumption. As a preamble to the succeeding sub-sections, the daily amounts of fuel wood and charcoal supplied are presented.

Figure 4.1: Daily Supply Stock of Fuel wood

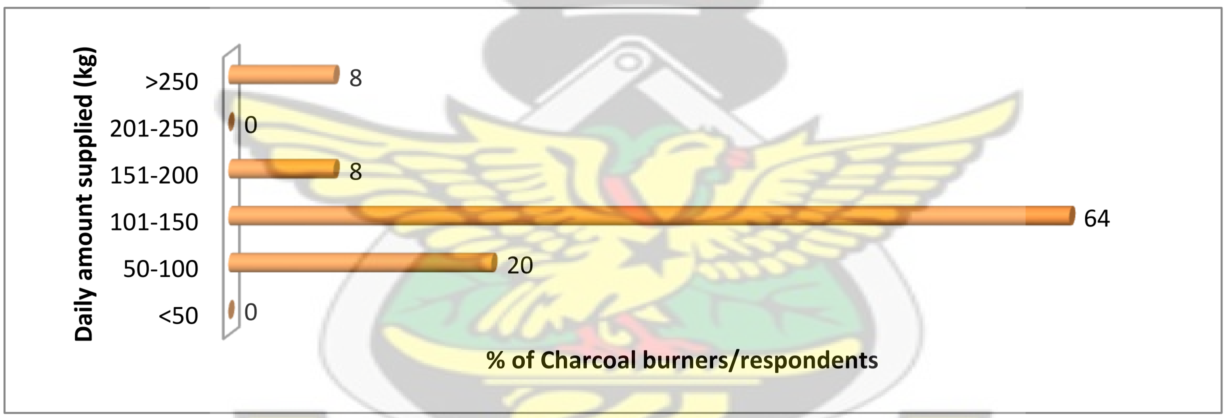


Source: Nzema East Municipal Field Survey, 2012

It is very clear that majority (68 percent) of the producers provide between 150 and 200 kg of fuel wood daily and the average daily supply based on the study sample is 175.5 kg. More than 50 percent of the interviewed producers fell trees to provide raw material for their business while about 20 percent were picking tree shrubs from their farms and forest as raw material for supply. Only 2 percent buy wood from carpenters and wood lot operators.

From figure 4.2 below, it is understood that, majority (64 percent) of charcoal burners produce between 100 and 150 kg of charcoal daily for merchandise and the average daily supply based on the study sample is 125 kg. About 75 percent of the interviewed producers fell trees to provide raw material for charcoal burning while about 20 percent were picking tree shrubs from their farms and forest as raw material for supply. Only 5 percent buy wood from carpenters and wood lot operators.

Figure 4.2: Daily Supply of Charcoal production



Source: Nzema East Municipal Field Survey, 2012

4.3.3.1 Expenditure on Fuel wood

Fuel wood consumption is measured in this context in terms of kilograms (kg) and on a daily basis. This section looks at the daily consumption levels in addition to the amount of money spent on it.

From table 4.5, the daily average quantity of fuel wood consumed is 13.3kg, with the lowest consumption occurring in Dominase (5.8kg per day) and the highest consumption seen in Gwira Banso (18.2kg per day). There exists a positive correlation of r = 0.4, between the quantity of fuel wood consumed and the average monthly income of the sampled households. The higher the monthly income, the more fuel wood households consume daily. This phenomenon affirms the speculation made in chapter two of this study by ExxonMobil (2011), that increase in economic gains directly increases the demand for energy.

Table 4.5: Daily Quantity of Fuel wood consumed by households

Zones	**Communities**	**Daily Quantity [kg]**					**Community Average daily qty (kg)**	**Zone Average daily qty. (kg)**	**Entire study Average daily qty (kg)**
		≤ 5	6-10	11-15	16-20	>20			
Moist deciduous forest	Kutukrom	-	60%	20%		20%	10.10	14.0	13.31
	Gwira Banso	-	60%	-	20%	20%	16.30		
	Gwira Eshiem	-	60%	-	20%	20%	18.20		
Secondary forest	Baimankor	20%	20%	60%	-	-	10.30	9.1	
	Anibil	-	30%	70%	-	-	11.60		
	Dominase	70%	30%	-	-	-	5.80		
Coastal savannah	Aguafo	20%	10%	20%	10%	40%	21.20	11.50	
	Nsien	90%	-	-	-	10%	7.33		
	Edelesuazo	70%	10%	10%	-	10%	7.10		

Source: Nzema East Municipal Field Survey, 2012

Businesses and industries on the other hand were consuming an average of 180kg daily on fuel wood for their respective activities, which explains high consumption levels when compared to residential fuel wood consumption. Comparing both residential and industrial fuel wood consumption to the daily supply of fuel wood, discussed above, it could be seen that, businesses alone are over-demanding the average supply stock recorded among the producers. This has shown a backlog of 17.8kg daily; however what the study has not been able to clarify is the other options businesses and households have in obtaining this backlog of fuel wood.

Table 4.6 explains the daily expenditure on fuel wood consumption and it is compared to the quantity consumed shown in table 4.5 above. Generally, an approximate average of GHS 0.60 is spent daily on fuel wood in the sampled rural households. There is a weak negative relationship between the amount spent on fuel wood and the monthly average incomes of households. Figure 4.1 shows this relation in a scatter plot with a correlation coefficient of r = -0.2.

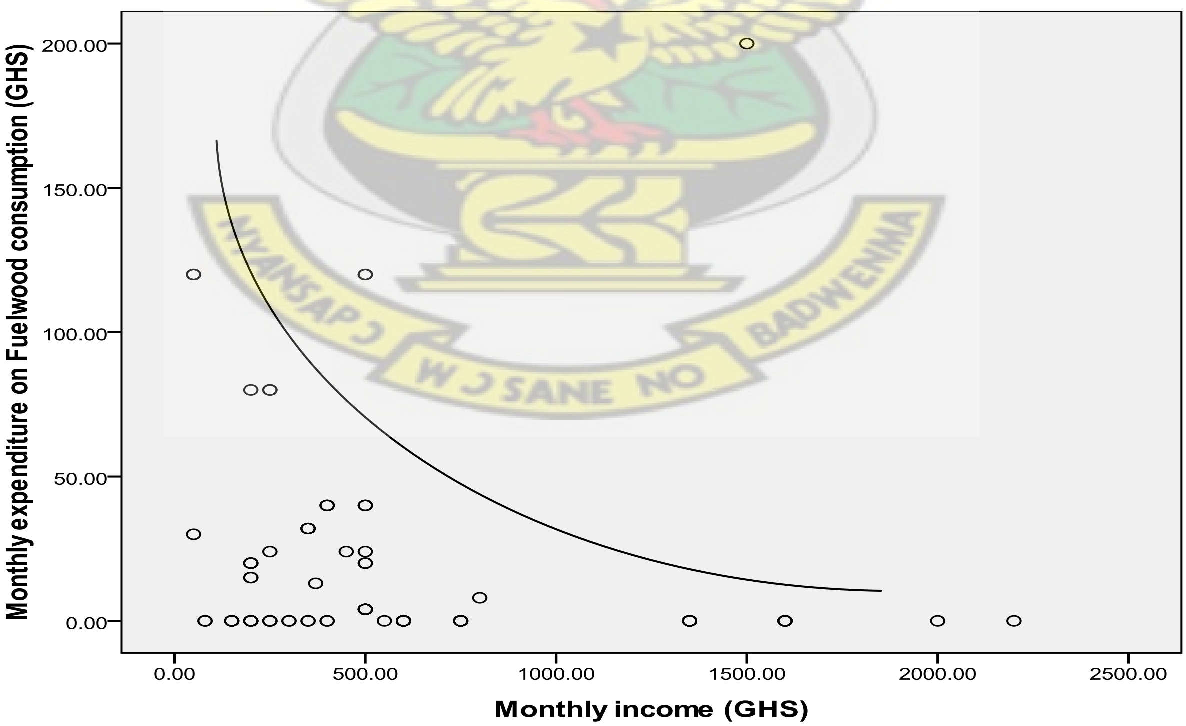
Table 4.6: Daily Expenditure on Fuel wood consumed by households

Zones	Communities	Expenditure (GHS)					Community Average daily exp. (GHS)	Zone Average daily exp. (GHS)	Entire study Average daily exp. (GHS)
		0.0	≤ 0.5	0.6-1.0	1.1-2.0	>2.0			
Moist deciduous forest	Kutukrom	90%	10%	-	-	-	0.30	0.45	0.60
	Gwira Banso	75%	25%	-	-	-	0.50		
	Gwira Eshiem	60%	40%	-	-	-	0.55		
Secondary forest	Baimankor	40%	60%	-	-	-	0.30	0.47	
	Anibil	70%	-	30%	-	-	0.65		
	Dominase	70%	30%	-	-	-	0.45		
Coastal savannah	Aguafo	30%	10%	40%	-	20%	1.00	0.82	
	Nsien	60%	30%	10%	-	-	0.60		
	Edelesuazo	50%	40%	10%	-	-	0.85		

Source: Nzema East Municipal Field Survey, 2012

From the table above, an extreme case was seen in Aguafo where about GHS 1.00 was spent daily on fuel wood and as low as GHS 0.30 was spent daily on fuel wood in Kutukrom. On the other hand, businesses/industries are spending GHS 4.10 daily on fuel wood; this could possibly explain their high level of consumption.

Figure 4.3: Scatter Plot of Household incomes and Expenditure on Fuel wood consumption



Source: Author's construct, 2012

4.3.3.2 Expenditure on Charcoal

Charcoal consumption is also measured in terms of kg and on a daily basis. This section looks at the daily consumption levels in addition to the amount of money spent on it.

Table 4.7: Daily Quantity of Charcoal consumed by households

Zones	**Communities**	**Daily Quantity [kg]**					**Community Average daily qty (kg)**	**Zone Average daily qty (kg)**	**Entire study daily qty. (kg)**
		≤ 5	6-10	11-15	16-20	>20			
Moist deciduous forest	Kutukrom	100%	-	-	-	-	2.00	2.0	3.22
	Gwira Banso	100%	-	-	-	-	2.00		
	Gwira Eshiem	100%	-	-	-	-	2.00		
Secondary forest	Baimankor	100%	-	-	-	-	2.52	4.1	
	Anibil	70%	30%	-	-	-	4.50		
	Dominase	65%	35%	-	-	-	5.17		
Coastal savannah	Aguafo	100%	-	-	-	-	1.75	2.0	
	Nsien	70%	30%	-	-	-	1.42		
	Edelesuazo	100%	-	-	-	-	2.90		

Source: Nzema East Municipal Field Survey, 2012

The average amount of charcoal consumed by households per day based on the sample was 3.22kg, with the lowest consumption being recorded in Aguafo (1.42kg) and the highest consumption being recorded in Dominase (5.17kg). There is a weak negative correlation between average monthly income and the average quantity consumption of charcoal; with correlation coefficient, r = -0.2.

Businesses and industries on the other hand were consuming an average of 10kg daily on charcoal for their respective activities; higher when compared to residential charcoal consumption. Comparing both residential and industrial fuel wood consumption to the daily supply of charcoal, it could be seen that, there is excess supply of charcoal of over 100kg on daily basis. This is mostly taken to urban cities or sold to middle women who were found to be ranked highest among the customers of charcoal of the interviewed charcoal burners.

There is a match between quantity consumed and expenditure on charcoal with the average daily expenditure on charcoal being GHS 0.96. On the other hand, businesses/industries are spending GHS 1.20 daily on charcoal; this could possibly explain their high level of consumption.

Table 4.8: Daily Expenditure on Charcoal consumed by households

Zones	Communities	Expenditure (GHS)					Community Average daily exp. (GHS)	Zone Average daily exp. (GHS)	Entire study Average daily exp. (GHS)
		0.0	≤ 0.5	0.6-1.0	1.1-2.0	>2.0			
Moist deciduous forest	Kutukrom	5%	90%	-	5%	-	0.50		
	Gwira Banso	-	-	92%	8%	-	1.00	1.5	
	Gwira Eshiem	10%	-	-	90%	-	1.80		
Secondary forest	Baimankor	-	-	-	100%	-	1.44		
	Anibil	-	-	-	15%	85%	2.25	0.60	0.97
	Dominase	-	30%	-	10%	60%	2.55		
Coastal savannah	Aguafo	40%	50%	-	10%	-	0.50		
	Nsien	10%	10%	40%	30%	10%	1.43	0.80	
	Edelesuazo	-	70%	30%	10%	-	0.60		

Source: Nzema East Municipal Field Survey, 2012

4.3.4 Education

From the study, 12 percent of sampled household members aged 15 years and older had completed a secondary school, post-secondary certificate, diploma or degree, while 19 percent had never been to school. There was a higher percentage of adults with a BECE or equivalent qualification. This scenario appeared consistent across the various communities and table 4.9 shows the details of this below.

Table 4.9: Educational Attainment of household members

Zones	Communities	Highest Educational Attainment (for 15+ years)			
		Never been to school	**Less than MSLC/BECE**	**MSLC/BECE/VOC/Tech**	**Secondary of higher**
Moist deciduous forest	Kutukrom	13.3	19.2	54.5	13.0
	Gwira Banso	14.0	19.3	53.5	13.2
	Gwira Eshiem	13.0	19.8	54.1	13.0
Secondary forest	Baimankor	34.5	5.9	54.8	4.8
	Anibil	33.7	6.8	54.4	5.1
	Dominase	34.1	6.2	55.3	4.4
Coastal savannah	Aguafo	19.6	16.5	45.4	18.5
	Nsien	19.3	16.1	46.8	17.8
	Edelesuazo	20.1	16.7	46.2	17.0
Entire Study Area		**19.2**	**17.0**	**52.0**	**11.8**

Source: Nzema East Municipal Assembly Field Survey, 2012

It can be said that the 19 percent of adults who have never been to school is lower when compared to the national percentage of 31. But those who have obtained a secondary qualification or higher (12 percent) is lower when compared to the national figure of 14 percent (GLSS 5, 2008). With a significant percentage of people being literates, its bears a positive implication for programmes which seeks to educate the people on the need for a sustainable energy supply and demand system. People will be able to understand the consequences of bad and inefficient use of fuel wood and charcoal.

4.3.5 Facility Availability

The facilities that are available in the communities make them capable or incapable to being able to adapt to changes in the climate. The study showed that, most of the selected communities were lacking some basic facilities and this could be said to affect their resilience to impacts of climate change. Table 4.10 shows the breakdown in the facilities that are available in all the selected communities.

Based on literature, certain facilities have been regarded as being a basic required in order for communities to be able to adapt to changes in climate. However, these facilities are dependent on the geographical and spatial location of the community.

Table 4.10: Facility Availability in communities

Zones	**Communities**	**Required Basic Facilities**					
		Road	**Health**	**Education**	**Market**	**Electricity**	**Forest Rv.**
Moist deciduous forest	Kutukrom	No	No	No	Yes	No	Yes
	Gwira Banso	Yes	No	No	No	No	No
	Gwira Eshiem	Yes	No	No	No	No	Yes
Secondary forest	Baimankor	Yes	Yes	Yes	No	Yes	No
	Anibil	Yes	No	No	No	No	No
	Dominase	Yes	No	No	Yes	Yes	No
Coastal savannah	Aguafo	Yes	No	No	No	Yes	No
	Nsien	Yes	Yes	Yes	Yes	Yes	No
	Edelesuazo	Yes	No	No	No	Yes	No
% of communities having access to facility		**80%**	**20%**	**20%**	**30%**	**60%**	**20%**

Source: Nzema East Municipal Field Survey, 2012

It is seen that, with the exception of access to roads and electricity, where over 50 percent of the communities have access to, the other facilities are limited to only 20 percent of the communities. Even with access to electricity, only communities located in the coastal savannah and some in the secondary forest zones have access to electricity. It can be said that, this phenomenon is not different from most rural communities and thus, inferentially, there is a limited capacity in rural communities to resist the shocks of climate change.

4.4 Energy Forms in Rural Communities

With basis from the previous section, this one builds on the established issues about the nature of the demographics in all the selected communities and the study as a whole. Energy forms in chapter three (section 2.3) had been explained and grouped into various categories. This study has shown that majority of energy forms in rural communities are traditional wood fuels. Details of energy forms have been shown in the following discussions.

Table 4.11: Energy forms available in rural communities

Energy Forms	Available	%	Not available	%
Fuelwood	90	100.00	0	0.00
Charcoal	90	100.00	0	0.00
Electricity	60	66.70	30	33.30
Kerosene/petrol/diesel	88	97.80	2	2.20
LPG	13	14.40	77	85.60
Solar PV	0	0.00	90	100.00

Source: Nzema East Municipal Field survey, 2012

Rural livelihoods are mostly characterized by poor access to modern energy sources and over-reliance on traditional biomass, especially wood fuels (Thiam, 2009). All the selected communities have access to fuel wood and charcoal as compared to the 33 percent of the rural communities who have access to electricity and 14 percent have access to LPG sources. The indication here is that, more reliance will depend on the local wood fuels which are in "abundant" in these areas - as was the main reason provided by respondents regarding why majority were using wood fuels. As a result of this, most households were using traditional wood fuels for domestic purposes. More than half (57 percent) of the households were using a combination of traditional wood fuels; either fuel wood only or a combination with charcoal and other fuels. The details of these are discussed in table 4.12.

Table 4.12: Energy forms used in households

Energy Forms used in Hh	Frequency	%
Fuelwood only	8	8.90
Fuelwood and Charcoal only	13	14.40
Fuelwood and electricity only	10	11.10
Charcoal and electricity only	3	3.30
Fuelwood, Charcoal and electricity only	25	27.80
Fuelwood and others only	24	26.70
Fuelwood, charcoal and others only	5	5.60
All energy sources	2	2.20
Total	**90**	**100.00**

Source: Nzema East Municipal Field survey, 2012

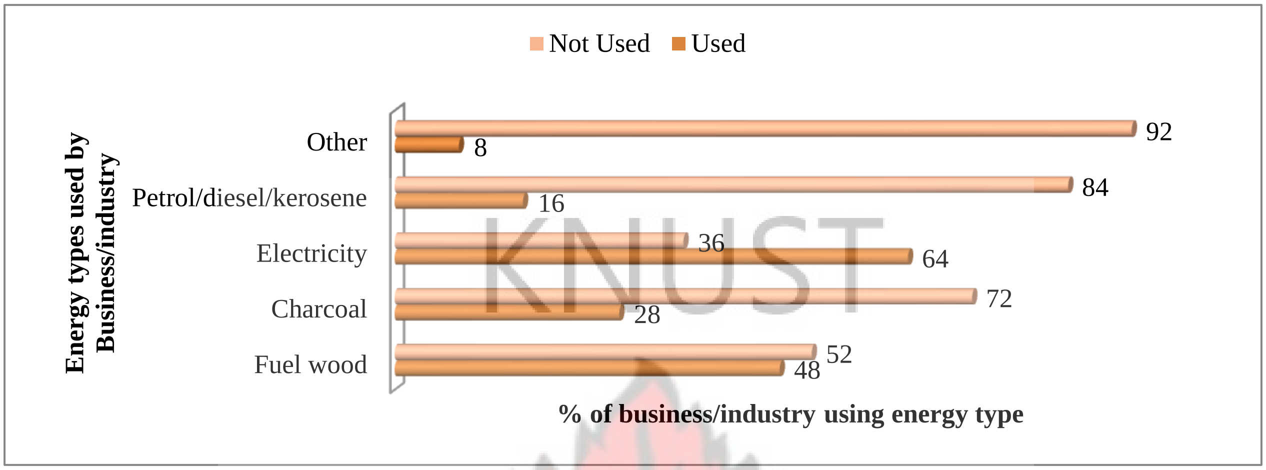
Inasmuch as rural residential energy is dependent on traditional fuel wood and charcoal, most (64 percent) rural commercial entities - figure 4.5 details out this discussion; relied on electricity for their activities. This was as a result of the nature of the commercial activity they were engaged in. About 60 percent of the businesses interviewed (as per the type of businesses available) were operating either groceries shops, hair dressing or milling operators; which require more of the use of electricity compared to the traditional types - fuel wood and charcoal.

Figure 4.4: Fuel wood being trolled for sale

Source: Source: Nzema East Municipal Field survey, 2012

But the study shows that, more business entities are willing to change from their traditional wood fuels and charcoal to electricity and LPG sources as about 76 percent of the businesses were in this bracket. Businesses who were willing to change from their current energy form, attributed their willingness to health related problems associated with the wood fuels and also the type of activities they were undertaking.

Figure 4.5: Energy forms used by Businesses/Industries



Source: Nzema East Municipal Field survey, 2012

This confirms studies which assert that, pollution from these fuels kills about 1.6 million women and children each year (World Bank, 2011). However, it should be added that, households were not as much willing to change from their preferred status quo. About 66 percent of interviewed households were not willing to change from their current energy form to a more modern energy form, that is electricity and/or LPG in this regard. The main attributing factor was that, current wood fuels and charcoal were easily accessible and the only available option; a significant percentage also concluded that, they had been accustomed to the traditional energy forms and so changing to a modern form is 'culturally unaccepted'.

These imply that, even with the introduction of modern energy forms like electricity and LPG, rural households are more likely to continue to use the traditional wood fuels and charcoal while on the other hand, commercial entities in rural communities are more likely to change to a more modern energy form for their activities. Given this prediction, pressure and over-exploitation on the natural forests for wood fuels needs to be checked. Data from the Forestry Services Division responsible for NEMA forest zones indicated that, the off-forest reserves were depleting at an alarming rate over the past five (5) years. The study was able to identify that, an average of about 2.5 hectares is lost every year in the area; with on-forest cover of about 104.45 hectares and off-forest cover of about 600 hectares[3]. It must be said here that, this figure was calculated based on certain socio-economic factors; these were average land coverage of farming (specifically cocoa) activities, mining activities, road construction and residential developments. The indication was that, obtaining absolute figures for off-forest reserve depletion was difficult if not undoable. This was due to the fact that, the department had no jurisdiction over such areas as compared to the on-forest reserves and data on the number of trees fell was difficult to obtain. Most threatening was the fact that, the rate of natural growth or forest replenishment had reduced due to increase in average temperature and evaporation (these will be discussed further in the subsequent sections).

4.4.1 Energy Forms at different altitudes in Rural Communities

The above discussions have outlined the nature of energy forms in the rural areas selected and their implications. However in most cases, the ecological and socio-economic conditions are varied in a given context being national, regional or local. As a matter of fact, these considerations are put forward in this study in order to identify further in detail the variations in each rural locality. The study identified three (3) varying zones in NEMA; the coastal savannah, the secondary forest and the moist deciduous forest zones.

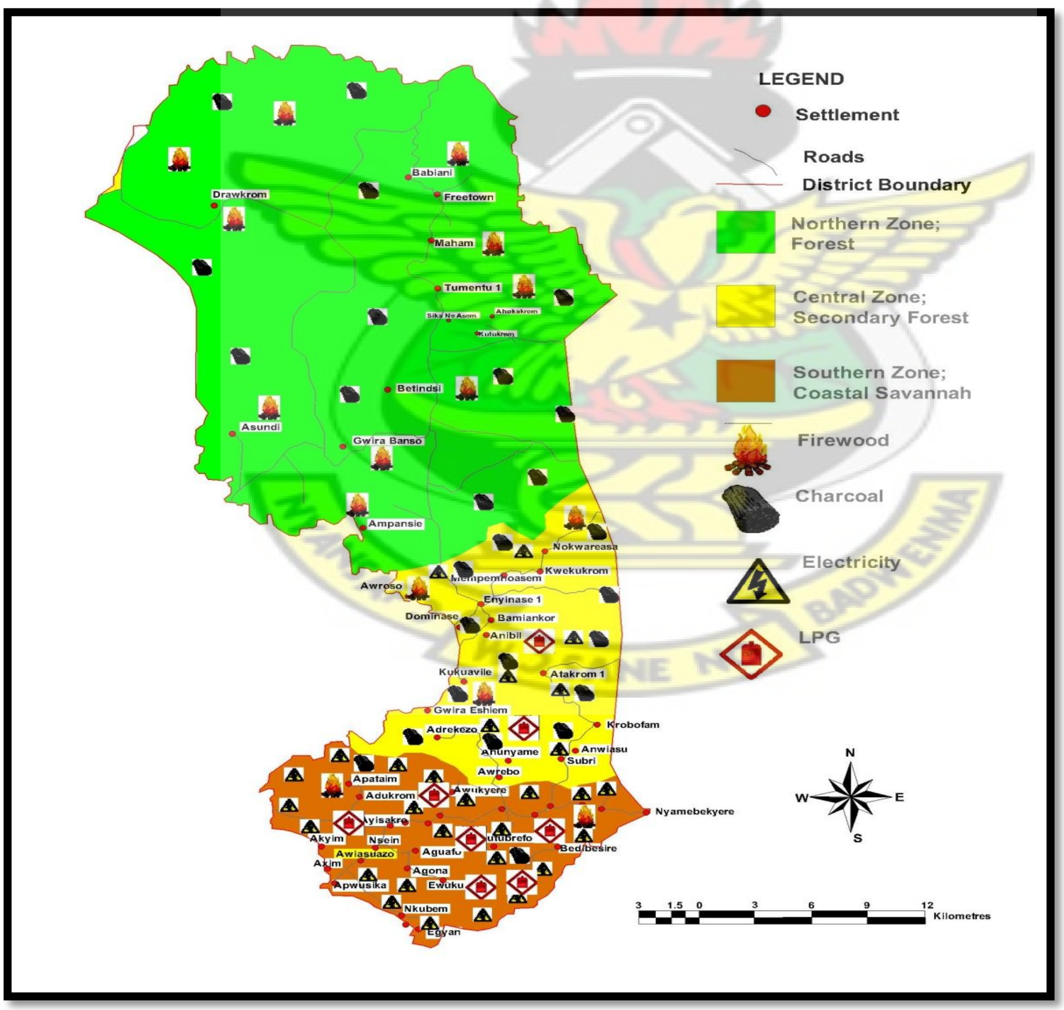
4.4.1.1 The Coastal Savannah

This area is located along the coastal belt of NEMA characterized by a vibrant economy and an appreciable level of infrastructure base and densely populated. This is as a result of the presence of the municipal's capital - Axim. The study indicates that, almost all communities (97 percent) selected have access to and use electricity and LPG while almost all households representing 90 percent expressed willingness to continue to use their current energy source. Indicating more access to modern energy forms as compared to a more large view of the rural context. The use of the traditional energy forms (fuel wood and charcoal) under consideration were dominant in this zone with about 85 percent of interviewed households using charcoal and all households using fuel wood. Despite the high access and use of modern energy, as discussed above, more people still use the traditional forms of energy sources for domestic cooking and heating.

[3] Estimated with the forestry service division and cartographer

It should be noted that, the forest cover in this zone is smaller in size compared to the northern and central parts of NEMA, largely as a result of road, housing and other physical developments occurring in the area, the study showed. Inferentially, it is logical to state here that, a less physical access to wood fuel sources will more likely propel the use of more modern and available alternatives of energy forms; however, there will still be more households using the traditional energy forms. This has been realized in the coastal savannah zone of the study area as more (97 percent) households are using modern energy forms in combination with the traditional ones, with 100 percent and 85 percent of households using fuel wood and charcoal respectively. Figure 4.6 shows the various geographic differences in the study area and their different rural energy forms.

Figure 4.6: Variations in energy forms across different geographies



Source: Author's construct, 2012

4.4.1.2 The Secondary Forest

This zone is within the centre of the study area where there is some level of development. Here the population is spread wider than the coastal zone with few agglomerations. It was found out that, 70 percent of the communities have access to modern energy in the form of electricity; however very few (8percent) had access and were using LPG. Compared to the coastal zone, less than 97 percent of households have access to and use the identified modern energy forms. The study showed that, in this zone, about 60 percent households were using charcoal while all the interviewed households were using fuel wood.

The reduced percentage of households using charcoal was explained by its high cost. This assertion is verified when the average monthly income of the zone computed for is compared with the coastal savannah zone; GHS 350.00 was recorded in the coastal savannah compared with a rather lower GHS 250.00 in this zone.

4.4.1.3 The Moist Deciduous Forest

The zone is located in the northern parts of the study area where there is large scale of forestry and where majority of the on-forest reserves of the municipal are located. Here the population is vastly spread with smaller communities. It was found out that, none of the selected communities in this zone have access to any form of modern energy; however it was identified that, there was oil sources in the communities, still none of the interviewed households were using it. Compared to the coastal zone and secondary zones, not as much as 97 or 70percent of households have access to and use any form of modern energy. The study showed that, in this zone, only about 20percent households were using charcoal while all the interviewed households were using fuel wood.

This zone was the highest monthly income earner; mainly due to large scale cocoa farming in the zone; recording a monthly average income of GHS 800.00. Paradoxically, its charcoal use was the least (20 percent) compared to the previous two zones. The small percentage of households using charcoal cannot be here explained by how expensive it is to buy it but was rare to come by in the area and most importantly, households responded that, the over abundance of fuel wood did not provide the impetus to consider maximum charcoal use.

In summary, the fuel wood consumption rate remained the same throughout all three zones, but the rate of charcoal use oscillated considerably across the different areas. It was realized that, in the northern parts where access to large forests were available, the use of more charcoal was very minimal; and even though there was no physical access to some modern energy forms (electricity and LPG), households had the economic ability to acquire them, but remained reliant on the traditional ones due to its abundance. It should be said here that, this attitude could lead to higher demand on forest resources to satisfy household energy needs.

Although the picture we get from such data is not conclusive, one gets an idea of the importance of wood fuel and charcoal, as well as the rural energy situation in these rural communities. This pattern is not likely to change in the next several decades, with dire consequences on natural forests which supply rural households with wood fuels and charcoal.

4.5 Energy Consumption and Supply

Against the fact that, majority of households are dependent on fuel wood and charcoal, and that access to and use of modern energy forms vary from the three zones identified, this section discusses the consumption and supply levels of fuel wood and charcoal and tries to calculate the volume of these energy forms consumed by households and businesses/industries as well as the amount supplied by the few energy markets identified.

4.5.1 Energy Consumption

Fuel wood and charcoal consumption in households are quite different from businesses/industries as discussed in section 4.4 above. The amount of these energies consumed are increasingly scaling up over the past five years in all selected communities. In households, for example, it was realized that, about 94percent admitted that there has been an increase in wood fuel and charcoal consumption over the past five years; with as much as 66percent confirming increase in consumption by more than twice their previous consumption level. Consumption levels in businesses/industries are however not very similar to the above. With about 70percent of the businesses/industries agreeing that the traditional energy consumed over the past five have increased, 55percent out of this confirmed that the increase had been more than 50percent of the previous level.

4.5.1.1 Quantity of energy consumed daily

The quantity of fuel wood and charcoal consumed varied across households and businesses; it was realised that the businesses/industries using fuel wood and charcoal were consuming bigger quantities as compared to household levels. On a whole, businesses were consuming about 180kg of fuel wood and about 10kg of charcoal daily while households were consuming a lesser 13.31kg of fuel wood and 3.22kg of charcoal averagely every day. Households were spending GHS 0.60 daily on fuel wood and GHS 0.97/day on charcoal; while businesses/industries were also spending about GHS 4.10/day on fuel wood and GHS 1.20/day on charcoal.

The tree types that were mostly used as fuel wood were "dahoma" (*piptadenniasastrum africanum*), "ofram" (*Terminalia Superba*), rubber tree, mahogany (*Khaya spp.*) and bamboo. From most used to least used is as follows, bamboo, "dahoma", rubber tree, "ofram" and mahogany respectively. Taking households' fuel wood consumption levels into consideration, the volumes of wood consumed per day varied from household to household; this was the case because it was found out that factors including the number of adults in a household determined the quantity in volume of wood collected per head-load per day. Data from the field survey showed a very strong positive correlation ($r = 0.893$ and $r^2 = 79\%$) between household size and quantity of fuel wood collected daily. Commonly, larger households are expected to increase fuel wood consumption since there is assumed larger demand as well as plenty hands to collect fuel wood.

On the case on charcoal, this was quite different as the purchasing power of households became the main factor affecting the quantity consumed daily; thus, there was a weak positive correlation ($r = 0.147$ and $r^2 = 2\%$) between household size and the quantity of charcoal consumed daily. When the correlation between household income and charcoal consumption was computed, it revealed a very weak negative correlation ($r = -0.069$ and $r^2 = 0.5\%$). Though this information is obscure, it is clear enough to say and infer that, the amount of charcoal consumed daily in rural households is very much dependent on household size as well as household income level. As discussed earlier in section *4.4.1.3* above, charcoal consumption could be strongly affected by its availability in the area as well as abundance or otherwise of fuel wood sources in the area.

4.5.2 Energy Supply

Though the fuel wood and charcoal are deemed as a renewable resource, their supply for consumption is making the forests disappear more rapidly than they are being replaced. The study results from the forestry service division estimates that about 2.5 hectares of off-forest reserve forests are being lost annually to fuel wood consumption , agriculture, uncontrolled burning, mining and other factors, with about 80percent of the cleared forest never replanted. This phenomenon is feared to continue into the future and thus lack of access to fuel wood and charcoal is feared in the area, "all other things being equal". The energy providing entities that were interviewed showed the trends and patterns of supplied and the most patronising consumers. Two different traditional energy producers/providers were identified and interviewed; charcoal burners and fuel wood sellers.

4.5.2.1 Quantity of energy supplied daily

It was realised that, all the interviewed charcoal burners were burning using the traditional earth mound method and they did not know of any other method when asked about the charcoal kiln and the sealed metal container; though these methods have been tested and found out that they burn effectively with less waste of wood and pollution to the environment and human health. It takes an average of about 72 hours (3 days) to complete a single charcoal burning batch, and from this, the majority (70 percent) were obtaining between 50 and 350kg of charcoal per day; with a daily average supply of 125kg.

It was understood from the survey that, the main customers of the daily charcoal produced were the middle women followed by food vendors and then households. This explains the previous assertion that businesses/industries were consuming more charcoal than the households. It also came to light that, majority (80 percent) of the charcoal produces were obtaining their wood by felling trees themselves and a few (20 percent) were buying wood from wood operators.

Looking at the daily supply from the fuel wood perspective, a different picture could clearly be seen. An average of about 175.5kg wood is collected daily for supply and this ranged between

120 and 300kg. The main consumers here were rather households then followed by food vendors before the middle women; when compared to the patronising consumers of daily charcoal production. The survey revealed that, majority (70 percent) of the respondents were either felling trees or hand picking woods for sale. This again emphasises the threats posed to the forest and the rate of annual depletion of about 2.5 hectares (NEMA, 2010).

Both charcoal and fuel wood producers were felling trees to obtain their raw materials for production and sales; and thus about 70 percent were very much unwilling to change their current energy market to an alternative one. The reasons they gave was that, demand for this form of energy is high in rural areas compared to the other alternatives like LPG, oil, among the modern energy forms. It was computed that there has been a large increase in supply over the past five (5) years due to increasing demand. The majority (80 percent) of the respondents indicated that between 80 percent and 200 percent increase in the supply of energy (both fuel wood and charcoal) had been recorded the last five years. However, the remaining 20 percent recorded a reduction in supply of about 20 percent and attributed it mainly to low labour capacity and limited wood for production. This triggers the alarming bells of no more forests for traditional fuels supply. If the current reduction in supply is about 20percent, then in the next few years given the rate of forest depletion, more reductions in supply will be recorded. Figure 4.6 shows forest depletion in pictures. This picture is seen in most parts of the study area, in pockets within forest zones and along major trunk roads in the area.

4.6 Willingness to Change current energy use

It is found out that, rural people are not willing to change from the use of charcoal and fuel wood into a more modern form of energy source. Although majority (80percent) of households are willing to use modern energy forms (electricity and to a smaller degree LPG), it was realized that, they are very unlikely to completely change their current energy use to modern energy to dominant the residential energy mix.

This is the case in the short run but in the long run, households are unable to accurately predict their preference changes. What is clear from the study is that, in comparing the communities having access to electricity and LPG to those having no form of modern energy, it was realized in both cases that, willingness to completely use modern energy was still minimal; households in both scenarios are heavily dependent on fuel wood and charcoal, with about 13 percent[4] using electricity and here, only as a source of lighting.

Figure 4.7: Forest depletion in pictures

Source: Nzema East Municipal Field survey, 2012

4.7 Climate Change Variables and their Behavior in Rural Communities

From the study it has been realized that the average weather conditions which make up the climate of NEMA have changed over the past 30 years. The variables that affect climate change may include wind speed, air pressure, relative humidity, precipitation, temperature among others. However, due to time and financial constraints the variables considered are only limited to rainfall, temperature and sunshine and evaporation; over a period of seven (7) years from 2005 to 2011, with additional estimates for the past 30 years being used as the benchmark.

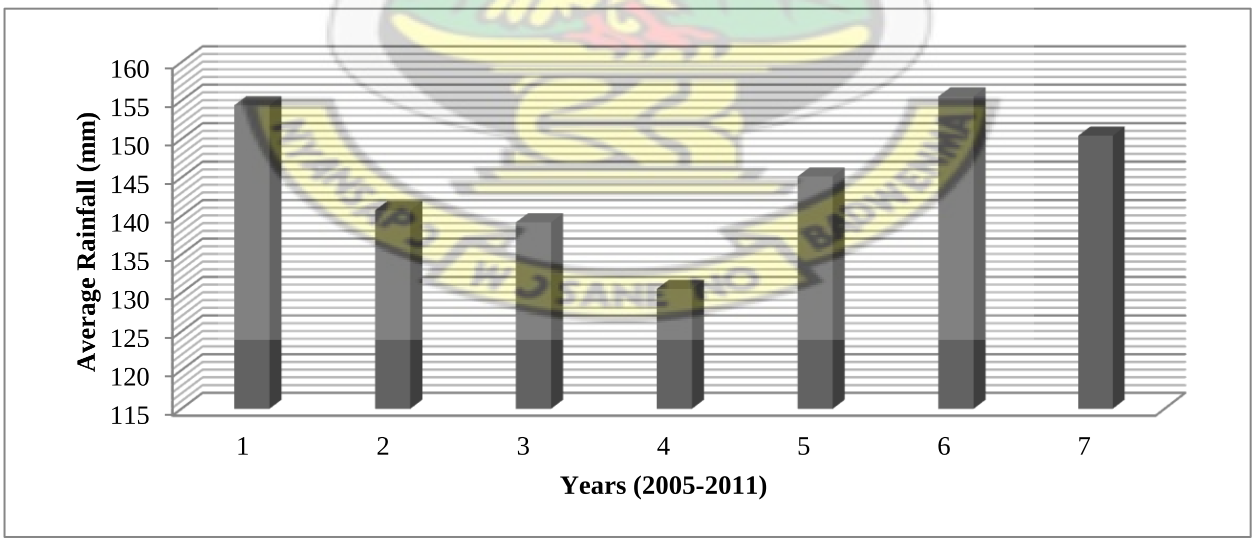
[4] This reflects households in communities with access to electricity and it was mainly found in the secondary forest and coastal savannah zones.

4.7.1 Rainfall

NEMA has over the past decade been seen as the wettest zone in Ghana, with Axim[5] recording the highest rainfall annually of over 3000 mm. The study showed that, the trend in rainfall was falling from 2005 to 2008 (154.4mm to 130.5mm) and then climb up again from 2009 to 2010 (145.1mm to 155.6mm) before starting to drop in 2011. Though from 2009, rainfall could be said to increase, it was realized from the survey that, this increase was not near the normal average rainfall over the past decade which stood at over 3000mm p.a. and even started dropping again in 2011. Currently, Tarkwa township records in highest average annually rainfall in Ghana, a feat which recently was recorded in NEMA.

The falling rainfall patterns between 2005 -2008 and 2010-2011 can be attributed, but not limited, to increase in daily sun shine - to be discussed in following section - which is causing large evaporations of water bodies as identified in the Axim, Bamiankor and Eshiem area. As a result, answers to the question why the rate of forest re-generation (after the annual 2.5 hectares loss) is very low, can be provided; that "due to the falling rainfall patterns, plants' growth rate are staggering and stunting", as identified by the district's Assistant Forestry Manager I (Mr. Tachie Samuel).

Figure 4.8 Average annual rainfall pattern



Source: NEMA Meteorological Service Department, 2012

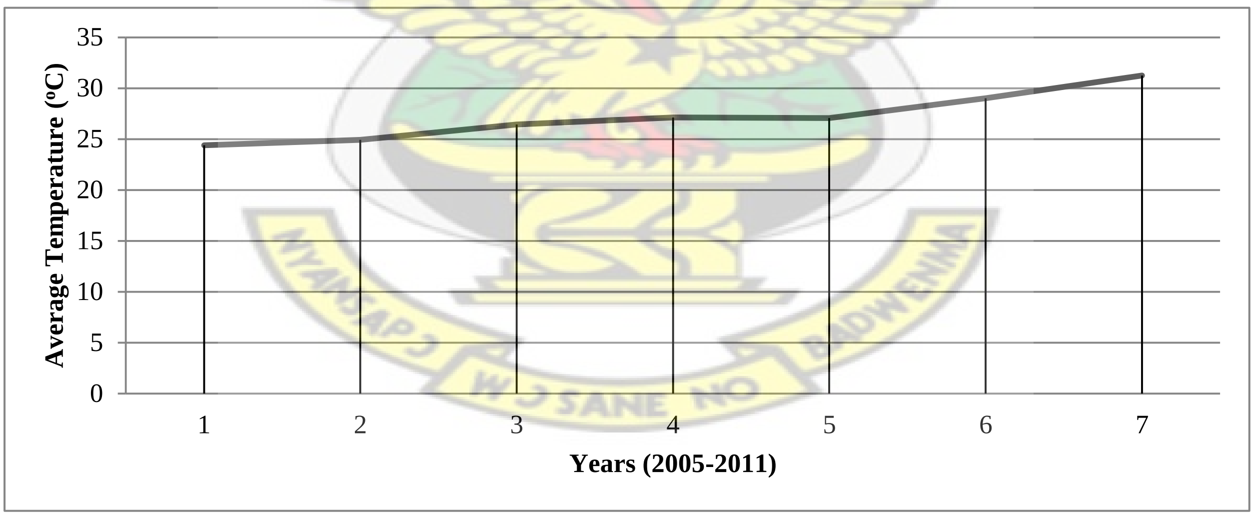
[5] Capital of NEMA

4.7.2 Temperature

The normal average temperature of NEMA for the past decades was 23.5^{o}C, but over the past 10 to 20 years this has increased significantly. The increase in temperature has now caused the normal temperature to range between 24.9 ^{o}C and 31.2 ^{o}C. The study has been able to identify that, temperatures over the seven years under consideration have generally been increasing; see figure 4.9. However, according to the municipal assembly's meteorologist, average temperatures are cooler; ranging between 19 ^{o}C and 22 ^{o}C; at night and dawn. It was found out that, this is only the indication of higher temperatures during most parts of the day. The increasing temperatures, a indication of atmospheric warming in the study area, and confirmation of global warming, is a contributing factor to high surface water evaporation rates.

It can be said here that, the increasing temperatures recorded over the seven years can be attributed to the fast rate of forest cover depletion (2.5 hectares p.a.); since the forest absorbs CO_2 in the atmosphere, lesser forests will allow large amounts of CO_2 causing atmospheric warming and hence increasing temperatures.

Figure 4.9: Average temperature

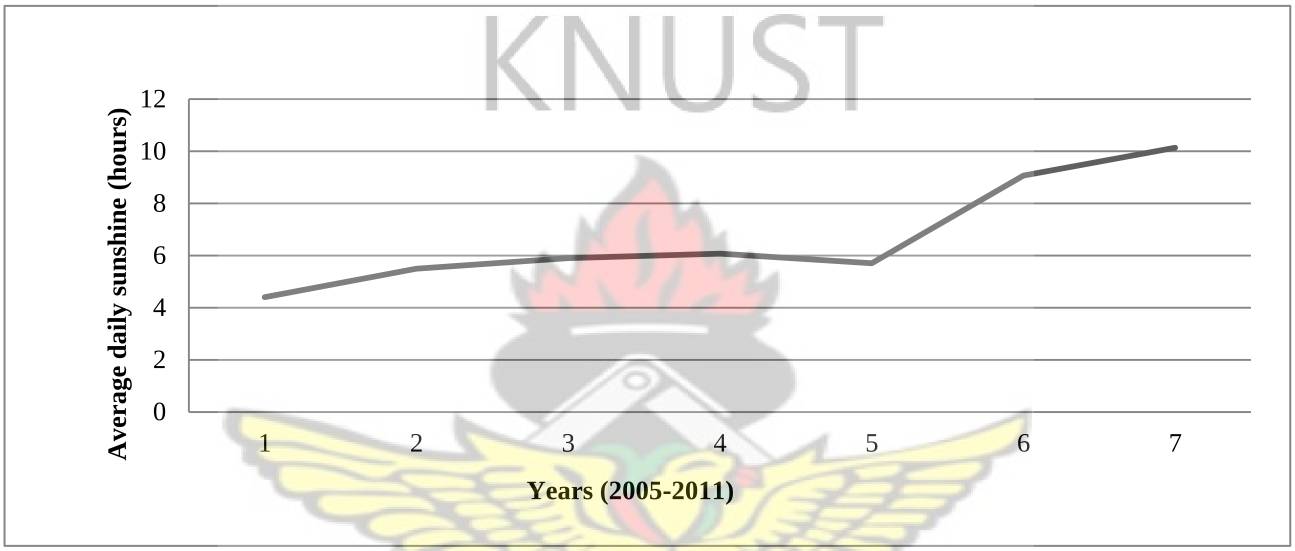


Source: NEMA Meteorological Service Department, 2012

4.7.3 Sun Shine and Evaporation

Over the past decade, sunshine was recorded at an annual average of between 2hours to 2.5hours daily, but since the past 20 to 30 years this has increased to between 5.7hours to 6.1hours. This has also affected water evaporation to increase from a normal average of about 0.02mm to about 1.5mm over the past 20 to 30 years.

Figure 4.10: Sun shine record in hours/day



Source: NEMA Meteorological Service Department, 2012

The increasing hours of sun shine per day becomes very disturbing especially now, when the amount of surface water bodies are also evaporating rapidly. The fear here is that, water bodies in NEMA supports plant growth in most (95percent) of the rural communities selected. Specifically, bamboo, which is one of the preferred tree types for fuel wood source, thrives better along these water bodies or areas near to water bodies.

Inferably, as the water bodies die, the number of bamboos that will be available for use as fuel will be limited; and coupled with the increase in demand and the already diminishing forests, bamboo species could go extinct with these continual prevailing factors.

In summary, the climate change indicators discussed above show that, climate change is a phenomenon in NEMA. Increasing temperatures, reduced rainfall regimes, increasing hours of sun shine as well as increase in rate of surface water evaporation are indications of a change in the climate of NEMA. It is known that, these indicators were decades ago more favorable with lower temperatures and high rainfall regimes as well fewer hours of sun shine and smaller amounts of surface water evaporations.

4.8 Rural Energy and Climate Change Impacts

It is known from literature that climate change would impact energy supply and demand as well as energy use also impact climate change (Ogunlade, 2001; REEEP, 2008; Thiam, 2009; Tester et. al., 2009). But, the data presented so far indicates that, it is impossible for methodological justifications to prove a single causal connection between, for example, the level of energy consumed or supplied within a period on one hand and rise in NEMA's mean annual temperature or mean annual rainfall. This makes quantification of the linkages between these two phenomenon also impossible.

Notwithstanding, it has become clear enough from the issues presented, that, changes in growing conditions have contributed to the fast depletion of biomass (fuel woods and charcoal resources), as well as reduce the prospects for carbon sequestration in forest resources. This could worsen current trends in the depletion of biomass energy stocks in NEMA, which is already depleting at 2.5 hectares annually. Although the traditional energy sources are renewable and may be adaptable to new climate, its heavy dependence might make NEMA's rural areas relatively more sensitive to climate.

The subsequent sections will look at the effects between climate change and both energy demand or consumption and energy supply. The issues under consideration will include, based on data gathered, how energy consumption is affected and affects climate change and also how the supply of energy in rural NEMA is affected and affects climate change.

4.8.1 Energy Consumption and Climate Change

Most (98 percent) rural communities in NEMA currently consume fuel wood and charcoal for water heating for domestic purposes; and out of this, 86percent and 9percent use fuel wood and charcoal respectively. With increasing average temperatures and its accompanying cooler dawns, households are more likely to increase the energy consumption on water heating as it was identified that water heating was mainly for bathing at early mornings before household members leave for work (mostly farming).

The average daily consumption of fuel wood, which is 13.31kg, is likely to increase exponentially given the strong positive correlation (r = 0.893) between household size and fuel wood consumption. This is so in the case of fuel wood because, majority of the households were using it for water heating and it was deemed cheaper by respondents when compared to charcoal usage. Inferentially, demand for "ice water" will also increase as a result of increasing temperatures causing warmer afternoons; and from the survey, most of the communities were using "ice block" to chill their household water sources since majority (60percent) did not own refrigerators. Energy needs for refrigerating will increase as a result.

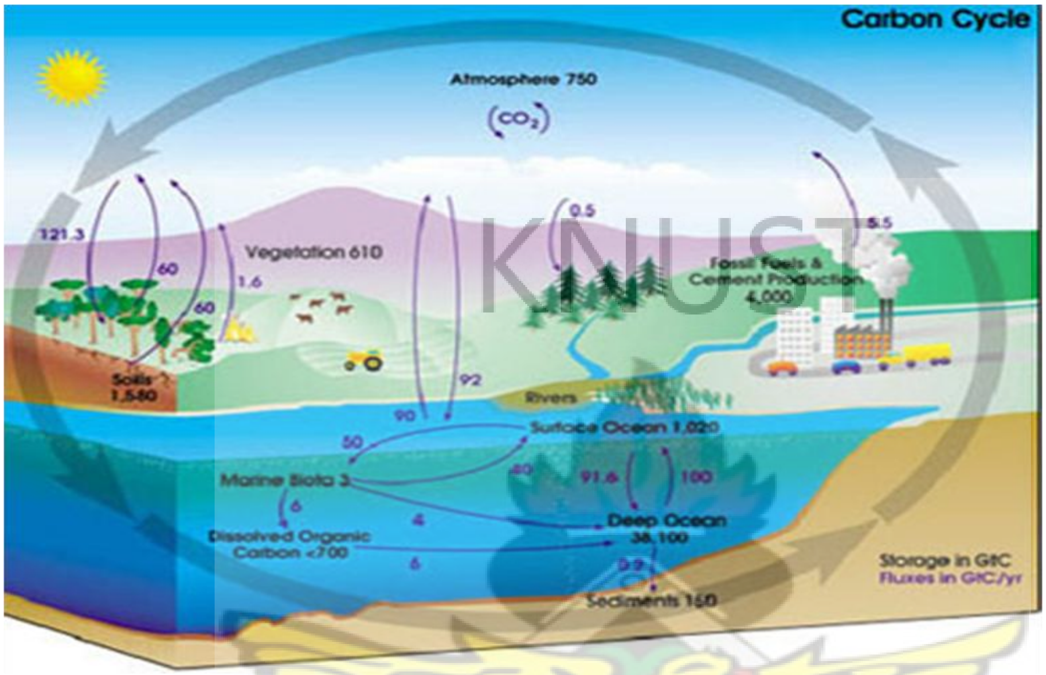
In addition, with household and business/industrial energy demand increasing and continue to increase, pressure will be on the natural forests which serve most of these rural communities with fuel wood and charcoal resources. If the further depletion of forests become imminent, carbon sequestration will freeze and contribute towards global warming and its consequences.

4.8.2 Energy Supply and Climate Change

The average daily fuel wood and charcoal supply in the study areas; 175.5 kg and 125 kg respectively; are more likely to increase exponentially over the next five to ten years. Based on the fact that, over the past five years, fuel wood and charcoal supply had increased by about 80 percent to 200 percent, using logical reasoning for forecasting, over the next five to ten years, fuel wood and charcoal supply could increase to about 351kg daily and 250kg daily respectively, with all other factors held constant. Looking at this scenario, natural forests which is the main source for fuel wood and charcoal, is gradually being extremely exploited.

But falling rainfall patterns coupled with increasing temperatures and longer hours of sun shine, also distorts forest regeneration after felling trees for fuel; as can be seen from figure 4.3. Since demand is concentrated on fuel wood and charcoal for domestic and commercial purposes, supply will respond with aggressive destruction of the natural forest and the impacts of the change in climate with respective to falling rainfall and increasing temperature, discussed earlier, will impede growth of depleting forests. The future looks bleak in terms of quantities of available energy stock from the natural forests. Figure 4.10 models the vicious cycle of forest regeneration and carbon sequestration; information from the survey was used in this modelling.

Figure 4.11: Model of forest regeneration and carbon cycle



Source: Cambridge Centre for Climate Change Mitigation Research, 2012

In summary, although the above discussed scenarios, statistically remain speculative, they have provided insights on the nature and orders of magnitude of future scenarios in rural communities. The fact still remains that energy demand is increasing exponentially with supply but the natural forest is not regenerating exponentially. However, the study has been able to attribute this to the indicators of climate change discussed - falling rainfall, increased temperatures, increased daily hours of sun shine and increased evaporation rates.

CHAPTER FIVE

MEASURING SUSTAINABLE ENERGY

5.1 Introduction

Fortunately, trees when properly managed are renewable energy sources; while some will take about 10 years to grow, others grow without planting. However, this advantage is now being threatened with the incidence of climate change which affects the regeneration rate of some tree types and even some tree species that will strife in certain ecological zones might go extinct. Hence trying to sustain energy in rural areas along the lines of climate change becomes a key development issue in recent times. There is the need to adapt to this changing climate through finding sustainable means of obtaining energy and its consumption.

On this premise, this section seeks to find the nexus between sustainable energy and climate change adaptation in rural communities. But as a baseline to the climate change phenomenon, which has been discussed earlier in the previous chapter, carbon emissions from fuel wood and charcoal consumption in the selected communities will be computed and discussed.

5.2 Carbon Emissions: Rural Contribution

It is very clear that no technology for energy production or its conversion is without waste. As a result, most literature on energy have argued for a more renewable energy alternative to fossil fuels and championed the use of water, wind, biomass among others. But, given that currently over a third of the world's population rely on fuel wood and charcoal (Thiam, 2009; REEEP, 2011) as confirmed by this study, that all rural households use fuel wood and charcoal, there is also the fear of carbon waste emissions.

Along the line of production and conversion, all energy chains, from the extraction of resources to the provision of energy services, pollutants are produced, emitted or disposed off. It is very important to identify and be able to measure the amount of carbon emitted via fuel wood and charcoal daily consumption, when the issue of sustainable energy is being analyzed amidst climate change. Although fuel wood and charcoal are renewable and are highly recommended, this cannot be taken for granted; as the amount of carbon emitted from such mass fuel consumption is often unnoticed. Often such renewables are regarded as environmentally and socially beneficial, unfortunately, it is not intrinsic in biomass energy, but dependent on "site- and fuel cycle-specific factors" (Hall and Scrase, 1998).

Against this backdrop, the carbon emissions are calculated in all the selected communities and this is done based on the various zones identified - moist deciduous zone, secondary forest zone and coastal savannah zone - as well as pertaining to the whole study area.

5.2.1 Calculating Fuel wood and Charcoal Carbon Emissions

The methodology[6] adopted for the calculating the amount of carbon emitted through the consumption of fuel wood and charcoal in residential and commercial/industrial activities is computed as follows;

1. *Carbon Footprint Calculations*

Emissions (tCO_2/year) = Per capita energy demand (kWh/person-year) x Population (persons) x Emissions Factor (tCO_2/kWh)

Alternatively;

Emissions (tCO_2/year) = Per capita final end use energy demand (kWh/person-year) x Population (persons) x Emissions Factor (tCO_2/kWh) / Efficiency (no units)

2. *Emission Factor (tCO_2/kWh)*

Emissions factor for Fuel wood (wood logs) = 0.382 tCO_2/kWh

Emissions factor for Charcoal = 0.018 tCO_2/kWh

3. *Population Figures*

Total population = number of households (90) x average household size (6.21)

= 558.9 (approximately 559)

[6] This approach is adopted from Cambridge centre for Climate Change, 2012

4. *Conversion from kg to kWh [Conversion units by Quaschning, 2012]*

1kg = 8.14kWh

5. *Calculations*

I: Fuel Wood

Energy Demand:

Fuel wood demand per day = 193.3kg

Conversion into kWh = 193.3kg/1kg x 8.14kWh

= 1,573.5434kWh

Fuel wood demand per annum (356days) = 878.5502kWh x 356days

= 560,181.45kWh/yr[7]

- Moist Deciduous = 231,466.98 kWh/yr (41.32%)
- Secondary = 143,742.56 kWh/yr (25.66%)
- Coastal Savannah = 185,980.24 kWh/yr (33.02%)

Emissions from Fuel wood

560,181.45kWh[8]/yr x 0.018 tCO2/kWh = ***10,083.27 tCO2/year*** ....**(1)**

- Moist Deciduous = 4,166.41tCO2/year
- Secondary =2,587.37 tCO2/year
- Coastal Savannah = 3,347.64tCO2/year

II: Charcoal

Energy Demand: Charcoal

Charcoal demand per day = 13.22kg

Conversion into kWh = 13.22kg/1kg x 8.14kWh

[7]The total energy demand per year already includes the total population (in that Energy/population: per person multiplied by population leads to energy demand)
[8] Refer to 1

= 107.61kWh

Charcoal demand per annum (356days) = 107.61kWh x356days

= 38,309.16kWh/yr[9]

- Moist Deciduous = 9,473.86kWh/yr(24.73%)
- Secondary = 20,112.31kWh/yr (50.25%)
- Coastal Savannah = 9,584.95kWh/yr (25.02%)

Emissions from Charcoal

38,309.16kWh/yr[10] x 0.382 tCO_2/kWh = ***14,634.10 tCO2/year*** ....**(2)**

- Moist Deciduous = 3,619.01 tCO2/year
- Secondary = 7,682.90 tCO2/year
- Coastal Savannah = 3,661.43 tCO2/year

From (1) and (2), the total carbon footprint of the community from fuel wood and charcoal is ***32,485.45 tCO2/year***. The emissions per person (from fuel wood and charcoal) = 58.11 tCO2/year.

Conclusions

Even though per capita consumption is low compared to fuel wood, its effects on climate change is high due to the emissions factor. Therefore if measures are not in place to efficiently use charcoal; via proper improved end use equipment, carbon emissions could be very high in charcoal consumption. Though these emissions cannot be compared to that of the carbon emitted via fossil fuels but it is still important identify and understand the contributions of fuel wood and charcoal to the emission mix in Ghana since majority of the population use these energy forms.

High energy demand or consumption does not necessarily mean or produces high emissions. The determining factor is the type of energy being used and the corresponding emission factors (high energy demand for fuel wood but produces less emissions as compared to charcoal demand). The

[9] Refer to 1
[10] Refer to 1

demand for fuel wood is approximately four times as much as charcoal, however the emissions is the reverse.

When the carbon emissions are compared to the various income groups in the sampled households, it is realised that there was strong positive correlation ($r = 0.85$) between higher incomes groups and higher per capita carbon emissions. This implies that, households with higher incomes consume more fuels and thus the higher carbon emissions.

5.2.1.1 Net Primary Production Calculation

After identifying and calculating the amount of carbon emitted through the consumption of fuel wood and charcoal in the study area, it is also very important to find out the rate at which the natural forests capture carbon (carbon sequestration); this process requires the net primary production calculation. Net primary production is the rate at which all the plants in an ecosystem produce net useful chemical energy; it is equal to the difference between the rate at which the plants in an ecosystem produce useful chemical energy (GPP) and the rate at which they use some of that energy during respiration. Both the gross and net primary productions are in units of mass/area/time. In terrestrial ecosystems, mass of carbon per unit area per year ($gC/m^2/yr$) is most often used as the unit of measurement. The carbon sink calculation is as follows (the same methodology as in the carbon emissions calculation is applied here);

- *Capture and Sequestration Sinks*

  Rate of movement from air to vegetation (tCO_2/yr) = $\sum$Net Primary Productivity-NPP ($tCO_2/m^2/yr$ or $gC/m^2/yr$) × Area (m^2)

- *Net Primary Productivity (NPP) of Tropical Forests = $925gC/m^2/yr$*
- *Conversion from acres to square meters*

  1acre = $4046.856m^2$; the forest cover of the study area is considered here.

  30,000 acres = $30{,}000 \times 4{,}046.856m^2$

  $= 121{,}405{,}680m^2$

- *Calculations*

  Carbon sink $= 925gC/m^2/yr \times 121{,}405{,}680m^2$

  $= 112{,}300{,}254{,}000\ tCO_2/yr$

  ≈***<u>112billion tCO2/yr</u>***

Conclusion

It should be said here that, though the carbon sink is a measurement of capture, it is only a crude way of indicating how the situation looks like as it is very difficult to segregate carbon in the atmosphere; notwithstanding, it provides some indications for decision making. Hence comparing the sink value (112billion tCO2/yr) to the emission value (32,485.45 tCO2/year), it is seen that, there is more room for carbon emission on the basis of charcoal and fuel wood only. However, this is never the case as carbon emission was not accounted for from other energy and non-energy sources in the case area. But what is clear here is that, even with the fuel wood and charcoal alone, the carbon emitted is still quite large for the forest; which also acts as a sink for other geographic area's carbon emissions; as it takes years for trees to mature enough to capture carbon in the atmosphere. There is need for afforestation and sensitizing people to plant trees or flowers since it induces good chemicals in the atmosphere that offset carbon emissions.

5.3 Sustainable Energy: Equating the indicators

Sustainable energy (SE) is a complex notion which can be "unpacked" in different ways; and it becomes more complex when the various energy forms are put together. No single measurement tells the whole story even for one energy form, let alone for more than one. Probably the best that that can be done is to put together a set of indicators; see figure 2.8 in chapter 2. If overall these are indicators are moving in the right direction, then we can say that sustainable energy is improving (or vice versa). Some of the indicators may enable us to say that SE has been achieved for certain groups; this has become the purpose of this section. The indicators under consideration are affordability; accessibility; reliability; equity; space; time and adaptive capacity.

5.3.1 Affordability

Taking points from the literature reviewed in chapter 2 and the conceptual framework, the term affordability is used in various ways and while some of which seem ambiguous, others are very subjected and statistically unsupportive. Affordability is not the same as "not expensive" but its essence lies in the resources that are available for a threshold at a particular time. This means that affordability only has meaning when speaking of a certain group getting particular products or services.

In reference to the literature in chapter 2 which defined the statistical boundary of affordability to be the ratio of a household’s per capita effective energy consumption to a subsistence threshold, the discussions under this section will be centered around this module. In a much more simpler term, measuring affordability will mean the ability to pay for necessary levels of consumption within normal spending patterns and this could be done using the consumer's Energy Burden (CEB) module; see box 1 below. of fuel wood and charcoal. The CED is expressed as a percentage of income used to pay energy bills (Economic Opportunity Studies, 2012). Based on the model from box 1, the CED for the sampled households is computed on annual basis below;

$$\textbf{Energy Burden} = \frac{GHS\ 561.60}{GHS\ 1{,}311.6o} \times 100\%$$

$$= 0.42 \times 100\%$$

Energy Burden = **<u>42%</u>**

Box **1**: Model for Energy Burden calculation

$$\text{ENERGY BURDEN} = \frac{\left[\text{ENERGY USAGE} \times \left(\text{PRICE} + \text{OTHER CHARGES}\right)\right] \text{FOR THE TIME PERIOD}}{\text{INCOME FOR THE TIME PERIOD}}$$

Source: Economic Opportunity Studies, 2012

From the Energy Burden calculation above, an CEB of 42 percent represents a high burden and it could be said from here that, energy in the current situation of rural communities in NEMA is not affordable based on the module and indicators used. The model explains that, the lower the income, the higher the burden for the same energy expenditure, and so invariably, the CEB is high in the study area. This scenario is not a positive indicator in the sustainable energy framework.

5.3.2 Accessibility

This indicator has been borrowed from transportation and land-use planning and it is a function of the mobility of the individual, under the opportunities relative to a spatial starting point, to be able to participate in an activity and of the times at which the activity is available. Thus accessibility here is not concerned with quality and number of activity but with the opportunity provided by the transport and land-use system. Hence based on the conceptual framework in the second chapter of the study, accessibility will be considered as the percentage of time that a particular energy source is available for use and a less percentage of damage to the environment as a result of access. It is assumed that, the only mode of travel to farms is by walking that is, foot paths. Also it is assumed that foot paths are class 3 access routes (when the accessibility map module is used). These assumptions are as a result from the findings from the study which showed all the sampled households walked to their farms and used a certain type of foot path.

It is upon these assumptions that subsequent calculations are based and hence the survey showed that, the average distance covered to have access to fuel wood is 4.5km; and out of this majority (52 percent) were obtained outside the various communities selected. It was also realised that, over the past 5 to 10 years, the distance covered to have access to fuel wood had been increasing since previously households were able to access fuel wood at their backyards but now they have to walk about 4.5km to have access and most of these are located in their farms and the forest. The picture here is that, the increase in consumption is affecting the forest resources in these communities and as a result, consumers will have to walk long distances (4.5km) to obtain wood for fuel.

Using the standard maximum travel times to access facilities based on the GIZ's standards, the computation of the access zones are done. Table 5.1 shows the maximum travel times in each access zone based on GIZ's module.

Tale 5.1: Accessibility Standards with respect to Travel time (in minutes)

Facility	High access zone	Medium access zone	Low access zone	Least access zone
Agriculture[11]	Up to 25	25-35	35-40	More than 40

Source: GTZ, 2007

Based on the accessibility standards, an average of walking to access agriculture facilities is 4km/hr and used in this context. Travelling by foot to the farms to access fuel wood along foot paths at 4km/hr, the maximum distance that one can travel to be in a high access zone within 25 minutes is calculated as;

60 minutes = 4km

25 minutes = $\frac{25}{60} \times 4km$ **= 1.7km**

This implies that, all those who are within 1.9km away from their farms can access fuel wood within 25 minutes and are classified as within the high access zone. This computed in the same way for all the other access zones and detailed in annex 5.4. Table 5.2 below shows the summary of results as well as percentage of the population within each access zone.

Table 5.2: Access zones and population within each access zone

High access zone		Medium access zone		Low access zone		Least access zone	
Distance (km)	**% of population**	**Distance (km)**	**% of population**	**Distance (km)**	**% of population**	**Distance (km)**	**% of population**
1.7	34	2.4	5	2.7	10	3.2	41

Source: Author's construct, 2012

The accessibility analysis summarised in the table above shows that majority (51 percent) of the sampled households are within the low (10percent) and least (41percent) access zones to fuel wood as is confirmed by the average distance (4.5km) covered to access fuel wood. This condition is not favourable under the sustainable energy framework since majority are located in the low access zones and also the over the past 5 to 10 years, this distance covered to access energy is increasing; as ascertained by the sampled household respondents. The effects on the environment was evident and one household respondent attested to the fact that increase in

[11] Agriculture is used because more than 97% of sampled households obtain fuel wood from their farms

energy consumption is affecting negatively affecting with no measures to protect it by stating that "now we cannot even get fuel wood in our backyard".

5.3.3 Reliability

Based on the literature on reliability in chapter 2 of this study, the multi-attribute utility theory (MAUT) model is used; *refer to section 2.8 for full description of model*. A group of 25 expert panel were interviewed for this assessment. Tables 5.3 (for the objective *adequacy*) and 5.4 (for the objective *security*) shows the average of the aggregated utility scores taken across all interviewed experts to determine reliability indices for the panel; see annex 5.4 for the Likert table of raw values of utilities from panel of experts/stakeholders.

From the model, it can be indicated that the experts perceived fuel wood and charcoal as likely to be unreliable in terms of both *adequacy* and *security*, based on the average scores from the model. The average scores of 0.54 and 0.53 for *adequacy* and *security*, respectively, as it could be recalled that the utility scores are on a scale from *0* to *1*, and nearer the scores are to 1, it represents poor reliability (energy source not reliable). The results are presented in the tables below.

Table 5.3: Average utility and importance ratings and aggregated concept and general objective reliability indices for *adequacy*

Functional zones / Attributes			**Primary Source of supply**	**Energy conversion**	**Transport**
Capacity	Utilisation	r_i	0.50	0.35	0.65
		w_i	1.00	0.80	0.80
	Intermittency	r_i	0.60	0.55	0.45
		w_i	0.80	0.60	0.60
	Capacity	$\boldsymbol{R_{ci}}$	0.55	0.45	0.55
		W	0.90	0.70	0.70
Flexibility	Response to demand fluctuations	r_i	0.45	0.46	0.65
		w_i	0.40	0.60	0.80
	Ability to expand facilities	r_i	0.85	0.66	0.25
		w_i	0.20	0.40	0.60
	Flexibility	$\boldsymbol{R_{fi}}$	0.65	0.56	0.45
		W	0.30	0.50	0.70
ADEQUACY		$\boldsymbol{R_i}$		**0.54**	

Source: Author's Construct, 2012

NB: Scores of 1 represent the worst reliability rating (u) and the highest important rating (w), while 0 corresponds to high reliability or low importance.

The results from table 5.3 above shows that, the experts felt that energy conversion and transportation of fuel wood and charcoal offers added *adequacy* by providing capacity to provide sufficient throughput to supply final demand and flexibility to adapt to volume and geographical fluctuations in demand. However, under the primary source of supply, the flexibility to adapt to fluctuations to changes in demand volumes negatively affects adequacy of fuel wood and charcoal; reflected by a high utility score of R_{fi} = 0.65. It was also realised that, the experts regard utilization (which is the degree to which the fuel wood and charcoal are being utilized) as the most important attribute to include in reliability issues under adequacy, across all three (3) functional areas; they rate its importance at W = 0.9. However, the experts showed that, all the attributes were important enough to be included as the least weight given to the attributes was 0.5.

In the case of security (see table 5.4), the experts perceived that, disruption in economic variables and environmental consequences as a result of disruptions in the fuel wood and charcoal conversion and transportation would be very high and unreliable with average utility scores of 0.6 in both functional zones. The panel of experts global influence on local fuel wood and charcoal supply source, conversion and transportation is very minimal and does not heavily affect local conditions, as seen in table 5.6 as '*N/A*'. But, they agreed that the large availability of forest cover and the good history of fuel wood and charcoal conversion rates, greatly improved security of primary energy supply and energy conversion (with average security utility scores of 0.20 and 0.25 for physical security and history respectively) over the other attributes, which are more difficult to secure.

Table 5.4: Average utility and importance ratings and aggregated concept and general objective reliability indices for *security*

Attributes		Functional zones		Primary Source of supply	Energy conversion	Transport
Infrastructure	**vulnerability**	Physical security	r_i	0.20	1.00	0.00
			w_i	0.64	0.82	0.43
		Interdependencies	r_i	0.60	0.80	0.60
			w_i	0.62	0.80	0.40
		Sector coordination	r_i	0.85	0.60	0.40
			w_i	0.21	0.42	0.22

Consequences	History	r_i	0.81	0.25	0.63
		w_i	0.43	0.63	0.80
	Infrastructure vulnerability	R_{vi}	0.60	0.60	0.40
		W	0.50	0.70	0.50
	Economic impacts	r_i	0.63	0.40	0.63
		w_i	0.60	1.00	0.64
	Environmental impacts	r_i	0.97	0.80	0.25
		w_i	1.00	1.00	1.00
	Human health impacts	r_i	0.45	0.85	0.22
		w_i	0.81	1.00	1.00
	Consequences of infrastructure disruption	R_{di}	0.68	0.65	0.30
		W	0.80	1.00	0.90
Energy security	Import levels	r_i	N/A	0.90	N/A
		w_i	N/A	0.14	N/A
	World excess production capacity	r_i	N/A	N/A	N/A
		w_i	N/A	N/A	N/A
	Price volatility	r_i	0.21	0.20	0.63
		w_i	0.61	0.61	0.72
	Energy security	R_{ei}	0.50	0.50	0.50
		W	0.43	0.40	0.40
	SECURITY	R_i		**0.53**	

Source: Author's Construct, 2012

From the model so far, it is clear that the panel perceives that energy conversion and transport may improve reliability in fuel wood and charcoal supply (from both the adequacy and security attributes). On average, the experts rated these two functional zones as more reliable than the primary source of supply source; with average utility scores for adequacy = 0.50 and average utility scores for security = 0.49; which means it is perceived that current energy mix is more secured than adequate.

While the method provides an effective mechanism to calculate the reliability of energy types and also compare the reliability of various energy pathways, an absolute quantitative prediction into the future cannot be extrapolated from the aggregated reliability scores in the tables; this has become a major limitation to the model. Notwithstanding, the scores provide clear enough picture to conclude that these experts perceive the likely unreliability of fuel wood and charcoal supply in terms of the attributes selected. It becomes a valuable tool to consider in measuring reliability and it is however only useful to the extent the assessment is transparent and accepted among expert panel of stakeholders.

5.3.4 Equity

The study showed a clear disparity in physical and economic access to energy sources in NEMA; with basically Axim and its environ which form the coastal savannah zone, having access to all facilities available in NEMA, the secondary forest zone and the moist deciduous zones are not able to access such energy facilities.

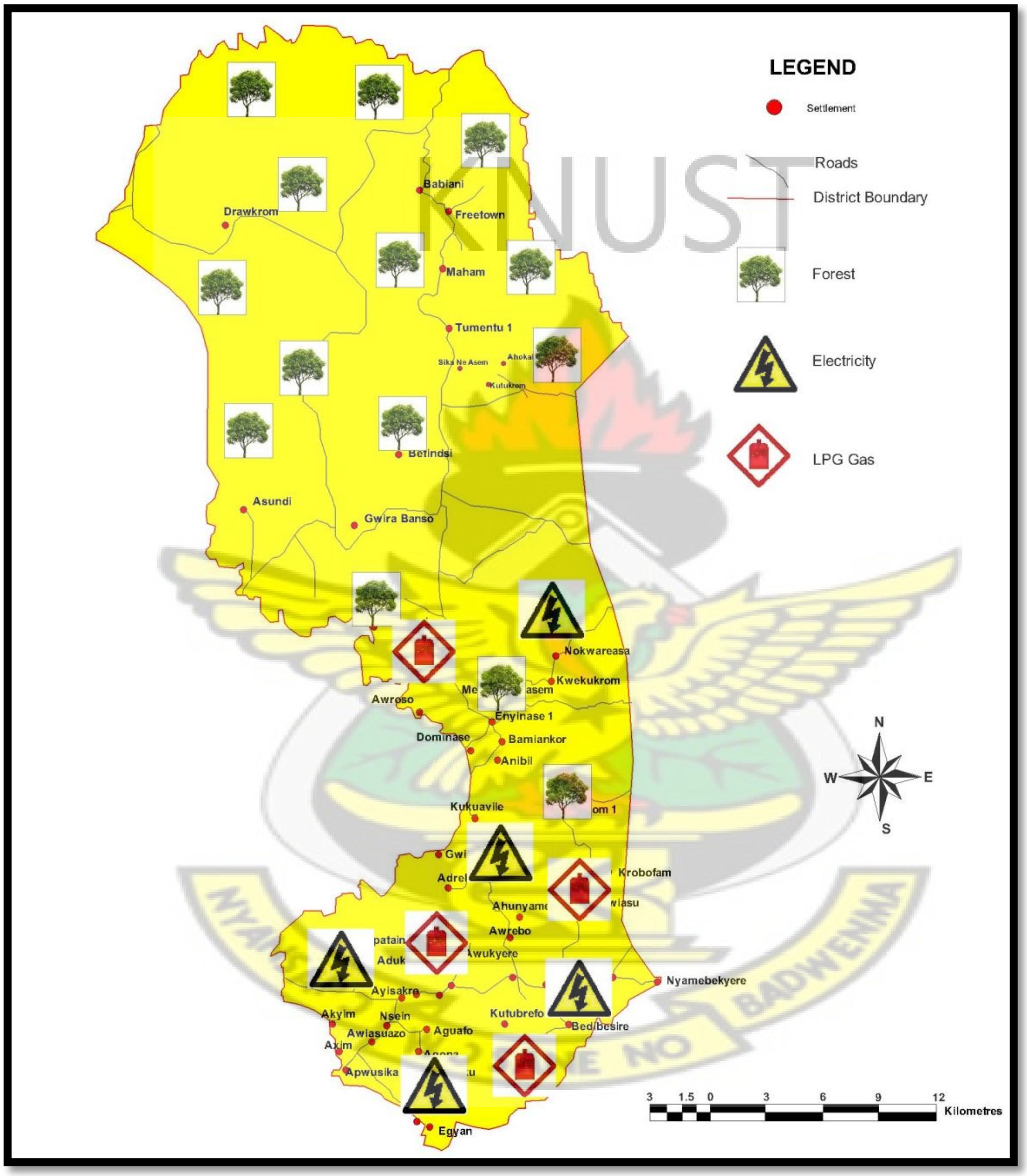
A case in point is access to charcoal in the moist deciduous zones; there is a weak negative correlation between income and consumption of charcoal in this zone. It was realized that, due to lack of physical access in most parts of the year, inhabitants in this zone consume very less charcoal compared to those in the other zones. The main attribute was the poor nature of roads in this zone. This shows an unfavorable measure under the sustainable energy framework indicator.

5.3.5 Spatial Dimension

The spatial dimensions of energy systems are very important to achieving sustainable energy in rural and even bigger urban cities. Spatial differentiations have considerable influence on different aspects of the energy demand and supply spectrum and with spatial planning and integration (space-energy resource-planning), the energy resource availability and use are influenced. Different spatial locations have their distinct advantages on the type of natural resource available for energy form and this affects the planning and decision making under sustainable energy. It is based on this that the spatial aspects of energy systems are considered under the framework of sustainable energy in the study. Figure 5.1 shows the spatial distributions across the study area.

Three distinct spatial locations have been used as seen from figure 5.1, in the study to represent the different spatial distribution of energy resources and how to effectively coordinate these into the sustainable energy framework. The deciduous forest, secondary forest and coastal savannah zones are the locations used for analysis. It was realised from the study that, energy resources (fuel wood tree species and charcoal tree species) were unevenly distributed across these zones; while the deciduous forests (located in the northern parts), as the name suggests, were covered with large forest cover and thus plenty energy resources, the coastal savannah zone (located in the southern or coastal belts) was limited to few forest resources from which they could have access to energy sources (fuel wood and charcoal tree species). The intermediate secondary forests (centrally located) were seen with some forest covers however not as much as compared to the northern parts.

Figure 5.1: Spatial distribution of Energy resource availability



Source: Author's construct, 2012

This differentiation sees the growth of the energy resources towards the northern parts of the study area; see figure 5.1; where there are fewer developments and thus more virgin forests yet to be tapped. The implications of spatial differentiation of energy resources has been understood by comparing energy demand and supply as well as energy expenditure in these three zones. Taking notes from tables 4.5 to 4.8 (see pages 70-73), table 5.5 below summaries the quantity and amount of fuel wood and charcoal used in each zone.

Table 5.5: Daily quantity and daily expenditure on fuel wood and charcoal among different zones

Zones	Fuel wood		Charcoal	
	Quantity (kg)	**Amount Spent (GHS)**	**Quantity (kg)**	**Amount Spent (GHS)**
Northern	14.0	0.45	2.0	1.5
Central	9.1	0.47	4.1	0.6
Southern	11.5	0.82	2.0	0.8

Source: Nzema East Municipal Field Survey, 2012

Places within the northern parts (deciduous forests), where it was realised that there were large forest covers, were consuming more fuel wood than the rest of the zones, consuming about 14kg of fuel wood per day and those in the central and southern zones consuming 9kg and 12kg of fuel wood respectively daily. This could mean that, much access to resources will mean increase and large demand as seen in the case of table 5.5 above. Making inferences from the accessibility zones discussed earlier, within the high access zone of 1.7km from resource, it was realised from the study that, out of the 34 percent of people leaving within this range, majority (76 percent) were found in the northern zone. The case under charcoal looks not very different, as the highest daily consumption (4.1kg) is recorded in the secondary forest zone, though not much forest resources are located as compared to the northern parts, have some levels of forest resources.

It could be said here that, spatial attributes of energy resources have serious bearings on how energy and supplied and consumed in each spatial context. While one context will increase more than proportionately in demand and supply, the other will lurk behind and the essence of sustaining energy will not have been achieved. Hence within the current context of sustainable energy, having large differences in resource availability in different spatial locations affects the extent to which energy demand and supply will be sustainable. But this is the case in every part of the world and hence there has been the need for resource and information coordination among the various spatial settings in order to support energy.

5.3.6 Time Dimension

Looking at sustainability, time becomes an important factor in understanding what happens now and in the future. Current demand and supply as well as future (short, medium and long term) demand and supply play major roles in ensuring a sustainable energy. The section tries to look at the consumption patterns in the short, medium and long terms and drawing comparism with the national consumption levels. The forecast models are based on the growth rate of fuel consumption over a period between 5-10 years. Two scenarios are described here; with scenario one using the growth rate obtained from the household survey and scenario two is based on the national trends of consumption.

These two scenarios are used because, in national documents, the rate of fuel wood (3 percent) and charcoal (2.5 percent) annual growth (Energy Commission, 2006) is lower when compared to the rates obtained from the household surveys in rural NEMA which were 30 percent and about 25 percent respectively for fuel wood and charcoal. It is very important to establish that, the following forecasts are only valid under certain assumptions and constants. Firstly, it is assumed that all socio-economic and physical characteristics will remain the same over the projection period of 20 years (2012-2032). Second, it is also assumed that, population growth will grow exponentially over 20 years. Thirdly, it is assumed that the household size will remain the same.

5.3.6.1 Forecast Scenarios

The following tables shows the various scenarios and how much fuel wood and charcoal will be consumed annually in rural NEMA. Graphically, the information in table 5.6 above is shown in figures 5.2 and 5.3 below.

From the details in table 5.6 below, it can be seen that in scenario 1, average annual household energy consumption is expected to increase from 68,814.80kg/annum and 4,706.32kg/annum in 2012 to 13million kg/annum and 408,208.19kg/annum for fuel wood and charcoal respectively by the end of 2032. When this is compared to the forecast in scenario 2, it is seen that the average annual household energy consumption increases from 68,814.80kg/annum and

4,706.32kg/annum in 2012 to 113,311.12kg/annum and 8,458.87kg/annum for fuel wood and charcoal respectively by the end of 2032.

Table 5.6: Average Annual Household Energy Demand forecast from 2012-2032

Time Dimensions	Projection Years	Scenario 1		Scenario 2	
		Fuel wood (kg)/annum	Charcoal (kg)/annum	Fuel wood (kg)/annum	Charcoal (kg)/annum
Short term	**2012**	68,814.80	4,706.32	68,814.80	4,706.32
	2013	89,459.24	5,882.90	70,879.24	4,823.98
	2014	116,297.01	7,353.63	72,651.23	4,968.70
Medium term	**2015**	151,186.12	9,192.03	74,467.51	5,117.76
	2016	196,541.95	11,490.04	76,329.19	5,271.29
	2017	255,504.54	14,362.55	78,237.42	5,429.43
	2018	332,155.90	17,953.19	80,193.36	5,592.31
	2019	431,802.66	22,441.48	82,198.19	5,760.08
Long term	**2020**	561,343.46	28,051.85	84,253.15	5,932.88
	2021	729,746.50	35,064.82	86,359.48	6,110.87
	2022	948,670.45	43,831.02	88,518.46	6,294.20
	2023	1,233,271.59	54,788.78	90,731.42	6,483.02
	2024	1,603,253.07	68,485.97	92,999.71	6,677.51
	2025	2,084,228.99	85,607.46	95,324.70	6,877.84
	2026	2,709,497.69	107,009.33	97,707.82	7,084.17
	2027	3,522,346.99	133,761.66	100,150.52	7,296.70
	2028	4,579,051.09	167,202.07	102,654.28	7,515.60
	2029	5,952,766.41	209,002.59	105,220.64	7,741.07
	2030	7,738,596.34	261,253.24	107,851.15	7,973.30
	2031	10,060,175.24	326,566.55	110,547.43	8,212.50
	2032	13,078,227.81	408,208.19	113,311.12	8,458.87

Source: Author's construction, 2012

The huge difference between these two scenarios here is attributed to the different growth rates used. In scenario 1, the rates obtained from the rural household surveys in NEMA were used and it was found out that, over the past 5 years an average annual rate of increase in energy consumption was 30 percent for fuel wood and 25 percent for charcoal. However, under scenario 2, the rate was based on Ghana's national rate of fuel wood and charcoal consumption (with both rural and urban settings) between a 4-year period. In explanation to the above, it means that in taking averages from both urban and rural setting, the total average will be lesser than only rural where predominant consumption is fuel wood and charcoal as compared to the urban cities who enjoy a wide range of modern and the traditional energy mix.

This notwithstanding, the expected consumption rate for both fuel wood and charcoal after 20 years is still high in both scenarios (13.4million kg and 121,769.9kg for scenarios 1 and 2 respectively); and as such planning and decision making bodies need to seriously consider the future scenes into current agenda. It is very necessary to also discuss the supply side of the future scenario and provide a better comparism picture; only then will proper analysis and meaning be given to these demand forecasts. Borrowing from figures 4.1 and 4.2 (daily supply of fuel wood and charcoal), it is known that the average annual supply of fuel wood in the study district is 62,478kg and charcoal is 44,500kg. From the field survey, the average rate of growth of fuel wood and charcoal supply was very varying among the suppliers of fuel wood and charcoal. Interestingly, there is little information on national supply trends only that in 2000 an average of about 18million tones (Energy Commission, 2006) of wood fuels - both fuel wood and charcoal - were supplied and based on the Ghana Commission's data, this is constant throughout the years up to 2004 and beyond; this makes comparism with national trends very difficult and impossible.

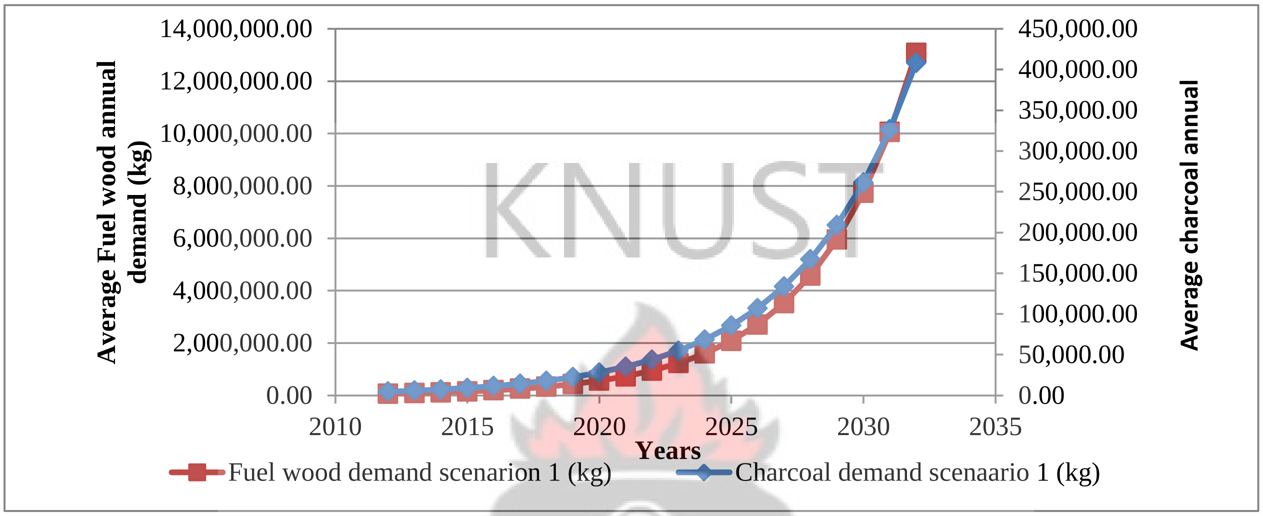
But a way of projecting the future scenarios of supply can be discussed here using the trends of supply among fuel wood and charcoal suppliers interviewed during the survey. According to the sample interviewed, it was realized that an annual average rate of 4.7 percent growth was recorded for fuel wood and 0.3 percent growth for charcoal. Under the supply forecast, 2 scenarios are discussed; scenario discusses with the assumption that rate of growth will remain constant throughout the years and scenario 2 discusses with the assumption that, beyond 2020 there will be an annual reduction in supply in both fuel wood and charcoal by 1percent[12]. The logic behind scenario 2 is that, it is assumed that by 2020 the national rural electrification programme would have been implemented and all rural communities will have access to electricity. This assumption was also based on the fact that, people are more willing to add modern energy sources to their regular residential energy consumption but not in the near future, as revealed by the survey.

Figures 5.2 and 5.3 shows the graphical projections of demand and supply of fuel wood and charcoal. The trends show that, though in the short and part of medium term, energy supply will be capable of supporting demand, it becomes over stretched out when the time periods enter into the long term (in both scenarios). From figure 5.2, it is seen that, in the first forecast scenario, from the beginning of the period, fuel wood demand is ahead of the supply and as the years move on, the gap becomes large. However, considering charcoal, it is realized that not until the

[12] This was based on qualitative data obtained from household interviews and energy suppliers; averages of assumed reduction by the interviewed energy suppliers were compiled to achieve this average

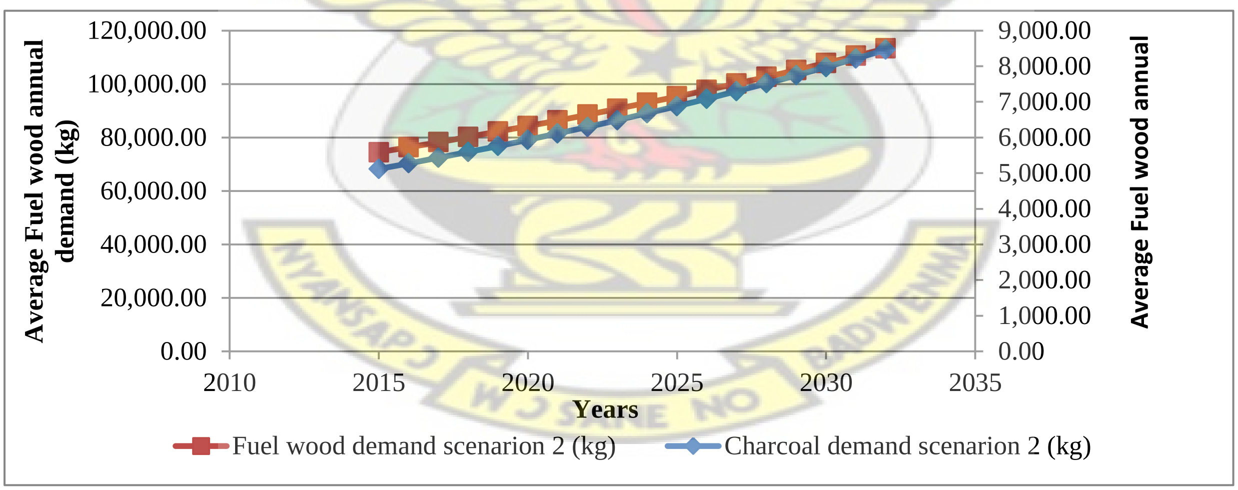
year 2024, charcoal supply has been ahead of its demand. The peak year for charcoal is in 2023 where supply stood at approximately 62,000kg/annum and demand stood at approximately 55,000kg/annum.

Figure 5.2: Scenario 1 - Energy demand forecast with household survey growth rate



Source: Author's construct, 2012

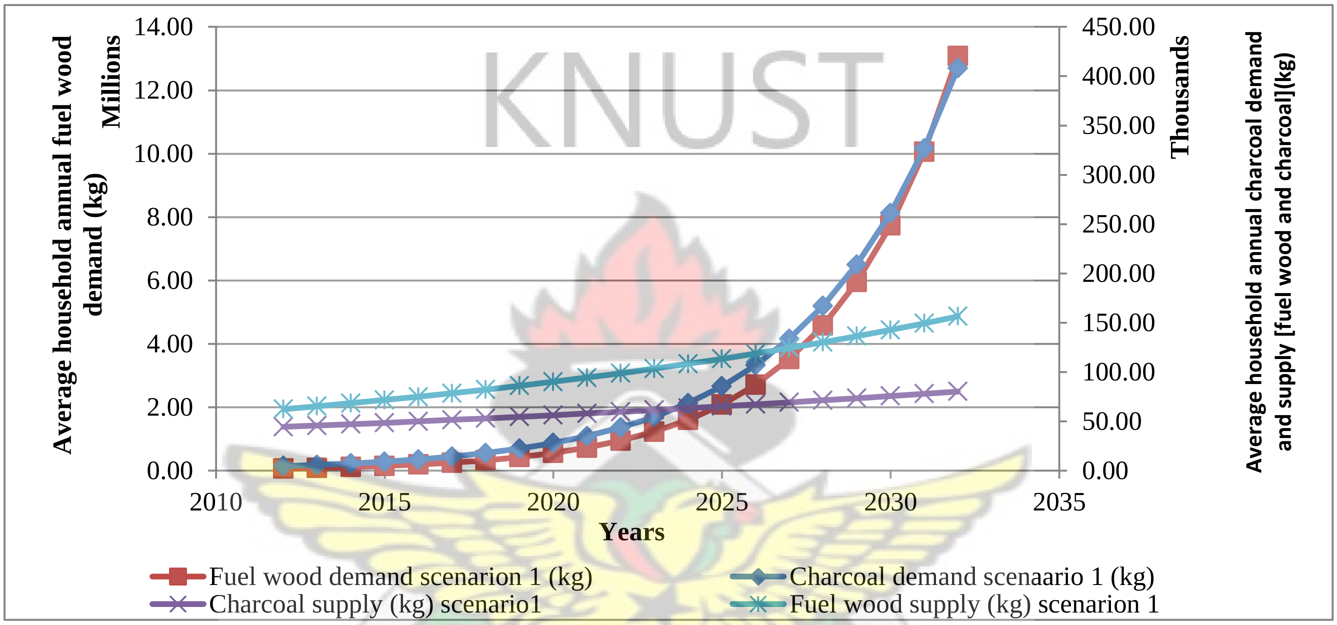
Figure 5.3: Scenario 2 - Energy demand forecast with national growth rate



Source: Author's construct, 2012

The regression function for the forecast curves in figures 5.2 and 5.3 were computed for and the coefficient of determination (R^2) for charcoal and fuel wood demand over the forecast period are 0.99 and 0.97 respectively. This means that 99 percent and 97 percent (for charcoal and fuel wood respectively) of the total variation in energy demand can be explained by data obtained from the field and also the linear relationship between the forecast period and the demand; however, the other 1 and 3percent of the total variation in demand remains unexplained. The R^2 for the supply side were 0.12 and 0.04 for charcoal and fuel wood respectively; this meaning the data obtained can only explain 12 percent and 4 percent of total variations in charcoal and fuel wood supply respectively.

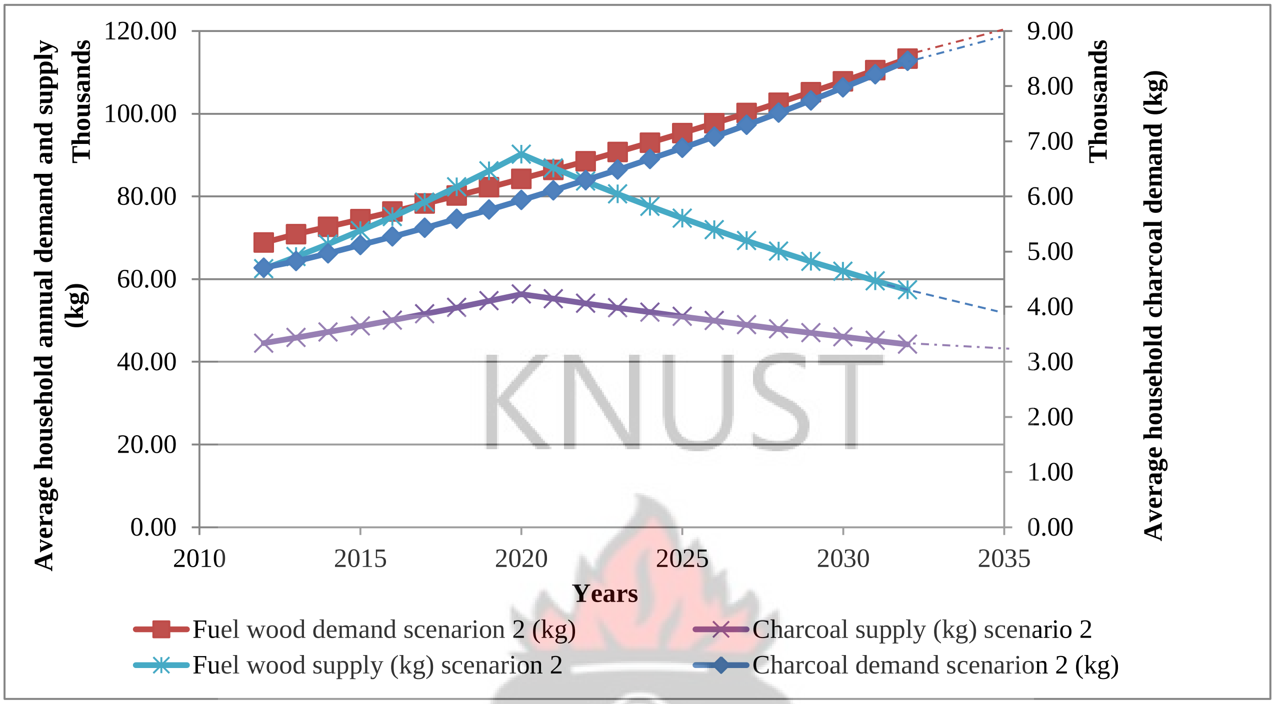
Figure 5.4: Demand and Supply of Energy for Scenario 1



Source: Author's construct, 2012

It is very clear from scenario 2 that, fuel wood demand is ahead of its supply throughout the forecast period as was the case in scenario 1. However, under charcoal, 2 equilibriums were found in the years 2016 and 2023; here charcoal demand was equal to its supply. This has shown that, within the short and medium terms, charcoal supply will be adequate to support demand but in the long run (beyond 2020), care needs to be taken as demand over exceeds the supply line.

Figure 5.5: Demand and Supply of Energy for Scenario 2



Source: Author's construct, 2012

5.3.7 Adaptive Capacity

Given the numerous difficulties in the uncertain nature in understanding adaptive capacity, using the current adaptation of social systems becomes an acceptable proxy for the system's capacity to adapt in the future (Cooper *et al.*, 2008; Fussel and Klein, 2006; Challinor *et al.*, 2009; cited in Below *et al.*, 2012). Building from the literature reviewed in chapter two (section 2.7) of this study, five features that determine the adaptive capacity of communities or regions are discussed in detail: economic wealth, technology, information and skills, infrastructure, and institutions and equity (Smit et al., 2001). Based on these elements, the following discussions will be focused on determining the adaptive capacity of rural NEMA within the energy-climate change context. But due to the peculiar nature of the energy context, the extension of the Smit et al. (2001) concept into six (6) major determinants first designed by Yohe and Tol's eight determinants (2002) is adopted. In all these determinants, a rating scale of 1-5 using Likert scale (with 1 being the least and 5 the highest quality; and an average rate from 0.0 being no quality in determinant and 1.0 being perfect quality in determinant) was used to rate the quality its possess in aggregate adaptive capacity.

5.3.7.1 The Range of Available Technological options for Adaptation

The range of available technology in rural NEMA to support energy and help the rural communities in extreme scenarios could include access electricity and other modern energy markets, example LPG, solar technologies among others. However, based on the study it was realised that, about 85percent of selected communities were lacking in technological options to support adaptation to extreme conditions of climate; refer to table 4.10 for details on access to certain facilities in all selected communities.

From the rating scale, which was averaged from interviewed households and opinion leader, it showed an average rate of 0.15 which shows a very low quality of technological support to adaptation in these communities.

5.3.7.2 The Availability of Resources and their Distribution across the Population

This deals with both economic and physical resources and equity issues; large access to resources and evenly distribution across a geographic scope of interest are key in determining the adaptive ability of communities to changes in climate. With respect to physical availability of resources for fuel wood and charcoal, it was seen from the study that, over 30,000 hectares of off-forest reserve were available as a natural resource and energy extraction and a good supportive determinant for adaptive; however when the demand supply forecast is referred, it could be seen that this resource will not be that supportive in the long (see section 5.3.6.1). Economically, it can be said here that, given an average monthly household income of GHS 109.3 (refer to table 4.4), households the case communities could be said to be earning a little above the national average for rural households of GHS 101.4 (GLSS 5, 2008). Notwithstanding, this monthly average is still not enough to cater for an average household size of 6.

On the case of equity, the spatial dimension discussed earlier have extensively provided details on spread of energy resources - refer to section 5.3.2 above; this showed that most people (51percent) were located within low access zones. Put together, the average ratings from the interviewed sample showed a rating of 0.67 which indicates that quality of available resources and its distribution to support adaptation to changes to climate is high.

5.3.7.3 The Structure of critical institutions

The investigated relevant institutions included the municipal assembly, ECG, Meteorological Survey Department, Lands commission, Forestry Service Department and the EPA. The institutional survey showed that these institutions worked independently of each other and there was no coordination in terms of energy issues and policy. Also it was realised that, the MoEn is very centralised and operates from the head office in Accra with no decentralised unit in the district assemblies. It was raised in an interview during the field study that, since the MoEn is centralised, issues concerning energy in the municipal assembly was weakly handled by district authorities. This has made the holistic structure of the critical institutions in the area very weak. As a result, the average of rating scores by the interviewed sampled showed a rate of 0.25.

5.3.7.4 The Stock of Human capital, including education and personal security

Human capital represents a very important determinant in adaptive capacity of rural communities. A literate society is an asset and development grows faster compared to the illiterate society. Based on the survey, it was realised that majority (52percent) of the adult age cohort had obtain basic educational level and about 11percent had obtained above secondary education; while about 19percent were illiterates. Given the fact that more adults were literates and had obtained basic education the rating scale for this determinant was at 0.87.

5.3.7.5 The Stock of social capital, including the definition of property rights

The ability to collectively agree and achieve results becomes a strong qualitative measure of adaptive capacity to extreme climate change impacts. It was realised from the study that, the acquisition of certain infrastructure by collective means was very evident in most of the communities. In all the communities, there had been collective efforts in constructing drains and toilet facilities as well as feed stock warehouse for their farm produce. The interviewed sample rated this determinant at an average of 0.77.

5.3.7.6 The Public's perceived attribution of the source of stress and the significance of exposure to its local manifestations

It is very common for the locals of an ecosystem to be able to identify sources of climate change stresses and its direct effects to their ecosystem. This determinant becomes important when people are able to identify these stresses and its potential or current damage to their livelihoods. Knowing this, it puts inhabitants in the best position to either adapt or mitigate these stress sources. Knowing these factors, the survey conducted among the sample households and opinion leaders showed that, people in rural NEMA were moderately able to identify stress source and its exposure to the local livelihood. The average score was thus 0.45 from the interviewed sample.

Based on the above six determinants, showing the capacity of communities to adapt to climate change, it is seen that, the total average rating score of the adaptive capacity of the selected communities is 0.52. This means that, rural NEMA could cope adequately with climate change impacts within the energy mix. However, care should be taken as future projections of the demand and supply reveal very threatening scenarios that require urgent attention.

In summary, it could be said that, these six determinants are used to gain better understanding and a clear picture of how capable rural communities are adapting amidst climate change within the energy context.

5.4 Conclusion

Understanding sustainable energy in rural areas through the selected indicators has been the crust of this chapter. It has been realized that the use of fuel wood and charcoal in rural areas has consequences on the environment and human health and at large, climate change. On the environmental side, fuel wood and charcoal consumption pose threats in a form of carbon emissions. Though Ghana and most African countries are not heavy carbon emitters, it becomes very important to consider this when fuel wood and charcoal burning is one major source of residential and industrial energy resource. From the study, household and industrial/commercial fuel wood and charcoal consumption, emitted 24,171 tCO2/year and the net carbon capture[13] was

[13] Here, the forest cover was the only consideration since data on size of soil and water bodies of selected areas were not available from the secondary data.

112billion tCO_2/year. The balance between carbon emitted and capture provides an indication of more room for carbon sequestration in the area and its environs; however high growth in fuel consumption coupled with increasing forest reduction and water evaporation (refer to section 4.6.3 on data on evaporation) presents a case for concern over the years. Comparing this to national level, it is realized that, Ghana's carbon emission rate is 8.6million tCO_2/year (World Bank, 2008). Data on carbon sequestration and current carbon emissions is very inadequate and not available hence making clearer comparism and taking actions are limited.

Understanding the effects of fuel wood and charcoal use on the environment and climate change, the framework towards sustaining energy (fuel wood and charcoal) becomes very relevant to consider. Based on the indicators discussed, it is very clear, from an aggregated point of view, that the current use of fuel wood and charcoal is less likely to be sustainable within the short, medium and long term periods. Firstly, considering how affordable energy is to households and businesses, it is seen that current energy use is not very affordable to the minimum earners and this was measured by the energy burden of 42percent. Secondly, accessibility to the energy sources was increasingly decreasing. The surface accessibility analysis was used here and it showed that 51percent of the population were within low and least access zones to energy sources. Thirdly, considering how reliable fuel wood and charcoal is, it was realized that, current energy use is more secured (with average utility rating score of 0.49) than adequate (with an average utility rating score of 0.59).

In addition, the spatial distribution of resources and how equitable these resources are distributed were considered under SE. It was realized that, resources (natural and man-made) were not equitably distributed with large gaps between different geographical areas in terms of infrastructure and natural resources. Under time factors, it was realized that there will be two possible equilibriums between charcoal supply and demand in the years 2016 and 2023; but beyond 2023, demand exceeds supply. Looking at fuel wood, it is realized that over all the projected years demand exceeded supply. Only within the short term that, supply will be able to meet its demand. Finally, determining the adaptive capacity of the selected communities indicated that, an average rating score of 0.52 was recorded. This means that the people are more likely to be able to moderately adapt to climate change impacts but will face a more difficult challenge in the future against adaptation.

Looking at all the indicators of SE, it is possible to say that, the designed framework of SE will be able provide a more clearer and better understanding of sustaining energy demand and supply within the long term and also help in the decision making process of all SE issues.

CHAPTER SIX

KEY FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

The research questions posed in the introductory chapter are more or else answered and elaborated in this chapter following the analysis in the previous 2 chapters. This is done by exploring the key findings and the way forward in sustainable energy in rural communities. As a point of reference to the research questions, the summary of findings in this chapter will describe the answers to these questions in a real situational context seen in the selected communities. The research questions included;

1. What is the nature of the relationship between energy forms and climate change?
2. To what extent is the energy forms affected and/or affects climate change?
3. Is rural energy use sustainable amidst climate change?

6.2 Key Findings

The key findings are grouped under the research questions and other arising findings which included the willingness of households and commercial/industrial enterprises to change their current sources of energy to a more modern source. The following findings are expressed at significant level of 95 percent.

6.2.1 Nature of the Relationship between Rural Energy forms and Climate Change

The study shows that, the main energy forms in the study area are fuel wood and charcoal, which represents over 90 percent of household energy consumption. In this regard, it was realized that household's energy consumption increases with increase in household size (r = 0.78 for fuel wood and r = 0.75 for charcoal). An average of 13.31 kg and 3.22 kg of fuel wood and charcoal was consumed daily among households; with commercial and industrial enterprises consuming an average of 180kg of fuel wood and 10kg of charcoal daily. It was revealed that, given the above findings, households spend, on the average, GHS 0.6 and GHS 0.97 daily on fuel wood and charcoal respectively. In addition to the above findings, it is realized that, the quantity of fuel wood and charcoal supplied daily stands at 175.5kg and 125.0kg respectively. These demand and supply rates were projected to increase exponentially over a period of 20 years, with the assumption that certain factors remaining constant.

The climate change indicators from the study show a worrying trend. The study revealed that, rainfall pattern is falling at an average rate 0.6 percent per annum, while temperatures are rising at averages ranging between 24.9 ^{o}C and 31.2 ^{o}C (compared to previously 23.5^{o}C). Sunshine records over the past 20 years has increased from between 2 to 2.5hours to between 5.7 to 6.1 hours daily; and this has increased evaporation rates from an annual average of about 0.02mm to about 1.5mm over the past 30 years.

In addition to the above, the study showed that, the forest cover is depleting at a rate of 2.5 hectares annually. Forest depletion was attributed to tree felling for fuel wood and charcoal, agriculture, mining and physical development. It was found out that, the forest regeneration rate was very low compared to the rate of depletion. With the continued unfavorable climate change conditions discussed in the previous paragraph, the regeneration will further reduce and will not support the demand of fuel wood and charcoal obtained mainly from the forests.

The foregoing discussions have only been able to show how energy forms are related to climate change factors in a very broad manner; however, the study is unable to statistically relate the two variables. What is clear from these findings is that, the nature of the relationship between the two variables is a reverse linear relationship, where increase in fuel wood and charcoal consumption from the natural forests, invariably increases negative impacts of climate change in the form of falling rainfall patterns, increasing temperature, increasing sunshine hours and increasing rates of evaporation of water bodies.

6.2.2 Cyclical Effects of Energy and Climate Change

Based on the reverse linear relationship between energy consumption and climate change established in the previous section, the following findings tries to establish the effects of fuel wood and charcoal consumption on climate change and vice versa. Owing to the fact that, CO_2 presents one of the main contributors of global warming - the propelling engine of climate change, it was realized that, the daily consumption of fuel wood and charcoal were emitting amounts of CO_2 into the atmosphere. It was calculated that the annual CO_2 emissions in the rural communities were 10,083.27 tCO_2 and 14,634.10 tCO_2 for fuel wood and charcoal respectively. In addition, it was found out that, the natural forest cover[14] of the case area was able to capture 112billion tCO_2/year from emitted carbon.

Inversely, climate change also affects fuel wood and charcoal demand and supply. It was found out that, the increasing evaporation rates of water bodies are negatively affecting bamboo species, for example, which is one of the main tree types preferred by households and industrial enterprises as a source of fuel wood. It was also found out that, due to falling rainfall amounts coupled with increasing temperatures, the regeneration of planted trees has reduced, raising concerns over availability of rich sources of fuel wood and charcoal sources.

6.2.3 Rural Sustainable Energy (*is rural energy sustainable?*)

Based on the selected indicators within the framework for sustainable energy, in chapter 2 of this study, the findings that are shown in this section, tries to discuss the extent to which rural energy is sustainable or otherwise.

Firstly, under affordability, the study showed a CED of 42 percent indicating high burden on energy for rural communities. This indicates a poor contributor towards the SE equation. Secondly, under accessibility to energy sources, it was realized that majority (51 percent) of households and industries are within the low and least access zones to energy sources. Again, here it shows a negative condition towards the SE equation. In addition, when considering the reliability indicator, the study showed, from the MUAT model, that, rural energy is more secured than adequate. The rating scores for energy security and adequacy was 0.49 and 0.50 respectively. Furthermore, the study was able to identify the settings under which equity is viewed. The study shows that, clearly, there were large disparities in physical and infrastructural resources among the rural communities and NEMA at large. Apart from Axim and its

[14] It is important to mention here that, only forest cover was used in calculating carbon sequestration. The other factors such as soil, water bodies and other elements of matter were included because, the study was not able to obtain the size of soil and water among the others.

neighboring rural communities, which had access to a large range of facilities and infrastructure base, the rest of the hinter communities were severely lacking.

In considering the spatial dimensions under the SE equation, the study succinctly shows that, energy resource distributions in the form of natural forest covers and raw material for charcoal production in NEMA are unevenly distributed. The semi-deciduous zone and small parts of the secondary forest zone enjoy much of the abundance of access to natural forest as a source of fuel wood and charcoal. This results in how energy is supplied and consumed across the different zones; where fuel wood and consumed most in the semi-deciduous zone and consumption reduces as the one moves towards the coastal savannah.

Another indicator which was considered under the SE equation was the time dimensions. This was considered in terms of short, medium and long term consumption and supply implications of fuel wood and charcoal. The study showed that, current annual energy consumption (fuel wood and charcoal combined) is 73,521.12kg p.a. and this was projected under 2 scenarios. Under Scenario 1, the study showed that, the current consumption could reach 13,486,436kg p.a. and 121,769.99kg p.a. after 20 years; based on certain assumptions. The supply of energy on the other, showed a different picture in 2 scenarios; where under scenario 1, energy will meet demand at 2 equilibriums in 2024 and 2027 for charcoal and fuel wood respectively. Beyond these years, demand exceeds supply. Under the second scenario, supply peaks in 2020 and beyond that, supply begins to fall.

The last but not least indicator under the SE equation was the adaptive capacity of communities to climate change impacts. It was identified by the study that, the total average rating score from the Likert analysis of the determinants was 0.52, which means the case area has an advantage in coping with current climate change impacts. However, the study emphasized that, looking at the future scenarios under the time dimensions, this rating will be very different in the future scenarios.

6.2.4 Willingness to Change Current Energy form to Modern Forms

The study shows that, rural people are unwilling to change from the use of charcoal and fuel wood into a more modern form of energy source. It was realized that, it is very unlikely for rural households to completely use modern energy in their homes and businesses. This was mainly due to fear of cost and lack of knowledge about the modern energy form. The interesting finding here, which could be useful to policy and decision making is that, in making provision for rural households and industries to move towards alternative modern energy sources, greater attention needs to be given to fuel wood and charcoal both in the short and long run.

6.3 Recommendations

6.3.1 Short and Medium Term Recommendations

For the purposes of this study, short term is defined as two (2) years, that is, between 2012 and 2014; and medium term is defined as five (5) years, that is, between 2015 and 2020. Within this period, the study recommends that, wood lot plantation programme be initiated by the Government under the MoFA and Forestry Service Division with the opportunities being made available to the private bodies in an enabling environment. The study revealed that, under reliability indicator of the SE equation, energy is not adequate for current needs; based on this finding, this recommendation is anchored. It is also recommended here that, acacia tree species should be encouraged as it grows faster, more durable and mostly preferred by fuel wood and charcoal consumers and suppliers.

Again in the short term, it is prudent to recommend that, more studies need to be done on the importance of fuel wood and charcoal to rural households and industries by the academia. In addition, such studies should help determine the exact statistical relationship between energy forms and climate change since current knowledge only provides a generic and broad perspective nature on the subject.

Within the medium term, the study recommends that existing energy research centres be strengthened on rural energy, mainly traditional wood fuels, for training, information dissemination, research and development on relevant standardized approaches in quantifying fuel wood and charcoal. The study was limited by lack of secondary data on quantity of fuel wood and charcoal consumption in Ghana. Most literature about wood fuels in Ghana fails to adequately provide data on the subject.

The MoEn under the GoG, should make assessments of the main energy needs of rural communities and focus on supporting energy development projects that are consistent with those energy needs, particularly energy for cooking. It was realized that, rural communities were not willing to change from the current use of fuel wood and charcoal to modern energy forms (electricity and LPG) which is the backbone of GoG's path to rural electrification. It is accepted that, most MoEn projects on rural energy have considered the main energy needs of rural communities, they are all silent on its application in project implementation, hence this recommendation.

6.3.2 Long Term Recommendations

For the purposes of this study, long term is defined as more than five (5) years, that is, after year 2020. It is recommended that, the MoEn decentralize some authority and responsibility to district level planning and implementation. This has been realized as a key solution to most of rural lack of access to modern energy sources - as described by the NEMA officials interviewed. This unit should be adequately staffed and resourced in order to achieve the aim for which it was set up. Alternatively, due to limited resources, the MoEn could train some existing MA staff and resource them with the needed tools and equipment to function as MoEn decentralized body at the district level.

The MAs and MoEn should include capacity building in every energy development project they promote, whereby members of the community are taught and exposed to the necessary knowledge pertaining to need for efficient use of fuel wood and charcoal. Efficiency is rarely mentioned in the wood fuel debate, but it has become very necessary especially when the use of wood fuels in increasing with population.

Again, in view of the carbon footprint calculated for the case area, the study recommends that, options to deal with emission reduction should look at feasibility (political, social, technological and legal aspects), cost (micro and macro levels), effectiveness (policy, source reduction and sink increase) and other multi-criteria inputs in a holistic scope.

As a long run goal, it is recommended that, the taste and preference of rural communities towards the traditional wood-based biomass be shifted towards improved modern renewable forms like hydro/mini-hydro electricity, solar and wind. This could be spearheaded by the local government ministry through the district assemblies via sensitisation mechanisms and using ***snowball approach*** in reaching the masses. Literature has shown that, rural people are more likely to believe and follow their own people on a matters which are new to them.

In addition, at the technical level, it is recommended that, focus should be placed on promoting community-based forest management, which is the current approach, and improved kiln technology, which include socio-organizational changes, strengthening the use of modern information and communication technology, investing in infrastructure, and promoting the distribution of improved cook stoves (AFREA, 2011).

6.4 Way forward

The study and experience has shown that, wood base energy expansion in rural communities has neither the chance nor the reach to provide the reliability and long-term durability to fight poverty; though it continues to be the widely used energy source. In moving forward, a drive towards a more modern, cost effective and accepted energy technology is needed. Further analysis of the empirical information and an expansion in the dissemination of the findings are fundamental for sustainable rural energy is necessary.

6.5 Conclusion

Population growth, increase in energy consumption, reducing supply capacity of wood-based biomass fuel and accelerated negative impacts of climate change has resulted in a rapidly changing framework of concern for future biomass energy use in most rural communities. Against this background and coupled with the likelihood of increase in future wood-based biomass, focus on wood-based biomass energy should be given much attention as it could be used as an important source/intervention for meeting the most basic energy needs of most rural consumers.

In meeting the goals of sustainable energy and reduction in carbon emissions, the ultimate global aim of the MDGs could invariably be achieved as a result. From this premise, the study presented the nature of the relationship between rural energy forms and climate change to some extent and showed how sustainable current energy use is and also predicted the likely picture in the future over a 20 year period. Much of the debate on sustainable energy has been on increasing the supply of renewable energy forms like solar and wind as well as hydro/mini-hydro electric sources to the rural homes. A plethora of such projects have been implemented and still in implementation; this has been the spine of SE in most countries and rural settings. However, understanding the rural energy mix which is mainly wood-based biomass and also building a strong analytical and operational portfolio for it is prudent.

The recommendations suggested geared towards managing and incorporating wood-based biomass into all rural SE projects and trying to change the taste of demand towards a more modern energy source. With respect to this, strengthening the policy dialogue through economic and sector work is always a valuable entry point to determine the specific issues in a particular community (AFREA, 2011).

This study has been able to reveal a number of issues regarding rural SE, there are still gaps in research that needs to be filled in order to fully achieve the goals of SE. More research is needed in the field data on quantity of wood-based biomass consumption and supply in rural areas. There should be an agreed valuation standard for the quantity of consumption and supply. These further studies will provide the literature on rural SE an informed database for accurate predictions and decision making.

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Lists of Annexure

Annex 1: Most common sustainable development indicators in policy-based sets

Rank	Broad Indicators	Number of indicator sets where found*
1	Greenhouse gas emissions	22
2	Education attainment	19
3	GDP per capita	18
4	Collection and disposal of waste	18
5	Biodiversity	18
6	Official Development Assistance	17
7	Unemployment rate	16
8	Life expectancy (or Healthy Life Years)	15
9	Share of energy from renewable sources	15
10	Risk of poverty	14
11	Air pollution	14
12	Energy use and intensity	14
13	Water quality	14
14	General government net debt	13
15	Research & Development expenditure	13
16	Organic farming	13
17	Area of protected land	13
18	Mortality due to selected key illnesses	12
19	Energy consumption	12
20	Employment rate	12
21	Emission of ozone precursors	11
22	Fishing stock within safe biological limits	11
23	Use of fertilisers and pesticides	10
24	Freight transport by mode	10
25	Passenger transport by mode	10
26	Intensity of water use	10
27	Forest area and its utilisation	10

Source: UN, 2008

*Based on indicators where 10 or more countries/institutions have adopted them.

Annex 2: Data Source and Analysis Techniques

Data	Sources	Mode of Data Collection	Relevance/Usage	Analysis Technique
Energy Supply (Global, Regional and National Context)	Relevant Literature	Desk study	Provides platform to further ascertain rural energy supply and energy sources	Review of Literature
Rural energy demand	Household and business/industry survey	Questionnaire administration and institutional surveys		Correlation analysis with supply and economic variables
Rural energy supply	Field study (case area) and relevant literature. Institutional survey	Questionnaire administration and desk study. Institutional interviews	Provides understanding as to the issues relating to rural energy supply problems	Statistical frequency tabulations
Factors affecting energy supply shortage	Field study, institutional survey and literature	Questionnaire, interviews and observational tools	Provides the foundation to provide the best approach to securing energy supply and adaptation to climate change	Cross tabulation, correlation and regression analysis to link factors. Chi-Square analysis to test hypothesis
Willingness to Adapt to Climate Change (new approaches to sustained energy supply)	Field survey (case area)	Questionnaire	To identify the willingness of the local people to adapt to the new approach in energy supply as a means to climate change adaptation	Regression analysis and cross tabulation of identified indicators on the willingness to adapt
Approaches to energy supply security	Field survey, institutional survey and relevant literature	Questionnaire, interviews and literature review	Provides options to choose from sustainable energy supply and climate change adaptation	Review of Perceptions of affected people and other stakeholders. Review of literature

Source: Author's Construct, 2011.

Annex 3: Sample size and Minimum Sample Computation

Sample Size (n) = $\frac{N}{1+N(\alpha)^2}$

Minimum Sample Size (n) = P%×q%×(Z/e%)^2

N = Sampling Frame

α= Margin of Error

P = Population Belonging to the specified category

q = Population not belonging to specified category

Z = the z value corresponding to the level of confidence
e = margin of error

<u>Calculations</u>

N=total number of households (32,069[15]) and

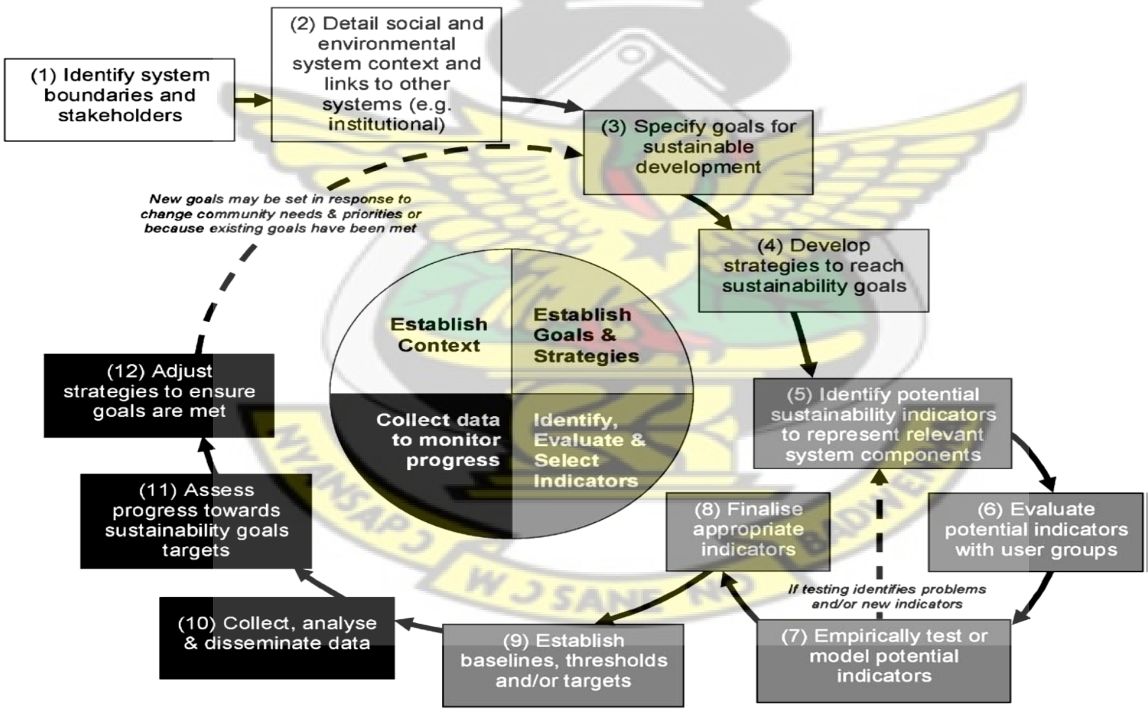
α=0.05

Given this, n = 32069/1+32069(0.05)^2

'n' is thus given as 395. Therefore the sample size is 395 households

However since no pilot survey have been conducted yet, it is impossible to compute the minimum sample required. This will however be done in subsequent surveys.

Annex 4: Process involved in Formulating Indicators for Measurement of SD



[15] Projected figure for 2011

Annex 5: Charcoal production

Daily Supply (kg)	Number of Charcoal Burners /Respondents	Percent (%)
<50	-	-
50-100	5	20
101-150	16	64
151-200	2	8
201-250	-	-
>250	2	8
Total	**25**	**100**

Annex 6: Fuel wood production

Daily Supply (kg)	Number /Respondents	Percent (%)
<50	-	-
50-100	-	-
101-150	5	20
151-200	17	68
201-250	1	4
>250	2	8
Total	**25**	**100**

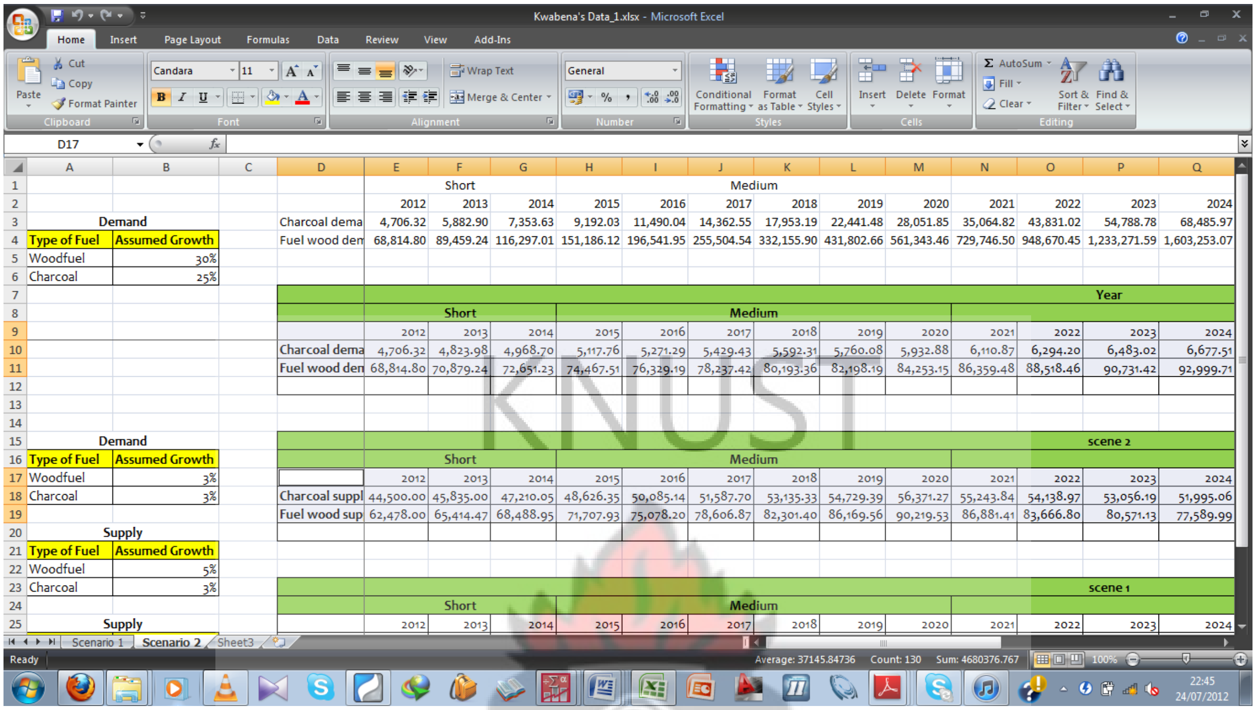
Annex 7: Energy forms used for business

Energy type	Used	Not Used
Fuel wood	48	52
Charcoal	28	72
Electricity	64	36
Petrol/diesel/kerosene	16	84
Other	8	92

Annex 8: Average distance covered to access fuel wood

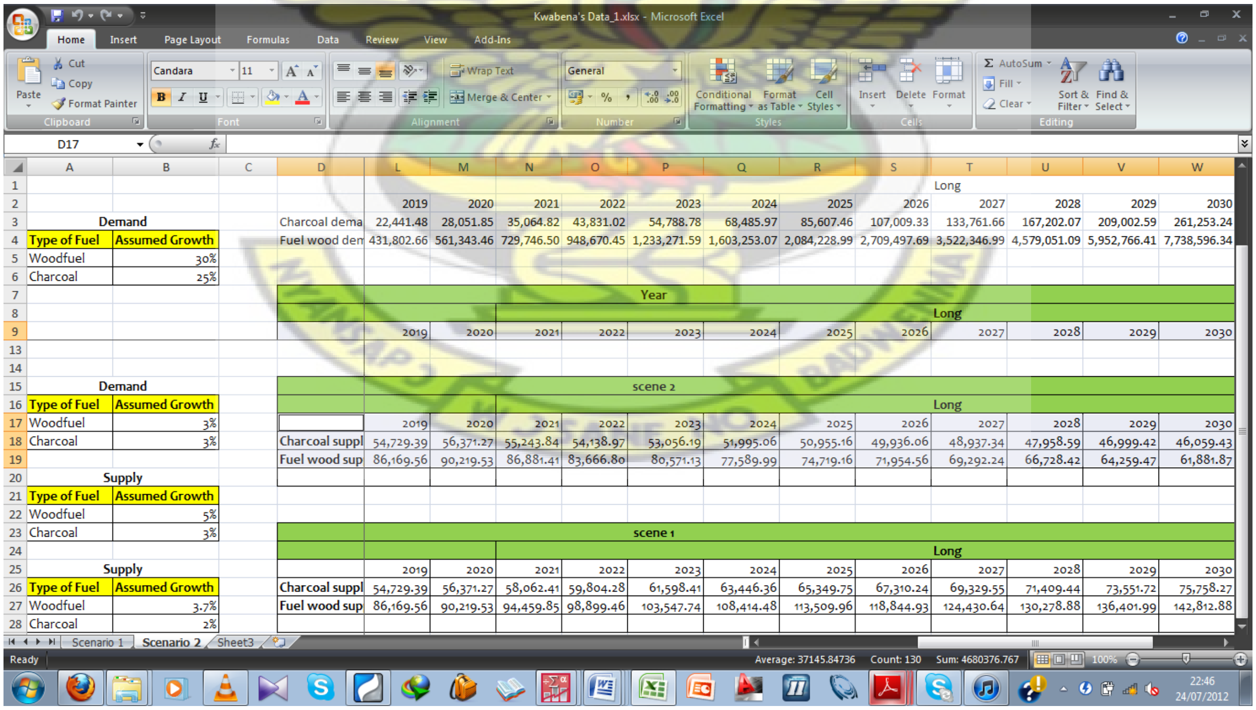
Distance (km)	Frequency	Percent
Less than 1	33	37.0
1-5	50	55.0
6-10	6	7
More than 10	1	1
Total	**90**	**100**

Annex 9: Snapshot of energy demand and supply projection model I



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1						Short				Medium							
2					2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
3	Demand			Charcoal dema	4,706.32	5,882.90	7,353.63	9,192.03	11,490.04	14,362.55	17,953.19	22,441.48	28,051.85	35,064.82	43,831.02	54,788.78	68,485.97
4	Type of Fuel	Assumed Growth		Fuel wood den	68,814.80	89,459.24	116,297.01	151,186.12	196,541.95	255,504.54	332,155.90	431,802.66	561,343.46	729,746.50	948,670.45	1,233,271.59	1,603,253.07
5	Woodfuel	30%															
6	Charcoal	25%															
7																Year	
8						Short				Medium							
9					2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
10				Charcoal dema	4,706.32	4,823.98	4,968.70	5,117.76	5,271.29	5,429.43	5,592.31	5,760.08	5,932.88	6,110.87	6,294.20	6,483.02	6,677.51
11				Fuel wood den	68,814.80	70,879.24	72,651.23	74,467.51	76,329.19	78,237.42	80,193.36	82,198.19	84,253.15	86,359.48	88,518.46	90,731.42	92,999.71
12																	
13																	
14																	
15	Demand															scene 2	
16	Type of Fuel	Assumed Growth				Short				Medium							
17	Woodfuel	3%			2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
18	Charcoal	3%		Charcoal suppl	44,500.00	45,835.00	47,210.05	48,626.35	50,085.14	51,587.70	53,135.33	54,729.39	56,371.27	55,243.84	54,138.97	53,056.19	51,995.06
19				Fuel wood sup	62,478.00	65,414.47	68,488.95	71,707.93	75,078.20	78,606.87	82,301.40	86,169.56	90,219.53	86,881.41	83,666.80	80,571.13	77,589.99
20	Supply																
21	Type of Fuel	Assumed Growth															
22	Woodfuel	5%															
23	Charcoal	3%														scene 1	
24						Short				Medium							
25	Supply				2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Annex 10: Snapshot of energy demand and supply projection model II



	A	B	C	D	L	M	N	O	P	Q	R	S	T	U	V	W
1													Long			
2					2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
3	Demand			Charcoal dema	22,441.48	28,051.85	35,064.82	43,831.02	54,788.78	68,485.97	85,607.46	107,009.33	133,761.66	167,202.07	209,002.59	261,253.24
4	Type of Fuel	Assumed Growth		Fuel wood den	431,802.66	561,343.46	729,746.50	948,670.45	1,233,271.59	1,603,253.07	2,084,228.99	2,709,497.69	3,522,346.99	4,579,051.09	5,952,766.41	7,738,596.34
5	Woodfuel	30%														
6	Charcoal	25%														
7									Year							
8													Long			
9					2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
13																
14																
15	Demand								scene 2							
16	Type of Fuel	Assumed Growth											Long			
17	Woodfuel	3%			2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
18	Charcoal	3%		Charcoal suppl	54,729.39	56,371.27	55,243.84	54,138.97	53,056.19	51,995.06	50,955.16	49,936.06	48,937.34	47,958.59	46,999.42	46,059.43
19				Fuel wood sup	86,169.56	90,219.53	86,881.41	83,666.80	80,571.13	77,589.99	74,719.16	71,954.56	69,292.24	66,728.42	64,259.47	61,881.87
20	Supply															
21	Type of Fuel	Assumed Growth														
22	Woodfuel	5%														
23	Charcoal	3%							scene 1							
24													Long			
25	Supply				2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
26	Type of Fuel	Assumed Growth		Charcoal suppl	54,729.39	56,371.27	58,062.41	59,804.28	61,598.41	63,446.36	65,349.75	67,310.24	69,329.55	71,409.44	73,551.72	75,758.27
27	Woodfuel	3.7%		Fuel wood sup	86,169.56	90,219.53	94,459.85	98,899.46	103,547.74	108,414.48	113,509.96	118,844.93	124,430.64	130,278.88	136,401.99	142,812.88
28	Charcoal	2%														

Annex 11: Snapshot of carbon capture standards

Table 1: Global estimates of land area, net primary productivity (NPP), and carbon stocks in living plants and soil organic matter for ecosystems of the world

Ecosystem	Area (10^{12} m^2)	NPP ($gC/m^2/year$)	NPP(PgC/year)	Plant C (g/m^2)	Plant C (PgC)	Soil C (g/m^2)	Soil (PgC)	Total (PgC)
Tropical forest	14.8	925	13.7	16500	244.2	8300	123	367
Forest Temperate and plantation	7.5	670	5.0	12270	92.0	12000	90	182
Boreal forest	9.0	355	3.2	2445	22.0	15000	135	157
Temperate Wood land	2.0	700	1.4	8000	16.0	12000	24	40
Chaparral	2.5	360	0.9	3200	8.0	12000	30	38
Tropical Savannas	22.5	790	17.8	2950	65.9	11700	263	329
Temperate grasslands	12.5	350	4.4	720	9.0	23600	295	304
Tundra, arctic and alpine	9.5	105	1	630	6	12750	121	127
Desert and semi desert scrub	21	67	1.4	330	6.9	8000	168	175
Extreme desert	9	11	0.1	35	0.3	2500	23	23
Perpetual ice	15	0	0	0	0	0	0	0
Lake and streams	2	200	0.4	10	0	0	0	0
Wetland	2.8	1180	3.3	4300	12.0	72000	202	214
Northern Peatland	3.4	0	0.0	0	0.0	133800	455	455
Cultivated and permanent crop	14.8	423	6.3	200	3	7900	117	120
Human areas	2.0	100	0.2	500	1.0	5000	10	11
Total	150.8		59.1				2056	2542

Annex 12: Survey Instruments

1. FORESTRY DIVISION

Part 1 – Forest Cover

1. What is the current forest cover size (km^2) of the Nzema East Municipal area?...................................

2. Has this size decreased over the past 5 years?

Yes..................[1]   No....................[2]

3. If yes, by how much size (km^2) has it decreased?..

4. Can you please provide a trend in this depletion on an annually basis or any basis deemed fit?

Years	**2007**	**2008**	**2009**	**2010**	**2011**
Rate of Depletion (%)					
Actual Size of Depletion					

5. What has caused this reduction in the size of the forest cover?

....

6. What are some of the immediate effects affecting the district, especially the rural communities?

....

Part 2 – Forest Cover and Climate Change

7. Do you think the impacts of climate change have contributed to the depletion of the forest cover?

Yes.................[1]   No.................[2]

8. If yes, in what forms is/are impacts of climate change contributing to this depletion?

....

Part 3 – Adaptation Issues

9. Do you think rural communities in your Municipality, fell trees for wood fuels?

Yes................[1]   No.................[2]

10. If yes, what do you think will be a likely option of fuel for these communities if all the trees are depleted?

....

11. Are there plans and/or policies to improve and control current activities on the forests?

Yes...............[1]   No...............[2]

12. Please provide such plans and/or policies if yes in Q11 above

....

2. WOOD-BASED PRODUCERS/SELLERS

<u>Part 1 – Personal Profile</u>

1. Age of interviewee…………………………………………..
2. Sex of interviewee   Male.............. [1]   Female…............[2]
3. Marital Status
    - Married………………………………………………[1]
    - Single (never married)……………………………[2]
    - Widow (er)………………………………………   [3]
    - Divorced ……………………………………….……[4]
    - Separated……………………………………………[5]
    - Others (specify)……………………………………...[6]
4. Educational Background
    - None……………………………………………….........[1]
    - Elementary School (Nursery –Class 6)………...............[2]
    - Did not complete Elementary School ....[3]

- Completed Basic School (Elementary to JHS/Form 4).....[4]
- Did Not Complete Basic School……………………….[5]
- Completed Secondary School…………………………[6]
- Did Not Complete Secondary school………………….[7]
- Completed Tertiary Education…………………………[8]
- Did not Complete Tertiary Education…………………[9]
- Islamic…………………………………………………[10]
- Others (Specify)………………………………………[11]

Part 2 Information about the Industry

5. What type of fuelwood venture are you into?
   - Charcoal burning only...[1]
   - Firewood only...[2]
   - Both charcoal and firewood production................[3]

6. How long have you been in this industry?
   Below 1 year .... [1] 2-5 years ....[2] 6-10 years....... [3] above 10 years........ [4]

7. How many employees do you have?
   - Sole Proprietorship....... [1]
   - 1 employee................... [2]
   - 2-5 employees.............. [3]
   - Above 5 employees...... [4]

Part 3- Fuelwood Production and Climate Change

Charcoal Producers Only – from Q8 –16

8. What method of charcoal production do you employ?

- Earth Mound...........................[1]
- Sealed Metal Container..........[2]
- Charcoal Kiln...........................[3]
- Others...................................[4]
  specify...

9. How long (hours) does it take to complete a single production unit?

....

10. What is the average number of bags produced per week?

- Less than 1 bag...............[1]
- 1-5 bags..........................[2]
- 6-10 bags.........................[3]
- 11-15 bags.........................[4]
- 16-20 bags.......................[5]

- More than 20 bags.........[6]

11. What is the average weekly and monthly expenditure on production?

Weekly Expenditure (GHS)	Monthly Expenditure (GHS)

12. Monthly income from charcoal production?

....

13. What tree/wood type (s) do you prefer to use?

....

13 i. Give reasons for the above response in Q13

....

14. Rank your main consumers on a scale of 1-5 {with 5 being the main and 1 being the least consumer}?

- Households..................................
- Industries.....................................
- Food vendors................................
- Service providers..........................
- Retailers (i.e. middlemen).............
- Others (specify)............................

15. How do you obtain your wood for charcoal?

- Tree cutting by self.........................[1]
- Buy from wood operators..............[2]
- Hand picking from the woods........[3]
- Others ....[4] specify...

16. Do you obtain your wood within the community or outside the community?

- Within the community..............[1]
- Outside the community............[2]
- Both..[3]
- Others....................................[4] specify...

Firewood Sellers Only – from Q17-23

17. 8. How do you obtain firewood for merchandise?

- Tree felling by self...........................[1]
- Wood lot cultivation.......................[2]
- Mangrove Plantation......................[3]

- Hand picking from farm.................[4]
- Buy from other communities........[5]
- Others ....[6]specify..

18. How much (kg) firewood is collected per week?

....

*calculate with respondent using a bag of cement = 50kg as the benchmark for calculation. i.e. the number of firewood that can fit into a bag of cement as a Comparism to pile of firewood collected.

19. What is the average weekly and monthly expenditure on firewood collection?

Weekly Expenditure (GHS)	Monthly Expenditure (GHS)

20. Monthly income from charcoal production?

....

21. What tree/wood type (s) do you prefer to collect as firewood?

....

21 i. Give reasons for the above response

....

22. Rank your main consumers on a scale of 1-5 {with 5 being the main and 1 being the least consumer}?

- Households.................................
- Industries....................................
- Food vendors...............................
- Service providers..........................
- Retailers (i.e. middlemen).............
- Others (specify)............................

23. Do you obtain the wood within the community or outside the community?

- Within the community..............[1]
- Outside the community............[2]
- Both...[3]
- Others.....................................[4] specify...

<u>Part 4- Trade-offs Between Energy Supply and Climate Change</u>

24. Can you say that the quantities of the energy you produce/sell have increased over the past 3 – 5 years?

Yes........[1]   No........[2]

25. How much (%) has it increased/decreased?
....

26. Give reasons for your answer to Q24 – (what caused the increase, decrease or constant);
....

27. Do you think rural energy demand patterns will change from its current woodfuel to more sophiscated energy sources in the next 5-10 years?

Yes..........[1]   No..............[2]

28. What are your reasons for the above response?

....

29. What is your idea about the rate of tree felling for charcoal and firewood and its effects on the environment?

....

30. How do you think your supply can be made sustainable for future demand without affecting the environment?

....

31. Are you willing to change your energy supply sources for an alternative source if you are asked to?

Yes.................[1]   No.....................[2]

3. BUSINESS/INDUSTRY SURVEY

<u>Part 1 – Personal Profile</u>

8. Age of interviewee…………………………………………..
9. Sex of interviewee   Male.............. [1]   Female…...........[2]
10. Educational Background
    - None………………………………………………........[1]
    - Elementary School (Nursery –Class 6)……….............[2]
    - Did not complete Elementary School ....[3]
    - Completed Basic School (Elementary to JHS/Form 4).....[4]
    - Did Not Complete Basic School……………………….[5]
    - Completed Secondary School…………………………[6]
    - Did Not Complete Secondary school………………….[7]
    - Completed Tertiary Education…………………………[8]
    - Did not Complete Tertiary Education…………………[9]
    - Islamic…………………………………………………[10]

- Others (Specify)……………………………………….[11]

11. What is the status of the interviewee?
    Owner................ [1]   Employee ....[2]

Part 2 Information about the Industry/Business

12. What is the nature of your Industry (activities you undertake)?
    ....
    How long have you been in this type of industry?
    Below 1 year .... [1]   2-5 years ....[2]   6-10 years....... [3]   above 10 years........ [4]

13. How many employees do you have?
    ....
    - Sole Proprietorship....... [1]
    - 1 employee................... [2]
    - 2-5 employees.............. [3]
    - Above 5 employees...... [4]

14. What are your typical hours of operation?
    ....

15. When your business is not in full operation, what do you do?
....

Part 3- Energy Use and Energy Demand

16. What are the main source(s) of energy your industry consumes for production?

Energy Source	Yes	No
Fuelwood		
Charcoal		
Electricity		
Solar PV		
Petrol/Diesel/Kerosene		
Others (specify)		

12. How much quantity of energy is consumed every week and every month?

Energy Source	Weekly	Monthly
Fuelwood ***(kg)***		
Charcoal ***(kg)***		
Electricity ***(KWh)***		
Petrol/Diesel/Kerosene ***(gallons)***		

Others (specify)		

12i. How do you rate the frequency to which your industry have access to its source of energy?

- Highly Frequent ....[1]
- Moderately Frequent........[2]
- Stable................................[3]
- Moderately Infrequent.....[4]
- Highly Infrequent.............[5]

13. How much money is spent on energy consumption every week and every month?

Energy Source	**Weekly** (GHS)	**Monthly** (GHS)
Fire wood		
Charcoal		
Electricity		
Petrol/Diesel/Kerosene		
Others (specify)		

14. In total, how much do you spend on energy for the **month?**
....

15. How much **do you earn** at the end of the month from this business?
....

16. On the average, how much profit do you make out of this business every month?
....

17. With reference to the energy sources mentioned above, can you say that the quantities of the energy you use have increased over the past 2 – 5 years?
Yes........[1] No........[2]

18 How much (quantity) has it increased?
....

19. Give reasons for your answer to Q17 – (what caused the increase, decrease or constant);
....

<u>Part 4- Trade-offs Between Energy demand and Climate Change</u>

20. Do you think your demand for energy will increase in next 2-5 years?

Yes................[1] No.............[2]

21. If no, why?

....

22. If yes, how can you rate the increase in demand?

- Increase by less than half the current consumption level........................[1]
- Increase by half the current consumption level.......................................[2]
- Increase by more than half the current consumption level.....................[3]
- Increase by twice the current consumption level....................................[4]
- Increase by more than twice the current consumption level...................[5]

23. Given all energy options for you to choose, which energy source will you use for your industry?

Energy Source	Choice of Consumption
Firewood	
Charcoal	
Electricity	
Solar PV	
Petrol/Diesel/Kerosene	
Others (specify)	

24. What are the reasons for your above response?
....

25. Are you willing to change your current energy source for an alternative energy source if you are asked to?
Yes......................[1]   No........................[2]

26. What are your reasons for this response?
....

4. METEOROLOGICAL SURVEY DEPARTMENT

Part 1 – Climate Change Patterns

1. In your view, has the climate changed in this area?

Yes.........[1]   No..........[2]

2. What has been the normal annual average temperature record in your Municipality?..

3. Over the past 10 years, has this average been the same?

Yes.........[1]   No........[2]

4. How will you rate this change in temperature, if no in Q3 above?

i. Very high.......................[1]
ii. High.............................[2]
iii. Moderate...................[3]
iv. Low...........................[4]
v. Very low.....................[5]

5. What has been the normal annual average rainfall record in your Municipality?..

6. Over the past 10 years, has this average been the same?

Yes.........[1]   No........[2]

7. How will you rate this change in rainfall, if no in Q6 above?

i. Very high.......................[1]
ii. High.............................[2]
iii. Moderate...................[3]
iv. Low...........................[4]
v. Very low.....................[5]

Part 2 – Climate Change and Energy Supply

8. Do you think the changes in climate patterns have effects on rural energy supply, in terms of wood fuels and electricity?

Yes..........[1]   No...........[2]

9. If yes, what are some of these effects?

....

10. Are current energy sources (wood fuels and electricity) available to rural communities sustainable given the trend in climate patterns?

Yes.........[1]   No.........[2]

5. HOUSEHOLD SURVEY

Part 1 – Personal Information

17. Who is the head of your household?

- Self……………………………………………………………[1]
- Spouse…………………………………………………….[.2]
- Parents…………………………………………………….[3]
- Parents-in-law…………………………………………..[4]
- Siblings…………………………………………………[5]
- Others (Specify)………………………………………..[6]

18. Age of interviewee………………………………………..

19. a. Sex of interviewee Male [1] Female…[2]

b. Sex of Household Head (if not respondent)..... Male [1] Female… [2]

20. Marital Status

- Married…………………………………………………[1]
- Single (never married)………………………………[2]
- Widow (er)…………………………………………… [3]
- Divorced ………………………………………..……[4]
- Separated…………………………………………….[5]
- Others (specify)……………………………………...[6]

21. Educational Background

- None……………………………………………............................1
- Elementary School (Nursery –Class 6)……………………...…….2
- Did not complete Elementary School 3
- Completed Basic School (Elementary to JHS/Form 4)..................4
- Did Not Complete Basic School……………………...............…5
- Completed Secondary School…………..................…………….6
- Did Not Complete Secondary school…...................……………….7
- Completed Tertiary Education………..................………………8
- Did not Complete Tertiary Education……………....................……9
- Others (Specify)…………………………….................………10

Part 2 – Members of Household and Household Status

22. Type of Family

- Single…………………………………………………….…1
- Nuclear……………………………………………………2
- Extended…………………………………………………..…3

23. What is the size of your household? ……………………………

24. Please supply the information below about the members of your household

Name	Gender Male [1]	Age	**Level of education** *No schooling [1]*	**What is her/his employment status**

	Female [2]		*Currently in Elementary Sch [2] Completed elementary school [3] Currently in JHS [4], Completed JHS [5] Currently in SHS [6], Completed SHS [7] Some elementary Sch [8], Some JHS [9] Some SHS [10], Literacy skills [11] Vocational (eg. Technical) [12] Some vocational [13] Completed Tertiary [14] Some tertiary [15]*	*Employment fulltime [1] Employment part time [2] Self-employed [3] Pensioner/retired [4] Student (school children) [5] Housewife/home maker [6] Unemployed [7] Apprenticeship [8] Unemployed, looking for work [9] Unemployed disabled [10] Preschool child [11], Other [12] (specify)………………….*

<u>Part 3 - Energy Form Appropriate for Sustainability</u>

9. Which of the following energy sources is/are available in your community?

Energy Source	Yes	No
Fuelwood		
Charcoal		
Electricity		
LPG		
Kerosene/Petrol/Diesel		
Solar Panels		
Others		

10. Which energy source (s) does your household use?

- Fuelwood only.............................[1]
- Charcoal only...............................[2]
- Electricity only.............................[3]
- All of the above...........................[4]
- Others... [5] Specify..

11. Why does your household use the above choice?
....

12. Will your household continue to use this energy source for the next 2-5 years?

Yes...... [1] No..... [1], if no which energy source (s) will you use...

13. What are your reasons for the above answer?..

12. What is the main energy source, second and third sources the household use for **lighting, cooking, water heating, and ironing?**

End use	*Firewood [1] Charcoal [2] Electricity [3] Other (specify)* [4]		
	Main Energy	**Second Energy**	**Third Energy**
Lighting			
Cooking			
Water Heating			
Ironing			

<u>Part 4 – Extent of Energy Form Effects on Climate Change</u>

13. How much quantity of energy is consumed per week and month?

Fuelwood (kg)		**Charcoal (kg)**		**Electricity** *(KWh)*	
Weekly	Monthly	Weekly	Monthly	Weekly	Monthly

**Charcoal is measured in bags quantified in Kg – compared to a bag of cement (50kg and 40kg) firewood is measured with respondents in the same manner.*

14. How much money is spent on energy source per week and month?

Fire Wood (GHS)		**Charcoal (GHS)**		**Electricity (GHS)**	
Weekly	Monthly	Weekly	Monthly	Weekly	Monthly

15. What is the distance [*a return trip*] covered by household members to collecting firewood?

Less than 1km......... [1] 1 to 5km.......... [2] 5 to 10km........ [3] More than 10km.......... [4]

16. Has this distance been the same for the past 10 years?

Yes.......[1] No.......[2]

17. What is the reason (s) for the above answer?

....

<u>Part 5 – Required Tradeoffs between Energy Demand and Climate Change Impacts</u>

18. If you are given the option to choose from a list of energy types, which one will your household use?

- Charcoal.....[1]
- Fuelwood.....[2]
- Electricity.......[3]
- LPG.............[4]
- Solar..........[5]
- Petrol/Diesel/Kerosene......[6]
- Others..........[7] specify...

19. Are you willing to change your choice of energy use currently for a different source, should you be asked to change?

Yes...........[1] No............[2]

20. What reason (s) can you give for the above response?

....

21. Are you aware that frequent use of fuelwood and charcoal is destroying your forests?

Yes.............[1] No...............[2]

21. What do you as an individual do to protect the environment when you cut trees for firewood and charcoal?

....

22. Is there a particular tree type/species that you prefer to use for your firewood and charcoal?

Yes.....................[1] No.......................[2]

23. If yes, are you willing to stop using this tree type for an alternative if you are asked to do so as a result of environmental protection?

Yes....................[1] No..........................[2]

Part 6 – Time and Spatial Dimensions of Energy Security and Adaptation

24. In the next 2-5 years, do you think your current energy consumption will increase?

Yes....... [1] No............ [2]

25. If yes, in rating your future consumption, by how much do you think your energy consumption will increase?

- Remain the same...[1]
- Increase by less than half the current consumption level..................[2]
- Increase by more than half the current consumption level................[3]
- Increase by twice the current consumption level..............................[4]

- Increase by more than twice the current consumption level.............[5]

26. Where do you obtain your energy source from?

- Within the community.................[1]
- Outside the community...............[2]
- Others................................[3] specify.......................................

27. If outside the community, how far is the energy source from your residence?

Less than 1km......... [1] 1 to 5km.......... [2] 5 to 10km........ [3] More than 10km.......... [4]

Part 7 – Rural Capacity to adapt to Climate Change

28. Do you face lack of access to energy source sometimes in the year?

Yes................[1] No....................[2]

29. How do you rate the frequency to which your household have access to its main source of energy?

- Highly Frequent ....[1]
- Moderately Frequent........[2]
- Stable.................................[3]
- Moderately Infrequent.....[4]
- Highly Infrequent.............[5]

30. What do your household do when you are faced with no access to your desired energy source?

....

31. What facilities are available in your household that helps you in times of energy shortage?

- Generator ....[1]
- Electricity........[2]
- Solar PVs.........[3]
- Obtain help from neighbour........[4]
- Others............ [5] Specify..

32. Are you able to pay for your energy consumption on a regular basis?

Yes............[1] No................[2]

33. What is the reason (s) for the above response?

....

34. Is the energy source you desire, and are able to pay for, available in your community for demand?

Yes............[1]   No...............[2]

35. If no, where do you obtain this energy source?

....

36. What is your average monthly income
(GHS)?...

6. NEMA

Part 1 – Rural Energy and Climate Change Profile

1. What is this current source(s) of energy in rural areas in your municipal?

Source of Energy	**Approximate proportion of people who use it** *All rural communities [1], More than half [2], Half [3], Less than half [4], None [5]*
Charcoal	
Firewood	
Electricity	
Kerosene/Diesel/Petrol	
Farm Residue	
Solar PVs	
Other (specify)	

2. Please give examples of recent climate change impacts in your municipal, especially affected rural areas (if any).
....
3. Are there plans and programmes towards climate change issues in your assembly?
Yes............ [1]   No...........[1]
3a. If no, why?
....
3b. If yes, what are the plans and programmes outlined towards addressing climate change issues in your area?
....
4. What are the typical energy problems in rural communities of your municipal?
....
4a. What is/has been done to address these problems?
....
5. To what extent have energy policies been implemented in your municipal; using the rural electrification project as a stand point?
....

6. Is climate change affecting the supply of energy (Electricity; Firewood and Charcoal) in rural communities in your assembly?
Yes..........[1]   No...........[2]
7. If yes, in what ways
....

Part 2 – Rural Adaptive Capacity

8. What types of industries are available in rural communities in your assembly?
....

9. What infrastructures are available in the rural communities in your municipal?

Infrastructure	Available Yes[1], No [2]	Number Available
Educational Institution		
Hospital/Clinic/Health Centre/CHPS		
Roads (feeder)		
Financial Institutions		
Telecommunication Networks		
Internet Access		
Recreational Places		
Electricity Access		
Potable Water Access		
Others (specify)		

10. In what ways does the assembly help in providing support to rural areas in terms of energy need?
....

Part 3 – Trade-offs Between Sustainable Energy and Climate Change
11. In your view, which energy source is appropriate for sustainable consumption in rural areas within your municipal?
....

12. To what extent does rural energy consumption and/or supply affect climate change in your assembly?
....
13. To what extent does climate change affect rural energy consumption and/or supply in your assembly?
....
14. Do you think a change in the type of energy consumed in rural areas will be possible in the next 5-10 years?
Yes.................[1]   No.......................[2]
15. What are the reasons for the above response?
....
16. How do you think rural energy can be sustained without further damaging the natural forests and affecting climate change?

....

7. CHECKLIST FOR RELIABILITY ANALYSIS

Metrics / Attributes			Primary Source of supply	Energy conversion	Transport
Capacity	Utilisation	r_i			
		w_i			
	Intermittency	r_i			
		w_i			
	Capacity	R			
		W			
Flexibility	Response to demand fluctuations	r_i			
		w_i			
	Ability to expand facilities	r_i			
		w_i			
	Flexibility	R			
		W			
ADEQUACY		R	**0.56**		

Metrics / Attributes			Primary Source of supply	Energy conversion	Transport
Infrastructure vulnerability	Physical security	r_i			
		w_i			
	Interdependencies	r_i			
		w_i			
	Sector coordination	r_i			
		w_i			
	History	r_i			
		w_i			
	Infrastructure vulnerability	R			
		W			
Consequences	Economic impacts	r_i			
		w_i			
	Environmental impacts	r_i			
		w_i			
	Human health impacts	r_i			
		w_i			
	Consequences of infrastructure disruption	R			
		W			

Energy security	Import levels	r_i			
		w_i			
	World excess production capacity	r_i			
		w_i			
	Price volatility	r_i			
		w_i			
	Energy security	R			
		W			
SECURITY		$\boldsymbol{R}$	**0.47**		