KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ART AND SOCIAL SCIENCES

DEPARTMENT OF ECONOMICS

ASSESSING THE EFFECT OF CLIMATE CHANGE ON ELECTRICITY DEMAND FOR ASHANTI-WEST REGION OF GHANA

BY

ERIC KWESI DADZIE

A THESIS SUBMITTED TO THE DEPARTMENT OF ECONOMICS, FACULTY OF SOCIAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF A MASTER OF PHILOSOPHY DEGREE IN ECONOMICS.

OCTOBER, 2013

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Telephone: Kumasi 5350, 5350, 5351-9 Ext, 457
Telegrams: KUMASITECH

DEPARTMENT OF ECONOMICS
(FACULTY OF SOCIAL SCIENCES)
KUMASI GHANA

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I hereby declare that this Master's Thesis has been completed by me under the supervision of Mr. J. D. Quartey. All the data and cases are authentic, which have been collected from respective accredited state institutions, or included indirectly from official reports. All private opinions introduced directly or indirectly, quoted or paraphrased in this thesis, their references are meticulously cited at the end of the quotation.

Signature .... Date 16-10-2013

ERIC KWESI DADZIE

(STUDENT)

I declare that I have supervised the student in undertaking the study submitted herein. The student has been consistent in interacting with me for guidance and direction.

Signature .... Date 21-10-13

MR. J. D. QUARTEY

(SUPERVISOR)

ABSTRACT

Climate Change is a convoluted phenomenon affecting directly or indirectly all forms of life, both human population and the natural ecological system. It affects human health, productivity (especially in agriculture), availability and accessibility of water resources, leisure (tourism destination choices), sea level, biodiversity as well as production and consumption of energy. Climate Change is expected to influence a range of climatic variables, and as electricity demand is closely related to some of them, it is likely to impact electricity demand patterns. The research presents an initial attempt to measure and quantify the relationship between changing weather conditions and demand for electricity in Ashanti-west region, using a dynamic process by employing autoregressive models. The main objective of the research was to explore Ashanti region residential energy demand responses to Climate Change, emphasising on electricity demand sensitivity to weather variations. Specifically, to ascertain the relationship between residential electricity demand and socio-economic and climate covariates, establish their respective short and long run elasticities and finally assess electricity demand sensitivity to seasonal variations. The electricity demand function was estimated and the socioeconomic values had their expected signs and consistent values. Negative and positive low elasticity values for price and income respectively showed that, electricity is a normal and strictly necessity good. Elastic values for population indicated that demand is highly responsive to demographic factors. Climate variables also had their expected signs, positive for temperature and negative for precipitation consistent with the cooling effect concepts that, demand for electricity for cooling purposes increases as society gets warmer. Climate Change was showed to have a positive relationship with electricity demand in that electricity demand increases as Climate Change effects intensify. Both climate variables had very low elasticities values indicating demand is highly inelastic to weather conditions in Ashanti-west region. Hypotheses tests revealed that, there were significant differences in patterns of electricity demand between dry season and wet season of the year. For individual climate variables, precipitation was significant but temperature was not. The findings implication for policy was that, residents have shown signs of reactions to weather conditions through changing patterns for electricity demand and that, it is most important to proactively make climate considerations in demand side energy policies and programmes. Furthermore, similar research should be undertaken nationwide and on wider timeframe to help quantify national environmental influence on energy demand due to the centrality and the monopolize nature of Ghana's electricity industry.

ACKNOWLEDGEMENTS

I wish to express my unalloyed gratitude to Almighty God who gave me the will and the strength to go through the period of writing this work.

I am most grateful to Mr J. D. QUARTEY of Department of Economics, KNUST for his guidance throughout the research. It is his constructive criticisms, comments and suggestions, patience, knowledge and also allowing me to work on my own way, that this product have emerged; one simply could not wish for a better or friendlier supervisor and for that I am so thankful.

I would also like to thank my friends and love ones who were always encouraging me with their best wishes, especially Patience Dawda who supported me in both prayers and emotions. Finally, I appreciate the efforts of all whom in one way or the other contributed to the completion of this research, I say a big thank you.

DEDICATION

I dedicate this thesis to my family. Without their patience, understanding, encouragement and most of all love, the completion of this work would not have been possible, especially to my mum and dad, Aunty Becky and Uncle Dadzie for their immense contribution not only into this research but into my life generally. I also, dedicate this work to all my friends who encouraged me in diverse ways to bringing this work to completion.

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ABBREVIATIONS AND ACRONYMS

Term	Description
ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag Model
EC	Energy Commission
ECG	Electricity Company of Ghana
EIA	Energy Information Administration
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
GMM	Generalised Method of Moment
IPCC	Intergovernmental Panel on Climate Change
NED	Northern Electrification Department
PURC	Public Utility Regulatory Commission
SNEP	Strategic National Energy Plan
UN-DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
VRA	Volta River Authority
WTP	Willingness To Pay

Units	Description
^0C	Degrees Celsius
CO_2e	Carbon Dioxide Equivalents
GWh	Giga Watt Hours
kWh	Kilo Watt Hours
GHc	Ghana Cedi
ppm	Parts Per Million
Btu	British thermal units

CHAPTER ONE

INTRODUCTION AND OVERVIEW

1.0 BACKGROUND

Global average temperature rose by about 1 degree Celsius during the last century and is expected to rise by more than 1 and between 1.8 and 4.0 over the current century, depending on the emission scenario of Intergovernmental Panel on Climate Change (IPCC 2007). This phenomenon termed Climate Change, has the potential of affecting many related phenomena, such as human health, through the diffusion of heat and cold related, vector-borne diseases (Bosello, Roson and Tol, 2006), productivity in agriculture (Bosello and Zhang, 2005), sea level rise (Bosello, Roson and Tol, 2007), availability and accessibility of water resources (Calzadilla, Pauli and Roson, 2006), as well as tourist destination choices (Berrittella et al., 2006). Among these and other economic consequences of Climate Change, the impact on energy use is of critical importance and may be a larger part of the total economic impact of Climate Change (Toll, 2009).

Today, the issue of Climate Change has become a scientifically established fact (UNDP, Ghana, 2012) and the consequences attributed to climatic change are commonly becoming obvious and affect human populations and the natural ecological systems in diverse ways. These adverse effects may also institute some behavioural changes for those who are affected. This can be referred to as an adaptation to Climate Change, "*that is the change of behaviour and habits consequent to the effects of Climate Change*" (De Cian et al, 2007).

There is an obvious relationship between Climate Change and energy demand. Climate Change is related to the concentration of greenhouse gases in the atmosphere. And there is a distinct impact of Climate Change on demand for energy due to variations in the geographical and temporal distribution of climatic variables (Toll et al, 2012; De Cian et al, 2007).

Obviously, the energy sector has been an area that contributes to and also suffers from the impacts of climate warming; therefore it is a sector that is very important to be considered in addressing Climate Change issues. One particular issue germane to this research is how the increase of global temperature has changed the patterns of residential demand for energy. Residential demand as against non-residential and industrial demand for energy should not be underestimated, in that, according to the Special Report on Emission Scenarios (2000) of the IPCC, residential demand for energy use in 1990 accounted for one third of the overall primary energy used, and it has been increasing since (cited in De Cian et al, 2007), current statistics shows that it is increasing at 1.1% per year from 52 quadrillion Btu in 2008 (US Energy Information Administration- international energy outlook, 2011). Similar statistics can be inferred from Ghana. According to the Ghana Energy Commission's national energy statistics 2000 – 2010 (2011), electricity consumption for residential purposes has always exceeded one third of the national total demand for almost a decade and recorded the highest at 41% of the national consumption in the year 2004.

The existence and attributes of Climate Change is clear indication of a long and continuous ignorance and abuse of the environment as individuals, firms and nations seek to achieve growth and development through their production activities. These persistent ignorance of economic insights regarding the side effects that our productive activities has on the environment has resulted in behaviours that apportion very less value on life by permitting too much pollution. Climate Change shocks, give credence to the assertion that the value of human life (the span of human activities and the exploitation of the environment) is never infinite and also the optimal value given to pollution is not zero (Anderson, 2010).

Ghana just like any other developing country and parts of sub-Saharan Africa suffers from the impact of Climate Change. According Ghana Environmental Protection Agency (2000), Temperatures have risen by about 1 degree Celsius over the last 4 decades in Ghana.

Within the same period rainfall and runoff also recorded to have declined by about 20% and 30% respectively. This has not only resulted in disrupting agricultural systems, flooding coastal areas and lowering water levels around the Volta River delta which provides around 80 percent of Ghana's electric supply as postulated by World Bank (2012), but it also affects demand for electricity. Climate Change is expected to influence a range of climatic variables, and as electricity demand is closely related to some of them, it is likely to impact electricity demand patterns. Climate Change affects Ghana power sector via various channels: first, Power generation from hydropower and second, changing demand for electricity for heating and cooling preferences. As Climate Change increases temperature, changes the amount of precipitation and also distorts the number of sunny days per year, this could affect consumption of electricity by changing residential demand for energy for heating and cooling purposes. Heating effect is the decrease of the use of energy for heating purposes and cooling effect is the increase of energy demand for cooling purposes as global temperatures increases (De Cian et al, 2007). These are two important effects that influences the households final electricity consumption as the consequences of climate change increases and these effects act in opposite directions.

"*Ghana's electricity sector suffers from the chronic problem of frequent power outages with very high uncertainty levels in the timing, frequency and duration*" (Adom, 2013) now popularly termed as "Dumso" meaning load shedding. According to Brew – Hammond and Kemausuor (2007), the frequent and untimely power crises in recent times is not due to the old reason of low water levels in the Volta Lake. Clearly the problem is obviously the lack of capacity in keeping up to fast increasing national electricity demand. Since electricity production and consumption is affected by Climate Change, climates contribution to the power crisis is the limited rains to power turbines (supply side effect) or likelihood of indirectly changing the rate and patterns of electricity use (demand side effect).

The recent nature of the power crises raises a critical question as to how environmental dimensions are incorporated in energy policies.

The numerous negative effects of Climate Change on Ghana and consistently countless adverse effects worldwide arouse an attention of how Climate Change has created categories of dichotomous tension: weighing development against nature, present against future, and certainty against the unknown. The environment has also weighed morally, dilemmas over profits as against environmental amenities (Anderson, 2010).

1.1 STATEMENT OF THE PROBLEM

Climate Change could have significant effects on the energy sector in many countries, especially developing ones. Forecasted and currently rising temperatures, changes in the rate and amount of precipitation, the number of sunny days per year, variation in humidity and wind patterns could affect both consumption (via heating and cooling effects) and production of energy (Feenstra et al, 1998)."While the majority of climate impact assessments have concentrated on contributions of the energy sector to Climate Change, few have explored the reverse – implications of Climate Change on the energy sector" (Amato et al, 2004). Even that, almost all the assessment pertains to developed countries. Though Ghana has made some attempts and commitment to the assessment of Climate Change through collaborations among the International community, Intergovernmental Organisations (IGO) and some institutions in Ghana particularly Environmental Protection Agency (EPA). So far, almost all the attempts made to investigate the impacts Climate Change has on the energy sector are concentrated on the supply-side that is, the production of energy (see Bekoe and Logah, 2013; PURC, 2010; Akuffo, 2008; Otchere, 2006; Gyau-Boakye, 2001). This has resulted in the expansion of the sector evidence by the building of the Bui Dam, the extraction of petroleum and the impending establishment of the gas plant. Fewer investigations are done on the demand side of the adaptation equation and that is the changing energy consumption responses to Climate Change in Ghana.

The bias in the concentration of researches away from the demand side of the energy sector is even worse in developing countries. In Ghana, though there are institutions such as Ghana Energy Commission and Resource Centre for Energy Economics and Regulation that concentrate on researching and reporting on energy demand and projections. Also there are some few academic researches on energy demand, the most recent is by Adom (2013) on time varying analysis of aggregate electricity demand in Ghana. Yet there is still paucity of empirical literature on energy demand. From this scarce literature that exists, only minute proportions present formal econometric studies of the energy demand responses to relevant regressors.

The dearth studies concentrating on the demand-side management of electricity in Ghana, restrictively explores the usual historical socioeconomic factors as the drivers of electricity demand. These factors are population, urbanisation and economic growth (see SNEP report by Ghana Energy Commission (2012), Adom and others (2011) and Resource Centre for Energy Economics and Regulation (2005)); income, economic structure and industry efficiency (Adom, 2013). Clearly, Environment - energy demand relationship analysis is an unexplored area leaving a glaring gap for Ghana and sub-Saharan Africa. The existing challenges from the recent past in Ghana's electricity sector clearly necessitate the design and implementation of appropriate demand related policies. therefore going beyond the relatively overly studied socioeconomic factors by identifying and incorporating environmental factors, that affect aggregate electricity demand and quantifying their relative effects has important implications for effective demand-side management programmes.

1.2 OBJECTIVES OF THE STUDY

1.2.1 General Objective

The general objective of this research is to explore Ashanti-west region residential energy demand responses to Climate Change, emphasising on Electricity demand sensitivity to weather variations by residents in the region.

1.2.2 Specific Objectives

1) To ascertain the relationship between Climate Change and Ashanti-west region residential electricity demand.
2) To estimate short and long run weather variables elasticity of demand for electricity.
3) To assess electricity demand sensitivity to seasonal variations.

1.3 HYPOTHESES

1. H_0: there is no significant relationship between Climate Change and residential electricity demand in the Ashanti-west region of Ghana.

   H_1: there is significant relationship between Climate Change and residential electricity demand in the Ashanti-west region of Ghana.

2. H_0: there is no significant relationship between seasonality and residential electricity demand in the Ashanit-west region of Ghana.

   H_1: there is significant relationship between seasonality and residential electricity demand in the Ashanti-west region of Ghana.

Temperature is the overly used proxy for Climate Change in literature and in this research setting, Climate Change is accurately represented by the addition of sunshine and precipitation. Just as temperature has been generally significant in empirics, it is to be tested to see if temperature, sunshine and precipitation are relevant in determining residential electricity consumption patterns.

Again, literature has shown that, electricity consumption responds differently to changes in the seasons of the year. It is equally important to verify if there may be differences in electricity consumption between wet and dry seasons. The research also sought to find out whether these differences are significant.

1.4 JUSTIFICATION OF THE STUDY

Providing the empirical basis to revise the weight given to the environment can give an initial step towards understanding the potential impacts of Climate Change on the energy sector. The study buttresses the sparsely explored demand-side climate-energy policy considerations to balance the more explored supply-side investigations to well informed Energy policy, authority's decision making and energy projections.

"*Understanding people's ability to adapt their behaviour and habits to Climate Change is thus a key factor to contribute to the design of energy policies and policies addressing the reduction of residential energy demand*" (De Cian et al, 2007). This is very crucial to Ghana's electricity industry given the persistent and frequent electricity power crisis, currently predicted to be caused by over expanding demand for electricity over it production.

Also estimating the changes in energy use to Climate Change are needed by Ghana Energy Commission, Volta River Authority, Electricity Company of Ghana and Environmental Protection Agency to help meet Ghana's energy demand. The results of the study will aid in the development of adaptation policies that may reduce, prevent, or more equitably share benefits and costs brought about by Climate Change.

1.5 METHOD OF STUDY

1.5.1 Data Source

Data used for the purpose of the research were purely secondary and were accessed from Electricity Company of Ghana; Meteorological Services Department; Ghana Statistical Services. Annual time series data for residential electricity consumption and the critical climate variables that were used for the estimations are temperature, sunshine and precipitation. The following sub-sections describe the data needs in the energy demand sensitivity analysis.

1.5.1.1 Energy data

Ashanti-west region's residential electricity consumption and prices were accessed from Electricity Company of Ghana regional office and energy consumption statistics, published by Ghana Energy Commission. ECG/Energy Commission readily produce and make public such consumption statistics. The sample size mainly depended on data availability.

1.5.1.2 Socio-Economic data

For a demand function to be correctly specified not only the commodity and its price are relevant but also income, population and urban share of the population. Therefore GDP and population figures were the socio-economic data that played the critical role in computing disposable income, economic growth, and population and population shift (urbanisation) variables needed for the modelling. These critical variables were available at the Ghana Statistical Service.

1.5.1.3 Climate data

Historic climate data that consisted of computed monthly average temperature was accessed from meteorological services department, headquarters, Accra. In addition to temperature variable are sunshine and precipitation variables. This is to neutralize bias in the econometric estimates of demand sensitivity to temperature variable as many related studies do and also to comprehensively and accurately capture Climate Change effects in the study area.

1.5.2 Data Analysis

Descriptive statistics was employed to estimate descriptive summaries and applied line graph to analyse the research variables trends. This gave a pictorial view of how variables relate. Eviews was also employed to analyze relationships in the research variables through general method of moment (GMM) estimation.

1.5.3 Modelling

The research analysis was purely an econometric analysis and with a thorough consideration of econometric theories, koyk adaptive and autoregressive models were adopted. This approach modelled energy demand as a dynamic process, depending on a set of covariates and the lagged value of the dependent variable. This research builds on the works of De Cian et al (2007) and Bigano et al (2006), in modelling energy demand as a dynamic process which was pioneered by Balestra and Nerlove (1966). The method is better suited when dealing with meso (sector) and Macro(country) level and aggregate data (De Cian et al, 2007).

1.6 The Study Area

Ashanti Region is centrally located in the middle belt of Ghana. It lies between longitudes 0.15W and 2.25W, and latitudes 5.50N and 7.46N. The region shares boundaries with four of the ten political regions. Brong-Ahafo in the north, Eastern region in the east, Central region in the south and Western region in the South west.

Ashanti region by administrative and operation-wise (not political) has been divided in two by Electricity Company of Ghana (ECG). The division took effect from mid 2004 and now Ashanti region in context of ECG operations has two sub regions: Ashanti-west and Ashanti-east. Ashanti region is the second largest consumer of electricity in Ghana (Energy Commission, 2011) and Ashanti-west is the biggest sub-region and constitute about 55% in terms of regional power purchases from GRIDco. The sub-region largely encompasses most of the Kumasi metropolis and its peripheral districts, to name a few: Adum, Suame, Bohyen, Afrancho, Danyame, Ahodwo, Patase, TUC, Atonsu, Daaban, Santase, Agric, Abuakwa, Tanoso, Asuoyeba, Kwadaso; Dunkwa, Obuasi, Bekwai, Offinso and New Edubiase districts.

Residents in the region are known to be aware of the Climate Change phenomenon. A study conducted by Quartey (2010) for the 18 commonwealth forestry conference, assessed willingness to pay (WTP) for Climate Change mitigation by residents of Kumasi and two adjacent forested areas all in Ashanti region. The study revealed that, Local communities practically carry out within their limited resources local traditional projects which enable them adapt to Climate Change. Residents in these forested areas willingly expressed mean WTP which covers more than 40% of the World Bank (2009) estimated cost of Climate Change adaptation for Ghana, which is between $300 million and $400 million from 2010 to 2050.

Clearly residents in Ashanti region are increasingly aware of the changing weather conditions, how these changing weather conditions affect the electricity sector are well visible in the production-side considering the persistent yearly drought of the Akosombo dam which provides the major electricity in Ghana. But how these changing conditions in weather affect the demand-side of the sector is the focus of the research and the expectation is that if residents in Ashanti region had expressed demand for mitigation they must as well exhibit some changing behaviours in terms of changing consumption patterns in reaction to Climate Change.

1.7 Organisation of the Study

There are five main chapters to this research. The introductory section provided some reflections on the Climate Change - energy demand hypothesis and the general orientation of the paper. In chapter two, issues pertaining to theoretical and empirical literature on Climate Change and energy in the context of the research variables are addressed. Chapter three deals with the methodological needs for this research and it majorly applies regression estimates to diagnose energy demand responses to Climate Change in Ashanti-west region. Empirical aspects of the paper will be dealt with, in chapter four. The final chapter is devoted to conclusions and policy implications.

CHAPTER TWO

LITERATURE REVIEW

2.0 THEORETICAL REVIEW

2.1 "ANTHROPOGENIC CLIMATE CHANGE"

Climate may certainly not stay the same as time goes by, climate in the past centuries is definitely different from the present conditions and the present may surely not stay the same in the future. That is to say that Climate Changes, in that, it shows some natural variation with time but the pace and the rate of the variation in the recent past was believe to be and now scientifically established to be human induced. United Nations Framework Convention on Climate Change (UNFCCC) defines Climate Change as a "change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods". From the definition it is clear to note that in addition to climate natural variability is the human induced Climate Change, now commonly branded with the term "anthropogenic Climate Change"

2.2 THE ECONOMICS OF CLIMATE CHANGE: THE GLOBAL MARKET OR GOVERNMENT FAILURE?

The present time challenge to growth and economic development globally, is ubiquitously an environmental one and within the spectrum of environmental challenges, Climate Change is by no doubt the environmental factor championing and triggering other environmental hazards to growth and development. Economics of Climate Change has always been on the path on finding the cost, benefits and instrumental strategies to combat this worldwide environmental canker and almost all literatures on Climate Change abatement pursue the trails of mitigation or adaptation. Mitigation refers to the reduction of greenhouse gas emissions in order to prevent the future climate impacts on economies; adaptation refers to behavioural changes in individual, group, and institutions in order to limit economies vulnerabilities to climate (Pielke, 1998; Smit *et al*, 2000; Ingham et al, 2006; UN-DESA, 2009). Though the theoretical debate about which strategy (mitigate or adapt) is first best is necessary, progressing this debate a little beyond whether these two strategies are substitutes or complements to a level where mitigation or adaptation are seen as a goal instead as a strategies; will then in principle show mitigation and adaptation as different ways which economies and societies can limits the adverse effect that might be caused by global warming (Ingham et al, 2006 and UN-DESA, 2009). "*Mitigation and adaptation are often interdependent. This is because both can be influenced simultaneously by some events. Also, the level of efficiency in adaption could to a large extent depend on the level of Climate Change mitigation. Thus in the absence of mitigation action the cost of adaptation is going to be very high particularly in terms of irreversible changes due to Climate Change impacts*"(Quartey, 2010). This is a clear indication that Mitigation and Adaptation are not competing options to fighting Climate Change but they are inherently a unified goal to be pursued.

A deeper economic understanding of global warming issues is essential to properly address challenges posed by Climate Change. Most literatures on causes and effects of Climate Change; debate on Climate Change mostly on media, among politicians and also the general public, and currently, the growing interest in this problem on a very high political agenda worldwide have shown cogent argument and hold strong assumptions that can be used to model Climate Change as an externality, an open access good, common resource or a global public good. Also there is free ridership argument on the part of government responsibility to fighting Climate Change. Understanding these economic bases for Climate Change arguments is essential to making an informed Climate Change policy choices.

Climate Change has been argued to be the mother of all externalities the reason being that rich countries pollute and poor countries suffers for it (Urbanomics, 2009). The atmosphere has been managed like an open access or common resource where unlimited pollution has been dumped into, therefore Climate Change is an epitome of tragedy of commons. Some also argue that we all pollute (non-rivalous activity) and we all suffer for it (non-excludability) making the Climate Change a global public bad.

2.2.1 Climate Change the "Global Market Failure"

Climate Change can be seen as the by-product of economic activities whose effects concern, in principle, all individuals in the world. Its adverse impact "*cannot be properly addressed without a deep understanding of its economics. Climate Change in fact produces diverse economic effects: from reduced productivity of natural resources (e.g. agriculture), to damage to non-managed natural resources (e.g. biodiversity, landscapes, wilderness), from damage to human-built environment (e.g. coastal flooding from sea level rising), to risks to humans due to extreme weather variations*" (Grasso, 2004). Climate Change discourse about its economic problems, as discussed are all well known categories of market failure affecting climate stability. Climate Change can be a present day service or commodity with no market or price, and that prevents the appropriate incentives against overexploitation of the atmosphere.

2.2.2 Climate Change and "Global Governments Failure"

Global attempts have been made and are still ongoing to address Climate Change. The first and the best known attempt to address this issue globally were through the Kyoto Protocol. This Kyoto Protocol generally sets GHGs emission reduction limits for countries but according to Grasso (2004) the Kyoto Protocol is a fragile agreement, whose enforcement is unlikely and whose potential outcomes are limited. These lapses in the agreement foster countries to take a non cooperative decision in accordance to individuals benefit and cost ratios. Also global warming is a function of long term profile of emissions, since GHGs accumulate in the atmosphere for centuries, making the benefit from emission reduction highly unpredictable and later in the future. These create incentives for free-riding since it can be difficult for individuals and even nations to commit or give up resources and change behaviours for something that the outcome is very uncertain and also for benefit that may accrue to an unknown generations. Though dealing with global Climate Change depends on effective global or world cooperation that requires a well coordinated international response, this has become a very important challenge in this current world system where nation-state still reign supreme while international organisation continually remain relatively weak (Tietenberg, 2006).

2.3 CLIMATE CHANGE AND THE ENERGY CHALLENGE

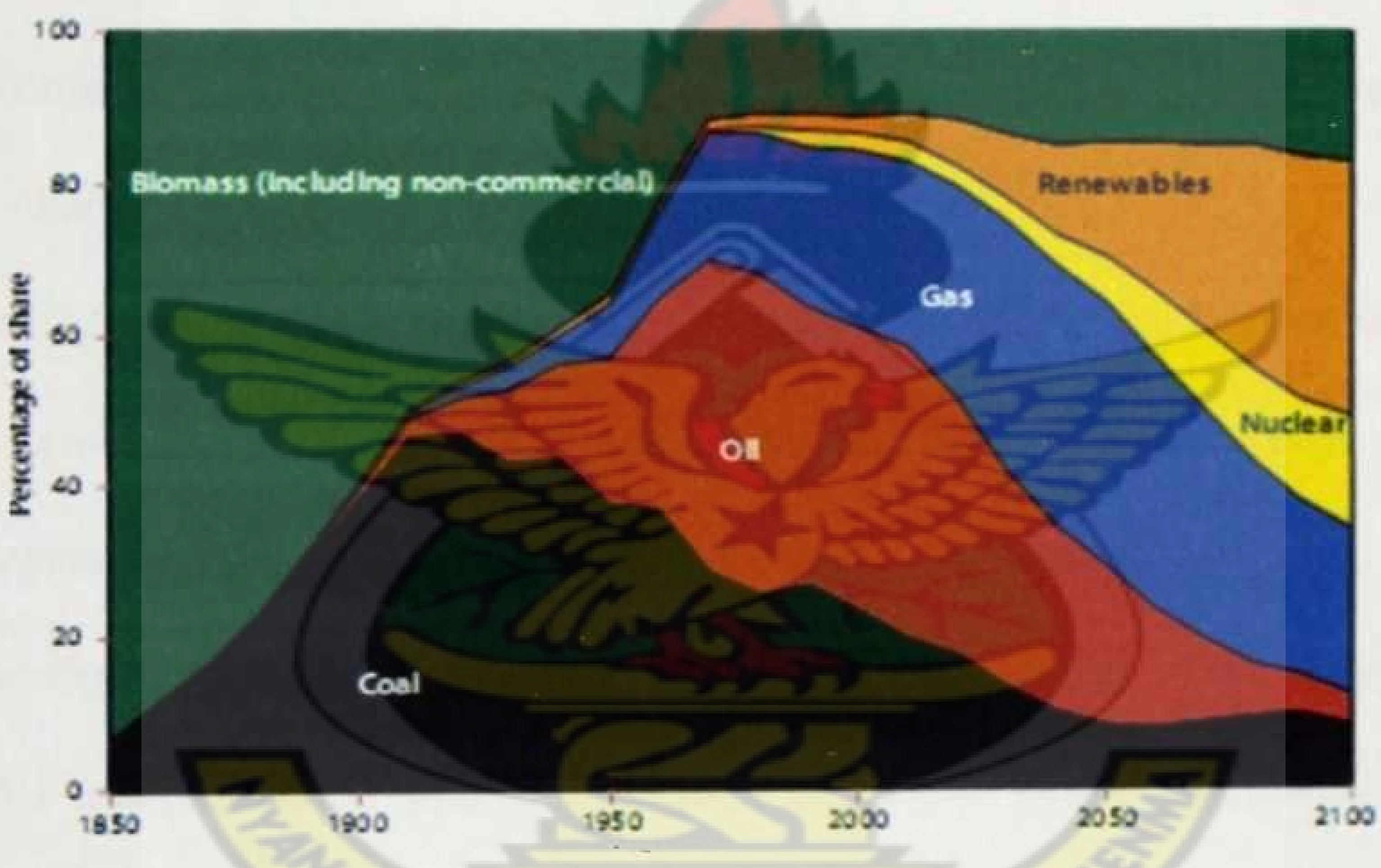
2.3.1 Energy: Breaking with the Past and Present

Satisfying the growing socio-economic needs in the context of Climate Change constraints as a pre-requisite for development, may inevitably result in an increase in energy consumption. It is about time global energy policies and strategies are redirected from the perspective based on energy supply solutions to an energy demand solutions; that is, analysis of energy services needs that must be satisfied.

The scientific community has set a maximum target range of temperature increase of 2^0C above pre-industrial levels for stabilizing carbon concentrations at a level that prevents dangerous interference in the climate system. This estimated temperature targets may correspond to a concentration of greenhouse gas target (in terms of carbon dioxide equivalents (CO2e)) of between 350 and 450 parts per million (ppm) and to reduce global emission by 50-80 per cent over 1990 levels, by 2050 (UN-DESA, 2009). These targets may be difficult to be actualised without a massive transformation in the way energy is produced and more importantly consumed.

"The energy sector, broadly defined, accounts for 60 per cent of global emissions and a stable climate will require reduction in the rate of energy intensity and improvement in carbon intensity by a factor of between 2 and 3 with respect to their historical levels" (Ibid). Figure 2.1 below shows the historical evolution of energy system and a futuristic development path scenario needed to achieve the 2^0C temperature threshold for climate stabilisation.

Figure 2.1 Evolving energy system: Towards a low-emissions future



Source: *United Nations, World Economic and Social Survey 2009: Promoting Development, Saving the Planet (http://www.un.org/esa/policy/wess/wess2009.pdf), based on Nakicenovic, N., and K. Riahi, eds. (2007). Technological Forecasting and Social Change, vol. 74, No. 7 (September).*

Figure 2.1 is history and a possible future of the global energy system in IPCC's B1 stabilisation scenario showing relative shares of most important energy sources. It is consistent with a stabilization scenario that can deliver faster growth in developing countries while avoiding more drastic Climate Changes. From the diagram, beyond the year 1950, an estimated continuous decline of coal and oil in terms of their percentage share of energy production and consumption for an increasing use of natural gas and renewable energy would be the best scenario for climate stability target to be achieved. This will, however, require a determined break with past policies, a renewed commitment to public investment and a super national cooperative effort.

2.4 THE DEMAND FOR ENERGY

2.4.1 Theoretical Foundations of Residential Electricity Demand

The household demand for electricity is very much different from the commercial demand and also residential electricity demand is amenable to theorisation and quantification. This research follows the model used by Tariq et al (2008) adopted from Filippini (1999). It is based on the household production theory but added Climate Change as an environmental index to the other variables used in the modelling instead of maintaining the variable for geographical characteristics.

According to this theory, household purchases goods from the market, which are then combined to produce commodities. The household derives utility from these commodities; hence they appear as arguments in the utility function of the household. In this case, the two goods are electricity and capital equipment. The household cannot derive utility from either of these goods independently. Thus it combines these two goods to produce a composite energy commodity; therefore the composite energy commodity becomes a derived demand. Thus the composite commodity Q is given as:

$$Q = Q(E, K) \qquad (1)$$

Where E is the electricity and K is the common stock in the form of electric appliances. The Utility function of the household is

$$U = U(Q, X; D, I) \qquad (2)$$

Where, D and I are demographic and environmental (Climate Change) characteristics affecting household preferences respectively. X is the composite numeraire good that directly yields utility to the household.

The household budget constraint is given by:

$$Y = P_Q.Q + 1.X \qquad (3)$$

Where Y is the income, P_Q is the price of composite good commodity and P_x is the price of composite numeraire good X.

The household has two stage optimization decisions. In the first stage it will decrease its cost of producing Q, thus behaving as firm. This can be written as

$$Min(P_E.E + P_K.K) \text{ Subject to } Q = Q(E, K) \qquad (4)$$

Where, P_E and P_K are the prices of electricity and electric appliances. The optimization will provide cost function:

$$C = C(P_E, P_K, Q) \qquad (5)$$

The derived input demand functions are obtained by applying Shephard's lemma as shown

$$E = \frac{\partial C(P_E,P_K,Q)}{\partial P_E} = E(P_E, P_K, Q) \qquad (6)$$

$$K = \frac{\partial C(P_E,P_K,Q)}{\partial P_K} = K(P_E, P_K, Q) \qquad (7)$$

In the other stage of the optimization problem, the household maximize utility

$$\text{Max } U(Q, X; D, I) \text{ Subject to } C = C(P_E, P_K, Q) + X\text{"}Y \qquad (8)$$

Formulating lagrangian function:

$$L = U((Q, X; D, I) + \lambda(Y - C(P_E, P_K, Q) + X)) \qquad (9)$$

Demand functions for commodities Q and X are:

$$Q^* = Q^*(P_E, P_K, Y; D, I) \qquad (10)$$

$$X^* = X^*(P_E, P_K, Y; D, I) \qquad (11)$$

Using equations (6), (7) and (10) we obtain the input demand functions given as follow:

$$E = E(P_E, P_K, Q^*(P_E, P_K, Y; D, I))$$

$$E = E(P_E, P_K, Y; D, I) \qquad (12)$$

$$K = K(P_E, P_K, Q^*(P_E, P_K, Y; D, I))$$

$$K = K(P_E, P_K, Y; D, I) \qquad (13)$$

Equation 12 is the required equation for this research. It shows the dependence of the electricity demand on the price of electricity, prices of appliances, income, demographic and environmental variables. The socio-economic variables (prices and demographics) are greatly studied and its effects are very direct. The focus of this study is on the environmental variable (I), as the theory establishes the fact that environmental dimension is a determinant in electricity demand, this research is to further estimate or to quantify its concise association and impact it has in the demand function.

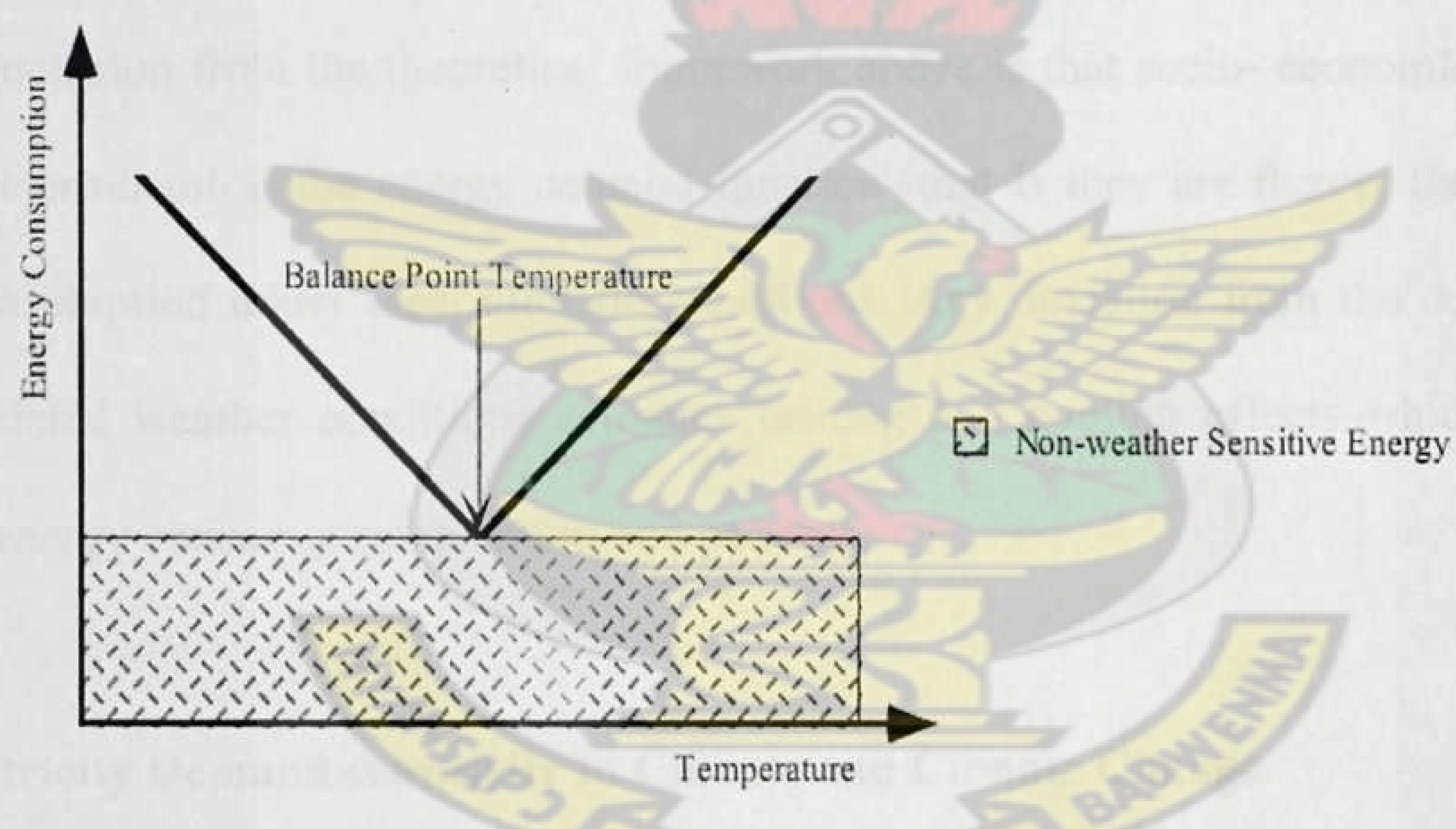
2.4.2 Heating and Cooling Effects: Climate Change and Energy Relationships

Energy is a global marketed normal commodity which demand is very much influenced by the same factors other normal goods face, postulated by the theory of demand. These determinants are majorly its price, related prices, income and the number of consumers. Global warming, an epitome and a proxy for the pressing environmental constraint in today's economic activities call for the redefining of the determinant of demand specifically in the context of energy production and consumption. There is an apparent link between Climate Change and energy use (as shown by eqn (12)) this is so because societal consumption of energy is likely to change in ways that affect their sensitivity to Climate Change. The relationship between climate and energy demand is captured in numerous literature using the concept of heating and cooling effect (see Amato et al 2004; De Cian et al 2007; feenstra et al 1998; Bigano et al. 2006 etc).

Heating and cooling effect is premised on the convention that society's use of energy is to satisfy heating and cooling preferences. In particular, it is important to distinguish between these two effects that are expected as the results of increasing global temperatures. first the heating effect, which is the decrease of the use of energy for heating purposes and on the other hand the cooling effect, that is the increase of energy demand for cooling purposes(De Cian et al, 2007), these two important effects influence the final use of energy by households and act in opposite direction.

Climate Change evidently causes alterations in terms of duration and severity of season's weather events that directly influences the consumption of energy. What opposing effects (heating verses cooling) dominate depends on the extent of distortion created by Climate Change. Example if Climate Change shortens the cold season and reduces the severity of cold weather events energy demand for heating will be less.

Figure 2.2 Theoretical Relationships between Temperatures (Climate Change) and Energy Use: Analytical Framework



Source: Amato el al, 2004 (page 25)

Figure 2.2 represents temperature-energy consumption relationship, an analytical framework for assessing the relationship between energy use and Climate Change. The V-shaped line is the temperature-energy consumption function and the bottom point of the V-shaped function is called the balance point where at that level of temperature, energy demand is at minimum in relation to climate conditions. The balance point is the optimum level where climatic conditions are assumed to create the desired indoor temperature. As climatic conditions deviate from the balance point (above or below the point) temperature, energy demand increases.

The amount of energy consumed at the balance point temperature is the non-weather sensitive energy load, which is projected to increase with the increasing proliferation of electronic devices (Amato et al, 2004). Particularly in Ghana, as income, population and urbanisation has been projected to increase in the near future (see Energy Commission, SNEP, 2012), these projections most definitely may result in increases in miscellaneous electricity uses, which are comprised mostly of demand to operate consumer electronics (Sanchez, Koomey et al. 1998). Energy consumed in excess of the energy demanded at the balance point temperature is weather-sensitive energy use. Large deviations in temperature from the balance point temperature results in large increases in energy consumption.

Conclusion from the theoretical framework above is that socio- economic factors are baseline determinant in the energy demand function- that is they are factors that determine energy consumption under ideal climatic conditions. Any deviation from the desired or the already existed weather conditions activates heating and cooling effects which results in changing energy consumption quantum and patterns.

2.4.3 Electricity Demand sensitivity to Climate and Climate Change

"The most significant impacts of Climate Change on energy consumption are likely to be the effects of higher temperatures on the use of electricity" (Feenstra et al, 1998) particularly for cooling purposes. "Climate Change is likely to affect the following major electric end uses: air conditioning; space heating, water pumping, refrigeration, water heating. Of these end uses, air conditioning and space heating are those most likely to be significantly affected by

Climate Change, since both are functions of the indoor-outdoor temperature difference" (ibid).

Rising temperatures may virtually increase air conditioning use and saturation - fraction of buildings having air-conditioning equipment. Countries in low latitudes, like Ghana which generally already have warmer to hot climates, such an increase can significantly affect overall energy demand. A study By Linden and Inglis (1989) found that in the southern United States having warmer climate, electricity demand would increase by 10 to 15 percent. In high latitude areas, which generally have cooler climates, the increase in the demand for air conditioning would be relatively small.

Electricity use for space heating will decrease with increasing temperatures, but locations in low latitudes with warmer climates the impact will probably be insignificant. For high latitudes cold climates locations, effect of global warming on electricity use will be significant particularly where electric space heating is used.

Rising temperatures may also increase electricity demands through water pumping and refrigeration requirements. For water pumping, the impact will be significant in warmer but not wetter climates due to an eventual increase need of water for irrigation, domestic and commercial watering. Refrigeration needs will increase in response to increase temperatures and a decrease in water heating requirements.

For warmer to hot climate like that of Ghana, an increase in temperature will eventually result in the increase in the demand for electricity but The magnitude of the impacts depends on the electricity usage patterns in the absence of Climate Change. That is, increases in electricity demand caused by socio-economic development and increased standards of living are likely to occur along with Climate Change. Example, electricity consumption durables especially air conditioning is more prevalent in high income countries.

As developing countries increase their standard of living, their use of such durables - air conditioning increases, as will their sensitivity to Climate Change.

2.5 CLIMATE CHANGE AND ENERGY: THE CASE IN GHANA

2.5.1 Climate Change in Ghana

Ghana is located in between latitude 4° and 11° north of the equator, on the west coast of Africa, It has a total surface area of 238,535 square kilometres. The country is posited on four climate Zones. Climates are classified by temperature and rainfall and generally Ghana has warm to hot temperatures throughout the year because of its proximity to the Equator and its relatively low elevation. The climate in most of Ghana is wet and dry tropical marked by warm to hot temperatures throughout the year, and abundant rainfall in only one season. This condition is especially noticeable in northern Ghana, because of less annual rainfall and the strictly seasonal nature of the rain.

Ghana just like any other developing country and parts of sub-Saharan Africa suffers from the impact of Climate Change. Traces of Climate Change adverse impact are less becoming rare: "disrupting agricultural systems, flooding coastal areas and lowering water levels around the Volta River delta which provides around 80 percent of Ghana's electric supply" (World Bank, 2012).

2.5.2 The Energy Sector of Ghana

Ghana's energy sector encompasses a mix of several energy products that are internally generated and also imported. The energy product in this sector are electric which is majorly hydro generated, biomass being the renewable energy resource that is being discouraged in its use due to its direct impact on Ghana's forest, solar energy only play an important role in the agricultural sector, specifically for crop production and drying. Crude oil and natural gas are new areas being exploited so they are mainly imported. Wind mill, coal plant and nuclear power plants are not in existence and also its product are neither being produced nor imported.

The integrated energy supply feeds the energy-demand economic sectors comprising Residential, Commercial & Services, Agricultural & Fisheries, Transport and Industries. The Energy Supply Sector of Ghana is thus Biomass, Petroleum and Power (Electricity), whilst the Energy Demand sectors of the economy are the Residential, Commercial & Services, Agricultural & Fisheries, Transport and Industries.

Given specific attention to the electricity industry due to the focus of this research, the players in the sector (electricity industry) are the Ministry of Energy, Volta River Authority (VRA), the Electric Company of Ghana (ECG), the Northern Electrification Department (NED), the Public Utility Regulatory Commission (PURC), the Energy Commission (EC), private generators and the energy foundation. These players interact for the effective development and utilization of electricity services available to the nation. Ghanaian electricity production and consumption mainly comes from the grid or public electricity and its shortfalls largely balanced from the private and back-up generation.

2.5.3 The Retrospect of Electricity Power and Consumption in Ghana

The origin and evolution of electricity power in Ghana can be trisected into three major periods of electricity generation. The first, being the period preceding the construction of Akosombo Hydroelectric Power Plant in 1966. This was a period of isolated generation facilities with low rates of electrification. The second period, was the "the Hydro Years", it covers the period from 1966 to the mid eighties- that is the Volta Development era. The Development includes the 1966 commissioning of Akosombo Hydroelectric Plant and the

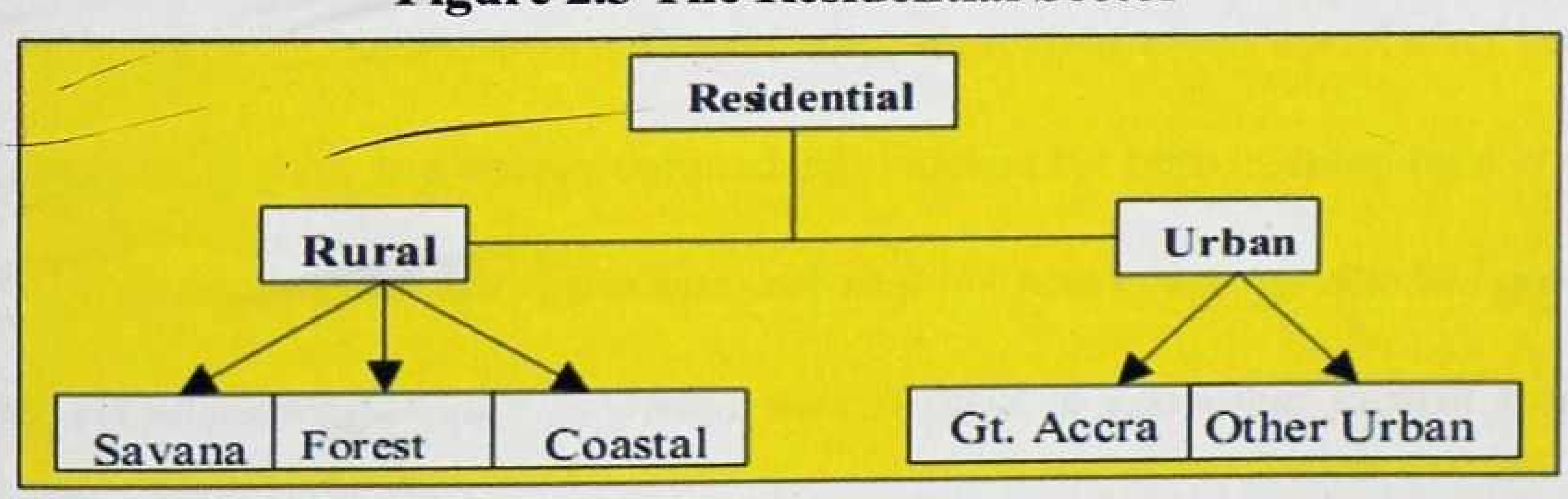
Kpong Hydroelectric Plant, which was completed in 1982. By the mid eighties, demand for electricity exceeded the firm capability of both the Akosombo and the Kpong Hydro Power Plants. The third period, "Thermal Complementation", from the mid eighties till now is characterised by efforts to expand power production through the implementation of the Takoradi Thermal Power Plant as well as the development of the West African Gas Pipeline to provide secure and economic fuel source for power generation (Resource Centre for Energy Economics and Regulation, 2005). "*There have been efforts to link the power facilities of Ghana with neighbouring countries including the implementation of the Ghana-Togo-Benin transmission line as well as the Ghana - La Côte d'Ivoire interconnection…… . As the economies of Ghana and its neighbours continue to grow, there are many challenge remaining in meeting the increasing demand for electricity in the region while at the same time pursuing policies of fuel diversification, grid integration and sector restructuring*" (ibid). In mid 2000s Ghana Electricity Company had a customer base of about 1.4 million, this translated into a nearly 50% (actually 45 – 47 percent) of Ghanaians, including 15 – 17% of the rural population, have access to grid electricity with a consumption per capita of 358 kWh. The ten regional capitals are fully connected to the grid but as there is considerable disparity between these capitals and their rural areas. Even among the rural areas access to electricity is higher in the coastal (27%) and forest (19%) ecological zones than, in the savannah (4.3%) areas of the country (Energy Commission, 2005). Ghanaians consumed 5,158 giga watt hours (GWh) of electricity in 2004 and about half of this amount is consumed by domestic (or residential) consumers for household uses such as refrigeration, air conditioning lighting, ironing, , television, radio and the like (see Resource Centre for Energy Economics and Regulation, 2005). The rest of it is consumed by commercial and the industrial sectors.

Generally, electricity consumption in Ghana has increased, aside the growth of socio-economic variables causing this increase in energy use, policy also has contributed immensely to the wide use of electricity. Government of Ghana for the past two decades has embarked on a policy of achieving national electrification through the rural electrification programme, so many of the Ghanaian populace residing in the peripherals are increasingly accessing electricity. From the national energy statistics 2000 - 2011 published by energy commission all the electricity indicators show an increase and more efficient consumption particularly from the period 2004 to 2011: total electricity consumed increased consistently throughout this period from 4503 to 7976 GWh and total electricity consumed per capita increased throughout the same period from 0.38 to 0.42 indicating an expansionary access and use of electricity. Also a continuous decline of statistical value for total electricity consumed per GDP consistently throughout the year 2000 to 2011 from 1272.9 to 806.4 kWh/US$1,000 of GDP, and for energy intensity declining from 1.02 to 082 during the period 2001 to 2011 toe/US$1,000 of GDP, shows that Ghana is being efficient in electricity and energy production and consumption.

2.5.4 The Electricity Demand Sectors in Ghana: The Residential Sector

Ghana generally has three demand sectors for electricity production, these are the residential, non-residential (commercial) and the industrial.

Figure 2.3 The Residential Sector



Source: Energy Commission, 2006: SNEP 2006 - 2020, pg21

Total number of households in Ghana was about 4 million in 2000 and is expected to reach between 5 – 6 million by 2020. Urbanisation is expected to increase from the 40 percent in 2000 to about 55 percent in 2015 and eventually 60 percent by 2020. A little more than a third of the urban population lives in Greater Accra and is expected to reach around 40 percent by 2020.About 50 percent of the rural households are found in the forest zone and this is not expected to change significantly by 2020. Energy sources in urban areas are more diversified than in rural areas, since access to alternative (modern) fuels and appliances are higher in the urban areas than in the rural areas (Energy Commission 2006).

In Energy Commission's strategic national energy plan (SNEP) 2006 – 2010 (2012) estimates, about 48 percent of households in the country use electricity for lighting and other purposes in the country. Urban households accounted for 88 percent of electricity usage, whilst rural households accounted for the remaining 12 percent. Refrigeration accounted for about 20 percent of the urban electricity consumption.

Most residential consumers comprise high-income and middle urban consumers. This consumer-class typically uses a number of high energy consuming durables - household appliances and items such as air conditioners, fridges, water heaters, electric cookers aside the substantial amount of lighting equipment and bulbs for the houses. A majority of the rest of the residential consumers use electric power for lighting purposes.

2.5.4.1 Determinants of electricity consumption in Ghana: the missing factor (climate)

It is obvious that rapid economic development of any economy commands large amounts of energy for consumption. Empirically, there is a close correlation between the rates of economic growth and energy demand an evidence for both developing and developed nations. "..... *statistics exist that show however that the rate of energy demand growth in the developing economies especially in Africa with respect to economic growth rates are far* *higher than the norm*" (Energy Commission, 2006). The Ghana statistics shows that rate of growth of Ghana's Gross Domestic Product (GDP) since post SAP era to 1997 has averaged 5 percent per annum and though has increased slightly beyond this period until recently, yet over the same period, the demand for electricity had grown at the rate of 10 – 14 percent per annum.

The preamble above is evident that the growth in electricity demand far exceeds the growth in the economy; that is, a slight increase in economic growth may require more than double the electricity services needed for that expansion. It is of no coincidence that socio-economic factors posses the energy challenge to Ghana and these factors mainly economic growth, population increase and urbanisation are what authority's based on to estimate Ghana's energy requirements.

Based on data released by the Ghana Statistical Services, Ghana's population was 18.9 million in 2000 and it is projected to reach about 29 million in 2015, the target year for the Millennium Development Goals and 31-32 million by 2020. The corresponding number of households and urbanisation would rise from 3.7 million households and about 34 percent urban share in 2000 to about 6.4 million households and 45 percent urban share in 2015; and 7.7 million households and 48 percent urban share by 2020.

"*Clearly, with the Ghanaian economy growing, increasing urban populations will consume more electricity. The Energy Commission (EC) estimates that, residential demand may reach anywhere between 7,000 and 13,000 GWh by 2020 depending on the rate of economic growth and urbanization*" (Resource Centre for Energy Economics and Regulation, 2005).

The environment is completely ignored in the analysis of Ghana electricity demand. Giving zero weight to the environment specifically, Climate Change in the energy sector analysis is a huge drawback. Since it is evidently accepted that activities in the socio-economic-political spheres are shaped and constrained by the environment, actually the environmental realm is the platform on which the other spheres interact. Therefore ignoring the environment underscores the potential inaccurate analysis of energy demand.

2.5.4.2 Regional Energy Demand Sensitivities

The argument that for policy analyses, energy demand sensitivities to climate and Climate Change should be performed at the regional scale is very important for a number of reasons. First, global Climate Change is anticipated to have spatial distinct impacts. As a consequence, analyses that apply a uniform temperature increase over entire continents or nations may miss important geographic impacts on energy use. The ability to capture and interpret geographical variations in Climate Change impacts on energy systems is particularly important since Ghana fairly has a heterogeneous climate.

Another justification for energy demand sensitivity analysis to be carried out at regional scales is that, residential, commercial, and industrial sectors exhibit distinct demand sensitivities to climate. Since sectoral compositions vary across regions, the structure of a region's economy significantly influences the sensitivity of regional energy demand to climate (Lakshmanan and Anderson 1980; Sailor and Munoz 1997). It is common to realize these differences as one moves from the southern to the northern part of the country.

2.6 EMPIRICAL REVIEW

The link between climatic variables and energy use has been widely documented. Empirically, in the literature on energy demand, temperature is often considered a good candidate for an explanatory variable of energy demand, but it is not the sole focus of this analysis. Industrial energy demand is not estimated since previous investigations indicate that it is non-weather sensitive (De Cian, 2007; Bigano et al, 2006; Amato et al, 2004; Elkhafif 1996; Sailor and Munoz, 1997).

There are lots of literatures that focuses on residential electricity demand, examples of these kind of studies are Giannakopoulos and Psilogou (2004) for Athens, Hanley and Peirson (1998) and Taylor and Buizza (2003) on Britain, Pardo et al.(2002) and Valor et al, (2001) for Spain Greece, Sailor (2001) for the United states, Al Zayer and Al Ibrahim (1996) for Saudi Arabia. These studies look at the relationship between daily and seasonal load demand variability and temperature, often expressed in terms of heating and cooling degree days. Given the very short run focus of these studies, their aim is mainly to explain (and often forecast) the variability of electricity demand, rather than estimating demand functions. Economic variables such as prices hardly play a role, except where time–use pricing is enforced. An example is Hanley and Peirson (1998). Other studies such as Pardo, et al. 2002; Morris (1999); Lam (1998); Yan (1998); Lehman 1994; Badri 1992; Downton, Stewart et al. 1988; Le Comte and Warren 1981; Warren and LeDuc 1981; Quayle and Diaz 1979; included price vector to explain energy consumption and to assist energy suppliers with short-term planning.

Asadoorian et al. (2006) addressed the impact of temperature on Chinese provinces; Mansur et al. (2004) studied the effect on the US electricity market; Vaage (2000) considered different technologies for residential heating in Norway, whiles Henley and Perison (1998) analyzed the effect of temperature on the British residential electricity demand. These are microeconometric studies, estimating, first the demand for energy-utilizing appliances and, subsequently, the conditional demand for energy.

An alternative approach is to model energy demand as a cointegrating process. Glasure and Lee (1997) study the cases of South Korea and Singapore, with no regard to temperature. Their interest lies in finding out the direction of causality between energy demand and GDP growth, which they can determine in the case of Singapore. Similar in spirit are the study by Stern (2000) on the US economy, and Masih and Masih (1996) on South-East Asian economies. In both cases the focus is on the cointegration of GDP and energy use, with particular regard on the direction of the causality of changes in these variables. Silk and Louz (1997) look at US residential electricity demand by means of a micro error correction model of residential demand. Variable used include degree days, disposable income, interest rates electricity and fuel oil prices. Beenstock et al (1999) apply three different estimation procedures (Dynamic Regression Model and OLS and Maximum Likelihood Cointegration) to Israel household and industrial energy demand. Their explanatory variables include heating and cooling degree days. Their focus however is on the different capabilities of the alternative estimation methods tested to account for seasonality and in particular, seasonal cointegration.

This research relates to above literature but departs from it in terms of methodology and focus of their studies, as the reviewed empirical literatures above focus mostly on short run analysis and some concentrated on many fuel types. This research focuses on only electricity and for that matter assesses residential electricity demand within a specific local reality and applies an econometric methodology which is applicable for both shot run and long run analysis. The research is fundamentally different from the above and any other empirical studies in terms of country coverage and specifically the locality (Ashanti region) under assessment.

Studies most akin in their methodological concept to that of this research are Toriq et al (2008), De Cian et al (2007), Bigano et al (2006) and Amato et al (2004). They model energy demand as a dynamic process depending on a set of covariates and the lagged value of the dependent variable, this approach was pioneered by Balestra and Nerlove (1966). The dynamic approach for this research is underpinned by the theory from autoregressive models and that is from the rationalisation of the Koyck model particularly the adaptive expectation model. Also with a careful consideration of Bentzen and Engsted (2001) rehabilitation of the standard autoregressive distributed lag model (ARDL) in time-series energy demand estimation. These approaches are applicable for analysing both short and long run effect of Climate Change on electricity demand.

Bentzen and Engsted (2001) argue in favour of a rehabilitation of the standard autoregressive distributed lag model (ARDL) in time-series energy demand estimation. Their point is that, although when variables are non-stationary spurious regression and consequently invalid t-and F-tests may results, short and long run parameters can be consistently estimated and valid inference can be made if there is a unique cointegrating relationship between the variables. They compare ARDL to Error Correction Models to Danish energy demand over the period 1960-1996 to find that they give very similar results and concludes that after fulfilling some requirements, the ARDL model gives valid results and can be used for estimating energy demand relationship. Temperature (in the form of heating degree days) was included and its elasticity found to be negative and significant. Other analysis have been performed with non-parametric estimation techniques, Studies such as Hanley and Peirson (1996, 1997 and 1998), who study the relationship between energy demand for heating purposes and temperature in the UK, and Zarnikau (2003), who analyzes consumption expenditures in the US.

Using the partial flow adjustment approach and simultaneous equation approach Kamerschena, and Porterb (2004), investigates the electricity demand for period 1973-1998 for U.S. Estimates of residential price elasticities vary from -0.85 to -0.94 in 3SLS. However, estimates of price elasticities by partial-adjustment model shows biased results since the problem of endogeneity is not taken into consideration. Narayan and Smyth (2005) uses two models to estimate electricity demand in Australia. In model 1 the natural logs of levels of the variables are taken, whereas in model 2 the natural log of the ratio of the real price of electricity to the real price of natural gas, per capita residential electricity consumption, real per capita income, and temperature are used. In model 1 income and own price elasticities in short run are 0.0121 and –0.263 respectively where as for long run they are 0.323 and -0.541 respectively. In model 2 income elasticities in short run and long run are 0.0415 and 0.408 respectively. The relative price variable, in both short and long run, is significant at 1 percent.

Clearly, afore-reviewed studies are all absent from Africa, indicating the paucity of such studies if not totally inexistent, on the continent. This is not to conclude electricity and energy demand in general has not been studied in the African setting. In Ghana, fairly few studies are done on demand-side management of electricity grossly base on historic socioeconomic factors that is, demand-side studies on electricity but excludes climates vectors. The current study in Ghana is by Adom (2013) who used rolling regression technique to investigate how the effects of income, economic structure and industry efficiency on aggregate electricity demand vary with time. Adom and others (2011) used an autoregressive distributed lag bounds cointegration approach to modelling aggregate domestic electricity demand in Ghana and Adom (2011) who investigated electricity consumption–economic growth nexus in Ghanaian.

2.7 CONCLUSION

The literature review reveals various conclusions and associations that build a holistic conceptual framework which form the analytical backbone for this research. It was established that climate may show some variation but the recent trends and debilitating impacts are human induced, termed anthropogenic Climate Change. The review also showed economic bases for social and political discourses in quest of fighting Climate Change problems and established that though Climate Change is clear cut "global market failure", the response to amend this situation also has resulted in "global government's failure".

Climate Change has created a bigger challenge for the energy sector and development, and for developing countries to meet their development goals, affordable access to modern energy services is of very high relevance. Therefore, an energy demand solution which is analysis of energy services needs that must be satisfied will ensure sustainable energy consumption as part of a wider, inclusive and integrated development strategy to meet economic and human development.

The theoretical relationship between Climate Change and energy demand is based on the concept of heating and cooling effect. And with the aid of Household production theory and Amato et al (2004) analytical framework for energy consumption and temperature diagram, theoretical relationship between energy demand and to be specific electricity consumption and temperature variations were also established. It concluded that a deviation from a desired weather condition results in an increase in electricity demanded

Various empirical studies reviewed made available various methodologies used for this assessment, and with careful consideration of the context of this research, it focus and theoretical conclusions, dynamic modelling will be adopted for the research analysis. Details of this modelling technique, data needed and other methodological related reviews are the main focus of the next chapter.

CHAPTER THREE

METHODOLOGY

3.0 INTRODUCTION

This chapter outlines the econometric theories and models that are drawn upon to investigate the Climate Change effects on electricity demand in Ashanti-west Region, discussion of principal research variables and their priori expectation, data source(s) and sampled years for the research. It was established in the previous chapter that this research relates to the empirical studies reviewed but fundamentally departs from them in terms of country and place specific coverage. The issues involved in the estimation of the energy demand are common to those faced by previous studies. First, how climate variability should be measured, second, what functional form is more appropriate to capture the relationship between energy demand, climate variables and other relevant variables?

3.1 MODELLING FRAMEWORK

The dynamics of energy demand has been accounted for in the empirical literature, using two particular approaches. First, energy demand is estimated at a micro level, conditional on the demand for energy-using appliances. This approach is mostly used in country/sectoral studies and it is quite data demanding. The second approach models energy demand as a dynamic process, depending not only on prices, income and temperatures, but also on the lagged value of energy demand (De Cian et al 2007). The latter approach is the method adopted for this research. The research particularly builds on the works of De Cian et al (2007) and Bigano et al (2006), in modelling energy demand as a dynamic process which was pioneered by Balestra and Nerlove (1966). A major reason for adopting Dynamic models (Autoregressive models) is the ease of analysing short-run and long-run impacts.

3.1.2 Model Specification

From the household production theory reviewed to estimate household electricity demand in chapter two, it was concluded that electricity is a derived demand for energy services and this is consistent with literature since energy as a whole is demanded not for its own sake but for the comfort that will be derived from the energy using appliances. In this regards, and also from the house hold production theory, demand for energy or electricity is related to the stock of energy-utilizing appliances and equipment in place. Variations in prices, related prices, demographics and environmental dimensions, therefore, induce changes in energy demand, which adjust progressively over time.

Dynamic specification in time series models are of particular interest, because they allow distinguishing between short-run and long-run changes. A dynamic model of the household demand for electricity is specified here. Electricity demand is modelled as an autoregressive process in which energy demand depends on its own lag values, as well as a set of independent variables, such as energy prices, climate and socio-economic variables.

For t months, the model assumes the common form in equation (1) below:

$$Y_t = \alpha_0 + \alpha_1 X_t + \alpha_2 Y_{t-1} + v_t \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where:

- Y_t - is the dependent variable: residential electricity consumption
- Y_{t-1} - lagged dependent variable
- X_t - vector of covariates: electricity, end-use price, climate and socio-economic variables
- v_t - disturbance term.

The dynamic model in equation (1) above is adopted as:

$$Y_t = \gamma_0 + Y_{t-1} + \alpha \sum SEC_t + \delta \sum CC_t + v_t \quad \ldots\ldots\ldots\ldots (2)$$

The difference here is that the explanatory variables have been split into two between socio-economic variables ($\sum SEC_t$) which form the baseline demand model for this research; that is what determines electricity demand under desired climate condition and Climate Change variables ($\sum CC_t$)

The above general form for autoregressive model equation (2) will be adopted. The mathematical form of the model for this research is

$$REC_t = f(REC_{t-1}, P_t, DY_t, PS_t, URB_t, TEMP_t, SSH_t, PREP_t)$$

Where:

REC_t : Residential Electricity Consumption

REC_{t-1} : Lagged Residential Electricity Consumption

P_t : Average End-use Residential Electricity Tariffs

DY_t : per capita gross national disposable income as a proxy for Disposable income

PS_t : Population Size

URB_t : Urban share - Urbanisation

$TEMP_t$: Temperature

SSH_t : SunShine

$PREP_t$: Precipitation

For the above variables P_t, DY_t, PS_t, URB_t are the socio-economic variables that form the baseline variables for the research and $TEMP_t$, SSH_t and $PREP_t$ are the proxy for Climate Change impacts.

3.2 ESTIMATION STRATEGY

3.2.1 Functional Form

A particular functional form a model should assume is a problem germane to all econometric studies. Econometric literature gives some theoretical basis for choosing a particular functional form: consistency with economic theory and type and nature of data; however literature does not pinpoint the exact form suitable for a case-specific study. Zaniku (2003), in studying functional forms in energy demand modelling, suggested that in the estimation of demand functions for energy resources, linear, log–linear and translog functional forms are commonly assumed and compares linear, log–linear and translog share equation functional forms against a non-parametric function. Though non-parametric performed better than the three common functional forms, within these three forms there were no significant differences. But since the main interest of this research is to derive short-run and long-run elasticities of energy demand to climate variability, the focus of attention will be upon log-linear and that is log-log demand modelling.

3.2.2 Generalized Method of Moment (GMM) Estimation

The inclusion of the lagged value of the dependent variable among the regressors leads to a violation of the exogeneity assumption which is required for consistency. As this endogeneity problem exist, applying method of moment estimation, particularly ordinary least squares yield biased and inconsistent results that are very and seriously misleading. Therefore, this research adopts a widely used methodology that is applying General Method of Moments (GMM) estimators. The rationale for relying on Generalized Method of Moments techniques is to obtain estimates under fairly general assumptions, using at the same time relatively simple techniques of analysis.

According to Arellano and Bond (1991) generalized method of moment is proven to be quite efficient; it allows for the existence of unobserved effects while relaxing the very strong hypothesis of strict exogeneity. GMM produces consistent estimators using instrumental variables, Arellano and Bond (1991) proposes the lags of the very dependent variable as the instrument whiles Anderson and Hsiao (1981,1982) proposes both lagged levels and the lagged first difference as possible instruments. Bigano et al (2006) is of the view that lag levels are more suitable than the lagged first difference of the original dependent variable and proposes that all the first difference of the remaining variables in the model are possible instruments provided they satisfy strict exogeneity assumption.

After the late 1980's Autoregressive models were abandoned for Cointegration models and ECMs in modelling electricity demand for short and long run analysis. The reason for the abandonment was that, in the presence of non-stationary variables, the standard statistical results in general were not authentic (Bentzen and Engsted, 2001) and differencing of non-stationary variables diminishes long run information. However, Sims (1990), and Pesaran and Shin (1999) have shown that the AR model is still valid in the presence of I(1) variables if there is unique long relationship among the variables. Since the non stationary variables in study were found to be I(1) and there is a unique cointegrating vector between them, AR model was applied in the estimations. The econometric model for analysis is given as:

$$REC_t = \beta_0 + \beta_1 REC_{t-1} + \beta_2 P_t + \beta_3 DY_t + \beta_4 PS_t + \beta_5 URB_t + \beta_6 TEMP_t + \beta_7 SSH_t + \beta_8 PREP_t + v_t \dots (3)$$

The variables in EQN (3) have already been defined, β_0 is the constant term, v_t the disturbance term and β_1 to β_8 are the parameters through which the regressors translate their individual influence unto the regressand.

These parameters (β's) show the immediate impact of a change in the explanatory variables on the dependent variable, therefore it represents adjustment in the short run. In the long-run, $REC_t = REC_{t-1}$, from equation (3):

$$REC_t = \beta_0 + \beta_1 REC_t + \beta_2 P_t + \beta_3 DY_t + \beta_4 PS_t + \beta_5 URB_t + \beta_6 TEMP_t + \beta_7 SSH_t + \beta_8 PREP_t$$

$$REC_t - \beta_1 REC_t = \beta_0 + \beta_2 P_t + \beta_3 DY_t + \beta_4 PS_t + \beta_5 URB_t + \beta_6 TEMP_t + \beta_7 SSH_t + \beta_8 PREP_t$$

$$(1 - \beta_1) REC_t = \beta_0 + \beta_2 P_t + \beta_3 DY_t + \beta_4 PS_t + \beta_5 URB_t + \beta_6 TEMP_t + \beta_7 SSH_t + \beta_8 PREP_t$$

$$REC_t = \frac{\beta_0}{(1-\beta_1)} + \frac{\beta_2}{(1-\beta_1)}P_t + \frac{\beta_3}{(1-\beta_1)}DY_t + \frac{\beta_4}{(1-\beta_1)}PS_t + \frac{\beta_5}{(1-\beta_1)}URB_t + \frac{\beta_6}{(1-\beta_1)}TEMP_t + \frac{\beta_7}{(1-\beta_1)}SSH_t + \frac{\beta_8}{(1-\beta_1)}PREP_t \quad \text{..........} \quad (3a)$$

The transformed parameters $\frac{\beta' s}{(1-\beta_1)}$, is the long run impacts of the explanatory variables and equation (3a) depicts long run adjustments.

3.2.3 Estimating Seasonal Variation and Variable Interaction

The starting model for energy demand described by equation (3) is modified so as to reflect the hypothesis that the relationship between electricity demand and weather/climates covariates plus the lagged dependent variable are different across the seasons of the year. Ghana has two major seasons that are dry and wet seasons. These seasons of the year are well profound in Ashanti region too. Where the wet season also known as the raining season is between the months of April and October, and the dry season is between November and late March.

In order to capture this feature, two dummies for the different groups of months reflecting both seasons are introduced into the regression. The dry season is associated with the unit and the wet season is identified by d_0. d_0 is the reference group and therefore its dummy-related variables will not be included in the regressions. The use of the dummies in level allows in capturing the different effect of the seasons on the intercept. Interacting the climate and lagged dependent covariates with a dummy captures the different effects on the slope. The focus of the equation is to investigate how seasons of the year affect residential electricity demand and also how climate variables in the initial models influences electricity demand within these two seasons. Therefore, socio economic variables in the original model are held constant. With these additional variables and modification, the model reads as follow:

$$REC_t = \alpha_0 + \alpha_1 d_1 + \beta_0 REC_{t-1} + \beta_1 REC_{t-1} d_1 + \beta_2 \bar{P}_t + \beta_3 \overline{DY}_t + \beta_4 \overline{PS}_t + \beta_5 \overline{URB}_t + \gamma_0 TEMP_t + \gamma_1 TEMP_t d_1 + \delta_0 SSH_t + \delta_1 SSH_t d_1 + \pi_0 PREP_t + \pi_1 PREP_t d_1 + v_t$$

The effect of climate and the lagged regressors now depends on the value of the dummy which identifies the season considered. This aspect becomes clearer if the model is formalized as follows:

$$REC_t = \alpha_0 + \beta_0 REC_{t-1} + \gamma_0 TEMP_t + \delta_0 SSH_t + \pi_0 PREP_t + v_t \qquad \text{if } d_0 = 1$$

$$REC_t = (\alpha_0 + \alpha_1) + (\beta_0 + \beta_1) REC_{t-1} + (\gamma_0 + \gamma_1) TEMP_t + (\delta_0 + \delta_1) SSH_t + (\pi_0 + \pi_1) PREP_t + v_t \quad \text{if } d_1 = 1$$

The two dummy equations above shows that relationships will have a different intercept for each season: α_0 for wet season and $\alpha_0 + \alpha_1$ for dry season. The marginal effect of covariates in wet season example $\frac{\partial TEMPT_t}{\partial REC_t} = \gamma_0$ is also different than the marginal effect in the dry season that is, $\frac{\partial TEMPT_t}{\partial REC_t} = \gamma_0 + \gamma_1$.

The overall significance of the dummy-interacted variables will be tested using Wald test with the null hypothesis: $H_0 = (\alpha_1 + \beta_1 + \gamma_1 + \delta_1 + \pi_1) = 0$.

3.3 RESEARCH VARIABLES AND PRIOR EXPECTATION

3.3.1 Price

According to the theory of demand, price has an inverse relationship with quantity demand and on this basis; a price increase for electricity should lead to a decrease in its consumption. But really, the price enters the model as elasticities and therefore measures rate of change and not direct impact. It can have both positive and negative relationship with the quantity demanded. That is theoretically, electricity demand can be a Giffen good or an ordinary good. And therefore price variable can assume either positive or negative sign.

3.3.2 Income

Other alternative energy vectors specifically coal has been noted for having negative relationship with income, meaning it is becoming more inferior in consumption as consumer's income increases (see Amato et al 2004). For electricity all reviewed studies had positive relationship with the exception of Wilson (1971). These results are not inconsistent with theory; income elasticity can be positive for normal good and also negative for inferior goods. Mostly all the literatures and empirical studies attest to the fact that increases in income increases demand for electricity. Narayan and Smyth (2005) cited in Neeland (2009), postulated that higher real GDP per capita is expected to increase electricity consumption through greater economic activity.

3.3.3 Population Size

In the simple demand theory (price-quantity relation), demand is about purchasing power and not necessarily number of consumers. The same micro economic theory suggest that as number of consumers increases quantity demanded increases all other things being equal, but in a macro analysis, number carries a lot of weight in determining quantity demand. Population size really accounts for energy consumption in that, as population increases household also increases that is, more housing are needed that uses energy. Population variable is expected to be positively related to electricity demand.

3.3.4 Urbanisation

According to Feenstra et al (1998) population shifts leads to changes in regional energy consumption. Consistent to this evidence is the various reports by Energy Commission that suggest that electricity is highly consumed in the capital cities and the more people shift to cities the more electricity consumption is likely to increase and therefore urbanisation is one of their major determinant of electricity demand. In this regard, urbanisation is expected to have a positive relationship with the electricity demand

3.3.5 Temperature

Temperature is the weather variable widely used in related studies and in all empirics it has a positive relationship with electricity consumption. This is very consistent with the heating and cooling effect concept underlying those related studies. Electricity has been the major energy source that is used for cooling effect mainly because air-conditions and refrigerators are electronic durables. "The cooling effect refers to the increase in energy demand, due to the use of cooling devices, such as air conditioners. As these appliances are fuelled by electricity, it is expected that the demand for this type of fuel will be positively associated with higher temperatures" (De Cian 2007).

3.3.6 Sunshine

Sunshine though not widely used in climate-energy demand studies, since it strongly contributes to or is an evidence of global warming it is more likely to foster or activate cooling effect uses of energy. Amato et al (2004) uses sunshine as a variable in forecasting electricity consumption in massachuset and had a positive relationship with electricity demand.

3.3.7 Precipitation

In Ghana and specifically Ashanti region, rains normally falls in the wet seasons. A season of the year marked by relatively cold weather/climatic conditions and this creates an environment less likely to use energy for cooling purposes. Therefore the longer the wet season the more it rains in the year and the lesser electricity is expected to be used for cooling purposes.

3.4 DATA ANALYSIS

3.4.1 Data Needs and Description

The variables employed in the residential electricity demand equation above were chosen based on gross theoretical and empirical considerations and Ghana's energy demand policy reports by Energy Commission. This thorough scrutiny is done to avoid under/over specification of the demand equation. The datasets needed are monthly time series observations of residential electricity consumption for Ashanti-west region, residential electricity tariff, temperature, rainfall, sunshine, population, urban share of population, and gross national disposable income per capita of Ghana that span from 2004 to 2012 solely due to data availability. As mentioned earlier in chapter two, the focus is on the residential sector, as industrial demand for energy does not seem to respond significantly if not at all to Climate Change (Bigano et al. 2006; Asadoorian et al., 2006; Amato et al 2004) and even price (Liu, 2004). As it can be noted from equation (3) the variables of interest are residential electricity consumption, average residential end-use tariffs, GNDI per capita, regional population size, urban share of population, temperature, sunshine and precipitation.

Both traditional and modern economic theory highlights price and income as the major basic determinant of every demand. These two variables form the locus that shapes consumers utility maximising ability. How much energy a resident can buy in the market is apparently dependent on these two economic variables (price and income). The price vector in the equation is an average end-use residential electricity tariff. In Ghana, the charges increases with quantity consumed and the quantity quotas consist of 0-50, 51-150,151-300, 301-600 and 601+ (Ghc/kWh) plus service charge (Ghc/month). So the average tariff for these quotas serves as the proxy for the price in the equation. For income, since the research is desk base and so the data are not as a result of survey that household disposable can directly be elicited. So the research will dwell on the compromise in literature and this will be using GDP per capita as a proxy of disposable income. This is empirically proven to give an accurate measurement (see Bigano et al 2006). Actually gross national disposable income per capita will be used as the proxy for disposable income.

The other demographic characteristics (population and urban share) in the equation were included purely due to electricity demand policy recommendation by Energy Commission though it has rigorous theoretical bases. Energy Commission engages in energy demand forecasting as one of their mandates for making energy supply and demand policy. And they have emphatically stipulated that, electricity demand in Ghana is driven by increasing population and urbanisation as part of the major determinant of electricity demand; therefore their inclusion in the model, regional population figures and urban share as the proxies for population and urbanisation respectively.

Almost all studies in this area are biased towards using temperature as the proxy for Climate Change. This is because of the global warming effect of Climate Change resulting in distorting energy demand for cooling and heating preferences. The research adopts this variable but adds other variables that are sunshine and precipitation to it, first to neutralized the biasness towards temperature and secondly to enhance the representation of Climate Change and also accuracy in capturing its effects. The use of temperature and the addition of sunshine and precipitation is not arbitrary; literature has it that "*the experience of many utilities indicates that the weather elements that influence electricity demand consist of temperature, humidity, wind and precipitation in decreasing order of importance*" (Robinson 1997 cited in Mirasgedis et al, 2006). Amato et al (2004) divided weather variable in the context of Climate Change and electricity demand as non-temperature weather conditions consisting of humidity, precipitation and wind and temperature related weather conditions where they used sunshine alongside temperature for their assessment.

Another reality is that Ghana lies in the tropical Africa. Particularly, it lies in the West Africa tropics marked by rain forest. In the same way Ashanti region majorly lies in the rainforest belt of Ghana where rainfall is major weather/climatic activity. In this regard ignoring precipitation may yield a model not fitting the context. It is in this regard that climate variability is being accounted for by including temperature, sunshine and precipitation.

Particularly, temperature variability has been accounted for by using heating and cooling degree days in almost all literatures. And these degree days have become particularly popular in the studies dealing with residential demand of space heating energy (Madlener and Alt, 1996; Parti and Parti, 1980). According to this literature, electricity demand is driven by the discomfort created by the temperature difference between outside and inside. The use of degree days allows to segment temperature variations and thus to easily capture the increase in electricity demand due to an increase in the cooling days or to a decrease in the heating days. However this measure has some drawbacks. First, it is threshold - dependent and it assumes the switch from heating devices to cooling equipments to be sudden. Instead, the adjustment to temperature changes is more likely to be gradual: the air conditioning will be turned on if the temperature rises significantly above 18.3 °C, a value often chosen as threshold. Secondly, this approach assumes a priori instead of estimating which temperature leads to certain behaviours. If it is to determine the sensitivity of energy demand with respect to temperature variations, it may be more appropriate to include temperatures directly.

3.4.2 Data Source

Data used for the purpose and completion of the research were purely secondary and were accessed from credible local (regional offices/departments) respective institutions in Ghana: Electricity Company of Ghana; Meteorological Services Department; Ghana Statistical Services. Annual time series data for residential electricity consumption and the critical climate variables that were used for the estimations are temperature, sunshine and precipitation. The following sub-sections describe the data needs in the energy demand sensitivity analysis.

3.4.2.1 Energy data

Ashanti-west region's residential electricity consumption and prices were accessed from Electricity Company of Ghana regional office and energy consumption statistics, published by Ghana Energy Commission. ECG/Energy Commission readily produce and make public such consumption statistics. The sample size mainly depended on data availability.

3.4.2.2 Socio-Economic data

For a demand function to be correctly specified not only the commodity and its price are relevant but also income, population and urban share of the population. Therefore GDP and population figures were the socio-economic data that played the critical role in computing disposable income, economic growth, and population and population shift (urbanisation) variables needed for the modelling. These critical variables were available at the Ghana Statistical Service.

3.4.2.3 Climate data

Historic climate data that consisted of computed monthly average temperature was accessed from meteorological services department, headquarters, Accra. In addition to temperature variable are sunshine and precipitation variables. This is to neutralize bias in the econometric estimates of demand sensitivity to temperature variable as many related studies do and also to comprehensively and accurately capture Climate Change effects in the study area.

3.5 THE STATIONARITY ISSUE: THE UNIT ROOT TESTS

In econometric analysis, especially using time-series data, a number of preliminary steps must be undertaken before it is used to run the regressions. This type of data typically contains a trend, which must be removed prior to commencing any estimation. The traditional detrending procedure separates the trend from the cyclical component of the series. This procedure is appropriate for the trend stationary time-series. However, many macroeconomic time-series are difference stationary. These series are non-stationary, contain unit roots, and must be differenced prior to any meaningful econometric estimation. The most common unit root test is the Augmented Dickey-Fuller (ADF) test. If one can reject the null hypothesis that a series possesses a unity root, then the series is trend stationary, or integrated of order zero (I(0)). If one cannot reject the null of a unit root, then the series is difference stationary. The testing procedure for the ADF is provided in Equation 4.

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \ldots\ldots 4$$

The equation above characterises a regression between changes in the variable *Y* against a constant, a time trend and lagged value of *Y*. After the stationarity of each variable has been determined, an analysis of their interaction can be performed.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

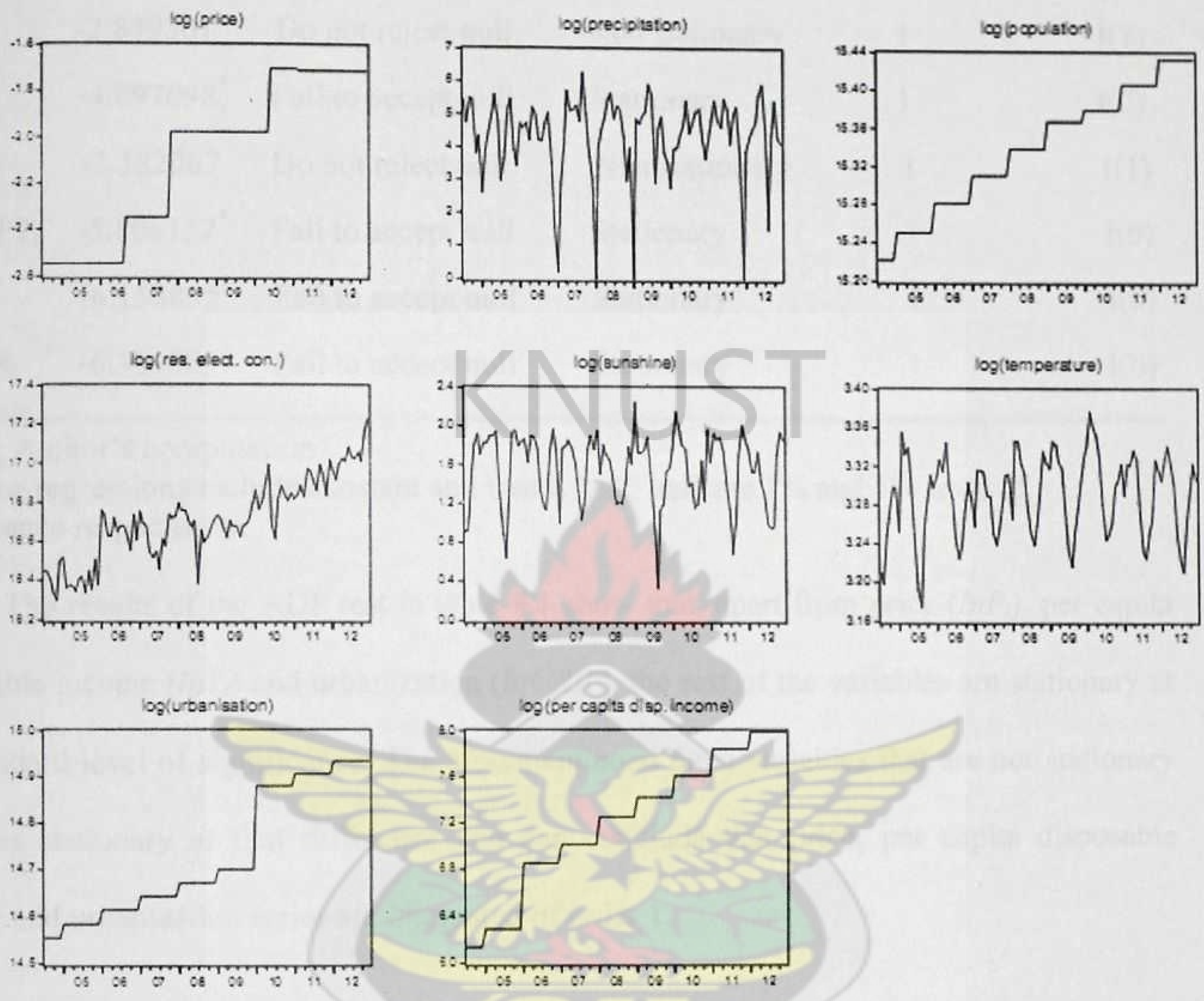
4.0 INTRODUCTION

This chapter explores the results and the interpretations of the econometric models developed in the methodology. The variables employed are monthly time series data that span from July 2004 to December 2012 given a total sample size of 102 observations. However the standard time series econometric procedure requires a preliminary testing for unit roots in all the series in order to check the stationarity of the variables, therefore Augmented Dickey-Fuller (ADF) unit root test was employed. Correlation matrix and factor/component analysis was done to scrutinize the level of statistical dependency among explanatory variables in order for the models to be well estimated. After, regressions were estimated, the first and the original regression is the short run dynamic model. It was then mathematical manipulated to derive the long run estimates. Dummy and interacted dummy regression was done to analyse the seasonal variation and interaction effect on electricity demand.

4.1 UNIT ROOT TEST

It is commonly a convention to have a visual plot of the data as the initial analysis of time series. Below are the trends of the variables employed for the analysis.

Figure 4.1 Time Series Trends of Research Variables



The first impression from fig 4.1 is that apart from precipitation, sunshine and temperature, all the other variables seems to be trending upward only residential electricity consumption trend upwards with fluctuations. These trends are all indications of non-stationarity of these variables and hence unit root test must be done prior to commencing the estimations. Following, is the summary of the test results of all the variables, details of each test results are in the appendices (appendix A1)

Table 4.1 Augmented Dickey-Fuller Test of Unit Root

Variable	ADF	Decision	Implication	lag length	Conclusion
$lnREC_t$	-4.040673^{**}	Fail to accept null	Stationary	1	I(0)
lnP_t	-2.280118	Do not reject null	Non stationary	1	I(1)
lnY_t	-2.839301	Do not reject null	Non stationary	1	I(1)
$lnPS_t$	-4.097098^{*}	Fail to accept null	Stationary	1	I(0)
$lnURB_t$	-2.382067	Do not reject null	Non stationary	1	I(1)
$lnTEMPT_t$	-5.806157^{*}	Fail to accept null	Stationary	1	I(0)
$lnSSH_t$	-6.158855^{*}	Fail to accept null	Stationary	1	I(0)
$lnPREP_t$	-6.381865^{*}	Fail to accept null	Stationary	1	I(0)

Source: Author's computation
Note: the regressions include constant and trend. *, ** indicate 1% and 5% level of significance respectively.

The results of the ADF test in table 4.1 show that, apart from price (lnP_t), per capita disposable income (lnY_t) and urbanization ($lnURB_t$), the rest of the variables are stationary at the standard level of significance. The aforementioned three variables that are not stationary becomes stationary at first difference and can conclude that price, per capita disposable income and urbanization series are integrated of order 1.

4.3 Preliminary Model Estimation and Data Reduction

Urbanization and sunshine shine series do not in the final estimation enter the equation estimated. In the initial estimation of the equation, it was found out that most of the variables were not significant though other indicators points (especially high R^2) to the fact that the model is well specified. This suspicion pointed clearly to the problem of multicollinearity in the series and called for correlation matrix where it was found out that temperature and sunshine, and urbanization and income series are highly collinear about 0.8 and above 0.5 respectively. The correlation matrix can be found in the appendix (A2), though these results are necessary, they are not adequate enough to exclude the variables (urbanization and sunshine). Further, factor analysis was employed, primarily for structure detection to identify and remove redundant (highly correlated) variables from the data to ensure the required numbers of uncorrelated variables are used. When the Eigen value (amount of variance) was set equal to one, most variables did not meet this criterion and so it was further decrease to 0.8 and yet urbanization, sunshine and precipitation series did not meet this criterion. But precipitation's Eigen value was above 0.7 while the other two were lower than 0.5 so therefore the researcher applied discretion not to exclude precipitation because these tests are purely statistical and must be balanced with theory and literature. The results of the factor/components analysis are in the appendix (A3). In all, urban share and sunshine variables were excluded and it made all the other variables that were insignificant initially became significant. Population and temperature can serve as proxies for urban share of population and sunshine respectively in the discussion of results.

For the application of autoregressive (AR) model and it validity for making long run analysis, there should be only one cointegrating relationship among a set of non-stationary variables. Thus it is necessary to check the number of cointegrating vectors among the variables. For this purpose, Johansen's VAR approach was used among the two non-stationary variables i.e. price and income. Table below shows the results of the Johansen test.

Table 4.2 Johansen Tests for the Number of Cointegrating Relationships

No. of CE(s)	Eigenvalue	Max-Eigen Statistic	Trace Statistics	Critical value (0.5)
None	0.24	26.35	46.59	15.49
At Most 1	0.19	20.34	20.24	3.84

Source: Authors Computation

Trace and max-eigenvalue indicates 2 cointegrating equations at the 0.05 significance level. Therefore, the null hypothesis of no cointegrating relationship is rejected. In conclusion, there is a unique long run relationship among the variables selected for estimation.

4.4 Regression Results

Short run residential electricity demand for Ashanti-west is presented below:

Table 4.3 Estimation Method: Generalized Method of Moments

Sample: 2005M02 2012M12, Observations: 95

Regressor	Coefficient	Std. Error	t-Statistic	Prob.
C	-12.71489	2.206314	-5.762957	0.0000
DLNP	-0.131488	0.224654	-0.585290	0.5599
DLNY	0.350700	0.129202	2.714348	0.0080
LNPS	1.237577	0.213105	5.807353	0.0000
LNTEMP	0.023524	0.116704	0.201572	0.8407
LNPREP	-0.012800	0.005926	-2.159851	0.0335
LNREC(-1)	0.623435	0.071688	8.696486	0.0000
J-statistic		0.194480		

Instruments: LNREC(-2 to 7) DLNP(-1 to -6) LNPS(-1 to -6) LNTEMPT(-1to -6) LNPREP(-1 to -6) C

Source: Authors Computation

The GMM estimation employed in the estimation above is robust against heteroskedasticity and autocorrelation of unknown forms, and since the model is over identified that is the number of instruments are greater than the number of parameters or the number of moment conditions is greater than parameter vectors the model is said to be over identified. The over-identification allows checking whether the moment conditions match the data well or not. To be sure if the model fits the data, J-test or test of over-identifying restrictions was done, details of the result are shown in the appendix (B1) where the estimated 'J' (18.4756) < $q_{0.95}^{x^2_{k-l}}$(36.4151), the null hypothesis that, the model is valid cannot be rejected. This implies that the data used comes close to meeting the restrictions and that the model is well specified.

Writing out the linear equation of the results above gives the following short run electricity demand function:

$$lnREC_t = -12.71489 + 0.623435lnREC_{t-1} - 0.131488\Delta lnP_t + 0.350700\Delta lnY_t + 1.237577lnPS_t + 0.023524lnTEMP_t - 0.012800lnPREP_t \ldots \text{eq.4.1}$$

$$R^2 = 0.814562 \quad \text{adjusted } R^2 = 0.801919 \quad \text{Durbin} - \text{Watson stat} = 2.305465$$

The coefficients of the regression are interpreted as elasticities due to the logged values of the variables and therefore it shows the responsiveness of the residential electricity consumption as a result of a percentage change in the explanatory variables. The estimates gives a reasonably high R square (0.814562) and adjusted R square (0.801919) which means close to 82% of the movement in the residential electricity demand is explained by the parameters estimated.

From table 4.3 above, income and temperature are not statistically significant at the standard 5% level of significance, the rest of the parameter are statistically significant below the 5% level. From eqn. 4.1 the long run estimates is computed by setting $lnrect_{t-1} = lnrec$, after mathematical manipulations, below is the long run residential electricity demand function:

$$lnREC_t = -33.76545 - 0.3492\Delta lnP_t + 0.9313\Delta lnY_t + 3.2865lnPS_t + 0.0625lnTEMP_t - 0.034lnPREP_t \ldots\ldots\ldots \text{eq.4.2}$$

For ease and clarity of interpreting and comparing both short and long run elasticities, the table 4.4 below shows both the estimated and computed short and long run parameters.

Table 4.4 Estimation Results for Short and Long Run Residential Electricity Demand

variables	Short run elasticity	Long run elasticity
constant	-12.71489	-33.76545
Price	-0.131488	-0.3492
income	0.350700	0.9313
Population size	1.237577	3.2865
temperature	0.023524	0.0625
precipitation	-0.012800	-0.034

Table 4.4 presents the elasticities for both short and long run; the signs of the parameters for short and long run are within literature and theoretical expectations. The variables are discussed one by one and to start with, in the short run price elasticity is approximately -0.13 indicating for every 1% increase in price electricity consumption decreases 0.13%. Suggesting that the electricity demand is price inelastic and though this value absolutely increases in the long run to 0.35, it still remains far below unity. Comparing short and long run price elasticities values, one may conclude that electricity is strictly a necessity both in short and long run.

The sign of the price variable is negative and is consistent with majority of the empirical literatures on this related research. The negative relationship that is found in literature and also is an expectation in the traditional demand of price elasticity of electricity demand, is based on the concept that when there is an increase in price of electricity, individuals in response reduces the rate of utilization in the short run. In the long run the concept says people then change the composition of the stock or electricity appliances in such a way that the demand for electricity further reduces, hence the long run elasticity greater than the short run.

The positive signs for both short and long run income elasticities indicate that electricity is a normal good. The short run income elasticity is approximately 0.35 and in the long run it is approximately 0.93. It means for every 1% increase in income, there is 0.35% increase in electricity demand in the short run and 0.93% in the long run. Again both short run and long run income elasticity are below unity implying they are inelastic though in the long run it gets closer to unity. Meaning in the long run residents are relatively responsive to income changes than in the short run and that there is the possibility of increasing their stock of electric appliances and utilization as income increases in the long run.

The third variable is the population size and also a proxy for urbanization is highly significant and has expected sign. Its short and long run elasticities are approximately 1.24 and 3.29 respectively, meaning a percent increase in population increases electricity demand by 1.24% in the short run and 3.29% in the long run. This suggests that electricity consumption is highly elastic to population size and shift in both short and long run. It can be concluded that as population increases then household size also increases and people adjust the rate of utilization according to their household needs. Population and population shift that results in larger household size means more members in a household which in turns requires more fans, bulbs, tube lights, air conditioners and air coolers for greater time period.

The last two variables that capture Climate Change effects on electricity demand are temperature and precipitation and clearly their result show the presence of cooling effects. It was reviewed in the literature that electricity consumption is a derived demand for heating and cooling purposes. And these was captured in the heating and cooling effect concept that says heating effect is the decrease in energy demand for heating purposes as community/society get warmer and the cooling effects is the increase demand for energy for cooling purposes as society get warmer and in the context of Ashanti-west locality and Ghana in general climates are usually warmer so the heating effect is inapplicable in this setting thus only cooling effect will be diagnose. The two climate variables are analysed below:

4.4.1 Climate Change and Residential Electricity Demand

The first objective of this study was to ascertain the relationship between Climate Change and Ashanti-west region residential electricity demand. Climate Change in the model is captured by temperature and precipitation variables.

From table 4.4, temperature bares it expected positive sign and precipitation expected negative sign. It explanation is within the concept of cooling effects is that as temperature increases and the locality get warmer, electricity demand for cooling purposes also increases thereby increasing the overall electricity demand. That is, as the locality get increasingly warmer then individuals may react to the increasing temperatures by installing cooling gadgets such as fans, air conditioners, air coolers and refrigerators resulting in the increase in the electricity demand. For precipitation, it usually happens with relatively low temperatures and that such demand for cooling purposes becomes less important and thereby leading to low demand and utilization of cooling gadgets resulting in lowering electricity demand. Cooling effect is however the explanation for the expected positive and negative signs for temperature and precipitation respectively.

The relationship between Climate Change and electricity demand becomes lucid when distortions created by Climate Change in the weather variables are known. According to Ghana EPA (2000), Temperatures have risen by about 1 degree Celsius over the last 4 decades in Ghana and within the same period rainfall has also recorded to have declined by about 20%. This weather distortions still ensue and increasingly getting worse especially making rains highly unpredictable. Consistent of this reality to the regression result is that, Climate Change has a positive relationship with electricity demand in that, demand for electricity in the model increases as temperature increases and again increases as precipitation decreases.

4.4.2 Short and Long Run Weather Variables Elasticities of Demand for Electricity

Table 4.4 again shows that, in the short run, temperature elasticity is 0.024 and in the long run it is approximately 0.063; precipitation also had a very inelastic values for both short and long run which are 0.013 in the short run and 0.034 in the long run.

4.4.3 Comparison with Previous Findings

The findings on the elasticities of the variables used in the model compares relatively well with similar results in literature. Negative price elasticity is usually consistent in literature, which in the model range between -0.13 and -0.35. A comparable study by Toriq et al (2008) presented negative short and long run price inelastic values: -0.63 and -0.77. Narayah and Smyth (2005) found short and long run price elasticities to be -0.263 and –0.541 respectively; Kamerschena, and Porterb (2004), investigates the electricity demand for period 1973-1998 for U.S. Estimates of residential price elasticities vary from -0.85 to -0.94 in 3SLS.

The short run and long run income elasticities in this study range between 0.35 and 0.93 and consistent with most related studies. Small income elasticities are common in numerous literatures and the income elasticities estimated are within the lower and the upper end range of income elasticities in literature. Typical examples from Africa are Babatunde and Shaibu (2009) reported 0.10 and 0.19 as their short and long run income elasticity respectively, for residential electricity consumption in Nigeria; Inglesi (2010) estimates the short and long run income elasticities of aggregate electricity demand for South Africa to be 0.415 and 0.8196, respectively; Ziramba (2008) and De Vita et al., (2006) also reported income elasticity of residential electricity demand for South Africa and Namibia to be 0.31 and 0.41 respectively.

Population elasticities for both short and long run are 1.24 and 3.29 respectively and this is much consistent with Tariq et al (2008) who found elastic short and long run population elasticities to be 4.70 and 5.76 respectively.

Temperature is the single proxy for Climate Change in energy demand analysis, almost all empirics tows that direction. Precipitation is nonexistent in energy demand – Climate Change analysis but is a vital indication of climate variability specifically in tropical regions. Precipitation elasticities to residential Climate Change in this research may serve as a basis for further considerations into energy demand studies particularly on tropical Africa. The positive temperature inelasticity estimates in the short run and long run is also very consistent to numerous empirical studies, example: De Cian et al (2007), Bigano et al (2006) and Asadoorian and other (2006), though most previous literatures had elastic values.

4.5 Seasonal Variation and Dummy Interactions

The table below shows residential electricity demand responses to the seasons of the year and how the climate variables affect demand during the seasons. The table is a dummy and interacted dummy regression explained in the methodology with wet season as the reference variable.

Table 4.5 Estimation Method: Generalized Method of Moments

Sample: 2004M11 2012M12 Observations: 98

	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.693419	2.704205	-0.996011	0.3219
Ds	18.89610	6.078167	3.108848	0.0025
lntemp	-0.275085	0.369883	-0.743707	0.4590
Lntemp*Ds	-3.663892	1.621538	-2.259516	0.0263
lnprep	-0.006280	0.031933	-0.196663	0.8445
Lnprep*Ds	0.030881	0.047999	0.643362	0.5216
Lnrec(-1)	-0.408042	0.391939	-1.041086	0.3006
Lnrec(-1)*Ds	1.216730	0.169863	7.163026	0.0000
Instruments: LNREC(-2 to -4) LNREC(-3) DLNTEMPT(-1 to -3) DLNPREP(-1 to -3) DLNPS(-1 to -3) DLNP(-1 to -3) C				
J-statistic	0.051518	D-W	1.9527	
R-squared	0.556365	Adjusted R-	squared	0.521861

Source: Author's estimation

Table 4.5 shows the estimated parameters for the dummy variable dry season and seasonal interaction with temperature, precipitation and past electricity consumption given wet season as the control variable. The model is fairly a good fit as models that are virtually ANOVA or dummy models do have a low R-squared. The estimated 'J' (5.048764) < $q_{0.95}^{x^2_{k-l}}$(15.5073), the null hypothesis that the model is valid cannot be rejected. Implying the data used comes close to meeting the restrictions and that the model is well specified (see appendix B2 for detail results).

The linear equation of the model is:

$$lnREC_t = -2.693419 + 18.8961Ds + -0.275085lnTEMP_t - 3.663892TEMP_tDS - 0.00628lnPREP_t + 0.030881lnPREP_tDs - 0.408042lnREC_t + 1.216730lnREC_{t-1}Ds \text{......... eq.4.4}$$

The coefficient of Dry Season Ds (18.89610) is a differential intercept and so it shows by how much the value of that intercept when d=1 for dry season differs from the intercept coefficient of the reference category (wet season). This coefficient for dry season is statistically significant at 5% significance, level implying there are differences in the residential electricity demand responses to seasonal changes. The computed values of the intercepts and coefficients of the dummies and it interactions as parametrically presented in the formalized models in the methodology are presented in the table below:

Table 4.6 regression results for seasonal variation.

Variables	Wet Season (D=0)	Dry Season (D=1)
Intercept	-2.693419	16.202681
Temperature	-0.275085	-3.938977
Precipitation	-0.006280	0.024601
Rec_{t-1}	-0.408042	0.808688

Source: Author's estimation and computations

The intercepts values in the table 4.6 above show the different responses of residential electricity demand to wet and dry season. Wet season is relatively colder just as dry season is fairly hotter and may support the cooling effect which their respective signs show. The values and signs for temperature and precipitation are the effects of these variables depending on the two seasons. At wet seasons, temperature which in the original model had a positive sign is now having a negative sign implying temperature's effects are outweighed by the cold characteristics of the wet season. For precipitation it has a sign consistent with the sign it had in the original model and that is a negative sign.

Precipitation in the dry season also had a positive sign implying it effect is outweighed by hotter character of that season. Rains are most often verily absent during this season and so may not affect electricity demand. Temperature in the dry season has an unexpected sign of negative, following the logic from the original model (eqn.4.1) higher temperature increases electricity demand so one may expect in the dry season when is already relatively hotter the same positive sign should be present. Explanation for this result is not far-fetched: electricity in Ghana is hydro dependant and that the quantities produce is highly constraint by the environmental dimensions. During dry season electricity production becomes highly constrained due to lack of water. Almost all electricity power crisis and load shedding occurs and intensifies during this season and until recently, lack of rains was the major reason for power crisis. The logic here is that, in the dry season water bodies dry up and when this is coupled with increasing temperatures then the situation worsens making the actual quantity consumed to be defined by quantity produce so a decrease in supply irrespective of any given demand curve will decrease the quantity consumed.

The overall significance of the dummy-interacted variables was tested using a Wald test, with the null hypothesis: $H_0 = (\alpha_1 + \beta_1 + \gamma_1 + \delta_1 + \pi_1) = 0$. The test result is presented below:

Wald Test:

Test Statistic	Value	df	Probability
Chi-square	7.527641	1	0.0061

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(2) + C(4) + C(6) + C(7)	14.85504	5.414327

Source: Author's estimation

The low probability value indicates that the null hypothesis is strongly rejected.

4.7 Summary and Discussion of Findings

Price elasticity values were negative and below unity, the short run value is relatively far from unity, these price inelastic values lead to the conclusion that electricity is strictly a necessity in both short and long run for Ashanti-west. From income elasticity values they were all positive suggesting electricity is a normal good and is consistent with the necessity conclusion made from the price results, in that, a necessity is one type of a normal good, which is further confirmed by the less than unity positive values of the income elasticities. From economic theory, when elasticity of income is positive then is a normal good but when the positive value is bigger than unity then it is a luxury but when the value is less than unity as it is in both short run and long run income elasticities, and then it is really a necessity. The necessity and normal good concluded to be the nature of electricity demand for Ashanti-west region residents may lead to the general conclusion that electricity has become an important part of life and that people are more becoming dependant on this commodity (electricity).

From the population size elasticities, it was clearly elastic for electricity demand and the reason was that higher population and urbanization may results in larger households which in turns may lead to increase utilization of electricity. This elastic short and long run values also lead to a very important conclusion that a high population growth rate and urbanization rate are important factor contributing to the increase in the demand for electricity in Ashanti-west region.

The results from the climate variables clearly conform to the cooling effect that is present or generally experienced in warm or hot climate regions. It shows the increase in electricity consumption due to increases in temperature and reduction in the consumption due to increases in precipitation and this changing consumption patterns to these climate variable shows the adaptation dynamics of residents to Climate Change. "*Temperatures are known to have risen by about 1 degree Celsius over the last 4 decades in Ghana. Within the same* *period rainfall and runoff were also recorded to have declined by about 20% and 30% respectively"* (Ghana EPA, 2000 cited in Quartey, 2010). Consistent of this reality to the regression result is that, electricity demand is definitely going to increase due to this dynamics in climate variables this is because, from eqn.4.1 demand increases with increasing temperature and also increases with decreasing rainfall.

Residential electricity consumption do respond differently to seasonal changes, demand increases in dry season and decreases in wet season, clearly showing how seasonal variation alters electricity consumption patterns and also an indication of how Climate Change effect could have on electricity consumption by distorting this seasonal changes. Precipitation's impact seems to be profound during wet season and with no impact in the dry season. The same way temperature have no impact on electricity consumption in the wet season but unexpectedly shows a different impact during dry season.

CHAPTER FIVE

CONCLUSIONS AND POLICY IMPLICATIONS

5.0 INTRODUCTION

The current generation has come to the realisation that the modern day threat to growth and development is highly an environmental phenomenon with Climate Change championing and triggering other environmental hazards. Though the scientific community has set a maximum range of temperature increase of 2^0C above pre-industrial levels in order to prevent dangerous interference in the climate, the same global temperature is expected to rise by more than a maximum of 4^0C. Clearly, this target and expectation defines the unusual interference in climate caused by humanity. The threat has effects on all forms of life: populations, health, agriculture, leisure (tourist destinations), biodiversity, ocean and uniquely affect energy in both production and consumption.

Climate Change is expected to influence a range of climatic variables, and as electricity demand is closely related to some of them, it is likely to impact demand patterns. In order to assess how climate impacts on Ghana's electricity demand, a case of Ashanti region was studied to diagnose climate effects on residential electricity demand. First, the sensitivity of electricity demand in the region with respect to climate and socio-economic factors was identified. Then the research adopted autoregressive models to estimate both short and long run effects by modelling electricity demand dynamically, depending on a set of climate and socioeconomic variables, and lagged value of the dependent variable. The analysis was performed using a statistical approach (multiple regression models) based on monthly historical data from mid 2004 to December 2012 with the hypothesis that, climate variables and seasonal changes significantly and differently affect electricity demand respectively.

5.1 Conclusions

In summary, the study has been able to establish the following:

- From the estimates, testing of hypothesis showed that, given the period understudy, precipitation and seasonality statistically affected electricity demand patterns but temperature do not.
- Less than unity negative price elasticities led to the conclusion that demand for residential electricity is strictly necessity.
- Residential electricity demand was also diagnosed to be a normal good given the estimated less than unity positive income elasticities
- More than unity elasticity values for population also lead to the conclusion that electricity demand greatly respond to population growth and population shift.
- Climate Change increases residential electricity demand.
- The very small inelastic values for the climate variables (temperature and precipitation) and their signs showed how residents may react to changing weather conditions but do not necessary determines electricity demanded.
- Though climate variables by themselves do not determine electricity demand (i.e almost perfectly inelastic values), seasons of the year greatly affects electricity consumption patterns. Changing weather conditions that alter seasons of the year may greatly impact on residential electricity consumption.

5.2 Implications for Policy

The results and conclusions from the study have cogent and relevant policy implications. First the low short and long run price elasticity (inelastic demand), means that market base policy that increases prices in order to change consumption behaviour may not be prudent, that is any policy on electricity conservation through increase in price alone may not be effective.

Income had low short run elasticity but the long run was almost unity, indicating the possibility of increasing their stock of electric appliances and utilization as income increases in the long run. The long run unit elastic value shows how Ashanti-west in the future becoming more consumption oriented society. It implies that trade policy on electric consumption durables must anticipate this future trend in other to regulate and monitor, making sure standard accredited goods enters the country. It is also to guide in the prevention of future dumping of second hand electronic goods already proliferating in the markets that are having bad electricity consumption performance.

The government should seriously focus upon population growth rate in the country and equally should either stabilize if not to reverse intra migration in the country specifically rural-urban migration (since 88% of residential electricity in Ghana is consumed by urban dwellers). It may put a lot of pressure on energy demand in the future.

Given seasonal differences gross elastic impact on electricity demand, implies a lot to meeting increasing electricity demands needs, climates change foot print in Ghana has been the prolong of dry season and shortening of wet season but with huge floodable rains. By the study, it implies an obvious increase in electricity demand. The dilemma is that, in the dry season that electricity demand seems to increase, the same season is prone with drought causing a decrease in the capacity to produce electricity. Clearly sustainability of the environment is key for the hydro dependent electricity sector in Ghana.

To conclude, though electricity demand shows very inelastic response to individual climate variables, it is very responsive to seasonal changes and therefore climate consideration is a need for both production and consumption policies and effective planning for energy related programmes. Particularly, Ghana Energy Commission must be proactive to include or revised the weight given to environmental dimension especially Climate Change in their Long-range Energy Alternative Planning (LEAP) modelling and forecasting tool in other to be more accurate in their electricity demand projections.

Furthermore, similar research should be undertaken nationwide and on wider timeframe to help quantify national environmental influence on energy demand due to the centrality and the monopolize nature of Ghana's electricity industry.

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APPENDICES

APPENDIX 'A1'

Unit Root Test Result

Residential Electricity Consumption

Null Hypothesis: LNREC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.040673	0.0104
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNREC)
Method: Least Squares
Date: 04/26/13 Time: 03:02
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNREC(-1)	-0.438700	0.108571	-4.040673	0.0001
D(LNREC(-1))	-0.162080	0.103348	-1.568295	0.1201
C	7.192888	1.780144	4.040622	0.0001
@TREND(2004M07)	0.002834	0.000721	3.929161	0.0002

R-squared	0.274284	Mean dependent var	0.007835
Adjusted R-squared	0.251606	S.D. dependent var	0.103079
S.E. of regression	0.089173	Akaike info criterion	-1.957294
Sum squared resid	0.763378	Schwarz criterion	-1.853088
Log likelihood	101.8647	F-statistic	12.09441
Durbin-Watson stat	1.999537	Prob(F-statistic)	0.000001

End Use Price

Null Hypothesis: D(LNP) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.14297	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNP,2)
Method: Least Squares
Date: 04/26/13 Time: 03:04
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNP(-1))	-1.029261	0.101475	-10.14297	0.0000
C	0.011287	0.010324	1.093266	0.2770
@TREND(2004M07)	-5.21E-05	0.000174	-0.299209	0.7654

R-squared	0.514717	Mean dependent var	-4.82E-18
Adjusted R-squared	0.504711	S.D. dependent var	0.071344
S.E. of regression	0.050210	Akaike info criterion	-3.115684
Sum squared resid	0.244536	Schwarz criterion	-3.037529
Log likelihood	158.7842	F-statistic	51.44162
Durbin-Watson stat	2.002121	Prob(F-statistic)	0.000000

Per Capita Disposable Income

Null Hypothesis: D(LNY) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.726321	0.0000
Test critical values:	1% level	-4.053392	
	5% level	-3.455842	
	10% level	-3.153710	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNDY,2)
Method: Least Squares
Date: 04/26/13 Time: 03:06
Sample (adjusted): 2004M10 2012M12
Included observations: 99 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNDY(-1))	-1.155448	0.149547	-7.726321	0.0000
D(LNDY(-1),2)	0.077318	0.102138	0.756993	0.4509
C	0.034419	0.015965	2.155922	0.0336
@TREND(2004M07)	-0.000247	0.000261	-0.944753	0.3472

R-squared	0.539471	Mean dependent var	0.000000
Adjusted R-squared	0.524928	S.D. dependent var	0.107041
S.E. of regression	0.073778	Akaike info criterion	-2.335941
Sum squared resid	0.517107	Schwarz criterion	-2.231087
Log likelihood	119.6291	F-statistic	37.09491
Durbin-Watson stat	2.014895	Prob(F-statistic)	0.000000

Population Size

Null Hypothesis: LNPS has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.097098	0.0088
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNPS)
Method: Least Squares
Date: 04/26/13 Time: 03:08
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNPS(-1)	-0.329419	0.080403	-4.097098	0.0001
D(LNPS(-1))	0.081410	0.102301	0.795793	0.4281
C	5.019066	1.224267	4.099649	0.0001
@TREND(2004M07)	0.000696	0.000175	3.967365	0.0001

R-squared	0.158124	Mean dependent var	0.002115
Adjusted R-squared	0.131816	S.D. dependent var	0.007373
S.E. of regression	0.006870	Akaike info criterion	-7.084262
Sum squared resid	0.004530	Schwarz criterion	-6.980055
Log likelihood	358.2131	F-statistic	6.010367
Durbin-Watson stat	2.011843	Prob(F-statistic)	0.000851

Urbanisation

Null Hypothesis: D(LNURB) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.24817	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNURB,2)
Method: Least Squares
Date: 04/26/13 Time: 03:12
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNURB(-1))	-1.039891	0.101471	-10.24817	0.0000
C	0.003176	0.003971	0.799754	0.4258
@TREND(2004M07)	1.47E-05	6.71E-05	0.219407	0.8268

R-squared	0.519872	Mean dependent var	0.000000
Adjusted R-squared	0.509973	S.D. dependent var	0.027664
S.E. of regression	0.019365	Akaike info criterion	-5.021111
Sum squared resid	0.036377	Schwarz criterion	-4.942956
Log likelihood	254.0555	F-statistic	52.51476
Durbin-Watson stat	2.003009	Prob(F-statistic)	0.000000

Source: Author's estimation

Temperature

Null Hypothesis: LNTEMPT has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.806157	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNTEMPT)
Method: Least Squares
Date: 04/26/13 Time: 03:13
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNTEMPT(-1)	-0.421073	0.072522	-5.806157	0.0000
D(LNTEMPT(-1))	0.347129	0.093601	3.708589	0.0003
C	1.384470	0.237985	5.817465	0.0000
@TREND(2004M07)	3.00E-05	9.77E-05	0.307230	0.7593

R-squared	0.276755	Mean dependent var	0.001064
Adjusted R-squared	0.254153	S.D. dependent var	0.032391
S.E. of regression	0.027974	Akaike info criterion	-4.275903
Sum squared resid	0.075124	Schwarz criterion	-4.171697
Log likelihood	217.7952	F-statistic	12.24502
Durbin-Watson stat	2.219000	Prob(F-statistic)	0.000001

Source: Author's estimation

Sunshine

Null Hypothesis: LNSSH has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.158855	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNSSH)
Method: Least Squares
Date: 04/26/13 Time: 03:15
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNSSH(-1)	-0.557163	0.090465	-6.158855	0.0000
D(LNSSH(-1))	0.251032	0.096988	2.588263	0.0111
C	0.933166	0.159605	5.846736	0.0000
@TREND(2004M07)	-0.001062	0.001017	-1.044598	0.2988

R-squared	0.283759	Mean dependent var	0.009400
Adjusted R-squared	0.261376	S.D. dependent var	0.338435
S.E. of regression	0.290862	Akaike info criterion	0.407243
Sum squared resid	8.121670	Schwarz criterion	0.511449
Log likelihood	-16.36213	F-statistic	12.67769
Durbin-Watson stat	2.163401	Prob(F-statistic)	0.000000

Source: Author's estimation

Precipitation

Null Hypothesis: LNPREP has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.381865	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNPREP)
Method: Least Squares
Date: 04/26/13 Time: 03:17
Sample (adjusted): 2004M09 2012M12
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNPREP(-1)	-0.728554	0.114160	-6.381865	0.0000
D(LNPREP(-1))	0.136457	0.100719	1.354834	0.1787
C	3.131568	0.548736	5.706881	0.0000
@TREND(2004M07)	0.000656	0.004045	0.162258	0.8714

R-squared	0.333677	Mean dependent var	-0.006329
Adjusted R-squared	0.312854	S.D. dependent var	1.408320
S.E. of regression	1.167416	Akaike info criterion	3.186641
Sum squared resid	130.8346	Schwarz criterion	3.290848
Log likelihood	-155.3321	F-statistic	16.02473
Durbin-Watson stat	2.025504	Prob(F-statistic)	0.000000

Source: Authors estimation

APPENDIX "A2"

Correlation Matrix

VARIABLES	DLNP	DLNURB	LNPREP	LNPS	LNSSH	LNTEMPT	DLNY
DLNP	1.000000	-0.033133	0.035629	-0.038530	-0.008468	-0.028705	-0.042614
DLNURB	-0.033133	1.000000	-0.299935	0.057431	0.106435	0.102559	0.537030
LNPREP	0.035629	-0.299935	1.000000	0.006531	-0.095071	-0.042372	-0.322956
LNPS	-0.038530	0.057431	0.006531	1.000000	-0.090646	0.156021	-0.022564
LNSSH	-0.008468	0.106435	-0.095071	-0.090646	1.000000	0.795540	0.147032
LNTEMPT	-0.028705	0.102559	-0.042372	0.156021	0.795540	1.000000	0.032220
DLNY	-0.042614	0.537030	-0.322956	-0.022564	0.147032	0.032220	1.000000

Source: Authors estimation

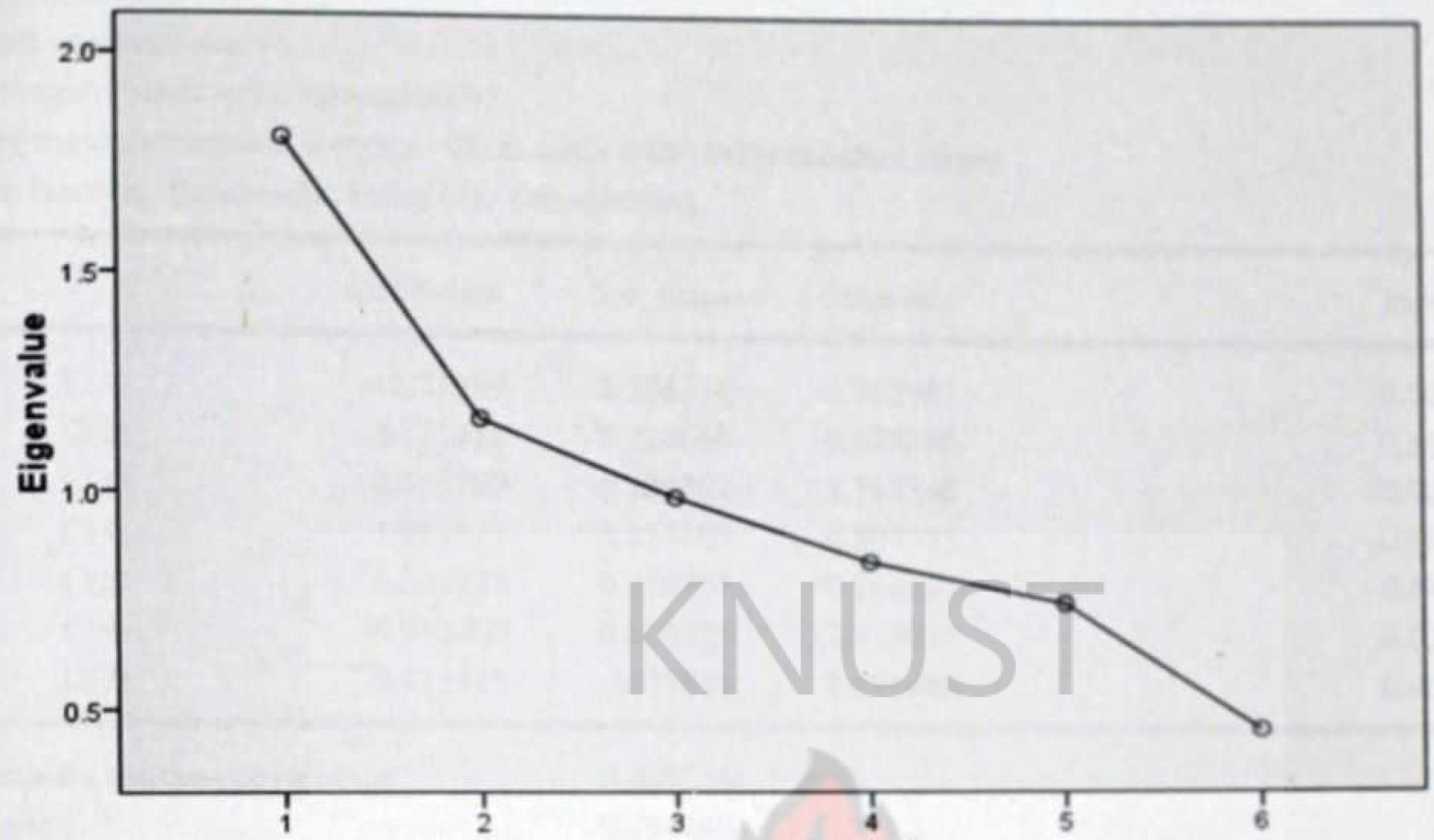
Component Analysis

Total Variance Explained

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.808	30.134	30.134	1.788	29.807	29.807
2	1.166	19.437	49.572	1.006	16.774	46.581
3	.987	16.449	66.020	1.006	16.773	63.354
4	.840	13.997	80.018	1.000	16.664	80.018
5	.745	12.419	92.437			
6	.454	7.563	100.000			

Extraction Method: Principal Component Analysis.

Scree Plot



Component Number

Rotated Component Matrix[a]

	Component			
	1	2	3	4
dlnP	-.032	-.020	-.014	.999
dlny	.831	-.033	.001	-.014
lnps	-.002	.994	.075	-.020
dlnurb	.810	.095	.109	.013
lntempt	.035	.076	.994	-.014
lnprep	-.662	.048	.037	.041

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

APPENDIX "B1"

System: ORIGINAL MODEL
Estimation Method: Generalized Method of Moments
Sample: 2005M02 2012M12
Included observations: 95
Total system (balanced) observations 95
Identity matrix estimation weights - 2SLS coefs with GMM standard errors
Kernel: Bartlett, Bandwidth: Fixed (3), Prewhitening

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-12.71489	2.206314	-5.762957	0.0000
C(2)	-0.131488	0.224654	-0.585290	0.5599
C(3)	0.350700	0.129202	2.714348	0.0080
C(4)	1.237577	0.213105	5.807353	0.0000
C(5)	0.023524	0.116704	0.201572	0.8407
C(6)	-0.012800	0.005926	-2.159851	0.0335
C(7)	0.623435	0.071688	8.696486	0.0000

Determinant residual covariance	0.007211
J-statistic	0.194480

Equation: LNREC=C(1)+C(2)*DLNP+C(3)*DLNY+C(4)*LNPS+C(5)
*LNTEMPT+C(6)*LNPREP+C(7)*LNREC(-1)
Instruments: LNREC(-2) LNREC(-3) LNREC(-4) LNREC(-5) LNREC(-6)
LNREC(-7) LNTEMPT(-1) LNTEMPT(-2) LNTEMPT(-3) LNTEMPT(
-4) LNTEMPT(-5) LNTEMPT(-6) DLNP(-1) DLNP(-2) DLNP(-3)
DLNP(-4) DLNP(-5) DLNP(-6) DLNPS(-1) DLNPS(-2) DLNPS(-3)
DLNPS(-4) DLNPS(-5) DLNPS(-6) LNPREP(-1) LNPREP(-2)
LNPREP(-3) LNPREP(-4) LNPREP(-5) LNPREP(-6) C
Observations: 95

R-squared	0.814562	Mean dependent var	16.73183
Adjusted R-squared	0.801919	S.D. dependent var	0.198242
S.E. of regression	0.088230	Sum squared resid	0.685045
Durbin-Watson stat	2.305465		

Source: Author's estimation

Test of over-identifying restriction

Number of parameters (K) = 7
Number of observations = 95

Number of moments (L) = 31
degrees of freedom (L – K) = 24

H_0: the model is "valid"
H_1: the model is not "valid"
J stats = number of observation multiplied by J statistics = 95x0.194480= 18.4756
Distribute chi squared: 5%, L-K (24) = 36.4151
J stats (18.4756) is less than X^2(18.4756) fail to reject null hypothesis

APPENDIX "B2"

SEASONAL VARIATION AND INTERACTION

System: SEASONAL VARIATION
Estimation Method: Generalized Method of Moments
Sample: 2004M11 2012M12
Included observations: 98
Total system (balanced) observations 98
Identity matrix estimation weights - 2SLS coefs with GMM standard errors
Kernel: Bartlett, Bandwidth: Fixed (3), Prewhitening

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-2.693419	2.704205	-0.996011	0.3219
C(2)	18.89610	6.078167	3.108848	0.0025
C(3)	-0.275085	0.369883	-0.743707	0.4590
C(4)	-3.663892	1.621538	-2.259516	0.0263
C(5)	-0.006280	0.031933	-0.196663	0.8445
C(6)	0.030881	0.047999	0.643362	0.5216
C(7)	-0.408042	0.391939	-1.041086	0.3006
C(8)	1.216730	0.169863	7.163026	0.0000

Determinant residual covariance	0.017980
J-statistic	0.051518

Equation: LNREC=C(1)+C(2)*DS+C(3)*LNTEMPT+C(4)*LNTEMPT*DS +C(5)*LNPREP+C(6)*LNPREP*DS+C(7)*LNREC(-1)*DS+C(8) *LNREC(-1)
Instruments: LNREC(-2) LNREC(-3) LNREC(-4) DLNTEMPT(-1) DLNTEMPT(-2) DLNTEMPT(-3) DLNPREP(-1) DLNPREP(-2) DLNPREP(-3) DLNPS(-1) DLNPS(-2) DLNPS(-3) DLNP(-1) DLNP(-2) DLNP(-3) C
Observations: 98

R-squared	0.556365	Mean dependent var	16.72290
Adjusted R-squared	0.521861	S.D. dependent var	0.202352
S.E. of regression	0.139922	Sum squared resid	1.762024
Durbin-Watson stat	1.952729		

Source: Author's estimation

Test of over-identifying restriction

Number of parameters (K) = 8
Number of observations = 98
Number of moments (L) = 16
degrees of freedom (L – K) = 8
H_0: the model is "valid"
H_1: the model is not "valid"
J stats = number of observation multiplied by J statistics = 98x0.051518 =
Distribute chi squared: 5%, L-K (8) =
J stats (5.048764)is less than X^2 (15.5073) fail to reject null hypothesis

APPENDIX "C"

JOHANSEN TESTS FOR THE NUMBER OF COINTEGRATING RELATIONSHIPS

Included observations: 96 after adjustments
Trend assumption: Linear deterministic trend
Series: DLNP DLNDY
Lags interval (in first differences): 1 to 4
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.240066	46.59167	15.49471	0.0000
At most 1 *	0.190069	20.23744	3.841466	0.0000

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.240066	26.35423	14.26460	0.0004
At most 1 *	0.190069	20.23744	3.841466	0.0000

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values
Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

DLNP	DLNDY
-0.112439	35.87044
47.84585	2.935969

Unrestricted Adjustment Coefficients (alpha):

D(DLNP)	-0.000752	-0.024181
D(DLNDY)	-0.039942	0.002722

1 Cointegrating Equation(s): Log likelihood 258.8344

Normalized cointegrating coefficients (standard error in parentheses)

DLNP	DLNDY
1.000000	-319.0204
	(61.2174)

Adjustment coefficients (standard error in parentheses)

D(DLNP)	8.45E-05
	(0.00067)
D(DLNDY)	0.004491
	(0.00086)

APPENDIX "D"

RESEARCH DATA (TIME SERIES)

RESIDENTIAL ELECTRICITY CONSUMPTION (kWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		14964394	18981974	18902386	19753527	18489021	21069315	20075209	23469399
FEB		12742987	18615701	17774116	18920393	18235286	19087606	20552804	22210255
MAR		12979390	16726973	17538492	19019454	17173743	20025901	21574315	24054514
APR		12884523	16679093	15433245	18151342	16552985	21680454	20391433	24833359
MAY		12512450	18304951	14912011	17430317	18067333	24055464	23517145	24377025
JUN		13455048	16981169	15394622	18008375	17489200	17550378	23323943	26301077
JUL	13910825	13581457	17480286	14037754	13067412	17548529	16446295	21994955	24906211
AUG	13894545	12458498	17520159	16405791	17203502	16588235	20135576	21047705	24778638
SEP	13358216	13960457	16844309	15837845	16169812	17569688	21551780	24093897	25635960
OCT	12455221	12664823	15510400	18594459	16533628	17719974	20491434	22903349	24388634
NOV	11991370	14800702	18604162	18284590	17252935	18172285	19918137	20483961	28641495
DEC	14633379	12958406	16333743	18350687	18095185	19719077	20831370	24620433	30416190

Source: Ashanti-west regional office.

AVERAGE END USER RESIDENTIAL ELECTRICITY TARIFF (Ghc/kWh)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.182275748	0.180863787
FEB		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.182275748	0.180863787
MAR		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
APR		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
MAY		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
JUN		0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
JUL	0.078386023	0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
AUG	0.078386023	0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
SEPT	0.078386023	0.078386023	0.095747508	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
OCT	0.078386023	0.078386023	0.095747508	0.095747508	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
NOV	0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787
DEC	0.078386023	0.078386023	0.095747508	0.138612957	0.138612957	0.138612957	0.138612957	0.180863787	0.180863787

Note: these are weighted averages computed by the Author from the figures received from Energy Commission report. Below are the original and the whole categories of the tariffs charge for electricity use.

Table 3. 4: Electricity Tariff (October 2003 – March 2011)

Tariff Category	Effective Date							
	October 2003	February 2004	November 2004	February 2005	September 2006	November 2007	June 2010	March 2011
Residential								
0-50 (Ghc/kWh)	1.908*	1.908*	1.908*	1.908*	0.070	0.095	0.095	0.095
51-150 (Ghc/kWh)	0.058	0.058	0.058	0.058	0.070	0.120	0.161	0.160
151-300 (Ghc/kWh)	0.058	0.058	0.058	0.058	0.070	0.120	0.161	0.160
301-600 (Ghc/kWh)	0.102	0.102	0.102	0.102	0.120	0.160	0.210	0.208
601+ (Ghc/kWh)	0.102	0.102	0.102	0.102	0.140	0.195	0.230	0.230
ServiceCharge (Ghc/month)					0.500	0.500	1.500	1.500
Non-Residential								
0-300 (Ghc/kWh)	0.085	0.085	0.085	0.085	0.102	0.140	0.237	0.229
301-600 (Ghc/kWh)	0.104	0.104	0.104	0.085	0.125	0.170	0.270	0.244
600+ (Ghc/kWh)	0.104	0.104	0.104	0.104	0.145	0.195	0.413	0.385
ServiceCharge (Ghc/month)	2.120	2.120	2.120	2.120	2.500	2.500	2.500	2.500
SLT-LV								
Maximum Demand(Ghc/kVA/month	14.310	14.310	14.310	14.310		1.000	14.000	14.000
Energy Charge (Ghc/kWh)	0.040	0.040	0.040	0.040	0.120	0.160	0.260	0.239
ServiceCharge (Ghc/month)	6.360	6.360	6.360	6.360	7.500	7.500	10.000	10.000
SLT-MV								
Maximum Demand(Ghc/kVA/month	9.752	9.752	9.752	9.752	9.000	9.000	12.000	12.000
Energy Charge (Ghc/kWh)	0.038	0.038	0.038	0.038	0.050	0.091	0.198	0.185
ServiceCharge (Ghc/month)	6.360	6.360	6.360	6.360	12.500	12.500	14.000	14.000
SLT-HV								
Maximum Demand(Ghc/kVA/month	8.904	8.904	8.904	8.904	9.000	9.000	12.000	12.000
Energy Charge (Ghc/kWh)	0.037	0.037	0.037	0.037	0.045	0.081	0.173	0.170
ServiceCharge (Ghc/month)	6.360	6.360	6.360	6.360	12.500	12.500	14.000	14.000
SLT-MINES								
Maximum Demand(Ghc/kVA/month	-	-	-	-	-	9.000	14.000	14.000
Energy Charge (Ghc/kWh)	-	-	-	-	-	0.081	0.270	0.270
ServiceCharge (Ghc/month)	-	-	-	-	-	12.500	15.000	14.000

*Exclusive Block Charge

Source: Energy Commission, national energy statistics (2000 – 2010) report.

POPULATION

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
FEB		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
MAR		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
APR		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
MAY		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
JUN		4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
JUL	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
AUG	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
SEPT	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
OCT	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
NOV	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005
DEC	4080743	4197875	4331518	4459435	4589377	4720732	4780380	4909450	5042005

Source: Ghana statistical service, Ashanti region office

Note: Urbanisation figures are generated by applying 51.3% and 60.6% (urban share) to 2004 – 2009 and 2010 – 2012 population figures respectively.

GROSS NATIONAL DISPOSABLE INCOME PER CAPITA

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
FEB		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
MAR		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
APR		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
MAY		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
JUN		538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
JUL	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
AUG	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
SEPT	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
OCT	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
NOV	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67
DEC	461.41	538.15	944.19	1114	1408.89	1669.94	2006.69	2539.35	2936.67

Source: Ghana statistical service, national accounts statistics, 2012 report.

MEAN MONTHLY TEMPERATURE (CELSIUS)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		25.85	27.35	26	26.2	27.6	28.25	26.85	27.25
FEB		28.65	27.85	27.55	28.4	28.4	29.3	27.75	27.9
MAR		28	27.5	27.55	28.4	28.3	28.8	27.7	28.25
APR		28.2	28.35	27.5	27.75	27.8	28.6	28.15	27.65
MAY		27.1	27.1	26.85	27.45	27.6	27.85	27.85	27.2
JUN		25.5	26.75	26.8	26.55	26.45	26.6	26.4	25.7
JUL	24.8	24.35	25.65	25.8	25.8	25.3	25.65	25.3	25.05
AUG	24.5	23.9	25.15	25.5	25.5	24.95	25.75	25.15	24.8
SEPT	25.75	26	25.45	25.95	26.05	25.8	26.1	25.85	26.15
OCT	26.35	26.65	26.45	26.65	27.05	26.5	27.1	26.15	26.8
NOV	27.05	27.4	27.2	27.4	28.1	27.1	27.25	27.85	27.75
DEC	27.05	27.05	26.8	27.45	27.75	27.9	27.75	27.55	27.25

Source: Ghana meteorological services Department.

MEAN MONTHLY RAINFALL (mm)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		12.5	111.1	0.2	0.0	0.0	14.7	65.8	48.1
FEB		48.9	98.4	16.4	53.7	131.4	52.7	136.4	74.9
MAR		84.2	112.8	56.2	97.4	110.6	52.6	230.5	92.0
APR		146.4	66.9	310.9	132.0	139.8	77.3	122.8	119.3
MAY		272.1	187.3	164.2	239.6	164.6	108.9	100.1	270.8
JUN		121.3	145.4	176.0	286.7	376.7	225.8	244.4	379.8
JUL	229.4	18.3	66.7	192.9	131.1	273.5	83.3	178.6	93.8
AUG	115	36.7	65.2	117.7	192.6	17.6	113.1	60.6	3.4
SEP	243.5	174.1	111.4	534.5	170.7	99.3	165.9	155.6	82.5
OCT	232.4	236.9	158.4	153.9	75.1	138.6	178.0	188.1	225.6
NOV	43.5	49.8	32.5	51.7	18.3	45.2	80.9	38.9	70.6
DEC	76.5	29.8	3.7	19.8	54.8	33.4	38.3	0	60.6

Source: Ghana meteorological services Department.

MEAN DAILY DURATION OF SUNSHINE (HOURS)

	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN		6.2	6.3	2.7	7.1	9.5	5.9	5.1	5.9
FEB		6.2	6.5	5.9	4.5	5.6	8.6	6.9	4.6
MAR		6.7	5.1	6.0	6.1	5.6	7.2	6.5	4.6
APR		6.7	6.7	6.4	5.5	5.8	6.1	6.6	5.7
MAY		7.0	6.6	5.9	5.2	6.6	5.9	5.7	4.2
JUN		3.7	5.9	5.0	4.4	4.6	4.0	4.2	3.7
JUL	2.5	2.6	3.8	3.8	3.3	2.9	4.1	3.1	2.7
AUG	2.5	1.9	3.2	2.8	3.4	1.4	3.2	2.0	2.6
SEP	4.3	3.8	3.1	3.3	3.3	3.1	3.3	2.8	2.6
OCT	6.1	6.9	5.7	5.9	4.1	3.3	5.2	5.5	5.5
NOV	6.8	7.1	7.2	6.7	6.0	4.6	3.4	7.5	7.0
DEC	5.5	6.0	5.9	5.8	5.0	4.8	7.2	6.4	6.4

Source: Ghana meteorological services Department.