A COMPARATIVE ANALYSIS OF COMMERCIAL ENERGY DEMAND IN NIGERIA AND CAMEROON

(1971-2010)

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UNIVERSITY OF LAGOS

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A COMPARATIVE ANALYSIS OF COMMERCIAL ENERGY DEMAND IN NIGERIA AND CAMEROON

(1971-2010)

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SUPERVISORS' ATTESTATION

This is to certify that this topic "A Comparative Analysis of Commercial Energy Demand in Nigeria and Cameroon (1971 – 2010)" submitted to the School of Postgraduate Studies University of Lagos, for the award of the degree of Doctor of Philosophy in Economics, is the work of Mr. Balouga, Jean.

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CERTIFICATION

This is to certify that the Thesis:

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Submitted to the School of Postgraduate Studies
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For the award of the degree of
DOCTOR OF PHILOSOPHY (Ph.D.)
is a record of original research carried out

by

BALOUGA, JEAN
In the Department of Economics

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DEDICATION

I dedicate this research effort to the Almighty God, the creator of the heavens and the earth and all that is in them, without whom there is nothing. Lord, you have made it possible. To you be all honour and glory now and forever.

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Abstract

Given energy security and climate change challenges occasioned by increased hydrocarbon consumption, and increased trade between Nigeria and Cameroon, a holistic study of commercial energy (petrol, diesel, kerosene) demand in both countries is undertaken. Our main objective is to find out which of the two economies has performed better, in terms of energy intensity (i.e. which is less energy intensive) between 1971 and 2010. For this, five specific objectives were addressed, namely to: (a) compare the structure of commercial energy demand in Cameroon and Nigeria between 1971 and 2010; (b) compute the short-run price and income elasticities of demand for commercial energy in Cameroon and Nigeria during the period under investigation;(c) compare the mean energy intensity in Cameroon and Nigeria during the period under investigation; (d) identify the determinants of energy intensity in Cameroon and Nigeria, during the period under review, and (e) ascertain the direction of causality among commercial energy intensity, technology and energy price in Cameroon and Nigeria during the period under consideration. Most of the data used were obtained from the International Energy Agency (IEA) and the World Bank. Additional data were extracted from the Central Bank of Nigeria (CBN) Statistical Bulletins and website and the Petroleum Products Pricing and Regulatory Agency (PPPRA) for Nigeria and the Bureau National de la Statistique website for Cameroon. Simple descriptive statistics were used to determine the structure of commercial energy consumption in both countries. The transcendental logarithmic model was used to estimate long-run income and price elasticities while short-run elasticities were computed using the traditional, neoclassical, method; and the reduced demand model was used for the analysis of the energy intensity of both countries. Granger Causality tests were also carried out. Findings are that (i) Cameroon and Nigeria have similar pattern of energy consumption (ii) demand for commercial energy is price and income inelastic in the short run in Cameroon but price and income elastic in the short run in Nigeria; and price and income inelastic in the long run in Cameroon and Nigeria (iii) the ratio of commercial energy intensity of Cameroon relative to Nigeria is 1:1.57, (iv) whereas neither Cameroon nor Nigeria has critical energy intensity challenges yet, capital-labour ratio largely determines energy intensity in Cameroon while capital-labour ratio, investment-capital ratio and energy price largely determine energy intensity in Nigeria , and (v) a bi-directional Granger Causality relationship exists in Nigeria between energy consumption and economic growth (proxy GDP). However, only a unilateral Granger Causality relationship, GDP Granger causes total commercial fuel consumption, exists between these two variables in Cameroon within the same period. Moreover, commercial energy pricing policy and commercial energy consumption (demand) appear disconnected in both countries. However, energy consumption policy in Cameroon is independent of that of Nigeria and same goes for environmental policy. Moreover, whereas energy pricing policy takes into account environmental considerations in Nigeria, there seems to be a complete divorce between commercial energy pricing, commercial energy consumption and environmental policies in Cameroon. Finally the quantum of petroleum products smuggled from Nigeria into Cameroon is insignificant and Nigeria's environmental challenges resulting from commercial energy consumption are not a threat to Cameroon's environment. Total eradication of energy poverty, reduction in income inequality, investment in infrastructure, supply of qualitative and functional education for all, elimination of barriers to economic competitiveness, job creation, good governance, among others, are recommended to both countries.

Key words: Economic Development, Energy Consumption, Energy Intensity, Energy Demand, Commercial Energy

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Energy has been defined in many ways. According to Banks (2000) energy can be defined as anything that makes it possible to do work, that is, bring about movement against resistance. For Bhattacharyya (2011), energy is the ability to do work or to produce heat. Energy takes many forms, and one of its most interesting characteristics is that all aspects of motion, all physical processes, involve to one degree or another, the conversion of energy from one state to the other (Banks, 2000). Energy is the lifeblood of every economy as well. It provides light, heat and air-conditioning for homes, schools and businesses. It is needed to power office equipment and high-technological production facilities, to transport both people and goods, and to support all aspects of the industry. Energy is also a critical ingredient in many other goods consumed, ranging from medicines and toys to food appliances and automobiles. It, therefore, appears that energy is an essential ingredient of socio-economic growth and an important determinant of the quality of life in human settlements.

Growth in energy demand for transportation and for residential, commercial and industrial uses- a characteristic of economic growth- is reflective of the changing composition of the consumer bundle. Energy is required for the utilization of durable goods such as household appliances and motor vehicles. As per capita incomes rise, consumers are more able to afford particular items such as air-conditioners, microwave ovens, refrigerators and cars. Furthermore, to the extent that services such as heating, refrigeration, and personal transport yield increasing utility to the representative consumer, utilization will increase thereby further increasing energy demand. As per capita income increases there will be periods of large increases in the aggregate vehicle stock followed by incrementally smaller increases (Medlock & Soligo, 1998). As utilization of the vehicle stock begins to increase so must demand for fuel. An obvious pre-requisite for satisfying the increased demand for transportation services is the development of sufficient transport infrastructure. Government has the incentive to do this as per capita gross domestic product (GDP) increases (Medlock &Soligo, 1998).

Between 1961 and 1977, agriculture was the mainstay of the economy of Cameroon. Agriculture accounted for 34 percent of the gross domestic product (GDP), 85 percent of exports and employed about 80 percent of the labour force. Petroleum production took the lead in Cameroon between 1978 and 1985. By the mid 1970's the share of petroleum was about 18 percent of Cameroon's GDP. Cameroon's economy collapsed in the mid 80's with devastating effects. GDP growth rate fell from 8 percent per annum to less than -5% in 2002 (Amin, 2002). This was partly because of the sharp fall in world oil and commodity prices and partly because of poor domestic economic management (Nkonlak, 2008). The combined effect of these phenomena is that today Cameroon, with about half of her 17 million people living on less than two United States (U.S.) dollars a day, is ranked among the poor countries of the world. In fact the World Bank (2005) classified Cameroon under "poor and heavily indebted countries" categorization.

Cameroon produces about 70,000 barrels of crude oil per day (bpd), associated gas and hydro-power as primary sources of energy. Whereas crude oil and hydro-power are put to profitable use, aside from re-injection there is little or no industrial use of gas. Gas is therefore seen as a waste product. This is a flagrant waste of an asset that otherwise could have been used by local consumers, by the industry and/or exported. Furthermore, the annual consumption of gas per capita per annum in Cameroon is very low: 1.9 kilograms compared with 2.1 kg for Ghana, 0.2 kg for Nigeria, and 3.5 kg for West Africa (NOG). This incredibly low gas consumption is largely attributable to the fact that the government has not been forthcoming in the area of sound policy formulation aimed at providing an enabling environment to encourage liquefied petroleum gas (LPG) utilization by the public. Many low-income urban and most rural households are so poor that economic conditions dictate that the bulk of the households will be dependent on wood for the foreseeable future and rural households in particular have such limited incomes that they cannot possibly opt out of this cycle to utilize commercial energy (petrol, diesel, kerosene).

Nigeria is a net importer of fuel products and a global leader in gas flaring, distributing 3,200 megawatts of electricity to 40 percent of about 170 million of her citizens through a superannuated transmission network (Adesanya, 2009). Nigeria is a valuable member of the Organization of Petroleum Exporting Countries (OPEC), who has to climb rapidly from a factor- to an efficiency-driven economy in less than 12 years before attempting transiting into an innovation-driven-economic class presently occupied by thirty-one nations including the G8 countries. The stage of economic development of advanced economies makes Nigeria a pedestrian economy yet to overcome political and executive meddlesomeness. Gaunt energy infrastructure remains a major impediment to growth in a country where one per cent of the population benefits from 80 percent of hydrocarbon revenue, 70 percent of inhabitants are below the thick poverty line (living on income below US$1 a day), fuel subsidy consumed N 74 billion or 1.42 percent of GDP in 2003 rising to N450 billion or 3 percent of GDP at the end of 2007, gross fixed investment standing at 24.9 percent of GDP (2007), a public debt representing 14.5 percent of GDP and a current account balance of US$1.205 billion (2007). Nigeria is more vulnerable to oil price increases as the terms of trade effects of the joint food and energy price hikes since January 2007 are beyond 10 percent of GDP thus limiting macroeconomic flexibility. The country’s status as the eleventh largest producer of crude oil in the world, number one in

Africa and a valuable member of the OPEC, has not translated into an emerging and efficiency-driven economy, a prerequisite for a higher quality of living (Adesanya, 2009).

1.2 Statement of the Problem

The fact that energy is a critical factor input was largely overlooked during the first 70 years of the 20th century, because in the industrial world most politicians, civil servants, and opinion leaders were inclined to believe that virtually an infinite supply of reasonably-priced energy would continue to go in the manner to which many of their constituents had become accustomed (Banks, 2000).

The sharp increase in energy demand observed at the beginning of this millennium was mostly attributed to the rapid growth of China, India and other emerging economies. This was a stark reminder of how crucial energy is as less developed economies – often based on agriculture – gradually become industrial economies. During this process, the energy intensity - which the United Nations Environment Project (UNEP, 2007) defines as the cost at which energy resources are converted into GDP- of each additional unit of output (i.e. the marginal energy intensity of output) increases. This process of development, the climb up of the 'energy ladder', is familiar to the energy literature: industrialized countries have followed similar paths in the process of their development.

Energy intensity has long been of interest to energy researchers (Atkinson & Manning, (1995); Bjorner & Jensens, (2002); Bernstein *et al*., (2003); Sue Wing & Eckaus, (2004); Gellings et al,. (2006); Huntington & Smith, (2011); Imhof (2011); Takahashi & Asano, 2011). Understanding the drivers of energy consumption and energy intensity has been a major focus of research activity for the past thirty years and one approach commonly used is a decomposition methodology that allows one to separate structural shifts in the economy from more fundamental improvements in use of energy. This decomposition has contributed to the understanding of the extent to which changes in economic activities (the activity effect) have reduced the demand for energy as opposed to improvements in the use of energy (efficiency effect). While these indices (activity and efficiency effects) are useful for understanding trends in energy consumption as well as trends in economic activity that influence energy demand, we have limited understanding of the economic forces, namely price and income, that drive changes in these indices over time.

Observing the historical behaviour of developed economies reveals that, at the end of their climb on the energy ladder, countries stand on different rungs on the said ladder; in other words countries reach very different energy intensity levels. This is due to a number of factors. Some are predetermined by their geographical location, size, and climatic exposure, which all have a strong influence on energy intensity. But factors such as industrial structure, efficiency and mass mobility solutions are significant and are results of explicit economic and policy choices made by countries. Therefore, understanding the way in which energy demand has responded to economic growth and price variations in developing countries can provide some foresight on where these countries will reach by the end of their climb on the energy ladder. In addition, every economy needs to know the cost at which its energy resources are converted into GDP (UNEP, 2006) and compare of this cost with peers' cost. The comparison of this index between two contiguous countries like Cameroon and Nigeria is very relevant, particularly now that Nigeria is Cameroon's first trading partner (AfDB Group, 2013).

Existing empirical literature on the relationship between economic growth and energy demand addresses all of these issues for Organization for Economic Co-operation and Development (OECD) countries, most of them for specific developing regions (e.g. Asia, Latin America, The Middle East). Somehow there are fewer works that attempt to draw a broader picture of the experience of developing countries using advanced econometric tools (Bentham & Morani, 2009; Iwayemi et al. 2010). For example, there is the rise in concerns about global warming which requires a very long-term understanding of the implications of energy use. Moreover, there are growing concerns about future security of fuel supply and large capacity expansion needs worldwide, which is fueling a closer look at the energy infrastructure development either for replacing old and worn-out assets, or for meeting new demand.

Energy projects tend to be capital-intensive and often require long lead time. Medium-to-long-term analysis is, therefore, essential for energy-systems-related decisions, more so as mobilizing resources for energy projects is not always easy. Consequently, decision makers have to form a view about the future well in advance and plan for new projects and actions, as misjudgments can lead to costly spare capacities.

Also, with the arrival of competitive market segments in various energy industries, the focus has shifted to short-term analysis, covering hours or days, essentially for operational purposes. Therefore, countries need to analyze past trends to forecast the likely paths of energy demand growth in the short run as well as the long run (Bhattacharyya, 2011). The question now is: which of these two neighbouring countries and trading partners, Nigeria and Cameroon, is better at using commercial energy resources?

1.3 Objectives of the Study

The broad objective of this study is to analyze and compare the commercial energy demand of Cameroon and Nigeria between 1971 and 2010. In order to achieve this broad objective the following specific objectives are addressed. They are to

i. Compare the structure of commercial energy demand in Cameroon and Nigeria during the period under investigation.

ii. Compute the short-run and long-run price and income elasticities of demand for commercial energy in Cameroon and Nigeria between 1971 and 2010.

iii. Compare the mean energy intensity in Cameroon and Nigeria during the period under investigation.

iv. Identify the determinants of energy intensity in Cameroon and Nigeria, during the period under review, and

v. Ascertain the direction of causality among commercial energy intensity, technology and energy price in Cameroon and Nigeria during the period under review.

1.4 Research Questions

Based on the objectives of the study the following five research questions are asked:

i. Are the structure of commercial energy demand in Cameroon and Nigeria the same during the period under investigation?

ii. What are the short-run and long-run price and income elasticities of demand for commercial energy in Cameroon and Nigeria between 1971 and 2010?

iii. Are the mean energy intensities of Cameroon and Nigeria equal?

iv. What are the determinants of energy intensity in Cameroon and Nigeria during the period under review? and

v. What is the direction of causality among commercial energy intensity, technology and energy prices in Cameroon and Nigeria during the period under consideration?

Finding answers to these questions is the motivating force driving the study.

1.4.1 Research Hypotheses

The following null hypotheses result from the objectives stated above.

i. The structure of commercial energy demand in Nigeria is not significant in Cameroon and Nigeria during the period under review.
ii. Short-run and long-run price and income elasticities of demand for commercial energy are all equal to zero in Cameroon and Nigeria between 1971 and 2010.
iii. The mean energy intensity of Cameroon is equal to that of Nigeria between 1971 and 2010
iv. The determinants of energy intensity are all not significant in Cameroon and Nigeria during the period under review.
v. There is no Granger Causality among energy intensity, energy price and technology in Cameroon and Nigeria within the period under study.

1.5 Significance of the Study

There is relatively little prior work to which this study can be compared, as most studies on energy demand have focused on OECD countries; and probably because of data limitations, the relatively few studies on non-OECD countries' energy demand tend to concentrate on single sectors and/or single nations, are limited in scope and may end up with conflicting policy recommendations. So far, and to the best of our knowledge, we have not come across any comparative study on commercial energy demand between Nigeria and Cameroon.

Information gotten from a holistic study of a country's energy demand function (e.g. its energy demand structure, short- and long-run price and income elasticities, energy intensity and causality, etc.) helps in understanding such a country's economic structure, its level of development, and many aspects of that country's energy policy decision formulation and implementation processes**.** A comparative study of two neighbouring countries is the more useful: one country may learn energy efficiency and conservation lessons from the other. It is our belief that the ministries of national planning, finance, petroleum resources, environment, science and technology, other arms of government of both countries as well as researchers in energy policy will find this research work of immense benefit.

1.6 Scope and Delimitation of the Study

This research work attempts to uncover the links between demand for commercial energy (petrol, kerosene and diesel) and economic growth in Nigeria and Cameroon between 1971 and 2010 and then compare them. Petrol, diesel, kerosene, High Pour Fuel oil, Low Pour Fuel Oil, Lubricating Oil, Greases, Waxes and Base Oils are some of the refined products from crude petroleum, a non –renewable, conventional/unconventional hydrocarbon. Petrol, diesel, kerosene, High Pour Fuel oil and Low Pour Fuel Oil, are also classified under petroleum liquid fuels, secondary or commercial energy. In this research work, petrol, kerosene and diesel in particular are classified under final energy or end-use energy because they are not used primarily for the production of some other energy source/carrier (e.g. electricity). This work is limited to the analysis of structure, activity, intensity and causality on the one hand, and to the use of petrol, diesel and kerosene on the other hand.

1.6.1 Choice of time frame

There is no unique time period for which a utility function should be defined. However, there are restrictions upon the possible length of the period. The consumer usually derives utility from variety in his diet and diversification among the commodities he consumes. Therefore, the utility function must not be defined for a period so short that the desire for variety cannot be satisfied. On the other hand, tastes (the shape of the function) may change if it is defined for too long a period. Any intermediate period is satisfactory for the static theory of consumer behavior (Henderson & Quandt, 1980). In 1971, the Organization of Petroleum Exporting Countries (OPEC) opened negotiations with oil-producing companies on a 5-year pact and forced a price increase of 21 percent for Saudi Light, an increase in tax rate from 50 to 55 percent and an escalation of 2.5 percent in prices per year for inflation (Bhattacharyya, 2011). This was followed by the first oil price shock in 1972 which put an end to cheap oil prices, thereby signaling perhaps a permanent break from the past (Alhajji, 2005). The choice of year 2010 was arbitrary as we wanted a study covering a 40 – year period.

Cameroon and Nigeria are developing countries. According to de Lavergne (1994), developing countries share a number of economic and energy characteristics, some of which are (i) rapid population growth and low educational standards, (ii) high degree of central planning, (iii) regulated and constrained domestic markets, (iv) significant traditional agriculture and artisanal sectors, (v) narrowly specialized economic structures and production, (vi) constrained levels of capital and investment, and (vii) weak currencies, etc. Despite these similarities, there are sufficient differences among developing countries to argue against the use of a single multi-country model. These are (a) differences in the level of development, (b) geographical size, (c) degree of openness of the economy, (d) energy – importing or exporting status, (e) technological advancement, etc.

Cameroon and Nigeria are poor countries (Jhingan, 2005). They operate a public-led, mixed, economic system; share similar climatic conditions as they lie within the same latitudes, with their landmasses stretching from the Atlantic Ocean in the South to Lake Chad, in the North. The structure of their economies is practically the same, both countries export crude oil and are now members of the Extractive Industries Transparency Initiative (EITI); both are involved in economic reforms, and battle against decaying infrastructure. However, whereas Cameroon has never been under military rule since independence in 1960, the military were in power in Nigeria for about 28 years. Second, Nigeria produces about 2.3 million bpd against an average of 90, 000 bpd for Cameroon. Third, Nigeria's landmass is about twice the size of Cameroon. With the exception of military rule, time fixed effects and country fixed effects cancel out all other differences thereby making any comparing between Cameroon and Nigeria valid.

1.7 Plan of Study

This work is structured as follows: Chapter 1 is the Introduction. It presents an overview of the energy consumption-economic growth nexus, as well as objectives of, and justification for, the study. Chapter 2 discusses the socio-economic backgrounds of Cameroon and Nigeria. In Chapter 3, literature relevant to energy consumption, economic growth, technology, renewables, institutions and the role of government, is reviewed. It is followed by the theoretical framework. The methodology and models form the bulk of Chapter 4. Data Cameroon and Nigeria are presented and analyzed in chapter 5 and the Summary, Conclusion and Recommendations are contained in Chapter 6.

1.8 Operational Definition of terms

In this study energy demand and energy consumption are used interchangeably.

ACRONYMS

AC – Alternate Current

ADF – Augmented Dickey – Fuller

AfDB – Africa Development Bank

ARIMA – Autoregressive Integrated Moving Average

BP – British Petroleum

CBN – Central Bank of Nigeria

CDM – Clean Development Mechanism

CFA – Communauté Financière de l'Afrique

CGC – China Geo-Engineering Corporation

CGGC – China Gezhouba Group Corporation

CO2 – Carbon Dioxide

DC – Direct Current

DCs – Developed Countries

E.U. – European Union

EDF – Electricité de France

EGF – Energy-Growth Feedback

EI – Energy Intensity

EIA – Energy Information Administration

EITI – Extractive Industries Transparency Initiative

ET – Emissions Trading

E-Views – Electronic views

EWEC – Electronic Wave Energy Converter

EXIM – Export-Import

FEM Fixed Effect Method

FID – Final Investment Decision

FPSO - Floating Production Storage Offloading

GDP – Gross Domestic Product

GHG – Green House Gas

GTL – Gas to Liquids

HEV – Hybrid Electric Vehicle

HFO – High Fuel Oil

HIPC – Highly Indebted Poor Countries

IDA – International Development Association

IOC – International Oil Company

IRP – Integrated Resource Planning

JDZ – Joint Development Zone

JV – Joint Venture

Kgoe – kilograms of oil equivalent

LAP Lighting Africa Policy

LDCs – Less Developed Countries

LFO – Low Fuel oil

LIURP – Low-Income Usage Reduction Program

LPG – Liquid Petroleum Gas

MEEDE – Modèle d'Evaluation de la Demande de l'Energie

MEND – Movement for the Emancipation of the Niger Delta

MIGA – Multilateral Investment Guarantee Agency

MSMEs – Micro, Small and Medium Enterprises

MW – MegaWatt

NLNG – Nigerian Liquefied Natural Gas

NNPC – Nigerian National Petroleum Corporation

NOG – Nigeria’s Oil and Gas Monthly

NO_X – Nitrogen Oxides

OECD – Organization for Economic Cooperation and Development

OGJ – Oil and Gas Journal

OPEC – Organization of Petroleum Exporting Countries

OTA – Office of Technology Assessment

PETCO – Plastic Energy Technology Corporation

PGR – Population Growth Rate

PMM – Permanent Magnet Motor

PPMC – Petroleum Products Marketing Company

PPP – Purchasing Power Parity

PPPRA – Petroleum Products Pricing Regulatory Agency

PSC – Production Sharing Contract

PV – Photovoltaic

R&D – Research & Development

RELS – Recursive Least Squares

REM – Random Effect Method

REP- Renewable Energy Potential

SCDP – Société Camerounaise des Depôts Pétroliers

SNH – Société Nationale des Hydrocarbures

SONARA – Société Nationale de Raffinage

SONEL – Société Nationale d'Electricité

SO_X – Sulphur Oxides

SSA – Sub-Saharan Africa

TAM – Turn Around Maintenance

TFC – Total Fuel Consumption

TFP – Total Factor Product

Toe – Tons of oil equivalent

TPER – Total Primary Energy Requirement

TSGP – Trans-Saharan Gas Pipeline

U.S. – United States of America

UK – United Kingdom

UNDP – United Nations Development Program

UNEP- United Nations Environment Project

WAGP – West African Gas Pipeline

WEC – World Energy Council

CHAPTER TWO

SOCIO-ECONOMIC BACKGROUNDS OF CAMEROON AND NIGERIA

2.1. CAMEROON

Cameroon's economy has exhibited steady economic growth since the mid 1990's. However, the country saw a slight decline in real GDP growth after the completion of the Chad-Cameroon pipeline. In 2005, the real GDP growth rate was 2.6 percent. High energy prices have helped offset economic growth declines, but they have also increased inflationary pressures in Cameroon. In 2005, inflation was 2 percent. In May 2006, the International Monetary Fund (IMF) and the World Bank indicated that Cameroon had completed its obligations under the Enhanced Heavily Indebted Poor Countries (HIPC) Initiative. Cameroon will now receive more than $1 billion in bilateral debt relief and additional multilateral aid, which together, will provide a 50 percent reduction in the country's total external debt.

Cameroon has experienced a fairly steady decline in its domestic oil production over the past 20 years. The country is still a net oil exporter, but if new fields do not come online in the near future, Cameroon could become a net oil importer. Currently, Cameroon does not produce any natural gas, but the country has plans to develop its natural gas reserves for generating electricity in the future. Most of the electricity generated in Cameroon comes from hydroelectric power stations, though droughts (although not yet common) can often leave the country dealing with electricity shortages (IEA, 2007). According to the LAP Report (2011) the total energy consumption of Cameroon in 2008 was estimated at 6,027 kilotons of oil equivalent (ktoe) per year. Biomass was the predominant energy source, representing 77 percent (4,636 ktoe) of total energy consumption. Electricity (426 ktoe) and oil products (965 ktoe) represented seven percent and 16 percent, respectively. The consumption of hydrocarbons has declined over the last three decades. Cameroon consumes approximately 80,000 barrels of oil each day, down from 190,000 in the mid 1980s. Characteristics of the current energy situation Cameroon is a net energy exporter, but the present energy situation can be described as poor (REP Country Report, 2006).

2.1.1 Oil

As of January 2006, the *Oil and Gas Journal (OGJ)* estimated that Cameroon had proven oil reserves of 400 million barrels, with the majority of reserves located offshore in the Rio del Rey basin of the Niger Delta. Less significant reserve deposits are located in the Douala/Kribi-Campo basins off Cameroon's western coast, and onshore in the northern Logone-Birni basin.

The Cameroon government revised its petroleum laws to include financial incentives and tax breaks on exploration in both 1999 and 2002. Major players in Cameroon include ExxonMobil, ChevronTexaco, Petronas, TotalFinaElf, Shell, and Perenco.

It has already been said that over the past 20 years, Cameroon has experienced a fairly steady decline in its domestic oil production. Although the country has been well explored, Cameroon's state oil company, the Société Nationale des Hydrocarbures (SNH), believes that discovery and development of smaller fields is still possible. Renewed interest in oil investment has led to exploration in all three of Cameroon's major petroleum basins - Logone Bimi, Douala/Kribi-Campo and Rio del Rey. SNH, which Cameroon has committed to privatize, engages in exploration and production in conjunction with several foreign oil companies, the largest being Total. In 2005 Total brought its Bakingili discovery on stream. This international oil company (I0C) also conducted exploratory drilling in three fields.

In 2005, SNH awarded Total the first production sharing contract (PSC) in Cameroon's history for the Dissoni permit in the Rio del Rey basin. In 2006, Total announced that it struck oil after drilling its first well on the block. In 2007, Cameroon has plans to open a licensing round which will offer six oil blocks for bid in the Rio del Rey region. The blocks will be awarded under PSCs. In the medium term, Cameroon is expected to open a licensing round for the Bakassi

Peninsula, which Nigeria agreed to withdraw from in June 2006. Industry experts believe Bakassi acreage could contain significant amounts of oil reserves as it borders areas in the Gulf of Guinea that, in the past, have yielded numerous oil discoveries.

Cameroon's only refinery, operated by the Société Nationale de Raffinage (SONARA), is located in the port city of Limbe and has production capacity of 42,000 barrels per day (bpd). Cameroon has plans to invest $383 million in refinery upgrades. The upgrades should increase SONARA's capacity and allow the refinery to handle more of the country's heavy crude oil. Currently, most of Cameroon’s heavy crude oil is exported, while light oil processed in the refinery is imported from Nigeria and Equatorial Guinea. Cameroon has also upgraded its port facilities, which now allow tankers with capacity as large as 90,000 deadweight tons (Aframax) to access the refinery. Total, ExxonMobil; and ChevronTexaco market refined products in Cameroon. The petroleum products are distributed domestically by the Cameroon Petroleum Depot Company (SCDP) (EIA, 2007).

2.1.2 Natural Gas

According to Oil and Gas Journal (*OGJ),* Cameroon has 3.9 trillion cubic feet (Tcf) of proven natural gas reserves. The majority of the reserves are located in the Rio del Rey and Douala/Kribi-Campo basins. In 2006, Perenco signed a 25-year contract with SNH to develop the offshore Sanaga Sud natural gas fields. The Sanaga Sud natural gas fields are located in the Doualal/Kribi-Campo basin. Cameroon will use natural gas produced from the fields to generate power at the Kribi plant. Both Perenco and SNH will invest $50 million in the project. Previously, in 2005, Syntroleum Corporation had studied the feasibility of developing gas-to-liquids (GTL) at Sanaga. However, it now appears that power generation projects will preempt the GTL development. Currently, Cameroon utilizes natural gas to enhance oilfield performance and generate in-field electricity (EIA, 2007).

2.1.3 Electricity

In 2004, Cameroon had installed electricity generating capacity of 900 MW, of which 95 percent was hydroelectric and five percent was conventional thermal. Cameroon generated 3.92 billion-kilowatt-hours (Bkwh) of electricity in 2004, and consumed 3.65 Bkwh (EIA, 2007). Only 48 percent- less than half- of the total population has access to electricity yet most of this access is concentrated in the urban centers; 90 percent of urban households are electrified as compared to a mere 23 percent of rural households. Moreover, the high rate of access to electricity in urban areas masks several regional and socioeconomic disparities. 35 percent of poor urban households and 88 percent of poor rural households do not have access to electricity, which suggests that the poorest strata in both the urban and rural areas are the most disadvantaged groups (LAP Report, 2011).

2.1.3.1 Sector Organization

In 2001, US-based AES Corporation purchased a majority stake in Cameroon's state-run, Société Nationale d'Electricité (SONEL). Since then, AES-SONEL has managed Cameroon's power generation and distribution to around half a million people. Most of Cameroon's population does not have access to electricity, while those who do are often subject to brownouts, which ultimately forces AES-SONEL to implement load-shedding and power cuts to maintain electricity supplies. During 2003-2009, AES-SONEL plans to invest $500 million to improve Cameroon's electrical infrastructure. The completion of an 85-MW, oil-fired plant at Limbe, in August 2004, marked the first step in the electricity network improvements. AES-S0NEL has additional plans to build hydroelectric plants, as well as Cameroon's first natural gas-fired plant at Kribi, which will be supplied with natural gas from the Sanaga natural gas fields (EIA, 2007).

2.1.4 Hydroelectricity

Cameroon possesses the second greatest hydroelectric potential in Africa, after the Democratic Republic of Congo, with an estimated 20 gigawatts (GW). However, only five percent (1,000 megawatts, MW) of this potential is currently realized (LAP Report, 2011). Cameroon's two main hydroelectric stations, Edéa and Song-Loulou, are located on the Sanaga River, while the smaller Lagdo station is located near Garoua. In the future, successful development of Cameroon's hydroelectric potential could make the country a net electricity exporter. However, Cameroon's heavy reliance on hydroelectric power leaves its electricity sector extremely vulnerable to droughts. Cameroon relies on approximately 30 ageing diesel power stations as back-up facilities, the largest of which are located in Garoua (20 MW), Douala (15MW), and Yaoundé (11 MW) (EIA, 2007).

Cameroon continues to study the Lom Pangar Dam project. Construction on the dam has yet to occur as environmental impact studies are currently ongoing. The Wood Bank has voiced concern over the Lom Pangar project, especially since a reservoir created by the dam would submerge part of the Chad-Cameroon pipeline. AES-SONEL and Electricité de France (EDF) have also conducted studies concerning a Chad-Cameroon inter-connector project. Power would be transported from the Lagdo Hydroelectric plant to N'Djamena, in Chad (EIA, 2007).

According to the REP Country Report (2006) production of electricity is an open market in Cameroon. However, the distribution is not open. The state-owned company responsible for electricity production and distribution was privatised in 2001. The government sold 56% of the shares in a 20 year concession. Privatisation has not yet yielded the desired effects of increasing power production and expanding the grid. Private companies and organisations active in the field of smaller renewable energy (RE) systems criticise the energy policy: import taxes on equipment are high and bank loans are hard to get. Furthermore projects initiated by foreign organizations encounter difficulties with the management and maintenance in some regions. This leads to a negative attitude towards RE.

2.1.4.1 Present Renewable Energy status

Present RE use (including large hydro) is about 4% of the total primary energy. The RE % will be 18% when traditional biomass is excluded in the total primary energy use. Almost all the RE use is derived from medium and large hydro power. However, renewable energy policy is being prepared, with policy goals to increase the share of renewables in power and heat generation, and to involve private capital in the delivery of energy (REP Country Report, 2006).

According to the LAP Report on Cameroon (2011) several types of lighting products and methods are used in Cameroon. Examples include kerosene lamps, candles, car battery systems, photovoltaic (PV) systems, solar lanterns and lamps, and rechargeable and non-rechargeable LED lamps. Kerosene lamps are used for lighting by over two-thirds of the rural population and 10 percent of the urban population. Household consumption of kerosene is estimated at 1.9 liters per month in rural areas and 0.8 liters per month in urban areas. The primary factor affecting consumption, especially among the poor, is the high price of oil products, approximately 350 FCFA (US$0.7) per litre.

The near complete removal of kerosene subsidies in Cameroon has led to an 80 percent increase in its price, a decrease in its consumption as well as an increased access to electricity in some areas. Despite its high cost, households still use kerosene as back-up.

According to Bainkong (2013) the Cameroon government is embarking on a project to reduce energy consumption in public buildings, and another to distribute 9.6 million energy efficient lamps and 3.2 million solar lanterns to Cameroonian households. All of these will be financed in part by carbon credits. No doubt Cameroon is facing considerable energy challenges but ongoing projects and those still in the pipeline could in no distant future bail the country out of this energy deficit. The 216 MW Kribi Gas Fired Plant to go operational shortly, as well as the optimum functioning of the 100 MW Energy Thermal Plants in the country, could greatly solve the problem. Work on giant hydroelectricity dam projects in the country, notably Lom-Pangar, Memve'ele and Mekin, will intensify while negotiations to kick-start other projects, namely, Warak, Menchum, Katsina Ala as well as to rehabilitate the Lagdo dam will continue.

2.2 NIGERIA

The Nigerian economy is heavily dependent on the oil sector, which accounts for 95 percent of the country's total export revenues. In 2004, Nigeria's energy consumption mix was dominated by oil (58 percent), followed by natural gas (34 percent) and hydroelectricity (8 percent). Coal, nuclear and other renewables currently play a little part in the country's energy consumption mix. Between 1984 and 2004 the share of oil in Nigeria's energy mix has decreased from 77 percent to 58 percent. Natural gas consumption increased from 18 percent to 34 percent. Hydroelectricity has seen a slight increase as well from 5 percent to 8 percent (IEA, 2007).

2.2.1 Oil

According to Oil and Gas Journal (OGJ), Nigeria had 36.2 billion barrels of proven oil reserves as of January 2007. The Nigerian government plans to expand its proven reserves to 40 billion barrels by 2010. The majority of reserves are found along the country's River Niger southern Nigeria and offshore in the Bight of Benin, Gulf of Guinea and Bight of Bonny. Nigeria has total production capacity (total potential production capacity if all oil currently shut-in came back online) of three million bpd including two million bpd onshore and one million bpd offshore.

2.2.1.1 Recent Developments

The big shift from palm oil to crude oil, from 1958, for purposes of revenue derivation, brought consequential challenges and opportunities, including resource control. Understandably, the vision and mission of the Movement for the Emancipation of the Niger Delta (MEND) as well as burning issues which inflamed passions took centre stage (Tamuno, 2011). Since December 2005, Nigeria has experienced increased pipeline vandalism, kidnappings, and militant takeover of oil facilities in the Niger Delta. As of April 2007, an estimated 587,000 bpd of crude production is shut-in. The majority of shut-in production is located onshore in the Niger Delta, with the exception of the offshore 115,000 bpd EA Platform. Since December 2005, Nigeria has lost an estimated US16 billion dollars in export revenues due to shut-in oil production. Shell has incurred the majority of shut-in oil production (477,000 bpd), followed by Chevron (70,000 bpd) and Agip (40,000 bpd). Militant attacks on oil infrastructure have also crippled Nigeria's domestic refining capabilities. In February 2006, militant attacks in the western delta region forced the Warri (125,000 bpd) and Kaduna (110,000 bpd) refineries to shutdown due to a lack of feedstocks. In December 2006, operators shut down Nigeria's two Port Harcourt refineries for two months due to technical problems. The Niger Delta rebel group, MEND and other militia organizations in search of monetary compensation and/or political leverage are the ones behind the attacks. In addition to abductions, thousands of foreign workers and their families have left the Niger Delta due to continued hostilities. MEND has stipulated numerous conditions to the Nigerian government that it wants met. Chief among the conditions is greater revenue sharing of the oil wealth, increased local control of oil property, the release of tribal prisoners, and transparency of government budgets. IOCs are not expected to repair damaged oil infrastructure until after the elections are over (EIA, 2007).

2.2.1.2 Production

Nigeria is largest oil producer in Africa, the eleventh largest producer of crude oil in the world and a member of the Organization of Petroleum Exporting Countries (OPEC). In 2006, total Nigerian oil production, including condensates, natural gas, liquids and refinery gain, averaged 2.45 million bpd (of which 2.28 million bpd, was crude oil). If Nigeria could bring back online all oil currently shut-in, Energy Information Administration (EIA) estimates that Nigeria could reach crude oil production capacity of three million bpd. With the help of new projects coming on stream, the Nigerian government hopes to increase oil production capacity to four million bpd by 2015.

Despite the recent attacks on Shell's oil facilities, the company's deepwater Bonga field began producing oil at the end 2005, reaching production of 225,000 bpd in April 2006. Bonga is estimated to hold recoverable oil reserves of 600 million barrels. Oil from the field is stored in a floating production, storage and offloading (FPSO) unit, with capacity of two million barrels. In August 2008, Shell plans to bring online its Gbaran/Ubie field (220,000 bpd), located offshore of the eastern delta.

ExxonMobil produces around 750,000 bpd of oil in Nigeria. The company plans to invest $11 billion in the country's oil sector through 2011, with the hope of increasing production to1.2 million bpd. In March 2006, ExxonMobil brought online its Erha development, which is located offshore of the western delta. Erha reached peak production of 200,000 bpd in July 2006. Oil from Erha is stored in a FPSO, with capacity of 2.2 million barrels of oil. Very Large Crude Carriers (VLCC) capable of holding up to 300,000 deadweight tons are used for exporting the oil from the terminal. ExxonMobil also operates the Yoho field, with current output of around 150,000 bpd. Yoho contains around 400 million barrels of oil reserves. Yoho will be re-injected with natural gas to maintain field pressure. The $1.2 billion field is located in the shallow waters of the eastern delta. In June 2008, ExxonMobil plans to bring online its Bosi field (110,000 bpd) located the western delta.

Chevron's offshore Agbami field is scheduled to come online in 2008, with peak production estimated at 250,000bpd. The majority of Agbami lies in Block 127, while one-third of it lies in the adjacent Block 128. In February 2005, the Nigerian National Petroleum Corporation (NNPC) awarded Chevron a $1.1 billion contract for the construction of an FPSO for the field, which will be undertaken by Daewoo Shipping and Maritime Engineering (South Korea). The FPSO is expected to export up to 250,000 bpd of oil and 450 million cubic feet of natural gas per day (MMcf/d).

Total, Agip, and ConocoPhillips are also involved in the Nigerian oil sector. Output at Total's Amenam field reached 120,000bpd in January 2005. The Amenam field contains reserves of around one billion barrels of oil equivalent. In January 2009, Total plans to bring offshore Akpo field (180,000 bpd) and in January 2010, its offshore Usan field (150,000 bpd).

2.2.1.3 Licensing Rounds

Deepwater projects may represent the future of Nigerian oil production by allowing multinational operators to avoid security risks inherent to the unstable Niger Delta region. In a licensing round held in March 2005, Nigeria offered a total of 77 deepwater and inland blocks. Beginning in April 3, 2007, the Nigerian government opened a licensing round in which 44 blocks are being offered. A number of the blocks in the April round were also offered in 2005. According to the Department of Petroleum Resources (DPR), companies that plan to invest in Nigeria's infrastructure and refinery projects will be given right-of-first refusal on 17 of the blocks.

Along with the increased foreign investment in Nigeria's oil and natural gas sectors, the Nigerian government has been working to promote local investment in the hydrocarbon industry. Nigeria's Marginal Field Development Program (MFDP) provides tax breaks and government incentives to encourage local involvement (local content) in the extractive industries. The government has called for the current 10 percent local ownership to be increased to 45 percent in 2008 and 70 percent in 2010.

2.2.1.4 Joint Development Zone

The Joint Development Zone (JDZ) shared by Nigeria and neighboring Sao Tome and Principe (STP), contains 23 exploration blocks and could potentially hold up to 14 billion barrels of oil reserves. Nigeria and Sao Tome have agreed to split revenues from the blocks on a 60-40 basis, respectively. The IMF estimates that STP could net more than $700 million per year if oil production output of 80,000 bpd is attained before 2013. Block One is currently the only block in the JDZ undergoing development. The block is controlled by Chevron (51 percent), with partners ExxonMobil (40 percent) and Equity Energy Resources (9 percent). If oil is located, Chevron plans to bring it on stream by 2010. In 2005, JDZ put Blocks 2-6 up for offer. In March 2006 Nigeria and Sao Tome and Principe signed PSCs for three of the blocks.

2.2.1.5 Exports

Nigeria is the world's eighth largest exporter of crude oil and the country is a major oil exporter to the United States. In 2006, Nigeria's total oil exports reached an estimated 2.15 million bpd. Nigeria shipped approximately one million bpd or 42 percent of its crude exports to the United States in 2006. Additional importers of Nigerian crude oil include Europe (19 percent), South America (7.6 percent), Asia and the Caribbean. Despite shut-in production, major importers of Nigerian crude have experienced little-to -no decrease in Nigerian crude imports over the past 15 months. The steady exports suggest that the new production capacity additions (approximately, 545,000 bpd) have mostly offset shut-in production.

Nigeria has six export terminals including Forcados and Bonny (operated by Shell); Escravos and Pennington (Chevron); Qua lboe (ExxonMobil) and Brass (Agip). According to the *International Crude Oil Market Handbook,* Nigeria's export blends are light, sweet crudes, with gravities ranging from API 29 - 36 degrees and low sulfur contents of 0.05 - 0.2 percent. Forcados Blend is considered one of the best gasoline-producing blends in the world.

2.2.1.6 Refining and Downstream

Nigeria's refining capacity is currently insufficient to meet domestic demand, forcing the country to import petroleum products. According *OGJ,* Nigeria's state-held refineries (Port Harcourt I and II, Warri, and Kaduna) have a combined nameplate capacity of 438,750bpd, but problems including sabotage, fire, poor management and a lack of regular turn around maintenance (TAM) contribute to the current operating capacity of around 214,000 bpd. To increase refining capacity, the Nigerian government is granting permits/licenses to build several independently-owned refineries. Oando, a leading petroleum-marketing company in Nigeria, is considering building a refinery in Lagos. The refinery would be built in two phases, with each phase providing 180,000 bpd of refining capacity.

Nigeria is trying to privatize state entities by selling Nigerian National Petroleum Company's (NNPC) four oil refineries, petrochemicals plants, and its Pipelines and Products Marketing Company (PPMC). IOCs have shown little interest in investing in refinery privatization. However, the Nigerian government recently opened negotiations with Libyan, Indian, and Chinese investors. As of March 2007, Mittal Steel of India was looking to purchase a controlling stake in the Port Harcourt Refinery Company (PHRC), although, no deal has officially been signed (Balouga, forthcoming,a).

2.2.1.7 Sector Organization

In 1977, Nigeria created the NNPC. At that time, the NNPC's primary function was to oversee the regulation of the Nigerian oil industry, with secondary responsibilities for upstream and downstream developments. In 1988, the Nigerian government divided the NNPC into 12 subsidiary companies in order to better manage the country's oil industry. The majority of Nigeria's major oil and natural gas projects (95 percent) are funded through joint ventures (JVs), with the NNPC as the major shareholder. The largest JV is operated by Shell Petroleum

Development Company (SPDC). Additional foreign companies operating in JVs with the NNPC include ExxonMobil, ChevronTexaco, ConocoPhillips, TotalFinaElf, Agip and Addax Petroleum. The remaining funding arrangements are comprised of production sharing contracts (PSCs), which are mostly confined to Nigeria's deep offshore development program.

2.2.2 Natural Gas

2.5.2.1 Overview

OGJ estimates that Nigeria had an estimated 182 Trillion cubic feet (Tcf) of proven natural gas reserves as of January 2007, which makes Nigeria the seventh largest natural gas reserve holder in the world and the largest in Africa. The majority of the natural gas reserves are located in the Niger Delta. In 2004, Nigeria produced 770 billion cubic feet (Bcf) of natural gas, while consuming 325 Bcf. The government plans to raise earnings from natural gas exports to 50 percent of oil revenues by 2010. However, NNPC estimates that $15 billion in private sector investments is necessary to meet its natural gas development goals by 2010.

Because many of Nigeria's fields lack the infrastructure to produce natural gas, it is flared. According to NNPC, Nigeria flares 40 percent of its annual natural gas in the production, while the World Bank estimates that Nigeria accounts for 12.5 percent of total flared natural gas in the world. Nigeria is working to end natural gas flaring by 2008. However, Shell indicated in its 2005 annual report that it would not be able to eliminate routine natural gas flaring until 2009. Shell listed reduced funding and poor contractor performance on some projects as barriers to eliminating natural gas flaring.

2.2.2.2 Liquefied Natural Gas (LNG)

A significant portion of Nigeria's natural gas is processed into LNG. Nigeria's most ambitious natural gas project is the $3.8 billion Nigeria Liquefied Natural Gas (NLNG) facility on Bonny Island. Partners including NNPC, Shell, Total and Agip completed the first phase of the facility in September 1999. In 2006, NLNG completed its fifth train increasing annual production capacity to 17 million tons per year of LNG. NLNG has brought a sixth train online in late 2007, raising production capacity to 22 million tons per year. A seventh train could come online in 2011. The facility is currently supplied from dedicated (non-associated) natural gas fields, but it is anticipated that within a few years half of the natural gas feedstock will consist of associated (currently flared) natural gas from existing oil fields.

Additional LNG facilities in Nigeria are also being developed. In January 2005, Chevron announced the possibility of constructing the $7 billion OK-LNG plant at Olokola in Western Nigeria. The plant would have an initial capacity of 11 million tons per year and a maximum capacity of 33 million tons per year. In March 2007, NNPC awarded a contract to France-based Technip for construction of the OK-LNG plant. The project includes connecting the LNG plant to oil and natural gas reserves in the Niger Delta through a network of pipelines. OK-LNG is -expected to produce its first LNG in 2011. In December 2005, ConocoPhillips, Chevron and Agip met with NNPC to sign a shareholders' agreement for the establishment of the $3.5 billion Brass River LNG plant. The project, which includes two LNG trains, could be operational by late 2009 depending on a final investment decision (FID) to be made in 2007.

Chevron is working on the Escravos gas-to-liquids (EGTL) project, which is located in the western Niger Delta, and is expected to have production capacity of 33,000 bpd. Completion of the GTL project was scheduled for 2009. However, in January 2007, work on the EGTL project came to a halt after a breakdown in salary negotiations. A year earlier, the Nigerian government halted the implementation of the EGTL project due to high costs. Plans for the project include linking the Escravos pipeline system with the West African Gas Pipeline (WAGP) for natural gas export to Benin, Togo and Ghana.

2.2.2.3 International Pipelines

Progress on the West African Gas Pipeline (WAGP), which will deliver 140 MMcf/d of natural gas to power stations in Ghana is moving forward. The $590 million, 420-mile pipeline will carry natural gas from Nigeria to Ghana, Togo, and Benin Republic. Operational start-up of the project is expected during 2007, with initial capacity of 200 MMcf/d of natural gas. The pipeline is expected to function at a full capacity of 450 MMcf/d within 15 years. The Multilateral Investment Guarantee Agency (MIGA), and the International Development Association (IDA) are also helping to fund the WAGP by giving $75 million and $50 million, respectively.

Nigeria and Algeria continue to discuss the possibility of constructing a Trans-Saharan Gas Pipeline (TSGP). The 2,500-mile pipeline would carry natural gas from oil fields in Nigeria's Delta region to Algeria's Bani Saf export terminal on the Mediterranean. It is estimated that construction of the $7 billion project would take six years. The TSGP is currently in the study phase of development.

2.2.3 Electricity

The Nigerian power sector operates well below its estimated capacity, with power outages being a frequent occurrence. To compensate for the power outages, the commercial and industrial sectors are increasingly using privately-operated diesel generators to supply electricity. In 2004, total installed electricity capacity was 5.9 gigaWatts (GW). Total electricity generation during 2004 was 19 billion kiloWatthours (BkWh), while total consumption was 18 BkWh. Only 40 percent of Nigerians have access to electricity, the majority of whom are concentrated in urban areas. Despite endemic blackouts, customers are billed for services not rendered, partially explaining Nigeria's widespread vandalism, power theft and Power Holding Company of Nigeria's (PHCN) problems with payment collection.

China is becoming increasingly involved in Nigeria's electric infrastructure developments. In early 2007, Nigeria awarded China Gezhouba Group Corporation (CGGC) and China Geo-Engineering Corporation (CGC) a hydroelectric project contract. Nigeria hopes the Mambilla power station, which will be located in northeastern Nigeria, will add 2,600 megaWatts (MW) to the national grid. The project could be completed by 2012. In addition, China's EXIM Bank, Su Zhong, and Sino Hydro have committed to funding the Zungeru (950-MW) hydroelectric projects. In March 2007, Nigeria's Minister of Energy announced that the Zungeru project should be online soon, but he did not give a specific start-up date (EIA, 2007).

The next chapter contains a review of relevant literature.

CHAPTER THREE

LITERATURE REVIEW

In this chapter, divided into eleven sections, we review literature relevant to energy consumption and its consequences on the economy. Specifically, the following issues are discussed: energy consumption, economic growth, technology and renewable sources of energy.

3.1 Review of Conceptual Literature

3.1.1 Energy demand

Demand is the quantity of a good, buyers wish to purchase at each conceivable price (Begg *et al*, 1991). Five main variables are assumed to influence the quantity of each product that is demanded by each individual consumer: the price of the product, the price of other related products; the consumer's income and wealth, consumer's tastes, various individual-specific or environmental factors. The above list is summarized in a demand function as follows:

$$Q_n^d = D\ (P_n, P_1, \ldots, P_{n-1}, Y, S) \text{ ------- } (3.1)$$

Where Q^d_n is the quantity that the consumer demands of some product, n; P_n is the price of the product, while P_1, …, P_{n-1} are prices of all other related products, Y is the consumer's income, and S is a host of factors that will vary from individual to individual (for example age, number of children, etc..) . There are also environmental factors that will affect demand patterns, such as the state of the weather and time of the year.

The basic economic hypothesis is that the lower the price of a product, the larger the quantity that will be demanded, other things equal. This negative relationship between price and quantity is referred to as the law of demand. When the price of a product increases, all things equal, the product becomes a more expensive way of satisfying a want. Some consumers will stop buying it altogether; others will buy smaller amounts; still others may continue to buy the same amount. But no rational consumer will buy more of it. Because many consumers will switch wholly or partially to other products to satisfy the same want, less will be bought of the product whose price has risen. Second, when the price of a good falls consumers will buy more of it and less of other similar products whose prices have not fallen. These other products have become more expensive relative to the product in question (Thompson & Formby, 1993).

From the point of view of economics, the principle for estimating and analyzing the demand for energy is not different from that for any commodity. Although there are characteristics of energy demand, institutional features of energy markets, and problems of measurement that require particular attention in analyzing energy markets but the microeconomic foundation of energy demand is the same as for other commodities.

Demand for energy can arise for different reasons. Households consume energy to satisfy certain needs (heating, cooling, cooking, lighting, etc.) and this is done through the use of appliances. Any commercial energy demand requires monetary exchanges and the decision to switch to commercial energies can be considered as a three-stage decision-making process (see Hartman ,1979; Stevens, 2000; and Bhattacharyya, 2006). First, the household has to decide whether to switch or not (i.e. the switching decision). The switching decision is largely determined by monetary factors: the amount and regularity of income, alternative uses of money and willingness to spend part of the income to consume commercial energies as opposed to allocating the money to other competing needs. Second, it decides about the switching appliances to be used (i.e. appliance selection decision). Third, consumption decision is made by deciding the usage pattern of each appliance (i.e. consumption decision). All these stages influence consumption demand. Households consume energy by allocating their income among various competing needs so as to obtain the greatest degree of satisfaction from total expenditure. Industries and commercial users demand energy as an input of production and their objective is to minimize the total cost of production. Therefore the motivation is not the same for the households and the productive users of energy and any analysis of energy demand should treat these categories separately (Bhattacharyya, 2011).

3.2 Review of Theoretical Literature

3.2.1 Energy demand Theory

3.2.1.1 Simple Descriptive Analysis

Three simple but commonly used indicators that are used to describe the change in demand or its relationship with economic variables are presented here. These are growth rates, demand elasticities and energy intensities.

Any demand analysis starts with a general description of the overall energy demand trends in the past. It enables qualitative characterization of the pattern of energy demand evolution and identification of periods of marked changes in the demand patterns (such as ruptures, inflections, etc.). These preliminary steps could set the scope and the priorities of the analysis.

3.2.1.2 Growth rates

Annual growth rate is an indicator commonly used to describe the trend. This can be on an annual basis or an average over a period. The year-on-year growth rates are calculated year after year so as to get a historical series.

3.2.1.3 Analysis of Change in Total Energy Demand

The framework for analyzing the change in energy consumption between two time periods is based on the simple relation where,

$$E = E$$
$$E = Q \cdot \frac{E}{Q}$$
$$E = Q \left[\sum\left(\frac{E_i}{Q} \cdot \frac{Q_i}{Q_i}\right)\right]$$
$$E = Q \left[\sum\left(\frac{E_i}{Q_i} \cdot \frac{Q_i}{Q}\right)\right]$$
$$E = Q\left[\sum(EI_i \cdot S_i)\right] \text{ ------------- } (3.2)$$

Where, EI_i = energy intensity in sector i (i.e. ratio of energy consumption in the sector to the driving economic activity of the sector), and S_i = structure of sector i (i.e. share of the activity of sector *i* relative to the overall activity of the economy); Q = overall economic activity with Q_i as the activity of sector *i*, E = energy consumption, and E_i is the energy consumption in sector *i.*

The total change in energy consumption (or demand) is then

$$E = Q_{effect} + I_{effect} + S_{effect} \text{ --------- } (3.3)$$

The decomposition leaves some residual, which is equal to the difference between the change of energy consumption actually recorded and the sum of the three components estimated above. The residual can be quite significant and the error could be great. To remove this problem, a number of sophistications are now available that distribute the residual to the components but these perfect or complete decomposition methods lose their intuitive appeal. Also it should be noted that in the above formulation, the unchanged variables are left at their initial or base year values. This follows Laspeyres index method. The final year values could also be used (which follows Paasche index method) (Ang & Zhang, 2000; Ang, 2004; and Sun, 1998).

3.2.1.4 Structural Analysis

The challenges encountered using the factor analysis approach to energy demand can perhaps be easily bypassed using the structural analysis approach, in which total energy consumed over time is dis-aggregated into energy consumed in the residential, industrial, transportation, agriculture, service and commerce sectors of the economy, and then analyzed using descriptive statistical methods (pie charts, bar charts, etc).

3.2.1.5 Demand Elasticities

Elasticities measure how much (in percent) the demand would change if the determining variable changes by 1%. In any economic analysis three major variables are considered for elasticities: output or economic activity (GDP), price and income. Accordingly, three elasticities can be determined. They are price, income and cross elasticities. There are two basic ways of measuring elasticities: using annual growth rates of energy consumption and the driving variable, or using econometric relationships estimated from time series data. The first provides a point estimate while the second provides an average over a period, and accordingly, the two will not give exactly the same result.

The short-term price elasticity captures the instantaneous reaction to price changes. In the short run consumers do not have the possibility to change their capital stock and can only change their consumption behaviour and hence only a partial reaction is normally felt. On the other hand, the long-term elasticity would capture the effect of adjustments over a longer period, during which consumers have the possibility of adjusting their capital stock as well as their consumption behaviour. This results in a better reflection of the reaction to price change.

3.2.1.6 Energy Intensities

3.2.1.6.1 The energy intensity index

Energy intensities (also called energy-output ratios) measure the energy requirement per unit of a driving economic variable (e.g. GDP, value added, etc.) Energy consumption may refer to a particular energy or to various energy aggregates and is expressed as a ratio or energy demand per unit of economic output. For an economic driving variable, normally the constant dollar values are used for better comparability across a time scale. In the productive sectors (industry, agriculture and commerce), the value-added of these sectors should be used to calculate their energy intensity. As for the case of non- productive energy consuming sectors such as household sector**,** the GDP of the whole country or the private consumption of the households should be used as driving economic variable. As the energy consumption of the transport sector includes the consumption of all vehicles, it is then irrelevant to use only the value- added of the transport companies to calculate the transport sector's energy intensity. Instead, GDP as the economic indicator is more appropriate for calculating transport energy intensity.

Although energy intensity is widely used as a measure of relative performance of economies, the ratio is subject to various conceptual and measurement problems. For example, the ratio is highly sensitive to the bases chosen for either of its components and any problem that may distort the size of either the numerator or the denominator distorts the picture presented by the ratio.

3.2.1.6.2 The Environmental Kuznets Curve (EKC) or "intensity of use"

The intensity of use hypothesis was first put forward by Malenbraum (1978). This hypothesis states that income is the main factor that explains consumption of materials; that is during the period of economic development countries would tend to increase consumption of energy and materials at the same rate as growth in income until a defined level of income ($11,000-$13,000) is reached. Beyond that level, however, it is expected that economic growth and the consumption of materials will be de-linked. That is, further increases in the level of output will no longer be followed by increases (at the same rate) of energy and material consumption.

3.2.1.6.3 The Complex Systems

This theory states that smooth and continuous behaviour of the energy intensity curve is not always possible. For example, a small change in GDP could lead to great disparity in energy intensity results: from big changes to almost no change (Ramos-Martin & Ortega-Cerda, 2003).

3.2.1.6.4 The theory of Punctuated Equilibrium or Phase Diagram (Gowdy, 1994)

The energy metabolism of countries can be explained by analyzing the energy intensification process. This method represents the intensity of energy use of the year t and that of year t-1 (Gowdy, 1994). This alternative methodology makes it possible to check the continuity of the de-materialization and re-materialization around certain 'attractor points' (De Brun, 1999).

3.2.1.6.5 The Constrained Optimization

3.2.1.6.5.1 Consumer's Utility Maximization

From basic microeconomic theory, the demand for a good is represented through a demand function which establishes the relation between various amounts of the goods consumed and the determinants of those amounts. The main determinants of demand are: price of the good, prices of related goods (including appliances), prices of other goods, disposable income of the consumer, preferences and tastes, etc. To facilitate the analysis, a convenient assumption (known as *ceteris paribus*) is made which holds other determinants constant and the relation between price and the quantity of goods consumed is considered. This simple functional form can be written as follows:

$$q = f(p) \text{ ------------------ } (3.4)$$

Where q is the quantity demanded and p is the price of the good.

The microeconomic basis for consumer energy demand relies on consumers' utility maximization principles. Such an analysis assumes that (i) consumers know their preference sets and ordering of the preferences, (ii) preferences ordering can be represented by some utility function and (iii) the consumer is rational in that she will always choose a most preferred bundle from the set of feasible alternatives.

Following consumer behaviour theory, it is considered that an incremental increase in consumption of a good, keeping consumption of other goods constant, increases the satisfaction level but this marginal utility (or increment) decreases as the quantity of consumption increases. Moreover, maximum utility achievable given the prices and income requires marginal rate of substitution to be equal to the economic rate of substitution. This in turn requires that the marginal utility per dollar paid for each good be the same. If the marginal utility per dollar is greater for good A than for good B, then transferring a dollar of expenditure from B to A will increase the total utility for the same expenditure. It follows that reduction in the relative price of good A will tend to increase the demand for good A and vice versa.

The market demand function for a particular good is the sum of each individual's demand for those goods. The market demand curve for the goods is constructed from the demand function by varying the price of the good while holding all other determinants constant.

3.2.1.6.5.2 Cost Minimization of the Producer

In the case of producers, the theory of the producers is used to determine the demand for factors of production. In the process, it is normally possible to replace one input by the other and the producer would try to find the combination of inputs that would minimize the cost of production.

Consider that a producer uses capital and energy to produce his/her output which follows the production function given in the following equation:

$$Q = 10K^{0.5}E^{0.5} \text{ --------- (3.5)}$$

Where Q is output, K is capital and E is energy.

Assume that the price of capital and energy per unit is $1 each. If K units of capital and E units of energy are used in the production process, the total cost will be K + E. The optimal choice would be at the point where the cost lines are tangent to the isoquant. For a given level of output, the demand for input energy can then be determined.

3.2.1.6.6 Pragmatic Approach to Demand

The traditional and modern theories of consumer behaviour based on cardinal and ordinal utility analysis (Lipsey & Chrystal, 1991) have been the cornerstones of theoretical economic analysis. In recent years, however, economists have questioned their usefulness in applied economics and have accordingly constructed models and formulated theories in order to make the demand theory more realistic. The so-called pragmatic approach to demand theory consists of the Lancaster attributes (or characteristics) demand theory, the indirect utility function theory, the expenditure function theory, linear expenditure functions, constant-elasticity demand function, the empirical demand functions (i.e.. linear and exponential), and the Dynamic demand function or Distributed-lag model of demand (Jhingan, 2009).

3.2.1.6.7 Empirical Demand Function

The empirical demand function theory states that in order to estimate an empirical demand function, it is necessary to specify what measurable impact the prices of other commodities have on the demand for the commodity of our interest. Two common forms of empirical demand functions are the linear demand function and the exponential demand function. They are specified respectively, as follows:

(i) $Q = a + b_1P + b_2P_c + b_3P_s + b_4Y + b_5T + b_6D + \mu$ -- (3.6)

(ii) $Q = P^aP_c^bP_s^cY^d$ ----------------- (3.7)

where c stands for complement, s for substitute, Y for income, T for taste and D for dummy variable. In (ii) above, the elasticities (a, b, c, d) are the exponents, and demand function (ii) can be written in log form as:

$$LogQ = aLogP + bLogP_c + cLogP_s + dLogY \text{ ------ } (3.8)$$

The Dynamic Demand Function (or Distributed-lag model of demand) includes lagged values of the quantity demanded and of income as separate variables which influence demand in any particular period. They are based on the stock-adjustment principle which says that current demand decisions are influenced by past behaviour. It assumes that current demand depends on past levels of income and demand. In the case of a durable consumer commodity, its past purchases constitute a “stock” of this commodity which clearly affects its current and future purchases. The more current of past levels of income or demand have a greater influence on present consumption patterns than the more remote ones.

3.2.1.6.8 The Econometric Approach

The econometric approach relies on the economic foundation of energy demand discussed earlier to analyze energy demand and the effects of price and policy changes. The level of analysis can vary from a single equation system to simultaneous equation systems and the method has evolved over the past four decades to take advantage of the developments in the econometric analysis.

As indicated earlier, any analysis of energy demand should consider three decisions made by the user, namely: equipment buying decision, fuel and equipment choice decision and the capacity utilization decision. The econometric method tries to capture the above ideas of derived demand for energy using a variety of modeling techniques, leading to a widely varying level of effectiveness. Two commonly used modeling approaches are known as the reduced form models and structural models. These two forms of models are discussed below.

The starting point in this modeling approach is the identity that links energy consumption with the stock of capital equipment and its rate of utilization indicated below [referred to as the Fisher & Kaysen (1962) model],

$$\mathrm{Qi} \equiv \sum_{k=1}^{m} Rki.Aki \quad \text{----------- (3.9)}$$

Equation (3.11) indicates that total consumption of fuel *i* is the sum of fuel consumption of each of *k* types of appliances, where the fuel consumption by an appliance type is obtained as the product of the stock of such appliance *(A)* and the utilization rate *(R).* For example, electricity consumed by a household can originate from a number of white goods namely, refrigerators, cookers, blenders, entertainment equipment, etc. The stock of such appliances multiplied by the kWh of electricity used by each good gives the electricity consumption by appliance type.

The total electricity consumption then is the sum of electricity consumed by all the appliances used by the household.

A structural model considers the derived nature of energy demand explicitly by specifying separate demand functions for the appliance stock and the utilization rate. A_i and R_i may be expressed as follows:

$$A_i = f_i(P_i, P_j, P_a, Y, X) \text{ ----- (3.10)}$$

$$R_i = f_2(P_i, Y, Z) \text{ ------------- (3.11)}$$

Where P_i is the price of fuel *i*, P_j, is the price of competitive fuel *j*, Pa is the price of appliance a, Y is income or output (in case of intermediate consumers), *X* and *Z* are other relevant variables. In the above equation, the appliance stock is hypothesized to depend on the fuel price, substitute fuel price, income and a vector of other variables. The rate of utilization is considered to depend on the own-price of fuel, income and other variables.

A structural model will simultaneously estimate the above functions to determine the fuel demand. However, this requires information on equipment stocks and such information is not always available. In such cases a reduced-form fuel consumption model can be used. These models (i.e. reduced forms) are most commonly used for energy demand analysis. Energy demand is estimated by combining the effects of inter-fuel substitution, stock adjustment of appliances and the rate of utilization of devices. Substituting Equations 3.10 in 3.11 leads to

$$Q_i = k(P_i, P_j, P_a, Y, X, Z) \text{ ----------- (3.12)}$$

Model (3.14) is known as the reduced form static model as it assumes an instantaneous adjustment process in the capital stock. In the dynamic models, the instantaneous adjustment process is relaxed. In the partial stock adjustment models, it is assumed that the stock of appliances cannot adjust rapidly due to time lags in the process of retirement and new capacity addition.

Probably the most widely used single equation specification takes the following form:

$$\text{Log}E_t = a + bLog(P_E) + cLog(Y_t) + \mu_t \text{ ----- (3.13)}$$

Where, E (the per capita real energy consumption) is determined by the relative price of energy (P_E), per capita real income or output (Y) and the disturbance term. Advantages of this particular specification are its straightforward allowance for both price and real activity influences. This type of specification has been applied to total final energy demand, and individual sector energy demand (industry, transport, residential, etc.).

In Equation (3.13), the estimated coefficients b and c are price and output elasticities of energy demand, which measure percentage changes in industrial energy demand for a percentage change in energy price and economic output. The equation can be used to analyze the effect of changes in energy prices on energy demand. The magnitude of the effect of price changes would depend on price elasticities of energy demand. If the price elasticity is greater than -1, the demand is said to be elastic and when it is less than -1, it is inelastic. For an elastic demand, the effect of price change would lead to more than proportionate reduction in demand. Energy conservation can be promoted for such energies through higher prices. The economic foundation of the above specification can be traced in the tradition of Cobb-Douglas function, where demand is considered to be a function of price and income. The log-linear form of specification provides direct estimation of price and income elasticities and is better suited to energy demand than a simple linear specification.

This equation is used very frequently in macro or sectoral demand analysis and can be written as follows:

$$\text{Log}E_t = Loga + bLogQ_t + cLogP_t + dLogE_{t-1} \text{ ------ (3.14)}$$

Where E_{t-1} is the one-time lagged E_t all other variables being the same as in equation (3.13) above. Equation (3.14) assumes that the total energy demand at period t is not only a function of the real price of energy and the level of output of the same period, it also depends on the level of energy demand of the previous period. The lagged model often explains the variation in energy demand better than the basic equation. This may be due to the fact that the level of activity and the level of energy consumption at any period in time are highly correlated to, and influenced by, those of the previous periods. However, this is generally considered to be an ad-hoc specification. Furthermore, the specification assumes a constant elasticity of demand and it (specification) may not be consistent with the demand theory. If the income elasticity is greater than one, the demand can be grossly overestimated as income increases. This can yield inconsistent results.

From Equation (3.14), the short-run and long-run elasticites are found as follows:

Short run income elasticity = b, long run income elasticity = $\frac{b}{(1-d)}$

Short run price elasticity = c, long run price elasticity = $\frac{c}{(1-d)}$

Although single equation, reduced form models have been widely used, researchers have often tried to adopt more sophisticated formulations as well. A commonly used refinement is the use of distributed lag structure on price and income variables. As the adjustment process takes time in the energy sector, the response is expected to be distributed over a number of periods. A series of lagged explanatory variables are then added in the model to capture this effect. However, as the number of lag periods increases, the degrees of freedom of the model reduce, leading to imprecise estimates of the lagged coefficients. This often limits the number of lag periods in a model.

3.2.1.6.8.1 Energy - Demand - Style Regression

This theory says that energy intensity of use is a function of many variables, some of which are the price of the fuel, personal consumption income, capital-labour ratio, investment-capital ratio, population growth rate, etc (Bhattacharyya, 2011).

3.2.1.6.8.2 Factor (Decomposition) Analysis

The simple indicators discussed earlier capture the nature of the change in energy demand or use but do not explain the underlying cause(s). However, for a better understanding of energy use and future energy requirements, it is important to understand the causal factors. A large volume of literature has been developed on devising methods and frameworks for explaining the demand. A particular method, known as decomposition method, has been widely used (see Ang and Zhang, 2000 for a survey of application of this method).

3.3 Review of Empirical Literature

3.3.1 Energy Consumption

Energy is the lifeblood of the global economy today. Like the red blood corpuscles which the heart pumps round the human body, an abundant supply of energy remains absolutely essential to provide the goods, services and living standards we now enjoy. There are no practical substitutes for energy in the short term. Recent renewed threats to Middle East and Central Asian oil and natural gas supply and shortfalls of natural gas and electricity in California has provided a salutary warning. Without adequate contingency planning, much new technology and abundant long-term investment in new and conventional energy sources, energy supply will plateau and fall, the pace of global economic growth will most certainly slacken and the system, as we know it, will atrophy (Tempest, 2002).

In *Energy Demand Analysis* (1993) it is reported that the key drivers shaping global energy supply and its use in the future are population growth, economic and social development, financial and institutional conditions, local and global environmental concerns, efficiency of energy supply and use, technological innovation and deployment as well as access to sufficient modern energy in the developing world (WEC, 1993).

Medlock & Soligo (1998) observed that during the period from 1978 to 1995, total final energy demand in China increased by approximately 150%, with most of the increase coming in the industrial and transportation sectors. The growth in the industrial sector was the result of continued reliance on the build-up of heavy industry as a basis for development. The growth in the transportation sector was reflective of the rapid growth, and subsequent utilization, of motor vehicle stocks.

The continued growth of energy demand in China will depend upon the growth of GDP as well as the future changes in the structural characteristics of production and consumption there, Medlock & Soligo (1998) argued. In particular, as the structures of production become more intensely represented by services, the energy intensity (the ratio of energy consumption to gross domestic product) of production will decline. As the structure of consumption changes to reflect consumer desires to obtain services such as heating, refrigeration, and personal transport, the energy content of the consumer bundle will increase. Whether or not the energy intensity of GDP increases or decreases in the short run is dependent upon the relative strengths of these two trends, they insist.

It is expected that the bulk of total energy demand will continue to come from industrial activities for the foreseeable future due to the fact that so much of Chinese GDP originates in the industrial sector -in the order of 50% in 1995 (Medlock & Soligo, 1998). Further growth in industry will only lead to increases in energy demand even if industry's share in total output declines. Residential, commercial and transportation energy use will begin to account for an increasing share of total energy consumption as more and more consumers achieve higher levels of income**.** Medlock & Soligo (1998) predict that motor vehicle stocks in China could grow to 30 vehicles per thousand individuals by 2015 at a per-capita GDP growth rate of 5% per annum.

With a projected population of about 1.4 billion, this amounts to a total stock of automobiles of about 42 million, an increase of about 37.5 million from their 1995 levels. Given the nature of the transportation sector, increased utilization translates into a huge increase in the demand for oil and petroleum products. Medlock & Soligo (1998) conclude that energy security in China will depend heavily upon China's ability to "play politics" with the nations of the Middle East. Moreover, the ability to overcome inefficient structures and mechanisms, which have slowed domestic exploration and development of oil resources, will have a significant impact on the energy security issue. Since such a large portion of oil demand must be satiated with imports, the geo-political environment of Asia can be expected to change dramatically in the coming years.

Henderson (1981, 1988) traces the history of the fossil-fuelled Industrial Revolution and the evolution of positivist science and classical and neo-classical economics in the United Kingdom (UK) and Europe. The author posits that economic theories of value changed over this period - leading to the Keynesian revolution from the late 1930s through the 1970s. He laments the lag in economic theories in properly evaluating the role of the factors of production - particularly the role of energy (which was subsumed under "capital" and "land"), and how this "error" had killed industrial societies into under-pricing and over-use of energy. This, together with their political, corporate and military power, had contributed to their addiction to petroleum.

Imbalances in world energy consumption have continued to worsen, exacerbated by the global hegemony of the US dollar. However, between 1974 and 1980, energy consumption was de-linked (or decoupled) from the U.S. GDP–growth due to efficiency gains, leading to a steady decline of the energy intensity from the Energy/GDP ratio of 1 in 1960 to an Energy/GDP ratio of 0.64 by 1998 (Henderson, 2000). Despite the massive energy consumption, population growth and the doubling of automobiles on the highways in the U.S., OPEC price increases clearly contributed to this change, together with price volatility, fears of supply disruptions and climate change.

Cluver *et al*. (Undated) observe that the growth rates of GDP and energy consumption would be somehow linked strongly in developing as well as developed countries. In other words if the developing countries aim at the economic level similar to the one enjoyed by the industrialized nations, huge amounts of energy sources will be required. The reason for such remarkable growth is explosive population growth. They contend that even if a very thorough and intensive energy conservation effort is implemented, the energy consumption in the world in the middle of the 21st century will be twice as much as is consumed at this moment.

Alamonová (Undated) reports that Slovakia is a country importing most of her primary energy resources. Thus, energy policy here is focused especially on extending international energy transport networks, in gas pipeline and crude oil pipelines, and the development of the international energy market. He adds that over the past six years energy intensity experienced the on-going decrease (by 17%). Since the revival of the national economy after 1993 the annual fall in energy intensity has increased by about 5%. This favourable development emerged especially as a consequence of the increased share of services in GDP, compared to the past, when a key role in the GDP was played by the energy-intensive industry.

However, Alamonová (Undated) laments that energy intensity in Slovakia is still relatively high. It is 2-3 times higher compared to Western European countries. The high level of energy intensity is first of all determined by the structure of industry in which energy-intensive manufacturing branches have a large share compared to most of the European countries. Alamonová (Undated) advises that since Slovakia is highly dependent on external energy sources, the reduction of energy intensity be one of the primary tasks of Slovakia's energy policy. He suggests three ways by which this objective might be achieved: one, by cutting down a share of intensive GDP creation; two, by increasing the share of less energy-intensive industrial branches in the GDP creation and three, by supporting a favourable development of a nation's national currency in relation to the single European currency. In addition, he cautions that the above–mentioned actions mean profound structural changes in the economy, which affect the development of strategically important industrial branches, such as the metallurgical industry, heavy chemical industry and the production of building materials, particularly cements. These structural changes are being enforced slowly in Slovakia. Alamonová concludes that as a result of the modest indigenous energy sources, Slovakia should implement better technology, greater openness of the economy and energy market liberalization. This journey is accompanied with plenty of structural changes both in the energy sector and the economy as a whole. Part of the process is also to carry on the implementation of changes in the cultural and institutional systems in the energy sector in Slovakia.

Writing on the rise and collapse of OPEC oil prices, Byrns & Stone (1992) report that crude oil prices ranged between $ 1.80 and $4.00 per barrel from World War II until the 1970's. During 1974-1975 alone, OPEC raised the price of crude oil from $4.00 to $10.00 per barrel. Price hikes continued, with a barrel of oil hitting the $20.00 mark by 1977, $30.00 in 1980, and finally peaking at an official price of $34.00 per barrel in 1982-83. By 1987, however, the spot price of oil had fallen about $10.00 per barrel. After adjusting for inflation, the real prices of petroleum products were close to pre-OPEC levels. Byrns & Stone (1992) then argued that the reason for this fall in price is in the demand side as well as the supply side. From the demand side, the long–term growth of world oil consumption dropped sharply throughout this era, as a result of sluggish economic growth and concomitant unemployment. Growth in the demand for oil also shriveled because the high price of oil stimulated energy conservation: more insulation was put into private residences, office buildings, and manufacturing facilities, automobiles and aeroplanes were modified to achieve greater fuel efficiency, and industry adopted less energy-intensive technology.

Byrns & Stone (1992) add that the other key to the collapse of OPEC high prices came from the supply side. The late 1970's were an era of feverish exploration for new sources of energy. Vast pools of oil were developed in such areas as Mexico, Alaska and the North Sea. Coupled with the decline in world energy demand, these swelling supplies of non-OPEC members caused OPEC to boost output quotas (officially and through cheating) because member-countries relied heavily on oil exports for their national income.

Cluver et al.(Undated) postulate that low energy prices stimulate economic growth. They argue that in pre-1950 Europe, in countries where land was relatively constant, growth of GDP had been estimated to be about 0.5% per community similar to the growth in population. As Britain started to use coal to fuel its early industrial age, GDP growth rose to 1.5% with a population growth of 1%. From 1820 to 1913 as the industrialized world adopted the steam engine fueled by coal, GDP rose to 20%, with a population growth (excluding the U.S.A) of between 0.5 and 1%. In the period from 1950 to 1973 when the world turned to extremely cheap petroleum GDP growth rates doubled to around 5% (nearly 10% in Japan). Thereafter, petroleum prices rose between 1973 and 1979 and the world returned to coal and nuclear fuels GDP growth rates dropped back to between 2 and 2.5% per annum. Cluver et al.(Undated) recommend that if low energy prices stimulate economic growth and if economic rates greater than population growth rates are desired, nations should adopt a policy of promoting supply of energy sources at the lowest possible prices. They argue that although adequate supply of energy remains the responsibility of the energy industries but governments have extensive power and a variety of instruments to influence the development of the energy sector. They conclude that strong economic growth in many developing countries is already leading to sharp increases in per capita energy consumption. Consumption will continue to rise, driven also by the projected two-fold expansion in world population during the 21st century that will occur overwhelmingly in the developing regions. Dependence on exhaustible energy resources is crucial in determining a nation's development pattern due to the implication that increasing scarcity leads to increasing prices. As the price of various fuels increases substitution to cheaper resources will occur thereby altering the composition of energy demand.

Goszcz & Michna (1996) observe that inflation, which always follows the increase of energy prices, is about the fundamental problem of the countries going through the process of economic transition. They advocate that to fight it, tough monetary policy must be applied even though this could cause social upheavals.

Leca et al. (Undated) report that during the time of centralized economy Romania's economic policy led to a forced industrialization and in particular to a strong development of energy-intensive branches of the economy and that economic efficiency options had played, in the time, a secondary role to political options. Meanwhile, energy subsidies had ensured that cheap power for certain industrial consumers, who used it often in an inefficient manner, was made available. Before this period several national programmes of energy efficiency had been drawn but they did not benefit the required financing sources, consequent upon which great difficulties were met in the course of implementation. High energy efficiency was then used, only to a small extent.

Sokona & Thoamas (1999) regret that Rural Africa is characterized by a heavy dependency on biomass, limited use of "modern" forms of energy, and low energy consumption that is decentralized and dispersed. They caution that low income levels, a shortage of skilled labor, and socio-political and economic instabilities are key constraints to improvements in energy-use, in the short and medium terms. Under the difficulties of a shrinking natural resource base, a decline in soil productivity and a commensurate reduction in agricultural output, villagers across sub-Saharan Africa have consistently migrated to urban areas. Demographic growth and climate – related factors will surely cause this trend to intensify, they observe.

Because of this heavy dependence on biomass, they argue, rural people are forced to over-exploit their natural resources together with their agricultural wastes. This has significant implications for the observed decline in soil fertility levels. Poor rural practices coupled with non-intensive production systems and inefficient energy habits in large parts of urban and sub-urban areas aggravate environmental degradation through deforestation and soil erosion (Sokona and Thoamas, 1999).

Rosemberg & Saavalainen (1998), report that four newly independent states around the Caspian Sea and in Central Asia have emerged from the former Soviet Union with substantial endowments of oil and gas. Their natural wealth, while an advantage in itself, makes these countries potentially vulnerable to what is often dubbed the Dutch Disease… They attempt to identify the economic risks associated with the use of large natural resources in a transition economy and propose a policy strategy to deal with them. They focus discussion on Azerbaijan, a country that has already embarked on a path to market reforms and at the same time has made substantial strides toward exploiting its natural resources.

Amundsen & Bergman (1998) describe the design and functioning of the new electricity markets in Norway and Sweden and make a preliminary evaluation of the performance of these markets. They describe the Norwegian-Swedish “model” of deregulation in terms of the basic deviations from the approach adopted in England and Wales.

Salamah (1996) reports that energy (of which oil is the key component) is an essential input in the production processes of oil-consuming countries. He posits that taxes on energy, irrespective of their stated objectives all translate into one thing: a redistribution of the oil barrel value between producing countries and consumer governments. And the end result is that more of the economic rent is being creamed off by consumer countries, while the implied price increase also reduces final demand.

According to Speth (1997) worldwide an estimated 2 billion people continue to lack access to modern energy services. He laments that though we know that energy is absolutely essential for development, little international attention has been devoted to this important relation. *Agenda 21* called on nations to find more efficient systems for producing, distributing and consuming energy as well as for greater reliance on environmentally-sound energy systems. Special emphasis was placed on sustainable energy. The United Nations Development Programme (UNDP), through its Initiative on Sustainable Energy, is assisting programme countries to reflect these objectives – in national energy policies, investment plans, and sustainable development strategies. However, Speth insists, the achievements of *Agenda* goals will require changes which go beyond aid policies and are reflected in international business, investment, trade, public and private sector policies and decisions. Speth (1997) suggests that a more direct and dynamic debate on the essential linkages between energy and socio-economic development is needed, followed by translation into action in the short term, of the objectives of sustainable energy to achieve sustainable human development. The important links between energy and development and the pathways that will allow energy to be deployed for the improvement of lives worldwide is a concern that is at the heart of sustainable human development and, as we enter the next millenium, is one of the key global issues that will challenge all nations.

Tempest (2002) posits that the long-term solution of global energy supply availability lies essentially not in the ground or under the sea. He counsels that to leave the future of energy entirely in the hands of assorted generals, politicians, diplomats, economists and the like would itself be dangerous. The long-term answers must lie in the well-spring of human energy, in human ingenuity, rational analysis and common-sense and what today and always lies deeply buried in the human brain. He adds that energy has played and will continue to play a principal role in promoting economic growth and improved human well-being. But balancing the energy requirements to ensure further social and economic progress will be no small challenge.

Medlock & Soligo (1998) report that the relationship between energy demand and output is simultaneous in so much as increases in one motivate increases in the other. They observe that energy is a necessary input into the production of most goods and services. As income increases, the demand for these goods and services expands, thus raising the demand for energy inputs. Hence, GDP growth results in increasing energy demand but, because energy inputs are required, insufficient energy resource supplies can retard economic growth. They lament that the majority of energy studies ignore the simultaneity of energy-GDP relationship by simply allowing GDP to be an exogenous component of the energy demand system.

As implicit prices, such as those associated with pollution, increased substitution to cleaner fuels will be encouraged, the extent to which explicit and implicit prices either offset or reinforce each other will be crucial in determining the composition of energy demand. Medlock & Soligo (1998) find considerable evidence in the literature that energy price increases reduce real GDP growth in the short run, but the long run effects are less clear. They advise the adoption of conservation policies and the encouragement of technological innovation in response to higher explicit and implicit prices warning that they can both potentially have enormous impacts on the future energy consumption patterns of all nations.

Gately & Streifel (1997) analyzed the growth in demand for eight major oil products in 37 developing countries over the period 1970-1993.They found that demand for oil is set to rise in all main regions, particularly in developing countries, led by increasing incomes, population, industrialization, investment and trade**.**

3.3.2 Economic Growth

Bearse and Vaughan (as cited in *what is Economic Development?*) define "economic growth" as a quantitative change in the scale of the economy in terms of investment, output, consumption and income, and "economic development", as a qualitative change which entails changes in the structure of the economy, including innovations in institutions, behaviour and technology. Development, they posit, is both a prerequisite to, and a result of, growth. To them development precedes growth in the sense that growth cannot continue long without the sort of innovations and structural changes noted above. But growth, in turn, will drive new changes in the economy causing new products and firms to be created as well as countless small incremental innovations. Together, these advances allow an economy to increase its productivity, thereby enabling the production of more outputs with fewer inputs in the long run. They add that development theories make different behavioural assumptions, use different concepts and categories, explain the development process differently, and suggest different policies. They conclude that theoretical insights influence how successful economic developers are in promoting local competitiveness.

Sarel (1996) began the study of economic growth by looking at the long-running debate over the nature of growth: Is growth the result of an accumulation of manpower and machinery or is it the result of employing the latest technology? Sarel (1996) then looked at the growth records of Hong Kong, Korea, Singapore and Taiwan, the so-called Asian Tigers, from three angles: one, the influence of government intervention; two, the extent to which investments and exports can be considered the main engines of growth, and three, the significance for sustained growth of the economic conditions prevailing at the very beginning of the country's period of extended growth. Curiously, however, Sarel (1996) does not offer clear and conclusive results nor does he make clear policy recommendations. Nevertheless, he ends his study arguing that from a positive point of view, a promising avenue for the explanation of growth performance is the examination of initial conditions. Nonetheless, from a normative point of view, it is far from clear what specific policies government should pursue, beyond the standard set of policies aimed at getting the basics right.

Economic growth and economic development are processes of enormous complexity and diversity (Duncan, 1997). The need to achieve higher economic growth and development in sub-Saharan Africa, for example, is predicated upon the overriding need to alleviate the endemic and pervasive levels of poverty, which is impossible without sustained growth and employment and income levels. The extent of poverty is evidenced by the fact that of the 30 poorest and least developed countries identified by the World Bank, 20 are in sub-Saharan Africa. This poverty is not only growing rapidly, but it is also manifesting in new forms and dimensions. While the role of energy in economic growth is well acknowledged (Speth, 1997), its role may even be more significant in the case of sub-Saharan Africa, especially given its economic structure and the urgency required for its restructuring and transformation.

Studies show that at the early stages of economic development, less energy is required per unit of GDP, but demand for energy rises as development gathers momentum, and energy starts decoupling from GDP as economic development accentuates. However, energy decoupling is a function of energy efficient capital stock and energy substitution possibilities, and where these factors are missing, as in the case of sub-Saharan Africa, energy intensity could be relatively high (Ebohon et al., 2000).

The energy imbalances in sub-Saharan Africa, as defined by the gap between energy demand and supply indicate that there are huge deficits for all types of fuels, including commercial and biomass energy. Availability of commercial energy, including electricity, oil, gas, and kerosene in sub-Saharan Africa is marked by acute shortage, supply interruptions, and rising cost, resulting in crippling effects on economic activities. This is particularly the case in urban areas where commercial fuel scarcities have reversed the gains from energy transitions in the decades of the late seventies and early nineties. Additionally, such scarcities have drastically reduced the expansive capacity of urban cities and have imposed severe limitations on the ability of cities to fulfill the widely acknowledged role as the “engine of economic growth” (Ebohon et al.,2000). Interruptions in electricity supplies often force many industries to operate far below capacity utilization or incur huge additional costs in producing off-grid energy supply equipment such as electric generators. For small domestic firms, such equipment costs are a huge addition to costs and are often forced out of business as a result. For large firms, the cost implication is such that they become internationally uncompetitive with regards to price and non-price competitions. Price wise, and because of the uncompetitive cost structure, domestically produced goods become relatively more expensive than imported goods and services. Other non-price impacts exist in that it becomes difficult to guarantee delivery dates, plan outputs and investment levels, which adversely affect the growth and levels of economic activities. Additionally, huge repair costs are incurred due to power “outages” and power surges (Ebohon et al.,2000).The service sector is particularly hit as power failure and scarcities of alternative non-grid energy sources often force business to close early thus forfeiting the opportunity for trade and income generation.

At the household level, commercial energy scarcities have forced many households to use more than one fuel source as a strategy for minimizing the impact of fuel shortages. However, fuel-wood becomes the prime fuel consumed as initial capital outlay for energy equipment can hardly diversify to other fuels because of cost and lack of income. Similarly there are significant disruptions to the consumption of domestic goods such as refrigerators, televisions and other electrical appliances, which function majorly with electricity supply.

Given the predominant use of commercial fuels in urban areas on the one hand, and on the other, the significant contribution of cities to economic growth and development, commercial fuel scarcities have surely dampened the levels of economic activities in sub-Saharan Africa.

The effects of electricity supply interruptions are particularly severe, especially given that traditionally, electricity provided the means by which energy was reliably delivered over large distances and together with its diversified end uses in industry and households makes it an essential component of economic growth. Thus unless there is access to alternative and non-grid energy sources, the economy is forced to operate below its full capacity with adverse consequences for income and employment (Edame & Effiong, 2014).

Rohatyn's view is that the only thing keeping the U.S. economy from growing at 4% or 5 percent per year is the Federal Reserve ease up on interest rates.

For Taylor, marginal changes in tax policies could easily boost the rate of economic growth by a full one percentage point per year or more. Meanwhile**,** Barro holds that rates of economic growth are ultimately determined by (a) an economy's technological gap vis–à-vis the world's "best practice" frontier, and (b) its politico-economic institutions, viz: maintenance of the rule of law and property rights, market distortions, the extent of political freedom and monetary/inflation policy. However, in faulting Rohatyn's, Taylor's and Barro's views on economic growth, DeLong stresses that Rohatyn's view of the determinants of growth is wrong because there is no evidence that looser monetary policy over the twenty–three years since the 1973 oil shock that tripled world energy prices began the current régime of relatively slow economic growth. Some eighty percent of the variation in year–to–year real GDP growth rates is accounted for by changes in the unemployment rate and changes in the rate of labour force growth: holding all other things constant, a one percentage point increase in labour force growth over a year increases real GDP by an estimated 0.54 percent; holding all other things constant, one percentage point decrease in the unemployment rate over a year increases real GDP by 1.67 percent. "Background" growth in real GDP holding both the labour force and the unemployment rate fix has averaged 1.57 percent per year (DeLong, 1996). DeLong further points out that each dollar worth of tax cut triggered at most a dollar's worth of additional real GDP. Thus one and a half percentage points of GDP reduction in income taxes triggered, on Lindsay's (as cited in DeLong, 1996) estimates, a one – time one and a half percent boost to real GDP – an increase in the real GDP growth rate of 0.3% per year over the five years after implementation. Since the U.S. is still the world's industrial leader, there is no possibility of boosting growth by closing the technology and productivity gap because there is no gap to close.

Having observed that the growth of the American economy is slowing down, which impacts negatively both on the standard of living of the American people and on their political scene and that reviving even a part of the productivity growth slowdown will pay enormous benefits in higher living standards as well as in greater welfare directly and in changing the political climate in a way that would make better choices easier, DeLong (1996) attempts to show how different policies could affect economic growth**.** In the process he identifies one, the Solow base-line model; two, the Extended and Augmented Solow model and three, the endogenous growth theory**,** as the growth theories on which hinges the outcome of any economic growth policy. DeLong (1996) then comes up with the following conclusions, having warned, though, that one's conclusion about the ability of economic policies to affect economic growth depends crucially on which vision of economic growth one adopts. His conclusions are that: first, there is strong reason to believe that the American economy invests too little in that the persistent budget deficits are damaging and that, especially in times of inflation, the tax system is badly in tune to provide incentives for investment and growth even if one holds to the base line Solow framework, in which the economic growth rate is hard to move and successful policies with high cost-benefit ratios have little visible impact on time series of economic growth. Second, as one moves away from the baseline Solow framework the case of turning American economic policy in the direction of a budget surplus and low taxation on perspective investments becomes much stronger. In addition, the U.S. has what is considered good political and economic institutions: so there is no how Barro's argument could hold water.

Having pointed out that the Harrod-Domar growth model was incompatible with people respond to change Solow assumed that production was a function of capital and labour, as well as technology. His startling result was that growth in the long run was a function only of technical change and not of savings or investment. Saving, he stressed, determined the level of income but not its growth rate. Therefore, trying to use saving as the source of growth would run into diminishing returns as the amount of capital per worker kept increasing. So, higher savings would yield higher growth only temporarily.

In one exercise on sources of growth Solow himself found total factor productivity (TFP) growth to explain almost all of the growth in U.S. output between 1900 and 1999. This startling finding was consistent with his theoretical conclusion that technical change determined long-run growth. Ironically, some modern sources of growth accounting exercises that place themselves in the Solow tradition claim to account for much of growth with capital accumulation (where capital includes both human and physical capital). Perhaps the best known of these exercises are those of Young (1994, 1996) who found that Asia's rapid growth was no miracle at all because transitional capital accumulation explained it; and Krugman (1996) who posits that Asia's

Miracle was simply what to expect from rapid but temporary growth in human and physical capital. In addition, Blomstrom et al. (1996) find that growth causes investment rather than the other way around. Attributing growth to capital accumulation in this circumstance is fallacious, because the incentive–creating force is TFP growth. Looking at some specific examples Easterly (1998) concludes that capital accumulation does not explain the bulk of cross–country growth differences. For example, Zambia over 1960 – 1975 had an average investment rate of over 35 percent yet could only manage 0.4 percent per capita growth. Korea had an investment rate of 19 percent over 1960 – 1975 and enjoyed per capita growth of over 6 percent. Another exhibit is the former Soviet Union, where rapid growth of capital ran into sharp diminishing returns. Soviet per-capita-income growth fell to near zero in the 1980s, despite rising investment rates of over 30 percent (Easterly, 1998). According to Easterly (1998), this evidence suggests that reliance on human and physical capital accumulation alone does not necessarily yield growth. He therefore advises development economists to shift their emphasis from increasing human and physical capital investment to increasing technology adaptation, from improving investment to improving policies.

For Atkeson & Kehoe (2000) the process of development occurs across countries at different times, with some countries developing relatively early and others developing much later. Does the timing of a country's development relative to that of the rest of the world affect the path of the country's development? To answer this question Atkeson & Kehoe (2000) use a dynamic Heckscher-Ohlin model composed of a large number of small open economies. They use for each country the productive structure of the standard two-sector growth model with consumption and investment goods in which the two sectors have different capital intensities. These countries differ, however, in the timing of their development. They found out that some countries, the early bloomers, reach their steady-states before other countries, the late bloomers, begin to develop. However, late-blooming countries converge to a permanently lower level of output per capita than do early-blooming countries. This is true even though the late Bloomers have the same preferences, technology, and initial capital stock that the early-bloomers had when they started to develop. This result stands in stark contrast to that of the standard one-sector model in which identical countries converge to a unique steady state, regardless of when they start to develop.

Toman & Jemelkova (2003), attempt to pull together some of the ways in which energy might exert a significant influence on the development process. This influence may be especially important at lower levels of development, where the overall opportunity cost of less efficient energy forms and the relative pay-off to the use of more efficient forms seem especially high. Some empirical confirmation does exist to substantiate this view. However, the quantitative information generally is quite limited. They conclude that more case study work is needed to document how improved energy availability contributes in some broader way to economic development, especially at lower levels of income. Where more systematic sectoral data of reasonable quality is available, econometric analysis can be pursued, but with underlying models that make it possible to investigate a wider range of ways in which energy could drive economic progress**.** To more fully capture these effects, they suggest that general equilibrium research on the energy-development linkage also would need to be undertaken. The models need to be constructed in a way that reflects the structural and institutional realities of developing economies.

Ebohon et al. (2000) observe how the fuel-wood crisis has increased the hardship, drudgery and time involved in the collection of fuel-wood, and how it affects women. Obviously an increase in the energy efficiency and new energy carriers in cooking would alleviate this problem.

Using Bangladesh as a case study where the replacement of traditional paddy huskers operated by men, with small-scale mechanized milling operated by women, has significantly reduced the number of poor women earning income in this field, Standing (2002) demonstrates the need to analyze energy-related impacts on the poor in the ways that show the effects on women and men as, because of their different and unequal roles in the division of labour, men and women have different priorities and make different trade- offs of their time and energy.

Wilkinson (2002) bases his judgment on two case studies of micro-hydro installations in Nepal and Kenya, and finds ample evidence that when traditional sources of energy have been augmented by modern energy systems economic development will follow on condition, however, that local energy infrastructure is so planned as to have maximum impact. Wilkinson notes that electric light has permitted people to spend more time tending livestock and agriculture, which has led a number of households to produce surpluses for sale. Electric power has also contributed to building human and social capital. Both children and adults are to be benefiting educationally from the opportunity to study and hold evening classes under electric light. Over all the economic well-being has increased as a result of using micro-hydro power to develop other physical capital—the irrigation scheme—as well as financial, social, human and natural capital. In Nepal, the proliferation of village-level micro-hydro schemes has contributed to the development of a manufacturing industry, and virtually all turbines are now made nationally. There may be other outcomes that could be more readily achieved and which would have greater positive impact on livelihood, such as using the micro-hydro power to pump potable water, improving health and hence human capital. Wilkinson advises that feasibility studies must include both the design of technically feasible interventions and an evaluation of the social, economic and environmental costs and benefits before micro-hydro schemes are started.

Ferriter (1996) posits that continued economic growth in both the developed and developing worlds provides promise for the future, but, unfortunately, there exists a plethora of problems which may arise as a result of this very progress. Today's world is characterized by both a burgeoning human population base as well as markedly-increasing energy consumption intensity in all economic sectors. Although developing countries today have a per-capita consumption of 790 kilograms of oil equivalent (kgoe) as compared with the world average figure of 1447 kgoe, they are experiencing a rate of growth of energy consumption of 7.8 percent, twice the rate of world average growth. These growth rates translate to a massive increase in the quantity of primary energy consumed, and the resultant problems of supply shortages, air pollution, global climate change, and political and economic security.

Ferriter (1996) adds that in the past seven years, central and eastern European countries have passed through a difficult period of economic readjustment and hardship. Declining economic activity has led to a significant contraction of energy production and use in the region. For the last two years, however, many of these countries have begun to enjoy economic recovery. This will require a continued, sustained effort to adapt and restructure their energy sectors to lay the foundation for dynamic economic growth into the 21st century

Many of the conventional fossil energy resources are limited in supply and can be depleted in the foreseeable future. Thus sustainable development has become a worldwide vision for growth (Wu, 2003). With globalization, bottlenecks on energy supply would cause an economy to miss opportunities for profitable trade. Developing and utilizing new and clean energy resources, such as renewable energy, is a positive way to address the limitations inherent in sustainable development. Another point is that one long-term strategy to simultaneously achieve the objectives of economic development, energy security, and environmental protection is to invest in research and development in energy technology so as to achieve breakthroughs in both technology and costs (Wu, 2003). What will therefore be critical for poorer countries in achieving economic growth in a sustainable development way is access to the technologies of development catch-up, application of the managerial know-how pioneered in industrial economies and generous terms to these accesses (Duncan, 1997).

3.3.3 Energy-Economy Nexus

Morana (1997) considered a neo-classical model set in the cost function approach to estimate primary energy factor demands for the Italian economy. He uses a translog cost function specification and a co-integration theory to estimate the long-run factor share model, and the general-to-specific methodology to derive an error correction formulation for the short-run adjustment process. Later Morana (1998) used a SUTSE model embedded in a dynamic framework to estimate an energy cost share model for the same economy in an evolutionary environment. He achieved this by allowing stochastic seasonal and trend components in the long-run specification and constructing an error correction mechanism to model short-run dynamics.

For Clements & Madlener (1997), much of the short-run movement in energy demand in the UK appears to be seasonal, and the contribution of long – run factors to short-run forecasts is slight. They use a variety of techniques, including a recently developed test that is applicable irrespective of the orders of integration of the data; they find a long-run income elasticity of demand of about one third, and are unable to reject the null hypothesis of a zero – price elasticity.

Mahmud (1998) re-examines the role of energy in the manufacturing sector in Pakistan using a partial equilibrium approach. He estimates the GL restricted cost function along with the factor demand equations using Zellner’s iterative procedure. Mahmud concludes that one, higher energy prices do not seem to adversely affect investment in capital (this is in line with Atkeson & Kehoe, 2000) and two, substitution possibilities between energy and non-energy inputs are very limited and therefore energy price hikes may directly affect the cost of production in Pakistan.

Leca *et al* (Undated) found out that industry is the highest consumer of energy. Whereas industry consumes 26.7 million tons of oil equivalent (toe) of energy resources, it contributes only 35 percent to Romania's GDP. Metallurgy and Chemistry, on the other hand, consume 14 percent of primary energy resources but contribute only 2 percent to GDP. Moreover, they found out that energy intensity of Romania's industrial branches is 3.6 times higher than the industry average and 6.7 times higher than Romania's national average (Leca et al., Undated.). They concluded that: One, reduction of energy intensity which leads to competitiveness of industrial enterprises, is a basic pre-requisite of Romania's national economic policy. This reduction, they suggested, could be done by structural economic changes although structural changes are feasible only in the long-run and require major investment, and by improving energy utilization efficiency, through the provision of a reasonable level of energy services to the population. Two, that, because industrial capital is a chronic scarcity in Romania, apparently cheap but obsolete technologies and equipment may be imported into Romania: This impacts negatively on the environment, aside from low energy performances. Three, that although per capita electricity consumption is low in Romania, it is expected to double or triple in the near future by more and a wider range of appliances. Therefore, only high-energy efficient appliances should be considered and allowed into Romania's market. Four, that the installation in Romania of the technologies and equipment normally used in developed countries results in a potential reduction of the energy demand in intensity and of at least 15 percent of energy consumption for the population and Five, that the highest potential of energy efficiency is in heat and fuel–consuming processes (electricity utilization is no exception), made with performances similar to those of developed countries. They recommended that the Romanian Government should intervene in the energy sector in the areas of consultancy, energy education, subventions, and financial facilities as it is done in some other countries.

Alvarado et al**.** (Undated**)** observed that natural gas is increasingly becoming a major energy carrier in many countries. This phenomenon, they posit, may be explained by three important characteristics: natural gas is less pollutant than other fossil fuels; it is extremely abundant and widely dispersed, and dramatic technological progress has been achieved with respect to gas–user equipment, such as gas turbines.

In countries where gas is available its demand has been a gradual phenomenon and, therefore, there has been resolution of problems of technical, commercial and regulatory nature. Meanwhile, some countries are experiencing the massive and rather sudden introduction of natural gas. This has not permitted a smooth adjustment to the new situations created by the distribution and end–use of natural gas, i.e. the lack of preparation has led to the adoption of part, or compromise, solutions. Alvarado *et al.* further observed that around the mid 1970's, Chile started a process of political, economic and social reforms leading to, among other policies, total deregulation of the energy sector. This process of a massive and non-gradual introduction of natural gas in Chile raised a number of issues which needed to be addressed. These issues, according to Alvarado et al. are regulatory, contractual, dependence, financial, infrastructural, security, customer migration, national policy, and the environment (Alvarado et al.) They attributed the Chilean gas success story to one, the Chilean open economy, where fuel prices are based on international market prices and the predicted high economic growth whose consequence is a substantial growth in the demand for energy services; two, the great interest shown from the beginning by experienced companies, who were trying to find real solutions to the Chilean energy market; three, Government's pronouncement that her participation in the introduction of natural gas in Chile would be limited to regulation, and four, the massive support given to natural gas by both the public and private sectors as a result of their concern for a clean environment in Chile (Alvarado et al., *Undated*).

In 1994, the Consumer Services Information System Project completed an investigation of the relative effect of several low-income payment assistance programs on the reduction of energy consumption by households participating in the Pennsylvania Low-Income Usage-Reduction Program (LIURP). In this investigation, which questioned whether or not any direct causal relationship exists between enrollment in Consumer Assistance Programs (CAPS) and additional reductions in energy consumption, Shingler (1995) makes two findings: one, there is no validity to the view that payment assistance such as LIHEAP promotes a lack of responsible behaviour on the part of the recipient and two, there is no compelling reason not to coordinate the implementation of energy conservation programs with the receipt of payment assistance.

The results of this study have implications for the development of social theory. First, the fact that LIHEAP is not associated with increased energy consumption indicates that the receipt of payment assistance does not promote wasteful or irresponsible levels of energy consumption. This finding, combined with the fact that public assistance and other sources of income assistance are not associated with lower reductions of energy consumption suggests that theories which view low-income consumers as irresponsible and unresponsive to assistance are not valid.

Liao & Shu-Chaun (2001) report that with the development of technology gas can now be used much more cheaply in power generation, transportation and many industrial sectors, in addition to the traditional uses of gas for cooking, and heating in residential and commercial sectors. Many Island countries, the likes of Taiwan are, therefore, induced to import gas more so as its transportation cost is low. However, even though the Taiwanese government has tried very hard to encourage more use of gas through the imposition of environmental restrictions and subsidizing gas, the consumption of gas increases only slowly. The reasons for this are technological and consumption habit restrictions (Liao *et al*.). This has led Liao and others to seek out how each group of energy end – users responds to those economic, technological and institutional stimuli and to attempt to predict the substitution rate between oil and gas in Taiwan. In the process they identify three groups of end-users *viz*: power generation, residential and commercial, and the industrial sectors. They ignore the transportation sector because according to them, it does not consume gas in Taiwan. They formulate a Kaya-type model based on which they separated the impact on gas/oil consumption into a relative intensity effect, the industry structural change effect and the sector-change effect. Using the autoregressive integrated moving average (ARIMA) method, they found that gas is substituting for oil slowly in Taiwan, and that this substitution process varies from one end-user to another. They extrapolated the relative energy consumption share of gas to oil, which they found should increase from 10 percent in 1994 to 15 percent in 2000, if Taiwan's economy maintained steady growth.

The miraculous economic growth in East Asia is expected to have heavy repercussions on future energy demand and the state of the environment in the Asian region, because it is believed that energy consumption supports economic growth in East Asia. This belief led Matsuoka (1997) to carry out an "Analysis of Energy Consumption in Asia and the Environment" from which the following findings emerged: one, Japan pursues economic growth while improving energy efficiency; two, the NIES countries have achieved economic growth while improving energy efficiency and increasing per capita energy consumption; and three, China and the countries of South East Asia are supporting economic growth primarily through increasing energy consumption. In addition to the above, Matsuoka (1997) was able to one, explain per capita GDP using the ratios of income to energy consumption and per capita energy consumption as follows:

$$\frac{Y}{P} = \frac{Y}{E} \cdot \frac{E}{P} \quad \text{-----------} \ (3.15)$$

and two, to analyze per capita income using the ratio of income to pollution, and the pollution to energy consumption ratio, thus:

$$\frac{Y}{P} = \frac{Y}{S} \cdot \frac{S}{P} \text{ ---------- (3.16),}$$

Where, Y = GDP; E = Energy consumed, P = Population and S = Pollution. Matsuoka deduced that Japan was able to achieve reductions in pollutants emitted, and increases in energy efficiency with little increases in energy consumption.

The NIES and South East Asian countries achieved increase in energy efficiency and reduction in pollutants emitted with increases in energy consumption. China and the countries of South Asia are gradually increasing energy efficiency while expanding energy consumption with no change in the amount of pollutants emitted.

In a related study of the relationship between economic growth, energy consumption and the environment in Japan and China, Matsuoka came up with the following findings: one,

up till 1973, Japan's rapid economic growth was due in large part to increases in the amount of energy consumption, but after 1973 economic growth was achieved while improving energy efficiency and reducing the amount of air pollutant emissions. Two: improvements in combustion efficiency, a shift to the use of sweet oil, and the installation of de-sulphurizing equipment were important measures in reducing the amount of $S0_2$ emissions in Japan. These efforts were supported by the efforts of private companies in increasing investment in pollution-prevention equipment. Three, rapid economic growth in China in recent years has been supported by increases in the amount of energy consumed, with some improvements in energy efficiency. However, there has been little change in those practices contributing to the mitigation of the pollution problem. Although investment for the prevention of pollution continues to increase it still comprises a relatively small percentage of GDP.

Given the above, Matsuoka (1997) concludes that, China uses the most energy out of any Asian country to produce the same amount of GDP, meaning that growth is being supported in China by pumping large amounts of energy into a relatively non-energy efficient economy. Second, China emits the highest level of pollutants per unit of energy consumed and the amount of GDP produced per unit of pollutant is the lowest in Asia. Third, past economic development in China was achieved by increasing the amount of energy consumption with little progress in increasing energy efficiency and strengthening pollution prevention measures. Fourth, while China has the legal framework and administrative structures in place for improving the quality of the environment, such policies as concentrated investment in pollution prevention equipment are not at present effective. Because energy prices are held artificially low, improvements in energy efficiency may be enhanced through raising energy prices, as seen during the development process in Japan. Fifth, thermal power generation in China produces 30 times as much S0x as in Japan per unit of energy produced. This is due, in large part, to the differences in pollution counter measures in effect in the two countries. Sixth, in China around 1.78 times as much coal is used to produce a single unit of electricity for final consumption as in Japan. This is due to thermal efficiency of power generation, and quality of coal used as fuel in power plants, power transmission loss and the amount of power used in – house by power plants.

Francœur et al. (Undated) analyzed the contribution of energy efficiency, economic activity mix and weather to the evolution of energy use and Green House Gas (GHG) emissions in Canada, with a view to highlighting the relationships among them that would assist policy makers in developing effective responses to Canada's GHG emissions reduction objectives and the progress made so far in this regard. In the process, they examined the influence of key factors in energy use and emissions, expressing total GHG emissions as the sum of emissions from a number of users of energy, *viz.:* electricity generation, oil and gas production and secondary (or end-use) consumption. Their findings are that from 1960 to 1996 there was a decline in the CO_2 intensity which resulted from a shift from crude oil to natural gas used in energy demand in Canada; two, the structure, or mix of economic activity favoured a shift in the distribution of sectors towards more energy – intensive components of the Canadian economy, and that the weather also contributed to the increase in secondary energy use; and three, during the study period residential energy use decreased by over 12 percent. This change in residential energy use was largely influenced by growth in economic activity which increased by almost 12 percent. The negative energy intensity effect was the result of increased energy efficiency of buildings and equipment, improved energy management practices of the occupants as well as a decline in occupancy rates. The 11.8 percent industrial energy increase from 1960 to 1996 was occasioned by growth in economic activity and changes in the mix of activity. This shift towards more energy – intensive industries also contributed to an increase in energy use of 25 percent, and the effect of energy intensity gave rise to an increase in energy use of 1.3 percent as well. During this study period total energy used on passenger as well as freight transportation increased by 10.2 percent meanwhile the energy used for agricultural activities increased by over 9 percent.

Bentham & Romani (2009) investigate the relationship between energy demand, economic growth and prices in 24 non-OECD countries and 3 sectors from 1978 to 2003. They estimate linear and non-linear income and price elasticities, using time fixed effect to control for unobserved dynamic effects such as technological change. They also test for asymmetric responses to price changes. They conclude that: First, the income elasticity of energy demand is high and increases with income, both on the country and sector level. Second, energy demand is more responsive to end-use price than international oil price changes. Third, the price elasticity of energy demand increases with the general price level. According to them this result, driven by the residential and agricultural sectors is new to the literature for developing countries, and is consistent with the hypothesis of stronger responsiveness to high energy prices. Finally they find that including time fixed effects and, allowing for price asymmetry add little to the results.

The deregulation of electric power production and distribution appears to have come to stay in mature, as well as in developing, economies around the world. For rapidly developing economies, deregulation offers the opportunities to use foreign investment to satisfy a growing appetite for electrical energy, while mature economies see deregulation as a way to sustain a low cost supply of electric power through competitive market incentives. In this case, the shift from a regulated, guaranteed cost–recovery, poor infrastructure to a deregulation–based, cost–competitive, operating structure has profound implications on how electricity is produced, distributed and consumed, says Little (2001). In the case of an industrial company, such as a steel or paper manufacturer, where power can be as much as 25 – 30 percent of the cost of the total operation, deregulation, potentially, could translate into significant gains in improved productivity, competitive asset management and even ultimate success if power costs could be substantially reduced. Residential consumers can realize similar cost benefits if they act accordingly. In either case opportunities presented by deregulation will drive radically different thinking and purchasing behaviour on the part of the consumer.

Little (2001) sees abundant opportunities for those companies innovative and fast enough to capitalize on change even though there are daunting challenges and associated risks. One of the challenges facing traditional electricity producers and distributors is the task of leading their organizations through major cultural change; they also find themselves ill-prepared, entering competition with non-competitive generation facilities for distribution networks. Without a timely strategy, producers could easily find themselves swept away by market forces, evidenced by declining revenues, financial losses and idle facilities. Despite the uncertainties of deregulation it is possible for owners of existing generating plants to develop specific operating strategies and investment plans for competitive generation. Such strategies are one, a competitive benchmark defined by analyzing an entire distribution grid to plot competitiveness of not only individual power plants by each generation system within; two, divestment of existing markets and three, the repositioning of existing generation assets by applying technology, service, and economic solutions to the dispatchability and profitability of older, more costly facilities (Little, 2001). For instance, plant modernization programmes, featuring turbine–generation and boiler up improve plant output and efficiency while increasing availability and reducing operation/maintenance costs. Such a programme can be surgically implemented either all at once in one time cycle, or rolled out, incrementally, over several months or years. In any case, deregulation moves the facility closer to the front of the line for dispatch and ahead of competition through smaller, highly – focused investments with attractive payback periods.

"Repowering" is the process of replacing any older power stations with newer ones that either have a greater name-plate capacity or more efficiency which results in a net increase in the power generated. The efficiency and capacity are improved by means of retrofit to the latest technology. Repowering is another approach with notable potentials. It can improve efficiency by over 20 percentage points, with coinciding lead and availability while still leveraging much of the original plant assets. Repowering also offers significant benefits in reducing emissions while lowering operational/maintenance costs and it can be accomplished in a matter of months using an already permitted site.

Some of the possible benefits from employing the above strategies are increased salable megaWatt (MW) capacity, improved plant capacity factors, reduced plant emissions, improved plant heat rate, increased plant automation, reduced operating and maintenance costs, improved plant operating flexibility, increased fuel burning flexibility and increased plant availability among others (Little, 2001).

Naturally, the revolution in world power markets has an enormous impact on major suppliers of power equipment and services. In an industry already rife with over-capacity and brutal competition, major suppliers must continue aggressive investments in both new techniques and service programmes to serve the burgeoning demand for solutions and to stay competitive in their own right (Little, 2001). In the very near future, industry leadership will belong to those who are not constrained by out-paradigms, to those who embrace change as opportunity while investing in, and delivering, innovative systems that achieve the lowest cost of power (Little, 2001).

Ballut et al.(Undated) use a two–step methodology and the "MEEDE" (*Modèle d'Evaluation de la demande de l'énergie*) to investigate the impact of both economic growth and energy conservation on future energy demand in Libya. They report that the implementation of energy policies concerning energy conservation can have a significant impact on the evolution of energy demand. First, there are savings potentials in fuel cost as a result of substituting high fuel oil (HFO) and low fuel oil (LFO) for natural gas. These savings are as high as 2075 million US dollars over the entire study period for the medium economic scenario. Second, the demand for crude oil could be as high as 150 million barrels in the year 2020 for the high economic scenario case. However, this can drop to about 19 million barrels if energy management policy is adopted (Ballut et al.). Third, according to a high economic growth rate scenario total primary energy demand by the sectors could surpass 250 million barrels of oil equivalent (boe) if no energy conservation policy is implemented of which 150 million boe is crude oil, and 100 million of boe is natural gas. The potential impact of improved energy utilization efficiency on energy management can be quite significant, amounting to a reduction of this demand by 50 million boe in the year 2020 (Ballut et al., Undated). Similarly, the country's electricity generation requirements could be significantly reduced if improved energy utilization efficiency by the major economic sectors is achieved. This would amount to a 2160 MegaWatts reduction in capacity to be added by the year 2020, which is equivalent to savings in total capital investments of approximately 1700 million US dollars. Furthermore, savings in fuel cost could amount to an additional 1900 million US dollars over the entire study period. Substitution of HFO and LFO for natural gas for electricity generation could save a further 2000 million US dollars up to the year 2020.

Atkeson & Kehoe (2000) report that capital and energy are highly complementary and that capital is subject to adjustment costs. Because of the adjustment costs, the capital stock moves slowly over time in response to changes in energy prices. Since energy and capital are highly complementary in production, energy moves slowly as well. In the long run, the capital stock adjusts to permanent differences in energy prices and so does energy use.

In the Pindyck-Rotemberg model, countries with permanently higher energy prices have dramatically lower capital stocks and output, while in the putty-clay model, they do not. The response of capital in the Pindyck – Rotemberg model is much larger than that estimated by Griffin and Gregory (1976) & Pindyck (1979) in the cross section. In contrast, the response of capital in the putty–clay model is similar to estimates in those studies.

One of the economic implications of this difference is that models give drastically different predictions about the effect of an energy tax on output. Atkeson & Kehoe (2000) find that energy tax that doubles the price of energy leads to a fall in output of only 5.3%. This drop in output in the Pindyck – Rotemberg model is an order of magnitude larger than typical measure of the effects of energy taxes, such as those of Goulder (1992, 1993, 1995) and Jorgenson & Wilcoxen (1993). The drop in output in the putty-clay model is comparable to the drop shown in these studies. In the putty-clay model a large variety of types of capital goods are combined with energy in different fixed proportions. The putty – clay model delivers a low elasticity of energy use in the short run, because existing capital uses energy in fixed proportions. In the long run, in response to permanent differences in energy prices, agents invest in different capital goods with different fixed energy intensities. As a result, in the long run, energy use is responsive to energy prices (Atkeson & Kehoe, 2000).

But when simulated, both models deliver similar predictions for the evolution of energy use and energy expenditure relative to GDP. However, the difference between the models is in their cross–section implications for low capital and output response to permanent differences in energy prices. This difference in the cross – section implications of the two models stems from the different ways the models deliver the low short-run and the high long-run elasticities of energy use. In the Pindyck-Rotemberg model, capital and energy are highly complementary in both the short-run and the long run. Since capital and energy are so complementary, energy use responds a lot in the long run only if the capital does as well. In contrast, in the putty-clay model, capital and energy are highly complementary in the short run but are substitutable in the long run.

Atkeson & Kehoe (2000) conclude that in the short run energy use does not respond to energy price changes. In the long run, however, the capital-to-energy ratio changes as economic agents invest in new types of capital with different energy intensities. In the long run, therefore energy use changes with energy prices even if the capital stock does not.

The first type of new theories rejects the diminishing returns to capital that prevented capital being a permanent source of growth in Solow's model. According to this view, individuals can accumulate all factors of production. The existence of a fixed supply led to diminishing returns in Solow's model. In Rebelo's (1991) model, investing in human capital augments labour. Physical capital and labour–augmenting human capital will grow together at the same rate in the long run, preventing diminishing returns to physical capital.

In Rebelo's (1991) model, growth is a function of the strength of the incentives to invest in physical and human capital. Therefore, policy changes that change those incentives will change the long – run rate of growth. Change in saving rates will change the long run rate of growth, unlike in the Solow model where saving rates determined only the level of income not its long-run growth rate. Rebelo's model is the simplest version of what the literature calls "endogenous growth models", where growth is an endogenous function of policy incentives and private behaviour. The strong policy effects on growth that were observed in practice are evidence for this kind of model (Easterly, 1998).

Although growth was endogenous in Rebelo's (1991) models and exogenous in the extended Solow model of Mankiw – Romer – Weil, the difference between the two models is not as great as it appears. Mankiw, Romer, and Weil saw a very high share of capital when they included both human and physical capital (up to 0.8 in the Mankiw (1995) formulation). Rebelo (1991) postulated the share of capital as 1.0. The difference between a capital share of 1.0 and that of 0.8 is not so important in practice. Policy will have large level effects in the Mankiw (1995) model, which in the transition from one income to another will look a lot like growth effects of Rebelo's (1991) model.

The second type of theory saw the individuals' productivity influenced not only by their own investments, but also by spillovers from other individuals' investments. The potential for this kind of spillover is most clear when we consider the nature of technological knowledge of a public good. If the spillover effect is strong enough, then virtuous and vicious circles will form. Public policy would shift the economy from the vicious circle to a virtuous one by removing taxes on investment in schooling or by subsidizing schooling. The literature calls the vicious circle a "poverty trap" (Easterly, 1998).

In sum, Easterly (1998) concludes, there is substantial direct and indirect evidence for endogenous growth models in general and for poverty trap models of growth in particular. Policy–induced incentives have strong effects in such models. Countries that start poor tend to stay poor, because the incentives are poor.

3.3.4 Energy-Development Linkages

How GDP per capita changes with energy availability could be examined over time. The literature on energy-development contains a number of examples of the reverse relationship, that is, how energy usage is strongly driven by economic development as indicated by per capita income. While this relationship clearly is valid, the discussion highlights the difficulty in sorting out complex interactions between energy and development with simple macroeconomic relationships. In particular, drawing conclusions about the process of development from the cross section experiences of disparate countries can be risky (Ramos-Martins & Ortega-Cerda, 2003). The time profile of energy and GDP growth for today's developing countries does appear to be quantitatively, if not qualitatively, different from the past experiences of today's industrialized countries.

A better approach in principle would be the development and empirical implementation of sectorally detailed general equilibrium modeling for developing countries using a simple framework. General equilibrium considerations are increasingly being incorporated into development economics analysis (Lopez, 1994, 1998). To our knowledge, however, use of these models remains relatively uncommon; and what uses have been made of them usually focus on other parts of the economy than energy. A partial exception to this statement is the usage of international general equilibrium models for examining energy and climate change policies (Weyant & Hill, 1999). But these models tend to be highly stylized representations of the economies in question; indeed they often replicate the structures of the developed economies, including assumptions about returns to scale, and differ only in specific parameter values. This approach does not provide the right platform for assessing the questions of interest.

A third option is to develop more micro-economically oriented case studies that help illuminate the questions. Here a small empirical literature does exist. As already noted much of the energy and development literature concentrates on the microeconomics and policy issues of the energy supply side – the potential for expanding energy supplies and reducing their costs- and the policy measures that might be needed to accomplish this. Less apparently has been done to assess the broader economic consequences of such energy sector accomplishments.

To illustrate, the two excellent studies by the Office of Technology Assessment (OTA) provide valuable information on the potential importance of energy progress for economic progress (OTA, 1991, 1992). In particular, they cite figures on how much household labour time is invested in subsistence energy provision, and how energy-inefficient human hand labour is relative to even simple machines powered by external energy sources. These kinds of figures strengthen the conviction that energy progress is a key element of economic progress, especially at the earlier stages of economic development. However, the OTA reports do not supply figures on the economic value of such energy advances; their main emphasis, as in much of the other energy and development literature, is on discussing technical options for improved provision of energy services and policies to encourage that outcome.

3.3.5 Technology

New technology has, throughout the history of mankind been a key which opens the door to economic development and growth. Technological breakthroughs and their effective application cut costs, achieve higher efficiencies and above all, open up wide new options. Herein lies the strongest and safest route to affluence, enhanced welfare and enhanced competitiveness, the most robust protection against economic deprivation, inertia and decay, and, in the longer term, hopefully, the path to a transition to non-fossil-fuel and non-pollutant industry.

Precisely how individual genius has to interact with favourable economic and social circumstances to generate new and highly useful technology and how commercial and financial mechanisms can translate these breakthroughs most effectively into new machines, new industries and new markets still remains a matter of conjecture, lively debate and divided opinion. Clearly demand pressures, supply constraints and the availability of capital are significant factors.

In any analysis of the global economy or any single national economy within the global total, it soon becomes abundantly clear that there is also a very wide range of obstacles blocking or inhibiting the transfer of new technology and that there are many vested interests and rigidities which resist the displacement of old and out-of-date tools, machines, systems and practices. Indeed the harnessing of scientific and technical research worldwide brings massive economies of scale and progress to many parts of the world simultaneously. At the forefront of this progress is the energy sector (Tempest, 2003).

Goldemberg & Johansson (Undated) report that traditional methods of cooking have dismally low efficiency rates, converting only about 10 to 15 percent of the energy contained in the fuel wood into useful energy in the pot. Analysis shows that by shifting to high-quality energy carriers and by exploiting cost–effective opportunities for more efficient use of energy, it would be possible to satisfy basic human needs and provide considerable further improvements in living standards without significantly increasing per capita energy use above the present level.

With a path of development that makes use of technologies with such energy performance, energy supply need not become a constraint on development.

Putting side by side the large–scale opportunities offered by the biogas approach, and the dispersed electricity generation, Goldemberg & Johansson show the necessity and complementarity of these approaches to the overall development context. They conclude that energy use, as practised today, is indeed a serious obstacle to development and to the improvement of living standards and that improved energy end–use efficiency and increased use of renewable sources of energy would go a long way in solving the energy problems of developing countries, They suggest building indigenous human capacity, and creating a policy environment that will promote sustainable energy development and leapfrogging past old, unsustainable technologies and patterns directly to newer, more sustainable approaches .

Bracho (2000) reports that large car manufacturers like Ford and Daimler – Chrysler have invested in the firm Ballard (in Vancouver, Canada), a leader in the development of fuel cells, whose investors want to secure such novel technology for their future cars. Of course any technological breakthrough in the transportation sector will necessarily affect oil consumption, as transportation is oil's most important customer, accounting for 31% of its consumption. Despite the efforts of traditional corporations to be an active part of changes, a constellation of energy small-to-medium firms, feverishly working in new technologies and products, continue to hold the initiative in the new energy markets. In the North West of North America, for example, there are over 300 corporations operating in a wide range of areas from applied research and consulting to production.

Uiterkamp (Undated) asserts that the European energy supply system is still strongly dominated by non-renewable resources. Among Western–style regions, he posits, Europe is unusual in its relatively large dependence on nuclear energy: one third of the electricity used in the E.U. countries in 1990 was generated from nuclear power. He warns that although operating nuclear power plants produces essentially direct CO_2 – free electricity (although the indirect CO_2 production is substantial), nuclear power presents a whole range of problems ranging from siting difficulties and safety and security concerns to plant decommissioning and the handling and storage of nuclear waste. For all these reasons, Uiterkamp adds, the stage in many European countries is set for a shift away from nuclear power. In the use of fossil fuels, three trends are predominant. The first is toward more efficient energy generation. For example, present state-of-the-art combined-cycle gas turbines now produce electricity with over 55% efficiency, a substantial improvement from the 35-40% typical of classical steam power plants. Secondly, energy generation is becoming cleaner, especially as a result of implementing environmental controls such as flue gas treatment and desulphurization technology. Thirdly, there is a clear trend towards ‘de-carbonization”, implying a decrease in the specific amount of $C0_2$ emitted per unit of energy used. For example, a shift from coal to natural gas for power generation means moving from a source of 94kg of $C0_2$ per Gigajoule to a source of 56kg of $C0_2$ per Gigajoule. If we assume that the overall energy use is not increasing simultaneously, such a shift fits very well in “post-Kyoto” policies aimed at reducing $C0_2$ emissions, he concludes.

Mark (1990), reports that a most profound change in the electric utility industry could be wrought by a commercially available low-cost, efficient source of electric power from the sun. He gives examples of such forthcoming solar energy conversion technologies as the LEPCON and LUMELOID systems, which are the trademarks of Phototherm, Inc. of Amherst, New Hampshire, a public corporation (OTC), dedicated to the research, development, manufacture and marketing of these products. Glass panels and plastic sheets of LEPCON and LUMELOID respectively convert sunlight to electric power with an efficiency of 70 to 80%, at a cost of $ 0.01 to $ 0.02 per kiloWatt-hour (kWhr). The investment in one square meter of a LEPCON glass panel is about $ 250.00. It produces 500 Watts of electric power in bright sunlight. The investment then is $ 0.50/W, spread over a life expected to exceed 25 years. The investment in LUMELOID, a thin, continuously cast polymer film, including electrodes, and lamination to a supporting sheet is about $ 5/sq m. The investment cost will be $ 0.01/W, spread over an expected life of 6 to 12 months in strong sunlight.

LEPCON panels are particularly applicable to large-scale solar/electric power farms. They may be sited to produce an average of 400 W/sq m or 400 MW/sq km during the daytime, for example, in New Mexico, Nevada and similar regions where clouds seldom obscure the sun. An area 200 km x 200 km will produce 16 million MW at $ 0.01 /kWhr during the daytime hours. Two-thirds of this energy must be stored for use during the dark hours. Electric energy storage technologies are known, and are being developed, which would serve this requirement. This would be enough to supply the electric grid for the entire U.S.

Alternatively, LUMELOID sheets will be utilized by many consumers of electric power to produce their own electric power. Such sheets may be installed on roofs or building sides, and connected through an electric storage device and an AC/DC inverter to directly provide electric power for all domestic needs at a few cents per kWhr. Excess electric power may be fed into the grid and charged to the local electric company, which will provide standby power to the consumer. The existing electric power grid will be essential, however, for industry and urban use, particularly in those areas where the sunlight is frequently obscured by clouds. To totally convert the electric utility industry to solar electric power farms using LEPCON panels will require an investment of trillions of dollars over many years. The economic and health benefits to the nation will be enormous: one, lower energy costs; two, elimination of nuclear hazards; three, elimination of the need to burn coal or oil fuel, thus diminishing air pollution, and preventing a disastrous Greenhouse Effect; four, decreased dependence on foreign oil imports, with consequent improvement in the balance of trade and reduction of the federal deficit; five, a substantial increase in useful employment on a vast long-term project, which will enable a cutback in the funding of the wasteful military industrial complex and six, if the electric utility industry becomes involved, as it must, then it can benefit from the large profits to be made in this huge endeavour. To start, it must provide the funds for the R & D, manufacturing facilities and the installation of the LEPCON and LUMELOID technologies.

According to Grotz (1990) a great concern has been voiced in recent years over the extensive use of energy, the limited supply of resources, and the pollution of the environment from the use of present energy conversion systems. Electrical power accounts for much of the energy consumed. Much of this power is wasted during transmission from power plant generators to the consumer. The resistance of the wire used in the electrical grid distribution system causes a loss of 26-30% of the energy generated. This loss implies that the present system of electrical distribution is only 70-74% efficient. He posits that a system of power distribution with little or no loss would conserve energy, reduce pollution and expenses resulting from the need to generate power to overcome and compensate for losses in the present grid system. Based on the 1971 world-wide power generation of 908 million kiloWatts, approximately 207 million kiloWatts are being produced to make up losses. This results in a cost of 454 billion U.S. dollars at 5 cents a kiloWatt. The power wasted in transmission now costs over 100 billion dollars a year**.** Wireless transmission of power, if fully utilized, could save over 90 billion dollars per year. Any technology that can reduce these losses and the corresponding costs is of extreme importance.

He says the proposed project would demonstrate a method of energy distribution calculated to be 90-94% efficient. An electrical distribution system, based on this method would eliminate the need for an inefficient, costly, and capital-intensive grid of cables, towers, and substations. The system would reduce the cost of electrical energy used by the consumer and rid the landscape of wires, cables, and transmission towers. He concludes that there are areas of the world where the need for electrical power exists, yet there is no method for delivering power. Africa is in need of power to run pumps to tap into the vast resources of water under the Sahara Desert. Rural areas, such as those in China, require the electrical power necessary to bring them into the 21st century and to equal standing with western nations.

As first proposed by Buckminster Fuller, wireless transmission of power would enable world-wide distribution of off-peak demand capacity. This concept is based on the fact that some nations, especially the United States, have the capacity to generate much more power than is needed. This situation is accentuated at night. The greatest amount of power used, the peak demand, is during the day. The extra power available during the night could be sold to the side of the planet where it is day time. Considering the huge capacity of power plants in the U.S. this system would provide a saleable product which could do much to aid U.S. balance of payments.

In 1971, nine industrialized nations, (with 25% of the world's population), used 690 million kiloWatts, 76% of all power generated. The rest of the world used only 218 million kiloWatts. By comparison, China generated only 17 million kiloWatts and India generated only 15 million kiloWatts (less than two percent each). If a conservative assumption was made that the three-quarters of the world which is only using one-quarter of the current power production were to eventually consume as much as the first quarter, then an additional 908 million kiloWatts will be needed. The demand for electrical power will continue to increase with the industrialization of the world. A system of wireless transmission of power would make electrical energy available to people and nations which are not now privileged with the access to power developed nations take for granted.

Bearden (1990) laments that Western scientists still have not grasped the great potential of scalar Electro-gravitational Mechanism (EM) to utilize the phase conjugate replica, time-reversed waves, and vacuum structuring to achieve antigravity electromagnetically, engineer the nucleus of the atom in a controlled fashion, produce a unilateral thrust for propulsion without ejection of mass, directly tap and use the boundless energy of the universal vacuum, control and cure diseases electromagnetically, reverse the aging process, and rid the world of chemical, nuclear, electromagnetic and sonic pollution by our present industries and power systems. He advises that we should hasten to apply the new scalar electromagnetic principles to secure a fuller, healthier and more prosperous life for everyone, with liberty, justice, energy, transportation and health for all.

Maglich (1990) states that energy–releasing nuclear reactions involving non-radioactive nuclei (both as the reactants and reaction products), and producing no neutrons have been known for half a century. They can be divided into three classes: fission of light metals by protons, fission of light metal by 3He nuclei, which produces protons, and fusion reactions involving 3He, which produce protons. This is why these reactions have been referred to as the "proton-based fuel cycle." He refers to them as aneutronic reactions.

He defines a nuclear reaction as "aneutronic" if not more than 1% of the reactants "fuel" and reactions products "waste" are radionuclides. Their final product in all cases is predominantly helium, a non-radioactive inert gas.

Before the 1970's, no effort was made to develop a reactor based on aneutronic fuels as a power source, even though these reactions have the potential to release twice as much power per fuel weight as uranium fission. This neglect was due to the absence of the necessary technology and lack of ecological or political motivations. Owing to the absence of chain reactions, aneutronic power production has no weapon (i.e. explosive) applications hence no military interest.

Almost all energy produced in aneutronic reaction is converted into electricity, versus 33% in conventional nuclear reactors. What to do with waste heat with a space reactor is a major tentacle problem, as the waste heat is 10-15% of the total energy generated, while for fusion the figure is 67%. He lists the following as applications of aneutronic reactions: aerospace, power supply for radar and telecommunications, naval application, terrestrial applications for utilities, non-proliferation (For Thorium and some of its applications, Balouga, forthcoming, b).

Callahan (1990) observes that the current chief solar energy conversion technique is the silicon solar cell, an established technology created for the space program. Sunlight impinging upon these smooth-surfaced cells causes electrons to flow, and thereby creates direct current**.** He further observes that solar cells presently have very poor conversion efficiency (about 15%) but that the electronic wave energy converter (EWEC), which was designed for the specific purpose of collecting the sun's electromagnetic energy and converting it directly into electricity for domestic use, promises some major advantages over solar cells. He says early calculations show that EWEC may have a theoretical conversion efficiency rate of 50 - 70%, adding that mechanical flexibility appears inherent in the EWEC if the absorber elements are mounted on a flexible substrate, while solar cells often crack and lose efficiency if not mounted on a sheet-roll process - a feat of economy not presently achieved in solar cells. Callahan (1990) admits that the greatest challenge with EWEC is in coupling into the collected infrared energy, and converting it to electricity. He is hopeful that from his observations of insects and plants, there is no doubt this can be done by copying nature!

Strachan (1990) reports that he and others are now in small scale production of flexible mirrors and they have even at this present level of production achieved the low cost of $600.00 for a variable focus 300 millimeters (mm) mirror with an uncorrected accuracy of 1/6th of a wave. He gives examples of the many uses of these mirrors, *viz*: light intensifiers, thermal amplifiers, laser colimators, variable focus-cutting laser optics and, of course, telescopes. He regrets that the mirror accuracy and stability will never seriously compete with the best glass mirrors. However, he explains that the advantage of variable focus means that there are many applications not open to glass, adding that when the low cost is taken into account, there are many applications for large aperture mirrors which were simply not worth the cost of a glass mirror.

Smith et al. (1990) observe that the Stiller-Smith Engine could revolutionize internal combustion engine design, adding that the need for cleaner energy conversion and improved performance makes this engine very attractive for further study. They assert that the effective use of advanced materials, which is the primary goal of this on-going project, will make it become a leader in clean energy conversion. They warn that this engine's performance reliability and user familiarity must first be developed before large-scale commercialization can be realized. Until that time this type of engine may find application only in research fields as a test frame for materials or other engine systems. Smith et al. then summarize the potential advantages of this device as follows: increased tap/weight ratio, fewer moving parts, improved balancing characteristics, isolated combustion/motion conversion processes, improved ignition delay characteristics, reduced maintenance/downtime. These potential advantages are viewed as fundamental requirements for improvements in efficiency and in the processes relating to environmental improvements. Being lighter and smaller reduces vehicle size requirements and decreases fuel consumption rates. The utilization of some of the specialty materials *viz*: plastics, polymers, ceramics and composites, will allow for higher combustion chamber temperatures and thus the use of heavier or multiple fuels. In addition to the end – use benefits derived by the consumer using this engine, the user-transparent expenses (both monetary and environmental) of producing the engine and the fuels to operate it would be greatly reduced. They conclude that research and technology are at hand to create new concepts in internal combustion engines. To take advantage of these, re-direction of present manufacturing is required, while not demanding the retooling of a whole industry, only rethinking about the way we convert our fuel to cleaner energy.

Harris (1990) says presently we can make engines up to 70% plastic, and he is aiming for a much higher percentage in the future. The connecting rod, crankcase, the gear cases, everything but the cylinder, piston and crankshaft, are plastic. He explains that there are generally three different plastics used by Plastic Energy Technology Corporation (PETCO), Canada in building engines. The main one of these plastics is known as Feutron, a compound of reinforcing glass-fiber with polyetherimide thermoplastic resin, is actually 50% glass, in 10 mm glass fibers, which gives this plastic great strength, and is excellent against vibrations, as well as being heat-resistant to 257 degrees Celsius. There are also higher resistance factors to fuels and fuel mixtures, ability to hold tighter tolerances than with die-cast metals, resistance to structural fatigue, high durability, better noise control within the plastic and high resistance to cracks. This allows manufacturers of products that use light engines, such as lawn-mowers and chainsaws, not to have to design around the engine since the plastic is more reliable. He further explains that the current plastic engines expel almost all of the burnt gas before it can contaminate the fresh gas. Due to this greater purity, the gas can also burn more efficiently. Instead of burning at about 50% in conventional internal combustion engines it burns at 95% efficiency. This, in turn, creates carbon dioxide instead of carbon monoxide, so it is not only environmentally cleaner, but utilizes the fuel more thoroughly. This is a radical departure from the standard two-cycle engines in which it is impossible to keep the gas completely pure. He concludes that the definite advantages of plastic engines and the practicality of their applications make this a wide open field for greater advancement for decades to come. At the present time, it has been restricted to usage for portable motors rarely more than 20 Horse Power, and for the most part, no more than 5 applications will undoubtedly be explored.

Jones (1990) describes the design of a novel electric motor with unique performance characteristics. The motor was designed originally as a scientific experiment to verify certain conclusions following studies into the behaviour and properties of magnetic fields. He also describes how existing doubly excited machines such as alternators and synchronous motors can be converted easily and cheaply to direct current (DC) motors with a performance at least comparable with their conventional counterparts.

Kelly (1990) posits that the quest to develop more efficient means of producing energy has mushroomed in recent years. Continued industrial expansion worldwide, the deleterious impact on the environment of current energy systems and diminishing resources are putting extreme pressure on clean energy solutions. The ideal solution would be a low-, or even a no-power, non-polluting, unlimited resource device that could, upon mass production and deployment, keep up with the growing technology in other fields. One avenue that is being explored but without any tangible success for now, is permanent magnet motors (PMMs). Kelly (1990) explains that the PMM is, in a sense, a basically simple notion. It involves the idea of placing magnets in such a position that when they repel each other, they create a spinning motion. What still has to be solved, however, is the ability to have this create enough power to be a viable source of energy.

Mark (1990) reiterates the inherent detrimental effects on the environment and health to which humanity is exposed as a result of the combustion of fossil fuels. He notes that so far the elimination of acid rain and other pollutants has been too costly or ineffective adding that this has impeded progress on the clean up. He suggests the use of charged aerosol air purifiers for the suppression of acid rain because they are simple, low-cost and effective. He explains how these purifiers work: charged water droplets break up into submicron droplets with over 10,000 times the surface area of the volume of uncharged water droplets; this greatly increases the speed and the amount of noxious gases and particulates absorbed and reacted. Alkaline reactants may be included in the submicron water droplets to neutralize the acid in the noxious gases. The alkaline reacts with sequesters and renders harmless the noxious gases. In stationary air purifiers, chemicals of considerable value may be recovered from the reactants. He concludes with the charge that charged aerosol purifiers should be attached to every stack or chimney exhausting noxious gases.

Canes (2003) observes that although hybrid technology is being applied to buses and trucks for the most part in experimental programmes designed to learn more about operating and emission characteristics as well as economics, well over 200,000 light duty hybrid electric vehicles (HEVS or HUMVEES) have been sold worldwide within the past few years and thousands more per month are being offered with additional models on the way. He observes further that hybrid electric technology has captured policy makers' attention because it is a means to conserve on fuel to reduce emissions. Next Canes (2003) examines the economics of HUMVEES in civilian and military use, using the net present value technique. This analysis examined the private economic returns to a hybrid owner as well as the social returns, which include the value of reduced emissions. Canes (2003) then concludes that one, HUMVEES offer a proven technology that can reduce motor vehicle fuel use and accompanying emissions. However, buyers of hybrids are unlikely to secure sufficient fuel or maintenance savings to offset the incremental costs of these vehicles; two, even if the value of emission reduction was factored in, HUMVEES generally do not pay their way, a possible exception occurring when a vehicle owner highly values onboard power generation, in which case a HUMVEE may have positive economic value to its owner as well as to the community in which it is located, and three, given present and foreseeable costs of producing HUMVEES, the civilian market will be largely based on non-economic factors. However, given the much higher cost of fuel to the military than to civilians, the technology can yield savings in military applications of such HUMVEES.

Meanwhile, public pressure on automobile companies and California's "zero-emission" standards are now paying off in electric and hybrid vehicles. The good news is that these technological advances, together with e-commerce, are a peaceful path towards reducing oil dependence. High oil prices are kick-starting additional business opportunities by hydrogen, fuel cells, solar, wind, wave and biomass companies. Much finance goes into continuous improvements in resource utilization, energy storage and efficiency gains (Henderson, 2000). Henderson (2000) advises OPEC countries to leapfrog huge infrastructure costs with off–grid solar photovoltaics, wind and biomass energy – as well as access the internet directly with solar-powered radio, computerized with modems. He adds that OPEC can also take advantage of the Kyoto Accords on Climate Change (1998). These accords include the Clean Development Mechanism (CDM), Joint Implementation (encouraging cross-country partnerships in "green" technology) and Emissions Trading (ET), which commenced in Chicago and other futures exchanges to trade "credits" in sulphur dioxide ($S0_2$) and carbon dioxide ($C0_2$).

Flavin (1999) is optimistic that technologies such as these as well as others being developed, could pave the way for a profound energy transition in the early 21^{st} century more so as although the details of the new energy economy are far from certain, the broad outlines are becoming clear. He forecasts that the new economy may be highly efficient and decentralized, using a range of sophisticated electronics. The new energy system may bear the same relationship to that of the 20th century as the personal computer age does to the era of mainframes, he concludes, adding that over time, new primary energy sources namely: the sun, the wind, and other renewable sources of energy are likely to emerge and over time, hydrogen – the highest and most abundant element in the universe may become the main fuel from the 21st century, derived at first from natural gas and agricultural residues (biomass), but later produced from water using solar and other renewable energy sources. Employed in fuel cells, hydrogen could power everything from automobiles and jet aircraft to electric power plants. He then advises that for developing countries to accelerate their adoption of new energy technologies, they will need immediate assistance in building up their capacity to effectively manage their energy markets, removing the heavy subsidies to traditional fuels, as the market barriers to the new players. In this, the World Bank has a catalytic role to play: helping developing countries acquire the knowledge base the new energy era will demand, encouraging the rapid reform of energy regulation and spurring private investment and innovation. Flavin's (1999) advice that developing countries accelerate their adoption of new energy technologies is welcome yet it may need to wait a while because according to Owen (2001) and Henderson (2000) there are price and non-price issues or restraints commonly at play in developing countries. Some of these restraints which are lack of available capital for efficiency improvements on conditions similar to those for energy supply investment, the problem that investors (landlords) may get little benefit from an energy-efficiency investment in situations where the benefit is collected by another party (tenants), structural and institutional restraints to the dissemination of renewable energy and the promotion of demand-side efficiency, lack of access to information on modern energy technologies, incomplete institutional arrangements with national, state and non-state sectors, and weak institutional or human capacity to adapt new technologies or approaches once introduced, to mention just a few of them. One of the most important barriers to large-scale exploitation of renewable energy technologies is related to their relatively high initial capital cost as compared with conventional generation, transmission and distribution networks. The latter have a great advantage over the former: the latter has often benefited from loans at favourable interest rates with extended repayment periods, whereas renewable energy technologies (particularly those best suited to distributed, rather than centralized use) must raise capital privately at prevailing market rates. Although capital costs have decreased with market penetration, technological development, and economies of scale and running costs are generally relatively low, it is estimated that, under current market conditions, most renewable technologies will not be able to compete with conventional ones before the middle of the 20^{th} century. However, these financial viability comparisons are based upon costs that generally ignore environmental externalities associated with the combustion of fossil fuels. Results from the ExternE project conducted in the European Union in 1998 show that external cost estimates may significantly change the current perception about the economic attractiveness of different energy sources and has stimulated a vigorous debate on the potential exploitation of the resulting figures in energy decision-making.

Despite these barriers, however, significant reductions in energy use can be achieved by using the most efficient technologies available today. Developing countries, in particular, have the opportunity to leapfrog the stages of technology through which the industrialized countries moved, and to employ the present and next generations of energy – efficiency and other technologies. The costs of improved energy efficiency typically are more than offset by reductions in the costs of energy.

The winds of change have not been absent in the South. China reports great progress in the wind, biogas, and small hydropower plants and in the utilization of tidal energy, including endogenous technology. The former has brought about significant savings in China's use and/or imports of fossil fuels. China also manufactures final consumption products as lamps, radios and laptops that are powered by solar energy. A Japanese oil refiner, Idemitsu Kosan Company, is hoping for a brighter future as it hastened the development of its kerosene-based hydrogen cell fuel. The company planned to begin mass production in 2006 of the cell fuel for use in home cogeneration systems expected to be commercialized in Japan within this decade. It has started testing its newly developed fuel cell at a five-kiloWatt test plant. The cell utilizes technology that extracts sulphur from kerosene and then produces hydrogen from the kerosene. The five-kiloWatt cell could meet electricity demand equivalent to volumes typically consumed at a small-sized restaurant or drugstore. The fuel cell requires about 1.7 liters of kerosene when it runs at full capacity for one hour. However, the major drawback remains the cost of production as one fuel cell costs more than 10 million Yen to produce. A cell fuel cogeneration will provide electricity and hot water to homes, helping Japanese home-owners trim power and gas costs while cutting CO_2 emissions (NOG, 2010). It is reported in BusinessDay (June 17, 2008) that a Japanese firm, Honda, has produced commercially a zero-emission hydrogen-fuel-cell-powered vehicle. It is three times more efficient than a traditional petrol-powered car.

Brazil hosts the largest renewable energy program in the world: sugar cane ethanol is powering nearly 4 million cars (Bracho, 2000). India, which ranks fourth in the use of eolic (i.e. wind) energy, manufactures windmills and solar panels. India has become a power in the development of electronic software as well. The Philippines hired the services of Blue Energy, a Canadian firm, to tap the tidal energy of the straits in its archipelago. It aims at a 2 billion-dollar investment in a low environmental impact system of modern turbines, which would be the largest investment to date in renewable sources. Costa Rica has decided to end the use of fossil fuels for electric power generation by the year 2010 and has established a 15% tax on CO_2 emissions. Bracho (2000) affirms that the South might even leapfrog to occupy positions in the new energy markets and, in turn, be able to meet the growing demand and particular need of its more demographically decentralized societies. Its lesser dependence on conventional industrial facilities and today's more fluent access to modern technical information and abundance of natural resources, would be factors in favour. Nationals of oil-producing countries like Saudi Arabia, Kuwait and Abu Dhabi, who hold a colossal trillion–dollar investment portfolio in the western financial system, may perhaps also play as investors in the lucrative business of developing the South's capabilities in new energy sources (Bracho, 2000). Venezuela has abundant tropical natural resources, many of which may serve as inputs for those new energies, as well as the technological and financial resources present in corporations like DVSA.

Henderson (2000) reports that between 1998 and 2000, the acceleration of technological changes (paradigm shift) and the growth of the e-commerce sector has speeded up the growth of the energy–efficiency ratio and led to an overall increase in U.S. productivity even though there is a new thesis that the productivity gains of the new economy are just the effect of cheap oil.

Henderson (2000) further observes that in most parts of the world today, conserving a KiloWatt-hour (KWh) of electricity or fuel is cheaper than producing an additional KWh. As a result, sustainable energy development strategies need to focus on improving the efficiency of present and future energy required to provide needed energy services and still be profitable, as well as reduce emissions since less primary energy would be required for obtaining the same energy service.

However, producing the level of energy services needed in the developing world cannot be done sustainably without minor adjustments in the conventional energy system. What is required instead is a major shift away from current approaches toward new ways of providing energy services – ways that contribute to, rather than, hinder development. The technological possibilities today are considerable. Technologies that improve energy efficiency, utilize renewable sources of energy, and use conventional fuels more efficiently all have significant potential. These are the options that must be developed and utilized further in order to advance along a more sustainable energy path (Singh, 2015; Buen, 2015; Craine, 2015; Giri & Niraula, 2015; Baron & Nicholson, 2015; Jiménez & Kahlen, 2015).

Instead of focusing planning on gross supplies to the various consuming sectors, Henderson concludes, energy planners should use integrated resource planning (IRP) to identify the lowest–cost means of performing energy services. IRP includes evaluating demand and supply side technology options for achieving given energy service goals at least cost. As investments are made, there is opportunity to build higher levels of energy efficiency into the entire economy--through more energy–efficient transport systems, and improved manufacturing processes. In fact, Henderson asserts, analysis shows that by shifting to high-quality-energy carriers and by exploiting cost–effective opportunities for more efficient use of energy, it would be possible to satisfy basic human needs and to provide considerable further improvements in living standards without significantly increasing per capita energy use above the present level.

For Nadel (1997) investments in energy efficiency technologies can contribute to lower energy expenditures and new employment opportunities for residents in New York, New Jersey, and

Pennsylvania, as well as generally strengthen economic activity and quality of life. They forecast that by 2010, cost-effective investments in energy efficiency in the Mid-Atlantic states can one, reduce energy use in the region by more than 20%, thereby reducing customer and business energy bills by more than $150 billion cumulatively over the 1997 – 2010 period; two, create 164,000 jobs in the region, and three, reduce emissions of critical air pollutants by up to 24%, helping to improve environmental quality. They conclude that the alternative energy strategy would have a positive benefit for the region's air quality as well. $C0_2$ emissions, which contribute to global climate change, would be reduced by 161 million short tons in 2010, a 29% decline over baseline 2010 emissions, and energy-related pollutants such as SO_x and NO_x would decline by over 400 thousand short tons in the year 2010, also providing significant reductions over the baseline use.

In *New Technologies, New Possibilities* (Undated), it is reported that over the long run, photovoltaic (PV) technology could provide a significant proportion of both decentralized and centralized power in developing countries. For PV cells the cost per unit of output has declined steadily as volume has increased. An investment of around US $ 10 billion could create a market large enough to bring down the costs of grid–connected PV electricity to levels comparable to those of electricity from conventional sources. Although sizeable, this amount is modest in comparison to global annual subsidies for conventional sources of energy. Recently, published costs for planned grid-connected PV power projects in the US suggest a much more rapid cost reduction path.

The transportation sector, in the early stages of rapid expansion in many developing countries, is an excellent area for technological leapfrogging, more so as in all growth scenarios the transportation sector takes up an increasing proportion of the total energy demanded. This is reflective of the growth of consumer demand for transportation services that occurs as economic development progresses (Medlock & Soligo, 1998). Recent breakthroughs in fuel cell technology, for example, offer new possibilities. This technology, which combines hydrogen from onboard containers with oxygen from the air to generate electricity, makes electric vehicles possible. These vehicles generate their power source on board, have virtually no emissions and require no pollution control technology. They can be easily and economically refueled, using fuels derived from natural gas, biomass or coal. With a development path that makes use of strong – performance energy – efficient technologies, energy supply need not become a constraint on development. The combined effect of efficient use of energy, materials and structural changes as well as good decisions by those involved in the energy decision-making process offer significant opportunities for cost-effective delivery of energy services and for limiting energy growth through reduction in energy intensity.

Sokona & Thoamas (1999) believe that improving the situation of the poor means increasing their access to water and health care. This implies placing ownership of energy technology in the hands of collectives, run not by the state, but by decentralized villages, communes, rural communities, etc. Presented in the context of the collective good, the introduction of energy technologies, including renewable technologies constitutes a response to the endemic problem of poverty. It enables communities to install refrigeration in a health centre here, develop agricultural activities there, etc. But this approach, they posit, requires people's collaboration and participation. Enabling access to energy sources and technologies so that poor people are able to meet their basic needs will require, in the African context particularly, a decentralized but community–based approach in which local people participate directly in the management of energy resources, that is to say, a new and different approach to managing energy resources.

Sokona & Thoamas (1999) emphasize that such a system would operate outside unaffordable commercial energy supply and finance systems, allowing the poor to provide themselves with energy (Sokona & Thoamas, 1999). They make two suggestions: one, start with the needs of the most deprived and two, support capacity building. “To start with the most deprived” means working with grassroots groups and supporting them as they find “ad-hoc” solutions from among the range of possible solutions that present themselves in the context of projects, to disseminate energy equipment, or through integrated resource management programmes (rural and urban). Sokona & Thoamas (1999) caution that, the complex problem of energy in rural Africa calls for a combination of solutions. In effect, resolving the wood-fuel problem will not meet the growing demand for small food – based industries for example. Singular solutions to diverse problems risk missing their targets, and they multiply costs by requiring adaptation to each specific problem. Moreover, the present equation of energy and environment issues with global sustainable development brings to reflections on rural energy a new perception that is, above all, based on the notion of diversification. They conclude that this needed diversification is thematic, geographic and financial.

Messner et al. (1997) introduce an approach to modeling the uncertainties concerning future characteristics of energy technologies within the framework of long-term dynamic linear programming models. The approach they choose explicitly incorporates the uncertainties in the model, endogenizing interactions between decision structure and uncertainties involved.

Chaton (1997) constructs a model to evaluate optimal investments in thermal plants scheduled to come on stream in 2005 in Germany. He evaluates, from an economic standpoint, arguments which have, or can, push the German authorities to consider a nuclear moratorium. Chaton

(1997) then argues that a nuclear stagnation could definitely make it difficult for the Germans to honour agreements entered into in Rio, Berlin and Kyoto.

While the technological and economic achievements of the 20th century energy paradigm are desirable, that century has now come to a close – and a new paradigm is beckoning (Flavin, 1999). Decentralized energy technologies could turn out to be a less expensive way of providing both rural and urban energy – leapfrogging into the 21st century**.** Moreover, most of the mass-produced devices can be readily manufactured in developing countries. Because they, in part, substitute labour for fuel these technologies will be significantly more economical in the developing world.

Villa (1998) observes that industrialized countries have known a circular fall in energy intensity after reaching a maximum. A line linking those maxima represents thus a "true" technical progress curve for the world. He adds that after those summits, technical progress overwhelms industrial revolutions and the fall in energy intensity expresses the technical progress trend. He concludes that developing countries are yet to reach the maximum (Ramos- Martin, 2001; Ramos-Martins & Ortega-Cerda, 2003).

Uiterkamp (Undated) adds that countries which have achieved great gains in energy efficiency since the 1970s have simultaneously expanded their national economies. Moreover national governmental and collective EU actions traditionally tended to focus on issues such as stimulating energy – efficient cars, refrigerators and light bulbs, and to subsidizing home insulation and co-generation. Energy–related research and development has mostly reflected this orientation.

Reddy & Shrestha (1998) present the results of the study on the barriers to the implementation of various electricity-efficient technologies. To identify these barriers, they conducted field surveys on the residential, industrial and commercial sectors in India. The results indicate that lack of awareness, high initial cost, uncertainty of savings and non-availability were some of the major barriers. They then ranked these barriers according to their relative importance in the residential, industrial and commercial sectors.

Collier's (1997) aim of identifying the main constraints to, as well as facilitating factors for their improvements and focusing on a number of sustainability indicators, namely CO_2 emissions, energy efficiency and renewable energies, lead him to examine energy policy developments of the European Union (EU) and in five member states-Germany, UK, France, Italy and Spain.

Kalunne (2002) observes that poor households in South Africa spent a large proportion of their income on energy services, for lighting, cooking and heating their houses. He notes that by designing houses with energy efficiency in mind, the amount of energy needed to keep the house comfortable can be reduced dramatically. Relatively simple interventions like orientation for new houses or providing ceilings in existing houses can bring huge benefits to the inhabitants. Passive solar design techniques could also be put to use. This involves applying energy flow principles and climate characteristics of a region in the design, construction and management of houses, so as to achieve thermal comfort with minimal conventional energy input. Applying these principles provides a low cost or no cost intervention and is applicable in all climatic regions. Kalunne (2002) then advises that all new houses to be built should feature at least the principles of passive solar design, supplemented by installation of a ceiling and a good floor. Existing structures need to be made more energy-efficient by installing ceilings or applying insulation materials.

Over the last 15 years the application of new technologies has been having a profound effect on oil and gas exploration and development (Zampelli, 1996). Examples include horizontal drilling, 3-D seismic and advanced recovery techniques such as CO_2 injection. These and other advances are believed to have contributed significantly to the improvements in finding rates, success rates, finding costs and lifting costs which have occurred over the past decade. He posits that technology is expected to play an even more important role in resource development in the future. Though the world is endowed with a considerable volume of undiscovered oil and gas resources, recovery of significant portions of this resource base is contingent on the rate of advancement in extractive technology and hence on the level of investment in R&D for oil and gas recovery by firms in the oil and gas industry.

Frokjaer-Jensen (1990) writes on Schauberger's water implosion device. He notes that Schauberger used the bipolarity theory to explain natural phenomena such as typhoons, whirlpools, certain shell forms, the meandering of waters, and new forms of energy generators (including his leviating implosion disk, a water-cleansing device), adding that this water cleansing device, whose main function is to kill bacteria, reduces to 15% the number of Colon and faeces bacillus originally present in the water, increases its pH-value from 7.3 to 7.5, and turns biologically active any water spiraled through the implosion whirl.

Technological change is an on-going matter affecting all branches of the energy industry. The pace and extent of technological change vary, however. At the present time, the spotlight is very much upon the rapid rate of technological advance in the upstream oil industry, which has had the effect of greatly extending the lives of existing reserves, as well as lending commercial viability to exploration and production in more remote areas. Nowhere is this truer than in the North Sea, where pioneering recovery techniques have given a new lease of life to reserves which, previously, had been expected to be on a downward trend by now.

Whatever the environmental issues we face today, it is widely recognized that promoting worldwide application of environmental technologies can be the answer to such issues.

Environmental technology transfers (cooperation) can be implemented in a form of mutual cooperation between private businesses acting as a donor and a recipient. In this case the key players are in the private sector. The public sector, mainly national governments, takes on a supportive role by facilitating such transactions. Second, in the financial aspects of environmental technology transfers, the private sector can also take a greater role than the public sector, as its amount of direct investment and other capital investment is many times greater than that from the public sector. Public funds can be seed money to direct the flow of private sector funds, for example, or more appropriately to finance the areas where it is difficult for private capital to reach. Third, it is widely recognized that transferable technology needs to be extremely site-specific. Not many of the technologies prevailing in the donor's market have established themselves in the recipient's market in the same form. The key point is that the transferring technology must be adaptable to the recipient's market situation, its infrastructure, and distribution of capital and resources. This is the basis of the so-called "appropriate technology"**.** Such reasoning has not yet fully developed, but the only way to determine the adaptability of a certain technology is to examine it, sector by sector and site by site. Fourth, mere transfer of technology itself will be worthless unless it is packaged with the building of capacities to utilize such technologies in recipient countries. One quite convincing argument is that what is transferred through technology transfer is not only the technology itself but the capacity to use it. Fifth, to build a structure of national regulations and systems in recipient countries it is vital to utilize environmental technology transfers commercially feasible in recipient countries. Sufficient market demand for such technologies and products should be promoted in the recipient's market. It is often the case, however, that the demand is suppressed in the recipient's market by low energy prices, lenient enforcement of environmental regulations, and less priority placed on environmental issues among policies and measures (Seiki, 1997).

3.3.6. Other Renewable energy technologies

3.3.6.1 Thermal Energy Sources

During the last decade, technological developments and operating experiences have made many technologies (particularly those utilizing renewable energy) more mature and competitive, creating many new opportunities. What is needed now is to identify existing and potential opportunities and to design policies and other measures to capture their benefits. To take advantage of these new opportunities the following activities are needed: conducting and promoting demonstration projects to illustrate the technologies' potential and cost – effectiveness, utilizing existing markets, and building up new markets. These steps will facilitate large-scale dissemination of renewable energy technologies. In addition, continued research and development is needed to improve some technologies still further *viz*: technologies to improve end-use energy efficiency (Chawla and Pollitt, 2013), and renewable energy technologies (Neuhoff et al., 2013).

3.3.6.2 Renewables

Coyne et al. (1981) lament that Africa currently harnesses only about 2% of her renewable energy capacity, which is derisory in view of her enormous energy problems and the fact that the technologies required to harness these resources are tried and tested and readily available. These technologies, especially those relating to PV, have successfully been innovated and adapted in many household appliances, telecommunications, health facilities, water treatment and irrigation equipment. Evidently, sub-Saharan Africa cannot satisfy its huge energy demand from conventional sources alone because of the huge socio-economic and environmental constraints.

Several constraints have been advanced for the lack of progress in the area of new and renewable energy consumption despite the obvious benefits of doing so. These constraints range among technical, manpower, institutional and economic factors (Karekezi, 1994). For example cost constraints cannot be ignored as a potential limiting factor to the wider use of some of these technologies, especially at a cost–effective scale. Biomass and wind energy are cases in point where overheads and organizational structure render these technologies uneconomic at small-scale levels. Be that as it may renewable energy should be explored together with a combination of planning tools and strong fiscal policies to minimize the intensity of energy consumption. This forms the basis of this section.

Most renewable energy derives either directly or indirectly from the sun. Renewable energy now provides about 20 percent of all the primary energy people use, most of it as biomass and hydropower (UNDP, 2006). Renewable sources of energy have the potential to meet the major part of the world's demand for energy services. Technological innovations of the last decade are now ready to tap various renewable energy sources. Examples include coal and biomass gasification technology, gas turbine technology, production of liquid and gaseous fuels from biomass, approaches to handling intermittent generation of electricity, wind energy utilization, electricity generation with photovoltaic and solar thermal electric technologies, fuel cells for transportation and power generation, and hydrogen as a new energy carrier, produced first from natural gas and later from biomass coal and electrolysis**.**

Goldemberg & Johansson (Undated) discussed decentralized small–scale renewable energy systems (photovoltaic, wind and small hydro) for electricity production in Central America. They posit that these systems are benefiting a number of villages which have no hope of being linked to centralized systems in the foreseeable future, emphasizing that they (systems) have a tremendous impact on improving living conditions in small villages on isolated households, especially when combined with energy efficient end–use technology.

Bracho (2000) sees a change of corporate attitude from the "old order" to the new order. He cites Shell and B.P. Amoco, which call themselves "green energy corporations" as examples. In specific support of the above, Shell manages the scenario that by year 2050, at least half of its investment portfolio shall be in new renewable energies, based on the assumption that renewable energies shall reach full competitiveness by the year 2020.

Uiterkamp (Undated) reports that continuing research and investment programmes seek to increase the EU-wide share of energy from renewable sources such as solar, wind, hydropower and biomass from 4% in 1991 to 8% in 2005, adding that sustainable efforts are underway to achieve this goal. He argues that initiating and maintaining renewable energy supply systems has its own environmental impacts as well as socio-economic consequences. He concludes that in general, energy from non-renewable sources is needed to realize the transition towards renewables, explaining that unlike the stock-based non-renewables, renewable sources are flow-based. He warns though that because the sun is not always shining and the wind is not always blowing, adequate and effective energy storage systems are needed to maintain energy supply during night time or calm. Unlike sub soil–derived non-renewables such as oil and natural gas, renewable energy sources need space at the earth's surface. All this has spatial consequences. Uiterkamp (Undated) concludes that without an overall life-cycle assessment this policy target is more an initiative to resolve a problem of excess agricultural food crop production than a solution to an energy or environmental problem. Upgrading biomass such as wheat chaff or wood to motor fuels implies efficiency losses that can be avoided when biomass is incinerated directly to generate heat.

Sokona & Thoamas (1999) report that a return to renewable energy is often considered the solution to the energy needs of the poor who are excluded from modern energy systems.

Arguments in favour of this position from a macro-economic perspective hold that renewable energy will reduce long-term dependency on oil and lower national debts, thereby improving economic conditions and benefiting the poor. Sokona & Thoamas (1999) are of the view that this argument does not, however, take into account the high cost of renewable energy that makes it accessible only to the rich and excludes the poor in towns and rural areas. They lament that the world is faced with global solutions that absolutely do not respond at least in the short run, to the needs of the poor people. In other words, the logic of renewable energy solutions that incorporate high-tech equipment for individual users leads to a market logic, of which the exclusion mechanisms are already known, they conclude.

Mathieu (1998) stresses that recourse to renewables and in particular to bio-fuels by countries rich in agricultural and forestry resources, has sometimes been evoked during periods of tensions in petroleum markets as well as during lean agricultural harvests. He adds that the problem of efficiency of these alternative sources of energy has posed itself more or less sharply thanks to increases in the cost of oil and the price of biomass.

Macedo (Undated) shows that the production of ethanol from sugar cane to replace gasoline as a fuel for transportation on a large scale in Brazil had important positive social impacts. It helped to create higher quality jobs (some 710,000 in ten years), helped to reverse migration to large urban areas, and to increase the overall quality of life in many small towns.

For Voogt et al. (2000), the currently low share of renewables in Total Primary Energy Requirement (TPER) (1-5%) could increase to around 4 percent in 2010 and 7 percent in 2030 if large additional policy efforts are taken. Biomass and waste have the largest potential, up to 100 picojoules (PJ), (1 PJ = 10^9 Joules) in the year 2030. The potential of wind power is small, therefore only a small market share is gained. Extension of hydropower and installation of solar thermal systems and solar photovoltaic capacity is not cost-effective without additional promotion measures.

Having identified seven key drivers moving global energy use viz: (i) population growth, (ii) economic and social development, (iii) financial and institutional conditions, (iv) local/ regional/ global environment, (v) efficiency of energy supply and use, (vi) technological innovation, and (vii) access to modern energy in non-OECD area, Trindade (2003) asserts that biomass energy systems are coming back to worldwide attention. With science and technology applied to biomass resources conversion and end-use will lead to modern biomass energy systems. He uses Vietnam as an example: Vietnam remains an essentially rural society. Though the share of traditional energy - mostly wood and other biomass fuels –in total energy consumption dropped to 66 percent in 1996, it continued to be more than 3 times modern energy consumption. He adds that properly managed, wood-fuel production and distribution can be profitable and environmentally sustainable. However, Vietnam urgently needs to boost hydrocarbon resource development for two reasons. First, oil exports earn significant foreign exchange. Second, gas will be an environmentally and economically important source of energy.

Larson and Williams (Undated) pointed out that the popular idea that biomass is the poor man's oil can be radically changed by converting biomass into more desirable forms of energy (like electricity) where the prospects are particularly good. Biomass contributes about 15 percent of the world's primary energy, most of it used inefficiently as traditional energy in developing countries and causing serious indoor pollution. Now, however, technologies are becoming available to convert biomass resources to modern energy carriers such as electricity, and liquid and gaseous fuels, making it possible to use biomass much more efficiently and cleanly. Modernizing biomass will have benefits in both the rural and the modern sectors of developing societies. Biomass is also used for co-generation of heat and power in Scandinavia, the U.S. and some other European and developing countries in the forest and agricultural industries, using steam–turbine technology.

With the application of modern technology for co-generation of heat and power, the sugar cane industries in developing countries could become major power producers. In fact, the projected potential for sugar cane–based power generation in developing countries in 2027 is larger than the total amount of electricity in developing countries today. Biomass can also be used to produce liquid and gaseous fuels. Brazil is pursuing this approach in its ethanol programme, which provides about half of Brazil's automotive fuel; this programme has helped to reduce migration to large urban areas, and increase the overall quality of life in many small towns. Biomass reduces air pollution and carbon dioxide, can be grown on sustainable basis and can be converted to fuel or electricity with great efficiency. Bio-energy production also contributes to job creation. Larson and Williams (Undated) estimate that the recovery of marginal lands in developing countries with high-yield forests (energy plantations) might generate as many as 13 million direct rural jobs in developing countries by 2050 under acceptable environmental conditions. In addition, biomass has reduced Brazil's dependence on oil imports, stabilized sugar cane prices, promoted growth in the sugar cane industry, reduced automobile pollution, and contributed significantly to job creation in accounting for an estimated 700,000 rural skilled and unskilled jobs.

Geothermal energy, and mini and micro–hydropower are also important energy supply options, although they are site specific. However, the useful potential of these possibilities is less than the technical potential would suggest, because social and environmental concerns reduce the possibilities of exploiting the technical options.

In many places throughout the world there is increasing interest in developing wind power plants as a clean source of electricity. However, many electric generating companies are reluctant to install significant wind capacity because of the intermittent nature of the resource. Wind power plants cannot be controlled in the same way as their conventional cousins, and are subject to the availability of the wind itself. It is also likely that the yield from wind power plant will vary. Both of these issues can be characterized as different aspects of risk, which is becoming an important topic as the electricity industry moves toward a greater degree of competition under restructuring. To reduce the risk of depending too heavily on one specific type of generation or fuel, resource-planning techniques have incorporated methods of portfolio diversification theory. Financial option theory is also used to evaluate the relative costs of building a power plant now or building it later. Another strategy is hedging, which can consist of forward trading or contracts for differences. Applying these theories and practices to resource planning helps companies assess and reduce risks in the emerging competitive environment.

3.3.6.2.1 Wind Power Plants

Henderson & Bracho (2000) assert that whereas in the past we saw the substitution of one energy source by another but within the fossil fuels paradigm, today's energy transition means a shift from one source to several sources of renewable energy. This transition, they insist, will require action on many fronts, including energy demand and supply and implies value changes and education. They counsel that policies must be integrative, mentally reinforcing and systematic in order to ensure the economic viability of needed changes, emphasizing that what is at stake is nothing less than a change in the dominant development model, a paradigm change in the prevailing consumption, production and technological patterns. They conclude that natural gas is poised to provide a major role in the energy transition. A hydrogen-based economy, particularly related to transport is a likely development. A major trend toward micro-generation of electricity is being driven by current market forces and the requirements of climate change issues. Emissions trading in CO_2, $S0_2$, and other pollutants can smooth the energy transition, even as the Kyoto Accords are refined and re-shaped toward greater equity and efficiency.

Reddy et al. (1998) describe a successfully decentralized community-based biogas facility, for electricity generation in a rural village in South India. The electricity produced and used in high efficiency end – use equipment provides for both lighting and water pumping. The rural village story is now being replicated in many villages in India as well as in China, where its adoption at the household level is proceeding rapidly. In 1993, 5.21 million farm biogas digestors were developed and popularized as a good example of ecological agriculture with excellent results for the economy and the health of the populace.

Pearson (1996) posits that in spite of their current limitations primarily of cost competitiveness with fossil fuels in many existing situations, renewables have some potential advantages. There are some attractions to smaller-scale local systems, particularly when the necessity and desirability of large single utilities providing power is being increasingly questioned, and when, as it has shown scale economies need no longer dominate and mean that only big can be beautiful.

Little (2001) asserts that after year 2000, the world economy has become more dependent on gaseous fuels. Especially after year 2100 it is predicted to be highly dependent on hydrogen. It is a hydrogen economy and represents sustainable development.

Foley et al. (1997) report that in the hydrogen economy hydrogen is the primary energy used in electricity generation, transportation, industrial, business, and residential sectors. Use of hydrogen reduces reliance on imported oil, coal, and LNG thereby enhancing national security.

Hydrogen is a renewable resource and can reduce the impacts of energy on the environment, contributing to clean air and clean water. Hydrogen can be produced using primary energy sources such as solar power, wind, biomass, and fossil fuels, and clean air energy technology, such as photo-conversion, generation, electrolysis and re-forming. Existing technology for gas storage and transportation can be improved for use in storing and transporting hydrogen.

Renewable energies currently need government support to compete with the conventional energies although some of them are close to becoming competitive especially if external factors, particularly the control of the environment, are taken into account. Government support has been given successfully in the U.K. indirectly through the non-fossil fuel obligation and in India directly by grants and concessional credit provided by IREDA*. The problem on end-use efficiency was the different one of overcoming the market barriers, which impeded economically effective investment (Pearson, 1996)

The question now is: Do institutions have any role to play in the energy-economic-growth linkage?

3.3.7 Institutions

3.3.7.1 The role of institutions

Society is a complex organization of relationships and activities which bring together different stakeholders, who need to develop partnerships, and nurture the relationship with each other in order to develop and implement successful policies. These partnerships are not a one-time effort, but rather a continuous development.

Institutions are the humanly-devised constraints imposed on human interaction. They consist of formal rules; informal constraints, such as norms of behaviour, conventions, and self-imposed codes of conduct; and their enforcement characteristics. In short, they are the structure that humans impose on their dealings with each other. The degree to which there is an identity between the objectives of the constraints institutions impose and the choice individuals make in that institutional setting depends on the effectiveness of enforcement. Enforcement is carried out by the first party, self-imposed codes of conduct by the second party; retaliation by the third party, and societal sanctions or coercive enforcement by the state. Institutions affect economic performance by determining, together with the technology employed, transaction and transformation and production costs. If institutions are the rules of the game, then organizations are the players.

A great deal of economic research in recent years suggests that institutions are vital for economic growth and development. Typically, economists have looked at the level of economic development, as measured by per capita GDP, and found that differences in per capita incomes around the globe are closely related to differences in the quality of institutions.

To determine to what extent institutions affect economic performance, Edison (2003) developed a simple econometric framework relating the macroeconomic outcome, for each country to one, a measure of its institutions; two, a measure of macro-economic policy; and three, a set of exogenous variables. This framework allows one to consider competing explanations to have been put forward in the literature notably, the roles of institutions, policies, and geography and to assess their quantitative impact. Edison (2003) finds that institutional quality does have a significant effect, not only on the level of income but also on growth and the volatility of growth. This is in agreement with Rodrih & Subramanian, (2003) and also consistent for all measures of institutions.

Lipsey & Chrystal (1995) report that institutions are as important today as they were in the past and that almost all aspects of a country’s institutions can foster or deter the efficient use of a society's natural and human resources. They find social and religious habits, legal institutions, traditional patterns of national and international trade as well as the political climate all important. Historians of economic growth, they add, such as Paul David and Nathaniel Rosenberg, attribute much of the growth of Western economies in the post-medieval world to the development of "new institutions", such as the joint-stock company and limited liability. Lipsey & Chrystal (1995) suggest that the societies that are most successful in developing the new institutions that are needed in today's knowledge-intensive world of globalized competition will be those that are at the forefront of economic growth.

Having observed that poor countries, such as those in sub-Saharan Africa, Central America, or South Asia, often lack functioning markets, their populations are poorly educated and their technology is outdated or non-existent, Acemoglu (2003) posits that the aforementioned are only proximate causes of poverty, insisting that there must be some fundamental causes leading to these outcomes, and *via* these channels, to dire poverty. He goes on to state that the two main candidates to explain the fundamental causes of difference in prosperity between countries are geography and institutions. The geography hypothesis maintains that the geography, climate and ecology of a society shape both its technology and the incentives of its inhabitants. It emphasizes forces of nature as a primary factor in the poverty of nations. The alternative, the institutions hypothesis is about human influences that encourage investment in machinery, human capital and better technologies. Institutions not only affect the economic prospects of nations but are also central to the distribution of income among individuals and groups in society-in other words, institutions not only affect the size of the social pie, but also how it is distributed.

According to Acemoglu (2003), good institutions have 3 key characteristics: one, enforcement of property rights; two, constraints on the actions of *èlites*, politicians and other powerful groups and three, some degree of equal opportunity for broad segments of society, so that individuals can make investments, especially in human capital, and participate in productive economic activities. He concludes that the institutions hypothesis appears to be weightier than the geography hypothesis, warning though that there are no compelling reasons to think that societies will naturally gravitate toward good institutions.

Recognizing the importance of institutions in economic development and the often formidable barriers to beneficial institutional reform is the first step toward significant progress in jump-starting rapid growth in many areas of the world today. This perhaps explains why it was true that the Cantonese who moved to Hong-Kong were, by the mid- 1930's, 30 times richer than the people in China that they left behind. Clift (2003) suggests that this explanation has very little to do with the people who moved and a lot to do with the institution that they came to. In Hong-Kong, he posits, they came under British institutions that had protection of property rights, the rule of law, and all that. Even though, they did not have democratic accountability, yet they had a very effective humane government operating under British rules and institutions. And growth occurred without very many resources, including the fact that they had to buy water from the land they had left. Clift (2003) concludes that institutions make so much difference in world development.

However, Rodrih & Subramanian (2003) seem to have a different view from that of Acemoglu's (2003) in respect of the explanation of the huge difference in average incomes between the world's richest and poorest nations. For Rodrih & Subramanian (2003), geography takes pride of place being the key determinant of climate and natural resource endowments. They emphasize that geography can play the fundamental role in the disease burden, transport costs and extent of diffusion of technology from more advanced areas that societies experience. Next to the geography hypothesis comes the integration view—the role of international trade - as the latter drives productivity change and income growth, and thirdly the role of property rights and the rule of law. In this view, what matters are the rules of the game in society, as defined by prevailing explicit and implicit behavioural norms and their ability to create appropriate incentives for desirable economic behaviour. Using regression analysis, they came up with some sharp and striking results that have broad implications for development conditionality. These results indicate that the quality of institutions overrides everything else. Controlling for institutions, geography has at best a weak direct effect on incomes although it has a strong indirect effect through institutions by influencing their quality. Similarly, trade has a significant effect on institutional quality, but it has no direct positive effect on income. Geography can affect income directly as well as indirectly, through the impact on the extent of market integration or the quality of institutions. With trade integration and institutions, however, causality can run both ways.

However, while better institutions and better protection of property rights increase investment and foster technological progress, thereby raising income levels, better institutions can also be the outcome of economic development, not least because the demand for better institutions rises as countries and their citizens become wealthier.

To answer the question as to how much can good institutions boost incomes, Rodrih & Subramanian’s (2003) estimates indicate that an increase in institutional quality can produce large increases in income per capita.

Rodrih & Subramanian (2003) identify four types of institutions, namely: one, market-creating institutions, without which markets either do not exist or perform very poorly. The three other types of institutions to sustain the growth momentum, build resilience to shocks, and facilitate socially acceptable burden-sharing in response to such shocks are two, market regulating – namely those that deal with externalities, economies of scale and imperfect information ; three, market stabilizing, namely those that ensure low inflation, minimize macroeconomic volatility and avert financial crises. Examples include central banks, exchange rate régimes, and budgeting and fiscal rules, and four, market legitimizing: namely, those that provide social protection and insurance, involve redistribution, and manage conflict. Examples include pension systems, unemployment insurance schemes, and other social funds.

They observe that no fewer than 15 sub-Saharan countries grew at rate exceeding 2 – 5 percent a year before 1973. But, because of weak domestic institutions, few of them, if any, were able to withstand the effects of the oil price increases and other macro-economic shocks in the 1970's, so growth declined sharply in the subsequent period. Indeed, there is growing evidence that desirable institutional arrangements have a large element of context specificity arising from differences in historical trajectories, geography, political economy, and other initial conditions. They sound a note of warning, though: institutional solutions that perform well in one setting may be inappropriate in a setting without the supporting norms and complementary institutions. In other words, institutional innovations do not necessarily travel well.

Indeed, while measures of democracy do not always explain which countries grow faster or slower over selected periods of time, they do explain long-term income levels, that is, while it is possible that growth spurts can be achieved with different political institutional arrangements, as the experience after World War II confirms, it appears that sustaining such spurts and transforming them into consistently higher standards of living are facilitated by democracy.

Some researchers believe that the strong role of history and geography in shaping institutions does mean that current policies have little impact and the trajectory of human development is predetermined.

One indicator of institutional quality is the index measuring the constraint on the executive branch of government. How institutional changes can be effected is a difficult question but that institutions can change and that they have a long lasting impact on development should not be in doubt.

3.3.7.2 Institutions and Income level

Todaro & Smith (2003) say that research found that institutions have a statistically significant influence on economic performance, substantially increasing the level of per capita GDP. These findings hold whether institutional quality is measured by a broad–based indicator or by more specific measures. Furthermore, the empirical results take into account the possibility of reverse causation. These results suggest that economic outcomes could be substantially improved if developing countries strengthened the quality of their institutions. For example, an improvement in sub-Sahara's institutions from their current average quality to that of developing Asia would represent an 80 percent increase in per capita incomes in sub-Saharan Africa from about $800 to over $1,400. These results provide empirical sense of the importance of institutions for economic development.

If institutions provide the incentive structure of an economy then the productivity of an economy is a function of both the technology employed and the institutions within an economy.

Surely the cataclysmic events of the past decade in Central and Eastern Europe should have convinced even the most dedicated neo-classical economists that institutions matter, and more important, they must be integrated with the classic sources of productivity change if we are to understand the long-run and the short-run performance of economies. In underdeveloped nations, it is equally true that even with the economic opportunities for self employment, still, in the absence of proper institutional and structural arrangements development may not succeed (Todaro & Smith, 2003).

The immense productivity increase resulting from the technological developments of the past century and a half could only be realized by fundamental changes in the institutional and organizational structure and the consequent tensions induced by the resulting societal transformation have resulted, and are continuing to result, in politically-induced fundamental changes in the institutional structure to mitigate these tensions**.** Institutional changes have been, and continue to be a fundamental influence on productivity change.

The kinds of skills that will pay off will be a function of the incentive structure inherent in the institutional matrix. [If the highest rate of return to the society is piracy, for example, then organizations will invest in knowledge and skills that will make them better pirates. If the pay-offs are highest for firms and other organizations that increase productivity, then they will invest in skills and knowledge to achieve that objective]. The resultant institutional matrix imposes severe constraints on the choice set of entrepreneurs when they seek to innovate or modify institutions in order to improve their economic or political positions.

But change is continually occurring although the rate will depend on the degree of competition among organizations and their entrepreneurs. As entrepreneurs enact policies to improve their competitive positions, the result is alterations of the institutional matrix, therefore revised perceptions of reality, and therefore new efforts by entrepreneurs to improve their position- in a never-ending process of change.

Perceived reality produces a set of beliefs, which produce in turn, a set of institutions and policies, and then as a result of those policies, alter reality and therefore revise beliefs, and on, and on, in a continuous change. Evolving institutions have altered the payoff so that it pays to cooperate.

This process of cooperation requires that not only economic institutions be altered but political institutions be altered as well. This is because as the size of the market grows beyond some limit then reputation mechanisms and other devices that have traditionally been used to enforce cooperation become ineffective. It requires that there be third party enforcement, and that means the state.

The real problem is to be able to find some way to, at the margin, modify or alter the way the game is played, so that gradually and incrementally, a country can move in the direction of getting institutions that work better. That is hard to do, and it means that you must understand the kind of mind set, institutions and belief systems that exist in the society in order to be effective at even beginning to modify.

Edison (2003) looked at the role of institutions in economic growth. Just as with the level of per capita GDP, the results indicate that institutions have a strong and significant impact on per capita GDP growth. This impact may partly reflect the role of institutions in enhancing the sustainability of policies. On the average, improving institutional quality by one standard deviation –corresponding roughly to the difference between institutional quality in Cameroon and the average quality of institutions in all countries in the sample -- would lead to an increase of 1.4 percentage points in average annual growth in per capita GDP. Again, the empirical results suggest substantial gains. For instance, annual growth in per capita GDP in sub-Saharan Africa would increase by 1.7 percentage points if countries there had institutions as good as the average quality for the entire sample (Edison, 2003).

The results also indicate that institutions have a strong effect on volatility. The better the institutions, the lower is the volatility of growth. In addition, the impact of institutions appears to be significant even when policy measures such as difference in inflation, exchange rate overvaluation, openness, and government deficits are controlled for. The results suggest that an increase of one standard deviation in the aggregate governance index measure would cut volatility by about 25 percent. For example, if institutions in sub-Saharan Africa were as good as those in the average country in the sample, countries in that region would experience a 16 percent reduction in economic volatility.

3.3.7.3 Institutions and Policies

In each country economic activities, irrespective of the degree of economic liberty, are organized by a system of laws, including economic law, property law, enterprise law, etc.

The activities of the government and other economic institutions designed to influence the level and distribution of social products are called economic policy. In economic policy, it is possible to distinguish four main areas *viz*: order policy, business conditions policy, distribution policy of the state, and structural policy (Michna, 1997).

When institutional and policy variables are considered together, institutions are found to be the dominant influence on economic performance, with policies having little independent influence.

The correlation between institutions and policies points to the fact that sound policies need to be supported and sustained by good institutions, meanwhile weak institutions may reduce the chance that good policies will be adopted or may undermine policy effectiveness. The bottom line is not that policies are unimportant but that their influence on economic performance is already reflected in the strength of institutions (Edison, 2003). To illustrate: it would be wrong and impracticable to try and prevent the economic development of the developing countries, which in any case on their own, lacked the resources and the administrative structure and skills to implement major programs to restrain emissions.

3.3.8 The Role of Government in the Economic Process

Given its importance for the economy as a whole, the energy sector has a traditional history of government involvement in the economy. Governments intervene in the energy sector for a number of reasons and with a variety of ways. Many instances and types of intervention are explicitly intended to support energy policy goals and are specific to the energy production and supply industries or to the use of energy. Other actions, designed to support broader economic and social objectives, also affect the supply and the use of energy among a range of goods as a practice. Because energy is an essential input to most economic and human activities almost all government actions impinge on the energy supply and demand in some way.

There is a vast range of measures governments use in pursuit of energy policy goals. These measures can be broadly classified into five main groupings: economic and fiscal instruments, trade instruments, government administration, management and ownership, energy sector regulation, energy research and development.

Governments can use these measures to tax or subsidize the use of energy sources and through these actions, encourage or discourage these fuels (Cluver et al., undated). Two energy policies then emerge: One, for developed countries with high standards of living and reasonably stable populations, and a second policy for the developing and poor nations.

In the developed nations, major problems/challenges associated with energy consumption revolve around pollution, global warming, and traffic congestion. In these countries it would make sense that petroleum fuels be taxed heavily and the use of nuclear power and gas encouraged at the expense of coal and biomass. Some of the petroleum tax revenues could be used as aid to the developing countries.

In his discussion on institutional policies Suarez is very critical of the current environment in which governments and international organizations are promoting privatization, deregulation, and “indiscriminate access to other countries”. He admits, however, that it is well known that heavy government subsidies to conventional sources of energy in many countries, is one of the obstacles to a sustainable energy strategy. Because subsidies make it harder to introduce energy efficiency and renewable sources of energy such subsidies are likely to be reduced in a more competitive market economy.

For Lipsey & Chrystal (1995) government needs to provide the framework for the market economy that is given by such things as well-defined property rights secure from arbitrary confiscation, security and enforcement of contracts, law and order, a sound money, and the basic rights of the individual to locate, sell, and invest where and how he or she decides. Moreover, governments need to provide infrastructure. For example transportation and communication networks are critical to growth in the modern globalized economy. Some of these facilities, such as roads, bridges and harbours, are usually provided directly by governments; others, such as telecommunications, rail and air services, can be provided by firms, but government regulations and competition policy may be needed to prevent the emergence of growth-inhibiting monopolies in these areas. General education, trade schools, and other appropriate institutions for formal education as well as policies to increase on-the–job training within the firms are required for the creation of appropriate factors of production, critical to creating comparative advantages in products that can be exported. Other possible government policies include favourable tax treatment of saving, investment and capital gains, research and development, tax incentives and funding assistance, and policies to encourage some fraction of the large pools of financial capital held by pension funds and insurance companies to be used to finance innovation (Lipsey & Chrystal, 1995).

Two examples of government intervention in the energy sector follow: one, the region of Brussels – capital of Belgium- has adopted what appears to be one of the most generous acts of legislation in the world to ensure a right to a minimum of electricity for low-income households (Wooden, 1997). Two, a radical new strategy for dealing with the problems of energy and the environment in the Sahel is being implemented in Niger Republic. Rather than have urban wood traders go into the countryside to cut the wood and truck it back to the cities, the government is giving village communities control over their natural woodlands in return for a commitment to manage the woodland and the production of fuel wood sustainability. Foley et al. (1997) give details of the rationale, history and prospects of this innovative energy strategy describing local physical and socio-economic conditions, with particular attention to the "tiger bush" that forms much of Niger's natural woodland. They conclude that if this strategy can be expanded, it will have potential for replication over much of the Sahel and other countries in sub-Saharan Africa.

Lee (2003) reports that the Korean government supported an approach to set targets in terms of emissions growth, given a desired rate of economic growth, and that Korea would participate, on a voluntary and non-bounding basis, in a régime of limiting green house gases (GHGs) formulated along those lines. Lee adds that government policy actions aimed at improving energy and materials efficiency in various sectors of the Korean economy and stimulating fuel substitution in the energy system**,** include measures to promote fuel-efficient vehicles and improve overall efficiency through development of environmentally-friendly transportation and distribution infrastructure, the tightening of automobile fuel efficiency standards to stimulate technology development for energy- efficient transportation. Policy actions which aimed at bolstering industrial activity that has been the backbone of the export - driven economic development of Korea include measures to improve energy efficiency in buildings and dissemination of district heating and small co-generation, the provision by government of R & D funds for energy conservation technology development, and the sponsoring of technology seminars and awareness campaigns to promote energy-efficient technologies. In addition to increases in nuclear and LNG – powered electricity generation, the government also plans to increase renewables–based electricity generation. These will be mostly for remote area power service through wind power or PV sources.

Lee concludes that because these policies are inappropriate as measures addressing climate change problems the new system that will be based on climate–friendly technologies will provide a platform for sustainable development for Korea (Lee, 2003).

Much empirical work has been done on the linkage between energy consumption and economic growth. Some of it is summarized in the next sub-section.

A review of additional empirical works on the energy-economy nexus follows in the next section

3.3.9 Empirical evidence on policies and growth

All of the growth models discussed above predict that national economic policies will have a more or less strong effect on economic growth. Government policies in the augmented Solow model with a high share of capital will affect strongly the level of income. During the transition from the old to the new levels, this will imply growth effects. Policies will have a direct effect on growth in the Rebelo model in which human and physical capital accumulation responds to policy-induced incentives. In the poverty trap models, policy can raise or lower the threshold of initial income below which a poverty trap forms, as well as affect the rate of growth of countries that have the poverty trap.

There is empirical evidence in support of these predictions. Here is a list of policies that each by itself goes with an increase of one percentage point in growth:

- A 1 percent increase in the stock of infrastructure is associated with a 1% increase in the GDP across all countries (World Bank, 1994).

- Increase of 1.2 years in average schooling of labour force.
- An increase in secondary school enrolment of 40 percentage points
- A reduction of 28 percentage points in the share of central bank credit in total credit.
- An increase of 50 percentage points in financial depth (M2/GDP).
- An increase of 1.7% of GDP in public investment in transport and communication.
- A fall in inflation of 26 percentage points.
- A reduction in the government budget deficit of 4.3 percentage points of GDP.
- A fall in the black market premium on the exchange rate of 36 percentage points.
- An increase in openness, i.e. (export + imports) /GDP, of 40 percentage points.
- A fall in government consumption/GDP of 8 percentage points.
- An increase in foreign direct investment/GDP of 1.25 percentage points (Easterly**,** 1998).

First, there are many theoretical models that show policy-causing growth, but perhaps, there is no model in the literature that shows growth-causing policy. Second, the literature has used statistical methods to try to resolve causality. King & Levine (1993a) use the initial value of financial depth to predict growth over the next 30 years. Levine (1998) uses the legal system as an instrument for financial depth and still finds a strong effect of financial depth on growth. Easterly (1998) remove any third factors by regressing growth changes, as well as instrumenting for the latter with initial values. They still find strong effects of variables such as openness and government consumption and other policy variables.

What policies might boost economic growth and by how much might they boost it? Answers to these questions depend on the underlying determinants of economic growth: different visions of growth produce different conclusions about which policies can boost growth, and by how much. However, the base-line vision of economic growth is that set out by Robert Solow in the 1950s. Solow's vision can be summarized in the statement:

$$y/L = \alpha\ [(Y/k)\ (1\text{-}\delta)\ \text{-}l] + \tau \quad \text{-----} \quad (3.15)$$

Where y/L is the rate of growth of GDP per worker; k is physical capital stock; l is labour force growth rate; δ is depreciation of physical capital stock; τ is growth in technology; α is "share" of national product that is earned by owners of capital, and Y/k is output-to-capital ratio. This Solow model tends to produce pessimistic conclusions about the ability of anything except for raw improvements in "technology" broadly understood to boost economic growth. Because the capital share parameter α is relatively small, boosts to investment are not that effective at boosting GDP per worker growth in the short run. Because increases in investment decrease the output–to–capital ratio, in the long run such increases have had even smaller effects on economic growth (DeLong, 1996).

Economists have no consensus view of economic growth. The modal view is most likely the view set out by Mankiw, Romer, and Weil (1992)**,** whose version is the extended version of Solow's model, *viz.:*

$$y/l = \alpha\ [(y/k)I - h - 1)] + \beta\ [(H/K)E - \delta_h - 1)] + \tau \quad \text{------} \ (3.16)$$

The above model is extended in two ways. First, it allots a powerful role to "human" capital (and to the share of national product devoted to investment in education (E). Second, the Mankiw - Romer - Weil (1992) vision has higher values for the parameters α and β that govern the returns on investments in physical and human capital: α is in the range of 0.45 or so; β is in the range of 0.25 or so (DeLong, 1996).

These differences combine to give shifts in policy significantly larger effects on growth than in the Solow framework. The differences spring from two sources. The first is that the addition of "education capital" increases the importance of accumulation in economic growth and slows down the approach of diminishing returns. The second is that Mankiw, Romer, and Weil's (1992) estimates of the parameters of the production function come from an examination of cross – country economic growth, and suggest a considerably larger return to even investment in physical capital – than did the Solow framework.

The most optimistic version of the potential impact of policy on growth of all goes several steps beyond Mankiw–Romer–Weil (1992) in playing up the pervasiveness of economic "externalities" and their role in economic growth. The most powerful exponent of this view is Paul Romer. It goes under such names as "new growth" or "endogenous growth", and is made up of a number of different and inconsistent strands.

The optimistic version begins by noting that the main engine of growth is and has been the advance of economically useful knowledge: better ways of using machines, better ways of organizing production and communications, and better ways of using natural resources.

Using an evolutionary model of growth in which agents choose to allocate their time between private and social activities Antoci et al. (2001) argue that a shift from social to private activities may foster market-based growth, but also generate poverty. They use a game theoretical analysis of the evolution of social participation and a model of dynamic accumulation of its effects on the social environment. Antoci et al. (2001) then show that growth and well-being may evolve in opposite directions (a plausible outcome for advanced and affluent societies). For Ayres & Van den Bergh (2003) a new approach to growth theory involves at least two modifications of the conventional theory. First, to explain endogenous growth it must reflect the existence of self – reinforcing feedback mechanisms or "growth engines" apart from population growth and the traditional savings-investment-capital accumulation mechanism. They argue that the knowledge accumulation mechanism proposed by various versions of endogenous growth theory is one candidate, but not the only one. The role of learning and "experience", as well as the role of declining natural resources (notably fuel prices), as drivers of past and present economic growth, need to receive attention in formal models of economic growth. Second, a modified growth theory should explicitly reflect the fact that important (i.e. scarce) factors of production in economics can and do change over time. When renewable natural resources were perceived as available without limit they could be regarded as intermediate products of scarce labour and scarce produced capital. However, in the future as growth continues, both renewable and non-renewable natural resources may be scarce and limiting, and increasingly so, whereas unskilled labour and produced capital will be plentiful and increasingly so. They find fault with the Neo-classical one-sector growth model, leading to the formulation of the New Theory of endogenous growth, by Romer. They then present another alternative view on economic growth. Finally, they incorporate three feedback mechanisms to the theory of economic growth, as follows:

3.3.9.1 The Resource Use (Fossil Fuel) Growth Engine

Economic history suggests a quite robust energy-growth feedback (EGF) relationship (Ayres & Bergh, 2003). This resource–driven feedback mechanism for growth can be described as follows: technological progress has made fossil fuels steadily and dramatically cheaper and more convenient to use since the early eighteenth century. This, in turn, encouraged the substitution of fossil fuel-derived energy and mechanical power for work by humans and animals. It also had a powerful impact on metallurgy – especially the smelting, refining and working of iron and steel.

Both cheaper fuels and better metal made it possible to construct better, cheaper and more efficient machines, including steam engines and machine tools. This, in turn, permitted continuous and drastic further reductions in the cost of mining and transporting coal (later other fuels), and the delivery of mechanical power to users, including the coal mines and the transport systems themselves. This, according to Ayres & Bergh (2003), constitutes the early form of the EGF cycle.

Conceptually this cycle consists of two separate elements. First, economic growth since 1800 has been driven to a large extent by utilizing machines (steam engines, internal combustion engines) powered by fossil fuels as a substitute for, and multiplier of, human and animal labour. Second, the extensive use of fossil- derived chemical fertilizers and pesticides on farms is another, more recent, technique of increasing productivity by using less labour. Naturally, as labour costs fall due to the economy using more and more natural resources, economic growth is stimulated, resulting in a further increase in the overall use of raw materials and fossil fuels**.** In other words**,** a positive feedback mechanism is operative. It should be noted, however, that this growth mechanism must falter and eventually become scarce and prices of materials and energy derived from them will start rising.

The other key element of the EGF is innovation and the creation of new commodities and products, some from the fossil fuels themselves, and some from other material resources. Coal itself became a commodity to compete with, and eventually replace, charcoal. Coke and coke oven gas followed as commodities. Electric power is now a commodity. The same kind of thing happened later when petroleum was exploited at first to provide an alternative to whale oil for illuminating purposes (oil lamps). Gasoline was a refinery by – product, used only as a cleaning agent at first. Of course, heating oil, diesel fuel, lubricants, petrochemicals, plastics, synthetic fibres, and numerous other products were developed over time to exploit the raw material more fully. The development of internal combustion engines and self-propelled vehicles has followed the availability of low-price fossil fuel energy.

It should be emphasized that the feedback cycle is not merely a particular form of learning – by – doing, nor is it fundamentally attributable to scale economies, although both learning and scale are obviously involved and can reinforce it. One of the two key elements of the cycle is the availability, at ever-lower costs, of fossil fuels, initially coal, and subsequently petroleum – and natural gas or nuclear energy. These are, of course, material resources. But they differ from other resources, such as construction materials, in that they are not embodied in products (except plastics and synthetic fibres). They are entirely consumed for the purpose of generating heat, mechanical power or (a slight generalization) electric power.

A growth theory that includes the EGF cycle can address several new questions, viz: to what extent was past economic growth dependent on the exploitation of this form of capital? To what extent is current and future growth still dependent, directly or indirectly, on fossil fuels? Is there another possible feedback cycle "growth engine" that could replace it in the future?

3.3.9.2 The Salter Cycle Growth Engine

A second mechanism for driving economic growth by reducing costs became increasingly important in the 19th century. Scale economies, standardization, division of labour by specialization and 'learning by doing' were important in all kinds of manufacturing. Once again, cost reduction encouraged demand growth and vice versa. This has been called the "Salter cycle". Of course, growing demand for manufactured products implies increased consumption of raw materials of all kinds. It is important to emphasize that the scale – learning mechanism, by itself, is unable to generate perpetual experimental growth at a constant rate. The reason is that costs decline in relation to output at a declining rate, and demand increases in relation to prices at a declining rate. To maintain a constant rate of growth, therefore, it is necessary to postulate a product mix that changes and evolves (becoming more complex, for instance) with a continuously increasing price elasticity. Up till now businesses have been quite successful in fostering such a process via product innovation and marketing (shape, fashion, packaging, etc.)

It would seem that economic growth in the industrial countries, at least until recently, has been driven primarily by a combination of these two feedback mechanisms. What does this approach then say about the relationship between environment, resources and growth?

Economic activity is very materials-intensive at present, which is partly related to the fact that economic growth has been very tightly linked to natural resource extraction and use. However, neither the resource-driven growth nor the scale–driven mechanism is sustainable for the indefinite future. This is partly because the natural resources themselves are bound to become scarcer and partly because the resulting pollution is becoming increasingly intolerable. The need for dematerialization therefore naturally presents itself.

3.3.9.3 The Value Creation or "Dematerialization" Growth Engine

Value creation is the third growth mechanism essential to permit sustainable future economic growth: Resource productivity and labour productivity at the expense of consuming ever more natural resources. The mechanism for achieving this result can only be to add value to, and extend the useful life, of durable products while simultaneously reducing use of fossil fuels and other disputative intermediates. This strategy can be characterized as "dematerialization"; it also includes reuse, renovation, re-manufacturing and recycling at various levels. This is tantamount to substituting man-made "useful" information for natural resources. Macro-level dematerialzation may result from lighter products, miniaturization and new technologies (computers and information technology), and sectoral shifts to services. The latter may go along with demographic and life–style changes. Through these processes, the economy will automatically focus on the production of final services rather than material. It will then be natural for managers to develop means for delivering services with the minimum possible requirement for material and energy inputs.

Of course increased useful lifetime by means of repair, renovation and re-manufacturing, will necessarily sacrifice some of the advantages of mass production. These activities are inherently more labour-intensive than capital-intensive, which may seem, at first, like a disadvantage from the perspective of labour productivity. But if more labour is needed for each machine or other material product in service, where are macroeconomic gains? Part of the answer is that repair, renovation, and re-manufacturing not only reduce the losses of primary extractive raw materials but also reduce the loss of value previously added to materials by prior production processes. In other words, the dematerialization and recycling mechanism sharply reduces the rate of depreciation of duration goods and physical capital. This is a real macroeconomic benefit, because depreciation means a significant loss (or cost) to the economy. But cutting back depreciation does not *ipso facto* generate new demand in some other way. The obvious (and probably only) mechanism for doing so is via accelerated technological innovation in the service sector. This mechanism is very similar to the one that Romer (1986) has proposed, except that there is no need for new knowledge to be published. Spillovers can, and usually do, occur at the product level, e.g. lasers have facilitated unexpected applications in eye surgery, printers and a host of other sectors. We are now seeing this cycle process operate in the domain of information technology. We may see it soon in bio-technology, it may then affect both recycling/reuse and dematerialization.

Ideally, one might think that a complete growth model should reflect each of these feedback effects explicitly, and independently of the others. However, this is easier said than done. For instance during the early phases of the industrial revolution there was a very strong interaction between economies of scale and learning in the manufacturing sector and the cost of energy/power and similarly for the cost of metals (iron and steel) and machinery. This generated a new technology (railroads and steamships) which cut costs of transport dramatically and promoted trade. There was virtually no R & D in the modern sense, until the last third of the 19th century, (Ayres & Bergh, 2003). Before that, R & D was indistinguishable from the cost of capital equipment, and essentially all of what we would call R & D went into improving production processes. Resources were not devoted to consumer product development until the last two decades of the century, beginning with the telephone, bicycle, automobile and a variety of household kitchen appliances. The point is that some of the most important feedbacks of the early industrial revolution may no longer be quantitatively significant, because of structural change. Yet a simple single–sector model must allow for all possible feedbacks but cannot distinguish between sector specific mechanisms.

In sum, economic growth must be accompanied by structural change, which implies continuous introduction of new products and new production technologies, and changes in efficiency and dematerialization, and when an innovative new product or service is introduced it stimulates a competition among followers and initiators to find the best technical solution**.** Now how are the impacts, if any, of energy consumption on the economy measured?

In order to measure the effect of energy consumption on the economy, the change in growth of GDP over long periods in a country and also between countries for the same period are compared (Cluver et al., undated).

3.3.10 Energy and Industrial Progress

Schurr (1982, 1984) begins his argument on the potential for positive synergy between energy development and broader economic development for industrial societies by noting some apparent paradoxes in income, energy, and productive statistics for the U.S. From roughly the end of World War I to the first oil shock in 1973, the U.S. economy experienced both substantial increases in overall productivity and a drop in energy intensity; moreover, the drop in energy intensity occurred during a period of stagnant or falling energy prices. This combination of circumstances seems paradoxical because one would expect productivity increase to be stimulated in part by substitution of machines and energy services for labour, and because energy intensity should not be falling (other things being equal at least) under the conditions observed for energy prices.

Part of the explanation for the figures is to be found in changes in the composition of economic activity toward less energy-intensive goods and services, and an increase in the thermal conversion efficiency of energy in the economy. But Schurr (1982) argues that this is only part of the story. Energy use rose relative to labour and capital but not relative to output. The energy intensity of output fell because of technical advance throughout the economy that accelerated output growth.

The last and most critical part of Schurr's (1982) hypothesis is that the productivity increase for other factors was in turn partly the result of the changing energy picture in the U.S. economy. Because of increased use of more flexible energy forms (liquid fuels and especially electricity), "…the discovery, development, and use of new processes, new equipment, new systems of production, and new industrial locations" was enhanced (Schurr, 1984). Even though energy use rose relative to labour and capital, the effect of increased use of flexible energy forms through greater productivity of other factors was large enough, so much so, that energy intensity of output fell. Schurr (1984) provides a more detailed illustration of the argument in the context of the electrification of the U.S. manufacturing and broader productivity benefits provided by electric motors.

Schurr (1982) also adds a few remarks concerning the relevant trends after 1973. During this time higher energy prices stimulated great increases in energy efficiency and therefore in measures of energy productivity (these trends later abated somewhat after the drops in energy prices experienced from the mid-1980s). At the same time, overall economic productivity stagnated or even declined. Schurr (1982) suggests that while there is need for further exploration of the many relevant interconnections linking energy and the economy, the possibility of reduced overall productivity as a consequence of higher energy costs must be considered.

Jorgenson (1981, 1984) addresses both the pre-1973 and post- 1973 energy-economy links through more formal econometric analysis of 35 U.S. sectors. Jorgenson uses a trans-logarithmic dual function approach that emphasizes relationships among factor prices, factor shares, and the overall technology level of a sector as represented by a time proxy. A five-input model is used: capital, labour, electricity, non-electrical energy, and materials. By dividing energy in this way, Jorgenson seeks to isolate the special role that electrification may have played in industrial productivity advance. The model incorporates a time index as a proxy for technical change but it does not incorporate capital stock adjustment dynamics.

A key concept introduced by Jorgenson is the extent to which productivity growth is electricity-using**.** Electricity-using productivity growth is observed when technical progress increases the share of total value added accounted for by electricity (growth is electricity-saving if the share drops). Similar definitions can be applied to the other factors (e.g., labor-saving productivity growth implies a drop in the value share of labour as technology improves).

The concept of electricity-using productivity growth is important because it expresses not just the way that an input's value share evolves with changes in technology; it also expresses the dependence of productivity growth on input prices. Specifically if productivity growth is electric-using then a decrease in the price of electricity will raise the rate of productivity growth, other things equal. Again similar relationships apply to other factors (e.g. with capital-using productivity growth an increase in the cost of capital would dampen productivity growth). Thus the concept of electricity-using (or electricity-saving) productivity growth provides a unifying framework for interpreting both historical evidence on changes in patterns of electricity and other energy use in manufacturing as technology has advanced, and evidence on the ways that energy and other input prices can affect productivity (as discussed in Schurr, 1982, 1984; and Rosenberg, 1983).

As Jorgenson (1984) notes one finding is that for 23 of the 35 sectors studied, and 15 of the 21 manufacturing sectors, technical progress tended to be electricity-using over the period, highlighting an apparent connection between electrification and broader economic progress. As Jorgenson (1984) points out, however, in 19 of these sectors, technical progress was also non-electric-energy-using. Moreover, there were more sectors (28 versus 23, and 19 versus 15 manufacturing) in which non-electric-energy-using progress was observed compared to electricity-using progress. This suggests a more complicated picture than is explained by electrification alone.

Some sectors that show significant non-electric-energy-using technical progress are those in which one would expect augmentation effects from greater use of more flexible fluid energy forms such as agriculture and transport. In other cases, non-electric-energy-using technical change would be expected given the sheer importance of non-electric-energy-inputs, such as chemicals, crude oil and gas production, refining, and gas and electric utilities. Some of these sectors also are electric-using, while others are electric-saving.

The pattern of sectors that are capital-using and capital-saving also paints a mosaic. Many of the sectors that are electricity-using and non-electric-energy-using are involved with light industries, consumer goods, more technical intermediate products, and services. Some of these sectors also are capital-using (implying that technical progress was primarily economizing on labour and/or materials), while others were capital-saving. Chemicals and primary metals production were capital-saving, while refining and various mining activities were capital-using. Taken as a whole, the results do indicate the important connections between patterns of energy use and productivity changes, but they also indicate a number of other influences at work.

Jorgenson (1984) takes up the point raised by Schurr (1982) that higher energy prices since 1973 would be an important part of the productivity slowdown. Since 32 of 35 sectors studied are energy-using (electricity, non-electrical, or both), the fact that energy-using sectors would lower productivity growth in the face of higher energy prices would seem to underscore the point. It is worth pointing out, however, that most of the sample period considered by Jorgenson (1984) involved steady or declining energy prices, and prices were distorted in the U.S. between 1973 and 1979 by oil and gas price controls (not to mention regulatory lag in the adjustment of electricity rates to rising fuel costs). In any event, 6 years of data is a short period from which to draw conclusions about longer-term productivity consequences of factor price changes.

Subsequent macroeconomic research has tended to confirm the conclusion that energy price shocks have disproportionate adverse consequences for the economy (for a review see Brown and Yücel, 2002). However, the emphasis in much of that work has been on the various adjustment costs experienced by markets in the face of abrupt price changes, as opposed to long-term productivity effects. The transmission mechanisms for these adjustment costs and their magnitudes are still under debate. We may therefore conclude that patterns of energy use do seem to have some important broader productivity implications, but more work is needed to determine their importance *vis-à-vis* other influences and to understand the interactions between energy and non-energy influences.

3.3.11 Rural Household Energy Use

In this section we shift emphasis to the household sector, which is of particular importance in considering energy-development relationships in poor countries. A World Bank study of the economic and social benefits of rural electrification in the Philippines (ESMAP, 2002a) seeks to capture a variety of direct and indirect benefits through detailed survey-based research and a theoretical solid analytical framework (see p.109 for findings of the study). The various categories of benefits overlap and simply adding them up, involves double counting. Still, the magnitudes indicate the potential for significant augmentation effects relative to the more direct benefits.

The first two categories of benefits – lower cost and expanded use of lighting, and lower cost and expanded use of radio and TV- are relatively easy to define as direct increases in household consumer surplus from rural electrification. The fourth item, time saving for household chores, also could be considered a direct benefit - though such time savings also reduce the opportunity cost of education and home business activity, and the survey analysis notes but does not evaluate this connection. There is also an illustration of how improved energy access can spill over to enhance economic productivity. While the figures are hard to compare, it does appear that these broader benefits are the same order of magnitude as the direct household benefits – not a trivial consideration in the overall social evaluation of energy services augmentation.

A methodologically similar draft study by Barnes et al. (2002) considers the benefits of rural electrification in India. The authors consider benefits associated with improved lighting, ability to irrigate with electric pump sets, and complementary returns to education. While the study does not provide the same summary comparison as for the Philippines work, it further confirms the observation that broader benefits from education are very much in evidence.

The lighting benefits expressed in terms of percentage increases over the consumer surplus derived from inferior kerosene lighting are enormous. The benefits from the ability to improve farm income through pump irrigation also are quite significant- depending on farm size and other factors, income increases of roughly 50% or more are recorded. The education benefits are more indirect but no less important. The availability of electricity appears to markedly accelerate the rate at which household income rises with years of schooling. This can then be translated into substantial increases in the potential for increased farm and non-farm income when improved education is coupled with electricity availability.

Yet another study in this work program examines the importance of various infrastructure services (water, electricity, sanitation, telephone) for poverty alleviation and social development in Peru (World Bank, 1999). The findings of this work suggest that electricity appears to be the most important service among those considered for improving household welfare. Both electrification and sanitation interact positively with education – that is, education is more productive the greater the availability of either of these services. Finally, access to two or more infrastructure services appears to have greater than proportional impacts on household income, so there appears to be some economies of scope in infrastructure service provision.

CHAPTER FOUR

METHODOLOGY

4.1 Model 1: Simple Descriptive Analysis of Structure of Energy Demand

The International Energy Agency (IEA) disaggregates total energy consumed, proxied by total fuel consumption (TFC), into energy consumed in the residential, industrial, transportation, agriculture, and commerce and public service sectors of the economy. Simple bar and pie charts depicting percentages of each of these fuels are used in this work to analyze the structure of energy demand in Cameroon and Nigeria. This is expected to address objective one.

4.2 Model 2: Energy demand, Economic growth and Technological change

4.2.1 Unit Root Tests

Test of stationarity is used to investigate whether the mean value and variance of the stochastic process are constant over time. It tests the order of integration of the individual series. The procedure adopted in this work is the Augmented Dickey-Fuller (ADF) test credited to Dickey and Fuller (1979). This test relies on rejecting a null hypothesis of non - stationarity in favour of the alternative hypothesis of stationarity. The tests are conducted for each of the time series. The general form of ADF test is estimated by the following equations:

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_1^n (\alpha_i * \Delta Y_{t-1}) + \varepsilon_i \quad \text{---------------} \ (4.1)$$

$$\Delta Z_t = \beta_1 + \beta_2 t + \delta Z_{t-1} + \sum_1^n (\alpha_i * \Delta Z_{t-1}) + \varepsilon_i \quad \text{-------} \ (4.2)$$

Where Y and Z are the time series variables under study; t is a linear time trend; Δ is the first difference operator; β_1 is the constant; n is the optimum number of lags in the dependent variable; sigma is the summation sign and ϵ is pure white noise error term. Models (4.1) and (4.2) above are the general form of ADF tests with intercept, and trend and intercept respectively.

A variable is stationary if the absolute ADF value, tau (٢), is greater than any of the absolute Mackinnon tau critical values.

The ADF test is applied to find the existence of unit root in each of the time series by testing the null hypothesis H_0: $y_t = 0$ versus H_1: $y_t < 0$, using the following decision rule: reject Ho if the absolute value of calculated tau is greater than table tau; and do not reject if otherwise. If H_0 is rejected, then the series is stationary or integrated or order zero.

Next Bentham & Romani (2009) are followed, as mentioned in the literature review section, who adopted a simple and well-established specification to estimate the relationship between energy demand, economic growth and prices, applying it to the full data set for 24 non-OECD countries. Following Medlock & Soligo (2001), they assumed the following relationship between energy demand, income and price.

$$tfc^*_{ijt} = f(gdp_{it}, p_{ijt}, \theta_{ij}, \lambda_t) + \varepsilon_{ijt} \quad \text{--------} \ (4.3)$$

Where *tfc** is long-run equilibrium per capita total final energy consumption, *gdp* is per capita GDP, *p* represents either an index of domestic end-use real energy prices or a real international oil price index, θ is a country-sector fixed effect, λ is a time fixed effect and ε is a normally distributed error term, *i* is an index for countries, *j* for sectors. They use country-sector fixed effects and time fixed effects (yearly dummies) to control for static differences between countries and sectors and dynamic effects, such as technological trends not controlled for by economic growth. Fixed effects estimation is obtained by ordinary least squares (OLS) on the deviations from the means of each cross-sectional unit. Bentham & Romani (2009) allowed for a non-monotonic relationship between energy consumption, GDP and prices by assuming that energy demand has the following form:

$\ln\ tfc^{*}_{ijt} = \alpha_0 + \alpha_1 \ln gdp_{it} + \alpha_2 ln\ (gdp_{it})^2 + \alpha_3 lnp_{ijt} + \alpha_4 ln\big(p_{ijt}\big)^2 + \theta_{ij} + \lambda_t + \varepsilon_{ijt}$ -- (4.4)

They started by estimating a restricted linear form, in which $\alpha_2 = \alpha_4 = 0$, and then tested whether a non-linear specification should be preferred. This equation should be seen as a long-run relationship between energy demand, income and prices. This specification does not explicitly control for technological change. However, following the Griffin & Schulman (2004) method, time fixed effects capture, among other unobservable, elements of technological progress over and above those normally associated with economic growth. The logarithmic functional form facilitates the interpretation of the coefficients as income and price elasticities (e_{gdp} and e_p) of energy demand, viz.

$$e_{gdp} = \alpha_1 + 2\alpha_2 \text{ and } e_p = \alpha_3 + 2\alpha_4 \text{ ------- (4.4'a and 4.4'b)}$$

The sign of (α_1+2α_2) is used to test if the income elasticity increases or decreases with economic growth; a positive value means that every additional unit of GDP produced becomes more energy intensive, a phenomenon typically observed in industrializing economies. The (α_3+$2\alpha_4$) parameter tests the non-constancy of the price elasticity. A negative value indicates that economies become more sensitive to the same relative price changes if absolute price levels rise, i.e. if the share of energy-related expenses in total income increases.

The income elasticity given by equation (4.4'a) captures, besides the effect of economic growth the average effect of technical change that has been historically associated with it. Griffin and Schulman (2004) argue for time effects to control for energy savings linked to technical change uncontrolled for by economic growth. They suggest that time fixed effects are appropriate proxies for a number of omitted variables that change similarly over time for all countries in the data set, including but not limited to technical advances and energy efficiency improvement above and beyond those associated with economic development (Huntington, 2006).

Equation (4.4) is flexible in many ways. However, when income or price changes, there is no immediate adjustment towards this long-term equilibrium demand. To incorporate a term that allows for short-term adjustment to the long-run equilibrium relationship the partial adjustment mechanism in Medlock & Soligo (1998) is applied and a lagged dependent variable is added to equation (4.4), giving equation (4.5):

$$\ln tfc_{ijt} = \alpha_0 + \alpha_1 \ln gdp_{it} + \alpha_2 ln\ (gdp_{it})^2 + \alpha_3 lnp_{ijt} + \alpha_4 ln\left(p_{ijt}\right)^2 + \gamma \ln\left(tfc_{ij,t-1}\right) + \theta_{ij} + \lambda_t + \varepsilon_{ijt} \quad \text{--- (4.5)}$$

The elasticities specified in (4.4'a and 4.4'b) now represent the short-run, immediate, income and price elasticities, *y* indicates the speed of adjustment, where a lower γ value indicates a more rapid adjustment process towards the long-run equilibrium per capita energy consumption. To obtain the implied long-run elasticities from (4.5), Medlock & Soligo (1998) divide the short-run elasticities by (1 – *y).*

Finally, it is noted that the parameters estimated from specification (4.5) should be interpreted as best linear predictor of energy demand given GDP and prices. Also, prices may be endogenous in specification. This is an argument for two-stage least square (2SLS) estimation, but we lack the right instrument to do this. Unfortunately, specification (4.5) does not lend itself for using lagged prices as an instrument, since they enter the right-hand side directly through the lag of energy consumption. Hence the exclusion restriction for instrumental variables would be violated.

Running equation 4.5 using data for Cameroon and Nigeria returned a "near singular" result. This suggests that the use of this model in this study should be restricted to the long run as it (equation 4.5) is not adequate for the short run. Secondly the monotonic version of this model (equation 4.4) is used in this study as it has returned a better result compared to the non-monotonic version.

4.2.2 Measuring Short Run Elasticity

Price elasticity of demand for a good is measured by the percentage change in quantity demanded divided by the percentage change in price that brought it about. Its formula is given below

$$E = \frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q} \quad \text{---------} \ (4.6)$$

Where E is the short-run elasticity, ΔQ is change in quantity, ΔP is change in price, p is price and q is quantity.

With a straight-line demand curve the elasticity measured at every point (p, q), according to equation (4.6) above, is independent of the direction and magnitude of the change in price and quantity. This follows immediately from the fact that the slope of a price line is a constant. If we start from the point (p, q) and then change price, the ratio $\Delta Q/\Delta P$ will be the same whatever the direction or the size of the change in P. However, when equation (4.6) is applied to a nonlinear demand curve, the elasticity measured at any one point varies with the direction and magnitude of the change in price and quantity. This happens because $\Delta Q/\Delta P$ gives the average reaction of q to a change in p over a section, range or arc, of the demand curve, and depending on the range that we take, the average reaction will be different. This is unsatisfactory. This problem can be avoided when measuring elasticity between two separate points on the curve by taking p and q as the average values between the two points on the curve. This measure has two properties. First, it is independent of the direction of the change; second, it gives a value of unity for any point on the demand curve whose true value is unity (Lipsey & Chrystal, 2007).

Equation (4.6) is now transformed to equation (4.7) as follows:

$$E = \left[\frac{Q_2 - Q1}{P_2 - P_1}\right]\left[\frac{P_2 + P_1}{Q_2 + Q_1}\right] = \left[\frac{Q_2 - Q_1}{Q_2 + Q_1}\right]\left[\frac{P_2 + P_1}{P_2 - P1}\right] \text{------ (4.7)}$$

This model is expected to address objective two.

4.3 Model 3: Energy Intensity

The Environmental Kuznets Curve (EKC), phased diagram and integrated assessment of exosomatic metabolism theories are different approaches to the study of dematerialization of economies. According to Ramos-Martin (2001) all developing countries are still “materializing”. Therefore, none of these three theories should be applied to Cameroon and Nigeria owing to the fact that Cameroon and Nigeria are developing countries, still materializing. Consequently, the energy-demand style regression theory is used in this study.

A key driver for residential energy consumption is personal consumption expenditures/incomes. This is preferable to disposable income because a portion of disposable income goes to savings which should have no appreciable impact on residential energy demand. For energy demand in the other sectors value added to the economy is used. Value added is a measure of the contribution to the final production from a given sector.

Regression variables include energy prices and per capita income, both in natural log form. For the energy price variable a proxy, the pump price of premium motor spirit (PMS) in Nigeria and the pump price of Super in Cameroon are used. This price includes excise taxes. Under the assumption that countries are price takers in energy markets, this regression is interpreted as an energy demand-style regression. The natural log and the natural log squared of income to account for possible non-linearities in the response of energy use to income are included in the equation.

In addition to price and income variables, a number of other socioeconomic variables that could account for differences in energy intensity are included in the equation. First the natural log of the capital-labour ratio and the squared natural log of capital-labour ratio to allow for differences in capital intensity to affect energy intensity. This reflects a finding that capital and energy are likely substitutes in production [see Jaccard, (2008) on this point]. Second, a variable measuring population growth in the country is included. A fast-growing country may be adding infrastructure that is more energy efficient than slow-growing countries. On the other hand fast-growing countries may be less efficient in their use of energy if their capital investment does not keep pace with growth (e.g. traffic congestion).

Different vintaging (i.e. maintenance or replacement) of the capital stock is also allowed for (Gittleman et al., 2003). Slower turnover of the capital stock means that a country is likely to have less energy-efficient capital on average. Conversely, a fast-growing country may have a newer, more energy-efficient capital stock and so lower energy intensity. In an effort to measure the vintaging effect included is the natural log of investment relative to capital stock in a given year. Finally the error term is included. The mathematical representation of the above narrative is as follows:

$$INT_{ijt} = lnPMS_{it} + lnPCI_{it} + ln(PCI_{it})^2 + ln\left({}^{K}/_{L}\right)_{it} + ln\left({}^{K}/_{L}\right)_{it}^2 + ln\left({}^{I}/_{K}\right)_{it} + PGR_{it} + \mu_{1it} \text{ - }$$

(4.8)

where INT_{ijt} is energy intensity in country i, sector j and time t, natural log is the logarithm in base e, PMS_{it} is energy price, PCI_{it} is per capita income, K/L_{it} is capital-labour ratio, I/K_{it} is investment relative to capital in a given year, PGR_{it} is population growth rate, and μ_{1it} is the error term.

One challenge faced with equation (4.8) is that energy intensity is assumed to respond immediately to changes in economic variables. More realistically, energy prices likely affect energy intensity with some lag. There is, therefore, the need for re-specification from an instantaneous-response model to a dynamic model. Three models present themselves for consideration; (i) the Koyck model; (ii) the adaptive expectations model and (iii) the partial-adjustment model (Gujarati, 2003, 2014). The use of either of these models -the Koyck, adaptive expectations or partial adjustment model would have been preferred in this work but for the fact that standard fixed effect regression procedures may produce biased estimates because of the lagged dependent variables. Equation (4.8) should be used as it is the best alternative. Model 3 is expected to address objective four.

4.4 Granger Causality

The study of causality between several variables depends on the order of integration of the series. For this reason, a three-stage procedure is followed to examine the direction of causality among the three variables, namely energy price, intensity and technology. First, unit root tests are applied to determine the order of integration of each variable. To this end, the Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979) is used. If energy intensity, energy price and technology turn out to be non-stationary at levels, a test for co-integration among the three variables using the Johansen (1988) procedure is carried out. Finally, a test for causality among the three variables is undertaken (Gujarati, 2003, 2014). The Granger causality test is expected to address objective five.

4.4.1 Granger Causality Theory

In analyzing Granger Causality relationships, the interest is to find the lead/lag relationship between variables. The Granger (1969) approach to the question of whether X causes Y is to determine how much of the current Y can be explained by past values of X, and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger Caused by X if X helps in the prediction of Y. The statement "X Granger causes Y" does not imply that Y is the effect or result of X, as Granger causality measures precedence and information content but does not of itself indicate causality in the more common use of the term.

It is necessary to choose a lag length, I, that corresponds to reasonable beliefs about the longest time over which one variable could help predict the other. The following equations are used to determine the causality:

$$\Delta Y_t = \alpha + \sum_1^k(\beta_i \cdot \Delta X_{t-1}) + \sum_1^m \gamma_i \quad \text{------------- (4.9)}$$

$$\Delta X_t = \alpha + \sum_1^k \beta_{i-1} + \mu + \sum_1^m \psi_i \cdot \Delta Y_{t-1} \quad \text{----- (4.10)}$$

Where Y_t and X_t are defined as Y and X observed over time periods, Δ is the difference operator; m represents the number of lags; α, β, ψ and γ are parameters to be estimated; and μ represents the serially uncorrelated error terms. The test is based on the following hypotheses: H_0: $\gamma_i = \psi_i = 0$, for all i's versus H_1: $\gamma_i \neq 0$ and $\psi_i \neq 0$ for at least some i's.

The criteria for causality are as follows: the hypotheses would be tested using chi-square statistic. If the coefficients of γ_i are statistically significant but those of ψ are not, then X causes Y. On the other hand, if the coefficients of ψ are statistically significant but those of γ_i are not, then Y causes X. If both are significant, then there exists a bi-directional causality between X and Y, otherwise a case of independence (or no causality) exists between X and Y.

Two series of Granger Causality tests shall be carried out in this work. One, the causality link between energy intensity, technology and energy prices and two, causality link between GDP and the pump price of petrol in Nigeria and Cameroon within the period of our investigation. The reason for these tests is to understand how the variables tested interact with one another and the implication of these interactions to policy formulation/recommendations.

4.4.2 Tests for Structural or Parameter Stability

When a regression model involving time series data is used, it may happen that there is a structural change (or break) in the relationship between the regressand and the regressors. If this happens, then the results of the regressions will lack credibility.

Structural breaks may be due to external forces, policy changes, government actions, or a combination of other causes. To find out whether a structural change has occurred or not, a Chow test, Wald test or a recursive least squares (RELS) test is run. These tests assume that the intercept as well as the slope coefficient remain the same over the entire period of study- a hypothesis that there is parameter stability (no structural break). In this study, we do not know the point(s) of structural break, if any, (a pre-requisite for the use the Chow test; see Greene, 2008); so we use the recursive least squares (RELS) test which does not require our knowledge of structural break points (Gujarati, 2014).

Figures 4.1 and 4.2 depict the RELS results of LNTFCKC, LNPMSC and LNGDPKC for Cameroon and LNTFCKN, LNPMSN and LNGDPKN, for Nigeria, respectively; where LNTFCKC is the natural log of total fuel consumption per capita in Cameroon, LNPMSC is the natural log of the pump price of fuel in Cameroon, LNGDPKC is the natural log of gross domestic product per capita in Cameroon; and LNTFCN is the natural log of total fuel consumption per capita in Nigeria, LNPMSN is the natural log of the pump price of fuel in Nigeria, LNGDPKN is the natural log of gross domestic product per capita in Nigeria. In both graphs, the continuous line is within the broken lines, indicating that there is parameter stability in both countries.

Table 4.1: Table of Definition of Variables

TFC	Total fuel consumption
ERZ	Energy consumed in residences
EIN	Energy consumed in the industry
ETR	Energy consumed in the transportation sector
ECM	Energy consumed in Commerce and public sector
EAG	Energy consumed in the Agricultural sector
TFCPK	Per capita total energy consumption
PMS	Energy price
GDPPK	Per capita gross domestic product
INT	Energy intensity
PGR	Population growth rate
KLR	Capital-labour ratio
PCI	Personal consumption income
IKR	Investment-capital ratio
GDP	Gross domestic product

Source: Author's Compilation

Figure 4.1: RELS result for Cameroon

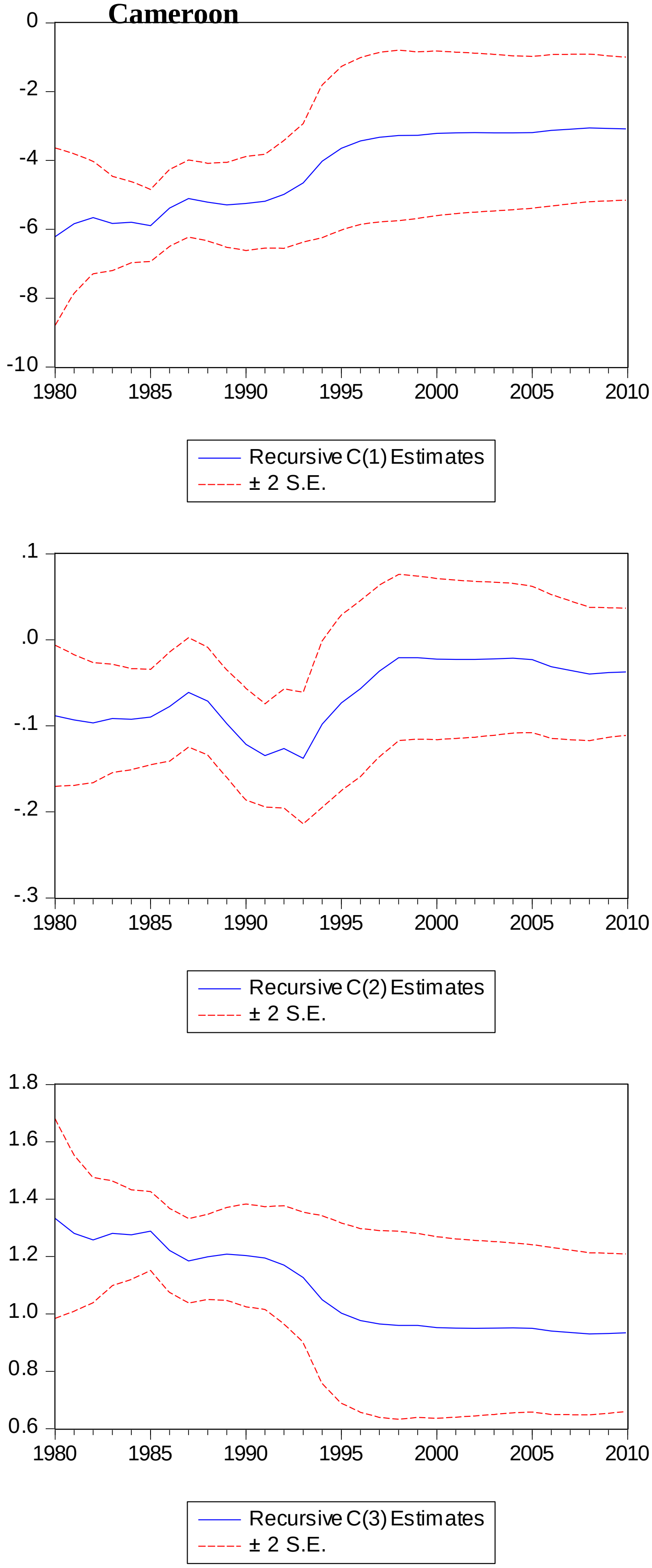
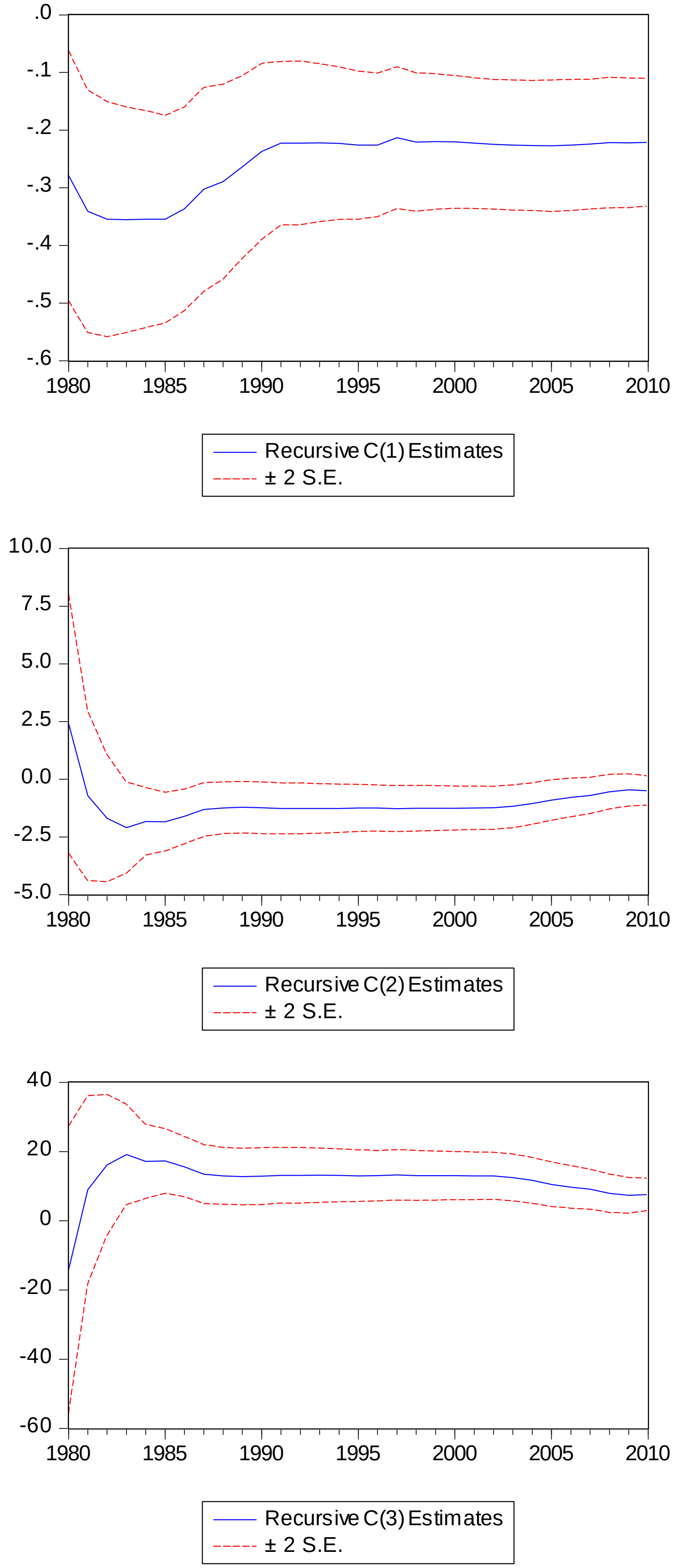


Figure 4.2: RELS result for Nigeria



4.5 Choice of Method of Estimation

There are different methods of panel data estimation, out of which two are discussed here: estimation allowing for fixed effects (FEM) and estimation allowing for random effects (REM). The choice of either FEM or REM is determined by the Hausman test. The requirement before using the REM is that the number of cross sections should be greater than the number of the variables (dependent and explanatory) used in the model. Since the number of cross sections is 2 and the number of variables in our model is 3, the REM should not apply. The Hausman test was run (Table 4.2). Its results confirm that FEM should be the preferred method (Destais et al. 2007; Gujarati, 2003, 2014).

Table 4.2: Redundant Fixed Effects Tests

Test cross-section fixed effects

Total pool (balanced) observations: 80

Effects Test	Statistic	d.f.	Prob.
Cross-section F	18.876274	(1, 74)	0.0000
Cross-section Chi-square	18.176250	1	0.0000

Source: Author's computation, 2015

In the next chapter, data are presented, analyzed, and the results interpreted.

CHAPTER FIVE

DATA PRESENTATION AND ANALYSIS

5.1 Data Presentation

This study relied, in part, on the World Bank World Development Indicators data. They are: total population (in millions, 1971 to 2010), population growth rates (1971 to 2010), gross fixed capital formation (in millions of dollars, 1971 to 2013), real change in investment (in millions of US dollars, 1971 to 2013), total labour force (in units, 1971 to 2009), household final consumption income (in millions of real US 2005 dollars, 1971 to 2007), contribution of services to GDP (in millions, at constant 2000 US dollars, 1971 to 2007), contribution of manufacturing to GDP (in millions, at constant 2005 US dollars, 1971 to 2004), contribution of industries to GDP (in millions, at constant 2000 US dollars, 1971 to 2007), and contribution of agriculture to GDP (in millions, at constant 2000 US dollars, 1971 to 2007).

For international comparisons, the GDPs must be expressed in the same units. It is well known that the best converters are the purchasing power parities (PPP), which aim at neutralizing the effect of broad disparities of prices among countries. Besides, Shrestha (2000) shows that choosing a wrong unit of measure of GDP (market exchange rates, for example) may lead to wrong and therefore misleading results. GDP at PPP for Cameroon and Nigeria, expressed in millions of US dollars (1971 to 2010), GDP per capita (in millions of US dollars, 1971 to 2010), Gross capital formation (in millions of US dollars, 1971 to 2008), and population growth rate (1971 to 2010) were also extracted from the World Bank database.

Instead of mileage (as used by Metcalf, 2008) the inverse of carbon dioxide (CO_2) emissions as a proxy for technology/technical progress was used in this study because it is believed that the inverse of CO_2 emissions is a better (more representative) variable than mileage. Whereas mileage is limited to the transportation sector only, CO_2 is emitted in all the sectors of the economy and the better a country's technology the more her capacity to limit (reduce) her CO_2 emissions, all things equal. CO_2 is available for the period 1980 to 2007, and it is expressed in kilograms per PPP dollar of GDP.

Household final consumption for Nigeria could not be found at the World Bank database. It was obtained from the Central Bank of Nigeria (CBN) statistical bulletin, 2009, volume 20, pages 99-102. It is expressed in millions of Naira. Similarly, contributions to GDP of services, manufacturing, industry and agriculture for Nigeria were all obtained from the CBN statistical bulletin of 2009.

Two energy price variables are available: the more commonly used international oil prices as well as a domestic end-use energy price series for each country. The two price indices also deserve some further inspection. As taxes, subsidies and losses from, for example, transportation and conversion vary widely across countries; the international oil price is an imperfect measure of the energy prices faced by consumers. Therefore end-use energy prices are used in this study.

Energy price (PMS) for Nigeria, for the period 1977 to 2013, was obtained from the Petroleum Products Pricing and Regulatory Agency (PPPRA). Energy price beyond 2009 was obtained from the CBN statistical bulletin, volume 21, and energy price between 1971 and 1976 was generated using the autoregressive model $P_t = \beta_0 + \beta_1 P_{t-1} + \varepsilon$, where Pt is current PMS price, P_{t-1} is PMS price a year before, β_0 and β_1 are regression coefficients and ε is the error term. The reason for choosing this model is the presence of correlation between consecutive residuals (Keller, 2009). All Naira-denominated data were converted into US dollars using Naira official cross exchange rates – End Period (www.cbn.ng).

Data for Total final energy consumption (TFC) expressed in kilotons (ktons) of oil equivalent, energy consumption in industry, transport, agriculture, residential and commercial and public service sectors, between 1971 and 2010 are available for all countries from the IEA database.

Total fuel consumption per capita was computed by dividing TFC_i by its corresponding population. Energy intensity was obtained by dividing TFC_i by GDP_i.

There are two different premium motor spirits in use in Cameroon: “Super” and “Ordinaire”. Super is the reference PMS in Cameroon. The *Institue National de la Statistique* in Yaoundé, quotes its prices for the period 2003 to 2012 only. So the data for the rest of the study period (1971 to 2002) had to be estimated. This estimation was done as follows: assuming that one thousand francs CFA is equivalent to 300 Naira, the price of Super was converted into Naira by multiplying its yearly price by 300 and dividing by 1,000. Then, the mean price of Super in Naira was found for the last 10 years (i.e. N151.65) as well as that of PMS (i.e.N49.85) over the same period. Next the mean price of Super was divided by that of PMS, giving a ratio of (approximately) 3:1. It was hypothesized that on average, over the last ten years the price of Super is about three times that of PMS. The chi square statistical technique was then used to test the null hypothesis (H_o) that the mean price of Super is not three times that of PMS over the last ten years, against its alternative (H_1), that it really is, at 5 percent level of significance.

A comparison of the calculated $\chi^2 = 191.74$ with the theoretical or table $\chi^2_{(9;\ 0.95)} = 16.9$ was made. H_o was rejected because 191.74 is by far greater than 16.9, thereby confirming that over the last ten years, the average price of Super was at least 3 times that of PMS in Nigeria. Fagbule (2013) confirms this price relationship. The price of Super was then generated by multiplying the price of PMS by three (3) for the period for which data were not available for Cameroon.

Let energy intensity be EI. Energy that would have been consumed had energy intensity remained at its 1971 level (EICAP) and energy savings due to changes in energy intensity (ΔEI) in Cameroon and Nigeria respectively may be computed as follows:

$EI = \frac{TFC_i}{GDP_i}$, therefore $TFC_i = EI_i \cdot GDP_i$ ------- (5.1)

and $EICAP_i = EI_{(1971)} \cdot GDP_i$ ------------ (5.2)

Energy savings due to changes in energy intensity over time (ΔET) is computed by subtracting EICAP from EI, thus:

$\Delta EI_i = EI_i - EICAP_i$ ---- (5.3)

Energy intensity for Nigeria relative to Cameroon (E_N/E_C) is the simple mean energy intensity for Nigeria divided by the simple mean energy intensity for Cameroon between 1971 and 2010. On the average then Nigeria is about one and a half (1.57) times as energy intensive as is Cameroon.

Traditionally, one of the guiding factors in the measurement of growth and improvements in people's lives is the GDP. Yet GDP may be an inaccurate indicator in the poorest countries, which is a concern not only to policy makers but also to researchers. The challenges of calculating GDP are particularly acute in Sub-Saharan Africa (SSA), owing to weak national statistics offices and historical biases that muddy crucial measurements (Gates, 2013).

In Table 5.2 TFCC, PMSC and GDPC are total fuel consumption, energy price and gross domestic product in Cameroon, while TFCN, PMSN and GDPN are total fuel consumption, energy price and gross domestic product in Nigeria.

5.1. Structure of Energy Demand in Cameroon and Nigeria

Table 5.1: Descriptive statistics of model 1

Sample: 1971-2010

	CAMEROON					
	TFCC	ERZC	EINC	ETRC	ECMC	EAGC
Mean	714.175	134.175	54.425	525.075	0.5	0
Median	794	133.5	53	564	0	0
Maximum	1130	238	121	887	6	0
Minimum	232	12	19	188	0	0
Std. Dev.	246.4516	67.20802	22.01967	176.2129	1.414214	0
Skewness	-0.68126	-0.30503	1.077346	-0.38757	2.754288	NA
Kurtosis	2.420149	1.986335	4.794951	2.542015	9.497041	NA
Jarque-Bera	3.654444	2.332797	13.10757	1.350998	120.9266	NA
Probability	0.16085	0.311487	0.001425	0.508902	0	NA
	40	40	40	40	40	40
	NIGERIA					
	TFCN	ERZN	EINN	ETRN	ECMN	EAGN
Mean	6765.125	1059.975	555.05	5112.925	8.875	28.3
Median	7212.5	1189	457.5	4779	0	0
Maximum	1044	1804	1361	8745	89	204
Minimum	1388	227	149	887	0	0
Std. Dev.	2395.839	480.672	312.3	2210.799	20.66607	46.8222
Skewness	-0.6948	-0.23992	0.806261	-0.08782	2.486895	2.116856
Kurtosis	2.857876	1.811754	2.943071	2.302951	8.597995	7.478498
Jarque-Bera	3.251975	2.736971	4.339113	0.861213	93.46022	63.30211
Probability	0.196717	0.254492	0.114228	0.650115	0	0
Observations	40	40	40	40	40	40

Source: Author's computation using data from IAE's database, 2015

Between 1971 and 2010, while commercial energy consumed by Nigeria's residential sector is about 8 times that consumed in the same sector in Cameroon, Nigeria's industrial sector's consumption is about 10 times that of Cameroon and her (Nigeria's) commercial energy consumption in the transport sector is about 10 times that of Cameroon. In agriculture both countries' energy consumption is laggard, yet Nigeria's consumption in this sector is about 28.3ktoe, on the average, while that of Cameroon is about zero ktoe, on the average. However, in commerce and public service, Nigeria records consumption of about 18 times that of Cameroon. Overall, Nigeria used about 9.5 times as much total commercial energy as did Cameroon within the period under review.

Correlation of the Variables

Table 5.2 Covariance Analysis for Cameroon

Covariance Analysis: Ordinary

Sample (adjusted): 1971-20

Included observations: 39 after adjustments

Balanced sample (listwise missing value deletion)

Covariance t-Statistic Probability	TFCC	ERZC	EINC	ETRC	ECMC	EAGC
TFCC	1586429. -------------------					
ERZC	896543.9 8.515089 0.0000	765217.6 --------				
EINC	41943.90 4.145137 0.0002	32392.52 4.885322 0.0000	3496.999 ----- -----			
ETRC	172565.6 7.619311 0.0000	133261.6 10.68063 0.0000	7527.028 6.422393 0.0000	30734.50 -----		
ECMC	120237.5 4.710969 0.0000	106100.4 7.532024 0.0000	720.2137 0.476637 **0.6364***	17154.76 4.904105 0.0000	24305.86 ----- -----	
EAGC	534.1637 2.069900 0.0455	394.1302 2.215605 0.0330	66.80605 10.16709 0.0000	92.33991 2.655523 0.0116	-62.99145 -1.961562 0.0574	1.733070 ----- -----

Source: Author's computation, 2015 ***** no covariance

Table 5.3 Correlation Analysis for Cameroon

	TFCC	ERZC	EINC	ETRC	ECMC	EAGC
TFCC	1.000000	0.813708	0.563133	0.781503	0.612314	0.322148
ERZC	0.813708	1.000000	0.626188	0.868959	0.777981	0.342247
EINC	0.563133	0.626188	1.000000	0.726044	0.078119	0.858143
ETRC	0.781503	0.868959	0.726044	1.000000	0.627648	0.400100
ECMC	0.612314	0.777981	**0.078119***	0.627648	1.000000	-0.306915
EAGC	0.322148	0.342247	0.858143	0.400100	-0.306915	1.000000

Source: Author's computation, 2015 ***** no correlation

Table 5.4 Covariance Analysis for Nigeria

Covariance Analysis: Ordinary
Sample (adjusted): 1971-20
Included observations: 39 after adjustments
Balanced sample (listwise missing value deletion)

Covariance t-Statistic Probability	TFCN	ERZN	EINN	ETRN	ECMN	EAGN
TFCN	4.49E+08 ----- -----					
ERZN	3.30E+08 12.45031 0.0000	3.00E+08 ----- -----				
EINN	41125093 17.20657 0.0000	33366093 16.07837 0.0000	4236885. ----- -----			
ETRN	39336194 8.973005 0.0000	30937483 7.999013 0.0000	4103227. 11.80338 0.0000	5029128. ----- -----		
ECMN	2407120 13.11349 0.0000	1930722 11.85216 0.0000	241136.9 16.11601 0.0000	224083.4 8.054407 0.0000	15679.09 ----- -----	
EAGN	-564032.9 -4.286505 0.0001	-450329.0 -4.136627 0.0002	-58090.02 -4.692013 0.0000	-47656.88 -3.150545 0.0032	-2649.281 -3.133026 0.0034	2135.011 ----- -----

Source: Author's computation, 2015

Table 5.5 Correlation Analysis for Nigeria

	TFCN	ERZN	EINN	ETRN	ECMN	EAGN
TFCN	1.000000	0.898500	0.942821	0.827736	0.907158	-0.576036
ERZN	0.898500	1.000000	0.935304	0.795994	0.889673	-0.562342
EINN	0.942821	0.935304	1.000000	0.888906	0.935578	-0.610771
ETRN	0.827736	0.795994	0.888906	1.000000	0.798000	-0.459917
ECMN	0.907158	0.889673	0.935578	0.798000	1.000000	-0.457897
EAGN	-0.576036	-0.562342	-0.610771	-0.459917	-0.457897	1.000000

Source: Author's computation, 2015

Of all the variables in Table 5.2 only ECMC is not correlated with EINC. All the variables for Nigeria are linearly correlated (Table 5.4), suggesting the likelihood of multicollinearity. According to Blanchard (1967) multicollinearity is essentially a data deficiency problem.

In Table 5.6 TFCPKC, PMSC and GDPPKC are per capita fuel consumption, energy price and per capita gross domestic product in Cameroon, while TFCPKN, PMSN and GDPPKN are per capita fuel consumption, energy price and per capita gross domestic product in Nigeria.

Table 5.6: Descriptive statistics of Model 2

Sample: 1971-2010

Cameroon				**Nigeria**		
	TFCPKC	**PMSC**	**GDPPKC**	**TFCPKN**	**PMSN**	**GDPPKN**
Mean	0.055689	0.843792	1975.100	0.065982	0.281264	1535.275
Median	0.057112	0.740845	1946.500	0.070729	0.246948	1455.000
Maximum	0.075198	2.056109	2815.000	0.097225	0.685370	2135.000
Minimum	0.032561	0	1434.000	0.023627	0.000000	1171.000
Std. Dev.	0.010977	0.626439	351.7129	0.017953	0.208813	219.8569
Skewness	-0.57847	0.29679	0.684234	-0.60338	0.296790	0.701861
Kurtosis	2.988706	1.990793	2.861470	2.785852	1.990793	3.186094
Jarque-Bera	2.23106	2.284728	3.153155	2.503553	2.284728	3.341777
Probability	0.327742	0.319064	0.206681	0.285996	0.319064	0.188080
Observations	40	40	40	40	40	40

Source: Author's computation, 2015; per capita TFC in ktoe

From Table 5.6 it is observed that between 1971 and 2010, the mean per capita total commercial fuel consumption in Nigeria is 0.066 ktoe, which is about 1.2 times that of Cameroon. Nigeria records a maximum consumption of 0.097 ktoe and a minimum of 0.024ktoe which are about 1.3 and 0.73 times, respectively, that of Cameroon within the 40-year period. However, the mean price of commercial fuels in Cameroon is about 3 times that of Nigeria and the mean per capita GDP at PPP in Cameroon is 1975.100, that is about 1.3 times that of Nigeria. Moreover, Cameroon records a maximum GDP per capita of $2,815; meanwhile, Nigeria's maximum is $2,135. Cameroon's and Nigeria's minimum is $1,434 and $1,171 respectively.

Table 5.7: Descriptive Statistics of Model 3 for Cameroon

Sample: 1971- 2010

	INTC	PMSC	PGRC	KLRC	PCIC	IKRC
Mean	0.000028	0.843792	2.631069	570.0772	8193.566	0.090894
Median	0.0000282	0.740845	2.706715	486.9142	7563.66	0.074741
Maximum	0.0000378	2.056109	3.051176	1168.724	14460.38	0.661714
Minimum	0.0000205	0	2.186407	290.2489	3667.69	-0.17166
Std. Dev.	0.0000041	0.626439	0.306183	239.176	2997.5	0.143205
Skewness	0.361789	0.29679	-0.23088	1.111666	0.456425	2.040202
Kurtosis	2.315879	1.990793	1.430968	3.114702	2.43723	8.617689
Jarque–Bera	1.652641	2.284728	4.458461	8.260601	1.9166677	80.3469
Prob.	0.437657	0.319064	0.107611	0.016078	0.38353	0
Observations	40	40	40	40	40	40

Source: **Author's computation, 2015**

Table 5.8: Descriptive Statistics of Model 3 for Nigeria

	INTN	PMSN	PGRN	KLRN	PCIN	IKRN
Mean	0.0000445	0.281264	2.539925	0.000333	65719.08	-0.00074
Median	0.0000456	0.246948	2.492206	0.000265	66682	0
Maximum	0.0000707	0.68537	3.052247	0.000969	109824	0.001832
Minimum	0.0000153	0	2.326178	0.0000802	30561	-0.00842
Std. Dev.	0.0000158	0.208813	0.189328	0.000218	19831.33	0.001882
Skewness	0.026199	0.29679	1.400534	1.43246	0.033089	-2.20863
Kurtosis	2.277711	1.990793	4.183511	4.457998	2.250707	8.62061
Jarque-Bera	0.874078	2.284728	15.41113	17.22254	0.943034	85.17238
Prob.	0.645946	0.319064	0.00045	0.000182	0.624055	0
Observations	40	40	40	40	40	40

Source: **Author's computation**

Nigeria's mean population growth rate and that of Cameroon are similar within the period of study. However, Nigeria's mean commercial energy intensity between 1971 and 2010 is about 1.57 times that of Cameroon, and her (Nigeria's) mean capital-labour ratio is infinitesimal compared to that of Cameroon. Nigeria's mean investment ratio is negative while that of Cameroon is positive. In absolute terms Cameroon's investment-capital ratio is about 123 times that of Nigeria.

Table 5.9: Descriptive Statistics for Granger Causality

	CAMEROON			NIGERIA		
	INT	**PMS**	**TKN**	**INT**	**PMS**	**TKN**
Mean	0.000028	0.843792	0.86503	0.0000445	0.281264	0.183815
Median	0.0000282	0.740845	0.748603	0.0000456	0.246948	0.210083
Maximum	0.000037	2.056109	2.730881	0.0000707	0.68537	0.378759
Minimum	0.0000205	0	0.197324	0.0000153	0	0.035883
Std. Dev.	0.0000041	0.626439	0.582559	0.0000158	0.208813	0.09089
Skewness	0.361789	0.29679	0.886513	0.026199	0.29679	0.116517
Kurtosis	2.315879	1.990793	3.80384	2.277711	1.990793	2.101147
Jarque-Bera	1.652641	2.284728	6.316299	0.874078	2.284728	1.43707
Prob.	0.437657	0.319064	0.042504	0.645946	0.319064	0.487466
Observations	40	40	40	40	40	40

Source: **Author's computation, 2015**

The commercial energy intensity and price for Cameroon and Nigeria have been analyzed above.

5.2 Choice of Databases

Gates (2013) posits that Morten Jerven makes a strong case to the effect that a lot of GDP measurements that were thought to be accurate are far from it. Jerven (as cited in Gates, 2013) notes that many African countries have trouble measuring the size of their relatively large subsistence economies and unrecorded economic activity.

There are other problems with poor countries' GDP data. For example, many countries in SSA do not update their reporting often enough, so their GDP numbers may miss large and fast-growing economic sectors like cell phones (Gates, 2013).

In view of the foregoing, among others, the reason for the choice of the IEA and the World Bank as principal databases is that they are reliable and therefore respected. For instance, since its foundation in Paris in 1974, IEA has developed its expertise to become probably number one in the collection, collation and analysis of global energy data. IEA advises the world's biggest economies on energy policy and so its judgment, aggregation and informed commentaries are highly regarded and carry weight in the energy and financial markets (Bhaattacharyya, 2011, Tempest, 2003; Nystad, 2001). Moreover IEA and the World Bank are third parties to Cameroon and Nigeria. To avoid bias, using their reported data is probably safer.

5.3 Presentation of Results

Simple percentages are used to find the share of each sector to total commercial energy demand in Cameroon and Nigeria, respectively and the results presented in Table 5.4, from which, it is observed that there are great similarities in the pattern of sectoral commercial energy demand in Cameroon and Nigeria within the period under investigation.

5.3.1 Model 1

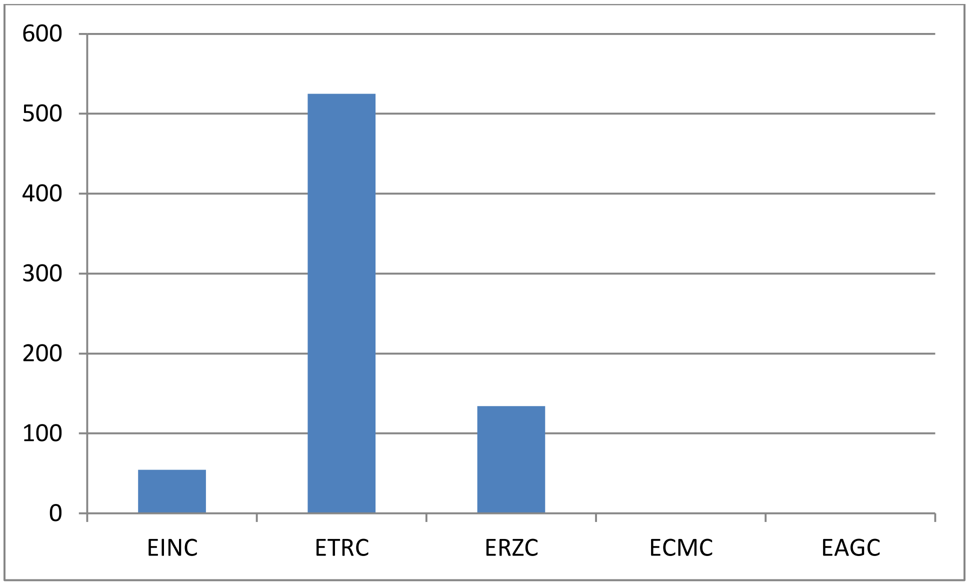
Table 5.10: Sectoral commercial energy consumption (percent of total) in Cameroon and Nigeria between 1971 and 2010

	CAMEROON	**NIGERIA**
Transport	73.52	75.58
Residences	18.79	15.67
Industry	7.62	8.2
Commerce	0.07	0.13
Agriculture	0	0.42

Source of data: IEA: Author's computation, 2015

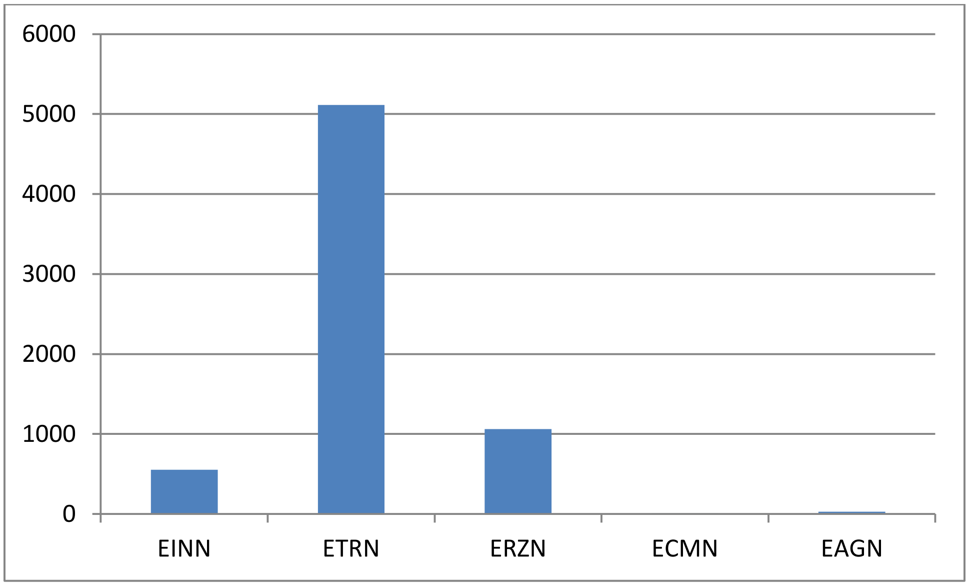
The following figures depict the similarities in sectoral energy consumption between 1971 and 2010 in Nigeria and Cameroon.

Chart 5.1: Sectoral distribution of commercial energy use in Cameroon (1971-2010)



Source: IAE **Cameroon**

Chart 5.2 Sectoral distribution of commercial energy use in Nigeria (1971-2010)



Source: IEA **Nigeria**

5.3.2 Model 2

Unit root test results

Because economic time series data are usually serially correlated, the need to test them for the presence (or otherwise) of a unit root arises. lngdp, lnpms and lntfc are tested for Cameroon and Nigeria, respectively using the Levin, Lin & Chu (LLC, 2002) and the Im, Pesaran & Shin (IPS, 2003) unit root test processes .The null of a unit root is rejected in both tests, suggesting that the series are stationary at levels.

Table 5.11 Group Unit Root Test Summary

Group unit root test: Summary

Series: LNGDP_CAM, LNGDP_NGN, LNPMS_CAM, LNPMS_NGN, LNTFC_CAM, LNTFC_NGN
Sample: 1971 - 2010
Cross Sections: 6

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	-1.99414	0.0231	227
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	-2.80671	0.0025	227
ADF- Fisher chi square	29.6834	0.0031	227
PP- Fisher chi square	26.6314	0.0087	234

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.
All other tests assume asymptotic normality.
Source: Author's computation, 2015

5.3.2.1 Model 2A (The restricted form of Model 2)

Table 5.12 depicts a priori and observed signs and significance of variables for Cameroon and Nigeria between 1971 -2010

			CAMEROON		NIGERIA	
Coeff. Of variable	**Expected Sign**	**Expected Significance**	**OBSERVED SIGN**	**OBSERVED SIGNIFICANCE**	**OBSERVED SIGN**	**OBSERVED SIGNIFICANCE**
LNPMS	-	SIGNIF.	-	NOT SIGNIF.	-	**SIGNIF.**
LNGDP	+	SIGNIF.	+	**SIGNIF.**	-	**SIGNIF.**
LNPCI	0, +, or -	SIGNIF.	+	NOT SIGNIF.	-	NOT SIGNIF.
LNKLR	+	SIGNIF.	-	**SIGNIF.**	-	**SIGNIF.**
LNIKR	-	SIGNIF.	-	NOT SIGNIF.	-	**SIGNIF.**
PGR	+	SIGNIF.	+	NOT SIGNIF.	**-**	NOT SIGNIF.

Source: Author's computation

Table 5.12, which applies to models 2 and 3, indicates that price elasticity is expected to be negative and income elasticity zero (when nothing is demanded), positive (for normal goods) or negative (for inferior goods). The coefficients of all the variables are expected to be statistically significant.

The unrestricted model 2 returned a "near singular" and therefore invalid result. Model 2 is, therefore, not suitable for long-run analysis.

The restricted model (2A), whose results are long-run income and price elasticities, is valid and fits well [Prob. (F-statistic) = 0]. All the regressors in the model are linearly related to LNTFC and significant, except LNPMS_CAM. The value of the adjusted R-squared is about 0.46; it indicates that about 46 percent of the variation in LNTFC is explained by variations in the regressors in the equation. From Table 5.8 the Prob.(Jarque-Bera) values of lnGDP_CAM (0.2066), lnPMS_CAM (0.3191), lnTFC_CAM (0.3277), lnGDP_NGN (0.18808), lnPMS_NGN (0.319064) and lnTFC_NGN (0.28596) are all greater than 0.1 (or 10 percent), suggesting that the error terms of each of these series follow the normal distribution. According to Gujarati (2014) for each entity we can assume that there is no autocorrelation over time. Finally, the recursive least square (RELS) plot indicates the absence of any structural break in Cameroon and Nigeria within the period under investigation (see Appendix).

Below is the tabular presentation of the regression results of Model 2A.

Table 5.13 Pooled Least Squares Regression Result of Model 2A

Dependent variable: LNTFC_CAM; LNTFC_NGN
Method: Pooled Least Squares
Sample: 1971-2010
Included observations: 40
Cross-sections included: 2
Total pool (balanced) observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.727552	1.212235	-3.899863	0.0002*
CAM-LNGDP_CAM	0.934593	0.199306	4.689227	0.0000*
NGN-LNGDP_NGN	-0.484452	0.256778	-1.886660	0.0631***
CAM-LNPMS_CAM	-0.036735	0.053238	-0.690011	0.4923
NGN-LNPMS_NGN	-0.221883	0.044857	-4.946481	0.0000*
Fixed Effects (Cross)				
CAM--C	-5.266778			
NGN--C	5.266778			

Effects Specification
Cross – section fixed (dummy variables)

R-squared	0.493462
Adjusted -squared	0.459236
F-statistic	14.41794
Prob(F-statistic)	0.000000
Durbin-Watson stat	0.585305

*Significant at 1percent ** significant at 5 percent *** significant at 10 percent
Source: Author’s computation, 2015

Short-run elasticites are found using the neoclassical (traditional) method, that is, by dividing the yearly percentage change in per capita commercial energy consumption in year i by its corresponding percentage change in price in Cameroon and Nigeria respectively.

The combined results of the short-run and long-run income and price elasticities of demand for commercial energy are presented in Table 5.13.

Table 5.14 Price and income elasticities for Cameroon and Nigeria

	CAMEROON		**NIGERIA**	
ELASTICITIES	**S.R.**	**L.R**	**S.R.**	**L.R.**
Price	-0.78	-0.04	+7.75	-0.22
Income	+0.87	+0.93	-4.13	-0.48

Source: Author's computation, 2015

5.3.2.1.1 Price Elasticity Analysis

Total fuel consumption (TFC) displays the characteristics of a normal good in Cameroon. Demand for TFC is price inelastic in the short as well as the long run, implying that , one, TFC has few close (good) substitutes and two, a fall in the price of TFC reduces total spending on TFC and a rise in price increases it. The negative sign of price elasticity of demand for TFC suggests that the economy becomes more sensitive to the same relative changes if the share of energy-related expenses in total income increases. On the other hand, in the short run, TFC in Nigeria displays the characteristics of an abnormal good. Demand for TFC is price elastic, implying that a fall in price increases total spending on TFC and a rise in price decreases it. Secondly, there is inadequate supply of TFC leading to massive use of alternatives (e.g. biomass and agricultural residues); and thirdly, the Nigerian economy is less sensitive to energy-related prices. On the long run, however, TFC appears to be a normal and inelastic good in Nigeria. Demand for TFC is price inelastic indicating that a fall in price reduces total spending on TFC and a rise in price increases it; and that the economy has become more and more sensitive to energy-related prices. This result for Nigeria is similar to that of Isola et al. (2013) who posit that irrespective of their origin (domestic or international) oil price shocks have short-term consequences on the growth of the Nigerian economy. In other words, if the market mechanism is allowed to work, the economic system will adjust in the long run to compensate for any negative consequences; in which case the economy will return to equilibrium position. Isola et al. (2013) add that increase in fuel price would lead to an increase in the general price level in the short run. However, Aliyu (2009a) finds that oil price shocks exert a positive influence on real economic growth in Nigeria. Ofonyelu (2013) also finds a strong relationship between increase in fuel price and inflation rate in the short run in Nigeria, which however weakens in the long run.

5.3.2.1.2 Income Elasticity Analysis

TFC for Cameroon is income inelastic and has a positive sign, which indicates that every additional unit of good produced in the economy becomes more energy-intensive, in line with fact that Cameroon is a developing economy. On the other hand Nigeria's TFC has the characteristics of an inferior good in the short as well as in the long run. Demand for TFC is income elastic in the short run but inelastic in the long run. The negative sign of income elasticity suggests that every additional unit of a good produced in Nigeria has become less energy-intensive, an indication that the economy has decoupled, a characteristic of a developed country. One possible explanation for this is the epileptic and inadequate supply of TFC, leading to the use of poor alternatives (e.g. biomass and agricultural residues). Our findings are in line with Saibu (2012)'s, who finds that energy consumption is income inelastic in Nigeria.

5.3.3 Model 3

5.3.3.1 Unit root test

The LLC (2002), IPS (2003), ADF- and PP – Fisher Chi- square procedures are used to perform unit root tests on the variables in Model 3. The results of the tests suggest that at 10 percent level of significance each of the variables in model 3 is stationary at levels as shown in the table below.

Table 5.15 Group Unit Root Test Summary

Group unit root test: Summary
Series: IKR_CAM, IKR_NGN, INT_CAM, INT_NGN, LNKLR_CAM, LNKLR_NGN, LNPCI_CAM, LNPCI_NGN, LNPMS_CAM, LNPMS_NGN, PGR_CAM, PGR_NGN

Sample: 1971 - 2010
Cross Sections:12

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	1.65696	0.9512	453
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	-1.41714	0.0782	453
ADF- Fisher chi square	33.3526	0.0969	453
PP- Fisher chi square	48.0359	0.0025	468

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution.
All other tests assume asymptotic normality.

Source: Author's computation

5.3.3.2 Results of estimated equation 4.4

(a) The restricted Model

The results of the estimated unrestricted Model 3.6 are presented below. The Model fits well [Prob. (F-statistic) = 0]. The adjusted R- squared is equal to about 0.72, indicating that about 72 percent of the variation in intensity of use of commercial energy in Cameroon and Nigeria is explained by the variables in the model. From Table 5.8 it seems that the error terms of the following series do not follow the normal distribution because the value of the Jarque-Bera probability of each series is about zero (Table 5.8). These series are lnKLR_CAM, lnPGR_NGN, lnKLR_NGN and IKR_NGN. All the variables in the equation have the expected sign except LNKLR_CAM and PGR_NGN. LNKLR_CAM is negative, contrary to expectation. An explanation to this could be that new and energy-efficient machines are purchased in Cameroon and they are serviced regularly. An explanation to the negative sign of PGR_NGN is rapid population growth, whose mean and median are 2.54% and 2.49% respectively and the massive use of biomass and agricultural residue in the household sector in Nigeria. For each entity we can assume that there is no autocorrelation (Gujarati, 2014).

Out of the five variables tested for each country in the model, three namely: LNPMS, LNKLR and IKR are significant at ten percent for Nigeria and one (LNKLR) is significant for Cameroon.

Table 5.16: Pooled Least Squares Regression Result

Dependent variable: INT_CAM; INT_NGN
Method: Pooled Least Squares
Sample: 1971-2010
Included observations: 40
Cross-sections included: 2
Total pool (balanced) observations: 80

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-2.55E-05	3.39E-05	-0.753114	0.4540
CAM-LNPMS_CAM	-1.10E-07	2.40E-06	-0.045865	0.9636
NGN-LNPMS_NGN	-8.62E-06	1.74E-06	-4.961584	0.0000*
CAM-LNPCI_CAM	7.39E-06	4.82E-06	1.533096	0.1299
NGN-LNPCI_NGN	3.58E-06	5.01E-06	0.714735	0.4772
CAM-LNKLR_CAM	-1.03E-05	4.57E-06	-2.262914	0.0268**
NGN-LNKLR_NGN	-6.04E-06	2.88E-06	-2.095119	0.0399**
CAM-IKR_CAM	-4.31E-06	8.79E-06	-0.490640	0.6253
NGN-IKR_NGN	-0.003681	0.000689	-5.343995	0.0000*
CAM-PGR_CAM	1.23E-05	8.81E-06	1.399707	0.1661
NGN-PGR_NGN	-4.21E-06	7.96E-06	-0.529198	0.5984
Fixed Effects (Cross)				
CAM--C	2.05E-05			
NGN--C	-2.05E-05			

Effects Specification
Cross – section fixed (dummy variables)

R-squared	0.757746
Adjusted -squared	0.718558
F-statistic	19.33611
Prob(F-statistic)	0.000000
Durbin-Watson stat	1.161915

*Significant at 1percent   ** significant at 5 percent
Source: **Author's computation, 2015**

The coefficient of LNPMS_NGN is negative indicating that intensity and the price of commercial energy in Nigeria vary inversely: the lower its price the higher the intensity and vice versa. The policy implication of this is that for intensity to decrease the price of commercial energy should be raised in Nigeria. Secondly, the coefficient of the LNKLR_NGN is negative, suggesting an inverse relationship between INT and the capital-labour ratio in Nigeria. For capital-labour ratio to increase, the rate of increase of capital must be greater than the rate of increase of labour employment. In other words this result suggests that the Nigerian economy should be capital -intensive, and which has many policy implications. A number of empirical studies (Griliches, 1969; Goldin & Katz, 1998; as cited in Borjas, 2010) suggest that unskilled labour and capital are substitutes, and that skilled labour and capital are complements. In other words as the price of machines falls, employers substitute away from unskilled workers. In contrast, as the price of machines falls and employers increase the use of capital equipment, the demand for skilled workers rises because skilled workers and capital equipment "go together." Clark & Freeman (1980) have found that a 10 percent fall in the price of capital reduces the employment of unskilled workers by 5 percent and increases the employment of skilled workers by 5 percent. This result has come to be known as the capital-skill complementarity hypothesis. This hypothesis has important policy implications. It suggests that subsidies to investments in physical capital (such as investment in tax credit) will have a differential impact on different groups of workers. Because an investment in tax credit lowers the price of capital to the firm, it increases the demand for capital, reduces the demand for unskilled workers, and increases the demand for skilled workers. The capital-skill complementarity also suggests that technological progress can have a substantial impact on income inequality again because it increases the demand for skilled workers and reduces the demand for unskilled workers (Borjas, 2010). Third, the coefficient of IKR_NGN is negative. Its interpretation is similar to that capital-labour ratio above.

(b) The unrestricted Model

The unrestricted model returned a "near singular" result. This suggests that this model is basically linear.

5.3.4 Results of Granger Causality Tests

5.3.4.1 Granger Causality Tests among energy intensity, technology and energy price

Unit root tests are performed among energy intensity, energy price and technology using LLC (2002) and IPS (2003) procedures. The causal relationship of these variables has been defined in the Methodology section.

Table 5.17 Group Unit Root Test Summary

Group unit root test: Summary

Series: INT_CAM, INT_NGN, PMS_CAM, PMS_NGN, TKN_CAM, TKN_NGN

Sample: 1971 – 2010
Cross Sections: 6

Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	-1.94460	0.0259	234
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	-1.74702	0.0403	234
ADF- Fisher chi square	18.5251	0.1007	234
PP- Fisher chi square	18.1352	0.1116	234

** Probabilities for Fisher tests are computed using an asymptotic Chi- square distribution.
All other tests assume asymptotic normality.
Source: Author's computation

The result of this test indicates that energy intensity, energy price and technology data series are stationary at levels. The results of the Pairwise Granger Causality follow on Table 5.18.

Table 5.18: Pair wise Granger Causality Tests

Sample: 1971- 2010; Lag: 2

No. of observations: 38

Null Hypothesis (Ho):	F-Statistic	Prob.	Remark
INT_NGN does not Granger Cause INT_CAM	0.93680	0.4021	Don’t reject
INT_CAM does not Granger Cause INT_NGN	0.04942	0.9518	Don’t reject
PMS_CAM does not Granger Cause INT_CAM	1.03548	0.3663	Don’t reject
INT_CAM does not Granger Cause PMS_CAM	0.53828	0.5888	Don’t reject
PMS_NGN does not Granger Cause INT_CAM	1.03548	0.3663	Don’t reject
INT_CAM does not Granger Cause PMS_NGN	0.53828	0.5888	Don’t reject
TKN_CAM does not Granger Cause INT_CAM	3.05138	00608***	Reject Ho
INT_CAM does not Granger Cause TKN_CAM	0.65351	0.5268	Don’t reject
TKN_NGN does not Granger Cause INT_CAM	1.53704	0.2300	Don’t reject
INT_CAM does not Granger Cause TKN_NGN	2.67466	0.0838***	Reject Ho
PMS_CAM does not Granger Cause INT_NGN	0.84306	0.4395	Don’t reject
INT_NGN does not Granger Cause PMS_CAM	0.74149	0.4842	Don’t reject
PMS_NGN does not Granger Cause INT_NGN	0.84306	0.4395	Don’t reject
INT_NGN does not Granger Cause PMS_NGN	0.74149	0.4842	Don’t reject
TKN_CAM does not Granger Cause INT_NGN	2.24978	0.1214	Don’t Reject
INT_NGN does not Granger Cause TKN_CAM	3.89874	0.0302**	Reject Ho
TKN_NGN does not Granger Cause INT_NGN	1.94019	0.1597	Don’t reject
INT_NGN does not Granger Cause TKN_NGN	5.88689	0.0065*	Reject Ho
PMS_NGN does not Granger Cause PMS_CAM	NA	NA	-
PMS_CAM does not Granger Cause PMS_NGN	NA	NA	-
TKN_CAM does not Granger Cause PMS_CAM	0.28274	0.7555	Don’t reject
PMS_CAM does not Granger Cause TKN_CAM	1.44619	0.2500	Don’t reject
TKN_NGN does not Granger Cause PMS_CAM	5.13121	0.0115**	Reject Ho
PMS_CAM does not Granger Cause TKN_NGN	0.82070	0.4489	Don’t reject
TKN_CAM does not Granger Cause PMS_NGN	0.28274	0.7555	Don’t reject
PMS_NGN does not Granger Cause TKN_CAM	1.44619	0.2500	Don’t reject
TKN_NGN does not Granger Cause PMS_NGN	5.13121	0.0115**	Reject Ho
PMS_NGN does not Granger Cause TKN_NGN	0.82070	0.4489	Don’t reject
TKN_NGN does not Granger Cause TKN_CAM	1.80172	0.1809	Don’t reject
TKN_CAM does not Granger Cause TKN_NGN	0.32933	0.7217	Don’t reject

***** Reject H_o at 1%; ** Reject H_o at 5%; *** Reject Ho at 10% level of significance

Source: Author’s computation, 2015

5.3.4.1.1 Pairwise Granger Causality Tests analysis

The Pairwise Granger Causality Tests are run using lags 2. These lags are gotten by default.

Pair 1:

Both null hypotheses are not rejected at 5 percent level of significance. Their respective p-values are 0.4021 and 0.9518. This suggests that Cameroon and Nigeria run independent energy intensity policies.

Pair 2:

Both null hypotheses "PMS_CAM does not Granger Cause INT_CAM" and "INT_CAM does not Granger Cause PMS_CAM" are not rejected at 5 percent level of significance. Their respective p-values are 0.3663 and 0.5888. This suggests that there is independence/disconnect between energy pricing policies and energy consumption in Cameroon.

Pair 3:

There is overwhelming evidence that both null hypotheses are not rejected at 5 percent level of significance. Their p-values are 0.3663 and 0.5888, respectively. This suggests that energy use (energy intensity) in Cameroon is independent of energy pricing in Nigeria and vice versa.

Pair 4:

Both null hypotheses "TKN_CAM does not Granger Cause INT_CAM" and "INT_CAM does not Granger Cause TKN_CAM" are not rejected at 5 percent level of significance. Their respective p-values are 0.0608 and 0.5268, suggesting that energy use (energy intensity) in Cameroon is not factored into environmental policy and environmental policy is not factored into energy intensity. So, it appears that energy use is totally divorced from energy policy on the environment in Cameroon.

Pair 5:

The null hypothesis that "TKN_NGN does not Granger Cause INT_CAM" is not rejected at 5 percent level of significance. Its p-value is 0.2300. This suggests that there is overwhelming statistical evidence to infer that, technology in Nigeria does not Granger Cause energy intensity in Cameroon. A possible explanation for this is that petroleum products (probably locally) refined in Nigeria and smuggled into Cameroon for use in industry and transport may be cheap and of low quality but do not add to intensity in Cameroon. Secondly, that Nigeria may be learning energy intensity abatement techniques from Cameroon.

Pair 6:

The non-rejection at 5 percent of the null that "PMS_CAM does not Granger Cause INT_NGN" (p-value = 0.4395) and that of "INT_NGN does not Granger Cause PMS_CAM" (p-value = 0.4842) suggests that petroleum products pricing policy in Cameroon is independent of energy intensity in Nigeria, and vice versa.

Pair 7:

The null hypotheses that "PMS_NGN does not Granger Cause INT_NGN" and that "INT_NGN does not Granger Cause PMS_NGN are not rejected at 5 percent level of significance. Their respective p-values are 0.4395 and 0.4842. This suggests that petroleum products pricing policy and energy intensity policy are independent in Nigeria.

Pair 8:

The null hypothesis that "TKN_CAM does not Granger Cause INT_NGN" is not rejected at 5 percent level of significance (p-value = 0.1214). This suggests that there is limited, if any, smuggling of petroleum products from Cameroon into Nigeria. Reverse is not the case: the hypothesis that "INT_NGN does not Granger Cause TKN_CAM" (p-value = 0.0302) is rejected at 5 percent level of significance. This suggests that environmental pollution in Nigeria does not pose a threat to Cameroon.

Pair 9:

The null hypothesis that “TKN_NGN does not Granger Cause INT_NGN” is not rejected at 5 percent level of significance (p-value = 0.1597). However, reverse is not the case (p-value = 0.0065). This seems to suggest that if the Nigerian authorities concerned themselves first about energy use there would automatically be a reduction in environmental challenges in Nigeria.

Pair 10:

It is not possible to analyze pair 10 owing to non-availability of their probability values.

Pair 11:

The non-rejection at 5 percent level of significance of the null hypotheses that “TKN_CAM does not Granger Cause PMS_CAM” (p-value = 0.7555) and “PMS_CAM does not Granger Cause TKN_CAM’ (p-value = 0.2500) suggest that the pricing policy of refined petroleum products does not take into consideration environmental pollution in Cameroon and vice versa.

Pair 12:

The rejection at 5 percent level of significance of the null that “TKN_NGN does not Granger Cause PMS_CAM” (p-value = 0.0115) suggests that the pricing policy of petroleum products in Cameroon is not led by environmental considerations in Nigeria. However, reverse is not the case (p-value = 0.4489). This does not seem plausible.

Pair 13:

The non-rejection at 5 percent level of significance, of the hypotheses that “TKN_CAM does not Granger Cause PMS_NGN” (p-value = 0.7555) and that “PMS_NGN Granger Causes TKN_CAM” (p-value = 0.2500) suggest that there is overwhelming statistical evidence that petroleum products pricing policies in Nigeria are independent of environmental considerations in Cameroon and vice versa.

Pair 14:

We observe an overwhelming evidence of the rejection at 5 percent level of significance of the hypothesis that "TKN_NGN Granger Causes PMS_NGN" (p-value = 0.0115). This suggests that environmental considerations lead to pricing of commercial energy in Nigeria but that reverse is not the case (p= 0.4489).

Pair 15:

The non-rejection at 5 percent of the null hypotheses that "TKN_NGN does not Granger Cause TKN-CAM" (p-value = 0.1809) and "TKN_CAM does not Granger Cause TKN_NGN" (p-value = 0.7217) suggests that environmental policies in both countries are independent.

5.3.4.2 Results of Granger Causality test between GDP and energy consumption

Unit root tests are performed between per capita gross domestic product in Cameroon (GDPC) and total commercial energy consumption (TFCC) using LLC (2002), IPS (2003), ADF-Fisher and PP-Fisher procedures and the results presented below.

(a) For Cameroon

Table 5.19: Summary of the group unit root Granger Causality test for Cameroon

Group unit root test: Summary
Series: GDPC, TFCC
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1

Newey-West automatic bandwidth selection and Bartlett kernel

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	-0.32151	0.3739	77
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	0.90139	0.8163	77
ADF- Fisher chi square	1.12375	0.8905	77
PP- Fisher chi square	0.99945	0.9099	77

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Source: Author's computation, 2015

Table 5.20 Summary of the Pairwise Granger

Causality Tests for Cameroon

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
TFCC does not Granger Cause GDPC	38	0.48819	0.6181
GDPC does not Granger Cause TFCC		3.65072	0.0370

Source: Author's computation, 2015

The null of a unit root is rejected at 1 percent, indicating the absence of a unit root at that level of significance (Table 5.19), which suggests that Granger Causality tests may produce reliable results. Moreover, the null that TFCC does not Granger Cause GDPC is rejected at 1 percent level of significance but the null that GDPC does not Granger Cause TFCC is not rejected at 5 percent level of significance (Table 5.20**).** It may therefore be concluded that TFCC Granger Causes GDPC but not vice versa. The implication of this result is that an increase in commercial energy consumption will have a positive impact /effect on GDP in Cameroon.

(b) For Nigeria

Table 5.21 Summary of the group unit root Granger Causality test for Nigeria

Group unit root test: Summary
Series: GDPN, TFCN
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Cross Sections:2

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	6.26628	1	78
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	4.78986	1	78
ADF- Fisher chi square	3.99218	0.4071	78
PP- Fisher chi square	3.99751	0.4063	78

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Source: Author's Computation, 2015

The analysis for Table 5.21 is similar to that of Table 5.19: the null of a unit root is rejected at 1 percent. Table 5.22 indicates the presence of a bilateral/bi-directional Granger Causality relationship between commercial energy consumption (TFCN) and GDPN in Nigeria between 1971 and 2010.

Table 5.22: Summary of the Pairwise Granger Causality Tests for Nigeria

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
TFCN does not Granger Cause GDPN	38	0.14089	0.8691
GDPN does not Granger Cause PMSN		0.04978	0.9515

Source: Author's computation, 2015

Finally, in order to find out whether or not there is a causal relationship between GDP and energy price, a Granger Causality test is run between these two variables for Cameroon and then for Nigeria. We begin with a unit root test, which is followed by a Granger Causality test.

Table 5.23: Group Unit Root Test Summary

Group unit root test: Summary
Series: GDPC, PMSC
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	-0.07841	0.4688	77
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	0.07271	0.5290	77
ADF- Fisher chi square	3.33298	0.5037	77
PP- Fisher chi square	3.39728	0.4937	78

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Source: Author's Computation, 2015

Table 5.24 Granger Causality Test for Cameroon

Pairwise Granger Causality Tests

Sample: 1971 2010

Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
PMSC does not Granger Cause GDPC	38	2.79077	0.0759
GDPC does not Granger Cause PMSC		0.43277	0.6523

Source: Author's Computation, 2015

Table 5.23 indicates the rejection of the null of a unit root and from Table 5.24 we find an indication of a unidirectional causality from GDPC to PMSC, meaning that economic performance influences the price of commercial energy in Cameroon between 1971 and 2010.

From Tables 5.25 and 5.26, we observe that the null of a unit root is rejected and the existence of a bilateral Granger Causality relationship between commercial energy price and economic performance (GDP) in Nigeria, within the period under investigation.

Table 5.25: Group Unit Root Test Summary

Group unit root test: Summary
Series: GDPN, PMSN
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Null: Unit root (common unit root process)			
	Statistic	Prob.**	Observations
Levin, Lin &Chu t*	6.82826	1.0000	78
Null: Unit root (individual unit root process)			
Im, Pesaran and Shin W-stat	5.04358	1.0000	78
ADF- Fisher chi square	2.90863	0.5732	78
PP- Fisher chi square	3.04810	0.5498	78

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Source: Author's computation, 2015

Table 5.26 Granger Causality Test for Nigeria

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
PMSN does not Granger Cause GDPN	38	1.48971	0.2402
GDPN does not Granger Cause PMSN		2.03411	0.1469

Source: Author's computation, 2015

5.4 Summary of Findings

5.4.1. Our results suggest similarity of commercial energy use in Cameroon and Nigeria. Moreover, the commercial energy used in the agricultural sector is infinitesimal compared to that used in other sectors of the economy in both countries. On the other hand, the transportation sector leads all the other sectors in commercial energy consumption. It is followed by the residential, industrial and commercial sectors in that order.

5.4.2 Demand for commercial energy is income and price inelastic in the short as well as in the long run in Cameroon, and price and income inelastic in the long run in Nigeria. However, in the short run in Nigeria, commercial energy is price and income elastic. This observation points to the fact that commercial energy is a necessity in both countries and that its inadequate supply in Nigeria in particular leads to massive use of alternatives, the use of biomass and agricultural residues for example, in productive activities in the domestic, commercial and industrial sectors (Bhattacharyya, 2011). In addition, the observation that commercial energy price is significant in the long run in Nigeria but not significant in Cameroon suggests that the pump price of gasoline could be increased in Cameroon but not in Nigeria. Income is, however, significant in both countries. The results in respect of Nigeria are consistent with those of Iwayemi et al. (2010) and Adagunodo (2014).

5.4.3 The ratio of energy intensity of Nigeria (En) over that of Cameroon (Ec) is 1.57:1, meaning that on the average, between 1971 and 2010, if Cameroon consumed one unit of energy to produce a US dollar's worth of a representative good (at PPP), Nigeria used up 1.57 (i.e. about

50 percent more) units of energy in the production of the same. This indicates that Cameroon is better/effective at using her commercial energy assets than Nigeria is within the period under investigation.

5.4.4 Two variables of the energy-intensity model, namely GDP and capital-labour ratio (KLR), contribute significantly to energy intensity in Cameroon. The higher is the KLR the lower the energy intensity in Cameroon, and vice versa. On the other hand the pump price of commercial fuels (PMS), GDP, capital-laour ratio (KLR) and investment-capital ratio (IKR) contribute significantly, and are inversely related, to energy intensity in Nigeria. Put differently, the higher PMS, GDP, KLR and IKR the lower energy intensity in Nigeria, and vice versa.

5.4.5 Between 1971 and 2010, a bi-directional Granger Causality relationship exists in Nigeria between energy consumption and economic growth (proxy GDP). However, only a unilateral Granger Causality relationship (viz. GDP Granger causes TFC) exists between these two variables in Cameroon within the same period. Moreover, commercial energy pricing policy and commercial energy consumption (demand) appear disconnected in both countries. On the other hand, energy consumption policy in Cameroon is independent of that of Nigeria and same goes for environmental policy. Moreover, whereas energy pricing policy takes into account environmental considerations in Nigeria, there seems to be a complete divorce between commercial energy pricing, commercial energy consumption and environmental policies in Cameroon. Finally the quantum of petroleum products smuggled from Nigeria into Cameroon is insignificant and Nigeria's environmental challenges resulting from commercial energy consumption are not a threat to Cameroon's environment.

The summary, conclusion and recommendations follow in Chapter six.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The main objective of this study is to find out which country, Cameroon or Nigeria, is more effective in terms of energy consumption between 1971 and 2010. To achieve the main objective five specific objectives were addressed. Most of the data used in the study were obtained from the International Energy Agency (IEA) and the World Bank. Other relevant data items are extracted from official Nigerian databases (for Nigeria) and the Bureau National de la Statistique (for Cameroon). Four models are used to analyze the data. Model One is descriptive. It is used to analyze structural energy demand. Models Two and Three are energy-demand style regressions, used to analyze the elasticites of demand for commercial energy, and commercial energy intensity, respectively. Model Four is Granger Causality. Finally conclusions are drawn.

6.2 Conclusion

The following conclusion is drawn from this study.

Although commercial energy is a normal good in Cameroon but an abnormal good in Nigeria, there is similarity in the pattern of its consumption in both countries. Energy supply is inadequate in both countries and there is a disconnect among energy demand, energy pricing and environmental policies. However, overall, Cameroon is more energy effective than Nigeria.

6.3 Recommendations

Based on the findings of this research, the following recommendations are made:

6.3.1: That both nations should restructure their economies, attract foreign direct investment, increase investment in appropriate human and physical capital, increase industrial capacity utilization (Nigeria in particular), mechanize and/or clusterize their agricultural sector, as well as apply energy efficiency/management techniques in all sectors of the economy (Balouga, 2014; Balouga, 2012b).

6.3.2 That there should be complete eradication of energy poverty using appropriate supply-side and demand-side policies, such as increase in energy supply; decrease in energy demand (through efficiency use); decrease in wastage; appropriate energy pricing, etc. Although Atuanya (2015) reports that stopping subsidies will release money for the development and facilitate the rebuilding of a healthy home-grown downstream sector, for now, because there is energy poverty in Cameroon and Nigeria, fuel subsidies should not be totally removed. Instead, the federal government of Nigeria should sell or rehabilitate the four refineries, resolve the Petroleum

Products Marketing Company (PPMC) and Petroleum Products Pricing and Regulatory Authority (PPPRA) inefficiencies, reduce the importation of petroleum products and reduce the cost of subsidy (if any). According to El-Rufai (2015) Nigeria can no longer afford to maintain an NNPC that arrogantly and unconstitutionally spends an unhealthy proportion of national oil earnings on itself. NNPC, he advises, should be replaced with brand new organizations (Balouga, forthcoming,a). In addition to the expansion of the 42,000 barrels-per-day Société Nationale de Rafinage (SONARA) refinery in Limbe, the Cameroon government should build another refinery. Both governments should also improve on the distribution of petroleum products; as well as initiate, encourage and facilitate the sustenance and expansion of renewable energy technologies.

6.3.3: That both countries should invest massively in their traditional and modern infrastructure, which should be sufficient, reliable and competitively priced. Both should also invest in less polluting renewable technologies, such as solar, wind, bio-energy (bio-digesters), energy-efficient cooking stoves, home insulation, etc.

6.3.4: Lack of requisite skills is identified as a major factor hindering businesses in Cameroon and Nigeria; both countries should address this issue (by providing adequate, qualitative and functional education) with immediate effect. Cameroon and Nigeria should also be very concerned with a vibrant industrialization/manufacturing sector if they want a formation of the middle class in their economies (Batra, 1993; Fasan, 2013). Nigeria in particular should control the rate of growth of her population by limiting the number of births through family planning methods, and discouraging child/early marriage.

6.3.5 That Government, in both countries, should ensure that there is synergy or cooperation among her agencies, particularly those in the commercial energy value chain. Also there should be sustainable security of supply of energy products, and effective joint border policing by both economies. Finally, that, as a matter of urgency, both countries should strengthen their institutions (Apampa, 2015).

6.4 Contributions to Knowledge

This study has made the following contributions to knowledge:

6.4.1. The theory of the structure of energy demand in developing countries is invalidated as the transportation sector has the highest share of energy consumption instead of the residential sector in both countries.

6.4.2. There is contribution to knowledge in terms of comparative analysis of energy demand in neighbouring, developing countries.

6.4.3 The use of the neoclassical method to compute short-run elasticities of demand and the use of the inverse of carbon dioxide emissions instead of mileage, as a proxy for technology is a contribution to knowledge.

6.4.4. There is a disconnect between energy pricing policy and energy consumption on the one hand, and energy consumption and the environment in Cameroon and Nigeria. This draws attention to the policy issues of oil subsidies (in Nigeria), climate change and synergy.

6.4.5. None of the studies reviewed in this research work was approached from a 'holistic' perspective, whose advantage is the avoidance of policy prescriptions that could work at cross purposes.

6.5 Limitations of the Study

Data paucity and reliability is a major challenge encountered in this study. Biomass is already in use in developed countries (DCs) as well as in less developed countries (LDCs) where formal and informal markets of biomass already exist. It is estimated that approximately 14.7 percent or 54.83 exajoules (1 exajoule = 1018 joules) of energy in the world is obtained through biomass (Hall, 1993). Both for DCs and LDCs, the size of the formal market is relatively better known than that of the informal market. The sizes of the informal and formal markets are underestimated because many biomass transactions are not normally recorded and many new biomass types have not yet appeared on any market due to their low energy conversion efficiency. For example, the use of palm fruit fiber for steam generation in palm oil mills is not recorded as a fuel on the formal market neither is the energy potential of existing biomass such as seaweed evaluated. Two factors will change the role and the status of biomass on the informal market: first, the energy generation by independent power plants (IPP) and second, the increasing efficiency of energy conversion provided by the new and advanced technologies (Joshipura & Yamaji, 1997).The dynamics of inter-fuel substitution (i.e. switching) between commercial and non-commercial energy in developing countries is an important factor which shapes the evolution of the level and the structure of energy demand in developing energy markets. Africa is characterized by a heavy dependency on biomass (Sokonna & Thoamas, 1999; World Bank, 2011; Afaha, 2014). Therefore, without taking non-commercial energy use into consideration, estimating energy demand - and by extension energy intensity- for developing countries, Cameroon and Nigeria inclusive, is likely not to reflect reality (Birol, 1997, Bhattacharyya, 2011).

Also, in this study we used the pump price of petrol as a proxy for energy price in Nigeria. The data for the pump price of petrol in Cameroon were available for ten years (2001 – 2010) only. The pump price of petrol in Cameroon between 1971 and 2000 was estimated based on our estimation of the statistical relationship between gasoline prices in Nigeria for the last ten years and those for Cameroon in the same time frame. This inadvertently introduces slight errors in the estimation of our variables (e.g. elasticities).

6.6 Suggestions for Further Research

Again, one challenge faced in this study was the paucity of data. We used gasoline price as a proxy to commercial energy price and excluded biomass - a source of energy now classified 'non-commercial' simply because its market is not well developed - which, undoubtedly introduced errors in our computations. There is, therefore, great need for further research to be carried out in this area as soon as demand for non-commercial (biomass) energy can be quantified or assessed and more data are available.

The total change in energy consumption (demand) is the sum of the activity effect, intensity effect and structural effect (Bhattacharyya, 2011). In this study we have limited our investigation to the decomposition of the activity and intensity effects. Further research could be done on the other effect.

Finally, because Cameroon and Nigeria are low-income economies, it might be necessary to investigate the incidence of energy poverty (barely mentioned in our research work) in them and its effect on the growth of their economies.

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APPENDIX 1

COVERIANCE - CAMEROON

Covariance Analysis: Ordinary
Sample (adjusted): 1971 2009
Included observations: 39 after adjustments
Balanced sample (listwise missing value deletion)

Covariance t-Statistic Probability	TFCC	ERZC	EINC	ETRC	ECMC	EAGC
TFCC	1586429.					

ERZC	896543.9	765217.6				
	8.515089	-----				
	0.0000	-----				
EINC	41943.90	32392.52	3496.999			
	4.145137	4.885322	-----			
	0.0002	0.0000	-----			
ETRC	172565.6	133261.6	7527.028	30734.50		
	7.619311	10.68063	6.422393	-----		
	0.0000	0.0000	0.0000	-----		
ECMC	120237.5	106100.4	720.2137	17154.76	24305.86	
	4.710969	7.532024	0.476637	4.904105	-----	
	0.0000	0.0000	0.6364	0.0000	-----	
EAGC	534.1637	394.1302	66.80605	92.33991	-62.99145	1.733070
	2.069900	2.215605	10.16709	2.655523	-1.961562	-----
	0.0455	0.0330	0.0000	0.0116	0.0574	-----

CORRELATION - CAMEROON

	TFCC	ERZC	EINC	ETRC	ECMC	EAGC
TFCC	1.000000	0.813708	0.563133	0.781503	0.612314	0.322148
ERZC	0.813708	1.000000	0.626188	0.868959	0.777981	0.342247
EINC	0.563133	0.626188	1.000000	0.726044	0.078119	0.858143
ETRC	0.781503	0.868959	0.726044	1.000000	0.627648	0.400100
ECMC	0.612314	0.777981	0.078119	0.627648	1.000000	-0.306915
EAGC	0.322148	0.342247	0.858143	0.400100	-0.306915	1.000000

APPENDIX 2

COVERIANCE – NIGERIA

Covariance Analysis: Ordinary
Sample (adjusted): 1971 2009
Included observations: 39 after adjustments
Balanced sample (listwise missing value deletion)

Covariance t-Statistic Probability	TFCN	ERZN	EINN	ETRN	ECMN	EAGN
TFCN	4.49E+08 ----- -----					
ERZN	3.30E+08 12.45031 0.0000	3.00E+08 ----- -----				
EINN	41125093 17.20657 0.0000	33366093 16.07837 0.0000	4236885. ----- -----			
ETRN	39336194 8.973005 0.0000	30937483 7.999013 0.0000	4103227. 11.80338 0.0000	5029128. ----- -----		
ECMN	2407120. 13.11349 0.0000	1930722. 11.85216 0.0000	241136.9 16.11601 0.0000	224083.4 8.054407 0.0000	15679.09 ----- -----	
EAGN	-564032.9 -4.286505 0.0001	-450329.0 -4.136627 0.0002	-58090.02 -4.692013 0.0000	-47656.88 -3.150545 0.0032	-2649.281 -3.133026 0.0034	2135.011 ----- -----

CORRELATION - NIGERIA

	TFCN	ERZN	EINN	ETRN	ECMN	EAGN
TFCN	1.000000	0.898500	0.942821	0.827736	0.907158	-0.576036
ERZN	0.898500	1.000000	0.935304	0.795994	0.889673	-0.562342
EINN	0.942821	0.935304	1.000000	0.888906	0.935578	-0.610771
ETRN	0.827736	0.795994	0.888906	1.000000	0.798000	-0.459917
ECMN	0.907158	0.889673	0.935578	0.798000	1.000000	-0.457897
EAGN	-0.576036	-0.562342	-0.610771	-0.459917	-0.457897	1.000000

APPENDIX 3: Redundant Fixed Effects Test Results

Redundant Fixed Effects Tests
Pool: POOL01
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	18.876274	(1,74)	0.0000
Cross-section Chi-square	18.176250	1	0.0000

Cross-section fixed effects test equation:
Dependent Variable: LNTFC_?
Method: Panel Least Squares
Included observations: 40
Cross-sections included: 2
Total pool (balanced) observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.918625	1.314041	-4.504140	0.0000
CAM--LNGDP_CAM	0.396102	0.173689	2.280525	0.0254
NGN--LNGDP_NGN	0.388662	0.177873	2.185053	0.0320
CAM--LNPMS_CAM	-0.062984	0.058861	-1.070044	0.2880
NGN--LNPMS_NGN	-0.274851	0.048038	-5.721506	0.0000

R-squared	0.364252	Mean dependent var	-2.837006
Adjusted R-squared	0.330345	S.D. dependent var	0.287397
S.E. of regression	0.235184	Akaike info criterion	0.003566
Sum squared resid	4.148369	Schwarz criterion	0.152442
Log likelihood	4.857375	Hannan-Quinn criter.	0.063255
F-statistic	10.74280	Durbin-Watson stat	0.583185
Prob(F-statistic)	0.000001		

APPENDIX 4: Descriptive Statistics Model 1
CAMEROON
Sample: 1971 2010

	EINC	ETRC	ERZC	ECMC	EAGC	TFCC
Mean	54.42500	525.0750	134.1750	0.500000	0.000000	714.1750
Median	53.00000	564.0000	133.5000	0.000000	0.000000	794.0000
Maximum	121.0000	887.0000	238.0000	6.000000	0.000000	1130.000
Minimum	19.00000	188.0000	12.00000	0.000000	0.000000	232.0000
Std. Dev.	22.01967	176.2129	67.20802	1.414214	0.000000	246.4516
Skewness	1.077346	-0.387572	-0.305025	2.754288	NA	-0.681256
Kurtosis	4.794951	2.542015	1.986335	9.497041	NA	2.420149
Jarque-Bera	13.10757	1.350998	2.332797	120.9266	NA	3.654444
Probability	0.001425	0.508902	0.311487	0.000000	NA	0.160860
Sum	2177.000	21003.00	5367.000	20.00000	0.000000	28567.00
Sum Sq. Dev.	18909.77	1210989.	176159.8	78.00000	0.000000	2368798.
Observations	40	40	40	40	40	40

NIGERIA
Sample: 1971 2010

	EINN	ETRN	ERZN	ECMN	EAGN	TFCN
Mean	555.0500	5112.925	1059.975	8.875000	28.30000	6765.125
Median	457.5000	4779.000	1189.000	0.000000	0.000000	7212.500
Maximum	1361.000	8745.000	1804.000	89.00000	204.0000	10414.00
Minimum	149.0000	887.0000	227.0000	0.000000	0.000000	1388.000
Std. Dev.	312.3000	2210.799	480.6720	20.66607	46.82220	2395.839
Skewness	0.806261	-0.087821	-0.239924	2.486895	2.116856	-0.694800
Kurtosis	2.943071	2.302951	1.811754	8.597995	7.478498	2.857876
Jarque-Bera	4.339113	0.861213	2.736971	93.46022	63.30211	3.251975
Probability	0.114228	0.650115	0.254492	0.000000	0.000000	0.196717
Sum	22202.00	204517.0	42399.00	355.0000	1132.000	270605.0
Sum Sq. Dev.	3803720.	1.91E+08	9010779.	16656.38	85500.40	2.24E+08
Observations	40	40	40	40	40	40

APPENDIX 5: Descriptive Statistics Model 2

Sample: 1971 2010

	GDPKC	PMSC	TFCPKC	GDPKN	PMSN	TFCPKN
Mean	1975.100	0.843792	0.055689	1535.275	0.281264	0.065982
Median	1946.500	0.740845	0.057112	1455.000	0.246948	0.070729
Maximum	2815.000	2.056109	0.075198	2135.000	0.685370	0.097225
Minimum	1434.000	0.000000	0.032561	1171.000	0.000000	0.023627
Std. Dev.	351.7129	0.626439	0.010977	219.8569	0.208813	0.017953
Skewness	0.684234	0.296790	-0.578470	0.701861	0.296790	-0.603381
Kurtosis	2.861470	1.990793	2.988706	3.186094	1.990793	2.785852
Jarque-Bera	3.153155	2.284728	2.231060	3.341777	2.284728	2.503553
Probability	0.206681	0.319064	0.327742	0.188080	0.319064	0.285996
Sum	79004.00	33.75169	2.227556	61411.00	11.25056	2.639269
Sum Sq. Dev.	4824378.	15.30461	0.004699	1885146.	1.700512	0.012570
Observations	40	40	40	40	40	40

APPENDIX 6: Descriptive Statistics for Model 3

CAMEROON

Sample: 1971 2010

	INTC	PMSC	PGRC	KLRC	PCIC	IKRC
Mean	2.83E-05	0.843792	2.631069	570.0772	8193.566	0.090894
Median	2.82E-05	0.740845	2.706715	486.9142	7563.660	0.074741
Maximum	3.78E-05	2.056109	3.051176	1168.724	14460.38	0.661714
Minimum	2.05E-05	0.000000	2.186407	290.2489	3667.690	-0.171658
Std. Dev.	4.10E-06	0.626439	0.306183	239.1760	2997.500	0.143205
Skewness	0.361789	0.296790	-0.230877	1.111666	0.456425	2.040202
Kurtosis	2.315879	1.990793	1.430968	3.114702	2.437230	8.617689
Jarque-Bera	1.652641	2.284728	4.458461	8.260601	1.916677	80.34690
Probability	0.437657	0.319064	0.107611	0.016078	0.383530	0.000000
Sum	0.001131	33.75169	105.2427	22803.09	327742.7	3.635778
Sum Sq. Dev.	6.55E-10	15.30461	3.656170	2231002.	3.50E+08	0.799798
Observations	40	40	40	40	40	40

NIGERIA

Sample: 1971 2010

	INTN	PMSN	PGRN	KLRN	PCIN	IKRN
Mean	4.45E-05	0.281264	2.539925	0.000333	65719.08	-0.000735
Median	4.56E-05	0.246948	2.492206	0.000265	66682.00	0.000000
Maximum	7.70E-05	0.685370	3.052247	0.000969	109824.0	0.001832
Minimum	1.53E-05	0.000000	2.326178	8.02E-05	30561.00	-0.008417
Std. Dev.	1.58E-05	0.208813	0.189328	0.000218	19831.33	0.001882
Skewness	0.026199	0.296790	1.400534	1.432460	0.033089	-2.208630
Kurtosis	2.277711	1.990793	4.183511	4.457998	2.250707	8.620610
Jarque-Bera	0.874078	2.284728	15.41113	17.22254	0.943034	85.17238
Probability	0.645946	0.319064	0.000450	0.000182	0.624055	0.000000
Sum	0.001781	11.25056	101.5970	0.013312	2628763.	-0.029391
Sum Sq. Dev.	9.72E-09	1.700512	1.397953	1.86E-06	1.53E+10	0.000138
Observations	40	40	40	40	40	40

APPENDIX 7: Descriptive Statistics for Granger Causality variables for Cameroon and Nigeria

Sample: 1971 2010

	INTC	PMSC	TKNC	INTN	PMSN	TKNN
Mean	2.83E-05	0.843792	0.865030	4.45E-05	0.281264	0.183815
Median	2.82E-05	0.740845	0.748603	4.56E-05	0.246948	0.210083
Maximum	3.78E-05	2.056109	2.730881	7.70E-05	0.685370	0.378759
Minimum	2.05E-05	0.000000	0.197324	1.53E-05	0.000000	0.035883
Std. Dev.	4.10E-06	0.626439	0.582559	1.58E-05	0.208813	0.090890
Skewness	0.361789	0.296790	0.886513	0.026199	0.296790	0.116517
Kurtosis	2.315879	1.990793	3.803840	2.277711	1.990793	2.101147
Jarque-Bera	1.652641	2.284728	6.316299	0.874078	2.284728	1.437070
Probability	0.437657	0.319064	0.042504	0.645946	0.319064	0.487466
Sum	0.001131	33.75169	34.60119	0.001781	11.25056	7.352614
Sum Sq. Dev.	6.55E-10	15.30461	13.23560	9.72E-09	1.700512	0.322177
Observations	40	40	40	40	40	40

APPENDIX 8: Group unit root test: Summary

Group unit root test: Summary
Series: LNGDP_CAM, LNGDP_NGN, LNPMS_CAM, LNPMS_NGN,
LNTFC_CAM, LNTFC_NGN
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 4
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.99414	0.0231	6	227
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-2.80671	0.0025	6	227
ADF - Fisher Chi-square	29.6834	0.0031	6	227
PP - Fisher Chi-square	26.6314	0.0087	6	234

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

APPENDIX 9: Pooled Least Squares Regression Result of Model 2A

Dependent Variable: LNTFC_?
Method: Pooled Least Squares

Sample: 1971 2010
Included observations: 40
Cross-sections included: 2
Total pool (balanced) observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.727552	1.212235	-3.899863	0.0002
CAM--LNGDP_CAM	0.934593	0.199306	4.689227	0.0000
NGN--LNGDP_NGN	-0.484452	0.256778	-1.886660	0.0631
CAM--LNPMS_CAM	-0.036735	0.053238	-0.690011	0.4923
NGN--LNPMS_NGN	-0.221883	0.044857	-4.946481	0.0000
Fixed Effects (Cross)				
CAM--C	-5.266778			
NGN--C	5.266778			

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.493462	Mean dependent var	-2.837006
Adjusted R-squared	0.459236	S.D. dependent var	0.287397
S.E. of regression	0.211342	Akaike info criterion	-0.198638
Sum squared resid	3.305250	Schwarz criterion	-0.019986
Log likelihood	13.94550	Hannan-Quinn criter.	-0.127011
F-statistic	14.41794	Durbin-Watson stat	0.585305
Prob(F-statistic)	0.000000		

APPENDIX 10: Group Unit Root Test Summary

Group unit root test: Summary
Series: IKR_CAM, IKR_NGN, INT_CAM, INT_NGN, LNKLR_CAM,
LNKLR_NGN, LNPCI_CAM, LNPCI_NGN, LNPMS_CAM, LNPMS_NGN,
PGR_CAM, PGR_NGN
Date: 05/27/15 Time: 14:51
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 8
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	1.65696	0.9512	12	453
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.41714	0.0782	12	453
ADF - Fisher Chi-square	33.3526	0.0969	12	453
PP - Fisher Chi-square	48.0359	0.0025	12	468

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

APPENDIX 11: Pooled Least Squares Regression Result

Dependent Variable: INT_?
Method: Pooled Least Squares
Sample: 1971 2010
Included observations: 40
Cross-sections included: 2
Total pool (balanced) observations: 80

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.55E-05	3.39E-05	-0.753114	0.4540
CAM--LNPMS_CAM	-1.10E-07	2.40E-06	-0.045865	0.9636
NGN--LNPMS_NGN	-8.62E-06	1.74E-06	-4.961584	0.0000
CAM--LNPCI_CAM	7.39E-06	4.82E-06	1.533096	0.1299
NGN--LNPCI_NGN	3.58E-06	5.01E-06	0.714735	0.4772
CAM--LNKLR_CAM	-1.03E-05	4.57E-06	-2.262914	0.0268
NGN--LNKLR_NGN	-6.04E-06	2.88E-06	-2.095119	0.0399
CAM--IKR_CAM	-4.31E-06	8.79E-06	-0.490640	0.6253
NGN--IKR_NGN	-0.003681	0.000689	-5.343995	0.0000
CAM--PGR_CAM	1.23E-05	8.81E-06	1.399707	0.1661
NGN--PGR_NGN	-4.21E-06	7.96E-06	-0.529198	0.5984
Fixed Effects (Cross)				
CAM--C	2.05E-05			
NGN--C	-2.05E-05			

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.757746	Mean dependent var	3.64E-05
Adjusted R-squared	0.718558	S.D. dependent var	1.41E-05
S.E. of regression	7.47E-06	Akaike info criterion	-20.63487
Sum squared resid	3.79E-09	Schwarz criterion	-20.27756
Log likelihood	837.3947	Hannan-Quinn criter.	-20.49161
F-statistic	19.33611	Durbin-Watson stat	1.161915
Prob(F-statistic)	0.000000		

APPENDIX 12: Group Unit Root Test Summary

Group unit root test: Summary
Series: INT_CAM, INT_NGN, PMS_CAM, PMS_NGN, TKN_CAM, TKN_NGN
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-1.94460	0.0259	6	234
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-1.74702	0.0403	6	234
ADF - Fisher Chi-square	18.5251	0.1007	6	234
PP - Fisher Chi-square	18.1352	0.1116	6	234

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

APPENDIX 13: Pairwise Granger Causality Tests

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
INT_NGN does not Granger Cause INT_CAM	38	0.93680	0.4021
INT_CAM does not Granger Cause INT_NGN		0.04942	0.9518
PMS_CAM does not Granger Cause INT_CAM	38	1.03548	0.3663
INT_CAM does not Granger Cause PMS_CAM		0.53828	0.5888
PMS_NGN does not Granger Cause INT_CAM	38	1.03548	0.3663
INT_CAM does not Granger Cause PMS_NGN		0.53828	0.5888
TKN_CAM does not Granger Cause INT_CAM	38	3.05138	0.0608
INT_CAM does not Granger Cause TKN_CAM		0.65351	0.5268
TKN_NGN does not Granger Cause INT_CAM	38	1.53704	0.2300
INT_CAM does not Granger Cause TKN_NGN		2.67466	0.0838
PMS_CAM does not Granger Cause INT_NGN	38	0.84306	0.4395
INT_NGN does not Granger Cause PMS_CAM		0.74149	0.4842
PMS_NGN does not Granger Cause INT_NGN	38	0.84306	0.4395
INT_NGN does not Granger Cause PMS_NGN		0.74149	0.4842
TKN_CAM does not Granger Cause INT_NGN	38	2.24978	0.1214
INT_NGN does not Granger Cause TKN_CAM		3.89874	0.0302
TKN_NGN does not Granger Cause INT_NGN	38	1.94019	0.1597
INT_NGN does not Granger Cause TKN_NGN		5.88689	0.0065
PMS_NGN does not Granger Cause PMS_CAM	38	NA	NA
PMS_CAM does not Granger Cause PMS_NGN		NA	NA
TKN_CAM does not Granger Cause PMS_CAM	38	0.28274	0.7555
PMS_CAM does not Granger Cause TKN_CAM		1.44619	0.2500
TKN_NGN does not Granger Cause PMS_CAM	38	5.13121	0.0115
PMS_CAM does not Granger Cause TKN_NGN		0.82070	0.4489
TKN_CAM does not Granger Cause PMS_NGN	38	0.28274	0.7555
PMS_NGN does not Granger Cause TKN_CAM		1.44619	0.2500
TKN_NGN does not Granger Cause PMS_NGN	38	5.13121	0.0115
PMS_NGN does not Granger Cause TKN_NGN		0.82070	0.4489
TKN_NGN does not Granger Cause TKN_CAM	38	1.80172	0.1809
TKN_CAM does not Granger Cause TKN_NGN		0.32933	0.7217

APPENDIX 14: Summary of the Group Unit Root Granger Causality Test for Cameroon

Group unit root test: Summary
Series: TFCC, GDPC
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.32151	0.3739	2	77
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.90139	0.8163	2	77
ADF - Fisher Chi-square	1.12375	0.8905	2	77
PP - Fisher Chi-square	0.99945	0.9099	2	78

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Summary of the Pairwise Granger Causality Tests for Cameroon

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
TFCC does not Granger Cause GDPC	38	0.48819	0.6181
GDPC does not Granger Cause TFCC		3.65072	0.0370

APPENDIX 15: Summary of the Group Unit Root Granger Causality Test for Nigeria

Group unit root test: Summary
Series: TFCN, GDPN
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	6.26628	1.0000	2	78
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	4.78986	1.0000	2	78
ADF - Fisher Chi-square	3.99218	0.4071	2	78
PP - Fisher Chi-square	3.99751	0.4063	2	78

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Summary of the Pairwise Granger Causality Tests for Nigeria

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
TFCN does not Granger Cause GDPN	38	0.14089	0.8691
GDPN does not Granger Cause TFCN		0.04978	0.9515

APPENDIX 16: Group Unit Root Test Summary for Cameroon

Group unit root test: Summary
Series: GDPC, PMSC
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 1
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.07841	0.4688	2	77
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	0.07271	0.5290	2	77
ADF - Fisher Chi-square	3.33298	0.5037	2	77
PP - Fisher Chi-square	3.39728	0.4937	2	78

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Summary of the Pairwise Granger Causality Tests for Cameroon

Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
PMSC does not Granger Cause GDPC	38	2.79077	0.0759
GDPC does not Granger Cause PMSC		0.43277	0.6523

APPENDIX 17 Group Unit Root Test Summary for NIGERIA

Group unit root test: Summary
Series: GDPN, PMSN
Sample: 1971 2010
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0
Newey-West automatic bandwidth selection and Bartlett kernel
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	6.82826	1.0000	2	78
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	5.04358	1.0000	2	78
ADF - Fisher Chi-square	2.90863	0.5732	2	78
PP - Fisher Chi-square	3.04810	0.5498	2	78

** Probabilities for Fisher tests are computed using an asymptotic Chi
-square distribution. All other tests assume asymptotic normality.

Summary of the Pairwise Granger Causality Tests for Nigeria

Series: GDPN, PMSN
Pairwise Granger Causality Tests
Sample: 1971 2010
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
PMSN does not Granger Cause GDPN	38	1.48971	0.2402
GDPN does not Granger Cause PMSN		2.03411	0.1469