جامعة أبو بكر بلقايد

UNIVERSITÉ DE TLEMCEN

Pan African University
Institute of Water
and Energy Sciences

Institute of Water and Energy Sciences (Including Climate Change)

CAUSAL RELATIONS AND ELASTICITIES BETWEEN RENEWABLE ELECTRICITY GENERATION EXCLUDING HYDRO AND ECONOMIC GROWTH IN KENYA

Eric Otieno Akumu

Date: 04/09/2017

*Master in **Energy, Policy track***

President: Prof. Ghouti Merad

Supervisor: Prof. Izael Pereira da Silva

External Examiner: Prof. Latifa Negadi

Internal Examiner: Prof. Amazigh Dib

Academic Year: 2016-2017

Declaration

I **Eric Otieno Akumu**, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics. The work was done under the supervision of Prof. Izael Pereira da Silva at Strathmore Energy Research Center in Nairobi, Kenya. I confirm that no part of this work has been published before submission.

Candidates Name: Eric Otieno Akumu

Signature:

In my capacity as the supervisor of the master thesis, I certify that the information provided above are true to the best of my knowledge.

Supervisor: Prof. Izael Pereira da Silva

ABSTRACT

This study examined the relationship between renewable energy generation excluding hydro and economic growth. It employed a multivariate approach hence other variables included in the study were financial development, export of goods and services, and carbon emissions. The study was prompted by the ambitious energy plan and the declining reliability of hydro power due to changing climate in Kenya. To ensure robustness in the outcome, the study used Cobb-Douglas production function, F-Bound test, and Vector Error Correction Model in achieving the objective of the study using time-series data from 1980 to 2014. There was evidence of a long run dynamic relationship between renewable energy generation excluding hydro and the other variables. The study discovered that, in the long run, 1% rise in economic growth would lead to 3.424% increase in renewable energy generation excluding hydro. Renewable electricity is also seen as a multifaceted development carrier as, in the long-run, 1% increase in RE influences financial development (0.44% increase), export of goods and services (0.352% decrease in value) and carbon emissions (1.06% decrease). The study advocates for extensive renewable energy generation development including improvement energy efficiency and energy saving regulations as reduced energy demand would not impact negatively on the economy. Such measures also lead to improved energy conservation and environmental protection through reduced emissions.

Keywords: Renewable generation, Electricity Supply, Cobb-Douglas

Résumé

Cette étude a examiné la relation entre la production d'énergie renouvelable, à l'exclusion de la croissance économique et de l'économie. L'étude a consisté en une approche multivariée, d'où le choix d'autres variables incluses dans l'étude dont le développement financier, l'exportation de biens et services et les émissions de carbone. L'étude a été justifiée par le plan énergétique ambitieux et la baisse de la fiabilité de l'hydroélectricité en raison de l'évolution du climat au Kenya. Pour assurer la robustesse du résultat, l'étude a utilisé la fonction de production de Cobb-Douglas, le test F-Bound et le modèle de correction d'erreur vectorielle pour atteindre l'objectif de l'étude en utilisant des séries chronologiques de 1980 à 2014. Il y avait des preuves d'un long terme relation dynamique entre la production d'énergie renouvelable hors hydroélectricité et les autres variables. L'étude a révélé que, à long terme, 1% de la croissance économique entraînerait une augmentation de 3,424% de la production d'énergie renouvelable, à l'exclusion de l'hydroélectricité. L'électricité renouvelable est également considérée comme un porteur de développement à multiples facettes car, à long terme, une augmentation de 1% de l'influence des RE a un impact sur le développement financier (augmentation de 0,44%), l'exportation de biens et services (baisse de 0,352%) et les émissions de carbone (1,06% diminution). L'étude préconise un développement étendu de la production d'énergie renouvelable, y compris l'amélioration de l'efficacité énergétique et des réglementations d'économie d'énergie, car la réduction de la demande d'énergie n'aurait pas d'impact négatif sur l'économie. De telles mesures conduisent également à une meilleure conservation de l'énergie et à la protection de l'environnement grâce à des émissions réduites.

Mots-clés: Production renouvelable, Approvisionnement en électricité, Cobb-Douglas

Acknowledgement

I would like to acknowledge persons that have been instrumental towards the completion of my Master Thesis. It would not have been a success without the guidance of PAUWES, and support from my family and fiancé.

First and foremost, I am grateful to **God** for enabling me get an opportunity at one of the African Union's flagship university aimed at training next generation of African leaders. I express my deepest gratitude to my academic supervisor, **Prof. Izael Pereira da Silva**, for his excellent guidance, patience and his provision of an ambient atmosphere for doing research. I would like to thank **Geoffrey Ronoh,** the Director of Strathmore Energy Research Center that ensured my stay at the institute was geared towards supporting my research. I would also like to recognize the contribution of my colleagues at Strathmore Energy Research Center. My research would not have been possible without their assistance. Every result described in this thesis was as a result of their help and support.

I would like to acknowledge the support accorded to me by **PAUWES.** The broad knowledge base attributed by wide sourcing of lecturers from all over the globe has helped in shaping my perspective that has influenced my research in a myriad of ways. This also includes spring school to Germany that helped me realize the extent of the development of renewable energy in the developed world.

I would like to thank my parents, my brothers, and my sisters. They were always supportive considering that I was doing my research closer to home. Finally, I would like to thank my fiancé, **Josephine Adhiambo.** She has been my number one supporter who continually encouraged me and stood by me in good and bad times.

TABLE OF CONTENTS

List of Abbreviations

ARDL:	Autoregressive Distributed Lag
ASEAN:	Association of Southeast Asian Nations
CO2:	carbon dioxide emissions
COP21:	Conference of Parties 21
EAP*and*L:	East African Power and Lightening Company
ERC:	Energy Regulatory Commission
EX:	Export of goods and services
Ex:	Export of goods and services
FD:	Financial Development
FiT:	Feed-in-Tariff
GDC:	Geothermal Development Company
GDP:	Gross Domestic Product
GIZ:	The German Federal Enterprise for International Cooperation
GOK:	Government of Kenya
GW:	Gigawatts
GWh:	Gigawatt-hours
IEA:	International Energy Agency
IRENA:	International Renewable Energy Agency
KenGen:	Kenya Electricity Generating Company
KETRACO:	Kenya Electricity Transmission Company
KPLC:	Kenya Power and Lighting Company
Kt:	kilotons
KWh:	Kilowatt-hours

LCPD:	Least Cost Power Development Plan
MW:	Megawatt
NO2:	nitrogen dioxide
OECD:	Organization for Economic Cooperation and Development
OPEC:	Oil Producing E
PPA:	Power Purchase Agreement
PV:	Photovoltaic
RE:	Renewable Energy
REN21:	Renewable Energy Policy Network for the 21^{st} Century
SO2:	Sulphur dioxide
Turbine CF:	Turbine Capacity Factor
TWh:	Terawatt-hours
UN:	United Nations
USD:	United States Dollar
VECM:	Vector Error Correction Model
WDI:	World Development Index
Y:	Economic growth in GDP

List of Tables

List of Figures

CHAPTER 1
INTRODUCTION

1.1 Background Information

Energy is a crucial element for the growth of an economy. According to Sathaye et al. (2011), there exists a strong correlation between increased energy use and economic development. The study also finds correlation between increased energy use and greenhouse gas emission. In the recent years, there have been calls for sustainable development that necessitates the use of secure, accessible, affordable, and sufficient supply of energy (Alexander Roehrl, 2009; Kaygusuz, 2012; Meadowcroft, 2009; Sathaye et al., 2011). As economies continue to grow, more and more energy is demanded. Developed economies have high electricity consumption rates compared to the developing or least developed countries.

As more economies aim at improving the level of their economic growth, demand for electricity is likely to increase on a global scale. As illustrated by Figure 1-1 from the International Energy Outlook 2016, electricity is the fastest growing form of end-use energy in the world expected to increase by 69% to 36.5 trillion kilowatt-hours (kWh) by 2040 from 21.6 trillion kWh in 2012 as per reference case projections. The non-Organization for Economic Cooperation and Development (non-OECD) countries are expected to have the largest share of the growth, with their world share of electricity generation increasing to 61% by 2040 owing to continued strong economic growth (IEA, 2016).

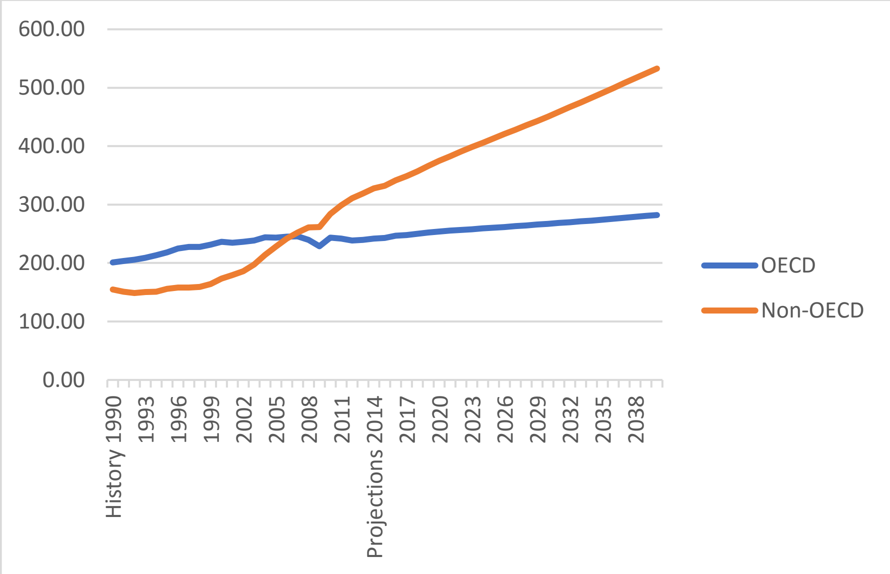


Figure 1-1 OECD and non-OECD net electricity generation, 1990-2040 (trillion kilowatthours) *Source: IEA (2016)*

The world gross domestic product (GDP) from the IEO 2016 reference case projections is expected to grow at an average of 3.3% per year from 2012 to 2040. However, much of the growth is expected to occur in non-OECD countries with a GDP growth averaging 4.2% per year compared to 2.0% average growth rate per year for the OECD countries (IEA, 2016).

The continued expected growth in electricity demand especially in emerging economies has raised issues with regards to the sustainability and security of supply (Asif & Muneer, 2007; Kruyt, van Vuuren, de Vries, & Groenenberg, 2009; Winzer, 2012). According to IEA (2016), carbon dioxide emissions are expected to increase from 32.2 billion metric tons in 2012 to 43.2 billion metric tons in 2040 from the reference case scenario. Much of the increase is expected to occur in developing countries that are projected to continue heavily relying on fossil fuels to meet the fast-growing energy demand. Such development would lead to increase in emissions by 51% for emerging economies compared to about 8% for the develop economies (IEA,2016).

There is growing consensus on the need to protect the environment by limiting electricity generation from sources that aggravate climate change through emission of carbon dioxide (Hansen, Sato, & Ruedy, 2012). There is also growing need to use alternative sources of electricity sources in order to avoid aggravating issues of climate change (Dhillon & von Wuehlisch, 2013). Renewable energy sources are an attractive alternative in ensuring sustainable energy that can lead to the achievement of world energy security through reducing dependence on fossil fuels. The development of renewable energy resources is as a result of improving cost-competitiveness, policy initiatives, improvement in the access of financing, growing demand for energy, environmental concerns and the need for access to modern energy.

The market for both centralized and distributed renewable energy are emerging globally. Global energy is under transition as the renewable energy share in the global final energy consumption stood at 19.2% in 2014 (REN21, 2016b). The year 2015 witnessed the highest annual increase ever in renewable energy power capacity with an addition of 147 gigawatts (GW) (REN21, 2016b). Despite the fall in crude oil prices that were witnessed in 2014, global investment in renewable energy continued to rise surpassing net investment in fossil fuel power capacity additions. The main drivers were concerns for global warming as well as continued decline in per unit cost of solar photovoltaics (PV) and wind. Moreover, 2015 witnessed the signing of high-profile agreement following the UN Climate Change Conference COP21 in Paris aimed at limiting global warming to well below 2 degrees Celsius.

In Europe, countries such as Germany, Sweden, Denmark, Italy, Belgium, Spain and Portugal have made huge investments in renewable energy. In the region, Germany was leading in total renewable energy generation capacity with or without including hydro by end 2015. The country was leading in biopower generation, solar PV capacity, and wind power capacity. Spain and Turkey were leading Europe in concentrated solar power and geothermal heat respectively during the same period (REN21, 2016b). In Asia and the Americas, China and the United States faired strongly in terms of total capacity of renewable power.

The United States was leading in total bioenergy generation and geothermal capacity while China led in hydro, solar PV, and wind power capacities (REN21, 2016b). Other countries such as India, Japan, Philippines and Brazil have also invested heavily in renewable energy generation in order to avoid dependence on fossil fuels and ensure sustainability in supply as well as security. India has extended its investments in solar PV as the country believes that it will provide more energy in future compared to other RE sources.

Developing countries have also increased investment in renewable energy. Supply of energy lags demand in most of Africa as approximately 600 million people lack access to electricity and about 730 million depend on traditional biomass (IRENA, 2015). As the economies grow at unprecedented speed in Africa, the major challenge has been energy. Modern renewable technologies were only contributing around 5% of the final energy consumption in 2013 (IRENA, 2015). The renewable energy technologies witnessing largest deployment in the

African continent are solar power, hydropower, wind, and modern biomass for cooking. Generally, most governments in developing countries have created regulatory policies and incentives that have led to an increase in the deployment of renewable energy.

Kenya is in the East African region and have improved its electrification rate from 23% in 2013 to 65% in 2017 (KPLC, 2017). The combined GDP of the region is increasing averaging 6.2% in 2014 way above the sub-Saharan African average of 4.4% with Kenya increasing its GDP five-fold since the 2000s (REN21, 2016a). Although agriculture has been the largest economic sector in the region, the East African Community has begun diversifying into service and industrial sectors. This has led to increase in energy demand in a region with an estimated electricity demand growth estimated to remain at 5.3% annually until 2020.

Electricity sector is based mainly on hydropower that accounts for approximately 65% of the total installed grid-connected power with the remaining contributed largely by thermal sources (REN21, 2016a). Although hydropower is the predominant energy source, it is being affected by the changing climate that has reduced its reliability prompting the region to diversify the energy source. With a GDP of $66 Billion USD, Kenya has the largest economy in East and Central Africa and the seventh biggest in Africa. The country has a population of 48 million people and has witnessed a GDP growth rate averaging 5-7% per year. The country has witnessed growth in the service sector as well as in telecommunication, manufacturing, and finance.

As illustrated in the country's vision 2030, a development program covering the period 2008-2030, the country hopes to improve the quality of life of its citizens by industrializing the economy while maintaining a clean and secure environment. The country has an installed electricity capacity of about 2.4 GW. Approximately 75% of the installed capacity comes from renewable resources with hydro and geothermal dominating and the remaining from fossil fuel mainly diesel generators. As demonstrated in the Least Cost Power Development Plan 2011-2031, the country hopes to increase the installed capacity to 22.7 GW.

There exists high potential in renewable energy in meeting the high demand. However, there is slow uptake of renewable within the domestic energy mix other than geothermal which can only supply a fraction of the total generation intended by 2030. Despite the low uptake, Kenya is ranked second to South Africa for investment in clean energy in Africa and sixth globally. In terms of geothermal energy generation, Kenya is the 8th largest producer of geothermal energy. The renewable energy potential of the country is vast. The country has also developed favorable policies that promote renewable energy generation such as the 20-year feed-in-tariff and removal of import duty tax on renewable equipment.

Apart from hydro and geothermal, there are other renewable energy resources that are largely untapped such as biomass, biogas, wind and solar. The renewable growth is expected at utility scale, commercial and industrial scale, and also in off-grid solution. Given the huge financial implication of the expected investment in energy generation, this study considered dependent variables that affect electricity generation from renewable energy resources. The identified variables are exports, foreign direct investment, economic growth, and financial development. Other factors that are likely to influence the deployment of renewable energy include wealth, income level, availability of RE resources, technological advancement, and the need to reduce on carbon dioxide emission to the atmosphere. The study will attempt at providing policy insights that will influence further development of RE generations.

1.2 Kenyan Economy

Among the East African countries, Kenya is considered the economic, financial and transport hub. The countries real GDP has remained on an average of 5 percent for since 2008. The country also attained the status of a lower middle-income country from 2014 after its GDP per capita crossed the threshold set by the World Bank. Although Kenya is experiencing a steady growth and a growing entrepreneurial middle class, the growth trajectory could be hampered by corruption and weak governance. The Corruption Perception Index provided by Transparency International (TI) put the country among the most corrupt countries ranking at 139 out of 168 countries. Although actual figures are not available, issues of unemployment and under-employment remain extremely high and are estimated at about 40 percent of the population. The Kenyan economy remains highly dependent on agriculture. As of 2015, the industry contributed over 25 percent of the country's GDP. It also accounts for about 75 percent of the labor force. The bulk of the agricultural output is from small-scale, rain-fed agriculture and livestock production.

The major export commodities for the country are mainly agricultural products with tea horticultural products being the most important. Other export items include coffee, petroleum products, fish, tobacco, iron and steel products, petroleum products, and cement. The main export countries are UK, Netherlands, Uganda, Tanzania, United States and Pakistan. Kenya's export of goods and services has been on the increase (at a constant value 2010 US$) as shown in Figure ***1-2***. The value increased from about 2.6 billion dollars (2010 US$) to 9.5

billion US dollars (constant 2010) (WDI, 2016). In terms of contribution to GDP, the export of goods and services contributed about 29.52 percent of GDP in 1980 with the share declined to 16.92 percent of GDP in 2014 (WDI, 2016).

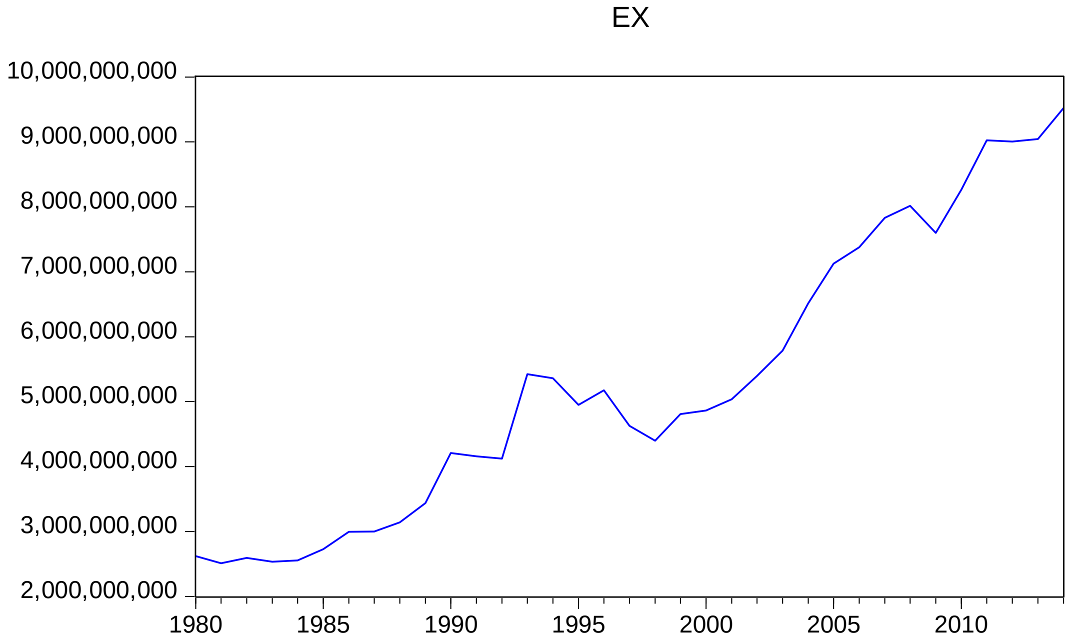


Figure 1-2 Export of goods and services in constant 2010 USD

The economic growth of the country GDP has been growing over the research period from 1980 to 2014. As illustrated in Figure ***1-3*** , the value of GDP moved from around 14.6 billion dollars (constant 2010 USD) in 1980 to around 49.4 billion dollars (constant 2010 USD) in 2014. This shows that the economy expanded by about three and a half times its value in 1980 by the year 2014. The GDP annual growth rate was highest in 1986 and 2010 with rates reaching 7.1 and 8.4 percent respectively (WDI, 2016). The lowest growth rate was actually a negative value at about -0.8 percent that was witnessed in 1992. This was largely affected by the political turmoil that affected the country as a result of the rising multiparty democracy. Despite the growth, the GDP per capita has remained nearly stagnant over the research period. The value was about 838 USD in 1980 (constant 2010 USD) and rising only slightly to about 1101 USD in 2014 (constant 2010 USD) (WDI, 2016). The increase in GDP per capita is only about 31 percent from 1980 to 2014 compared to the rise in the GDP by nearly four times over the same period. This was due to the increase in population growth. In 1980, Kenya had a population totaling about 16.2 million. By 2014, the figure had risen to about 44 million. The population growth rate remained above 3.0 from 1980 to around 1994, with the highest growth rates recorded in the early 1980s averaging about 3.8 (WDI, 2016). From 1994 up until 2014, the population growth rate remained at an average of 2.6.

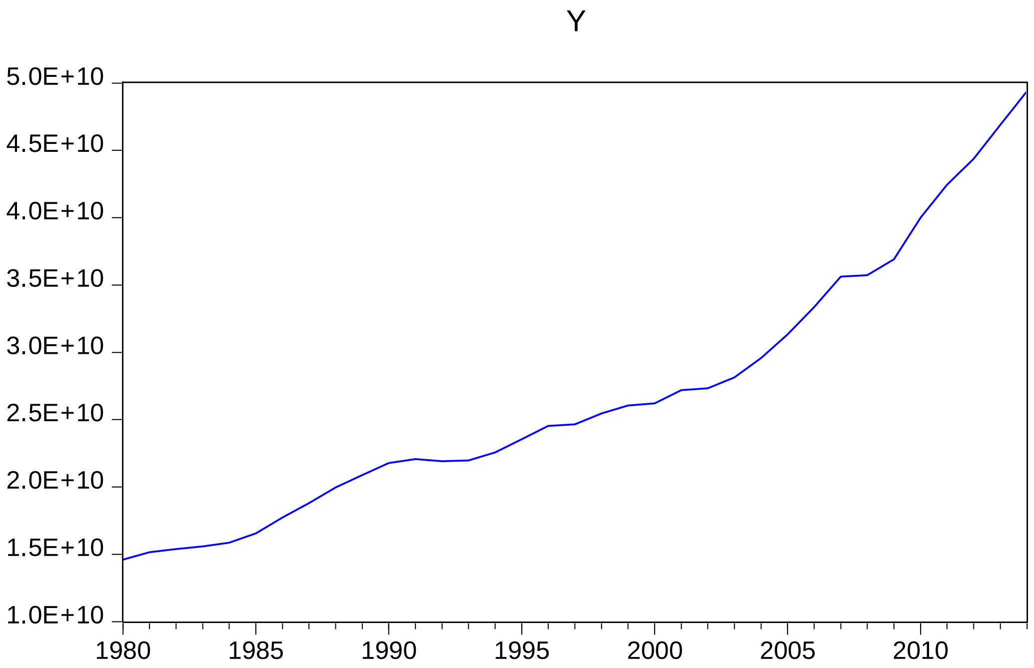


Figure 1-3 Gross Domestic Product for Kenya in constant 2010 USD

As is the case in most countries in the East African region, electricity supply for Kenya was widely dominated by hydro. The general supply mix includes hydro, geothermal, wind, thermal, and imports. However, due to the increasing unreliability of hydro sources due to climate change, the country is increasing its focus to other sources including natural gas, coal, nuclear, and scaling up wind, and geothermal. Solar is not widely considered in the national energy plan for Kenya despite the huge potential. As illustrated by Figure ***1-4***, the country has experienced variations in the share of electricity output from renewables with the value rising as high as 96 percent in 1993 and dropping to as low as 46 percent of the total electrical generation output in the year 2000. The access to electricity has also risen from about 5.6 percent in 1990 to about 36 percent in 2014 (WDI, 2016). With the rising demand promoted by extensive rural electrification program and the need to follow through with the Paris climate agreement, it will be essential for the country to focus its attention on renewable electricity generation excluding hydro. The generation potential of RE excluding hydro has increased over the years as shown in Figure ***1-4***.

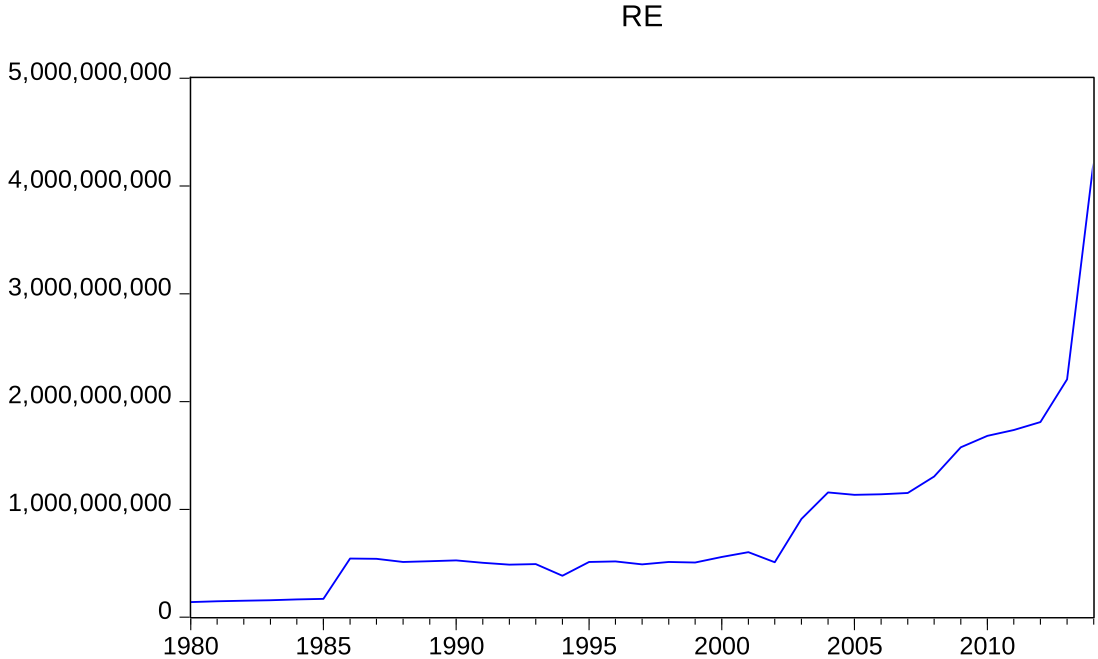


Figure 1-4 Electricity production from renewable sources excluding hydroelectric (kWh)

The country was producing about 140 GWh of electricity from renewable sources excluding hydro in 1980 with the figure rising to about 4,234 GWh in 2014. The rise has been as a result of investment in geothermal, wind, and use of biomass. However, geothermal is has the largest share contributing about 44 percent of the total electrical energy in the country (KPLC, 2017). The first geothermal generation plant was commissioned in 1981 at Olkaria and had a capacity of 15MW. Most geothermal developments have taken place after 2000 supported by multinationals mainly from Germany, the United States and the World Bank. Wind generation capacity has also grown from the two turbines that were installed in Ngong Hills in 1993 to a wind farm with a capacity of 5.1 MW in 2009. The wind farm capacity has been further increased to 25.5 MW and is currently the only one connected to the national grid. The ongoing wind projects include Turkana Wind Park, Kipeto Energy Wind Park, Kinangop Wind Park, Expansion of the Ngong Wind Park, and Mount Meru Wind Park. Wind power capacity is expected to increase to 931 MW by 2024 (ERC/LCPDP, 2016).

The development of the Kenyan economy has also been contributed by the domestic credit to private sector as a percentage of GDP that has risen over the study period from around 22 percent in 1980 to 34 percent in 2014 (Figure ***1-5***). The values indicate the extent of private sector development and investment. This is essential in tapping the private sector potential for socially useful purposes that are critical in reducing poverty. Investment in the private sector especially in an increasing competitive market like Kenya has tremendous potential to economic growth. The investments lead to productivity growth creating jobs and higher incomes. As the government plays a complementary role by providing regulation and service. The private sector has remained instrumental in providing basic services and conditions such as improving education, health, and infrastructure.

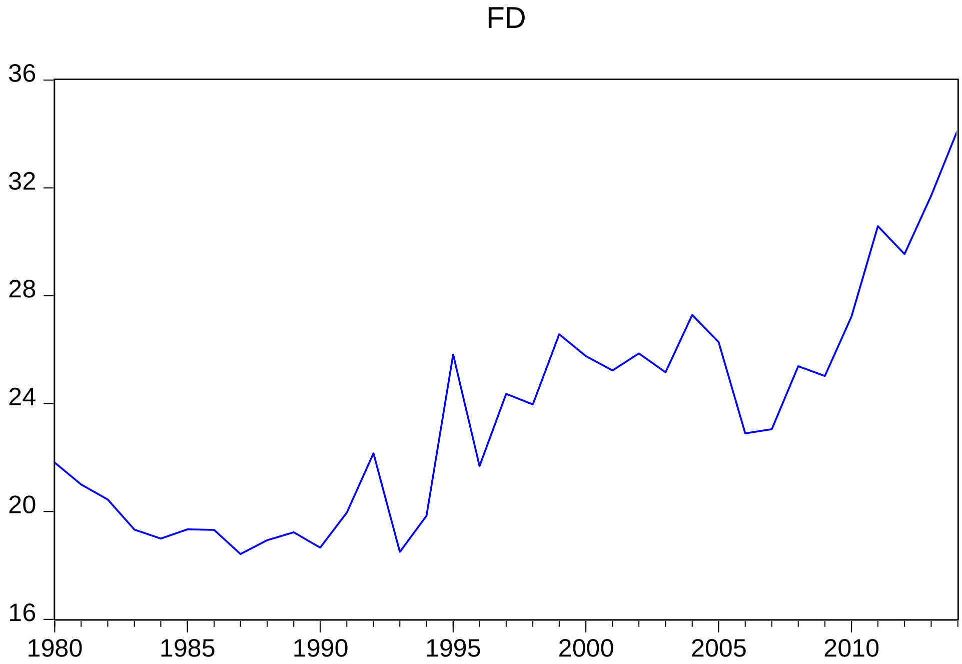


Figure 1-5 Financial Development: Domestic credit to private sector (% of GDP)

With regards to carbon emissions, the country has witnessed a generally growing trend of carbon emissions as shown in Figure ***1-6*** from about 6197 kilotons in 1980 to about 13300 kilotons in 2013. This can be attributed to the growth in the use of fossil sources of energy in the country due to the rising industrial activity as well as transportation. Considering the figures with regards to carbon emission per capita, the values have been reducing from 0.38 metric tons per capita of carbon emission in 1980 to 0.30 metric tons per capita of carbon emissions in 2013. This means that the country's carbon emission is declining per capita. However, considering plans enhance energy access with the plan including fossil fuels such as coal, the share of carbon emission from electricity generation that has averaged 20 percent over the years is likely to increase (WDI, 2016).

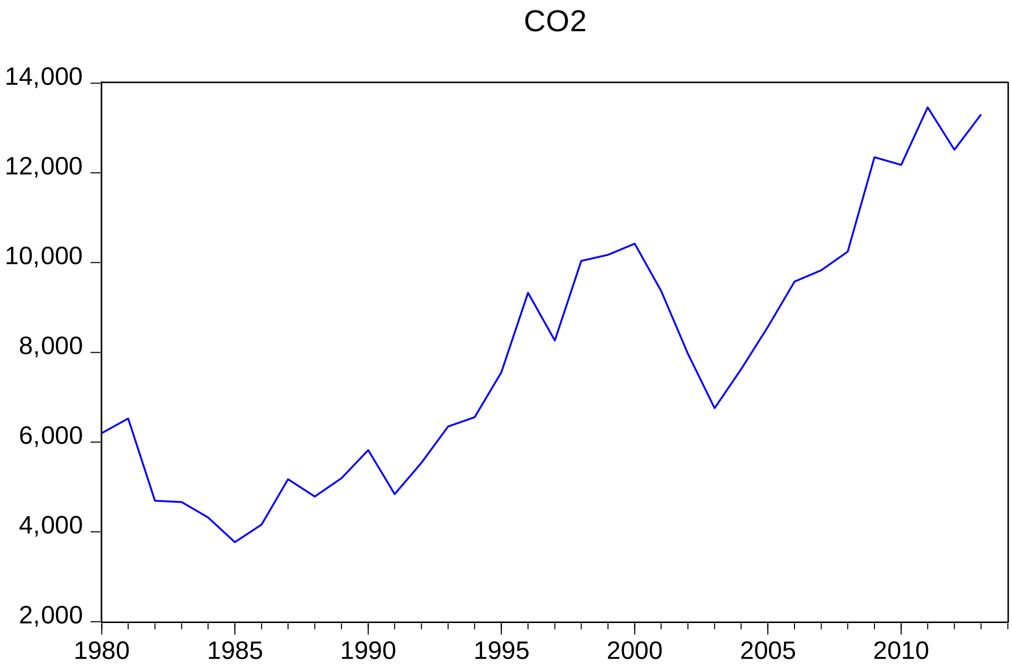


Figure 1-6 Carbon Dioxide Emissions (kilotons)

The country's effort to improve its annual growth to the range of 8 to 10 percent has been hugely affected by inadequate infrastructure. There has been increased external investment for infrastructure development. For instance, the Standard Gauge Railway aims to link Kenya with Uganda, Rwanda and South Sudan with possibilities of connecting with central African countries. After the promulgation of a new constitution in 2010, Kenya adopted a devolved system of governance in 2013 with the creation of 47 county governments. The intension of the new system of governance is to devolve state revenues and responsibilities to the counties. It is also intended at strengthening governance institutions including addressing other challenges such as land reforms and security to improve economic and social outcomes, accelerate growth and ensure equity in the distribution of resources. The devolved system of government will also work at reducing extreme poverty and youth employment. The emphasis on energy efficiency and enhanced exploration of renewable energy is likely to substitute fossil fuel generated energy. Geothermal electricity currently supplies over 40 percent of the country's energy demand with hydro providing around 21 percent and wind including imports providing 3 percent and the rest from thermal energy using fossil fuel (ERC, 2017). The ongoing wind projects, solar and explorations into biomass/biogas is likely raise the share of renewable energy even further. Therefore, it is essential to study renewable energy generation excluding hydro and growth nexus for the Kenyan economy.

1.3 Kenyan Energy Sector

1.3.1 Institutional Aspects

The Kenya power sector has been undergoing reforms since its establishment in 1922 as the East African Power and Lightening Company (EAPL) (Government of Kenya, 2011). Apart from name change to Kenya Power and Lightning Company Limited (KPLC) in 1983, the structural adjustment programs of the 1990s were critical in the liberalization of the sector with the formation of the Kenya Electricity Generating Company Limited (KenGen) that was responsible for generation assets while KPLC took charge of transmission and distribution. The period also saw establishment of the Electricity Regulatory Board.

Further reforms have occurred in the power sector in Kenya especially through the Energy Act of 2006 that led to the establishment of Energy Regulatory Commission as well as the Rural Electrification Authority. The developments in geothermal energy also led to creation of the Geothermal Development Company (GDC) whose purpose is to develop geothermal resources. The Kenya Electricity Transmission Company (KETRACO) was also formed in order to carry out transmission (plan, design, construct, and own high voltage transmission of 132kV and above) leaving the Kenya Power Company to take care of distribution.

1.4 Policy Measures on Renewable Energy in Kenya

The Kenyan National Energy policy has undergone a number of changes brought about through sessional papers, regulations and Acts of parliament. The sessional Paper No. 4 of 2004 led to changes that targeted the introduction of multiple renewable energy resources into the energy generation mix. The objective of the energy policy is ensuring adequate, quality, cost effective, and affordable energy supply while protecting and conserving the environment. Renewable energy resources were identified as vital in meeting the objective. However, the sessional paper identified a number of challenges influencing their introduction in the generation mix.

The challenge that affected solar energy was lack of fiscal and regulatory framework that would enable creation of an enabling environment to accelerate the development and utilization of the technology in the country. The government was also promoting wind-diesel hybrid systems in remote areas far from the national grid. However, there still existed the challenge of attracting substantial investment by the private sector in wind energy generation in upscaling it to become significant in the country's energy supply mix (Ministry of Energy, 2004).

The Energy Act of 2006 encouraged the development of multiple renewable energy resources but not limited to biomass, geothermal, solar, wind, small hydropower, municipal waste, biomass and biogas. The energy act allowed for the formulation of a national strategy that would promote research and provision of an enabling environment for the use of renewable energy. The support policy included economic instruments such as fiscal incentives and tax relief. This also included development of a national energy efficiency and conservation program that would further push for the use of renewable energy.

The establishment of the Energy Regulatory Commission in July 2007 as stipulated under the Energy Act of 2006 was a milestone in the growth of renewable energy. It led to the formation of the Renewable Energy Department whose mandate is to assist in developing and monitoring regulations and standards for all forms of renewable energy. The department was also mandated to work with other statutory bodies such as the Kenya Bureau of Standards and Kenya Forest Services. In addition, the department would use available energy data to prepare an indicative energy plan for renewable as well as promoting energy efficiency and conservation in all sectors, and carrying out relevant research activities aimed at improving the use of renewable energy.

In 2008, the Ministry of Energy introduced feed-in tariffs for electricity generated from renewable energy resources. The operators of the national grid were obliged to connect plants generating from renewable energy sources and guarantee priority purchase. A power purchase agreement was also developed outlining the capacities and the maximum tariff to be paid. The renewable energy sources that were considered under the arrangement were wind, biomass, and hydro energy sources.

The Energy Regulation 1009 on Biodiesel Licensing targeted the production and commercialization of biodiesel. It established mandatory requirements such as the need to have environmental impact assessment, safety and health standards compliance and a detailed report on the source of biodiesel, projected production output, as well as quantity sold. The intention of the regulation was to ensure food crops or farmlands are not used in the production of the biodiesel. The 2008-2012 Kenyan Biodiesel Strategy relates to the 1009 regulation with an aim of sourcing biodiesel from Jatropha plant.

The revision of the feed-in tariffs in 2010 was aimed at providing investment security to renewable electricity generators, reducing transaction and administrative costs, and encouraging more private investors to venture into renewable energy. The new FiT also expanded the number of renewable sources to include solar, geothermal, and biogas generated electricity. The enacted tariffs were also specific on the plant capacity and the renewable resource in use and were all valid for a period of 20 years. For instance, an investor in solar power will need to have a plant capacity of between 0.5 MW – 10 MW with maximum feed-in tariff of 0.2 USD/kWh for a firm generator and 0.10 USD/kWh for non-firm generator.

The Least Cost Power Development Plan 2011-2031 that came into force in March 2011 projected the country's least-cost energy generation plan for the following 20 years that would be updated yearly. The plan estimated that peak load by the year 2031 would be 13 times from the value in 2011. Geothermal was identified as the least-cost choice in meeting the country's growing energy demand and would contribute 5.5 GW equivalent to 26% of the peak demand by 2031. Wind and hydro were the other renewable sources that were considered in the plan with capacities of 9% and 5% respectively by 2031.

Second revision of the FIT for renewable energy was adopted in December 2012 taking effect in January 2013. The revision led to the introduction of standardized templates for power purchase agreements (PPAs) that would form basis for negotiations. The revision act also included guidelines for undertaking grid connection study for all small-scale renewables including a standardized application form and progress reporting and monitoring framework.

The Kenyan government introduced tax incentives for renewable energy in 2015 as an economic instrument targeting solar, hydropower, wind, and solar thermal. With regards to solar PV, the new policy offers an exception from value added tax (VAT) and import duties for solar modules imported and are not equipped with batteries or diodes. In addition, solar PV semi-conductor devices including PV cells and light-emitting diodes are subject to 5% import duty. Although the tax incentives make it possible for increased supply of solar PV modules through importation, energy storage systems that require the use of batteries that form an essential part of home solar systems are left out increasing the cost of the entire system. For this reason, the tax incentive is seen to largely favor large-scale grid connected solar PV systems excluding mini-grids and solar home systems that heavily rely on batteries as energy storage systems.

After the promulgation of the New Constitution in 2010, the government of Kenya has set to review the energy sector through policies and legislation that will see further development of renewable energy. For instance, establishment of an inter-ministerial Renewable Energy Resources Advisory Committee (RERAC) was among the proposals made under the Kenya power sector medium term plan 2015-2020. The body advises the Cabinet Secretary on areas entailing development and licensing of renewable energy generation such as geothermal, wind, and hydro (Government of Kenya, 2015). There are plans to transform the Rural Electrification Authority (REA) into the National Electrification and Renewable Energy Authority (NERA) that will take charge of developing renewable energy resources other than large hydro and geothermal power plants. The reforms show the importance of electricity generation from renewable energy sources in order to protect environmental issues and also in ensuring energy security for Kenya.

1.4.1 Electricity Supply

As of March 2015, Kenya had a total installed capacity of 2177 MW that consisted of 820.6 MW of hydro, 588 MW of geothermal, 717 MW of thermal, 25.5 MW of wind, and 26 MW from cogeneration. Isolated grid had a total capacity of 26 MW.

Table 1-1 Interconnected Capacity by Technology

	Installed	Effective	Contribution
Hydro	820.60	797.50	37.7%
Geothermal	588.00	563.30	27.0%
Thermal (MSD)	633.00	614.50	29.1%
Thermal (GT)	54.00	54.00	2.5%
Temporary Thermal (HSD)	30.00	30.00	1.4%
Wind	25.50	25.50	1.2%
Solar	0.00	0.00	0.0%
Cogeneration	26.00	21.50	1.2%
Interconnected System	2177.00	2106.00	100%
Off grid	26.00	20.70	
Total Capacity	2203.00	2127.00	

Source: (KPLC, 2015)

The Feed-in-Tariff (FiT) Policy of 2008 has made it possible for the development of renewable energy resources such as wind, small hydro, and biomass. The policy has attracted private investors leading to diversification of the national power sources, creating energy security, as a well as employment. The Policy also obligates the off-taker to prioritize purchase of electricity from renewable energy sources for a predetermined fixed tariff over a given period of time. The revision of the policy in 2010 and 2012 allowed for the introduction of off-grid solar and grid tie solar respectively. By 2015, more than 80 projects were approved utilizing renewable energy technologies (Government of Kenya, 2015).

Table 1-2 Renewable Energy Technologies (Government of Kenya, 2015)

	Wind	Biomass/ Biogas	Small Hydro	Solar	Geothermal	Total
With PPA approval	4	2	12	0	0	18
PPA negotiations underway	2	2	5	7	0	16
Doing feasibility studies	6	6	18	18	1	49
Total number of approved proposals	12	10	35	25	1	83
Total Capacity (MW)	554.2	121.85	162.27	758.1	15	1611.42

Currently, the FiT for electricity generated from the various renewable energy technologies is categorized depending on the amount of generation and is also specific according to the source. Table ***1-3*** and **Table *1-4*** shows feed in tariff for projects less than 10 MW and more than 10MW respectively.

Table 1-3: FiT for RE projects less than 10MW

	Duration	**Installed Capacity (MW)**	**Standard FIT USD$/kWh**	**Percentage scalable portion of the tariff**	**Max Capacity (MW)**
Wind	20 years	0.5 – 10	0.11	12%	10
Hydro		0.5	0.105	8%	10
		10	0.0825		
Biomass		0.5 – 10	0.10	15%	10
Biogas		0.2 – 10	0.10	15%	10
Solar (Grid)		0.5 – 10	0.12	8%	10
Solar (Off-Grid)		0.5 – 10	0.20	8%	1

Table 1-4: FiT for RE projects more than 10MW

	Duration	Installed Capacity (MW)	Standard FIT USD$/kWh	Percentage scalable portion of the tariff	Max Capacity (MW)
Wind	20 Years	10.1 – 50	0.11	12%	500
Geothermal		35 – 70	0.088	20% for first 12 years and 15% after	500
Hydropower		10.1 – 20	0.0825	8%	200
Biomass		10.1 – 40	0.1	15%	200
Solar (Grid)		10.1 – 40	0.12	12%	100

Source: LCPDP 2011-2031

Considering the planned future power capacity for Kenya, it is likely to be dominated by geothermal, nuclear, coal, and imports. As illustrated in the least cost power development plan, the electricity installed capacity by type for the base case is as shown in Table 1-5.

Table 1-5 the electricity installed capacity by type for the base case by 2031

Type	Installed Capacity (MW)	Contribution
Hydro	1039	5%
Nuclear	4000	19%
MSD	1955	9%
Import	2000	9%
Cogeneration	0	0%
GT-NG	2340	11%
Geothermal	5530	26%
Coal	2720	13%
Wind	2036	9%

Source: LCPDP 2011-2031

1.4.2 Electricity Demand

Kenya is witnessing an improved trend in both demand and supply. For instance, electricity generation in 2013/2014 was 8840 GWh, which was 9.3% higher than that generated in 2012/2013 at 8087 GWh (Government of Kenya, 2015). The growth was attributed to normal growth of increased connections to urban and rural areas as well as country's goal of transforming into an industrialized country as indicated in Vision 2030.

The number of customers connected to the national grid increased from 2,330,962 in 2013 to 2,766,441 in 2014 representing an increase of 18.7%. Electricity sales to industrial/commercial customer increased marginally by 11% over the same period from 3440 GWh in 2012/13 to 3819 GWh in 2013/2014. In addition, domestic consumption, both rural and urban, increased from 1254 GWh in 2009 to 1777 GWh in 2014 with the urban consumers taking up about 80% of the total domestic consumption.

1.4.3 Electricity Retail Tariff

Electricity tariff in Kenya incorporates cost of generation, transmission, and distribution. The structure of retail tariff includes fixed charge, demand charge and energy charge. The Fixed charge is meant to meet customer related costs such as metering, inspection, meter reading, customer accounting, and maintenance billing. The Demand charge entails the costs associated with transmission and distribution and are calculated from long run marginal cost of the transmission and distribution network. Both fixed and demand charges are constant but vary with the customer category.

The Electricity charge is calculated per kWh and is derived from long run marginal costs tariff rates that are adjusted in accordance to the revenue requirement of KPLC. The charges vary per kWh and also on different customer categories. There are other additional inclusions in the retail tariffs structure whose costs uncertain and out of control of the utility. They are fuel oil cost adjustment (FOCA), the foreign exchange rate fluctuations adjustment (FERFA), and inflation adjustment (INFL). As the tariff policy allows the regulator to pass on the cost of fuel to the consumers, they remain exposed to adverse fluctuations in prices.

1.4.4 Electricity Balance

Kenya has been witnessing an increase in electricity demand as well as growth in the supply. For the period 2009 to 2014, total electricity generated has rose from 6458 GWh to 8753 GWh while supply increasing from 6462 GWh to 8801 GWh over the same period. However, there has been an increase in system losses from 16.36% to 18.1%. The increase in losses has been as a result of system weaknesses and increased rural connections at low voltage (Government of Kenya, 2015).

1.5 Renewable Energy Landscape in Kenya

Kenya is a growing economy with a growing energy demand. It has an ambitious plan to increase supply of modern energy through extension of the national grid as well as increase generation capacity. The Sustainable Development Goal 7 advocates for affordable, reliable, sustainable, and modern energy access for all. This requires increase in the use of renewable energy sources as well as improvement in energy efficiency. Although Kenya is still grappling with inadequate power and high costs, it is yet to harness the full potential of its renewable energy resource. The energy development plan for the country has remained slow in adopting most renewable energy into the generation mix. Energy is critical in all sectors of the economy affecting jobs, food production, security, climate change, affecting health and/or increasing incomes. Sustainable energy is an opportunity to transform lives, the Kenyan economy, and the entire planet.

1.5.1 Biomass

Traditional biomass such as wood and charcoal are the main source of energy supply used for cooking and heating at both household and institutional levels. The share of traditional biomass in the final energy use is approximated at 75% in Kenya and 80% for the East African Region (REN21, 2016a). Biomass provides more than 90% of the energy needs in rural households (ERC, 2017). Biomass is also widely used in industries in Kenya such as in tea factories as wood fuel to provide heat, and in brick burning. Charcoal industry in Kenya employs approximately 1 million people across the value chain on a part- and full-time basis contributing about USD 1.3 billion to the national economy. The regulation of the biomass sector is essential in ensuring sustainability. However, attempts to have high-level policy support have not been possible due political sensitivity of the matter. In addition, the government agencies required to spearhead the process lack coherence making it difficult to develop a comprehensive regulatory framework.

There is increasing exploitation of biomass for power generation and co-generation of heat and power. There is substantial potential for power generation using forestry and agro-industry residues. Sugarcane bagasse has been the main source of biomass as a byproduct of sugar production with Mumias Sugar Company (Independent Power Producer) having an installed capacity of 35 MW, feeding 26 MW of the generated power to the national grid (REN21, 2016a). The government estimates the total potential for cogeneration using sugarcane bagasse at 193 MW (ERC, 2017). However, sugar factories have estimated the potential at about 300 MW.

1.5.2 Biogas

Biogas potential is also large in Kenya with Africa having a potential of 18.5 million installations (REN21, 2016a). However, its development is more complex compared to other forms of renewable energy. The low technology awareness has led to overall slow uptake of biogas. There is are no enough technicians as well as inadequacy in post-installation support leading to poor management and maintenance. Kenya has utilized the services of African Biogas Partnership Program (ABPP) that helps lower investment costs to promote the use of domestic biogas cooking. However, the country still has no subsidies for domestic biogas digesters. Under the ABPP program, the country managed to install about 16,120 domestic biogas digesters with a few commercial-sized digesters installed in several institutions, farms and abattoirs (REN21, 2016a). There is still significant potential in domestic biogas industry in Kenya. The largest impediment is lack of clear regulatory framework, technical and financial support, and limited access to water supply.

There exists potential in the use of biogas power through CHP systems in industrial and agricultural sectors especially those dealing in agro-processing such as flower, tea, fruits, and vegetable industries. The government estimates the number of domestic biogas installations at 8000. However, it argues that the situation is amorphous as the data on biogas production is not consolidated making it a challenge to determine the country's overall capacity (ERC, 2017).

The government has identified biogas potential estimated at between 29-131MW in municipal waste, sisal and coffee production. Given the lack of clarity on the actual potential of biogas in the country, biogas standards are currently being developed in order to pave way for formulation of relevant legislations. The overall potential is estimated at over 1000 MW.

1.5.3 Solar

Kenya has a huge solar potential with daily insolation averaging 4-6 kWh/m^2 with an average of 5-7 peak sunshine hours (Figure ***1-9***). Electricity generation potential in Kenya from solar PV is far greater than what is consumed yearly from the national grid (Rose, Stoner, & Pérez-arriaga, 2017). However, much of the development has been left for off-grid solar market that is well-developed compared to other East African countries. As shown in **Figure *1-8*** solar PV development started in the mid-1980s driven by the demand for lighting and television from high-end customers. Currently, market development is mainly driven by entrepreneurial initiative, government programs, donor activity and private sector investment. More than 30% of the population without access to the national grid use off-grid solar PV solutions. The innovative financing and distribution models such as the pay-as-you-go (PAYG) systems has driven the uptake. The system has been successful due to the use of mobile technology as well as the reduction in the price of solar modules. For instance, between 2010 and 2014, the sale of quality-verified pico solar products from Lighting Global in Kenya increased 17-fold (**Figure *1-7***) (REN21, 2016a).

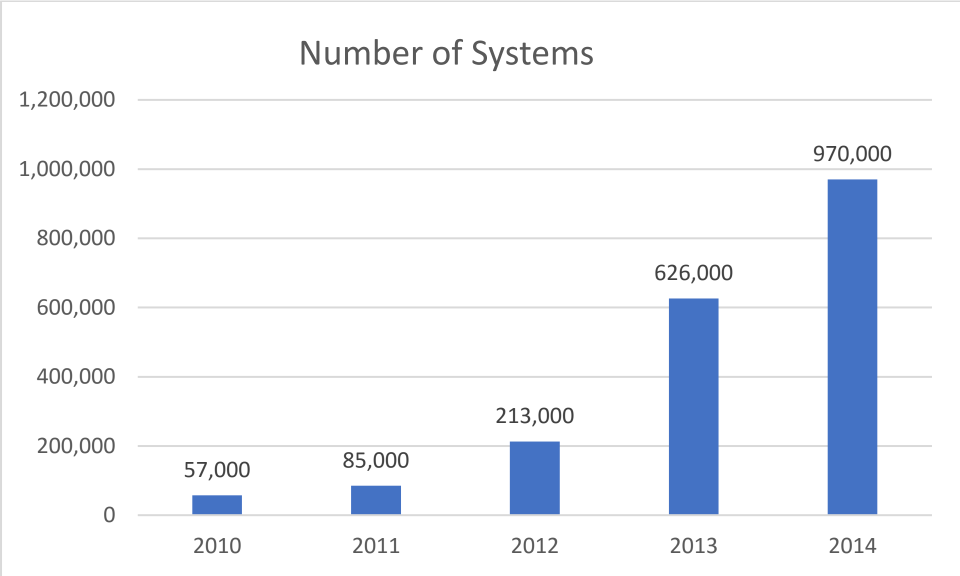


Figure 1-7:Reported sales of Lighting Global quality-verified pico solar products in Kenya, 2010–2014

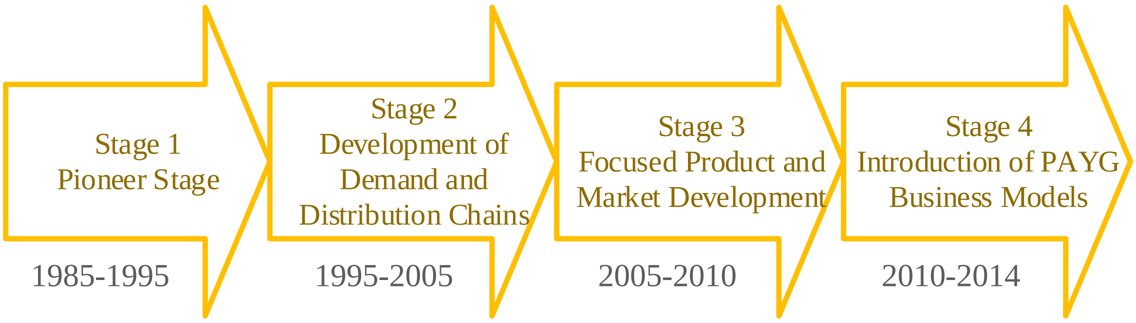


Figure 1-8: Overview of off-grid solar PV market development in Kenya, 1985 to present

There are hindrances to the increased deployment of solar PV especially for domestic use. For instance, the tax incentive on importation is only specific for solar modules. Other balance of system equipment such as charge controllers, batteries, inverters, and solar mounting systems are subjected to taxation raising the total cost of installation.

Apart from solar PV, solar thermal water heating has the potential to lower the demand of electricity. In Kenya, it is estimated that residential water heating consumes about 820 gigawatt-hours (GWh) of annual electricity. Given the high solar potential in the region, the use of solar water heating (SWH) reduces the power demand especially in the morning and night hours when it is at peak. In 2012, the Kenyan Government's Solar Water Heating regulation led to increased installation to 140,000 by 2015. The installations are projected to increase to 800,000 by 2020 (REN21, 2016a). However, there is increasing resistance for buildings constructed before 2012 as the grace period to have the retrofits with SWHs that expired in 2017 has not been implemented. This was largely due to a failure in the regulation that was supposed to make a follow-up on the retrofitting progress (Business Daily, 2017; Daily Nation, 2015).

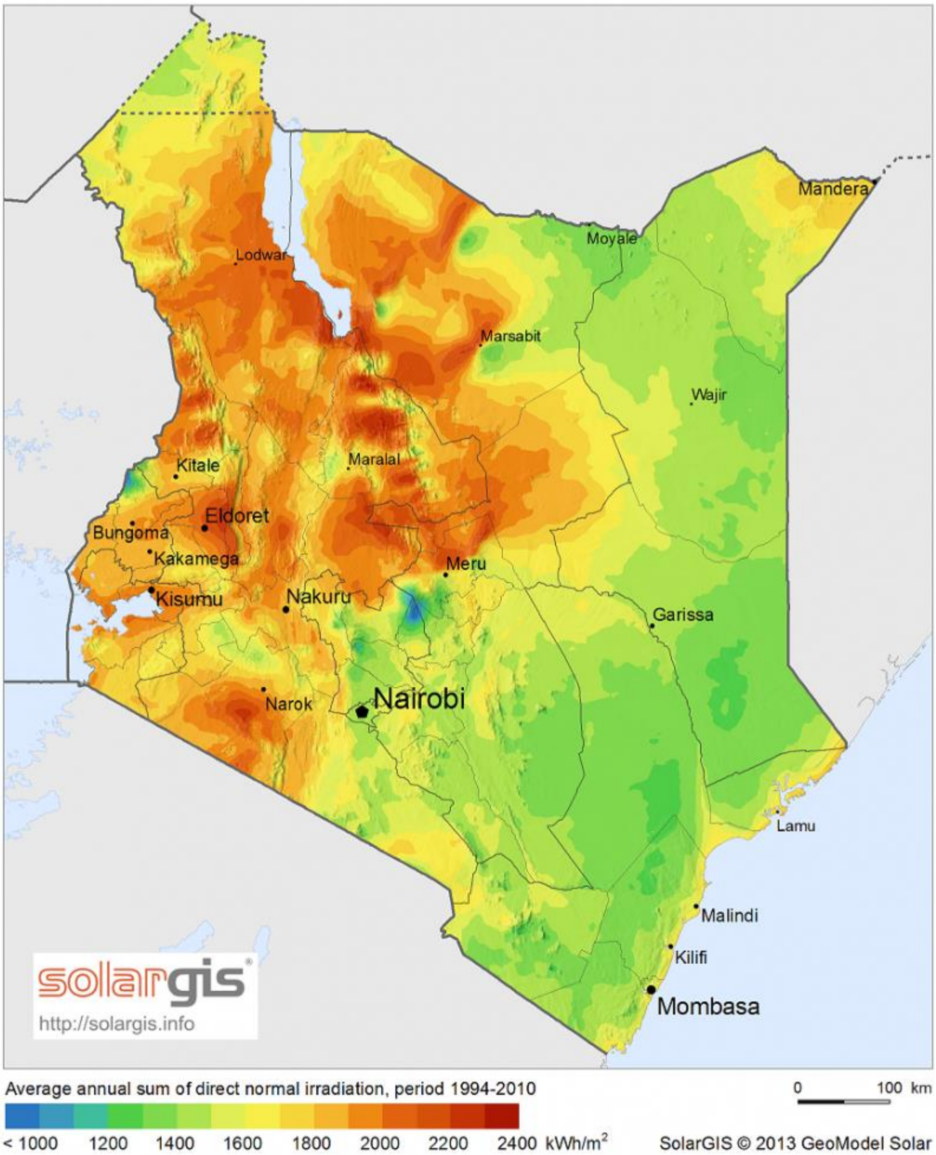


Figure 1-9 Direct Normal Irradiation for Kenya

1.5.4 Geothermal

Kenya has a huge geothermal electricity potential in the Rift Valley averaging between 7,000 and 10,000 MW. The exploitation of geothermal started in 1981 when a 15 MW plant was commissioned in Olkaria. The resource is becoming increasingly viable and an essential source of grid-connected electricity in Kenya as a large-scale electricity source. It provides a reliable source of baseload power and has relatively low cost and can be put up in relatively inhabitable areas. Kenya's installed geothermal capacity is 607 MW making the country the eighth in the world in terms of operational capacity.

There has been a continuous increase in geothermal power contribution to the generation mix rising from 13% in 2010 to 26% in 2015, then 47% in 2016 (REN21, 2016a). This has led to a reduction on reliance on hydropower that has proved unreliable due to changing climate. The government has played a crucial role in the geothermal development as it operates the Geothermal Development Company that does the exploration of geothermal resources while KenGen owns and operates about 80% of the geothermal power capacity. The explorations on geothermal energy in the high-potential areas is still on-going. The government hopes to have a total geothermal installed capacity of 5000 MW by 2030.

1.5.5 Wind

Kenya has some excellent wind regime areas with potential output depending on the turbine CF; 22,476 TWh/year (>20%), 4,446 TWh/year (>30%) or 1,739 TWh/year (>40%) (**Figure 1-10**). The windiest areas are found in northwest of the country and the edges of the Rift Valley with winds speeds of about 5-7m/s at 50m. Kenya is the only country in the East African Community with grid-connected wind power. Wind has comparably low electricity production costs and a potential capacity of over 1,000 MW. The existing wind farms are located in Ngong Hills near Nairobi with a total installed capacity of 25.5 MW.

There are a number of projects that are expected to come online including the Lake Turkana wind power project with a capacity of 310 MW, which construction began in 2015. There is also a planned 400 MW wind farm in Meru County with the French Development Agency (AFD) signing a EUR 60 million (USD 67 million) loan with KenGen in April 2016 (REN21, 2016a). The funds were for construction of the first phase of the project. The planned 60 MW Kinangop Wind Park project experienced a setback following the withdrawal of investors due to resistance from local governments and residents as well as delays in procuring the necessary documentations.

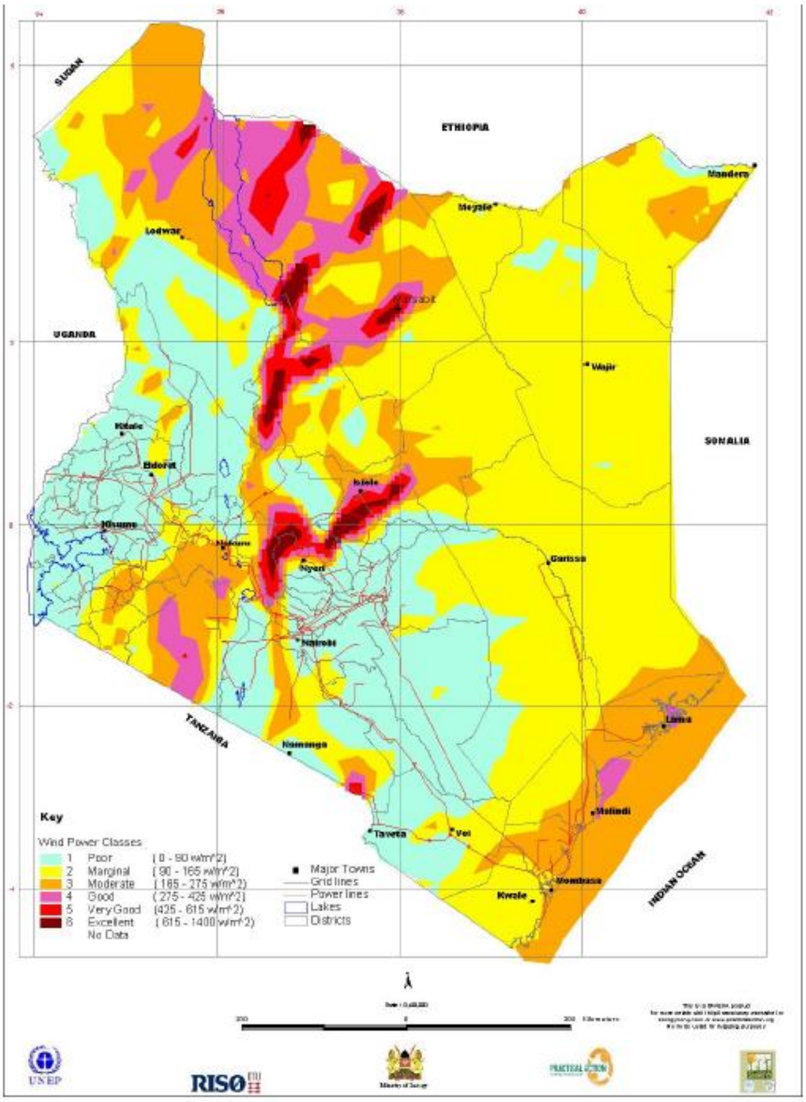


Figure 1-10 Simulated Annual Wind Power Density (W/m2) at 50m above ground

Grid-connected renewable power is providing a growing share of final energy consumption. The Kenyan government has already provided numerous PPA to different renewable energy projects. However, most of the projects have not gone online due to implementation difficulties. There are still no clear rules and procedures preventing investors from becoming more actively involved. For instance, the withdrawal of investment from the 61MW Kinangop Wind Park project that already had a PPA in 2013 indicates the extent of the implementation challenges. There are also challenges of securing a generation license even with a PPA.

1.6 Mini-Grids

In 2005, the government begun distributed generation program aimed at providing basic electricity to public facilities such as health facilities and boarding schools in remote areas led to increase in demand for PV panels by over 200 kilowatt peak. At the time, there were about 3000 eligible institutions (Figure ***1-11***). In the last 10 years, only about 750 have been equipped with PV systems with a combined capacity of 1.65 MW peak by KPLC. Apart from KPLC, private companies such as Powerhive and Talek Power Company have been licensed to develop and operate mini-grids in Kenya opening the market to the private sector. The Talek is a pilot project implemented by GIZ meant to demonstrate the financial feasibility and business model for solar hybrid mini-grids.

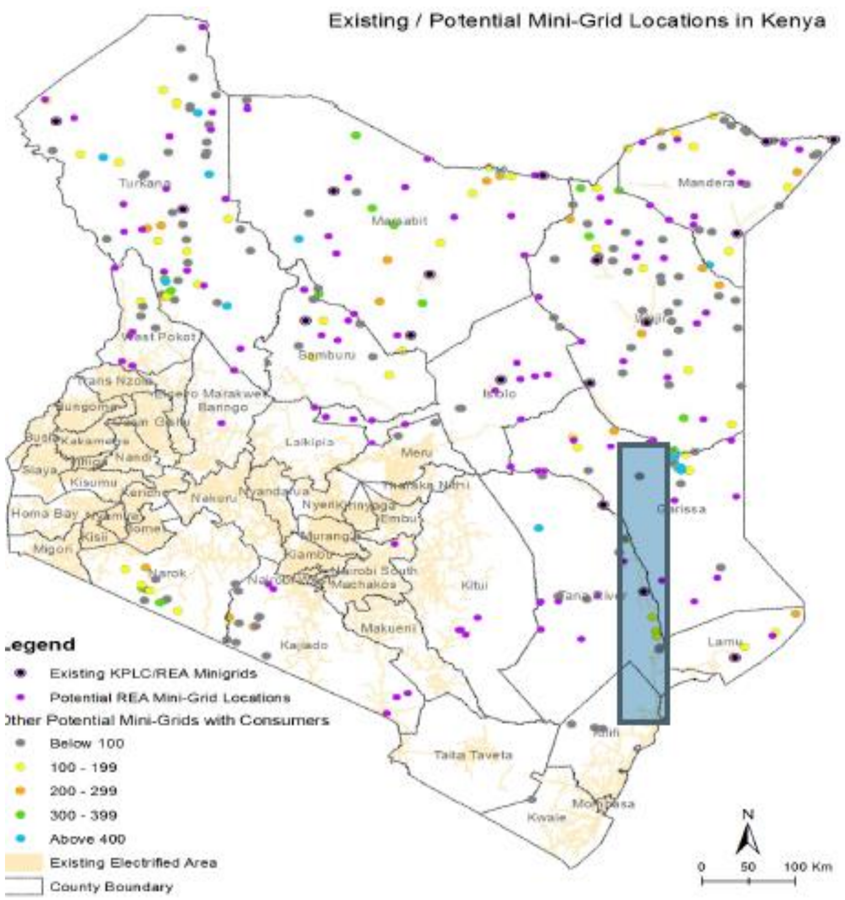


Figure 1-11: Existing and Potential Mini-grid areas in Kenya

The development followed the Rural Electrification Master Plan of 2009 that recognizes the role of renewable energy in electrifying areas far from the national grid. As at 2015, about 5 off-grid stations had been equipped with the hybrid system with a combined capacity of 210 kW. An assessment of the pilot projects has indicated that they are economical with Internal Rate of Return (IRRs) of about 20% (Government of Kenya, 2015). Apart from economic benefits, the use of solar PV also has environmental benefits as it reduces emissions associated with the use of fossil fuels such as diesel in the generation of electricity.

The use of distributed generation systems especially home solar systems has led to increased access to modern energy. There are about 400 thousand solar home systems throughout the country. The systems are of capacities between 25 to 30 W.

Although grid-connected systems are well covered through FiT policies, the development of distributed renewable energy generation such as mini grids and stand-alone systems lacks clarity on how they contribute to the renewable energy targets. As at 2014, Kenya had an estimated 19.2 MW of mini-grid installed capacity with about 5% of the capacity being from renewable sources (REN21, 2016a). The only support given to distributed generation is the tax incentives that affects importation costs. Given that renewable technology costs are on the decline, there is need to expand local technical capacity especially on non-hydro renewable energy sources in order to ensure continued growth of the share of renewables in the energy mix. This means that it will be possible to run on renewable energy without dependence on the grid or the use of fossil fuel for lighting. However, the medium-term power development plan 2015-2020 does not reflect the emphasis on renewable energy as indicated in **Figure *1-12***.

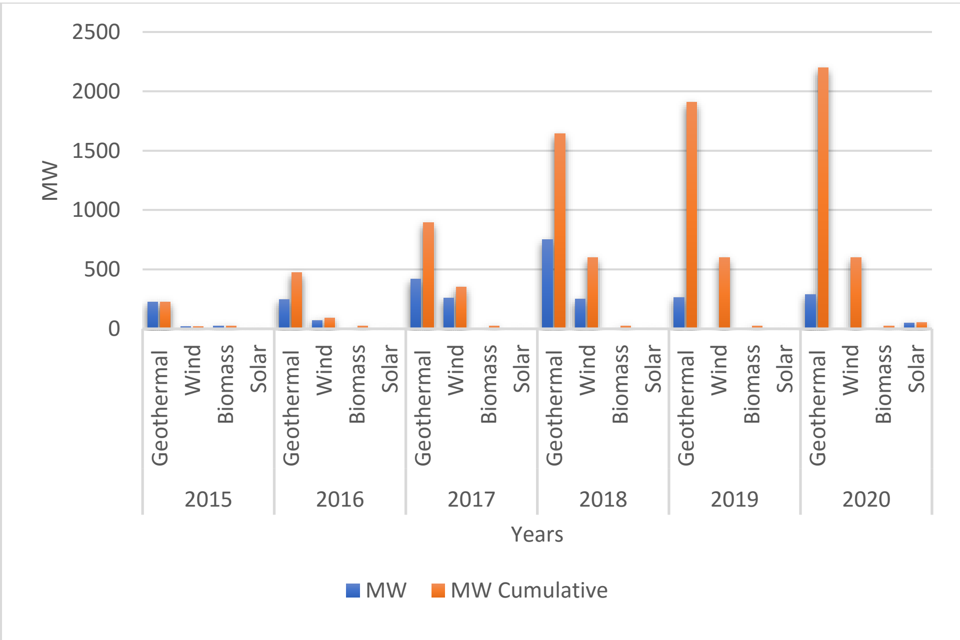


Figure 1-12: Installation of Renewable energy for the 2015 - 2020 Period

Source: (Government of Kenya, 2015)

The projected development of renewables has focused more on geothermal and wind with little or no emphasis put on other renewable sources of energy. For instance, the Kenyan government is aiming to install an additional 500 MW of solar PV to the grid while hoping for an additional 300,000 domestic solar systems by 2030. The projections are low compared to a total potential for solar PV installations estimated at 23,046 TWh/year.

1.7 The Effects of Fossil Fuels

Kenya is a country in need of modern energy to promote the growing economy. Given that the electrification rate stands at around 50% (KPLC, 2016), most of the population still have a problem of getting access to clean and affordable energy. The use of kerosene for lighting is common in most rural areas that lack access to electricity. In addition, the generation mix of the country has a significant contribution from fossil fuels with diesel generators accounting for about 30% of total installed capacity.

There are a number of costs associated with the generation of electricity that often go unnoticed. The costs are indirect and tend to affect third parties than those involved in the generation and consumption of electricity. Apart from global instability in fossil fuels, there are other factors that increase the costs that are external to the production and use. For instance, a study on the use of kerosene lamps for lighting has indicated other costs not considered when pricing the fuel such as the risk of respiratory illness and lung cancer (Apple *et al.,* 2010).

With regards to the use of diesel generators for electricity generation, a study conducted in Nigeria showed the continued use of the generators led to air pollution with the release of toxic substances such as carbon monoxide, NO2, and SO2 (Nnaji & Chimelu, 2014). Kenya is still working on having more electricity from diesel generation in the coming years with capacities contributing about 30% of the total generation mix. The negative externalities associated with generation of electricity need to be considered during policy formulation as the costs to third parties are rarely considered. There is need to address such impacts through development of corrective actions. The authorities in the Kenyan energy sector should still aim at ensuring every person has access to modern energy while at the same time reducing on the negative external effects.

CHAPTER 2
LITERATURE REVIEW

The demand for modern energy services is on the rise given its contribution to economic development as well as the well-being of humans. The energy-economic growth nexus is increasingly becoming an essential tool for policymakers, not just economist, due to its significant policy implications. Globally, about 1.3 billion people are without access to electricity, of which more than 95% are found in Sub-Saharan Africa and developing Asia (Muok, Makokha, & Palit, 2015). Although Sub-Saharan Africa is very poor in energy supply, it is very rich in terms of energy resources. Africa has numerous renewable energy resources. The predominant renewable energy source has been hydropower accounting for about 15% of total generation (IRENA, 2016). However, there still exist opportunities in the exploration of biomass, biogas, wind, and solar as additional sources of renewable energy.

It was not until in the 1970s that studies into causal relationship between energy consumption and economic growth became common (Jamil & Ahmad, 2010). The first study to look into causal relationship between energy consumption and economic growth was done by Kraft and Kraft (1978) in the United States. The findings of the study indicated a strong unidirectional causal relationship running from economic growth to energy consumption. The findings led to numerous empirical studies aimed at replicating the causal relationship between energy consumption and economic growth in different countries and regions across the globe (Akarca & Long, 1980; Alshehry & Belloumi, 2015; Apergis & Payne, 2011; Hamdi, Sbia, & Shahbaz, 2014; Islam, Shahbaz, Alam, Ahmed, & Alam, 2013; Magazzino, 2014; Mozumder & Marathe, 2007; Narayan & Smyth, 2009; Rafindadi & Ozturk, 2016; Soytas & Sari, 2003; Yu & Choi, 1985).

The studies were significant given the interaction between energy consumption and economic growth was considered essential to successful policies that would stimulate economic growth. For instance, if the findings of causal relationship reveal a unidirectional causality running from energy consumption to economic growth, any policy restrictions that would affect energy consumption would also have a detrimental effect on the economic growth. On the other hand, if the causal relationship reveals a neutral causal relationship between economic growth and energy consumption, then policy initiatives aimed to conserve energy may result in little or no impact on economic growth.

The findings of the existing empirical studies do not indicate any strong consensus of the causal relationship between energy consumption (electricity) and economic growth regardless of the studies being country specific, focusing on regions, as well as multiple countries. This makes it a challenge in providing reasonable policy recommendations for energy, environment and/or economic growth. The studies on causal relationship between energy consumption and economic growth soon led to two sets of outcomes. One school of thought argued that energy was an essential requirement for economic growth since it complemented other factors of production (Asafu-Adjaye, 1999) while others argued that there was a neutral relationship between energy consumption and economic growth (Soytas & Sari, 2003).

The two schools of thought led to numerous other studies whose findings were viewed to be largely dependent on the time series data and the method of analysis as they lacked uniformity (Mabea, 2014). The commonly used models in the identified studies were multivariate and bivariate models. However, they employed different time series, methodologies, and countries. The variables were also selected depending on their appropriateness to a given country. For instance, the comprehensive literature survey performed by Ozturk and Acaravci (2010) and Peyne (2010) on the energy-economic growth nexus consistently indicated that the major factors for the continued ambiguity in the research findings were: omission of relevant variables, flaws in the methodology, and variation in the time series data used for the study.

Karanfil and Li (2015) argued that changing the time period for analysis was not a sufficient contribution to the literatures or for policymakers to formulate effective policies. The study suggested exploring other variables with the potential to affect the relationship between energy (electricity) consumption and economic growth. That explains why various studies have evaluated the relationship between energy and economic growth using various parameters. There are studies that have focused on aggregated energy consumption (Akarca & Long, 1980; S. muhammad and hooi hooi Lean, 2011; Raza, Shahbaz, & Nguyen, 2015; Soytas & Sari, 2003), others considering electricity consumption (Aitor Ciarreta & Zarraga, 2007; Khatun & Ahamad, 2015; Menyah, Nazlioglu, & Wolde-rufael, 2014; Squalli & Wilson, 2006) some studies looked into electricity generation (Seung Hoon Yoo & Kim, 2006), others considered energy use (Ghali & El-Sakka, 2004; Islam et al., 2013), while others looking into domestic electricity consumption alone (Mabea, 2014). Given the growing concern about global warming, there is increasing interest on research on alternative sources of energy including variables of climate change.

Following the reasons in the study by Aitor Ciarreta and Zarraga (2007), studies have explored the inclusion of other variables such as carbon dioxide (CO2) emissions (Menegaki, 2011), exports (H. Lean & Smyth, 2010; Raza et al., 2015), population (Ismael *et al.*, 2013), labor and/or employment (Dogan, 2016; Menegaki, 2011), financial development (Islam et al., 2013), energy price (Asafu-Adjaye, 1999; Chandran, Sharma, & Madhavan, 2010; A Ciarreta & Zarraga, 2010), capital (Bekhet and Harun, 2012; Soytas and Sari, 2007), industrialization (Shahbaz and Lean, 2012), income (Charfeddine and Khediri, 2016; Asafu-Adjye, 2000), urbanization (Charfeddine and Khediri, 2016), trade openness, (Shabaz *et al.*, 2013), and foreign direct investment (Kivyiro and Arminen, 2014; Tang, 2009; Masih and Masih, 1997). There is also inclusion of specific sources of energy in certain studies in order to analyse their impact on economic growth. Some of the variables used in such studies include: non-renewable energy consumption and renewable energy consumption (Shahbaz, Zeshan, & Afza, 2012), crude oil and coal consumption (Bloch *et al.*, 2015; Caraini *et al.*, 2015). Various apsects of GDP have also been considered leading to various sets of variables used in investigating energy-growth nexus. They include real values of GDP (Bekhet and Othman, 2011; Ziramba, 2015), GDP per capita (Alshenry and Belloumi, 2015; Jebli and Youssef, 2015), GDP value added (Husaini & Lean, 2015), and GDP gross output (Bekhet and Harun, 2012).

In determining a causal relationship, the result of the causality test can lead to three possible relationships; bidirectional, unidirectional, or neutral. The findings, depending on the identified relationship, are then used to inform policy. There are studies that have identified a bidirectional relationship between energy and economic growth (Bloch *et al.*, 2015; Al-Mulali *et al.*, 2013; Shahbaz *and* Lean, 2012). This means that both energy and economic growth affect each other. The implication on policy is that there should be more emphasis on the development and deployment of renewable energy in order to sustain the economic growth. Renewable energy is thus identified as an alternative energy source whose exploration and use could enhance the sustained growth of the economy.

Unidirectional causal relationship can either be from economic growth to energy consumption or from energy consumption to economic growth. There are those studies that have found a unidirectional causal relationship from economic growth to energy consumption (Husaini *and* Lean, 2015; Jebli *and* Youssef, 2015; Lean *and* Smyth, 2010; Soytas *and* Sari, 2003). The findings of the studies indicate that energy demand may not have a significant impact on economic growth. This implies that a country can reduce on policies that affect energy demand without affecting economic growth. Such a scenario is eminent where a country develops policies on energy saving that reduce demand without impacting negatively on the economy. Such measures also lead to improved energy conservation and environmental protection through reduced emissions.

On the other hand, there are studies that have identified existence of a unidirectional causal relationship from energy consumption to economic growth (Dogan, 2016; Alshehry *and* Belloumi, 2015; Ziramba, 2015; Belloumi, 2009). In such a scenario, policies developed towards energy conservation have a detrimental effect on economic growth. The study by Alshehry and Belloumi (2015) on Saudi Arabia that is heavily dependent on fossil fuel is an example of how such unidirectional causal relationship emerge. Increased emphasis on energy conservation led to a negative effect on the growth of the national economy.

There are also studies that have revealed absence of a causal relationship between energy consumption and economic growth (Karanfil *and* Li, 2015; Kivyiro *and* Arminen, 2014; Yu *and* Choi, 1985). The study on Zimbabwe by Kivyiro and Arminen (2014) indicated no causal relationship between energy consumption and economic growth for data collected between 1971 and 2009. This was also the case for a study conducted on seventeen African countries with results for Algeria, Congo Republic, Kenya, South Africa and Sudan indicated no causal relationship between electricity consumption and economic growth. The results for a number of identified studies on bidirectional, unidirectional, and neutral causal relationship are presented in Table 5. It is evident that some studies have been carried out omitting critical variables as they have only examined the energy-growth nexus in a bivariate framework. The studies that have used bivariate setting have a challenge of finding cointegration and long-run causality meaning that the method is not accurate.

Table 2-1:Studies on Bidirectional, Unidirectional, and Neutral Causal Relationship

Country	**Reference**	**Method**	**Findings**
China	Bloch *et al.*, 2015	Multivariate	$RE \leftrightarrow Y, EC \leftrightarrow Y$
Germany	Rafindadi and Ozturk (2017)	Multivariate	$RE \leftrightarrow Y$
80 countries	Apergis and Payne (2012)	Multivariate	$RE \leftrightarrow Y$
Ukraine	Wolde-Rufael (2006)	Bivariate	$Y \leftrightarrow EL$
Tunisia	Shahbaz *and* Lean, 2012	Multivariate	$EC \leftrightarrow Y$
Malaysia	Husaini *and* Lean, 2015	Multivariate	$Yva \rightarrow EL$
Tunisia	Jebli *and* Youssef, 2015	Multivariate	$Ypc \rightarrow RE$
Hungary	Caraini et al. 2015	Multivariate	$Y \rightarrow RE$
Turkey, France, Germany, Japan	Soytas *and* Sari, 2003	Bivariate	$EC \rightarrow Y$
Turkey	Dogan, 2016	Multivariate	$RE \rightarrow Y$
Saudi Arabia	Alshehry *and* Belloumi, 2015	Multivariate	$EC \rightarrow Y$
South Africa	Ziramba, 2015	Multivariate	$ECcr \rightarrow Y$
Tunisia	Belloumi, 2009	Bivariate	$ECpc \rightarrow Ypc$
Sub-Saharan Africa	Karanfil *and* Li, 2015	Bivariate	$EL \neq Y$
Zimbabwe	Kivyiro *and* Arminen, 2014	Multivariate	$EC \neq Y$
UK, USA, Poland	Yu *and* Choi, 1985	Bivariate	$EC \neq Y$
European Countries	Menegaki, 2011	Multivariate	$Y \neq RE$
Algeria, Congo Rep., Kenya, South Africa, Sudan	Wolde-Rufael (2006)	Bivariate	$EL \neq Y$

Y :GDP, Yva: GDP value added, EC :energy consumption, ECcr: crude oil consumption, ECpc: Energy consumption per capita, ECng: natural gas consumption, EL: electricity consumption, RE: renewable energy consumption. →, ↔ and ≠ represent uni-directional causality, bi-directional causality, and neutral causality, respectively

The elasticity relationship is also crucial in determining the interaction between economic growth and energy consumption. Several studies have examined the response between economic growth and energy consumption and some studies have found that consumption of renewable energy does not impact positively on the economic growth (Al-Mulali *et al.*, 2013; Marques *and* Fuinhas, 2012; Lean *and* Smyth, 2010). The major impediment of the renewable energy is the associated costs needed to develop a renewable energy plant especially solar and wind that have affected their influence on the economic growth. However, the costs are on the decline. In addition, there are countries that have experience positive influence in the economy as a result of investment in renewable energy. The presence of both positive and negative response indicates a mixed effect in the use of renewable energy. In developed economies, the consumption of renewable energy has a higher likelihood of positive response as the countries tend to put more emphasis on environmental protection. The high per capita consumption of electricity has influenced development of policies that favor the use of renewable energy such as taxes on non-renewable sources of electricity. However, the developing countries are working towards improving consumption of energy per capita leading to subsidies that make renewable energy uneconomical.

From the reviewed literature, studies that look into causal relationship can be broadly put into two categories. The first category entails studies that have focused on multiple countries and the second category are studies that have been country specific. The results from the studies show that findings of the causal relationships have been mixed. One of the studies was conducted by Yoo (2006) that involved examination of causality between economic growth and electricity consumption in four ASEAN countries: Indonesia, Singapore, Malaysia, and Thailand. The findings of the study showed a bidirectional causality in Malaysia and Singapore. The remaining two countries, Indonesia and Thailand, had a unidirectional causal relation running from economic growth to electricity consumption.

A more recent study by Yoo and Kwak (2010) used cointegration and Granger causality techniques by Hsiao (1981) to investigate the economic growth – electricity consumption nexus for seven South American countries. The result indicated that a majority of the countries had a unidirectional relationship running from electricity consumption to economic growth. Those were Argentina, Brazil, Chile, Colombia, and Ecuador. The results for Venezuela indicated a unidirectional relationship running from economic growth to electricity consumption while Peru had a bidirectional causal relationship.

An investigation into 11 OPEC countries was carried out by Squalli (2007) investigating electricity consumption-economic growth nexus using the bound testing approach to cointegration and Granger causality test following Toda and Yamamoto (1995). The study found long-run dynamic relationship among the variables in the selected OPEC countries. With regards to causality, the study found a bidirectional causal relation between electricity consumption and economic growth in Qatar, Iran and Saudi Arabia. There was unidirectional causal relation running from economic growth to electricity consumption in Algeria, Iraq, Kuwait and Libya. In addition, the study found unidirectional causal relation running from electricity consumption to economic growth for Nigeria, Indonesia, United Arab Emirates, and Venezuela.

Narayan and Smyth (2009) investigated the causal relationship between economic growth, export and electricity consumption in Middle East that included the following countries: Iran, Israel, Kuwait, Oman, Saudi Arabia, and Syria. The findings of the study showed unidirectional causality running from electricity consumption to economic growth. In addition, economic growth was found to Granger-cause exports only in the short-run. Ozturk and Acaravci (2010) did a study investigating long-run causal relationship between economic growth an electricity consumption in four European countries. The countries were: Albania, Bulgaria, Hungary, and Romania. The findings indicated a bidirectional causal relationship between economic growth and electricity consumption for Hungary while the remaining countries had no causal relationship between economic growth and electricity consumption.

Apart from studies that have used multiple countries, there are numerous other studies that have carried out research on single countries. In a study conducted by Payne (2009), the researcher suggested grouping the studies based on four types of hypothesis in order to enhance clarity. The hypotheses are: growth, conservation, feedback and neutrality. The growth hypothesis follows that renewable energy generation excluding hydro has a direct contribution to the economic growth. The findings are supported by the hypothesis if the results indicate a unidirectional Granger-causality running from renewable energy generation excluding hydro to economic growth.

The conservation hypothesis indicates that energy conservation policies will not have an effect on the economic growth. This is witnessed when results indicate unidirectional Granger-causality running from economic growth to renewable energy generation excluding hydro. The feedback hypothesis indicates that economic growth and electricity consumption are interdependent and complement each other. This occurs where there is a bidirectional Granger-causality between economic growth and renewable energy generation excluding hydro. Lastly is the neutrality hypothesis where there is no Granger-causality between electricity consumption and renewable energy generation excluding hydro.

Table ***2-1*** highlights some of the studies that have been specific to a given country with findings supporting either of the hypothesis.

For the case of Kenya, there are limited studies that have explored the electricity consumption and economic growth nexus as shown in Table 1-1. One of the studies was conducted by Odhiambo (2010) and included three countries in the Sub-Saharan Africa namely Kenya, South Africa and Congo. The study used a multivariate approach with the methodology using ARDL and Granger Causality with the following variables: energy consumption per capita, real GDP per capita, and consumer price index in evaluating causality between energy and economic growth. The findings of the study indicated a unidirectional causal relationship running from energy consumption to economic growth for Kenya and South Africa. The results support the growth hypothesis meaning that energy conservation policies are likely to negatively affect the economy. Wolde-Rufael (2006) did a study on 17 African countries using the bivariate approach to test the long-run and causal relationship between electricity consumption per capita and real gross domestic product (GDP) per capita for the period 1971-2001.

The study employed Pesaran, Shin, and Smith's (2001) bounds testing approach to cointegration in examining the presence of long-run relationship. For causality test, the study used the test suggested by Toda and Yamamoto (1995). The findings of the study indicated existence of cointegration in only nine countries out of the seventeen; Kenya not among the nine. The results for Kenya showed no causal relationship between electricity consumption and economic growth. The bivariate study did not find cointegration and long-run causality implying that electricity consumption and economic growth do not affect each other. This can allow the implementation of energy conservation policies as they do not affect economic growth. However, economic growth was found to Granger-cause electricity consumption in Cameroon, Ghana, Nigeria, Senegal and Zimbabwe whereas electricity consumption was found to Granger-cause economic growth in Congo, the Democratic Republic of Congo, Benin, and Tunisia. Countries that had a bidirectional causal relationship were Egypt, Gabon and Morocco (Wolde-Rufael, 2006).

Country	**Reference**	**Method**	**Findings**

Kenya, South Africa and Congo	Odhiambo (2010)	Multivariate approach	$EC \rightarrow Y$
Kenya and 16 other African countries	Wolde-Rufael (2006)	Bivariate approach	$EC \neq Y$
88 countries	Apergis and Payne (2011)	Multivariate approach	$EC \leftrightarrow Y$

Table 2-2 Studies on relationship between Electricity Consumption and Economic Growth for Kenya

There are studies that have looked at different economies according to income classification. The study by Apergis and Payne (2011) examined the relationship between electricity consumption for 88 countries that followed the world bank categorization. The results were thus put in two classes. The variables used for the study were: electricity consumption, labor, and real GDP. The first class looked into high income and upper-middle income countries that indicated a bidirectional causal relationship between electricity consumption and economic growth. The second class, was the lower-middle income countries panel and the low-income countries that produces a unidirectional relationship running from electricity consumption to economic growth. However, bidirectional causal relationship occurred for the lower-middle income panel in the long-run. As Kenya is within the lower-middle income country level, the findings can be related to that of the country.

There are also studies that have focused on Sub-Saharan Africa such as Karanfil and Li (2005). The study used bivariate econometric technique and findings indicated that electricity consumption had a neutral relationship with economic growth. However, specific results for individual countries varied from the findings. For instance, a study on Malawi employing multivariate econometric technique revealed a bidirectional causality between electricity consumption and economic growth (Jumbe, 2004). Another study in Zimbabwe revealed employing multivariate econometric technique found a neutral relationship between energy consumption and economic growth (Kivyiro and Arminen, 2014). The study, which focused on Zimbabwe, was more recent compared to the previous studies and employed multivariate econometric technique using the following variables: carbon emission (CO2) per capita, energy consumption per capita, GDP per capita, and foreign direct investment. The variation in the research findings indicate the need to focus on one country in order to evaluate the local conditions.

With regards to the relationship between renewable energy and economic growth, studies in the recent past have focused on investigating the relationship between renewable energy consumption and economic growth (Apergis & Payne, 2012; Ben Jebli & Ben Youssef, 2015; Bloch, Rafiq, & Salim, 2015; Caraiani, Lungu, & Dascalu, 2015; Cerdeira Bento & Moutinho, 2016; Dogan, 2016; S. muhammad and hooi hooi Lean, 2011; Menegaki, 2011). Although the findings are not uniform across the studies, it is essential to investigate the developments in Kenya with a focus on the direction of causalities and the elasticities with regards to renewable energy generation excluding hydro and economic growth of the country.

Recent energy developments in Kenya has also seen increased investment in renewable energy with geothermal providing the largest share of generation mix at about 44 percent of the total electrical energy (ERC, 2017). The changing climate was also seen a decline in hydropower share of the generation mix to about 21 percent. This has led to increased use of thermal power contributing about 32 percent of the total electrical energy in Kenya as shown in Figure 2-1 (ERC, 2017). Wind generation and imports contribute the remaining three percent. There is still huge potential for other renewable sources such as solar and biomass that are yet to be fully exploited. For this reason, it is essential to investigate the impact of investing in other renewable sources for electricity generation other than hydro. Most of the identified studies have focused on energy consumption or electricity use. As per the findings of this research, no study has focused on renewable energy – economic growth nexus. Few studies have focused on renewable energy.

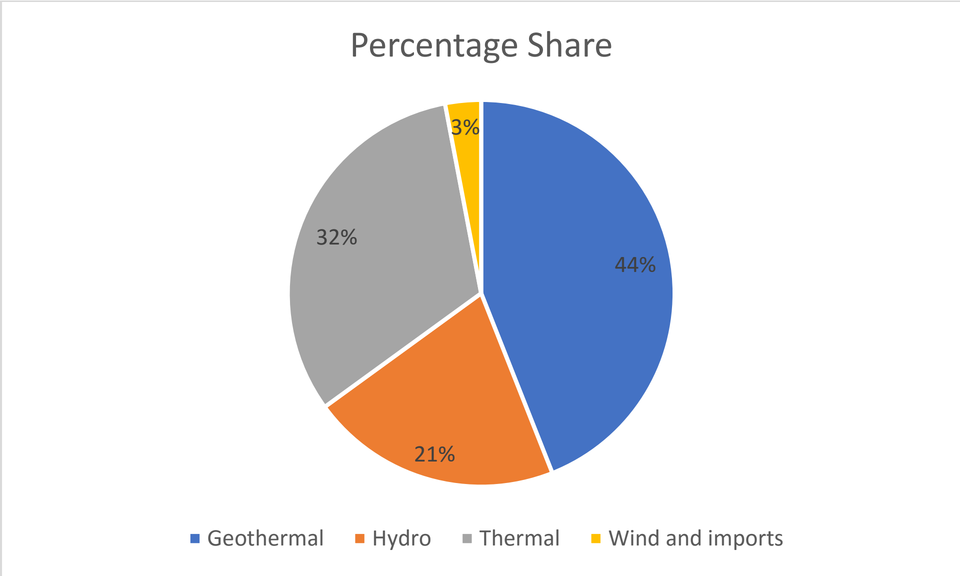


Figure 2-1 Electricity Consumption by Share as at July 2017

Due to the inconsistency causality evidences and the declining hydro potential in Kenya, this study attempts to examines the generation of electricity from renewable energy in Kenya excluding hydro, as a dependent variable while analyzing its relationship with the economic growth (GDP per capita) (Y) while considering other determinants (export of good and services (Ex), carbon dioxide emissions (CO2), and financial development (FD) in a multivariate approach. The identified potential variables avoid the omitted variables bias exhibited in studies utilizing bivariate econometric technique. Therefore, the results of the study are more robust, reliable and oriented towards policy as the variables are put into one model. The study utilizes an augmented production function. The methodology involves the use of Cobb-Douglas production function, F-Bound test, and vector error correction model (VECM) in determining the short-run and long-run equilibrium relationship between renewable generation excluding hydro, economic growth, financial development, carbon emissions, and export value in Kenya. The Granger causality test will verify the direction of the causality between the variables of interest and hence influence policy recommendations.

The following hypothesis are essential in the achievement of the study objective:

I. First Hypothesis: there is a short and long run dynamic relationship between generation of electricity from renewable energy excluding hydro and its determinants (Ex, CO2, Y, and FD) in Kenya.

II. Second Hypothesis: there are short and long run elasticities between generation of electricity from renewable energy excluding hydro and its determinants (Ex, CO2, Y, and FD) in Kenya.

III. Third Hypothesis: there is a short and long run causality between generation of electricity from renewable energy excluding hydro and its determinants (Ex, CO2, Y, and FD) in Kenya.

The augmented Cobb-Douglas production function and F-bound test are essential in examining the dynamic relationships and elasticities between generation of electricity from renewable energy and its determinants (Ex, CO2, Y, and FD) in Kenya. The vector error correction model (VECM) will be essential in analyzing the causal relationship between the variables. The result of the findings will then be used to develop policy implications on deployment of renewable electricity other than hydroelectric in Kenya.

CHAPTER 3
METHODOLOGY

3.1 Data and Method Development

The study used secondary annual data that was sourced from the *World Development Indicators* (WDI) database. It included economic growth in GDP (constant 2010 USD), Renewable electricity production excluding hydroelectric in kilowatthours (kWh), Export of goods and services (constant 2010 USD), Financial development (FD) given in terms of domestic credit to private sector (% of GDP), and carbon (CO2) emissions in kilo tons (kt). The study covered sample period from 1980 to 2014.

The Cobb-Douglas (C-D) production function has been widely used in the analysis of empirical and theoretical growth and productivity in representing the relationship between outputs and inputs. The method was proposed by Knut Wickesell (1851 – 1926) and tested against statistical evidence by Charles Cobb and Paul Douglas in 1928 (Kumar, Sharma, & Joshi, 2016). The use of the production function in energy by Stern (1993) enabled many researchers examine the relationship between economic growth (Y), energy (E), capital (K), and labor (L). The augmented C-D production function is as shown in equation (1).

$$Y = AE^{\alpha_1}K^{\alpha_2}L^{\alpha_3} \tag{1}$$

The economic growth *Y* represents the total production influenced by energy, capital, and labor inputs. *A* represents the total factor of productivity, while α_1, α_2, and α_3 are the output elasticities of energy capital and labor. The elasticities are then used to determine the responsiveness of output to a change in levels in either energy, capital, or labor. There are a number of researches that have used this approach (Ghali and El-Sakka, 2004; Soytas and Sari, 2007; Yuan *et al.*, 2009). Other studies have included other variables such as coal, oil and renewable energy as inputs in the production function (Bloch et al., 2015) while others have examined energy consumption from both renewable and non-renewable sources (Arbex *and* Perobelli, 2010).

The concerns about global warming has led to crucial attention to renewable energy especially with its potential in economic growth as well as enhancing environmental protection. Kenya is also upscaling the growth of its renewable energy potential although hurdles still exist that affect optimum exploitation of the resources. Given the stagnation in the development of hydroelectricity, there is a strong focus towards developing other renewable sources of electricity such as geothermal and wind. This has influenced the inclusion of renewable electricity production in the augmented production function excluding hydroelectricity, thus, replacing energy E as shown in equation 2.

$$Y = ARE^{\alpha_1}K^{\alpha_2}L^{\alpha_3} \tag{2}$$

Although A has been considered as a constant value, there are studies that used financial development (FD) (Shahbaz *et al.*, 2013). The authors argued that FD was essential in enhancing domestic production hence affecting other variables included in the study such as value of export, carbon dioxide emissions, and energy production needed to boost the economic growth. However, there are studies showing variation in causality patterns across countries between FD and economic growth (Demetriades, P., & Hussein, 1996). The study on sub-Saharan African countries (Kivyiro *and* Arminen, 2014) revealed the dangers of statistical inference resulting from treating different economies as a homogeneous entity. There are studies that have indicated that FD enhances confidence of local as well as foreign investors (Sadorksy, 2010) while others have pointed out limited support for finance-led and trade-led hypothesis (Menyah, Nazlioglu *and* Wolde-Rufael, 2014). It is essential to examine the Kenyan situation by using the value of FD to represent *A*. This can be represented in the production function as illustrated in equation 4.

$$A = \alpha FD^{\alpha_4} \tag{3}$$

$$Y = \alpha RE^{\alpha_1}K^{\alpha_2}L^{\alpha_3}FD^{\alpha_4} \tag{4}$$

The demand for electricity will continue growing with the economic growth. This is expected to result in increased generation of electricity to satisfy the growing demand. A number of factors are also likely to be affected. The carbon dioxide emissions for instance, will be influenced by the energy sources. Moreover, the state of economic growth will depend on FD and will be illustrated by the value of exports among other parameters. For these reasons, examination of causality issues, elasticities, and dynamic relationships will involve a detailed investigation of how the variables influence renewable energy production. Given the influence of climate on hydroelectricity in Kenya, it will be excluded from the renewable energy sources under consideration. Therefore, the study uses renewable electricity production excluding hydro as a dependent variable following other studies (Dogan, 2016; Shahbaz *et al.*, 2015; Yoo *and* Kim, 2006). The economic growth (Y) becomes the independent variable flanked with other factors; export of good and services, CO2 emissions, and FD. The model is thus written as in equation (5);

$$RE_t = \alpha {Y_t}^{\alpha_1} {Ex_t}^{\alpha_2} {CO_{2_t}}^{\alpha_3} {FD_t}^{\alpha_4} \tag{5}$$

In order to facilitate efficient analysis of the data, the variables are transformed into natural logarithms form. By using natural logarithm, it is possible to obtain stationarity in the variance covariance matrix (Fatai *et al.,* 2004; Chang *et al.,* 2001). The transformation enables linearization that reduces heteroscedasticity resulting in more consistent results (Shahbaz *and* Lean, 2012). In addition, it makes it possible to determine the elasticities of the dependent variable (RE) with respect to the independent variables (Y, Ex, CO_2, FD) using the coefficient estimates ($\alpha,\ \alpha_1, \alpha_2, \alpha_3, \alpha_4$).

$$\begin{aligned} LOGRE_t = \alpha + \alpha_1 LOGY_t + \alpha_2 LOGEx_t + \alpha_3 LOGCO_{2_t} \\ + \alpha_4 LOGFD_t + \beta_t \end{aligned} \tag{6}$$

The value *t* represents the time-series data in years and β represents the stochastic error terms that is assumed to be normally distributed including white noise that occurs in discrete time. EViews statistical software version 9.5 was used for the analysis. The software offers econometrics package for time-series analysis useful for this research.

3.2 Methodology

The first analysis will involve investigating the basic features of the data and existing relationships between the variables by conducting a descriptive analysis of the data using common samples. The test reveals the nature of the data such as normal distribution. From the distribution statistics Jarque-Bera Test is used to confirm normality as it test-matches the kurtois and skewness of data. This is followed by correlation analysis in order to determine inter-relationship.

The second analysis involve unit root test that will help determine the quality of data for regression. The tests applied are the Augmented Dickey and Fuller (1979) and Philips and Perron (1991) for all variables both at levels I(0) and first difference I(1). The Augmented Dickey Fuller test (ADF) eliminates the problem of autocorrelation as would have been the case with the Dickey Fuller Test. The test has three shapes that are used on each variable considering intercept only, trend and intercept, and when there is no trend and no intercept. The lag selection for the ADF test was automated and based on Schawarz Information Criterion. The Phillips-Perron (PP) Test is a non-parametric test when compared to ADF test. The asymptotic distribution assumption makes it suitable for large samples. The spectral estimation method under PP was left under default (Bartlett kernel) and the bandwidth was put on automatic selection following Newey-West Bandwidth criterion in the EViews software.

The third analysis will look into the first objective of the study. The examination of the dynamic relationship among variables, the long and short-run relationships employs the Autoregressive Distributed Lag (ARDL) model. There are a number of assumptions guiding the ARDL approach: ARDL does not work well with variables in second difference I(2), the lag lengths need to be optimal, errors must also be serially independent, the model itself need to be dynamically stable, the ARDL approach can be applied if variables are stationary at level or at first difference. In addition, the ARDL model can be used in a mixture stationary where variables are stationary at level and first difference.

There are a number of advantages of ARDL approach over the conventional cointegration techniques. One of them is that the bound testing approach can be applied to the model irrespective of whether the variables are all level or a mixture of level and first difference. The second advantage is that The Monte Carlo analysis has shown that the ARDL cointegration approach performs better in small samples (Pesaran, M. H., Shin, 1999). Thirdly, the ARDL procedure makes it possible to find the estimation even when the explanatory variables are endogenous (Alam *and* Quazi, 2003). Endogeneity is also less of a problem under the ARDL as long as the model is free of residual correlation. There is also an advantage of the ARDL approach when compared to Engle and Granger (1987), which is a single equation cointegration analysis that suffer from problems of endogeneity. The ARDL approach is unique compared to Engle and Granger in that it can distinguish between dependent and explanatory variables. Moreover, ARDL method can yield consistent estimates of the long-run parameters that are asymptotically normal irrespective of whether the variables are at levels, first difference or mutually integrated (Pesaran, M. H., Shin, 1999).

The F-bound ARDL test helped in identifying the short-run and long-run dynamic relationship among the variables. The test is essential for the study as it eliminates the endogeneity problems assuming all the variables are endogenous that occur when using the

Engle-Granger method (Al-Mulali, Fereidouni, Lee, & Sab, 2013). It also well suited for small samples, 30 ≤ t ≥ 80, and allows the use of a mixture of stationary and unit root variables. The test also makes it possible to have different optimal lags of the variables. The model for the test is as follows:

$$\Delta\begin{bmatrix} LOGRE \\ LOGY \\ LOGEx \\ LOGCO_2 \\ LOGFD \end{bmatrix}_t = \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \end{bmatrix} + \begin{bmatrix} l_{11} & l_{12} & l_{13} & l_{14} & l_{15} \\ l_{21} & l_{22} & l_{23} & l_{24} & l_{25} \\ l_{31} & l_{32} & l_{33} & l_{34} & l_{35} \\ l_{41} & l_{42} & l_{43} & l_{44} & l_{45} \\ l_{51} & l_{52} & l_{53} & l_{54} & l_{55} \end{bmatrix} \begin{bmatrix} LOGRE \\ LOGY \\ LOGEx \\ LOGCO_2 \\ LOGFD \end{bmatrix}_{t-1}$$

$$+ \sum_{j=0}^{k} \Delta \begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{14} & s_{15} \\ s_{21} & s_{22} & s_{23} & s_{24} & s_{25} \\ s_{31} & s_{32} & s_{33} & s_{34} & s_{35} \\ s_{41} & s_{42} & s_{43} & s_{44} & s_{45} \\ s_{51} & s_{52} & s_{53} & s_{54} & s_{55} \end{bmatrix}_j \begin{bmatrix} LOGRE \\ LOGY \\ LOGEx \\ LOGCO_2 \\ LOGFD \end{bmatrix}_{t-j} \qquad (7)$$

$$+ \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \end{bmatrix}_t$$

Where Δ is the first difference operator and *q* represents the intercepts; l and s represents the long- and short-run coefficients respectively; t is the time period; *j* the lag order selection; k represents optimal lag lengths; and u represent the residuals.

The F-bound test for the study will require the determination of optimal lag lengths to facilitate the analysis. This was done by running vector autoregressive (VAR) model using unrestricted VAR on the endogenous variables as LOGRE, LOGY, LOGFD, LOGEX, and LOGCO2 for the sample length 1980 to 2014. Constant C was taken as an exogenous variable. From the autoregressive estimates, the lag structure was selected using the VAR lag length criteria. The lags selection was based on the Schawarz information criterion (SC), Akaike information criterion (AIC), final prediction error (FPE), Hannan-Quinn information criterion (HQ), and sequential modified LR test statistic (each test at 5% level). Various lag specifications are tried in the model in order to find the optimal that is common among all criterions.

In the analysis of the long-run relationship, the significance of the F-Statistics on the lagged level explanatory variable is applied. The process compares the upper I(1) and lower I(0) critical bound of the small sample size. It allows the testing of the null hypothesis of no long-relationship against the alternative hypothesis of a long-run relationship. If the F-Statistic values exceed the critical value, the decision would be to reject the null hypothesis of no long-run relationship. On the other hand, if the F-statistic values are below the lower critical value, then the decision is not to reject the null of no long-run relationship. In the event that the F-statistic values lie between the lower and upper critical bound, then no exact conclusion can be made as the test is uncertain. In such a case, the result may be based on previous literature that made similar findings. There are studies that have suggested the use of error correction as a way of determining dynamic relationship (Matar *and* Bekhet, 2015; Boutabba, 2014). In their findings, the determination of a short-run relationship occurs if the null hypothesis of no short-run relationship is rejected.

The elasticities of RE Electricity production excluding hydroelectric considers that the use of RE has an influence on other determinants including economic growth. The ARDL approach is used in the determination of both short- and long-run elasticities. The result of the process helps achieve the hypothesis for short and long run elasticities between RE and its determinants.

Determination of causal relations will require the use of vector error correction model (VECM). This helps in detecting the direction of causality. As illustrated in the concept of Granger causality, a variable '*X* causes *Z*' if and only if the past values of *X* can be used in determining the changes in *Z*. The vector autoregression (VAR) can be used to find the causal relations. However, for a set of variables that are co-integrated, there exists short and long-run causality that cannot be captured by the standard first difference VAR model (Granger, 1988). In order to overcome this challenge, the structure of the model to implement Granger causality must have the VECM framework as follows:

$$\Delta\begin{bmatrix} LOGRE \\ LOGY \\ LOGEx \\ LOGCO_2 \\ LOGFD \end{bmatrix}_t = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix} + \sum_{j=1}^{k} \Delta \begin{bmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} \\ \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} \\ \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} \end{bmatrix}_j \begin{bmatrix} LOGRE \\ LOGY \\ LOGEx \\ LOGCO_2 \\ LOGFD \end{bmatrix}_{t-j} + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} [ECT_{t-1}] + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{bmatrix}_t \quad (8)$$

Where Δ is the first difference operator and c represents the constant value; α is for the short-run causal relationships while ε represents the serially uncorrelated random error terms. Optimal lag length is represented by *k*; *t* represents the time period while *j* represents the criteria used in determining the lag length on likelihood ratio test. The use of statistical significance of ECT_{t-1} (Error Correction Term) coefficients in a t-statistic also further validates the determined long-run relationship between the variables. The estimate of the coefficients also shows the adjustment rate from a short-run toward the equilibrium path in all models. The results are essential in determining the causal relationship between electricity production from renewable sources excluding hydro and its determinants.

The robustness of the error terms generated by the ARDL model were confirmed using a number of tests; serial correlation, heteroscedasticity, and normality tests. It included the use of Ramsey's reset test in correcting the functional form. The stability of the long and short run relationships was verified using cumulative sum and cumulative sum squared tests. The use of impulse response function (IRF) investigates how the selected variables react to the exogenous shocks. In addition, the estimation of the variance decomposition (VD) for RE generation and its determinants is made that helps determine the percentage of forecast error variance of the dependent variable that can be explained by exogenous shocks to the independent variable.

CHAPTER 4

RESULTS AND DISCUSSIONS

In order to make the research robust, the study started by carrying out descriptive statistics. The data set for the study consists of thirty-four years of annual observations from 1980 to 2014. The data quality tests and inter-relationships results of the descriptive statistics and correlation matrix are shown in

Table ***4-1***. The variables RE, EX, and CO2 are negatively skewed while FD and Y (GDP) are right skewed. Kurtosis statistic of the variables show that all variables are platykurtic (short-tailed or lower peak) with the exception of RE that is leptokurtic (long-tailed or higher peak). The Jarque-Bera test follows the condition where it assumes existence of a null hypothesis where residuals are normal.

From the results, the probability is higher than 5% level of significance indicating that the null hypothesis cannot be rejected. This means that all residuals of the variables are normally distributed. As illustrated in the findings in

Table ***4-1***, RE generation from non-hydro sources has a significant and positive relationship with the other variables which are consistent with existing literature (Ivy-Yap and Bekhet, 2015; Matar and Bekhet, 2015; Narayan and Smyth, 2009). The inter-relationships are important to forecast the behavior of RE changing positions.

Table 4-1: Descriptive Statistics and Correlation Matrix

	LOGRE	LOGY	LOGFD	LOGEX	LOGCO2
Mean	20.16	23.94	3.13	22.29	8.91
Median	20.06	23.93	3.13	22.31	8.93
Maximum	21.51	24.57	3.46	22.93	9.51
Minimum	18.76	23.41	2.91	21.64	8.23
Std. Dev.	0.78	0.33	0.16	0.42	0.37
Skewness	-0.26	0.17	0.21	-0.08	-0.06
Kurtosis	2.4	2.17	1.92	1.83	1.83
Jarque-Bera	0.9	1.15	1.9	1.97	1.97
Probability	0.64	0.56	0.39	0.37	0.37
Sum	685.55	813.8	106.5	757.7	302.84
Sum Sq. Dev.	20.08	3.56	0.83	5.82	4.56
Observations	34	34	34	34	34
LOGRE	1				
LOGY	0.95	1			
LOGFD	0.69	0.81	1		
LOGEX	0.92	0.97	0.77	1	
LOGCO2	0.75	0.88	0.85	0.85	1

Source: Output of the Eviews Software Student Version 9.5

Following the analysis of the descriptive statistics and relational matrix, the study conducted unit root test on the variables to ascertain whether they were stationary at levels or at first difference. To achieve this, the research applied the Augmented Dickey-Fuller and Phillips-Perron unit root tests.

Table ***4-2*** shows the results of the unit root test using for all variables both levels I(0) and first difference I(1). At level I(0), we can accept the null hypothesis of unit roots for all variables. This shows that the variables are not stationary at level. However, after taking the first difference of all the variables, the series were found to be stationary with intercept and trend. This led to the rejection of the null hypothesis of unit roots for all variables at first difference I(1) at a 5% level of significance. This means that all the variables are stationary at first difference.

Table 4-2: Unit Root Test Results.

			ADF		P-P	
Variable	**Exogenous**	**Order of Integration**	**Test Statistic**	**P Value**	**Test Statistic**	**P-Value**
LogRE	C	I(0)	-0.1997	0.9292	0.0549	0.9572
	C and T		-2.0045	0.5781	-2.0045	0.5781
	None		2.2758*	0.9933	2.6826*	0.9975
LogY	C		1.5688*	0.9992	1.251*	0.9978
	C and T		-0.30733	0.9871	-0.8739	0.9476
	None		2.883*	0.9985	7.210*	1
LogEx	C		-0.3083	0.9134	-0.2937	0.9157
	C and T		-3.4952[b]	0.0575	-2.676	0.2521
	None		2.9511*	0.9988	3.0275*	0.999
LogFD	C		0.6297*	0.9884	-0.1928	0.9301
	C and T		-3.3611[b]	0.0737	-3.2695[b]	0.0885
	None		1.6720*	0.9745	1.2261*	0.9406
LogCO2	C	I(1)	-0.4168	0.8948	-0.522	0.8743
	C and T		-2.862	0.187	-2.9165	0.1705
	None		0.9933*	0.9117	0.9551*	0.9061
D(LogRE)	C		-5.4681	0.0001	-5.4191	0.0001
	C and T		-5.3954	0.0006	-5.3495	0.0006
	None		-4.7435	0	-4.7397	0
D(LogY)	C		-3.3075[a]	0.0226	-3.3075[a]	0.0226
	C and T		-3.5056[b]	0.0552	-3.5841[a]	0.0468
	None		-1.5108	0.1206	-1.4669	0.1307
D(LogEx)	C		-2.4571	0.1354	-5.7208	0
	C and T		-2.4058	0.3696	-5.6191	0.0003
	None		-1.4932	0.1245	-4.7471	0
D(LogFD)	C		-6.0324	0	-8.0906	0
	C and T		-6.4676	0	-8.7739	0
	None		-7.5723	0	-7.7044	0
D(LogCO2)	C		-5.6354	0.0001	-5.6525	0
	C and T		-5.7609	0.0002	-5.7695	0.0002
	None		-5.5664	0	-5.6071	0

Test Null: the variable has unit root; Alt: the variable does not have unit root. Test conditions to reject null are Test Stat> Test Critical Value, P> % level of significance, [a,b,c]denotes the statistical significance level at 1%, 5% and 10% respectively. *denotes invalid model (having a positive coefficient for the ADF test model). C: constant, T: Linear trend, None: no trend and intercept.

Source: Output of the Eviews Software Student Version 9.5

The identified stationary variables were used in testing the existence of a dynamic relationship among them. This was carried out using the F-bound test that was favorable due to the small number of observations (obs = 34). The most appropriate model for the analysis was bound testing autoregressive distributed lag (ARDL) approach. The approach would help understand whether the variables are co-integrated or not. Before conducting the bound test, it was essential to determine the optimal lag as the result was dependent on the optimal lag selection based on a number of criteria. These were: Schwarz Bayesian information criterion (SC), Akaike information criterion (AIC), final prediction error (FPE), Hannan-Quinn criterion (HQ), and log-likelihood ration (LR) in vector autoregressive (VAR) model. The criterions are essential in selecting a suitable lag length that helps in determining the dynamic relationship as it determines selection of the best ARDL model in estimating elasticities. The results of optimal lag order tests in Table 4-3 show that the optimal lag length is one.

Table 4-3: Lag Length Selection Criteria for Co-Integration

Lag	LogL	LR	FPE	AIC	SC	HQ
0	77.924	NA	7.22E-09	-4.558	-4.328	-4.482
1	210.183	214.921*	9.05E-12*	-11.261*	-9.8873*	-10.806*
2	229.442	25.277	1.47E-11	-10.903	-8.3834	-10.066

*indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwarz information criterion. HQ: Hannan-Quinn information criterion.

Source: Output of the EViews Software Student Version 9.5

The F-bound tests was used in determining the dynamic relationships among the variables with one lag based on the result of the optimal lag (Table 4-3). The results of the test (Table 4-4) reveal that the F-statistic for the LogRE model is higher than the upper bound value at all levels of significance meaning that the null hypothesis of no co-integration among the variables cannot be accepted. The findings show an F-statistic value of 5.998 for LogRE that is higher than the lower and upper bound leading to rejection of the null hypothesis of no long run relationship. This means that there exists a long-run relationship among the variables. The computed F-statistic for the rest of the models were less than the upper and lower bound at all levels of significance except for LogFD that was within 5% level of significance. The other model that indicated co-integration and thus long-run dynamic relationship was LogFD. The findings are similar to that found in existing literature (Shahbaz *et al.*, 2015; Marques *et al.*, 2014). Although the results led to two vectors of dynamic relationship, the achievement of the objectives of the current study require the use of the first model (LogRE).

Table 4-4: Dynamic Relationship Results (Bound F-Statistic)

		I(0) - I(1) bound at (%)			
Model	**F-Statistic**	**10**	**5**	**1**	**Decision**
LogRE	5.9979[a]	2.45 -3.52	2.86 -4.01	3.74 – 5.06	Co-Integrated
LogY	1.9735				No co-Integration
LogEx	1.61				No co-integration
LogFD	3.7740[b]				Co-integration
LogCO2	2.288				No co-integration

Critical value bound with an unrestricted intercept and no trend (k=4, T=33) as computed by Narayan (2005). [a,b] as defined in

Table ***4-2***. RE: Renewable energy generation. Y: GDP. EX: Export value, FD: finance development. CO2: Carbon Dioxide Emissions.

Source: Output of the EViews Software Student Version 9.5

The estimation of the long-run relationship was carried out with LOGRE being the dependent variable. The results of long-run relationship in Table 4-5 were sensitive to the selected lag length in the model. The regressors were treated as long-run forcing variables as the coefficients were significant for LogY and LogCO2 at 5% level of significance in Table 4-5.

Table 4-5:Estimated Long-run Coefficients using ARDL model. Dependent Variable LOGRE

Variable	Coefficient	Std. Error	t-Statistic	P-Value
LOGYt	3.424501[a]	0.760404	4.503531	0.0002
LOGFDt	0.439321	0.826836	0.531329	0.6003
LOGEXt	-0.35226	0.511637	-0.6885	0.498
LOGCO2t	-1.060016[b]	0.410874	-2.57991	0.0167

[a,b] as defined in

Table ***4-2***. *Source: Output of the EViews Software Student Version 9.5*

In order to confirm existence of the long-run relationship, the Error Correction Term was used. From Table 4-6, ECT_{t-1} is significant and having a negative sign confirming the existence of a long-run equilibrium relationship among variables as consistent with other studies (Narayan and Smyth, 2005). The value of ECT_{t-1} indicates adjustment speed back to equilibrium in the dynamic model in case of any disequilibrium (Pesaran and Pesaran, 2009). In this study, the value of ECT_{t-1} was found to have a negative sign and significant (-0.7468, 0.0000). The coefficient was highly significant at the 1% level of significance with the correct sign reinforcing the existence of long-run relationship among variables. The findings imply a high speed of adjustment from a disequilibrium situation as 74.68% of disequilibrium from the previous year can be transformed back to long-run equilibrium in the current year.

Table 4-6: The Analysis of ECM and Short-run relationship using ARDL model. Dependent Variable DLOGRE

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**P-Value**
C	-34.3422	5.783405	-5.93806	0
D(LOGY)t	4.410293	1.37104	3.21675	0.0038
D(LOGFD)t	0.256954	0.354945	0.723926	0.4764
D(LOGEX)t	-0.00511	0.419095	-0.01219	0.9904
D(LOGCO2)t	0.099435	0.23216	0.428306	0.6724
$ECT_{(t-1)}$	-0.74678	0.12586	-5.93337	0

[a,b] as defined in

Table ***4-2***. *Source: Output of the EViews Software Student Version 9.5*

The results of the model were used in simultaneous running of the ARDL model in obtaining the long- and short-run elasticities. The results confirmed that there is a positive and significant relationship between GDP and RE generation excluding hydro sources in the long-run. The relationship is elastic and the positive coefficients (3.424 in the long-run and 4.41 in the short-run) implies that an increase in GDP variable by 1 percent would lead to an increase by 3.424 percent in the dependent variable RE in the long-run and by 4.41 percent in the short-run. The result is consistent with recent studies where increase in GDP led to an increase in RE (Lin *et al.,* 2016; Marques *et al.*, 2014; Rafiq *et al.*, 2014).

There is also a negative and significant inelastic relationship between carbon emission and RE generation in the long-run at 5% level of significance. It implies that an increase in RE generation by 1 percent would lead to a decrease by 1.060 percent in carbon emissions in the long-run. In the short-run the carbon emission is positive but remains inelastic in the RE generation.

In both short and long-run, financial development (FD) has a positive response and is inelastic to RE. One percent increase in RE is due to increase financial development by 0.44 percent in the long-run. In the short-run one percent increase in RE is likely to in attract a 0.26 percent increase in financial development. The result is consisted with other findings where FD promotes RE generation (Lin *et al.,* 2016; Pfeiffer and Mulder, 2013; Brunnshweiler, 2010).

Export of good and services had a negative response and is elastic to RE in the short and long-run. One percent increase in RE would lead to 0.352 percent and 0.005 percent in the long and short-run respectively drop in export of good and services value. Figure 4-1 shows a representation of the results of the short and long-run elasticity test from Table 4-5 and Table 4-6.

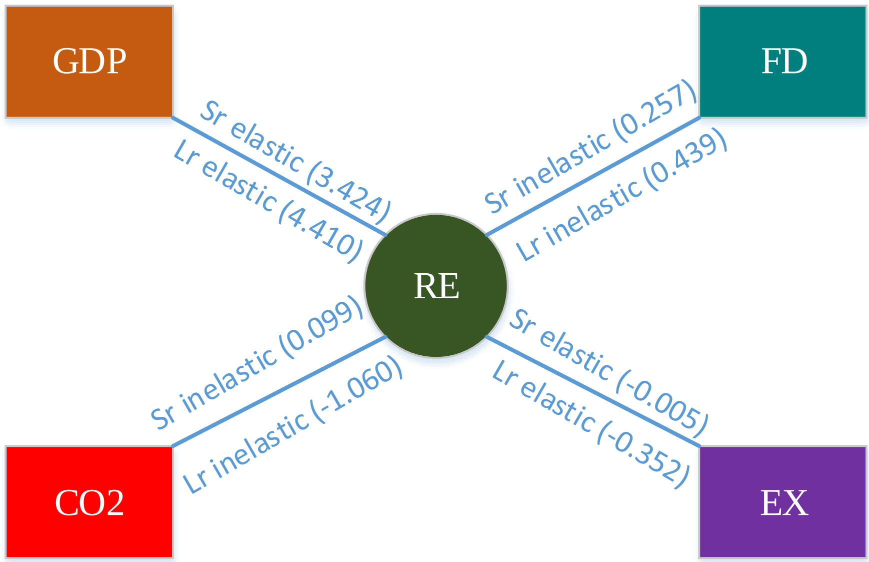
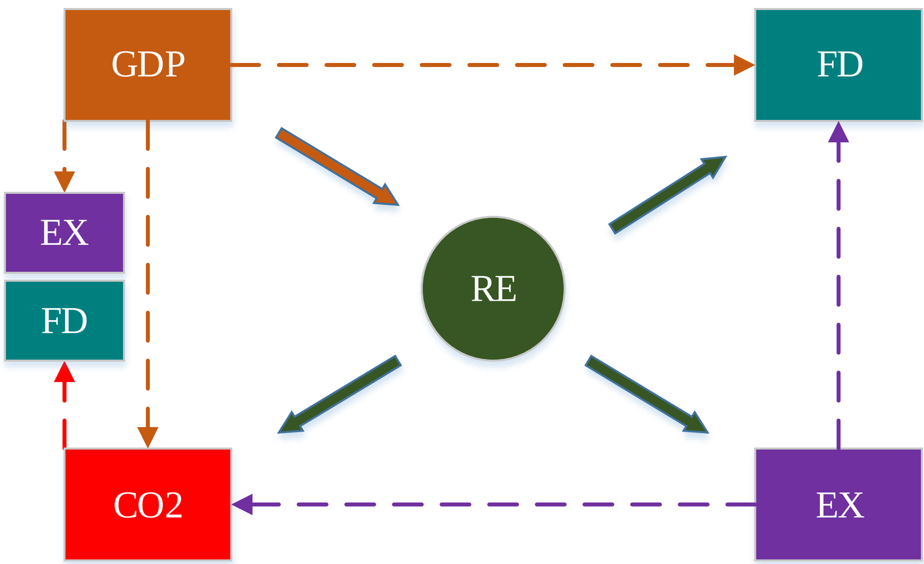


Figure 4-1 Short- and Long-run Elasticities

Sr = short-run elasticity, Lr = Long-run elasticity

In determining the causal relationship among the variables, the study proceeded to carry out VECM Granger causality test. The test would reveal the direction of causality among the variables that would help in informing policies affecting electricity generation from renewable sources other than hydro as well as policies affecting GDP, FD, Export value, and carbon emissions. The findings are critical in monitoring the country's economic growth towards the development of renewable electricity.



The solid arrows represent long-run unidirectional causal relationships and the dashed arrows represent short-run unidirectional causal relationship.

Figure 4-2: Short-run and Long-run causality

In the analysis of short and long-run causality that is represented in Figure 4-2, the results discovered existence of a long-run unidirectional relationship between GDP and RE generation as GDP was found to granger cause RE generation. The results were consistent with those found in other studies economic growth leads to increased investment in renewable energy (Youssef, 2015; Caraini *et al.*, 2015). However, there are other studies that provided contrary findings (Marques *et al.*, 2016; Menegaki, 2011). The results also show that RE generation excluding hydro granger causes Financial Development in the long-run. An increase in renewable energy investment would lead to increased domestic credit to private sector. RE generation from non-hydro sources was also found to granger cause Export Value and Carbon emission both in the long-run. The effect on export of good and services value was positive while that on carbon emission was negative as witnessed in the elasticities. The study by Kivyiro and Arminen (2014) on sub-Saharan Africa also revealed that GDP granger causes CO2 emissions.

There were also results that demonstrated unidirectional short-run causality for all models. GDP was found to granger cause CO2, FD and EX in the short-run. The causal relation was unidirectional. Export value was also seen to granger cause carbon emission and financial development in the short-run both through unidirectional relation. This means that increased production of high value export affected carbon emissions and domestic borrowing by the private sector. In addition, the study detected that Carbon emission granger-cause financial development.

The stability of the ARDL was tested based on error correction model (ECM) using cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) as a stability testing technique (Brown *et al.*, 1975). CUSUM and CUSUMSQ plots in Figure 4-3 and Figure 4-4 respectively show that all the residuals were randomly distributed around the fitted line. The plots remain within critical bounds at 5 percent level of significance confirming the structural stability of the ARDL model. The results coincide with existing literature (Sbia *et al.*, 2014; Islam *et al.*, 2013; Ghosh, 2009; Squalli, 2007; Narayan and Smyth, 2005).

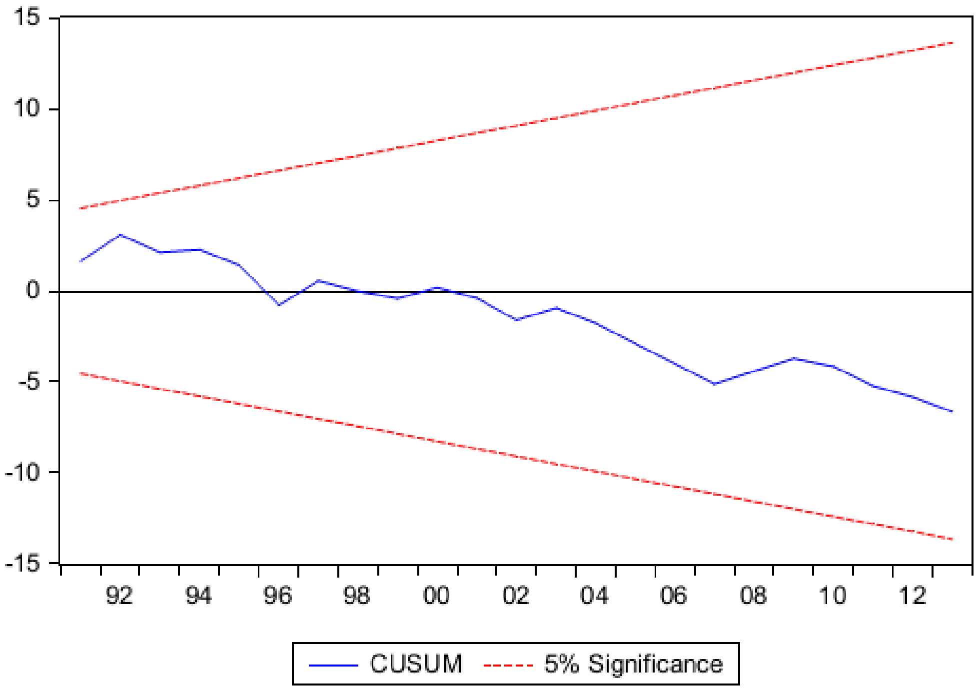


Figure 4-3: Plot of Cumulative Sum of Recursive Residuals for LogRE model

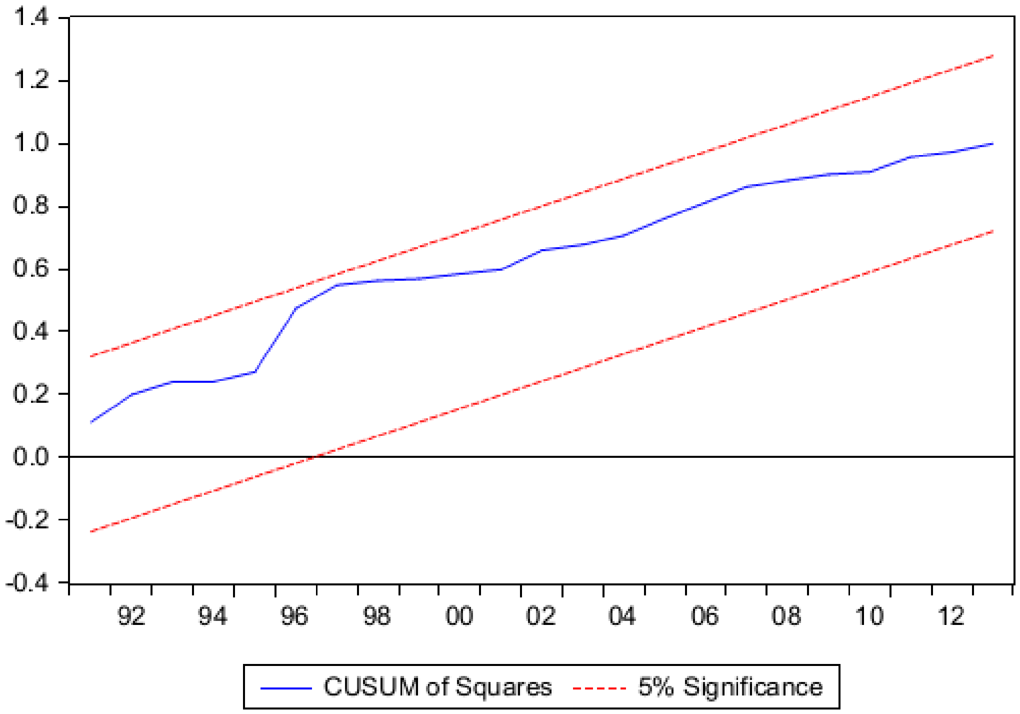


Figure 4-4: Plot of Cumulative Sum of Squares of Recursive Residuals for LogRE model

Table 4-7: Variance Decomposition of LogRE

Period	S.E.	LOGRE	LOGY	LOGFD	LOGCO2	LOGEX
1	0.221425	100.0000	0.000000	0.000000	0.000000	0.000000

2	0.259887	78.27790	14.65773	0.593508	6.002826	0.468029
3	0.325431	49.94985	39.88416	0.999345	8.447546	0.719097
4	0.371429	39.56082	49.95778	0.771215	8.199834	1.510347
5	0.414484	32.49937	55.51132	1.269088	7.374720	3.345495
6	0.454884	27.10597	59.85086	2.237744	6.234869	4.570562
7	0.498891	23.12342	63.34620	3.358340	5.309931	4.862113
8	0.541178	19.77616	65.73961	4.420004	4.877538	5.186687
9	0.573131	17.66859	66.98345	4.992345	4.777915	5.577706
10	0.595295	16.43889	67.46359	5.394175	5.010663	5.692688

Source: Output of the Eviews Software Student Version 9.5

The use of Variance Decomposition (VD) highlights the impact of the predicted error variance as contributed by each variable (Shahbaz *et al.,* 2015). The results of VD as presented in Table 4-7 using Cholesky ordering over 10 horizontal periods show the impact of other variables on electricity generation from RE sources excluding hydro. The findings show that RE generation excluding hydro is largely accounted for by GDP at 67.46% followed by itself at 16.43% then by Export (5.69%), Financial Development (5.39%), and lastly CO2 emissions (5.0%). The findings show that the identified variables play a significant role in influencing generation of electricity from RE sources excluding hydro. It also shows that the growth of GDP is the most influential determinant influencing such developments. The information matches what the country has been striving to do over the past few years as it strives to improve its economy to that of middle-income economies under the Vision 2030. The reduction of the proportion of carbon emissions per capita overtime indicates the impact such developments have had on carbon emissions.

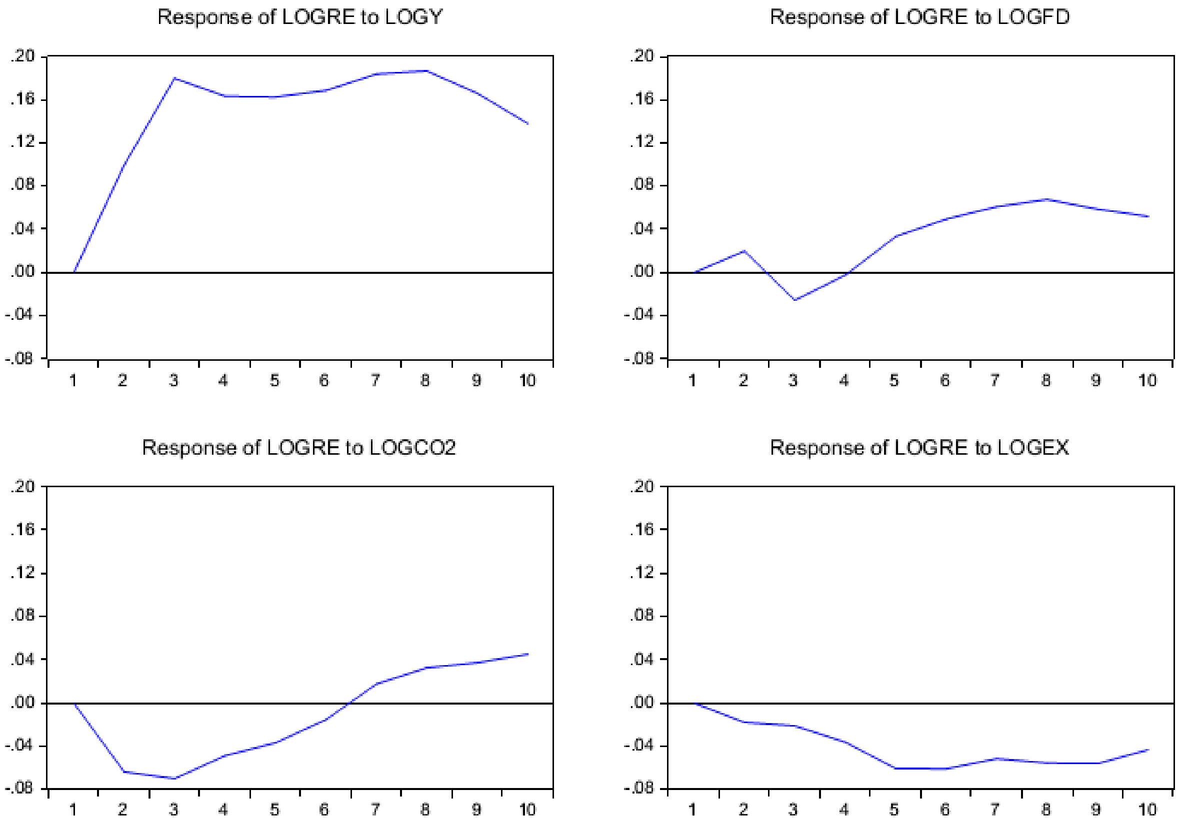


Figure 4-5: Impulse Response Function Results

Figure 4-5 shows line plots of the Impulse Response Function (IRF) between RE and its determinants. The computation is done by fixing an initial shock size equivalent to the time-series average of the stochastic volatility level for each series over the sample period. The findings are significant as they illustrate the reaction of RE generation to one standard deviation shock in the model. As illustrated in the findings, GDP has the most effective power of one standard deviation shock on RE generation from non-hydro sources. The findings show the primary role played by GDP growth towards the development of RE generation from sources other than hydro. It is also essential to note that RE generation excluding hydro also responds positively due to shocks in FD especially after the third-time horizon as well as CO2 after the sixth-time horizon. Value of export of good and services seems to have a depleting effect on RE generation with the response stagnating at negative values after the fifth-time horizon.

CHAPTER 5
CONCLUSIONS AND POLICY IMPLICATIONS

The paper examines the relationship between Renewable Energy generation excluding hydro in kilowatt-hours and the economy in terms of GDP (constant 2010 USD). It follows a multivariate econometric technique incorporating value of export of good and services (constant 2010 USD), carbon emission (kilotons), and financial development (Domestic credit to private sector as a percentage of the GDP) as the additional variables. The use of augmented C-D production function and F-bound test were utilized in analyzing dynamic relationship and elasticities respectively among the mentioned variables. In determining causal relationship, the study used ARDL time-series approach between the variables. The data set was from 1980 to 2014.

In this study, descriptive statistics and relational matrix were used to analyze the quality of data. The unit root test was then applied before determining integrating properties of the variables. The cointegration relationship that was tested using the ARDL bounds testing approach revealed that renewable generation excluding hydro, economic growth, financial development, export of goods and services, and carbon emissions are cointegrated for the long-run relationship. As a result of the findings, the research investigated the short and long-run elasticities as well as causal relationship among the variables.

The results of the elasticities and causal relations signified the importance of GDP (Y) in influencing increased investment in renewable energy generation excluding hydro (RE) as illustrated by both short and long run relationship. The causal relation indicated by unidirectional relationship from GDP to RE implies that economic growth stimulates investment in RE generation excluding hydro. Renewable energy investment is also seen to reduce carbon emissions in the long run given the negative response. Financial development (FD) is also another key feature as it has positive response for RE generation excluding hydro in both short and long-run. This implies that increased domestic credit to the private sector creates significant investment in RE generation excluding hydro. Export value was also seen to have influence on RE generation excluding hydro with a unidirectional causal relationship running from RE to Export value. There was also feedback effect between variables. In another related development, export of goods and services was seen to have an influence on carbon emissions as well as on financial development. The same inference was seen between GDP having an influence on financial development, carbon emission and export of goods and services. Carbon emissions was also seen to Granger-cause financial development.

The key distinguishing feature between this study and the past studies on Kenya is that it uses renewable energy generation excluding hydro as a key variable. Previous study on Kenya have focused on the relationship between electricity consumption and economic growth in developing policy implications. This research considers the growing energy demand in Kenya and challenges regarding environment and sustainability. It also looks at the growing potential in renewable energy generation from other sources other than hydro that is affected by the changing climate. Past studies have also provided conflicting results as some used multi-countries to draw conclusions for Kenya (Karanfil and Li, 2005; Apergis and Payne, 2011).

Studies that focused on Kenya and multi-country studies that included Kenya also used different econometric techniques with some using multivariate while others using bivariate approaches. Considering that there are studies that have used renewable energy consumption as a dependent variable, the study sought to investigate the relationship between renewable energy generation in Kenya on the economy. Given that it only focuses on Kenya, it avoids possible problems encountered in multi-country studies. The multivariate approach ensured that the study was able to uncover the level of impact of each macroeconomic variable on renewable energy generation excluding hydro in Kenya.

Following to this, the study found out that in both the short-run and in the long-run one percent rise in the Kenya's economic growth would lead to 3.424% and 4.410% increase in renewable energy electricity generation excluding hydro respectively. The study also found out that 1.060% decrease in carbon emission was as a result of 1% increase in renewable energy electricity generation excluding hydro in the long-run. Additionally, a 0.352% decrease in the value of export of goods and services was observed as a result any 1% increase in renewable energy generation excluding hydro. This is explained by the decrease in the cost of power leading to decrease in the cost of exports increasing their competition in the global market. Renewable energy electricity generation excluding hydro was also seen to have a positive influence on financial development. In this instance, it was discovered that any increase in renewable energy generation excluding hydro would increase financial development both in the short-run and in the long-run by 0.257% and 0.439% respectively.

The error correction model for this study established a high speed of adjustment prospects towards long-run equilibrium in response to shocks with regards to influence of renewable energy electricity generation excluding hydro to export of goods and services, financial development, carbon emission and economic growth. The study attributed the quick adjustment to the speed with which renewable energy sources excluding hydro come online. The situation makes it possible to improve exports, carbon emissions and financial development. Kenya has recently invested heavily in geothermal power whose effect has been felt in the economy by the reduction in the cost and increase in reliability of power. The development has seen electrification rates improve from 23% in 2010 to 36% in 2014 and 50% by 2016 driven mainly by increased generation capacity and the rapid rural electrification program.

The findings of the study show that economic growth granger causes renewable energy generation excluding hydro. Similar findings were discovered in previous research for Hungary (Caraini *et al.*, 2015) and Tunisia (Jebli and Youssef, 2015). The implications of the findings to the Kenyan economy is that economic growth will continue to drive electricity demand leading to the investment in renewable energy electricity generation excluding hydro. This is because growth in the economy will continue to require more energy and an efficient electricity supply will mean competitive industrial output for export. In addition, if investment in renewable electricity generation excluding hydro continues in the long-run, it will have tremendous effects on the country's macroeconomic development by reducing carbon emissions, reducing the cost of producing export goods, and enhance financial development.

In the short-run there is unidirectional causality running to financial development from economic growth, export of goods and services, and carbon emissions. This shows the influence the variables have on domestic credit to private investors. There is also short-run unidirectional causality running from export to carbon emissions and financial development. This shows that export of goods and services have an influence on carbon emissions and financial development of the country. There is another short-run unidirectional causal relationship running from carbon emissions to financial development. This shows that domestic credit to private sector is also dependent on carbon emissions.

The policy recommendations include radically reforming the subsidies systems allowing more investments into renewable energy generation excluding hydro. This includes clear policy frameworks for development of on and off-grid renewable electrical energy solutions that include hybrid systems, mini-grids and home systems that will improve financial development and reduce carbon emissions. This will include policies guiding the pay-as-you-go program that has characterized the deployment of most off-grid solar systems as well as systems guiding rooftop solar use in most commercial and industrial establishments. There should be a policy framework extending to all renewable sources of electricity in order to spur investment that will attract private investment in the sector.

The unidirectional causality running from economic growth to renewable energy electricity generation implies that the findings supports the conservation hypothesis whereby policy initiatives aimed at conserving energy may have less or no impact on economic growth. For this reason, the country should ensure the regulatory framework guiding energy efficiency is followed through. Given that renewable energy use has little or no impact to the economy, the government should encourage the use of renewable energy and energy efficiency by reinforcing actual implementation of energy efficiency measures and evaluating the current regulatory framework (the Energy Management Regulation of 2012) that requires audits to be conducted in industrial and commercial establishments after every three years. For instance, recommendations on energy use should include development of renewable energy options such as rooftop solar and other renewable energy sources that are applicable to a given establishment such as biogas electrical plants for agro-processing plants.

Another policy recommendation entails those aimed at improving export of goods and services. This is a sector that requires increased industrialization and the use of renewable energy to reduce emissions and encourage domestic credit to private sector. This is because renewable energy generation reduces the value of exports due to cheaper cost of power. The export of goods and services also affects carbon emission and financial development. There should be an elaborate strategy that would ensure energy costs relating to the export industrial zone reduces through the use of renewable energy that will attract more private-sector involvement and reduce carbon emissions. For instance, export industries can be located near renewable energy sources such as geothermal or near ports to reduce carbon emission during transport of merchandise.

There should also be an elaborate strategy highlighting the advantages of renewable energy technology for industrial, domestic, and commercial use in the country. Considering that the biggest impediment is capacity to install and operate the projects, Kenya should also look into developing renewable energy projects and developing capacity for its own consumption as well as export to the region. Moreover, recommendations for capacity building and renewable energy projects should aim at mapping and utilizing the renewable energy sources such as wind, solar, biomass/biogas, and geothermal.

Financial constrains have affected the development of renewable energy resources in the country. For instance, in 2013, Kenya launched an ambitious plan to improve its power capacity by an additional 5,000 MW out of which 1,900 MW would be from geothermal, 635 MW from wind, 794 MW from hydropower, and 44 MW from biomass. By the end of 2015, the country had only managed an additional 586 MW. Some of the projects like the Kinangop wind park fell as a result of inadequate funds and lack of community engagement. On the other hand, the Turkana wind project has delayed due to the inadequate electricity transmission infrastructure as well as community problems. There is need to develop policies aimed at guiding project identification and implementation to avoid similar circumstances in future.

The new Draft National Energy and Petroleum Bill 2015 has mentioned about new targets with regards to implementation of renewable. There is need to develop targets that reflect the renewable energy potential for the country. This will lead to more investment into renewable energy leading to reduced carbon emission from electricity generation and reduction in export value increasing competitiveness in the global market hence promoting financial development.

For future research, it will be essential to include both renewable and non-renewable consumption, trade openness (including both exports and imports) and carbon emissions as well as index of globalization in order to provide a comprehensive impact of economic growth on renewable energy generation.

REFERENCES

Acaravci, A. (2010). the Causal Relationship Between Electricity Consumption and Gdp in Turkey: Evidence From Ardl Bounds Testing Approach. *Ekonomska Istrazivanja-Economic Research*, *23*(2), 34–43.

Akarca, A., & Long, T. V. I. (1980). Relationship between energy and GNP: a reexamination. *Journal of Energy and Development*, *5*(2), 326–331. https://doi.org/10.2307/24806899

Al-Mulali, U., Fereidouni, H. G., Lee, J. Y., & Sab, C. N. B. C. (2013). Examining the bi-directional long run relationship between renewable energy consumption and GDP growth. *Renewable and Sustainable Energy Reviews*, *22*, 209–222. https://doi.org/10.1016/j.rser.2013.02.005

Alexander Roehrl. (2009). *Energy Indicators for Sustainable Development*. *Energy*.

Alshehry, A. S., & Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *41*, 237–247.

Apergis, N., & Payne, J. (2011). A dynamic panel study of economic development and the electricity consumption-growth nexus. *Energy Economics*, *33*(5), 770–781.

Apergis, N., & Payne, J. E. (2012). Renewable and non-renewable energy consumption–growth nexus: evidence from a panel error correction model. *Energy Economics*, *34*, 733–738.

Apple, J., Vicente, R., Yarberry, A., Lohse, N., Mills, E., Jacobson, A., & Poppendieck, D. (2010). Characterization of particulate matter size distributions and indoor concentrations from kerosene and diesel lamps. *Indoor Air*, *20*(5), 399–411. https://doi.org/10.1111/j.1600-0668.2010.00664.x

Asafu-Adjaye, J. (1999). The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Economics*, *22*(6), 615–625.

Asif, M., & Muneer, T. (2007). Energy supply, its demand and security issues for developed and emerging economies. *Renewable & Sustainable Energy Reviews*, *11*(7), 1388–1413. https://doi.org/10.1016/j.rser.2005.12.004

Ben Jebli, M., & Ben Youssef, S. (2015). The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. *Renewable and Sustainable Energy Reviews*, *47*, 173–185. https://doi.org/10.1016/j.rser.2015.02.049

Bloch, H., Rafiq, S., & Salim, R. (2015). Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution. *Economic Modelling*, *44*, 104–115. https://doi.org/10.1016/j.econmod.2014.09.017

Caraiani, C., Lungu, C. I., & Dascalu, C. (2015). Energy consumption and GDP causality: A three-step analysis for emerging European countries. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2014.12.017

Cerdeira Bento, J. P., & Moutinho, V. (2016). CO2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2015.10.151

Chandran, V., Sharma, S., & Madhavan, K. (2010). Electricity consumption–growth nexus: the case of Malaysia. *Energy Policy*, *1*(38), 606–612.

Ciarreta, A., & Zarraga, A. (2007). *Electricity Consumption and Economic Growth*. *WP* (Vol. 30).

Ciarreta, A., & Zarraga, A. (2010). Economic growth-electricity consumption causality in 12 European countries: A dynamic panel data approach. *Energy Policy*, *38*(7), 3790–3796. https://doi.org/10.1016/j.enpol.2010.02.058

Demetriades, P., & Hussein, K. A. (1996). Does Financial Development Cause Economic Growth. *Journal of Development Economics*, *51*, 387–411. https://doi.org/http://dx.doi.org/10.1016/S0304-3878(96)00421-X

Dhillon, R. S., & von Wuehlisch, G. (2013). Mitigation of global warming through renewable biomass. *Biomass and Bioenergy*. https://doi.org/10.1016/j.biombioe.2012.11.005

Dogan, E. (2016). Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data. *Renewable Energy*, *99*, 1126–1136. https://doi.org/10.1016/j.renene.2016.07.078

Ghali, K. H., & El-Sakka, M. I. T. (2004). Energy use and output growth in Canada: A multivariate cointegration analysis. *Energy Economics*, *26*(2), 225–238. https://doi.org/10.1016/S0140-9883(03)00056-2

Government of Kenya. (2011). *Updated Least Cost Power Development Plan. Study Period 2011-2031*.

Government of Kenya. (2015). Power Sector Medium Term Plan 2015-2020, (June).

Granger, C. W. J. (1988). Causality, cointegration, and control. *Journal of Economic Dynamics and Control*, *12*(2–3), 551–559. https://doi.org/10.1016/0165-1889(88)90055-3

Hamdi, H., Sbia, R., & Shahbaz, M. (2014). The nexus between electricity consumption and economic growth in Bahrain. *Economic Modelling*, *38*(4), 227–237. https://doi.org/10.1016/j.econmod.2013.12.012

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences*, *109*(37), E2415–E2423. https://doi.org/10.1073/pnas.1205276109

Husaini, D. H., & Lean, H. H. (2015). Does electricity drive the development of manufacturing sector in Malaysia? *Frontiers in Energy Research, 3*(APR). https://doi.org/10.3389/fenrg.2015.00018

IEA. (2016). *International Energy Outlook 2016*. *International Energy Outlook 2016* (Vol. 0484(2016)). https://doi.org/www.eia.gov/forecasts/ieo/pdf/0484(2016).pdf

IRENA. (2015). *Africa 2030: Roadmap for a Renewable Energy Future*. Abu Dhabi. Retrieved from www.irena.org/remap

IRENA. (2016). *Solar PV in Africa: Costs and Markets*. Abu Dhabi.

Islam, F., Shahbaz, M., Alam, M. M. M., Ahmed, A. U., & Alam, M. M. M. (2013). Financial development and energy consumption nexus in Malaysia: A multivariate time series analysis. *Economic Modelling*, *30*(28403), 29. https://doi.org/10.1016/j.econmod.2012.09.033

Jamil, F., & Ahmad, E. (2010). The relationship between electricity consumption, electricity prices and GDP in Pakistan. *Energy Policy*, *38*(10), 6016–6025. https://doi.org/10.1016/j.enpol.2010.05.057

Kaygusuz, K. (2012). Energy for sustainable development: A case of developing countries. *Renewable & Sustainable Energy Reviews, 16*(2), 1116–1126. https://doi.org/DOI

10.1016/j.rser.2011.11.013

Khatun, F., & Ahamad, M. (2015). Foreign direct investment in the energy and power sector in Bangladesh: Implications for economic growth. *Renewable and Sustainable Energy Reviews*, *52*, 1369–1377.

Kivyiro, P., & Arminer, H. (2014). Carbon Dioxide Emissions, Energy Consumption, Economic Growth, and Foreign Direct Investment: Causality Analysis for Sub-Saharan Africa. *Energy*, *75*, 595–606.

Kruyt, B., van Vuuren, D., de Vries, B. J. M., & Groenenberg, H. (2009). Indicators for Energy Security. In *The Routledge Handbook of Energy Security*. https://doi.org/10.4324/9780203834602.ch15

Kumar, A., Sharma, P., & Joshi, S. (2016). Assessing the impacts of climate change on land productivity in indian crop agriculture: An evidence from panel data analysis. *Journal of Agricultural Science and Technology*, *18*(1), 1–13.

Lean, H., & Smyth, R. (2010). Multivariate Granger causality between electricity generation, and GDP in Malaysia. *Energy*, *35*, 3640–3648.

Lean, S. muhammad and hooi hooi. (2011). Does financial Development increase energy consumption? role of indutrialization and urbanization in tunisia. *MPRA*, (33194).

Mabea, G. A. (2014). Modelling Residential Electricity Demand for Kenya, *5*(4), 145–153.

Magazzino, C. (2014). Energy consumption and GDP in Italy: cointegration and causality analysis. *Environment, Development and Sustainability*, *17*(1), 137–153. https://doi.org/10.1007/s10668-014-9543-8

Meadowcroft, J. 709. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*, *42*(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z

Menegaki, A. N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics*, *33*(2), 257–263. https://doi.org/10.1016/j.eneco.2010.10.004

Menyah, K., Nazlioglu, S., & Wolde-rufael, Y. (2014). Financial development , trade openness and economic growth in African countries : New insights from a panel causality ... *Economic Modelling*, *37*(November 2015), 386–394. https://doi.org/10.1016/j.econmod.2013.11.044

Ministry of Energy. (2004). Sessional Paper No . 4 on Energy: National Energy Policy. *National Energy Policy*, (4).

Mozumder, P., & Marathe, A. (2007). Causality relationship between electricity consumption and GDP in Bangladesh. *Energy Policy*, *35*(1), 395–402. https://doi.org/10.1016/j.enpol.2005.11.033

Muok, B., Makokha, W., & Palit, D. (2015). Solar PV for Enhancing Electricity Access in Kenya : What Policies are Required? The Energy Resource Institute.

Narayan, P. K., & Smyth, R. (2009). Multivariate granger causality between electricity consumption, exports and GDP: Evidence from a panel of Middle Eastern countries. *Energy Policy*, *37*(1), 229–236. https://doi.org/10.1016/j.enpol.2008.08.020

Nnaji, A. O., & Chimelu, C. C. (2014). Effects of Diesel Powered Generator Fumes on Ambient Air Quality over Lagos Island, Nigeria. *Research Journal of Agriculture and Environmental Management*, *3*(7), 320–325.

Odhiambo, N. M. (2010). Energy consumption, prices and economic growth in three SSA countries: A comparative study. *Energy Policy*, *38*(5), 2463–2469. https://doi.org/10.1016/j.enpol.2009.12.040

Payne, J. E. (2009). On the dynamics of energy consumption and output in the US q. *Applied Energy*, *86*(4), 575–577. https://doi.org/10.1016/j.apenergy.2008.07.003

Pesaran, M. H., Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis. In *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium.* (pp. 1–31). https://doi.org/10.1017/CCOL521633230

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of long run relationships. *Journal of Applied Econometric*, *16*, 289–326. https://doi.org/10.1002/jae.616

Rafindadi, A. A., & Ozturk, I. (2016). Effects of financial development, economic growth and trade on electricity consumption: Evidence from post-Fukushima Japan. *Renewable and Sustainable Energy Reviews*, *54*, 1073–1084. https://doi.org/10.1016/j.rser.2015.10.023

Rafindadi, A. A., & Ozturk, I. (2017). Impacts of renewable energy consumption on the German economic growth: Evidence from combined cointegration test. *Renewable and Sustainable Energy Reviews*. https://doi.org/10.1016/j.rser.2016.11.093

Raza, S. A., Shahbaz, M., & Nguyen, D. K. (2015). Energy conservation policies, growth and trade performance: Evidence of feedback hypothesis in Pakistan. *Energy Policy*, *80*, 1–10. https://doi.org/10.1016/j.enpol.2015.01.011

REN21. (2016a). *EAC renewable energy and energy efficiency regional status report*.

REN21. (2016b). *Renewables 2016 Global Status Report*. Paris.

Rose, A., Stoner, R., & Pérez-arriaga, I. (2017). Prospects for grid-connected solar PV in Kenya : A systems approach. *Applied Energy*, *161*(2016), 583–590. https://doi.org/10.1016/j.apenergy.2015.07.052

Sathaye, J. L. O., Rahman, A., Christensen, J., Denton, F., Fujino, J., Heath, G., … Shmakin A. (2011). Renewable Energy in the Context of Sustainable Energy (p. 1076).

Sathaye, J., Lucon, O., Rahman, A., Christensen, J., Denton, F., Fujino, J., … Shmakin, A. (2011). Renewable Energy in the Context of Sustainable Development. In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* (pp. 707–790).

Shahbaz, M., Zeshan, M., & Afza, T. (2012). Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests. *Economic Modelling*, *29*(6), 2310–2319. https://doi.org/10.1016/j.econmod.2012.06.027

Soytas, U., & Sari, R. (2003). Energy consumption and GDP: Causality relationship in G-7 countries and emerging markets. *Energy Economics*, *25*(1), 33–37. https://doi.org/10.1016/S0140-9883(02)00009-9

Squalli, J. (2007). Electricity consumption and economic growth: Bounds and causality analysis of OPEC members. *Energy Economics*, *29*, 1192–1205.

Squalli, J., & Wilson, K. (2006). *Working Paper Series A Bounds Analysis of Electricity Consumption and Economic Growth in the GCC*. *Working Paper Series*.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, *66*(1–2), 225–250.

https://doi.org/10.1016/0304-4076(94)01616-8

Winzer, C. (2012). Conceptualizing energy security. *Energy Policy*, *46*, 36–48. https://doi.org/10.1016/j.enpol.2012.02.067

Wolde-Rufael, Y. (2006). Electricity consumption and economic growth: A time series experience for 17 African countries. *Energy Policy*, *34*(10), 1106–1114. https://doi.org/10.1016/j.enpol.2004.10.008

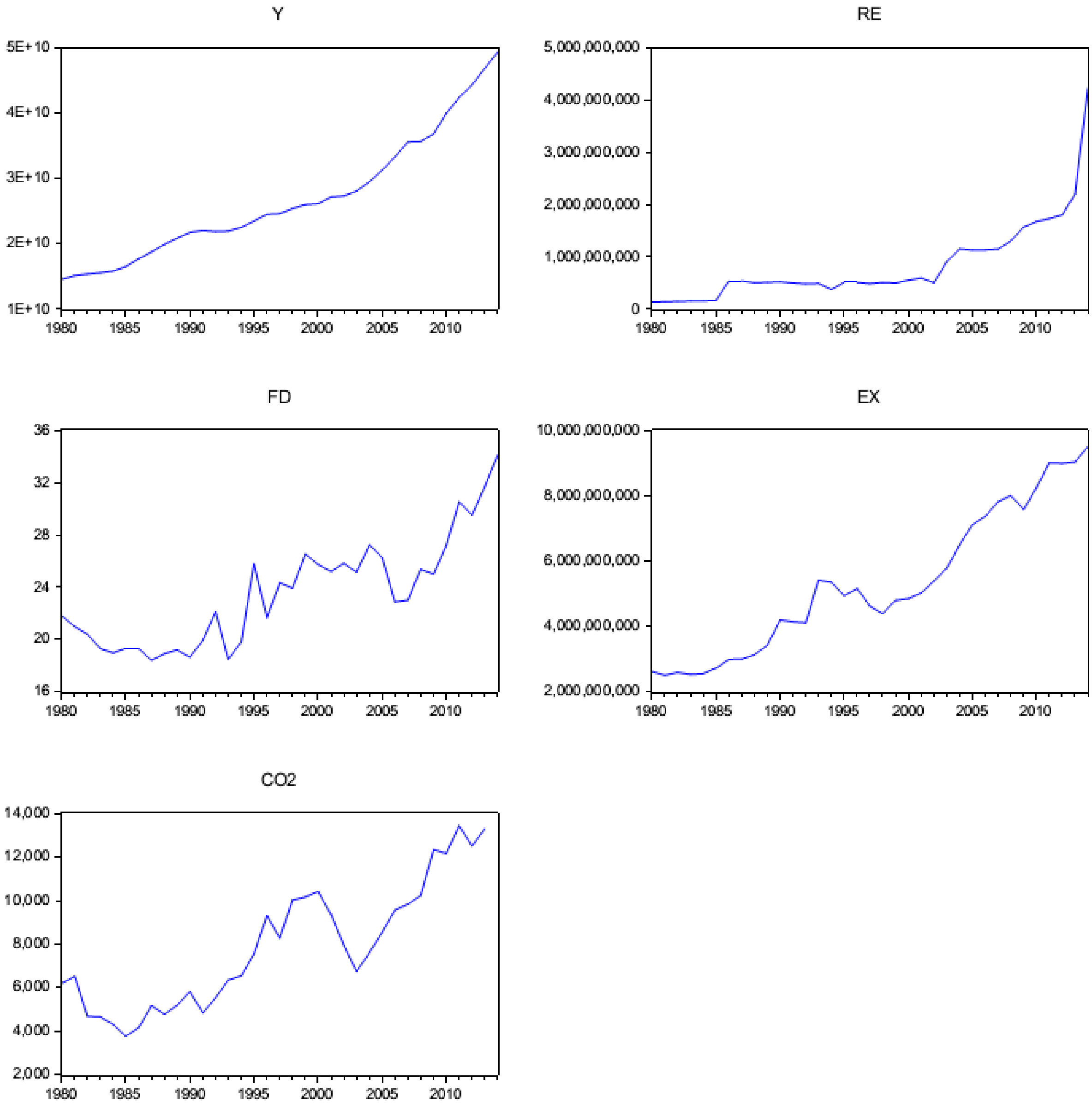
Yoo, S. H. (2006). The causal relationship between electricity consumption and economic growth in the ASEAN countries. *Energy Policy*, *34*(18), 3573–3582. https://doi.org/10.1016/j.enpol.2005.07.011

Yoo, S. H., & Kim, Y. (2006). Electricity generation and economic growth in Indonesia. *Energy*, *31*(14), 2554–2563. https://doi.org/10.1016/j.energy.2005.11.018

Yu, E., & Choi, J. Y. (1985). The causal relationship between energy and GNP: an international comparison. Journal of Energy and Development. *Journal of Energy Finance and Development*, *10*(2), 249–272.

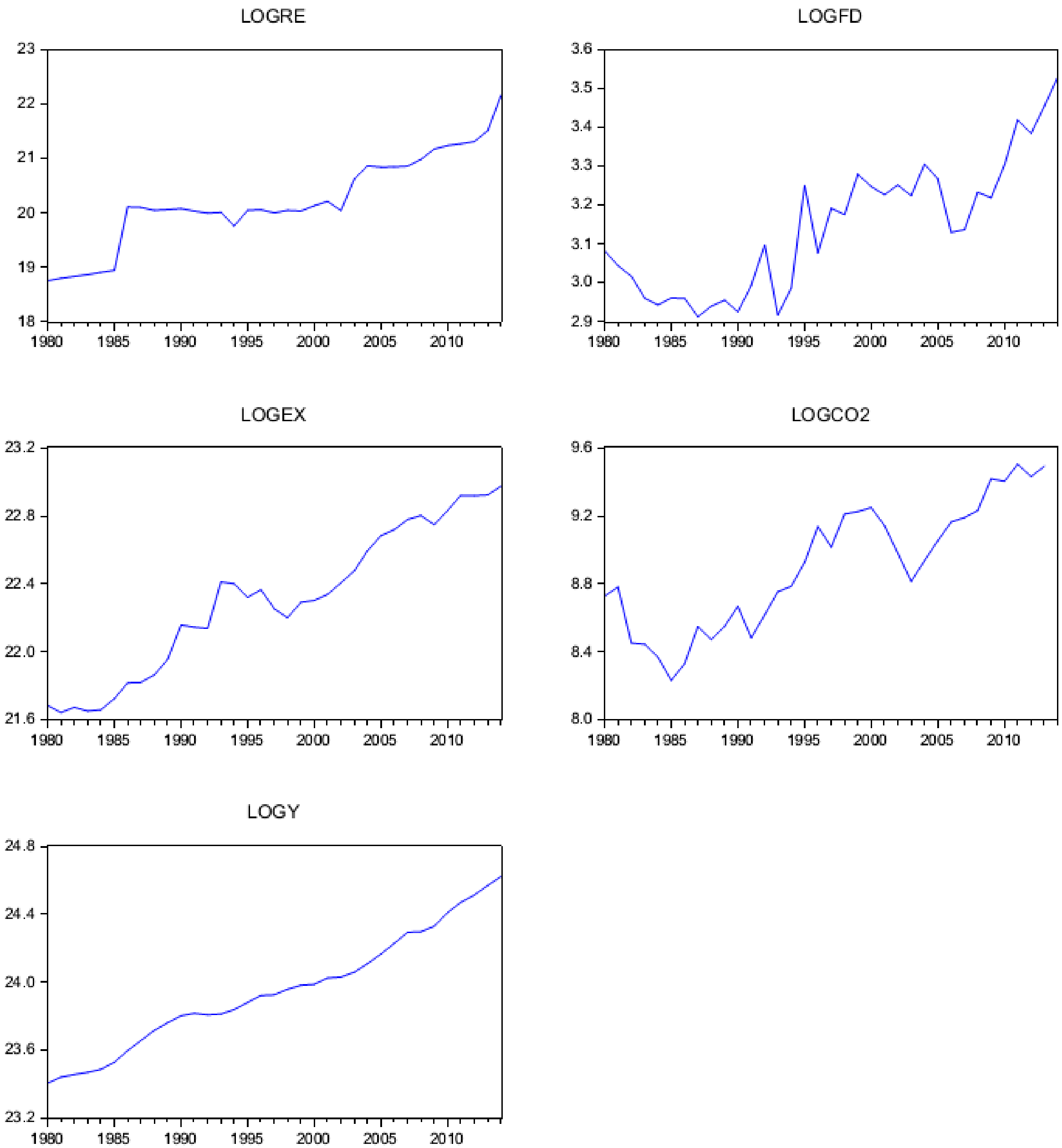
Appendixes

Data Trend



Source: Output of the Eviews Software Student Version 9.5

Trend for Log



Source: Output of the Eviews Software Student Version 9.5

Unit Root Test

Renewable Energy Variable

Augmented Dickey-Fuller Unit Root Test on D(RE,2)

Null Hypothesis: D(RE,2) has a unit root
Exogenous: None
Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.093051	0.0367
Test critical values:	1% level	-2.639210	
	5% level	-1.951687	
	10% level	-1.610579	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RE,3)
Method: Least Squares
Date: 06/24/17 Time: 12:47
Sample (adjusted): 1983 2014
Included observations: 32 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RE(-1),2)	-0.738675	0.352918	-2.093051	0.0446

R-squared	0.105233	Mean dependent var	51000000
Adjusted R-squared	0.105233	S.D. dependent var	3.56E+08
S.E. of regression	3.37E+08	Akaike info criterion	42.13694
Sum squared resid	3.51E+18	Schwarz criterion	42.18275
Log likelihood	-673.1911	Hannan-Quinn criter.	42.15213
Durbin-Watson stat	1.305493		

Source: Output of the Eviews Software Student Version 9.5

Granger Causality Test

Pairwise Granger Causality Tests

Date: 06/30/17   Time: 14:15

Sample: 1980 2014

Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.	Direction of Causality
LOGY does not Granger Cause LOGRE	34	5.22050	**0.0293**	**Y→ RE**
LOGRE does not Granger Cause LOGY		3.63912	0.0657	
LOGFD does not Granger Cause LOGRE	34	2.22816	0.1456	
LOGRE does not Granger Cause LOGFD		4.44660	**0.0431**	**RE → FD**
LOGEX does not Granger Cause LOGRE	34	1.09753	0.3029	
LOGRE does not Granger Cause LOGEX		5.93329	**0.0208**	**RE→ EX**
LOGCO2 does not Granger Cause LOGRE	33	0.09499	0.7601	
LOGRE does not Granger Cause LOGCO2		10.1012	**0.0034**	**RE → CO2**
LOGFD does not Granger Cause LOGY	34	0.03131	0.8607	
LOGY does not Granger Cause LOGFD		12.6125	**0.0012**	**Y → FD**
LOGEX does not Granger Cause LOGY	34	0.33314	0.5680	
LOGY does not Granger Cause LOGEX		5.20480	**0.0295**	**Y → EX**
LOGCO2 does not Granger Cause LOGY	33	1.88269	0.1802	
LOGY does not Granger Cause LOGCO2		9.50954	**0.0044**	**Y → CO2**
LOGEX does not Granger Cause LOGFD	34	10.8383	**0.0025**	**EX → FD**

LOGFD does not Granger Cause LOGEX		0.53113	0.4716	
LOGCO2 does not Granger Cause LOGFD	33	14.6428	**0.0006**	**CO2 → FD**
LOGFD does not Granger Cause LOGCO2		3.06795	0.0901	
LOGCO2 does not Granger Cause LOGEX	33	0.92349	0.3442	
LOGEX does not Granger Cause LOGCO2		11.4577	**0.0020**	**EX → CO2**

Source: Output of the Eviews Software Student Version 9.5