THE DYNAMIC RELATIONSHIP BETWEEN RENEWABLE ENERGY INVESTMENT, RENEWABLE ENERGY CONSUMPTION AND ECONOMIC GROWTH IN KENYA

BY

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DECLARATION

I hereby declare that this thesis is entirely my own original work and to the best of my knowledge; it has not been submitted by anyone else in any other institution of higher learning.

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Declaration by Supervisors

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Great appreciation to my friends; Nicholas Ogajo from the department of housing and Faith Magut of KEMRI CDC for the moral support throughout the journey of developing this masterpiece that I believe is a must read for serious energy economists and policy makers of this century.

DEDICATION

This thesis is dedicated to my entire family (The Namusasi Masibayi family) for their moral support in the development of this masterpiece.

ABSTRACT

Despite Kenya having a massive generating capacity of renewable energy, its supply and consumption levels remain significantly low. The low supply levels have driven the costs of production upwards leading to high energy prices thereby slowing economic activity occasioned by inadequate investments in the energy sector. However, there are conflicting results on the link existing between economic growth and renewable energy in the developing world; while some established positive association between renewable energies and economic growth, some suggested that no causality existed between the variables. The main objective of this study was to determine the dynamic relationship between renewable energy investment, renewable energy consumption and economic growth in Kenya. Specific objectives of this study were to; establish the effect of renewable energy investment on economic growth in Kenya, establish the effect of renewable energy consumption on economic growth in Kenya and to establish the effect of renewable energy investment on renewable energy consumption in Kenya. This study was anchored on the Neo-Classical Solow-Swan growth model. This study adopted the correlational research design and used time series data from *1980* to *2017* to determine the nature of the existing linkages. Vector Error Correction Model results showed that a unit increase in total renewable energy consumption led to a gross domestic product rise by 0.013340 million dollars in the second year; a unit increase in total renewable energy investment led to an increase in gross domestic product by 0.00209 million dollars in the second year. Also, a unit increase in renewable energy investment led to an increase in renewable energy consumption by 0.045097 million kilowatts in the third year; implying that in the short run, renewable energy investment and renewable energy consumption have a negative impact on gross domestic product but the returns on investments are realized from the second year onwards after the initial investments are recouped; hence the positive association in the long run as revealed by the granger and cointegration test results that established a feedback kind of relationship amongst renewable energy investment, renewable energy consumption and economic growth. Therefore, investment in modern energy generation and supply technologies and demonopolisation of the generation and supply of renewable energies to encourage private investments are recommended as the necessary measures to increase the level of renewable energy consumption. Interventions such as tax exemptions on renewable energy equipment may encourage more uptake and consumption of renewable energies. This study may assist the government in the formulation of sustainable energy policies.

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ACRONYMS AND ABBREVIATIONS

ADF	- Augmented Dickey Fueller
ARDL	-Auto Regressive Distributive Lag
BG	- Breuch Godfrey Serial Correlation Test
ECT	- Error Correction Term
EIA	-Energy Information Administration
EPRA	-Energy and Petroleum Regulatory Authority
ERC	-Energy Regulatory Commission
FDI	- Foreign Direct Investment
GDP	- Gross Domestic Product
HEP	-Hydroelectric Power
IEA	- Institute of Economic Affairs
ICT	-Information and Telecommunications Technology
LDC	- Less Developed Countries
MDG	- Millennium Development Goals
OECD	- Organization for Economic Co-operation and Development
OLS	- Ordinary Least Squares
SDG	-Sustainable Development Goal.
TRE	-Total Renewable Energy
TREC	-Total Renewable Energy Consumption
TREI	- Total Renewable Energy Investment
USA	- United States of America
VAR	- Vector Auto Regression

VECM - Vector Error Correction Model

USD - US Dollars

VIF -Variance Inflation Factor

WDI -World Development Indicators

OPERATIONAL DEFINITION OF TERMS

Renewable Energy consumption	-Refers to the use of renewable energy sources such as Hydroelectric power, wind energy, nuclear energy, solar and geothermal energy in the production processes
Renewable energy investment	-Refers to the maximum net generating capacity of power plants expressed in monetary terms. It's the renewable energy installed capacity expressed in monetary terms.
Economic growth	-Refers to the change in national output from all sectors in an economy. In this study, economic growth shall be used interchangeably with gross domestic product.
Gross Domestic Product	-This is the sum total of the value of all products produced in Kenya's geographic borders over a period of one year.
Correlation	-It's a statistical technique that shows how pairs of variables are associated. In this case, the relationship between renewable energies consumed and gross domestic product.
Renewable energy	-These are the inexhaustible energy forms, in this case, hydro-power, solar and geothermal energy and wind energy. For purposes of this study, the mention of renewable energy refers to both renewable energy investments and renewable energy consumption.
Renewable energies	-Renewable energy investments and renewable energy consumption.

Energy poverty	-Access to inadequate supply of energy
Decarbonisation	-Getting rid of excess carbon (iv) oxide emissions in the atmosphere.

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CHAPTER ONE

INTRODUCTION.

1.1. Background of the Study

According to World Bank (2014), energy consumption refers to the usage of raw energy before its transformation. The Institute of Economic Affairs statistics show that as at 2013, the total global energy consumption stood at 5.67×10^{2} Megawatts(MW); which saw the figure grow by about 10% in 2014, the greater percentage of this being from the nonrenewable energy sources. This serves to emphasize the crucial role played by energy in economic development. It is thought to be the key driver of economic development and industrialization. Furthermore, Singh, Nyuur and Richmond (2019) alludes that energy is pivotal in accelerating economic activities in economies; both developed and developing, since time immemorial. It castigates that nearly 80% of the global energy consumption is majorly from the fossil fuels that leads to a mismatch in demand and supply given the high depletion rates of the nonrenewable ores in the long run. The overreliance on the depletible energy sources poses a risk to industrial processes that require huge amounts of energy to run, now and in the foreseeable future. Energy is the power that drives all major production activities; in fact, it is at the center of the attainment of Sustainable development goal number 7 of accessibility to affordable, sustainable and reliable energy, Vision 2030 and the highly anticipated Big 4 agenda and according to Vera and Langlois (2007), energy poverty is a major hindrance to the attainment of the desired level of economic growth and its inadequacy is sure to lead to slowed economic progress hence, the global focus on renewable energy sources. Renewable energy is touted as the 'fuel of the future' by Singh et al (2019) and it acts as a key economic development driver by ensuring there is sufficient energies to power the envisaged industrialized economy now and in the foreseeable future due to the replenish ability of the renewable forms of energy.

In addition to cost effectiveness and affordability of the renewable energy sources, Jacobs (2012) and Fang (2011) note that renewable energy sources are environmentally friendly as they play a key role in decarbonization. Fang (2011) notes that the continued consumption of the renewable energy sources will reduce the carbon emissions in the earth's atmosphere by 8.2% by the year 2050.It also notes that investment in renewable energies is sure to help in job creation and offer support to rural industries by making them self sufficient as far as their energy needs are concerned. It recommends increase in the investment and consumption of renewable energies because a 1% increase in the consumption of renewable energy leads to a 0.12% increase in gross domestic product per capita.

As Kenya desires a more industrialized economy and a bubbling manufacturing sector as envisioned in the vision 2030, the Energy and Petroleum Regulatory Authority notes that Kenya faces an enormous task of meeting the huge amounts of energy needed to power the highly anticipated industrialized economy. The country has therefore been striving to come up with strategies and policies to secure sustainable supply of energy to meet the growing industrial demand, which saw Kenya zero rate import duties and remove value added tax from some key renewable energy equipment. These concerted and intentional measures have over time encouraged investments in the key sector, though the actual renewable energies supplied and consumed have remained significantly low, thus slowing down the process of industrialization as per the Economic Recovery Strategy Paper of 2014.

The desired bubbling manufacturing sector and a double-digit economy may not be realized if Kenya shall continue relying on the exhaustible sources of energy that leave no guarantee for the future energy demands. Kenya shall also not grow economically if it continues exporting fresh agricultural produce that has not undergone any form of value addition therefore attracting low output prices in the international market compared to her economic and business partners like Japan and China that mostly export manufactured and processed products. All these value addition processes need massive amounts of energy that Kenya currently lacks. Currently, manufacturing activities account for only 10% of Kenya’s Gross Domestic Product (Obange, Siringi & Mukras, 2013) hence the need to invest more in the sector instead of exporting fresh agricultural products that fetch lower output prices in the global market. These manufacturing and processing activities need huge amounts of energy, now and in the future, thereby facing a risk of slowed industrialization posed by the imminent depletion of the already overwhelmed nonrenewable energy sources. Kenya also dreams of increasing the share of manufacturing activities from the current 10% of the gross domestic product to 20% by 2022 and this requires massive investment in the energy sector. Increase in manufacturing activities leads to overall economic growth.

The subject of economic growth has been growing globally with all countries targeting to increase their Gross Domestic Product and sustain positive growth which is considered crucial to any economy. There has also been a varying perspective to the meaning and measure of economic growth and how this contributes to the envisaged positive growth. According to Amadeo (2020), economic growth is considered to be the increase or decrease in the output volume or real expenditure or income of residents residing in a country. The study suggests that gross domestic product is the better measure of economic growth because it takes into account the economy's entire output and does not include unpaid for services. The World Bank, however, uses the gross national income as the measure of economic growth. This measure factors in the value of imports, exports and income of local residents residing abroad. Economic growth is of utmost importance as it leads to increased productivity in an economy by optimizing on the 4 key factors of production; land, labour, capital and entrepreneurship. All these factors define an economy's wealth status over time.

Economic growth is desired because it leads to poverty alleviation, reduced unemployment levels and reduces misery amongst the residents of a country and therefore, efforts have to be made to improve it if the quality of human life is anything to go by (Palmer, 2012). According to the study, this can be achieved by putting in measures and strategies aimed at increasing the aggregate demand for goods and services produced in the economy through value addition in processing and manufacturing firms. These manufacturing and processing firms needs huge amounts of energy to run and therefore inadequate supply of energy slows down the whole process of industrialization. Therefore, the role played by energy in promoting economic growth can never be overemphasized, given the fact that energy affects all aspects of human life. In fact, energy poverty is considered as a major social and economic injustice in the 21st century. Figure 1:1 shows the gross domestic product trends for the study period (1980-2017) that explains how the economy has been growing in jumps and jerks after the global oil crisis and the recovery period thereby signaling the important role played by energy in stimulating economic activity.

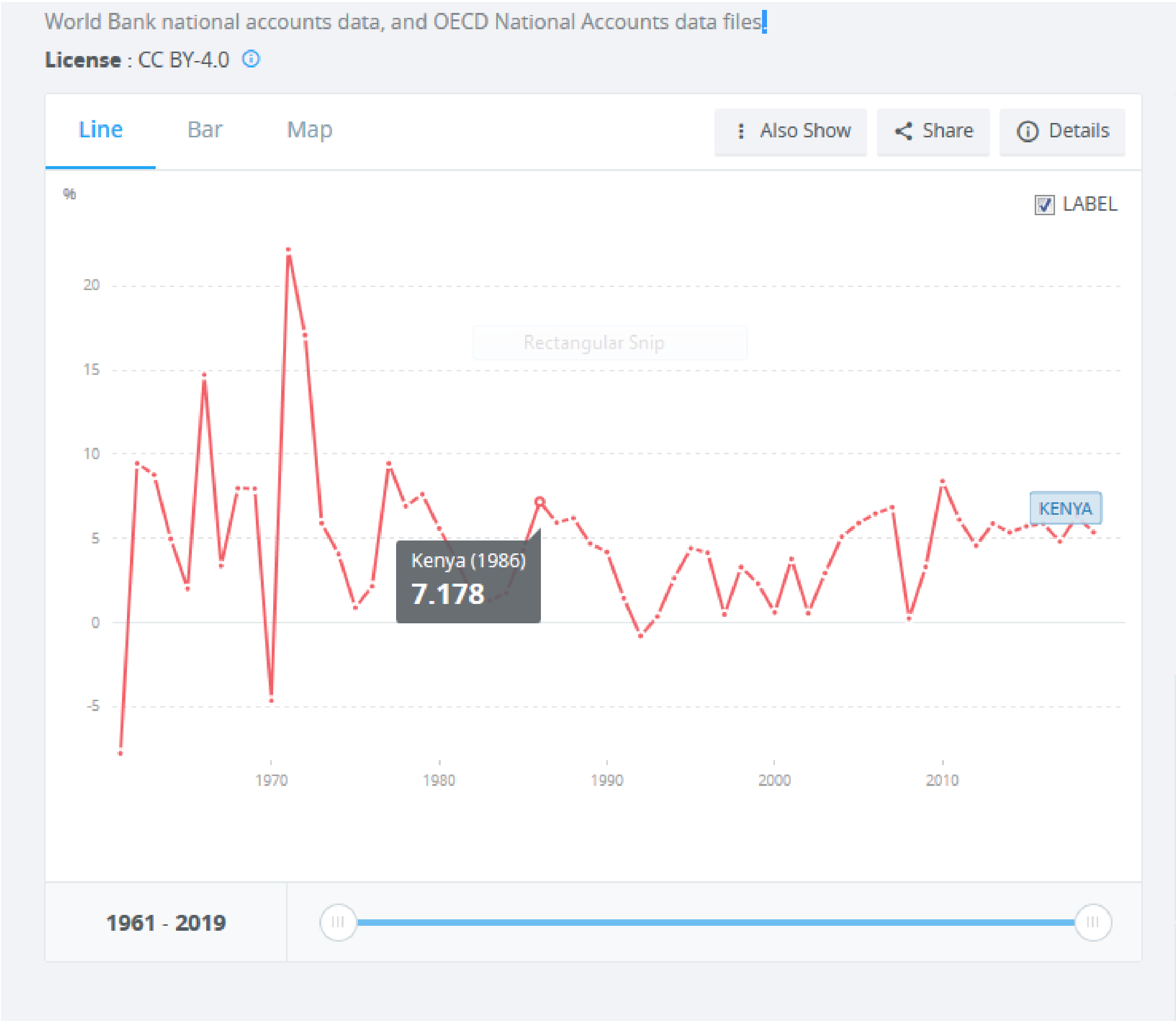

Figure 1:1-Kenya's GDP situation since 1969

(Source, WDI, 2020)

Economic growth is all about increasing productivity where sustainable energy plays a vital and central role. Harford (2013) gives a brief analysis of the United States of America economy in the analysis of the effect of energy on overall productive economic activities in an economy. It points out that energy per capita of the United States of America fell by 0.17%, the same period the gross domestic product per capita averaged 2.5%, between 1986-2011. In Africa, The Africa Research Bulletin records that there was a major electricity outage in South Africa leading to a major shutdown of firms resulting in loss of production which consequently led to slowed economic progress. Households were also not spared as energy prices skyrocketed making livelihoods miserable due to the interplay of demand and supply dynamics. According to the Journal of American History, the same phenomenon was also observed in less developed economies like Kenya and Zimbabwe between 1965 and 1980, thus highlighting the crucial role played by energy in promoting economic activities in an economy, both at the household level and the national level. The Kenyan government has therefore undertaken deliberate reforms aimed at achieving operational efficiency in the energy sector by doing away with distortions that existed and creating an environment conducive for competition so as to permit investments in this crucial sector. This is also in line with the attainment of the Sustainable Development Goal number 7 on affordable and clean energy.

According to Vera and Langlois (2007), availability and accessibility to affordable and sustainable energy sources has for a long time been regarded as one of the most important objectives of sustained economic growth and development as it was thought to be a precondition for poverty alleviation and a catalyst for increased employment levels. The topic of the role of energy in development has attracted an international debate and conversation on key issues among them; environmental and risk mitigation (UN, 2015; World Bank and IEA, 2015).While there was no Millennium Development Goal on energy by the time the Millennium Development Goal paved way for Sustainable Development Goals in 2015, accessibility to modern and reliable energy was necessary in the attainment of the Millennium Development Goal regarding poverty alleviation, human health, increased productivity, education and communication (Economic Consulting Associates,2014).Access to clean, sufficient , affordable and sustainable energy is also key in achieving the sustainable Development Goals' dreams regarding good health and well-being, quality education and industrial development. Access to sustainable energy in modern times has come to be regarded as a key human survival issue. In fact, accessibility to insufficient and inadequate energy is regarded as a major drawback to economic progress in emerging economies (Bugaje, 2006; Butler, 2018; UNDP, 2005).In light of these; it is therefore paramount to appreciate the crucial and very critical role played by energy in spurring economic growth in Kenya.

With the current high extraction rates of the exhaustible ores brought about by the enormous industrial needs and their impending depletion of the nonrenewable ores, turning to the renewable energy sources to mitigate the inadequacies of the latter is almost unavoidable. Environmental friendliness, budgetary and economy reasons make renewable forms of energy the best bet (Hadda, 2012). This explains why this study chose to concentrate on the renewable energy forms; being the only form of energy that is capable of sustaining Kenya's household and commercial energy demands now and in the unforeseeable future without the fear of depletion. The renewable energy forms are of invaluable use as they are capable of taking care of both the current and future commercial energy needs due to their replenish ability, besides being environmentally friendly and cost effective (Snorre,1994).

This study paid attention to hydroelectric power, wind power, solar and geothermal energy as they predominantly account for over 98% of the total renewable energy investments and consumption in Kenya as at December 2019. In fact, going with the capacity to produce the aforementioned forms of energy, Kenya ranks eleventh globally after Sweden, Costa Rica, Nicaragua, Scotland, Germany, Uruguay, Denmark, China, Morocco and the United States of America (Climate Reality Project, 2016).

1.1.1. Hydroelectric Power

Hydroelectric power is the single largest source of grid energy in Kenya contributing about 677 MW to the national grid and accounts for about 49% of total installed capacity. Hydroelectric power is installed at the seven forks scheme that comprises of Masinga, Gitaru, Kamburu, Kindaruma and Kiambere power stations. Hydropower plants have also been installed at Mutonga, Kindaruma, Sang'oro and Grand Falls.

Despite these tremendous developments, the sector is lagging behind due to high investment costs, inadequate hydro-logical data; climate change and limited capacity to manufacture local components (World Development Indicators, 2018).

1.1.2. Wind Energy

There have been major investments in wind power, the most recent being the installation of a wind power plant in January 2020 in Athwana, capable of supplying electricity to a whopping 200,000 households. Kenya is seeking to produce 2,036 MW of wind energy, that accounts for about 9% of the total renewable energy installed capacity, by the year 2030 (World Development Indicators, 2018). Kenya's largest wind generator according to Energy and Petroleum Regulatory Authority is installed at the Lake Turkana wind plant (LTWP) with a generational capacity of 310 MW.Another wind generator is installed at the Ngong Hills with a whopping capacity of 25.5 MW. Wind power is viewed as a more viable renewable energy source as it has a lower Feed-in-tariff (FIT) than solar. The Fit in tariff is meant to help and support renewable energy producers by offering above-market prices for the producers. As per the Ministry of energy and petroleum, the Fit in tariff value for wind power is 0.11 United States dollars while the Fit in Tariff value of solar energy is 0.12 United States dollars.

Wind power is a viable renewable energy source due to the reliable and high-speed winds (averagely 6.5m/s-9.5 m/s) experienced across the country's borders as illustrated by the Energy and Petroleum Regulatory Authority in Figure 1-2.

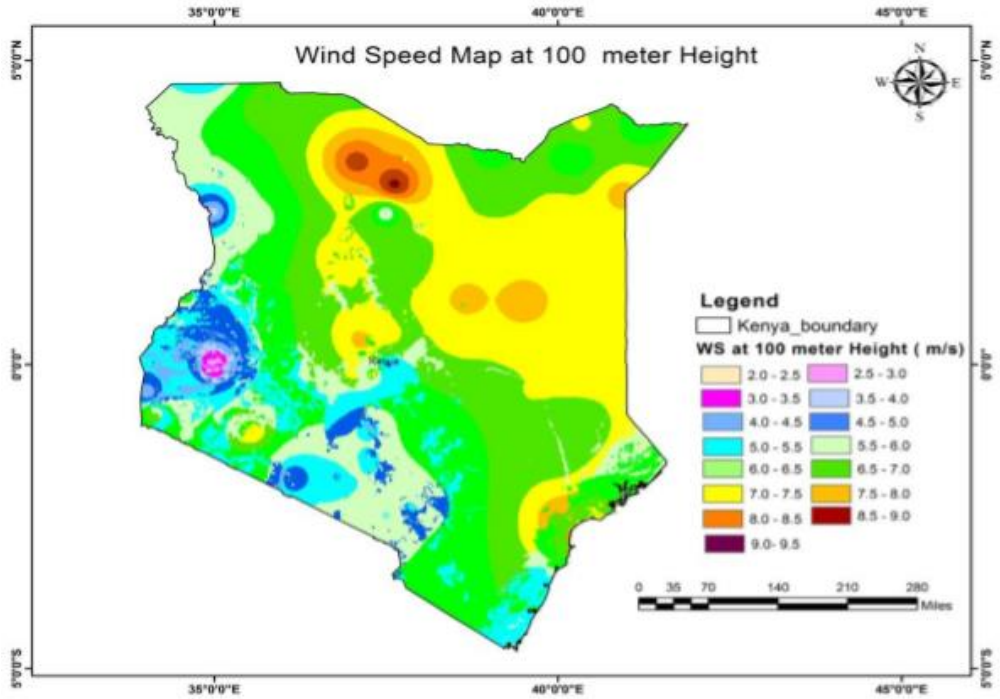

Figure 1:2-Wind patterns in Kenya

(Source: EPRA; 22nd January 2021)

As illustrated in the diagram above, the highest speeds are experienced in areas around Turkana and Ngong, making them the prime sources of wind energy in the country.

1.1.3. Geothermal Energy

Kenya is the continent's first geothermal power generator, alongside Ethiopia. In fact, geothermal energy accounts for approximately 20% of the total renewable energy installed in the national grid and accounts for about 51% of Kenya's total energy mix (Climate Reality Project, 2016).Kenya's geothermal energy is installed at the Olkaria with a national potential of about 10,000 MW. The geothermal source of power has been vouched as a least cost energy source by the Geothermal Development Company (GDC) which has led to even more explorations and investments in geothermal energy. Currently, Kenya has the capability to generate about 10GW of geothermal energy annually (GDC, 2019).Overally, Kenya aims to generate 19,200 MW against the national demand of approximately 15,000 MW by the end of the year 2030 as shown in figures 1-3 and 1-4 in the illustrations showing both the current and projected renewable energy situations in Kenya and the increasing gross domestic product trends to ascertain the long term sustainability of the consumption patterns.

1.1.4. Solar Power

Solar power is a form of energy that has widely been exploited in Kenya by households that are not connected or are far from the national grid. It is has proved to be very dear especially to the rural communities given the fact that Kenya experiences 5-7 peak hours of sunshine on average making it a relatively more reliable renewable energy source compared to other renewable energy forms such as geothermal energy that require huge capital investments. It is the second largest renewable energy source in Kenya after hydroelectric power. Solar energy in Kenya has been dominated by the giant telecommunications firm, Safaricom, trading as M-Kopa and other firms such as Sunking. The duo came up with comfortable payment plans to clients thus making solar energy available and affordable to low income earners. The friendly payment plans, coupled with 5-7 sunshine insolation hours, have endeared solar energy to many households despite a few households being risk averse making them to be skeptical on the idea of acquiring the equipment on credit. They fear the loaned equipment might lead to loss of their hard-earned property through auction as a result of loan non-repayment.

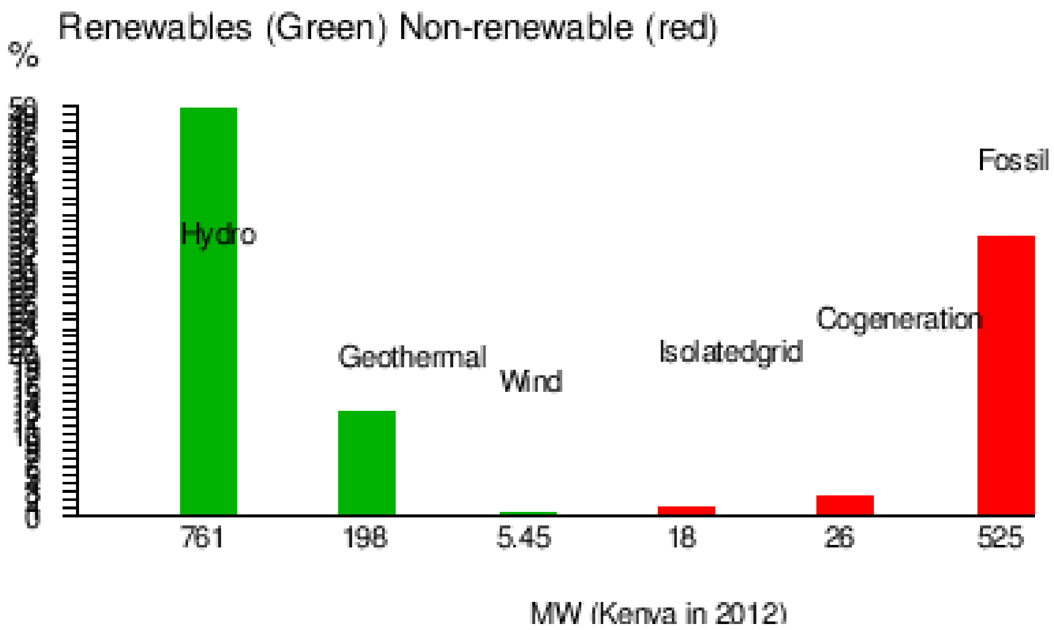

Figure 1:3-Kenya's renewable energy situation

(Source, international atomic energy agency, 2012)

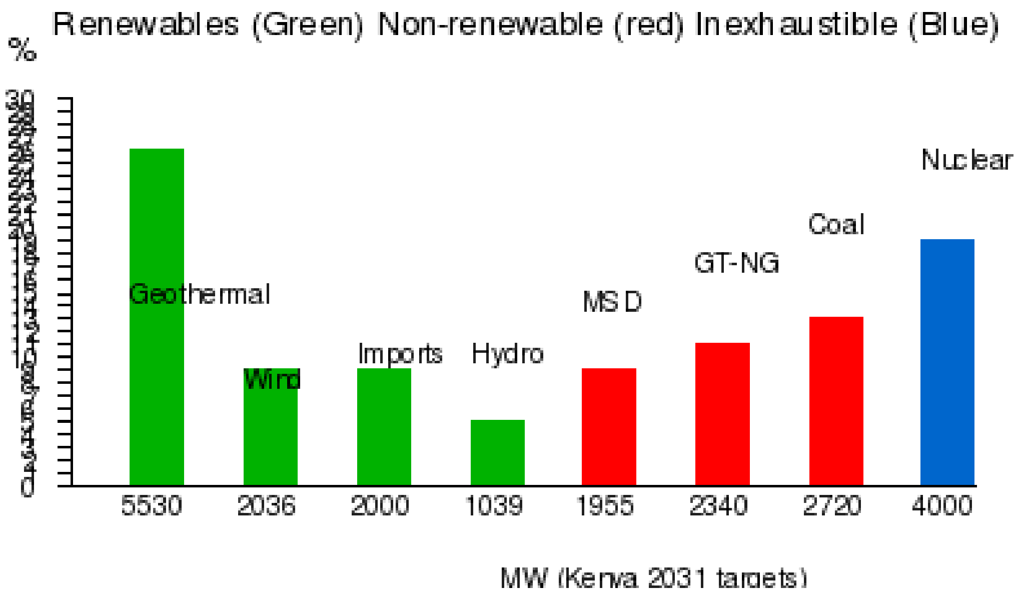

Figure 1:4-Kenya's projected renewable energy situation by 2030

(Source, *international atomic energy agency, 2012)*

There is a significant deviation between renewable energies investment and consumption patterns as depicted by the actual consumption levels Vis a Vis the installation capabilities, revealing possibilities of energy losses in the renewable energy value chain. Kenya's renewable energy consumption pattern is similar to that of Iran as depicted by Fung (2009) though Iran is on another level of economic growth compared to Kenya. Despite the huge installed capacities, Kenya still imports a whopping 17.17% of her net energy consumption (WDI, 2014). This casts a doubt on the sustainability of Kenya's energy consumption behavior in the long run and according to (Šimelytė & Dudzevičiūtė, 2017); this is not tenable in the long run. Reliance on imported energy to spur economic activity in the economy despite having the capacity to generate 100% of her total energy consumption needs to be examined. And as Fang (2011) alludes, renewable energies are meant to reduce the dependency burden of the energy poor economies.

Despite the massive current and projected investments in renewable energies in Kenya as discussed, supply and consumption levels are still too low to attain the much-envisaged level of industrialization. This is mainly due to inefficiencies in the value chain occasioned by use of outdated energy generation equipment leading to energy losses. Energy can neither be created nor be destroyed but it can be lost through conversion to other useless forms of energy such as heat (Kosky, Balmer, Keat & Wise, 2013). These losses serve to reduce the final amount of energy actually consumed despite the promising levels of investments in the important sector and according to Marinas, et al (2018); this can be reduced by investment in green energy that has useless and hazardous affluents. Emma and Katarina (2015) in Sweden suggested that large companies in the industry ought to work and bring about efficiency in the energy value chain thereby suggesting that the problem of lack of proper optimization in the energy value chain is not a problem specific to third world economies alone, but developed ones too suffer.Munene,Odongo and Nyambane (2019) went on to give policy recommendations for the achievement of efficiency in Kenya as a way of reducing the losses and bridging the gap between Kenya's recent investment in renewable energy against the actual amounts of renewable energies generated, supplied and consumed.

Sustainable energy is energy that is capable of taking care of the current energy demands and needs sufficiently without compromising with the capability of future generations to meet their own energy needs. Munene et al (2019) established that though Kenya's renewable energy consumption behaviour is sustainable, it's not desirable if the much envisaged level of industrialization is anything to go by. This expressly implies that if Kenya has to increase the share of manufacturing activities from the current 10% to 20% of the gross domestic product, more investments and better technology have to be employed in energy generation and supply.

This study focused on the key renewable energy forms, given their inexhaustibility and ability to sustain both current and future energy demands. In light of the ballooning industrial energy demand, it therefore behooves energy economists to establish how this can be sustained given the worrying depletion rate of non-renewable ores (Munene et al, 2019). It therefore makes sense that enough emphasis is accorded the key renewable energy forms in Kenya as they are sustainable, environmentally friendly, reliable and cannot be depleted, hence giving a guarantee to meet future energy needs. It is in light of these explanations that this study sought to establish the nature of the relationship that exists between the key renewable energy sources in Kenya, such as, solar energy, wind energy, hydroelectric power and geothermal energy consumption and economic growth.

Despite these tremendous developments in the renewable energies, limited studies have been undertaken to establish the contributions of the renewable energy resources on economic growth so as unearth their individual contribution to the economy and inform policy for the energy sector globally. Most of these past studies have studied energy at aggregate levels with the few done in Kenya also having issues of aggregation. The ones that have tried to disaggregate finding it difficult to apportion the percentage of the various forms of energy consumed to specific sectors of the economy. Most studies have also put more emphasis on exhaustible energy sources that are susceptible to depletion hence unreliable and undependable in the long run. Some of the most relevant studies in this area are from the developed economies and therefore cannot be replicated in developing economies such as Kenya. Going forward, it's almost impossible to ignore the contribution made by renewable energy on the Kenyan economy because it's an energy source capable of taking care of both current and future industrial energy requirements given its replenish ability.

In the recent past, the topic of the relationship between renewable energies and economic growth of nations has been analyzed extensively though limited studies took into account the renewable energy forms. The available empirical evidence on aggregated energy gives contrasting scholarly opinions on the relationship of the two variables and Jakovac (2017) made use of the Johansen's and attributed this to the exploitation of different econometric models and time periods. In fact, Borozan (2013) and Gelo (2009) studied the same economy, Croatia, but they also could not come to a unanimous conclusion despite conducting a study on the same economy, almost at the same time. Borozan (2013) used the Johansen's and Vector Auto Regression (VAR) while Gelo (2009) exploited the granger causality test.

Majority of the empirical studies treated energy as an aggregate variable and hence there is need to study each isolated form, more importantly, the renewable forms, and their impact on economic growth. The effect of renewable energy consumption Vis a Vis investment to establish the rates of conversion of renewable energy investments into consumption.

In summary, growth of economies is influenced by a combination of factors including consumption of renewable and non-renewable energy resources. Most developed economies such as the Oil producing and exporting countries (OPEC) and G7 nations are energy independent thereby revealing the critical role played by energy in influencing their economic growth and development. Energy is the source of power that drives major economic activities such as manufacturing, transport and information, communication and technology (ICT) services as its inadequacy is a serious economic problem. This is amplified by the 2008 power outages in South Africa that led to massive shutdown of firms in the giant economy. This serves to emphasize what can befall economies if they are to run out of energy to run the industries. The threat of depletion of the non-renewable energy forms such as fossil fuels which are being accelerated by the huge industrial demand, leave industrial sectors in most economies at risk of collapse should these crucial energy sources be depleted in the near future. It therefore becomes important to recognize the role of renewable energy in mitigating the unreliability behavior of the exhaustible forms of energy in Kenya.

1.2. Statement of the Problem

In Africa, Kenya tops in renewable energy installed capacity though the final supply and consumption levels are fairly low. Despite the massive installation capacity, there are inadequate interventions in converting the capacity into actual volumes of renewable energy supplied and consumed. The low levels of generated and supplied energy drive energy prices upwards thereby increasing the cost of production and subsequently reducing the level of national output as it serves as a disincentive to production agents in the economy. In fact, any increase in energy prices in Kenya has always been met by a corresponding increase in prices of all goods and services in the economy bringing about inflation, poverty and misery. The imminent inadequate investment in the supply and consumption of renewable energy can therefore drag the process of economic development, innovation and infrastructural development as envisaged by the majority of sustainable development goals , Big 4 Agenda and Vision 2030.The Kenyan economy is sure to only thrive when there's adequate and sustainable energy to power the desired level of industrialization to raise the current share of manufacturing activities from the current 10% of the gross domestic product to 20% by 2022.Hence, energy consumption, though in itself not a sufficient condition, is thought to be a panacea for industrialization and poverty alleviation. Despite the importance accorded to renewable energies in ensuring there is sustainable energy to cater for current and future household and industrial energy demands, limited studies exist to explain the relationship between the renewable energies and economic growth with the few available studies having the problem of aggregation by not isolating the specific effect of renewable energies on economic growth; but rather dealing with energy as an aggregate variable.

1.3. Objectives of the Study

The main objective of this study was to determine the nature of the dynamic relationship between renewable energy investment, renewable energy consumption and economic growth in Kenya

1.3.1. Specific Objectives of the study

(i) To establish the effect of renewable energy investment on economic growth in Kenya.

(ii) To establish the effect of renewable energy consumption on economic growth in Kenya.

(iii) To establish the effect of renewable energy investment on renewable energy consumption in Kenya.

1.4. Research Hypotheses

1. H_0: Renewable energy investment does not influence economic growth in Kenya.

   H_1: Renewable energy investment influences economic growth in Kenya.

2. H_0: Renewable energy consumption does not influence economic growth in Kenya.

   H_1: Renewable energy consumption influences economic growth in Kenya.

3. H_0: Renewable energy investment does not influence renewable energy consumption in Kenya.

   H_1: Renewable energy investment influences renewable energy consumption in Kenya

1.5. Justification of the Study

Energy is a very important input in the production process. Energy is used in households, industries, commercial institutions and the transport sectors, among others. This study was therefore necessary to investigate the dynamic relationship existing between renewable energy consumption, renewable investment and economic growth in Kenya. This study may be of use to academia, the government and policy makers. This study may help the academia expand knowledge scope of the scholars through new information on sustainable energy for economic growth. It may help scholars to appreciate the contribution of renewable energy investment and consumption towards steering sustainable economic growth. Further it forms a foundation for further studies by creating a new angle of thinking and doing things, out and about the field of sustainable energy for economic development.

The government may find this information invaluable in the budget making process in parliament or ministerial preliminary budgets and in the allocation of funds to various sectors that require substantial energy input. The ministry of energy will find this information crucial in identifying the gaps that need to be filled in the energy sector and also forecast the future of the sector in general as it is the sector that literally drives all the major sectors of the economy; processing, manufacturing, health, service and agricultural sectors.

Furthermore, this study may help the policy makers in establishing renewable energy policies that are realistic, time bound and those that enhance sustainable economic growth in Kenya.

1.6. Scope of the Study

The geographical area of this study is Kenya. This study was conducted to establish the dynamic relationship between renewable energy investment, consumption and economic growth in Kenya. Gross Domestic Product was chosen as the measure of economic growth as it’s a macroeconomic indicator that measures the strength of an economy by determining the value of all the final goods and services produced in an economy over a specified period. It considered the time period from the year 1980-2017, as it’s the period that preceded the global oil shocks that led to an upsurge in renewable energy demand and uptake globally. This data therefore covers a period of thirty-eight years. Renewable energy investment data for the period was also considered to check for efficiency and under-utilization in the renewable energy value chain by establishing the conversion rates. It was used to ascertain the success of the government’s efforts in bridging the energy gap and the extent of their success. Capital and labour for the study period were incorporated as the control variables. This is because the gross domestic product is not only affected by renewable energy investment and consumption, but a host of other factors too. This study had three main objectives; to establish the effect of renewable energy consumption on economic growth in Kenya, to establish the effect of renewable energy investment on economic growth in Kenya and to establish the effect of renewable energy investment on renewable energy consumption in Kenya. The study also revolved around determining if the level of Kenya’s investment in renewable energy is sufficient for the realization of a bubbling industrialized economy and if the amounts of resources so invested translate into increased renewable energy consumption.

1.7. Theoretical Framework

Energy exists as either renewable or non-renewable. Renewable energy includes wind power, solar energy, hydroelectric power and geothermal energy while the non-renewable energy includes the fossil fuels for instance, petroleum and natural gas.

Literature on growth and resources emphasizes on the conditions that shall permit sustainable economic growth. A combination of institutional and technical capabilities determines whether this is possible or not. The technical conditions connote the combination of both renewable and non-renewable energies while institutional conditions include market structure and property rights systems. Solow (1974) proved that sustainable economic growth can be attained in a model with a given level of exhaustible energy with growth and the level of consumption occurring indefinitely. On the other hand, the same conditions under a perfect market structure leads to depletion of the resources and according to Stiglitz (1974), welfare eventually falls to zero. This shows that given the current extraction rates, depletion of the non-renewable energy forms is inevitable in the long run, hence the focus on renewable energies. This may ultimately disrupt production activities in an economy (Dasgupta and Heal, 1979). Sustainable economic growth occurs when there is adequate investment in capital to replace the already exhausted energy resources. That is per Hartwick (1995) and Dixit (1980).

This study adopted the Solow swan growth model that was propounded by Robert Solow. It's an economic model that links output changes to changes in population, savings rate and technology. The Solow swan is the basis on which modern economic theory is anchored and has the following assumptions; constant returns to scale, savings ratio is constant, neutral technical progress, substitutability of capital and labour, full employment, flexible wages and prices and one composite commodity is produced. The model harbours some weaknesses, among them being the unrealistic assumption of homogeneous and malleable capital.

Investments in renewable energy were incorporated in the study to help establish the speed of conversion in the renewable energy value chain. The production function in the Solow growth model takes the Cobb Douglas form of;

$Y=aK^bL^{1-b}$……………………………………………………………………….……………….*(1.1)*

where $0<b<1$.

b is the capital share of income that capital receives.

A look at this literature reveals that substitution and technical changes have the ability to decouple economic progress from renewable energy and other crucial resources. Of importance are the institutional procedures and strategies that lead to sustainable economic growth but not technical arrangements.

As per the Solo-swan growth model, the relationship existing between renewable energy and economic growth is represented by;

$$LnY = A_t + \beta_1 LnK_t + \beta_2 LnL_t + \beta_3 LnTRI + \beta_4 LnTREC_t + {}_t + \varepsilon_t \quad \ldots\ldots (1.2)$$

A is efficiency or technology

K is capital

L is labour and

$\mathcal{E}$ is the error term

TREC is total renewable energy consumed while *TRI* is the total renewable energy investments. Capital and labour are the control variables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter highlights the theoretical and empirical literature reviews, summary of the gaps to be filled and other areas that are yet to be studied in the field of renewable energy.

2.2 Theoretical Literature Review

This study focused on the hypotheses from the energy consumption-economic growth nexus. These hypotheses are the growth hypothesis, neutrality hypothesis, feedback hypothesis and the conservation hypothesis**.** Growth hypothesis denotes a unidirectional causality relationship running from energy consumption to the level of economic growth. It emphasizes the critical role played by energy in accelerating and spurring economic progress. It therefore stipulates that any inaccessibility to modern energy acts as a suppressor to economic growth. Conservation hypothesis advocates for conservation and energy efficient policies that have no negative impact on the economy. It implies that economic growth is the dynamic that brings about an energy sector that is less energy dependent. The hypothesis conforms to the bidirectional independence existing between economic growth and energy consumption. This is meant to advocate and champion for the implementation of energy expansionary measures for the realization of sustainable progress in the economy**.** Feedback hypothesis connotes a complimentary relationship existing between energy consumption and economic growth which is supported if there is a bidirectional energy-economic growth kind of relationship. Neutrality hypothesis, on the other hand, propounds that there exists no significant association between energy and economic growth, and if any, it’s by mere coincidence and not design (Apergis & Payne, 2009). The hypotheses can be represented in Fig 2.1 below;

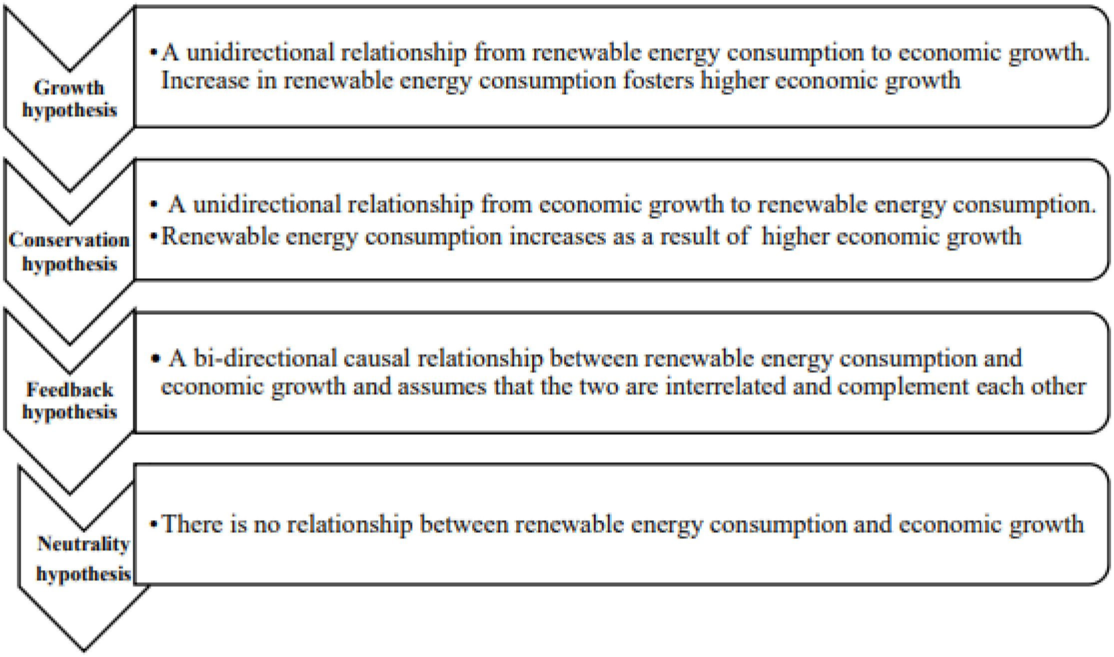

Fig 2:1- Energy-Economic growth nexus hypotheses

(Source; own conceptualization, 2022)

The hypotheses summarize the relationship between energy and the level of economic progress into unidirectional, implying a one-way relationship, bidirectional, implying the existence of a feedback relationship and neutrality, implying no cause-effect relationship existing between energy consumption and the level of economic growth. However, most empirical literature conforms to both growth and feedback hypotheses; implying that energy use leads to the increase in the level of economic growth. Eventually, a bubbling economy meant there were more resources invested in the energy sector which consequently leads to more energy consumption, hence the feedback relationship.

This body of knowledge is an invaluable tool to energy economists though it fails to account and provide for a way of assessing the intensity and magnitude of the causal relationship between renewable energies and economic growth. It only accounts for the sign of the relationship but ignores the magnitude of the associations. The existing body of knowledge is also mum on the critical role played by renewable energy investments in influencing the level of renewable energy consumed and the level of economic growth.

Whether renewable energy consumption affects the rate of economic growth has shaped an important question among economists. Previous studies in this area, however, have conflicting results and therefore economists have not come to a consensus on this issue. Several theories have been propounded to explain the relationship between energy consumption and economic growth.

This study considered the Harrod Domar and Solow swan growth models to explain the relationship existing between the three variables because they are exogenous models capable of explaining long run relationships as a result of the growth of the other, in this case, renewable energy investmets,renewable energy consumption and economic growth.

2.2.1 The Harrod Domar model

The Harrod-Domar is a Keynesian growth model. It was put forward by Roy F. Harrod in 1939 and Evsey Domar in 1946. It's mostly exploited in the field of development economics to compute economic growth associated with Capital and Savings rates. It suggests that economic growth is calculated by dividing the savings ratio by the capital-output ratio. $Y = s/k$……………………………………………………………………………………..*(2.1)*

Where Y is economic growth,

s is the savings ratio and

k is the capital-output ratio.

According to this model, three forms of growth exist; warranted growth, actual growth and natural growth. According to warranted growth, the growth rate doesn't grow indefinitely. Actual growth is the increase in a country's gross domestic product in a year while natural growth pertains an economy attaining full employment. According to the neoclassical economists, this model habours some weaknesses, amongst them, the instability of solutions arrived at using the model. The neoclassical economists therefore suggested the use of the Solow-Swan growth theory.

2.2.2 The Neoclassical Solow Swan growth theory

This study adopted the neoclassical Solow-Swan growth model to explain the relationship between the gross domestic product growth and renewable energy. Propounded by Robert W. Solow in 1956, the Solow swan growth model connotes a production function that is continuous and links output to the levels of capital and labour employed in the production process. Capital and labour are assumed to be easily substitutable.

Solow made use of Cobb-Douglas production function. It's an economic model that arbitrarily determines the output levels as brought about by changes in population and savings rate and technological advancement. The Solow swan is the basis on which modern economic theory is anchored and has the following assumptions; constant returns to scale, savings ratio is constant, neutral technical progress, substitutability of capital and labour, full employment, flexible wages and prices and one composite commodity is produced. The model harbours some weaknesses, among them being the unrealistic assumption of homogeneous and malleable capital. This study mitigated these inefficiencies by incorporating and modifying the model so that capital and labour were mere control variables. Basically; this study adopted a modified form of the Solow-Swan growth model. The Solow-Swan growth model was adopted due to its ability to explain long-run interrelationships among multiple variables because this study took into account five key variables; total renewable energy consumed, total renewable energy investments, gross domestic product, capital and labour.

Investments in renewable energies were incorporated in the study to help establish the conversion rates in the renewable energy value chain. The variable helped establish how fast investments were being converted into actual consumption of renewable energies. Therefore, the variable (investment in renewable energy) was used to bring out the sustainability of the study's key variable-renewable energy consumed. The production function in the Solow growth model takes the Cobb Douglas form of;

$$Y=aK^{b}L^{1-b}, \quad \ldots\ldots \quad (2.2)$$

Where $0<b<1$.

b is the capital share of income that capital receives.

A look at this literature reveals substitution and technical change have the ability to decouple economic progress from renewable energy and other critical resources. Neoclassical economists were mostly keen to establish institutional arrangements that lead to sustainable economic growth but not technical arrangements.

As per the adopted modified Solow-Swan growth model, the relationship between renewable energies and economic growth was logged and represented by;

$$LnY_t=A_t+\beta_1 LnK_t+\beta_2 LnL_t+\beta_3 LnTRI_t+\beta_4 LnTREC_t+\varepsilon_t \quad \ldots\ldots \quad (2.3)$$

2.3 Empirical Literature Review

2.3.1 Effect of Renewable Energy Consumption on Economic Growth

This section highlighted the previous studies that sought to establish the relationship between renewable energy consumption and economic growth. Renewable energy consumption is the usage of energy, both by households and firms is treated as an important input in the production process (Obange al, 2013). Empirical studies herein are supported by the four different hypotheses; Neutrality hypothesis, growth hypothesis, conservation hypothesis and feedback hypothesis. Some studies treated energy as an insignificant part of economic output and thus assumed that there is no causality existing between energy consumption and economic growth thereby conforming to the neutrality hypothesis. This therefore implies that the key renewable energy forms such as hydroelectric power do not in any way affect economic growth as propounded by Vlahinic and Zizkovic (2010) in Vietnam using the Auto Regressive Distributive Lag and Ozturk, Aslan and Kalyoncu (2010).These studies argue that the cost of energy is a mere small fraction of the national output and therefore cannot have a significant impact on the level of economic progress of a country. The studies exploited the granger causality test and therefore could only suggest existence and direction of the relationships but the magnitudes of the relationships were overlooked. This study therefore replicated the study using data specific to Kenya to unravel the exact nature of the relationship in the Kenyan economy using more robust analysis tools to determine the magnitude and intensity of the causal relationship existing amongst the variables.

Chiou-Wei et al (2008) did a panel study in two countries between 1954 and 2006 using the Johansen-juselius and Vector Error Correction Model and established that there was no relationship or causality existing between energy consumption and economic growth. Jobert and Karanfil (2007) did a study in Turkey for the period 1960-2003 using the Johansen's and also established that there was no causality or any significant relationship existing between energy consumption and economic growth. Gelo (2009) did a study in Croatia and exploited data for the period 1953-2005 using the granger and also established that there was no substantive relationship between energy consumption and economic growth. However, the three studies were done in developed economies and therefore do not reflect the renewable energy situation in developing economies like Kenya. There is also need to carry out the study with more recent data that can inform policy in the recent times. This study mitigated the inadequacies of the above scholars by using the most recent Kenyan data for the period 1980-2017.

Fang (2011) in China using data for the period 1978-2008 while exploiting the Ordinary Least Squares(OLS) established a unidirectional causality running from renewable energy consumption to the level of economic growth. The study, apart from making use of the less robust OLS, is from a more developed economy compared to Kenya.

For the Kenyan case, the closest study is a panel study by Wolde-Rufael (2006), using the granger causality test with data for the period 1971-2006; established that there was no causality between energy consumption and economic growth. The same results were established by Esso (2010) using Vector Error Correction Model and data for the period 1970-2007, and Odhiambo (2010) using data for the period 1971-2006 while exploiting the ARDL.However, the studies treated energy as an aggregate variable and therefore there's need to replicate the study using disaggregated data so as to isolate and identify the specific effect of renewable energy consumption on economic growth in Kenya to inform policy. The above studies treated energy as a single aggregate variable and therefore establishing the specific effect of the renewable forms of energy was not possible. This study mitigated this shortcoming by solely dealing with renewable energy, as opposed to the energy as a whole. This was meant to help in sustainable energy policy formulation for the highly anticipated industrialized economy.

According to Odhiambo (2010), an analysis using ARDL-bound test procedure revealed a significant positive causal relationship running from energy consumption to economic growth in Kenya. The study therefore, treats energy as a key factor in the production process and stipulated that any reduction in energy consumption adversely affects the economy. The study therefore supports the growth hypothesis. However, the study is silent on the intensity of the causal relationship between economic growth and renewable energy consumption and investments. The study also exploited the traditional ARDL procedure and therefore there's need to carry out the study using more recent data and a more robust analysis tool, such as the VECM. This study bridged this gap by making use of the robust VECM and most recent data for the period 1980-2017.

Jakovac (2017) in its analysis on the overview of electricity consumption and economic growth in Croatia used granger causality analysis and established existence of positive causality existing between energy consumption and economic growth. Binh (2011) similarly did a study in Vietnam using data for the period 1976-2010 using the granger causality analysis and also established a unidirectional causality relationship running from energy consumption to economic growth. Other studies in consonance with the findings of Jakovac (2017) are; Ito (2017), Bhattacharya et al (2017) and Pao (2013).The studies, however, are silent on the intensity of the causal relationship. The studies also made use of the granger causality test which is incapable of detecting more than one cointegrating relationship. The studies are also from developed economies and may therefore not portray the real situation in developing economies like Kenya.VECM that has been exploited in this study is capable of determining the magnitude and direction of any causal relationship amongst the study variables.

Tiwari (2011) did a study in India for the period 1960-2009 using the structural vector autoregressive (VAR) analysis and established that GDP growth is positively influenced by the consumption of renewable energy resources. The study, apart from being silent on the magnitudes of the associations between the two main variables, is from a country at a different stage of economic development and therefore its findings may not represent the true situation in most developing economies such as Kenya. This study sought to mitigate this by doing a study specific to Kenya.

Bartleet and Gounder (2010) in New Zealand for the period 1960-2004 using the ARDL established a unidirectional causality relationship running from energy consumption to economic growth. More robust analysis tools and more recent data need to be taken into account to help inform policy in current economic times. There is also need to replicate the study in the developing economies like Kenya. This study addressed this inadequacy by exploiting data specific to Kenya for the period 1980-2017.The more robust VECM analysis technique was also employed in this study.

Jakovac (2018) did a study on electricity-economic growth nexus in Croatia and identified a positive correlation between the two variables. However, it suggests use of new and robust econometric tools and use of new sets of data to counter the inconsistencies and conflicting results past studies have subjected us to. It suggests that new variables such as capital and labour should be incorporated. This study mitigated the inadequacies and adopted the recommendations by of Jakovac (2018) by incorporating capital and labour as the control variables. Investments were also incorporated to make the study more robust. This is because energy consumption is not the only determinant of economic growth, but a host of other factors, too.

Another class of researchers asserted that there exists a long-term relationship running from economic growth to energy consumption, and not the other way round. Their findings are supported by the conservation hypothesis. Thus, a reduction in the level of energy consumption would not adversely affect economic growth. They advocate for the implementation of energy conservation policies to accelerate economic growth. Conservation hypothesis postulates that economic growth plays a very important function in energy consumption as lauded by Hatemi and Irandaost (2005) for Sweden and Kraft and Kraft (1978) for the USA.Soihila and Sourball (2012) for Nigeria also affirms this unidirectional granger-causality relationship running from economic growth to energy consumption though magnitudes of the relations were overlooked. Ameyaw (2017) also asserts the conservation hypothesis; the granger causality tests conducted on the data from 1970-2014 indicated that there exists a unidirectional causality running from GDP growth to electricity consumption. The studies that support the conservation hypothesis, though done in the developed world, are Sica (2007) in Italy using granger, Tsani (2010) in Greece using Granger and the johansen's cointegration test, Borozan (2013) in Croatia using the Johansen's and VAR and Imran and Siddiqui (2010) in Bangladesh using the VECM.The studies above, apart from Ameyaw (2017), are from the developed economies and may therefore not portray the energy situation in Kenya.

Sadorsky (2009) exploited panel correction model to establish the relationship between renewable energy usage and economic growth in 18 emerging nations for the period 1994–2003 and found out that increased incomes lead to more renewable energy consumption. The study, apart from being from a developed economy, does not make use of the more recent data. Islam et al. (2013), using the VECM and data for the period 1971-2008 in Malaysia, established that energy consumption is influenced by GDP growth and financial wellbeing of an economy, both in the short and long runs. Malaysia is an economy at a different stage of growth compared to Kenya. This study, therefore, sought to mitigate this by using more recent data (1980-2017) specific to Kenya to unravel the relationship between the renewable energy consumption and the level of economic growth in developing and emerging economies such as Kenya.

For Kenya, studies that support this hypothesis are Onuong'a (2012), using a granger causality test and data for the period 1970-2005, though the study focused only on the manufacturing sector in Kenya. The two studies, however, are silent on the intensity of the causal relationships. This study sought to determine the magnitude of the associations so as to aid in making of sound sustainable energy policies that are also time bound. This was achieved by running the robust VECM.

Some studies such as Obange et al (2013) assessed the impact of disaggregated energy consumption on manufacturing activities in Kenya using the granger causality analysis and established a causality relationship running from electricity consumption to manufacturing activities. Manufacturing accounts for only 10% of the GDP and hence there was need to do a study that sets to unravel the impact of energy consumption on the entire economy, not just manufacturing. This study addressed this by determining the aggregate effect of renewable energy consumption on the entire Kenyan economy, not just sectoral performance. This is because of as stands, it's almost impossible to apportion volumes of renewable energy consumed in specific sectors of the economy hence the findings of these studies could be misleading.

It's notable that majority of the said studies only emphasize on the sign but ignored the intensity, that is, the magnitude of the relationship between the variables (that is crucial in policy making). It's only Borozan (2013) and Gelo (2009) that tried to address this on the Croatian economy but they also could not come to a consensus. While Borozan postulated that the intensity of the causal relationship was such that a 1% increase in energy consumption resulted in a 0.75% increase in GDP, Gelo had earlier stipulated the reverse suggesting a unidirectional causality running from GDP to energy consumption where a 1% increase in the level of GDP of Croatia led to a 0.51% increase in the energy consumption levels. This study therefore, tries to unravel the true nature of the relationship between the key renewable energies and economic growth in developing economies like Kenya.

Singh et al (2019), employing the Fully Modified Least Square (FMOLS) technique and data for the period 1995-2016 in 20 developing countries, established that a 1% increase in renewable energy consumption led to a 0.07% increase in economic output in developed economies while it only led to a 0.05% rise in developing economies. This study, however, assumed all the developing economies had similar energy situations. It is possible for economies to be at the same stage of economic development but have varying energy situations due to the difference in their geographic locations, political climate and country-specific energy policies. That is why this study concentrated on the Kenyan case.

Another class of economists came up with empirical studies that assume a bidirectional causality kind of relationship running from economic growth and energy consumption. Majority of studies conform to this hypothesis. Their findings conform to the feedback hypothesis. The findings of their studies encourage concerted policies aimed at increasing the uptake of energy if any significant economic progress is to be realized. Narayan and Smith (2009) examined the impact of electricity consumption on GDP of Middle Eastern counties between 1994-2002 and found a feedback relationship existing between the two variables. Other studies that established a bidirectional relationship between energy and economic growth are the likes of Paul and Bhattacharya (2004) in India, Ghali and Sakka (2004) in India and Aziz (2011) in Malaysia. They established a bidirectional causality running back and forth from energy consumption to economic growth. Consumption of energy leads to economic growth which in turn leads to more investment in the consumption of energy and the cycle continues. The two studies used the Johansen's cointegration test in their analysis.

Erdal and Esengun (2008) exploited the Johansen Cointegration test and pair-wise granger causality and established a bidirectional causality relationship existing between energy consumption and economic growth by using real GDP and primary energy consumption as the variables. The study used data from 1970-2006.Apergis et al (2016) also sought to establish the nature of the relationship between renewable energy consumption and the level of economic growth in the 10 largest HEP consumers (Brazil, Canada, China, France, India, Japan, Norway, Sweden, Turkey and the USA) using annual data from 1965 to 2012 using the VECM and established a bidirectional relationship running back and forth between renewable energy consumed and the level of economic growth. Other studies supporting the bidirectional relationship between energy consumption and economic growth, though may not portray the situation in the developing economies, are; Belke et al (2010) in 25 OECD member countries using the granger, Belloumi (2009) in Tunisia using the johansen's and VECM, Lee and Chang (2007) in six countries using the VECM technique. All the studies above are from developed economies that do not portray the situation as it is in Kenya. This study sought to do a case study on the Kenyan case.

Shahbaz et al (2012) in Pakistan exploited data for the period 1972-2011 using the traditional ARDL and granger causality tests and established a feedback relationship existing between renewable energy consumption and the level of economic growth, both in the short and long runs. The study, apart from being from a more developed economy, made use of traditional and less powerful ARDL; hence it was not possible to determine the magnitudes and intensities of the associations between energy consumption and economic growth. This study sought to unravel the situation in Kenya using the more robust VECM.

Bloch et al (2015) in China made use of annual data for 1969,1973,1997,1998,2001,2002 and 2003 using the ARDL and VECM and established a bidirectional association between renewable energy consumption and the level of economic growth. The study, apart from being a developed nation study, made of data that is not continuous, it instead made use of disjointed data and therefore the outcome of the study cannot really be relied upon to inform sound energy policies because the data was biased. There was no economic justification for using the disjointed data hence, unreliable. The study also settled on fewer observations that are deemed inadequate for a sound econometric study. This study corrected this by using continuous data for the period 1980-2017(38 observations).

Some studies found mixed results and could not really provide a clear conclusion on the effect of renewable energy consumption on economic growth. They include; Ozturk (2010) done in 51 countries using the pedroni and panel VECM.The study interestingly found out that economic growth positively affects energy consumption in low income countries while there was a bidirectional relationship of the two variables in middle income economies. Zizkovic and Vlahinic-Dizdarevic (2010) studied 12 countries between 1993-2007 and also found mixed results so does Choi-Wei et al (2008), Akinlo (2008) and Lee and Chien (2010). Soytas and Sari (2003) also using data in G7 countries between 1950-1992 using the johansen's also conforms to this hypothesis. These studies exploited the johansen's while Lee and Chien (2010) used the Toda-Yamagoto causality. This study was replicated in Kenya to determine the true situation in developing African economies amid the confusion.

Ziramba (2013) also asserts this hypothesis using the Toda and Yamagoto technique on data between 1980-2009 in Algeria, Egypt and South Africa. The study established a feedback relationship between hydroelectricity consumption in Algeria, while the case in South Africa was such that economic growth granger caused hydroelectricity consumption thereby conforming to conservation hypothesis while there was no causality reported in Egypt. There's also a class of energy economists like Okyay, Yucel and Ebru (2015), in their article on 'Energy consumption and economic growth nexus, a study of the developed European nations' used the granger causality and interestingly found that renewable energy positively affected economic growth while non-renewable energy consumption negatively impacts economic growth. It is of interest to energy economists in developing economies such as Kenya to also establish if the above inconsistencies arise and adequately address them.

The concern of conflicting results is made louder by Safaynikou and Shadmehri (2014) of Ferdowsi university of Mashhad in Iran where they put forward two schools of thought of biological and neoclassical economists. Biological economists treat energy as a dominant factor in the production function while capital and labor are mere mediating factors whereas neoclassical economists treat energy consumption as an insignificant factor in the production function. According to Jakovac (2018), these conflicting results could be due to use of different sets of data, model specification, use of different econometric tools and countries' prevailing economic, social and political climate at the time of study. This study sought to establish which of the two schools of economic thought are applicable to the Kenyan case besides exploiting capital and labour as the control variables to have a more robust study.

Amri (2017) sought to establish the nature of the relationship between energy consumption and economic growth and also found mixed results. The findings from his ARDL model established a long run causality existing between non-renewable energy consumption but no cointegration existed between renewable energy consumed and the level of economic growth. He, however, established a long run bidirectional relationship between nonrenewable energy consumption and economic growth. Furthermore; he established a unidirectional causality running from renewable energy consumption and economic growth in the long run. This study, therefore, sought to address the inconsistencies in the previous findings.

Methodologically, three generations of knowledge on the field energy exist. The first generation studies exploited the traditional VAR (Sims, 1872) for instance, the works as put forward by Kraft and Kraft (1978).The above body of works established a one way directional relationship running from the consumption of renewable energy all the way to the level of economic growth in the USA between 1947 and 1974.Other body of works in this category assumed the presence of stationarity of the residuals. The second-generation body of works factored in non-stationarity by conducting cointegration. The last generation, according to Engle and Granger (1987), exploited and made use of ECM to check for causality. This generation allowed multiple variables to be included in the model to define the relationships (Masih & Masih, 1997). They focused on the production side of the model and hence need arises to consider the consumption side of the model that has a direct bearing on the level economic growth. These generations considered the USA economy and energy situation and therefore cannot be a replica of the situation in developing economies such as Kenya.

Majority of these discrepancies were widely attributed to the use of Engle-Granger cointegration procedures which have been downplayed due to its low power and size properties of associated samples though this has been addressed by the more recent studies exploiting more robust, Johansen's, VECM, Toda-Yamagoto and Dolado-Lutkepohl which are conducted whether the variables have a unit root or not. They are also conducted whether there is cointegration amongst variables or not.

The existing literature and body of knowledge provide mixed and conflicting results with respect to the relationship between energy consumption and the level of economic growth. Some literature shows the existence of a bidirectional relationship between energy use and economic growth, some portray a unidirectional relationship, and others suggest that there's no relationship while others pose mixed results. The conflicting results of the past studies are largely attributed to the use of using different econometric and analysis techniques, different time periods, different climatic and weather conditions, different energy consumption patterns amongst the countries and the fact that some countries were at a different stage of economic development at the time of study.

In the existing body of knowledge in the field of energy economics in Kenya, none explains the specific effect of renewable energy consumption on economic growth. Again, majority of these studies are studies done in the developing world and may therefore not be replicated in the developing economies such as Kenya. The studies also treated energy as an aggregate variable hence disaggregating is important so as to isolate the specific effect of renewable energy on economic growth. This shall serve to aid in policy making as governments shall be to able identify specific effects of each form. The empirical studies, other than Borozan (2013), only address the sign of the causal relationship between the variables; the magnitude and direction of the causal relationships were overlooked.

2.3.2 Effect of Renewable Energy Investment on Economic Growth

Renewable energy investment is the channeling of resources to fund renewable energy generation and supply processes and is aimed at increasing the volumes of renewable energies available for consumption.

Ohlers and Fetters (2014) sought to establish the causal linkage between electricity investments and GDP from 20 OECD economies for the period 1990-2008 using the pedroni panel cointegration test and confirmed the existence of a bidirectional linkage between renewable energy investments and the level of economic growth, both in the short run and in the long run.

The study, apart from being from the richer OECD economies, does not make use of most recent data that can be exploited in policy formulation in recent times. The study also focused more on the nonrenewable energy forms that leave no guarantee for the future. This study sought to exploit the most recent Kenyan data to unearth the relationship between Kenya's renewable energy investment and her corresponding level of economic growth.

Amir et al (2020) did a study involving 18 different countries for the period 2008-2015 and established a positive association between renewable energy investment and economic growth. The study, apart from being from more developed economies, used annual data for a very short period and therefore the findings may not really be a true reflection of the energy situation in the 18 economies. This study mitigated this by making use of sufficient data for a period of 38 years (1980-2017).

2.3.3. Effect of Renewable Energy Investment on Renewable Energy Consumption

Sadorsky (2010), focusing on the non-linear effects of financial and income developments on energy consumption employed a panel threshold regression from 53 countries using data for the period between 1999-2008 and established that energy consumption had a positive impact on the level of traded stocks. It therefore implies that the level of energy consumption increases with the increase in the level of economic performance in both the high and low-income economies. The study also used fewer observations that cannot constitute a sound study econometrically. This study exploited the most current data specific to the Kenyan case to establish if the above findings are a true reflection of the Kenyan economy using 38 observations that are deemed adequate.

Zhang (2011) asserts that financial developments are correlated with the magnitude and intensity of capital flows, capital markets and Foreign Direct Investments (FDI) in China. It further argues that increase in financial well-being of an economy means there are enough resources that shall be available for investment in the renewable energy sector. These investments serve to increase the level of renewable energy available for consumption. On the part of households, it argues that increase in the financial well-being of the units increases their energy consumption in automobiles and machinery hence contributing to the overall increase in the level of energy consumption. The study, however, is from a developed economy hence may not be a true reflection of the Kenyan energy situation.

Some studies suggest that investment in the energy sector do not in any way influence the level of energy consumption (Islam et al, 2013).On the lack of consensus on the link between investments and consumption, Zhang (2015) suggests it could be due to heterogeneity across the countries, in terms of political climate, economic performance and location.

The studies above, however, treated investment as an aggregate variable. They could not isolate the exact percentage of the investments channeled to the energy sector. This study mitigated the said inadequacies by using energy specific data so that the findings and recommendations obtained can aid in formulation of sound renewable energy policies.

2.4 Summary of Literature and Knowledge Gaps

The previous studies have several gaps that need to be filled; theoretical, methodological and empirical gaps.

Methodological gaps in this study encompass all gaps regarding exploitation of traditional analysis techniques by past scholars. In the literature on energy consumption-economic growth nexus, the studies regarding the intensity and magnitude of the causal relationships amongst the three key variables in developing economies needs to be done for policy making purposes. There is also need to make use of more recent data so as to unearth the current relationships to inform policy in the recent times and current economic situations. Use of more robust econometric tools like the VECM also comes in handy to mitigate the inefficiencies posed by traditional analysis techniques like the granger besides exploiting data specific to Kenya, or economies at the same stage of economic growth as Kenya. The sign and intensity of any causal relationship between renewable energy and economic growth need to be well defined using robust analysis tools other than the traditional ARDL and granger. Also, some studies have studied energy as an aggregate variable hence there's need to disaggregate the various energy forms into renewable and nonrenewable, to establish the contribution of each form on economic growth. This will aid in determining the optimum level of renewable energy consumption that is sufficient for the attainment of the desired level of industrialization and economic growth in Kenya.

Empirical gaps include studies that were done in the developed economies and may therefore not be replicable to the Kenyan case and the fact that various studies posed mixed and conflicting results on the nexus between renewable energy and economic growth. Also, some studies, for instance Obange *et al* (2013), only focused on the effect of energy consumption on the manufacturing sector, which accounts for only 10% of GDP and hence there is need to establish how renewable energy investment and consumption impact the entire economy. This shall aid in appropriate decision making and policy formulation. Most of the relevant studies on the nexus between renewable energies and economic growth have been done in the developed countries and therefore the results may not portray the situation in Kenya and economies at the same stage of development as Kenya. Majority of the reviewed studies on the link between energy investments and consumption and the corresponding level of economic growth majorly focused on the production side models. Studies that focus on consumption side should also be done. Moreover, the studies reviewed also did not carry out stability tests to establish and confirm the stability and reliability of the models used in the analysis of renewable energy and economic growth dynamics. Similarly, some studies also used very short sets of data that that are econometrically considered insufficient to conduct a good study. The 38 sets of data (1980-2017) exploited by this study are good enough for a sound econometric study.

A theoretical gap in the energy-economic growth nexus concerns the use of the Cobb-Douglas model with capital (K) and labour (L) only to explain growth in GDP, thereby ignoring important factors like energy investment and consumption. The Cobb-Douglas model therefore had to be operationalized to include renewable energy investments and consumption. Therefore, GDP, renewable energy investments and consumption were incorporated as the main variables in this study while capital and labour were incorporated as the control variables to make this study more robust.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter highlights the philosophy of the study, research design, target population, sampling techniques, sample size, data types and sources, analysis and presentation.

3.2 Philosophy of the Study

This study adopted the pragmatist research philosophy as it sought to deal with actual facts out and about the field of renewable energy and the choice of its analysis tools were dictated solely by the problem being solved and the objectives. Therefore, the study had the freedom to exploit any scientific procedures, methods and techniques that address the renewable energy investment and consumption dynamics as it sought to unravel the nature and magnitude of the causal relationship existing between renewable energies and economic growth in Kenya.

3.3 Research Design

This is an action plan of a proposed research work (Creswell, 2003). Cohen (2013) alluded that a research design helps a researcher in keeping track of his research actions and goals. This study adopted the correlational research design to unravel the nature of the relationship existing between renewable energies and economic growth. The correlational research design was chosen as it's a research design capable of establishing the nature of relationships between variables (Kothari, 2004). Annual time series data from the Energy Information Administration and World Bank databases for the period 1980-2017 was used to establish the relationship existing between the key renewable energy forms and economic growth. This aided in understanding the interrelationships amongst the study variables and their interpretation for prediction, forecasting and policy making.

3.4 Study Area

This study focused on the energy sector in Kenya. Kenya is a country in the eastern part of Africa. Her neighbors include Ethiopia, Tanzania, Uganda, Somalia and Southern Sudan. Kenya lies at latitude 0.4252ºS and longitude 36.7517ºE. Kenya has an estimated population of 47 million people according to the Kenya 2019 census report. In Africa, Kenya tops in geothermal and solar power development. About 9 million people in Kenya have access to off-grid renewable energy supply and 49% of the country's population has access to hydro power connection. There's a mega geothermal power project installed at Olkaria. Kenya has a geographical advantage because it is located across the equator making it a flourishing solar energy market. In fact, Kenya tops Africa in the number of solar energy systems installed per capita and boasts of 5-7 peak insolation hours and an average daily insolation of about 4-6kWh/m^2.Solar energy has continued to provide affordable electricity to households that are far from the national grid. Kenya has notable solar power dealers, for instance, Mkopa, which is a product of the giant telecommunication firm, Safaricom Limited, and a number of institutions such as World Bank and International Finance Corporation (IFC) have come on board to form a Lighting Africa Initiative (LAI).

HEP accounts for 49% of the total renewable energy installed capacity. Hydro-electric power is produced mainly at the seven forks scheme.

3.5 Target Population

Target population entails the elements being considered in a study (Neuman, 2014). This study targeted the volumes of renewable energy in million kilowatts that were consumed and the corresponding renewable energy investments over the period under study (1980-2017). The study therefore considered a time period of 38 years. This study period was selected as it's the period that preceded the global oil crisis that brought the topic of sustainability and efficiency in energy value chain in focus. It is also the period that preceded massive investments and exploitation of renewable energy sources as alternative energy sources to mitigate the global oil crisis.

3.6 Model

This study adopted the Cobb Douglas production function to explain the relationship between the key renewable energy forms and economic growth (The key renewable energy forms are hydro-power, wind, solar and geothermal energies). The Cobb-Douglas production theory showed that energy investment and consumption determine the level of output and GDP. This, however, can be affected by extraneous variables, capital and labour. According to Gujarati (2011), the Cobb-Douglas production function is however crucial in estimating the relationship where the function is nonlinear in variables with non-constant slope. From equation 1.1, the Cobb-Douglas function was given as;

$$LnY_t=LnA_t+\beta_1LnK_t+\beta_2LnL_t+\beta_3LnTREC_t+\beta_4LnTRI_t+\varepsilon_t \quad (3.1)$$

Because the study involved the examination of effect, it was assumed that the variables were linear and had a constant slope. The Cobb-Douglas production function was modified into a new linear functional form of the model that was adopted and specified as;

$Y_t = A + B_1 TREC_t + B_2 TRI_t + \varepsilon_t$ ………………………….………. …..………………….. (3.2)

Incorporating capital and labour as the control variables yields;

$Y_t = A + B_1 K + B_2 L + B_3 TREC_t + B_4 TRI_t + \varepsilon_t$…………………………….………………………………………………… (3.3)

Where *A* is a constant

K is capital

L is labour

$TREC_t$ is total renewable energy consumed at time *t*

TRI_t is the total renewable energy invested at time *t*

$\mathcal{E}_{(t)}$ is the error term

K_t and L_t are the control variables. They are the factors other than renewable energy investment and consumption affecting GDP growth at time *t.*

According to Gujarati (2011), the model can be expanded to include more factors besides capital and labour. Renewable energy investment and consumption play a critical role in GDP growth. In Kenya, it drives all sectors of the economy, including manufacturing activities that contribute an approximate 10% to the Kenyan GDP. This justifies why the Solo-swan model as explained by the Cobb-Douglas production function was used to specify the energy model.

3.7 Data Set and Measurement of Variables

The data under study focused on the period 1980 to 2017 as this period came immediately after the major energy crisis which was hatched following the move by the members of Arab oil exporting companies declaring an oil embargo. The study therefore covered a period of 38 years. The main variables were GDP, renewable energy consumption and renewable energy investments while capital and labour were incorporated as the control variables. The study focused on annual time series secondary data from EIA and WDI.Secondary data is data that has been collected before. (Kombo & Tromp, 2006). It entails making use of data that is already published. Authority to collect the data was granted by the school of graduate studies, Maseno University.

No.	Variables	Measures	Sources
1.	GDP	Nominal price levels (millions dollars)	-WDI
2.	Renewable energy investments	Million dollars	-EIA
3.	Renewable energy consumed	Million kilowatts	-WDI
4.	Capital	Amounts invested (Million dollars)	-EIA
5.	Labour	Productive population (millions)	-WDI

(Source, own conceptualization,2022)

3.8 . Data Analysis and Presentation.

3.8.1 Diagnostic Tests

The validity and reliability of secondary data needs to be ascertained using pre-diagnostic tests so as to increase our level of confidence in the outcomes. The tests included the tests for the presence of multicollinearity, heteroskedasticity, serial correlation and the normality test.

3.8.1.1 Test for Stationarity

The ADF technique was used to test if the mean, variance and autocorrelation were constant over time, as it is a test capable of handling complex models and is more powerful (Fuller, 1976).Granger and Newbold (1974) propound that if the variables are found to be non-stationary, they may lead to spurious results. Therefore, it's crucial that the data under consideration becomes stationary.

3.8.1.2 Test for Autocorrelation

The serial autocorrelation test was carried out to test for correlation of error terms. This study made use of the Breusch-Godfrey serial correlation test as proposed by Breusch (1978) and Godfrey (1978) to test the null hypothesis of no autocorrelation. This method is preferred as it goes beyond just testing for first order autocorrelation. This test was conducted to determine if the error terms of any varying observations were found to be mutually independent. In this test, the following model was being estimated and residuals obtained;

$$In\ Y_t=\beta_0+\beta_1 TREC_t+\beta_2 TRI_t + \varepsilon_t \quad (3.4)$$

Where Y_t is the level GDP at time *t;*

RC_t is the level of renewable energy consumption at time *t*;

RI_t is the level of renewable energy invested at time *t*;

ε_t is the error term.

Residuals were then regressed and R^2 obtained;

$$RESID=\beta_0+\beta_1 TRECt+\beta_2 TRI_t+RESID\ (-1)\ +V_t \quad (3.5)$$

Where RESID and RESID (-1) were the corresponding residuals and lagged residuals respectively. The choice of a conventional lag length of one was chosen because the data being exploited is annual data (Gujarati, 2011).

3.8.1.3 Test for Multicollinearity

Multicollinearity arises when some explanatory variables in a model are highly correlated. It therefore makes it hard to establish how individual explanatory variables are influencing the dependent variable (Koop, 2013). This study exploited the correlation matrix to test for the presence of multicollinearity. If the correlation coefficients were found to be tending towards 0.8, VIFs could be used to confirm the presence or absence of severe multicollinearity. Use of VIFs, apart from identifying correlation amongst independent variables, is capable of determining the magnitude and strength of the said correlations. VIFs are calculated as follows;

$$VIF\ (b_i)\ =1/1-R_i^2 \quad (3.6)$$

Where R^2 is the squared multiple-correlation coefficient.

If $VIF\geq 10$, it's concluded that multicollinearity exists.

3.8.1.4 Test for Heteroskedasticity

Heteroskedasticity occurs when the error term is not constant and this serves to affect the efficiency of the OLS estimators (Breusch and Pagan, 1979). The Breusch-Pagan-Godfrey was used to test for heteroskedasticity as it has no restrictions and is statistically more powerful than Durbin's *h* statistic and its ability to test for higher order serial correlation. In testing for heteroskedasticity, the following hypotheses are tested;

$H_0 : Var\ (u/x) = \sigma^2$ indicating presence of homoskedasticity and

$H_0: Var\ (u/x) \neq \sigma^2$ indicating there's heteroskedasticity.

The B-G test for Heteroskedasticity requires that the p-value is less than 0.05 to reject the null hypothesis.

3.8.1.5 Normality Test

The J-B was used to test the normality of the residuals. This is because it is more comprehensive, robust than Skewness and kurtosis tests as it combines the two tests (skewness and kurtosis). This test sought to establish the normality of the distribution using the following hypotheses;

H_0: errors are normally distributed

H_1: errors are not normally distributed.

The J-B statistic of about 3 with a *p* value greater than 0.05 signifies the normality of residuals (Gujarati, 2011).

3.9 Test for Cointegration

This was used to establish the existence of long run relationship between economic growth and the key renewable energy forms as it is a technique capable of testing and detecting multiple cointegrating vectors (Russell & Mackinnon, 1999). The Johansen's cointegration test for the OLS was used. The VECM was also carried out to establish the short run relationships between renewable energy investments and consumption and economic growth. Variables were examined for first order stationarity then the lag length determined using the various available criteria such as the AIC.

3.10 Causality Test

This study adopted the granger causality test as it's a popular method for studying causal links between random variables (Granger, 1969).

3.11 Data Presentation

According to Leedy (1989) the need for researched data to be analyzed and interpreted is in order to draw information that can lead to decision making. Diagnostic and inferential analyses were performed to avoid spurious regression and results. This study made use of the granger causality test to establish the presence of relationships amongst the variables while the cointegration test and VECM were exploited to establish the intensity of the relationships amongst the study variables. The descriptive statistics were exploited to describe the data that was exploited while the inferential statistics, regression and correlation were used to analyze the data. Tests of significance were used to determine the acceptance and rejection criteria of the various null and alternative hypotheses in the study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter highlights the results of the findings in tables, graphs, charts and figures.

4.2 Descriptive Statistics

Descriptive statistics were run to define the basic distributional characteristics of GDP, renewable energy and the control variables' data. Computation of the mean, maximum, minimum, standard deviation, Skewness, and kurtosis was designed to reveal how good the data under consideration was. The mean was meant to give the overall average of the frequencies. The standard deviation defined the dispersion within the distribution while trend analysis helped assess the movement of renewable energy consumption Vis a Vis investment to determine long run sustainability. The Skewness, kurtosis and Jarque-Bera were meant to also test for the normality of the data. The study concluded that the variables are symmetric. It therefore rejected the null hypothesis that the variables were not normally distributed around their mean. The distributions are platykurtic to the means as all the three sets of data have a kurtosis value of less than 3. (A normal distribution should have a kurtosis value of 3).The kurtosis values also show that there are no extreme variations in the distributions relative to the normal.

Table 4-1: Descriptive statistics

	GDP	TREI	TREC	K	L
Mean	90.00000	0.635834	3.230229	17.79102	13.95605
Maximum	190.0000	0.925600	5.180000	40.81200	22.40000
Minimum	31.00000	0.249000	1.182000	6.748700	8.870000
Skewness	0.718672	-0.432891	-0.230624	0.934972	0.660348
Kurtosis	1.959598	2.416655	2.311474	2.269833	2.312029
Jarque-Bera	4.984963	1.725625	1.087461	6.380571	3.511107
Sum	3420.000	24.16170	122.7487	676.0589	530.3300
Observations	38	38	38	38	38

(Source, own computation, 2022)

There were a total of 38 observations (1980-2017).

The Skewness of a normal distribution is zero. Therefore, the positive skewness values (0.718672, 0.934972 and 0.660348) for GDP, capital and labour imply the distribution had a slightly longer right tail. The data was therefore symmetrical, whereas the total renewable energy consumed and total renewable energy invested have a slightly longer left tail as depicted by the slightly negative values of Skewness, -0.432891 and -0.230624, for total renewable energy investments and total renewable energy consumption respectively. The data set was thus symmetrical. The mean of GPD over the 38 years was established to be 90.00000 (million dollars), this being the average of the 38 observations. The average total renewable energy investments and consumption over the 38 observations was found to be 3.230229 million kilowatts and 0.635834 units respectively. The mean capital and labour employed over the 38 years was found to be 17.79102 million dollars and 13.95605 million people respectively, these being the averages for the study period.

The maximum and minimum values for GDP were found to be 190.0000 million dollars (value for the year 2012) and 31.00000 million dollars for the year 1986 respectfully. The greatest amount of total renewable energy invested was 0.925600 million dollars , which was invested in the year 2010 while the minimum was 0.249000 million dollars , an amount invested in 1980.The highest consumption of the renewable energy was observed to be 5.180000 million kilowatts (2010) while the lowest consumption was 1.182000 million kilowatts, an amount consumed in the year 1980.The maximum capital invested was 40.81200 million dollars, an amount invested in 2012 while the minimum was 6.748700 million dollars in 1986.The highest number of the productive population was found to be 22.40000 million people,being the workforce for 2017 while the minimum labour force was observed in 1988(8.870000 million people).

All the 5 variables have a kurtosis value of less than 3 implying the data is platykurtic (1.959598, 2.232129, 2.311474, 2.269833 and 2.312029 for *GDP*, *TREI*, *TREC*, *K* and *L* respectively).Since kurtosis measures how tall or flat (pickedness) of a distribution, it was observed that the normal distribution was relatively flat.

The sum of the *GDP* for the entire study period (1980-2017) was observed to be 3420.000 million dollars. The sums for the total renewable energy investments and consumption were found to be 24.16170 and 122.7487 million kilowatts respectively. The total capital employed for the period was 676.0589 million dollars.

4.2.1 Renewable Energy Consumption and Investment trends in Kenya.

Renewable energy investment and consumption trends were analyzed using the computed trend equations below as in figure 4-1 and figure 4-2.

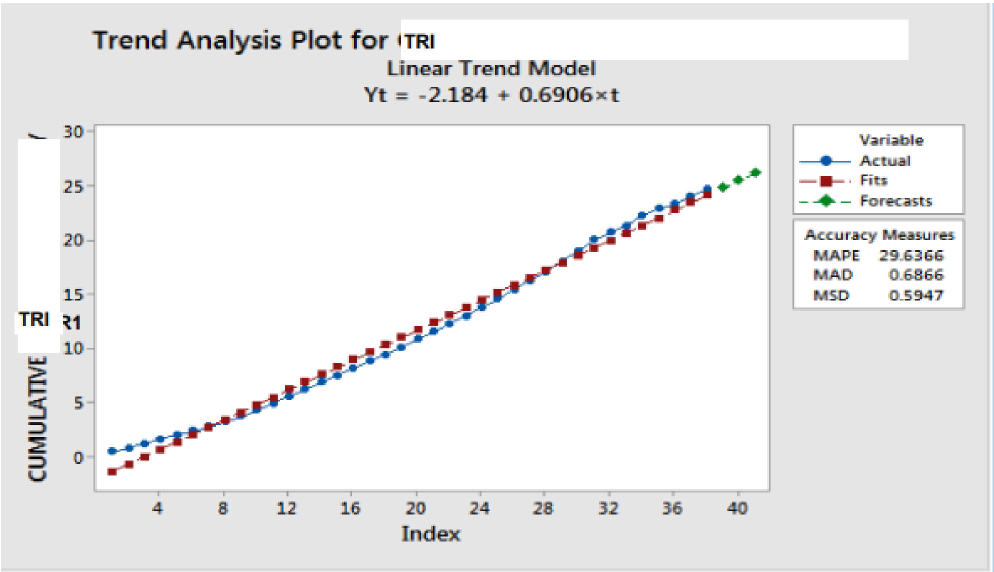

Figure 4:1-Kenya's TRI trends invested for the period 1980-2017.

(Source, own computation, 2022)

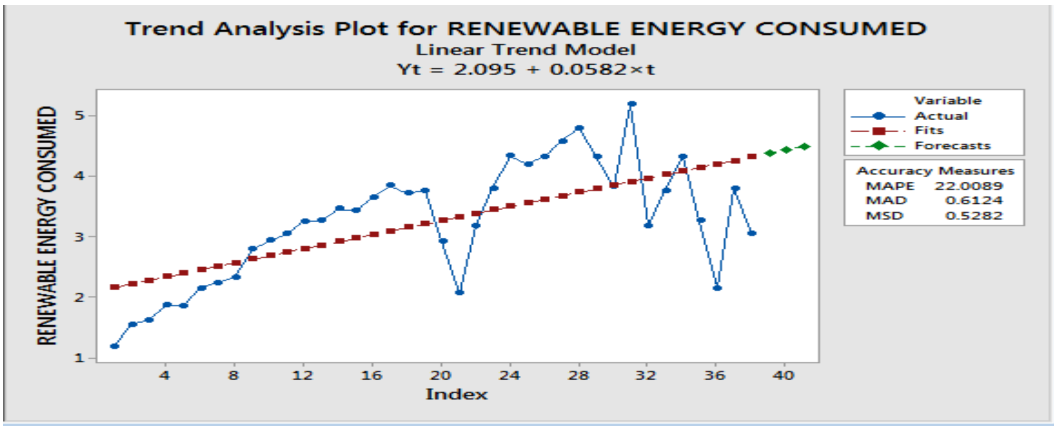

Figure 4:2-The trend analysis for total renewable energy consumed for the period 1980-2017

(Source, own computation, 2022)

From the trend analyses of renewable energy consumption and investments since 1980, it was observed that both investment and consumption graphs exhibited an increasing trend since the 1970s oil crisis, though the trends have risen in jumps and jerks as indicated by the linear trend equations;

Yt=-2.184+0.6906t ………………………………………………………………………………(4.1)

for the trend of Kenya's renewable capacity and

Yt=-2.184+0.6906t ……………………………………………………………………(4.2)

For Kenya's renewable energy consumption trend for the period 1980-2017.*t* is the trend factor. (This is because trend is explained in terms of time).These trends show that there have been significant investments in the renewable energy sector since the 1970s oil crisis as shown by the increasing installation capacities and investments though the renewable energy consumption levels have been increasing at a decreasing rate showing a mismatch between capital injections in renewable energy development and the amounts of renewable energy actually consumed, thereby revealing possibilities of inefficiencies and underutilization in the in the value chain that could be occasioned by exploitation of traditional and outdated energy generation and supply equipment. The levels of renewable energy installations are a reflection of the investments in the sector. This trend for Kenya's investment and consumption patterns is similar to that of Iran as established by Fung (2009) though Iran is not at the same stage of economic growth as Kenya. The weather and climatic differences between Kenya and Iran means it's not rational to compare the performance of renewable energy dynamics of the two economies for policy formulation.

4.3 Diagnostic Tests

4.3.1 Heteroskedasticity Test

Heteroskedasticity is a phenomenon where the error term is not constant. It was used to establish whether the error terms were constant across board in the time series data. The test involved testing the null hypothesis that the data did not suffer from homoskedasticity. Heteroskedasticity test was run and the results in the table below obtained;

Table 4-2: Heteroskedasticity results

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	3.138113	Prob. F(4,33)	0.0272
Obs*R-squared	10.47129	Prob. Chi-Square(4)	0.0332
Scaled explained SS	3.080794	Prob. Chi-Square(4)	0.5444

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample: 1980 2017
Included observations: 38

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-53.64714	45.29725	-1.184336	0.2447
TREC	24.41928	14.88248	1.640808	0.1103
TREI	-101.0540	77.67871	-1.300922	0.2023
K	-2.020750	1.141205	-1.770716	0.0858
L	8.680446	2.996164	2.897186	0.0066

R-squared	0.275560	Mean dependent var	46.17269
Adjusted R-squared	0.187750	S.D. dependent var	41.33253
S.E. of regression	37.25091	Akaike info criterion	10.19531
Sum squared resid	45791.81	Schwarz criterion	10.41078
Log likelihood	-188.7109	Hannan-Quinn criter.	10.27197
F-statistic	3.138113	Durbin-Watson stat	1.724041
Prob(F-statistic)	0.027169		

(Source, own computation, 2022)

The observed chi-square value (=nR^2) of about 10.47129 with a p value of 0.0332 suggested null hypothesis could not be rejected. The F-statistic (with a p value of 0.0272) was also significant and could not lead to rejection of the null hypothesis of homoskedasticity. It was therefore concluded that the regression did not in any way suffer from heteroskedasticity.

4.3.2 Test for Autocorrelation

The econometric problem of Serial correlation is said to exist when error terms of different time periods are correlated (Koutsoyiannis, 2004). The test involved establishing whether in the linear classical regression model, the random term in time *t* was correlated with the error term in time *(t-1)* or any other time period. Therefore, Serial correlation tests were done to check for correlation of error terms across time periods. The Breusch-Godfrey serial correlation LM test was exploited to check for autocorrelation. The null hypothesis was that no first order serial /auto correlation exists. The study accepted the null hypothesis of no serial correlation and thus concluded that serial correlation did not exist after increasing the number of lags from the conventional 1 to 5. The results were as presented in table 4-3;

Table 4-3: Serial Correlation test results

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	6.577246	Prob. F(1,32)	0.0152
Obs*R-squared	6.478828	Prob. Chi-Square (1)	0.0109

***(Source*, own computation, 2022)**

The observed R squared was the LM test statistic for the null hypothesis that stipulated that no serial correlation existed. As shown by the results, there was first order autocorrelation as both the F and X^2 values were significant because their p-values were less than 0.05 leading to the rejection of the null hypothesis of no serial correlation in residuals. There was therefore serial correlation and this was remedied by increasing the number of lags from 1 to the 5 as recommended by the Akaike Information Criterion (AIC), Final Prediction Error (FPE), Schwarz criterion (SC) and the Hannan-Quinnin (HQ) information criterion. Primarily, the data exploited by this study is annual hence previously settling on the conventional lag of 1. The other remedy was to drop one of the collinear variables but that would have meant doing away with one of the most important control variables. So, with the recommendation of Gujarati (2004), the study increased the number of lags from the conventional 1 to a lag of 5.

4.3.3 Normality Test

The J-B test was used to establish the normality of the residuals since it is stronger as it is a combination of both Skewness and kurtosis tests. The residuals are normally distributed when the Jarque-Berra statistic is not significant. The reported p value is the probability that the J-B statistic exceeds (in absolute value) the observed value under the null hypothesis. This implies that if the p-value is bigger than 0.05, the null hypothesis cannot be rejected but a smaller p-value would lead to rejection of the null hypothesis of normality. The test involved testing the following hypotheses;

H_0: errors are normally distributed

H_1: errors are not normally distributed.

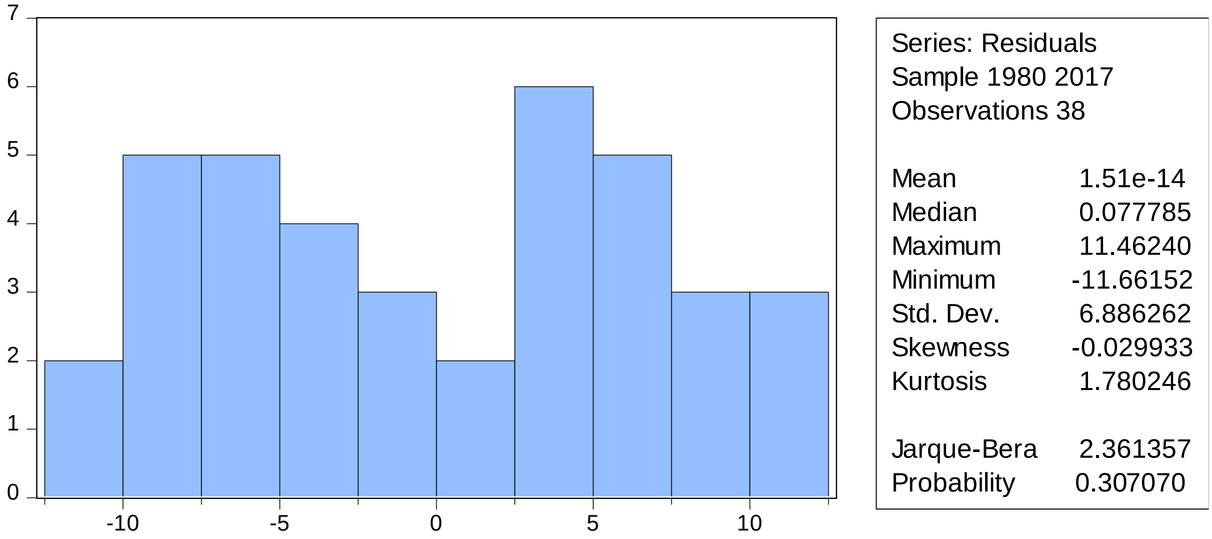

Figure 4-3 Normality test results

(Source, own computation, 2022)

Figure 4-3 indicated that the residuals derived from the model under study were normally distributed and were significantly different from zero and therefore the null hypothesis that there was normality was accepted, indicating presence of normality with a The J-B value of 2.361357, hence, the conclusion that the inferences made about the coefficients were good.

4.3.4 Test for Multicollinearity

4.3.4.1 Correlation Matrix

The correlation matrix is an analysis tool that seeks to analyze the covariance or the association of variables in a model. The results are as shown in table 4-4;

Table 4-4: Correlation Matrix results

Correlation t-Statistic Probability	GDP	TREI	TREC	K	L
GDP	1.000000 ----- -----				
TREI	0.543285 3.882693 0.0004	1.000000 ----- -----			
TREC	0.505285 3.513181 0.0012	0.904468 12.72279 0.0000	1.000000 ----- -----		

K	0.981868	0.446310	0.420276	1.000000	
	31.07716	2.992430	2.779000	-----	
	0.0000	0.0050	0.0086	-----	
L	0.766928	0.050989	0.022629	0.777697	1.000000
	7.170521	0.306332	0.135810	7.422659	-----
	0.0000	0.7611	0.8927	0.0000	-----

Covariance Analysis: Ordinary
Sample: 1980 2017
Included observations: 38
***(Source*, own computation, 2022)**

The results show a positive and significant correlation between GDP and the total renewable energy consumed, total renewable energy invested and total renewable energy consumed, capital and GDP, labour and GDP and total renewable energy invested and GDP because their corresponding p-values were significant as they were less than 0.05. The positive signs of the correlation coefficients implied that when one of the paired variables is high, the other variables moved in the same direction. This test therefore established that there was a positive association amongst all the study variables. All the correlation coefficients were less than 0.08 except for the coefficient for labour and total renewable energy consumption (0.8927) hence the need to confirm the presence or absence of multicollinearity using the variance inflation factors.

Test for multicollinearity involved ascertaining whether the centered VIF values were more or less than 10 (Gujarati, 2004).

4.3.4.2 Use of Variance Inflation Factors (VIFS)

Test for multicollinearity involved ascertaining whether the centered VIF values were more or less than 10 (Gujarati, 2004). This followed after some variables were found to have coefficients that were greater than 0.08 using the correlation matrix.

Table 4-5; Variance Inflation Factors

Variable	Coefficient Variance	Centered VIF
C	78.61847	NA
TREC	8.486555	5.674342
TREI	231.1985	5.774677
K	0.049901	4.486906
L	0.343963	3.606662

***(Source*, own computation, 2022)**

As per the VIF results in table 4-5, all the centered VIF values were less than the conventional 10. It was therefore concluded that the set of data did not suffer from severe multicollinearity.

4.3.5 Stationarity Test Results

The AADF was exploited to test for stationarity of the residuals since ADF augments the equations being tested by adding lagged variables hence making residuals purely random.

Table 4-6; ADF test results

	At Level			At First Difference			Inference
Variables	**t-statistic**	**Critical values 1%** / **5%**	**P-value**	**t-statistic**	**Critical values 1%** / **5%**	**P-value**	
GDP	0.756928	-3.621023 -2.943427	0.9918	-4.489095	-3.632900 -2.948404	0.0010	I (I)
TREI	0.25534	-4.252879 -3.548490	0.9975	-3.630092	-4.252879 -3.548490	0.0420	I (1)
TREC	-2.827786	-3.621023 -2.943427	0.0641	-6.464215	-3.632900 -2.948404	0.0000	I (1)
K	0.022871	-3.621023 -2.943427	0.9548	-5.170973	-3.626784 -2.945842	0.0001	I (1)
L	3.59961	-3.679322 -2.967767	1.0000	-3.774912	-3.679322 -2.967767	0.0079	I (1)

***(Source*, own computation, 2022)**

It was observed that all the three main study variables (GDP, total renewable energy investment, total renewable energy consumed) and the controls (capital and labour) became stationary at first difference. This is because the critical values for all the study variables both at 1% and 5% were observed to be greater than the absolute 2 at first difference. The associated probabilities were also observed to be less than 0.05 at first difference. The study therefore conducted the cointegration test so as to determine the existence of long run associations between the renewable energies and economic growth.

4.4 Cointegration Test

Test for cointegration was carried out to establish the presence of long run associations amongst the variables. The Johansen test, Trace and Maximum Eigen value tests were carried out. This test involved testing the null hypothesis of zero cointegrating relationships against the alternative hypothesis of one or more cointegrating relationships. Therefore, the test sought to establish the existence of a long run relationship existing amongst the study variables. Variables are cointegrated if they have a long run equilibrium relationship between them, that is, they move in the same direction, (Gujarati, 2004). It's a technique meant to analyze data that is not stationary at levels. In this study, this technique was exploited due to the existence of a unit root in the variables as indicated in table 4.6.A Johansen Cointegration test was done with $(\rho = 5)$ lags and results in table 4-7 obtained. Cointegration test was done to test the null hypothesis of zero cointegrating relationships against the alternative hypothesis of 1 or more cointegrating relationships. The null hypothesis was rejected as there were cointegrating relationships. The results are tabulated in table 4-7;

Table 4-7-Cointegration Test Results

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.830725	74.23016	29.79707	0.0000
At most 1 *	0.409983	17.39085	15.49471	0.0256
At most 2	0.015735	0.507525	3.841466	0.4762

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

Unrestricted Cointegration Rank Test (Maximum Eigen value)

Hypothesized No. of CE(s)	Eigen value	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.830725	56.83930	21.13162	0.0000
At most 1 *	0.409983	16.88333	14.26460	0.0188
At most 2	0.015735	0.507525	3.841466	0.4762

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

GDP	TREC	TREI
-0.142399	-1.668562	21.32527
-0.024533	8.891751	-38.79915
-0.174458	-0.835160	-5.347003

Unrestricted Adjustment Coefficients (alpha):

D(GDP)	5.328225	0.715491	-0.168225
D(TREC)	0.143921	-0.212948	-0.020216

D(TREI)	-0.006013	-0.001219	-0.006290

Sample (adjusted): 1986 2017
Included observations: 32 after adjustments
Trend assumption: Linear deterministic trend
Series: GDP TREC TREI
Exogenous series: K L
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 5
(Source, own computation)

In estimating the Johansen Cointegration, two variables Capital and Labour were added as exogenous variables to be considered in VAR.From the table, the null hypothesis of no cointegration was rejected at none and at most 1 cointegrating equation. Using Trace test and the Maximum Eigen value test, the Johansen Cointegration test showed that there were two cointegrating equations at the 0.05 level.

In the long run, with GDP designated as the dependent variable, the Johansen Normalization cointegrating equation results appears as shown in tables 4-7-1;

Table 4-7-1: Cointegration Test Results

1 Cointegrating Equation(s): Log likelihood-36.89606

Normalized cointegrating coefficients (standard error in parentheses)

GDP	TREC	TREI
1.000000	11.71754	-149.7575
	(7.96219)	(38.9526)

Adjustment coefficients (standard error in parentheses)

D(GDP)	-0.758732
	(0.11737)
D(TREC)	-0.020494
	(0.01482)
D(TREI)	0.000856
	(0.00198)

2 Cointegrating Equation(s): Log likelihood -28.45440

Normalized cointegrating coefficients (standard error in parentheses)

GDP	TREC	TREI
1.000000	0.000000	-95.53920
		(15.6926)
0.000000	1.000000	-4.627104
		(0.59893)

Adjustment coefficients (standard error in parentheses)		
D(GDP)	-0.776286	-2.528506
	(0.11560)	(7.23766)
D(TREC)	-0.015270	-2.133621
	(0.01238)	(0.77523)
D(TREI)	0.000886	-0.000807
	(0.00201)	(0.12606)

(Source, own computation, 2022)

Two cointegration results were obtained; the Trace and the Eigen value. The null hypothesis of no cointegration equation and at most one cointegration equation were rejected, both by the Trace and maximum Eigen values. Overally, the test indicated that there existed one cointegrating equation. Considering the normalized cointegrating coefficients, GDP was incorporated as the dependent variable. In the long run, signs of the coefficients are reversed and thus the results show that GDP is positively related to TREC and TRI, ceteris paribus. The null hypothesis of no cointegration was rejected against the alternative hypothesis of a cointegrating relationship in the model

In the short run, TREC had a negative impact while TREI had a positive impact on GDP, on average, ceteris paribus. This is mainly because it takes some time for any capital investment to be recouped. The coefficients were statistically significant at the 0.05% level. However, in the long run, the three key variables positively influenced each other. Thus; the null hypothesis of no cointegration was rejected against the alternative of a cointegrating relationship in the long run.

In order to determine cointegration between the variables, Trace and Eigen value techniques were used based on the null hypothesis of no cointegration. Findings indicated that both the unrestricted cointegration Rank (Trace) and unrestricted cointegration Rank test (maximum Eigen value) indicated the presence of cointegrating equation at 0.05 level of significance with (p=0.001), by rejecting the null hypothesis of no cointegrating equations. Further findings indicated a positive association in the long run between GDP and total renewable energy investments, consumption, capital and labour.

4.5 Lag length Determination

Since one independent variable in a series could affect the dependent variable belatedly, it was critical that a lag length be determined. A Vector Auto-regressive Model was estimated and used to establish the lag length. The optimal lag length (ρ) estimation yielded the results as shown in table 4-8;

Table 4-8; VAR Test Results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-300.3522	NA	74.95623	18.50620	18.73294	18.58249
1	-197.4112	168.4490	0.679466	13.78250	15.14296	14.24025
2	-181.8560	20.74025	1.347062	14.35491	16.84909	15.19412
3	-139.0488	44.10440*	0.625533	13.27568	16.90358	14.49636
4	-96.12020	31.22079	0.430189	12.18910	16.95072	13.79124
5	-14.11251	34.79114	0.068842*	8.734091*	14.62942*	10.71769*

* indicates lag order selected by the criterion

***(Source*, own computation, 2022)**

Using the Akaike Information Criterion (AIC), the appropriate optimal lag selected is 5 which is premised on the fact that the lower the value of AIC, the better the model and the fact that it has a less harsh penalty for adding regressors to the model (Ogajo, 2018).

This is also the lag length selected by most criterions such as Final Prediction Error (FPE) Schwarz criterion (SC) and the Hannan-Quinn (HQ) criterion..

4.6 Vector Error Correction Model (VECM)

Since there was cointegration established, it was thus important to estimate the Vector Error Correction Model using $(\rho - 1)$ lags because of using annual data. The estimation of the VECM model involved the use of a method developed by Johansen (1988) technique. It involved testing stationarity at 1st level, determining the optimal lag length, performing the basic VAR and diagnostic tests.

Table 4-9: VECM Results

Cointegrating Eq:	CointEq1
GDP(-1)	1.000000
TREI(-1)	-103.0589 (35.1484) [-2.93211]
TREC(-1)	-2.027698 (7.25740)

	[-0.27940]		
C	-16.25241		

Error Correction:	D(GDP)	D(TREI)	D(TREC)
CointEq1	-0.637764	0.000743	-0.011972
	(0.09835)	(0.00161)	(0.01204)
	[-6.48489]	[0.46040]	[-0.99454]
D(GDP(-1))	-0.268861	-0.000549	-0.025812
	(0.12383)	(0.00203)	(0.01516)
	[-2.17118]	[-0.27015]	[-1.70300]
D(GDP(-2))	-0.288348	0.001309	0.013340
	(0.12731)	(0.00209)	(0.01558)
	[-2.26499]	[0.62714]	[0.85613]
D(GDP(-3))	-0.288757	0.000666	-0.007316
	(0.14450)	(0.00237)	(0.01769)
	[-1.99829]	[0.28122]	[-0.41366]
D(GDP(-4))	-0.269569	-0.002095	-0.044773
	(0.15258)	(0.00250)	(0.01868)
	[-1.76674]	[-0.83710]	[-2.39739]
D(TREI(-1))	-69.46176	-0.277132	-1.558128
	(17.9410)	(0.29424)	(2.19597)
	[-3.87169]	[-0.94186]	[-0.70954]
D(TREI(-2))	-62.31975	-0.538682	-1.289805
	(17.9280)	(0.29402)	(2.19438)
	[-3.47611]	[-1.83210]	[-0.58778]
D(TREI(-3))	-15.77454	0.248376	2.477621
	(19.2185)	(0.31519)	(2.35235)
	[-0.82080]	[0.78802]	[1.05326]
D(TREI(-4))	3.752491	0.217596	1.159798
	(19.0437)	(0.31232)	(2.33094)
	[0.19705]	[0.69670]	[0.49757]
D(TREC(-1))	4.124137	-0.004883	-0.334759
	(1.94614)	(0.03192)	(0.23821)
	[2.11914]	[-0.15300]	[-1.40533]
D(TREC(-2))	4.581434	-0.007599	-0.032954
	(2.07177)	(0.03398)	(0.25358)
	[2.21136]	[-0.22364]	[-0.12995]

D(TREC(-3))	4.125101	0.045097	-0.162495
	(2.27405)	(0.03730)	(0.27834)
	[1.81399]	[1.20918]	[-0.58379]
D(TREC(-4))	2.234807	0.009978	-0.015853
	(2.21601)	(0.03634)	(0.27124)
	[1.00848]	[0.27454]	[-0.05845]
C	-49.78508	0.161789	-0.982979
	(11.5463)	(0.18936)	(1.41326)
	[-4.31179]	[0.85439]	[-0.69554]
K	2.372004	-0.003298	0.036540
	(0.30008)	(0.00492)	(0.03673)
	[7.90448]	[-0.67011]	[0.99481]
L	0.997588	-0.006708	0.043482
	(0.78727)	(0.01291)	(0.09636)
	[1.26715]	[-0.51957]	[0.45124]
R-squared	0.869293	0.779588	0.681698
Adj. R-squared	0.753963	0.585107	0.400844
Sum sq. resids	353.6461	0.095120	5.298231
S.E. equation	4.560999	0.074802	0.558266
F-statistic	7.537447	4.008556	2.427230
Log likelihood	-85.95949	49.68549	-16.64425
Akaike AIC	6.179363	-2.041545	1.978439
Schwarz SC	6.904943	-1.315966	2.704019
Mean dependent	4.363636	0.007576	0.036021
S.D. dependent	9.195169	0.116130	0.721225
Determinant resid covariance (dof adj.)		0.024973	
Determinant resid covariance		0.003414	
Log likelihood		-46.75731	
Akaike information criterion		5.924686	
Schwarz criterion		8.237470	
Number of coefficients		51	

Vector Error Correction Estimates
Sample (adjusted): 1985 2017
Included observations: 33 after adjustments
Standard errors in ( )& t-statistics in [ ]
(Source, own computation, 2022)

From the analysis in table 4-9 above, holding capital and labour constant, a unit change in total renewable energy consumption by a kilowatt hour in the current year leads to a decline in GDP by 0.024812 in the following year, an increase by 0.013340 in the second year and a 0.007316 and 0.044773 decline in the third and fourth year respectively. This is mainly because investment in total renewable energy consumption means resources are being spent in the energy sector hence the initial decline in GDP before it starts taking off again. Also it is important to note that resources spent in the energy sector take some time to be recouped in the subsequent periods before the long run positive relationship between total renewable energy consumption is realised as stipulated by the long run VECM equation. Every time resources are pumped into the energy sector they have an immediate negative effect on GDP because resources are being channelled out but become positive in the long run when the energy is spent on productive resources. The null hypothesis that renewable energy consumption does not influence economic growth is therefore rejected because from the analysis, renewable energy consumption influences economic growth in the long run.

It takes two years for investment in renewable energy to lead to economic growth, hence the negative coefficient for the first year. This is because after investments, it took a year to recoup the invested resources back before starting to have meaningful contribution to the level of GDP. However, during the following year, a unit increase in the value of renewable energy investments leads to an increase in the value of GDP by 0.00209 million dollars and 0.000666 million dollars in the third year. The null hypothesis that renewable energy investment does not influence economic growth is therefore rejected because investments in renewable energy positively influence economic growth in the long run.

Renewable energy investment takes an average of three years to start having a positive influence on the renewable energy consumption levels. In the third year, a unit increase in the value of renewable energy investments leads to an increase in the value of renewable energy consumption by 0.045097 million kilowatts in the third year and 0.009978 million kilowatts in the fourth year, hence an incremental unit of renewable energy investment yields less amounts of renewable energy consumption than the previous year . This low conversion rate reveals presence of inefficiencies in the renewable energy value chain that can only be mitigated by investment in modern green energy generation technology (Marinas, et al, 2018). Total renewable energy consumption, after leading to GDP growth, means there are more funds available for reinvestment in the energy sector; hence the positive feedback relationship amongst the 3 key variables. The null hypothesis that investment in renewable energy does not influence economic growth is therefore rejected because investments in renewable energy were found to positively influence renewable energy consumption levels in the long run.

-0.637764 is the adjustment coefficient which implies the previous period's deviation from the long run equilibrium is ultimately corrected in the current period at a speed of 63.8%.

In the long run, total renewable energy investment and consumption positively contributes to GDP growth. On the other hand, when the total renewable energy investment is zero, GDP will grow negatively. It would also grow negatively when the total renewable energy consumed and invested are zero, indicating that both total renewable energies consumption and investment positively influence the level of economic growth.

The above VECM results show the existence of both short run and long run association and causality amongst the study variables. (GDP growth, total renewable energy consumed and total renewable energy invested). The VECM results therefore conform to the feedback hypothesis.

Therefore, the cointegration test results established a positive long run association amongst the variables while the VECM results established a negative association amongst the variables in the short run because it takes time to realize the value of investments made in the renewable energy sector. However, in the long run, there is a positive association as depicted by the cointegration test results.

4.7 Granger causality Test

The existence of cointegration implies that there's either unidirectional or bidirectional causality amongst the study variables, hence the granger causality test was used to unearth the nature of the causality relationship existing between renewable energies and the level of economic growth as in table 4-15;

Table 4-10; Granger causality Results

Pair wise Granger Causality Tests
Sample: 1980 2017
Lags: 5

Null Hypothesis:	Obs	F-Statistic	Prob.
TREI does not Granger Cause GDP	33	2.51216	0.0606
GDP does not Granger Cause TREI		2.56349	0.0567
TREC does not Granger Cause GDP	33	1.45196	0.2455
GDP does not Granger Cause TREC		1.52942	0.2215
K does not Granger Cause GDP	33	0.88429	0.5081
GDP does not Granger Cause K		1.32939	0.2886
L does not Granger Cause GDP	33	0.56455	0.7261
GDP does not Granger Cause L		3.29780	0.0226

TREC does not Granger Cause TREI	33	2.02727	0.1142
TREI does not Granger Cause TREC		2.75674	0.0443
K does not Granger Cause TREI	33	3.35709	0.0210
TREI does not Granger Cause K		2.21648	0.0890
L does not Granger Cause TREI	33	3.37108	0.0207
TREI does not Granger Cause L		3.53225	0.0170
K does not Granger Cause TREC	33	1.34737	0.2818
TREC does not Granger Cause K		2.55342	0.0574
L does not Granger Cause TREC	33	0.16828	0.9716
TREC does not Granger Cause L		2.22540	0.0880
L does not Granger Cause K	33	0.78241	0.5732
K does not Granger Cause L		1.07977	0.3987

Pairwise granger causality test
Sample: 1980 2017
Lags: 5
(***Source, own computation, 2022)***

From table 4-15 above, the null hypothesis that the total renewable energy consumed does not granger-cause economic growth was rejected as the probability is greater than 0.05 (0.2455). Therefore, total renewable energy consumption brings about an increase in the level of GDP. On the other hand, a GDP growth leads to an increase in the level of the total renewable energy consumed as the null hypothesis that GDP growth does not granger cause total renewable energy consumed was rejected (p=0.2215).This set of results concluded that increased GDP levels implied there were more funds channeled towards renewable energy investments and hence more of it was made available for consumption, hence, a feedback relationship was established between annual GDP growth and the total renewable energy consumed.

The null hypothesis that renewable energy investment does not granger cause renewable energy consumption is accepted as the probability is less than 0.05(0.0443).However, renewable energy investment leads to GDP growth that leads to growth in renewable energy consumption, hence the possibility of a long run positive causality. The null hypothesis that the total renewable energy investments does not granger cause GDP growth was rejected (p=0. 0.0567). This confirmed that total renewable energy investment has a positive impact on the economy as more investments mean more renewable energy was available to spur industrialization. The null hypothesis that GDP growth does not granger cause total renewable energy investment was also rejected (p=0.0606) implying GDP growth availed more funds for renewable energy developments. Hence, there's a feedback relationship between GDP growth rates and renewable energy investments.

The null hypothesis that the total renewable energy consumption does not granger cause the level of total renewable energy investment was rejected (p=0.1142) implying that as more and more amounts of renewable energy are consumed, it causes a rise in the level of GDP. Rise in the level of GDP imply that more resources are available for reinvestment in the renewable energy sector. The control variables (capital and labour) also positively granger causes the three main study variables.

Therefore, the granger causality results in table 4-15 establish a feedback relationship between renewable energies and the level of economic growth. The test conforms to the feedback hypothesis of the Energy-Economic growth nexus proposition.

4.8. Discussion of Results

4.8.1 Effect of Renewable Energy Consumption on Economic growth in Kenya

The first objective was to establish the effect of renewable energy consumption on economic growth in Kenya. This study established a feedback relationship existing between renewable energy consumption and the level of economic growth in Kenya. The granger causality results in table 4.1 show that there exists a bidirectional relationship existing between renewable energy consumption and economic growth in Kenya. The null hypothesis that renewable energy consumption does not granger-cause GDP growth was rejected with a probability of 0. 2455. The null hypothesis that economic growth does not granger-cause renewable energy consumption was also rejected with a probability of 0. 2215. Other studies such as Narayan and Smith (2009) found similar results though the studies were from the developed economies. The study also conforms to the Biologists' school of thought as propounded by Safaynikou and Shadmehri (2014). The VECM results show that the intensity of association between the two variables in the short run is such that a unit increase in renewable energy consumption leads to an increase in the value of GDP by 0.013340 million dollars in the subsequent year. The null hypothesis that renewable energy consumption does not influence economic growth was thus rejected. This result was therefore in conformity with the growth hypothesis.

4.8.2 Effect of Renewable Energy Investment on Economic growth in Kenya

The second objective was to establish the effect of renewable energy investment on economic growth in Kenya. This study established a bidirectional granger causality relationship existing between renewable energy investments and economic growth. From the results on table 4.15, the null hypothesis that renewable energy consumption does not granger-cause GDP was rejected with a probability of 0.5514.The null hypothesis that GDP growth does not granger-cause renewable investment was also rejected with a probability of 0.4844. The results of this study are in agreement with the findings of researchers such as Ohlers and Fetters (2014). This study, apart from replicating the study in a developing economy (Kenya), exploited the most recent data. This study established that an increase in the level of renewable energy investments increases the amount of renewable energy available for consumption. Renewable energy consumption finally leads to more output in the economy, hence economic growth. The magnitude of the association in the short run is such that a unit increase in renewable energy investments leads to an increase in the value of renewable energy consumption by 0.00209 million kilowatts as established by the VECM results. The null hypothesis that renewable energy investment dos not influence economic growth was thus rejected. The findings of the second objective were therefore in conformity with the growth hypothesis.

4.8.3 Effect of Renewable energy Investment on Renewable Energy Consumption in Kenya

The third objective was to establish the effect of renewable energy investment on renewable energy consumption in Kenya. Renewable energy investment was found to have a positive effect on the level of renewable energy consumed in the long run as depicted by the Cointegration and granger causality test results. This study therefore conforms to the body of works as put forward by Sadorsky (2010) and Zhang (2011).The degree of the association in the short run as depicted by the VECM results is such that a unit increase in the value of renewable energy investments leads to an increase in the value of renewable energy consumption by 0.045097 million kilowatts in the third year and 0.009978 million kilowatts in the fourth year. The null hypothesis that renewable energy investment does not influence renewable energy consumption was thus rejected. The findings of the third objective were therefore in conformity with the conservation hypothesis in the short run but in tandem with the growth hypothesis in the long run.

In summary, the relationship existing amongst the three key variables could be explained as follows; Renewable energy investment causes the level of renewable energy consumption to rise. The availability of more energy investments meant the amounts of renewable energy supplied are subsequently increased. More generation and supply of renewable energy means more renewable energies are available for consumption. This serves to reduce the energy price levels in the market due to the interplay of demand and supply forces thereby reducing the cost of production. This is an incentive to production agents in the economy and thus economic activities in the economy are accelerated leading to increased national output. Increased output means there will be sufficient funds available for re-investment in the energy sector. More funds and allocations to the crucial sector means increased investment and generating capabilities that also lead to an increase in the level of renewable energy installed, generated, supplied and consumed. Investment in the renewable energy sector also includes acquisition of modern energy generating and supplying technology to reduce on inefficiency and energy losses in the value chain. Increased renewable energy consumption means producing agents are increasing output thereby leading to an increase in the level of national output. The cycle goes on and on. The study therefore conforms to the feedback hypothesis of the energy-economic growth nexus.

The Cointegration test results show that there is a positive long run association existing between the study's key variables; renewable energy consumption, renewable energy investment and GDP, though there's a negative short run association as depicted by VECM results. The short run negative association is basically because it takes some time before capital investments in renewable energy investment and consumption are recouped.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter highlights the summary of findings, conclusions, policy recommendations based on the findings, contribution of the study and areas that need further research.

5.2 Summary of the Findings

To assess the nature of the relationship that exists between renewable energy consumption and renewable energy investments and the level of GDP, the granger causality test was run and it conformed to the feedback hypothesis as propounded by Apergis and Payne; this study established a bidirectional causality relationship existing between renewable energy consumption and the level of economic growth in the long run. Both the granger causality test, Cointegration and the VECM results attest to the feedback relationship between renewable energy consumption and economic growth in Kenya. The null hypothesis that renewable energy consumption does not influence economic growth was therefore rejected and results to this objective therefore established that renewable energy consumption influences the level of economic growth.

There was a feedback causality relationship existing between renewable energy investment and economic growth in Kenya in the long run. Both the granger causality test and the Cointegration test results were in consonance with the fact that investments in renewable energy means energy prices in the energy market go down. This acts as an incentive to producers in the economy who respond by increasing their output, hence leading to growth of the economy due to reduced costs of production. The null hypothesis that renewable energy investment does not influence economic growth was therefore rejected. The results of this objective therefore established that renewable energy investment leads to economic growth.

As per the results discussed in chapter 4, renewable energy investment causes a rise in the level of renewable energy consumption. This is mainly because more investments in renewable energy sector means more volumes of renewable energy are available for consumption. Consumption of energy in the economy means more output in the economy. Increased output means there are more funds available for reinvestment in the energy sector; hence a feedback relationship is realized between renewable energy investment and renewable energy consumption. The null hypothesis that renewable energy investment does not influence renewable energy consumption was rejected. The results to this objective therefore established that investment in renewable energies leads to more consumption.

In summary, the VECM tests results indicate there's inefficiency in Kenya's renewable energy value chain and suggest that only a small fraction of Kenya's investments in renewable energy translates to final consumption of renewable energy. This leaves the question as to why Kenya imports an approximate 17.17% of her total energy consumption when she has a capacity to sustain herself if she optimally exploits her capacity. The rationale behind importing energy for Kenya's local use when she is capable of sustaining her consumption behaviour if she optimally exploited her capacity needs to be looked into. This is as a result of using outdated technologies in the value chain occasioned by poor energy use and generation policies that only focus on the consumption side of energy.

Sustainable energy is a precondition for economic growth and this cannot be achieved with the over-reliance on imports. Kenya's renewable energy consumption behaviour, though sustainable, is not desirable if the dictates the vision 2030 and the big 4 agenda are anything to go by. The consumption levels are too low signaling slowed economic activity within the Kenyan boarders occasioned by the inadequate supply of energy leading to huge and exorbitant energy prices that act as a disincentive to economic production agents.

5.3 Conclusions

Renewable energy investment and consumption is a key enabler of economic growth and plays a crucial role in steering the vision 2030 agenda of an industrialized economy. The study conformed to the feedback hypothesis that connotes a back and forth kind of relationship amongst the variables under study. For a blossoming manufacturing and industrialized economy, there is need to vouch for sustainable, reliable and environmentally friendly energy sources that shall drive the industrial processes; and no source bridges this other than the renewable energy sources-solar, hydro-power, wind, geothermal energy. This is because renewable energy investment and consumption have been found to positively influence the level of economic growth in the long run. The current supply and consumption of renewable energy is way below Kenya's capacity and commercial energy demands. Kenya relies heavily on the exhaustible energy forms like oil for industrial use that leave no guarantee to meet the future commercial energy demands. The renewable energy production capacity has been rising steadily in jumps and jerks since the 1970s oil crisis but not at as fast as the energy demands has been rising hence the significant variance between the desired industrialization level and the prevailing economic state of Kenya.

Although Kenya has in the recent made efforts to change the energy use practices in the country, most production agents and households still exploit traditional energy sources such as charcoal and crude oil for their household and commercial activities. There seems to be a big variation between the government's concerted efforts and the energy use practices in Kenya. This could be due to the huge communications gap and the inability of the populace to make use and exploit the availed opportunities by the state.

There's also the case of inefficiency, misuse, under-use and under exploitation of renewable energy resources as the huge investments in the important sector have not translated into the desired level of supply and consumption of renewable energy thereby raising concerns on possible losses, inefficiency, leakages and under-utilization in the system. This could be due to the energy losses in the renewable energy value chain occasioned by use of outdated technologies in the processes. This is because incremental units of renewable energy yields less amounts of renewable energies consumed than the previous unit. There's therefore need to address the gap between Kenya's renewable energy consumption patterns and her generating capacity. This is because going by the investment and consumption trends, it's established that the rate of renewable energy consumption in Kenya is way below her investments in the sector. Hence Kenya needs to come up with interventions aimed at increasing renewable energy consumption due to its replenish ability and environmental friendliness.

5.4 Policy Implications and Recommendations

The study mainly focused on the effect of renewable energy investment and consumption on economic growth in Kenya. Renewable energy consumption and investment was observed to have substantial effect on economic growth in Kenya in the long run. Since renewable energy investment and consumption are seen to steer economic growth through industrialization, this study recommends that Kenya as an LDC implements interventions aimed at increasing renewable energy consumption in all sectors of its economy as this will give impetus the process of accelerating sustainable economic growth as envisaged in vision 2030 ,The Big 4 agenda and attainment of majority ,if not all SDGs .This can be done by adopting measures aimed at reducing the high energy prices in the economy by investing in modern energy generation and supply equipment.

More embrace of the renewable energies can be facilitated by intentional policy measures by the state to encourage their uptake. The cost of acquiring renewable energy equipment like solar panels need to be mitigated by zero-rating solar equipment so that the tax absence lowers the cost of production of solar energy. This shall make renewable energy affordable to all, especially the rural communities that are not connected to the national grid. The government should not fight dealers but instead provide incentives to increase the supply of affordable renewable energy equipment in the market.

The Kenyan government can replicate some stringent but intentional renewable energy policies from countries with advanced energy policies like Berlin that passed legislation requiring all new and old building structures to be installed with Photovoltaic systems. Such measures will increase the uptake of the renewable energies by putting the obligation to building and structure owners.

The government also needs to educate its populace on the importance of renewable energies as the only reliable form of energy that is capable of taking care of both the current and future industrial energy needs due to its replenish ability. This can be achieved through civic education via print and social platforms.

Increased levels of renewable energy investment and consumption can also be achieved by offering incentives to dealers trading in renewable energy equipment. The incentives could include tax holidays and concessions. This measure is meant to reduce the cost of production of renewable energy. Consequently, energy prices shall fall. Reduced energy prices have an impact on all economic activities in an economy as it's an incentive to producers and service providers who shall offer their output at reduced rates. Therefore, there is need to match Kenya's massive renewable energy capacity with investments in the crucial sector if Kenya's global position as a renewable energy leader is to make any sense.

There is also need for budgetary allocations towards training energy professionals like engineers and energy economists to steer the process. More funds need to be channeled to research institutions so as to unearth more efficient ways of producing renewable energies. Professionals in the energy sector also need to be educated on ways of minimizing energy losses in the renewable energy value chain so that the massive investments in the sector translate to more renewable energies supplied and consumed. This can be attained through capacity building workshops and trainings. Kenya should also invest in the appropriate modern technologies that enhance efficiency and minimize energy losses in the value chain.

There is need to also address the ballooning variance between renewable energy investments and the amounts actually consumed. This can be achieved by acquiring and making use of modern energy generators that improve on efficiency and minimize on energy losses in the value chain and eliminate possible leakages. Kenya could be investing huge amounts of resources in outdated technologies that are expensive but inefficient. Some monies could also be misappropriated by the key players. This will ease the dependency on imported energy by reducing on energy poverty.

To increase efficiency and remove price distortions in the renewable energy market and consequentially increase the consumption of the key renewable energies, the government should consider the demonopolisation of the generation and supply of renewable energy. This move will pave way for privately owned enterprises that are more efficient and cost effective compared to the forever loss making but costly parastatals.How the parastatals buy a kilowatt hour at Kshs 0.5 and offload the same at Kshs 23 but still declares annual losses is puzzling, hence, the call for privatization. The move, apart from opening up the Kenyan energy market and increase efficiency, will serve to reduce the cost of production due to reduced energy prices that are a phenomenon of a perfect competition market structure. The reduced production cost is an incentive to encourage more economic production activities in the economy.

For the Kenyan case and other emerging economies, there is need for concerted efforts aimed at increasing the supply of renewable energy to meet the growing aggregate demand for the same. Increase in energy supply has a bearing on the energy prices which means the cost of production shall be revised downwards. In the short-run however, Kenya should make use of more efficient, sustainable, environmentally friendly and cost-effective renewable energies in order to deal and do sufficiently do away with the energy inadequacy problem occasioned by inefficiencies in the energy value chain and lack of sufficient investment in the crucial sector.

5.5 Contribution of the Study

5.5.1 Contribution of the Study to Economic Theory

This study on the effect of renewable energy consumption and investment on the level of economic growth adds to the body of knowledge; the specific isolated effect of the renewable energy investment and consumption on economic growth and shows the magnitudes of the relationships to evaluate Kenya’s investment in sustainable energies in the recent years. This is critical in forecasting, policy making and budgeting for the energy sector as the driver of all industrial and production processes.

5.5.2 Contribution of the Study to Policy Making

This study shall aid policy making regarding the attainment of a bubbling industrialized economy by suggesting the relevant policy measures in the key renewable energies that are capable of taking care of both present and future energy demands of the industry. This will go a long way in informing the budget process too.

The study also aids the policy makers to see out ways of increasing efficiency in renewable energy value chain so that the high levels of investment in the crucial sector are reflected in the amounts of renewable energies generated, supplied and consumed. This is because a sound renewable energy policy is a panacea for economic growth as renewable energy is intrinsically linked to economic growth.

5.6 Limitations of the Study

This study used time series data to establish the nature of the relationship existing between renewable energies and economic growth in Kenya. A panel study including more African economies could have been exploited to establish the nature of relationship existing amongst the three variables across the borders of the EAC economies. However, it’s noted that majority of African economies are at the same stage of economic development and therefore the findings of this study can be replicated in most of the African economies, with an exception of a few countries like South Africa that are classified as second world economies. This study is therefore a replica of the situation in over 95% of African economies hence its findings and policy recommendations can be exploited by majority of African economies at the same stage of economic development as Kenya.

5.7 Areas for Further Research

This study recommends that further research be done using panel data of the East Africa community countries. This will inform policy for the entire region as there are limited trade restrictions within the member states. Cross sectional renewable energy data on the EAC countries will also help in specialization in specific kinds of renewable energy as countries will now engage in renewable energy investment, supply and consumption of the kinds that they have comparative advantage in generating and consuming. Joint energy policies for the region should be encouraged as it also helps foster cross border cooperation amongst member states.

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APPENDICES

APPENDIX A: MAP OF KENYA

(Source; The master plan for Kenyan industrial development, MAPSKID)

APPENDIX B: DATA

Year	GDP (Nominal price levels)(m) $)('000')	TREI (m) $ ('000')	TREC (million kilowatts('000')	K(million dollars)('000')	L(Productive population) (millions)
1980	42	0.2490	1.1820	10.2942	18.33
1981	44	0.2640	1.5427	10.0804	19.99
1982	41	0.2740	1.6174	8.9626	12.62
1983	38	0.3840	1.8602	7.9534	9.57
1984	42	0.3990	1.8499	8.3202	12.80
1985	32	0.3960	2.1416	8.1024	15.36
1986	31	0.3990	2.2342	6.7487	11.09
1987	36	0.4090	2.3209	8.7444	11.45
1988	45	0.5410	2.7836	11.4525	8.87
1989	44	0.5425	2.9333	10.9384	10.72
1990	43	0.6490	3.0386	10.3888	8.87
1991	47	0.6490	3.2460	9.8559	9.21
1992	48	0.6490	3.2540	8.1216	9.57
1993	47	0.6490	3.4551	8.2767	9.95
1994	55	0.6490	3.4200	10.6095	10.33
1995	56	0.6490	3.6430	12.2192	10.72
1996	67	0.6490	3.8350	10.0500	11.09
1997	67	0.6480	3.7140	10.1438	11.45
1998	66	0.6450	3.7530	11.0154	11.81
1999	69	0.7195	2.9160	10.7088	12.19
2000	68	0.7195	2.0570	10.8388	12.43
2001	63	0.7200	3.1750	11.8377	12.62
2002	72	0.7340	3.7900	10.9008	12.81
2003	91	0.7707	4.3300	14.9968	13.01
2004	103	0.7922	4.1910	17.4688	13.19
2005	112	0.8424	4.3160	19.7680	13.35
2006	110	0.8454	4.5740	20.4930	14.01
2007	133	0.8584	4.7900	27.2118	14.68
2008	144	0.9054	4.3170	28.2384	15.36
2009	134	0.9254	3.8190	25.9022	16.06
2010	157	0.9256	5.1800	32.7188	16.79
2011	182	0.7000	3.1750	39.4940	17.54
2012	190	0.6450	3.7530	40.8120	18.33
2013	186	0.9254	4.3170	37.4046	19.15
2014	180	0.6490	3.2540	40.3740	19.99
2015	171	0.3990	2.1416	36.7137	20.86
2016	178	0.7340	3.7900	32.5028	21.75
2017	186	0.6490	3.0386	35.3958	22.40

(Source; WDI and EIA)