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ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

TITTLE OF THE PROJECT: RENEWBLE ENERGY CONSUMPTION AND ECONOMIC GROWTH OF RWANDA, 1990-2015

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DECLARATION

I, Aphrodice MBARUSHIMANA, the undersigned, declare that this dissertation is my original work and has not been presented for a degree in University of Rwanda or any other Universities. I also declare that information, sources of materials and results from other works presented herein have been fully cited, acknowledged and reference according to the academic rules and ethics. No part of s dissertation should be reproduced without author's consent or that of the University of Rwanda.

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SUBMISSION/APPROVAL

This final dissertation has been submitted for the examination with my approval as the University advisor

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Date: 10…./…11……../2021

DEDICATION

My father SINGIRABAKUNZI Joel;

My mother UMUTONIWABO Anastasie;

My beloved wife BAMPIRE Sylvie;

My beloved child ASHIMWE UWACU Charmante;

My brothers and sisters;

All UR/ACE-ESD Community;

My classmate in program of Energy Economics;

Anyone else who is not appearing in this list but whose role is recognized.

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May God bless you abundantly

Mr. Aphrodice MBARUSHIMANA.

ABSTRACT

Energy being the engine of economic growth is necessary would be of great role when it is clean so as to ensure the environmental sustainability for the benefit of not only single individual but also the one of the globe entirely. This study is about the renewable energy consumption and economic growth of Rwanda This study is about the renewable energy consumption and economic growth of Rwanda from1990-2015. It was guided by both general and specific research objectives whereby the major objective was examining the contribution renewable energy consumption and economic growth of Rwanda and the specific objectives were to identify renewable sources used in Rwanda, to find out the relationship between renewable energy consumption an economic growth of Rwanda growth of Rwanda. The useful data were obtained from the world development indicators dataset by considering the published data related to Rwanda. In this regards, the method which was used was the vector autoregressive model. The research considered the test of stationarity so as to avoid the spurious regression. By applying the Augmented dickey and fuller test have been used to ensure that the estimated results avoid the problem of spurious inferences. The estimated results reveal that, according to the ADF, PP tests, only the first difference of all the variables are stationary at the I (1) level. The data were presented through the descriptive statistics where the real gross domestic production was measured in 2010 US dollars, renewable energy consumption was measured in Terajoules (TJ), total labor force is measured as number of population, carbon dioxide emission as measure in the metric tons of CO_2 equivalence and the gross capital formation was finally measured as 2010 US dollars. Additionally, the intervention of cointegration revealed that the trace statistic of 6.25 is lower than the critical value of 12.53 for maximum rank of 3 cointegration equations at the 5% significance level. The findings on cointegration depicted the long run relationship between research variables namely GDP, renewable energy consumption capital, labor force, and he amount of CO_2 emissions which were expressed in Kiloton (kt). The country was recommended to reduce the dependence on energy imports especially fossil fuels, lower greenhouse gas emission, increase employment through job creation through deployment and dissemination of clean and non-polluting energy sources in the energy sector and improve innovation in the non-polluting industries.

Key words: renewable energy consumption, economic growth

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LIST OF ABBEVIATIONS, SYMBOLS AND ACCRONYMS

ACE-ESD: African Center of Excellence in Energy studies for sustainable development

AD: Anno Domini (After Christ)

ADF Test: Augmented Dicker Fuller Test

AIM/CGE: Asia-Pacific Integrated Model/Computable General Equilibrium

ARDL Autoregressive Distributed Lag

B.C: Before Christ

CH4: Methane

CO2: Carbon Dioxide

COMESA: Common Market for Eastern and Southern Africa

DOLS: Dynamic Ordinary Least Squares

DRC: Democratic Republic of Congo

EDPRS II: Economic Development and Poverty Reduction Strategy two

EIA: Energy Information Administration

EU: European Union

FMOLS: Fully-modified Ordinary least square

G7: Group of Seven Richest Countries

GDP: Gross Domestic Products

GFCF: Gross Fixed Capital Formation

GHGs: Greenhouse Gasses

GMM: Generalized Method of Moments

GoR: Government of Rwanda

GW: Gigawatt

IEA: International Energy Agency

IFC: International Finance Corporation

IPCC: Intergovernmental Panel on Climate Change

LF: Labor force

M^{2}: Square Metter

MDG: Millennium Development Goals

MININFRA: Ministry of Infrastructure

MW: Megawatt

NASA: National Air and Space Agency

NISR: National Institute of Statistics of Rwanda

PMG: Portfolio Management Guide

PP Test: Phillips and Perron

PV: Photovoltaic

RDB: Rwanda Development Board

RE: Renewable Energy

REG: Rwanda Energy Group

REN: Renewable Energy Network

REN's 2021: Renewable Energy Network for The 21st Century

RWC: Renewable Energy Consumption

SDGs: Sustainable development Goals

SE4all: Sustainable Energy for All

SREP: Scalling Renewable Energy Program

SVAR: Structural autoregressive model

TJ: Terajule

TLF: Total Labour force

TWh: Telajule-Hour

UNEP: United Nation Environmental Program

US$: United States Dollars

US: United States

USA: United States of America

USD: United States Dollars

VARM: Vector-Autoregressive Model

VECM: Vector-Error Correction Model

WDI: World Development Indicators

CHAPTER ONE: GENERAL INTRDUCTION

1.1. Background of the study

The history of energy and power is dating form long time in history across the world. The ancient people got fire by applying the wood combustion and the charcoal production for the purpose of smelting the metals and this was dated back in 5000 B.C in European country called Greek. In this the, the devices were powered using natural energy such as water and wind. With technological and research enhancement, in 18^{th} century where the industrial revolution arose, they started to use energy sources such as coal as fuel and this was associated with the extraction of crude oil which become the day-to day duties of many nations (Wheeler, 1985).

At global scale, the extraction of renewable energy has been faster growing comparing to other energy sources. Specifically, the estimates revealed that the global electricity will grow at the rate of 3% while the renewable energy consumption itself will grow by 2.6% percent at the yearly basis from 2007 till 2035.With this estimated growth rate, it was presented that the renewable share of global electricity will increase from 18% up to 23% in the year 2035. Linking the report to the day's purpose of economic growth, the increase in renewable sources will ensure the prosperity of the environment and boost global energy security and will impact towards economic growth in positive way Hara (2015) . Additionally, in the energy environment, the energy delivered for renewable sources is increasing, with over 181 gigawatt(GW) which was newlry got built in 2018 have led to the world enwabl energy capciy increase up 2,378GW (Hara,2015).

During the year 2019, there has been 90 countries which initiated to instal at least 1GWof gnrating capacity and this led to the reneable energy consumption increase at glaobl scale.In this regards, other 30 countries have instlled more than 10GW of the capacity. The dominants sources included the wind power and PV (photovoltaic) that occupy more than 20% of the various renewable sources from their respective countries which share more than 20% in the electricity mix. The Report (REN,2019) identified that 169 countries has adopted the use of renewable energy target and this increased the economic performance of countries as result of renewable energy consumption and exploitation of less polluting resources (Eckhart, 2019).

In Africa, the renewable energy consumption status as was elaborated by the Alliance for rural electrification as was launched in International Energy Agency (IEA) Data revealed that the total number of population with no access to electricity has reached 589 million in the year 2008 and this was to be linked with 90 millions of people who lived in the same condition of not having electricity in the year of 2002). The absence of electrify is coupled with high rural population with lower ability and willingness to pay and this bring about low per capita energy consumption. The majority of rural communities of Africa use locally-available energy sources like biomass from agriculture residuals, savannah and forest woodlands for cooking, heating. The Six renewable energy users of Africa (Mozambique, Zambia, Namibia, Kenya, Ghana and Cameroun all uses their renewable from hydro while only Kenya use renewable energy from Geothermal (Monforti, 2011).

In Rwandan perspective, through the intervention and target framewok of energy-based institution and stakeholders, there is an ambitious target to achieve 100% electricity access in 2024 which is at 512 MW installed power generation and this target is against which appear in 2020 where among the expected 512 MW of installed generation capacity, there is 216 MW. By the year 2023/2024, the contribution of on-grid will be 52% and 48% off-grid connections (Bimenyimana,2018).

Electricity will be used more frequently as the government demands. However, it barely represents for 2% of overall energy consumption in Rwanda, which is insufficient to accelerate the country's growth. Biomass, on the other hand, now accounts for 85% of all energy consumed, whereas petroleum accounts for only 13% of overall energy consumption in the country (Mininfra, 2018). When it comes to the needs of sorting the best electricity users in Rwanda, it was revealed that 82% of electricity users are households through the use of traditional energy fuel such as wood, the transport sector occupies 8% of the total country’s energy consumption. Fnally, the industries uses 6% and the public services consumes electricity at 4% (Mininfra, 2018).

With the policy of bringing renewable energy consumption towards economic growth is discovered by the size of investment which is inserted within the electricity support projects. Back to 2009, around 377 Million USD was inserted to enhance the access to electricity and it resulted to the electricity connection by 250,000 units in the period of 4 years starting form 2009 up to 2013.The financing scheme kept enhanced whereby the second round utilised 300million USD so s to bring the electrification at 70% as was the proposed objective. In this regards, the collaboration between European Union and word bank signed the deal of 200 Million Euro so as to enhance the off-grid electricity and other 50 Million USD was agreed inn 2017 to enhance the policy of Rwanda Scaling Renewable energy program (SREP) (Manfred Hafner ,2019).

According to RDB report of 2017, the Rwanda energy consumption was at 210.9 MW installed capacity and this quantity generated was the triple argument than how it was in 2010.In this procedure, the generation mix is presented as follow: hydro power plant at 48%, thermal power plant that contributes towards energy sector at 32% , the photovoltaic occupies (5.7%), and then it comes the methane to power which inserts 14.3%.In addition, the information from Rwanda Energy group in 2017 revealed that Rwanda achieved 40.5% whereby 29.5% was oriented to the on-grid part while the off-grid part took the portion of 11% (RDB,2017).

Rwanda's renewable energy consumption potential is underdeveloped, particularly in hydropower (which generates 300MW through micro generation but the country has initiated to invest in corporate electricity access with other regional countries whereby it has 145 MW at Rusizi III between Burundi and Tanzania, There is also 90MW from Rusumo fall . All these sources are also associated with the geothermal energy which generates between 170MW and 340MW, peat energy which generates around 1200MW and the solar energy potential that is capable to give around 66.8Twh (Manfred Hafner,2019).

The Past scholars in the general literature have adhered to empirical applications when it comes to renewable energy and economic growth. According to Apergis& Payne (2012), renewable energy consumption has an impact on a country's economic growth in one way or another, and it has been a key to econometric application.In addition, unlike previous research, the current study took into account the effects of GDP (gross domestic product), labor force, and CO2 emissions. Thus, the relationship between the amount of renewable energy consumption and economic with is the substitution of the fossil fuel as part of non-renewable energy which is the substitution of non-renewable energy for renewable energy, economic growth and the amount of labor will be considered, as it will show how the rate of use of renewable energy can also be correlated with the country's labor force, and this will aid in determining how to either plan for renewable energy use or plan for future population needs due to available energy sources.

Moreover, when Labor force is higher, there is a probability that the use of fossil fuel can happen and this lead to the environmental degradation which is in long run become the burden to the population hence the use of renewable energy can keep sustaining the environment and Labor force. The current research is expected to contributed towards the pre-existed literature in term of time coverage and variable which were used are to be complemented within the current work. The selection of long time series data (1990-2015) will give us good story of how these variables are related as methods such as Unit roots, cointegration granger causality and the vector autorressive model will be adhered to regress the useful research variables such GDP (Gross domestic product), renewable energy consumption , capital Labor force, and CO2 emission will be used.

1.2. Statement of the Problem

In the period from 2014-2021, The united Nation has designed the decade of sustainable energy for all (SE4all), with the goal of achieving energy sustainability by creating a clean environment, ensuring that people will be able to have access to clean electricity, improve the level of utilization of energy efficiency through low- carbon renewables and increasing investment in clean technology. This is also tied to the global competition to solve climate change, and it expands energy availability large number of citizen across to world who is currently living under poverty line. In 2013, it was seen that around 19.1% of the world final energy consumption was delivered from renewable sources with big portion of solar PV, winds and hydroelectric power (Pencheon ,2017).

According to the Energy Information Administration (EIA), the energy delivered from renewable sources has been the fastest growing source of energy in recent years (IEA,2009). In this context, industrialized countries encouraged the development of non-pollutant energy sources wich are also come from sources which can not be replinished so as to enhance the energy distribution and ensure the energy supply towards reduction of carbon emission and greenhouse gases emission (GHGs) (Moselle, 2011).By 2020, The European commission has ivested in boosting the level of renwable energy consumpton by 20% (Moselle, 2011).

Besides, the utilization of renewable energies is seen by developing countries as a solution to the challenges of rural electrification and limited access to electricity experienced by some people, particularly in rural areas. (Munasinghe, 2010) .The typical example is in Africa where the big portion of population has difficulties of getting electricity despite the continent has great abundance of alternative energy such as solar, thermal, woods, photovoltaic, biogas Kaygusuz et al.(2007) pointed out that the needs of promoting the utilization of renewable energy resulted not only the modernization of energy sector but also to support countries' perceptions of reaching to the sustainable economics in their respective areas. (Perreira,2010).

One of Rwanda's initiatives to accomplish the SDGs is through the Economic Development and Poverty Reduction) II (Sustainable development Goals). One of its major priorities is to focus on the energy sector, as mentioned in the sustainable development for all number 7 which is "affordable and clean energy." Rwanda's government has set a goal of increasing access to power from 42% to 100% by 2025 by boosting the use of renewable energy. (Mudaheranwa,2010).

Unlike the expected outcome, it has been proven that the rate of energy consumption was increasing at 6% while the level of economic growth was growing at 5% per annun and this result to the significant issue related to the market sustainability and satisfaction of aggregate demand and making the MDG future goals impossible to attain. The findings reveal that by 2050, fuel may be totally retired, resulting in a considerable reduction in CO2 emissions, indicating how the country can include the greatest amount of renewable energy generation into its energy system but normally Rwanda exposes to the big portion of renewable energy sources such as solar energy, hydropower plants, methane gaze and further the geothermal (Safari, 2010).

Unfortunately, the majority of these jewels stay underutilized, as indicated in that power generation resources totaling roughly 1,200 MW have yet to be used. The reason to justify this argument is seen by fact that the big proportion of energy which is used is wood whereby the total proportion of population who use wood as source of fuel is estimated at the rate of 90%, and this is against the policy of use of imported petroleum from abroad. However, the use of woods causes deforestation and harms the environment, so renewable energy must be used to reduce environmental degradation and CO2 emissions (Mininfra, 2018).

Hence, the idea about renewable energy consumption and economic growth nexus inspired several studies to investigate whether there is a dynamic relationship between the amount of renewable energy use and the economic growth of several countries in several time frames. For instance, Nicolas Apergis (2012) investigated the renewable and non-renewable energy consumption nexus for 80 countries by using the multivariate panel data in the period dated from 1990-2007.Sadorky, (2009) conducted a research on the relationship that can exist between energy consumption, carbon emission (CO2) and oil price in G7 (Group of 7 richest centuries from 1980-2005).

Furthermore, Menegaki (2011) examined the relationship between economic growth and renewable energy consumption (RWC) for 27 European countries considering the period from 1997-2007). In this study, the panel data was analyzed in the research but there was no causality was realized in the research between the considered variables namely economic growth (GDP) and renewable energy consumption (RWC). However, there are critics under these studies which show the gap. The first critics which can be seen in this context was the selection of because all these countries which were selected under study have a great degree of heterogeneity, secondly, they omitted the variable of Labour force while it is necessary to include the Labour force in the analysis of these variables due to the fact that Labour force has a significant effect on environmental use, affordability and choice of what energy source can be used.

Unlike the past studies, the current study employ GDP, Labor force and CO_2 emission so as to inject the current contribution to the pre-existed literatures because of fact that it is the first time the Labour force is used in the nexus between economic growth and the renewable energy consumption as it is of great importance to include the amount of labor due to the argument that the economic growth is achieved by population's contribution and this was omitted by past studies.

Additionally, the consideration of population over the variables used by past studies will solve the omitted variable bias in econometric estimation. Moreover, will give clear image on how the renewable energy and economic growth have the relationship as and this was not done by Payne B. (2010), Payne& Bowden (2010), Nasreen& Anwar, (2014). Moreover, method of grange causality test as was developed by Apergis & Payne (2010) will be used so as to investigate the relationship between renewable energy consumption and Rwanda from 1990-2015. In another words, does the consumption of renewable energy sources enhances the level of economic growth of Rwanda?

1.3. Objectives of the study

1.3.1. Major Objectives

The major objective of this of this research was to examine the contribution of renewable energy consumption to economic growth of Rwanda.

1.3.2. The specific objectives

1. To mention renewable sources used in Rwanda
2. To assess the role played by renewable energy in Rwandan energy sector
3. To find out where there is relationship between renewable energy consumption and economic growth of Rwanda

1.4. Research Questions

As referred proposed research objectives, the below mentioned research questions were formulated:

1. What are renewable sources used in Rwanda?
2. What are the roles played by renewable energy in Rwandan energy sector?
3. Is there any relationship between renewable energy consumption and economic growth of Rwanda?

1.5. Scope of the study

This research will focus on the relationship between renewable energy consumption and the Rwandan Economic growth as it have observed that energy plays an important ingredient in day-to day life, its availability enhances the economic performance and it becomes better when the environmental sustainability is also taken into consideration.

For this perspective, the renewable energy is preferred as it fits the environmental clearance and also being naturally-provided. Geographically, the research is being conducted in Rwanda. Timely considered the current research will consider the data from Renewable energy consumption from 1990 up to 2015.The reason of why other years above 2015 are not considered, is because their data are not available on world bank where the data were all gathered from. In content, the research will analyses role played by the renewable energy source towards the economic growth of Rwanda being on among the countries with target of developing the use of clear energy for the environmental sustainability, removal from darkness, development of energy security, ensure the environmental sustainability.

1.6. Expected Outcomes and Significance of the Study

1.6.1. Expected Outcomes of the Study

1. In Rwanda, there are different renewable energy sources

2. There are different roles played by renewable energy towards Rwandan energy sector such as reduction in CO_2 emission, reduction in airborne diseases, amount of renewable energies are used for the current generation and later by next generation and there is an increasing number of people who have access to electricity.

3. There is a positive relationship between renewable energy consumption and economic growth of Rwanda

1.6.2. Significant of the Study

When we say that the study has the significance, we want to mean the roles that the research injects towards the existing literature, policy analysis and implementation. It looks at how different individuals will benefit from the research like the researcher himself, the community and the University all expect to gain from the study. Briefly, the significance of this study is shown in the following arguments.

The current study is significant to the researcher because it contributes to digging deeper about knowledge on the consumption of these energy sources which are delivered from non-replenished areas and the extent to which this energy type contributes towards the economic growth of citizen

In this perspective, the policy framework related to enhance the use of renewable energy and relate it with the development target of Rwanda. Moreover, the accomplishment of this study will lead to the student be graduated for Master's Degree in Energy Economics.

The society will benefit from this study through evidences which will be provided in recommendation from the research about the fair use of renewable energy for the life safety, environmental protection, energy security among members, rural and urban electricity accessibility (both on-grid and off-grid electricity system).

Apart from the researcher and community, the current research will also be of great value to the University because the University will get the copy of this dissertation and will be used in Library by other generation of readers who will be working with the similar topic.

CHAPTER TWO: LITRATURE REVIEW

2.1. Definition of the key concepts

Within the context of the current research, there are different key concepts which are to be defined according to different authors' opinions and scientific application. These are the following:

Energy

The concept of energy means normally the state of making something active through application of force. In this perspective, energy acts as the conserved quantity which is converted in a form but no destroyed (Mendy, 2014).

The energy is all source of power that make activities start their motions which is delivered from utilization of physical and chemical sources specially to provide light and heat or to make the engine-attached devises to work (Buhaan,2015).

Renewable Energy

Renewable energy is that type of energy that comes from sources which are existing for a long time. These sources include for instance the sunshine, wind, rainfall, waves, tides, and the geothermal. Biomass is frequently taken into account in the statement, despite the fact that its carbon neutral status is debatable. This type of energy supply is renewable, unlike fossil fuels, which are exhausted faster than they are restored (REN, 2017).

Renewable energy is the type of energy which is collected from renewable sources that are naturally replenished on human time scale, (Bentx, 2015)

Renewable Energy Consumption

The renewable energy consumption is the practice of using the unlimited sources of energy for personal uses, industrial running, street lighting, cooking and cooling. This economic use of renewable source of energy ensures the sustainable development which is the development target of maximizing utilities by current generation but without compromising what will be used by future generation.

Therefore, the use of renewable energy is beneficial to human kinds through generation of outputs and saves the environment from being affected by the greenhouse gases (Cucchiella ,2018).

Economic Growth

Economic growth is all about the increase in harvested outputs associated with the removal of inflation's distorting effect on the values or prices attached to the merchandised, the resource increase that is usually evaluated in real, inflation-adjusted terms. Economic growth is measured using national income accounting. As a result, economic growth is defined as the annual percent change in gross domestic product (GDP) .Economic growth is the upwards shift in country's ability to increase its level of outputs using capital, labor, technology so that the efficiency in labor can indicates an increased level of research and development (R&D),the economic growth is the increase in outputs and ability to reach at these outputs (Robert.M.Solow, 1978).

2.2. Theoretical review

2.2.1. Theory of Renewable Energy Consumption

The conceptual perspective of scholar contributions towards elaboration of the theory was the formerly known as the renewable energy network of the twenty first century (REN's report of 202) under where the report said that the rise of the replenished source of energy has existed from many years ago and they have surpassed all the expectations due to the global installed capacity and production from renewable energy technologies which has increased substantially and supported the policies of spreading renewable energy consumption habit in many countries .The report showed that in 2000s, there has been an increased global renewable energy investment, capacity, and integration across all sectors. Moreover, various energy crises began in early 1970 where the globe experienced the subsequent economic downturns for both national and economic sector (Brower, 2014). Renewable energy, as opposed to the items related to the fossil fuel such as oil, and coal, was developed in Europe about 2,000 years ago. Of course, this was a primitive version, but it laid the groundwork for today's technological marvels.

It all began with 'waterwheels,' which simulate the workings of hydropower. The energy of moving water is converted into mechanical or electrical energy by a waterwheel. It converts the kinetic movement of the water into mechanical via a spinning shaft, which powers any associated machinery to serve its function (Project Solar, 2018). The popularity of windmills and those towering edifices that speak for a big portion of Dutch business and culture was at its peak in the 1590s in Europe, particularly in the Netherlands. Windmills first appeared in the Middle East and Central Asia around 635 AD, and it has expanded towards the Middle East and Central. Additionally, the technology that influenced today's wind turbines was developed in the Netherlands. These were far from the highly specialized wind turbines that exist today. A windmill operates via its blades and rotor shaft, so as the wind blows, it causes the blades to spin. At this early time, windmills were used primarily to pump water and to mill grain (Chontanawat, 2008).

Around 1860, with the first solar energy system, the first scenario began in France, where French investor Augustin Mouchot invented the world's first solar energy system in 1860. Mochet tested sun meter' after predicting that the coal supply will run out one day (we assume he was right). In 1876, William Gryll Adams, professor of natural philosophy at King's College, demonstrated to a board of fellow professors how to use selenium cells to harness solar rays and generate electricity, and his discovery was crucial in expanding the area of solar science. In the period of 19^{th} century that is in 1887 the wind turbine were built and started to generate wind related energy in the big parts of Europa (Breitung, 2000).

Charles F. Brush invented the first windmill used to generate electricity on a farm in Cleveland, Ohio, just a year later, in 1888. Denmark had 72 wind turbines providing energy by 1908. And by the 1930s, they had spread throughout the United States. Throughout the twentieth century, technology advanced in tandem with the growing need for clean, renewable energy. In 2016, it was discovered that there are roughly 341,320 wind turbines in operation worldwide. It has grown to the point that the worldwide wind industry employs 1,555,000 people as of the end of 2016 (Narayan, 2009).

The first commercial wind turbines were sold in 1927 to a group of rural US farmers for a significant price (at the time). This was the first time that renewable energy made a big commercial splash. People started to take notice. Colorado landmark was erected in 1935 to control the flow of water along the Colorado River and to ensure a stable supply of water to Southern California and Arizona. It was the largest hydroelectric facility in the United States at the time. Over 5,000 people were engaged throughout the five-year construction period, and at full capacity, it can retain enough water to cover Connecticut 10 feet deep (Boulila, 2004)

This combination allowed the energy to be stored for much longer, which was especially important when the light was covered by clouds. This meant that systems could continue to operate normally for up to three hours after the sun had set, which was a major accomplishment at the time. In the early 2000s, countries like Germany, Denmark, Spain, and the United States established large markets for renewables, paving the way for early technological advancements and economies of scale, and laying the groundwork for the prior decades of exponential industry boom (E.C. Bensah, 2010).

The practice of putting a greater emphasis on climate mitigation the growing emphasis on combating climate change and adjusting to its consequences has added to the momentum. Furthermore, the environmental consequences of global warming and the rise in greenhouse gas emissions raise worries about the usage of fossil fuels. As a result, renewable energy sources have emerged as a significant component of global energy consumption. The majority of the benefits of renewable energy sources are that they reduce carbon dioxide emissions and help to safeguard the environment (Pereira S, 2017).

Fossil fuels are thought to be able to regenerate (replace) themselves for a very long time in theory; however they are in danger of becoming extinct in the near future. (Oguz Ocal & Alper Aslan, 2013). Moreover, the International energy outlook pointed out that the renewable energy has seen fast expansion around the world, with biofuel production up 13.8 percent and wind energy usage up 15.5 percent in 2010 (Oguz Ocal&Alper Aslan, 2013)

The theoretical expansion of the renewable energy consumption and economic growth nexus has mentioned 4 hypotheses where each of them has a specific implication. The first is the growth hypothesis that states that there is the single directional (unidirectional) relationship that runs from renewable energy consumption towards the economic growth. The conservation hypothesis, on the other hand, states that there is unidirectional causality from economic growth to energy consumption, and therefore reducing energy use will have little or no influence on economic growth. Furthermore, it supports the idea that rising GDP leads to higher energy use (Al-mulali U, 2013).

The feedback hypothesis presents the existence of bidirectional relationship between energy consumption and economic growth and this wants to mean that there is an associated effect that lay between the research variables (Energy consumption and economic growth) Thus, the last hypothesis reveals that the neutrality hypothesis states that there is no causal relationship between energy consumption and economic growth .Therefore, it is seen that there's no causal relationship between energy consumption and economic growth under the neutrality theory, and vice versa (Menyah K, 2010).

When it comes to the practice of use of the replenished energy, it has been observed that this energy source has reduced the rate of greenhouses gases, the environmental challenges such as the acidic rainfall not only in western countries but also in Africa where there is a significant chance to improve the living conditions of a large portion of the current and future African population. It should be noted; however, that much of the information has been incorporated into the current research university infrastructure through partnership and co-operation there is a general shortfall of energy potential of energy resources actually installed systems and present use in comparison to the rest of the world. Due to a lack of information about the usage of renewable energy, renewable energy has fallen behind and the environmental specialist who always fights for the better environment where energy green is the dream of everyone (REN-21, 2010).

2.2.2. Renewable energy Consumption-Economic Growth Nexus

Several literatures have tried to mention the relationship between renewable energy consumption and economic of several countries. In doing so, they look at the sector performance and the level of renewable energy consumption which was to be expressed in total amount of renewable energy sources in terajules. The first among these findings are seen in the research carried out by Payne (2009) which found no causal association that lay between renewable energy consumption and the country's real outputs in his study of the dynamics of the utilised energy and output in the United States.

Currently, many findings from past researchers have identified different elements or variables which were taken into account n their respective studies and the concepts of economic growth. The majority of them considered the countries outputs (GDP), the area where these countries are located (geographical location), countries political follow-up, Labour force, and capital within the country.

Another typical example on the renewable energy consumption-economic growth nexus was developed by Sadorky (2009) where he conducted research on renewable energy consumption, CO_2 emission, oil prices for the group of seven richest countries of the world (G7) from 1980-2005). The research used the panel co-integration methods. Referring to the findings, it has been observed that the increase in county's real GDP per capita and the intervention of CO2 per capita have become the main driving force towards renewable energy consumption (RW). Therefore, the amount of renewable energy consumption was positively affected by both of its determinants at big percentage. Unlike real GDP and CO_2 per capita, the research revealed that the increase in amount of gasoline price prices has negatively the consumption of Renewable energy (Sadorky ,2009).

The study conducted by Apergis &Payne(2010) about th relationship bettween renewable energy consumpton and economic grwth of the 13 countries across Eurasie during the period from 1992-2007.The research applied the panel cointegration and error correction model.In the part of resuts elaboration, It has been observed that there is long-run relationship between GDP, renwable energy cnsumpton, real gross capita formaton , real gross fixed capia formation, and the amountt of labor force.

Looking at error correction model, it has been observed that there is bi-directional relationship causality between renewable energy consumption (RWC) and economic growth for both short and long-run. Manegaki (2011) conducted a research on the relationship between economic growth and renewable energy consumption for 27 European countries from 1997-2007 by using the panel data. Interestingly, no causal relationship was seen in the research but on another side, there was observed that there is causal relationship between carbon emission, employment and renewable energy consumption thus the higher increase of carbon emission (Co2 Emission) than the level of renewable energy consumption and this was delivered from fact that there is high cost of renewable energy investment across the countries under consideration and this affected the renewable energy consumption become less competitive with the Carbon dioxide emission

2.2.3. Rwandan renewable energy consumption status

Rwanda's renewable energy consumption potential is underdeveloped, particularly in hydropower (which generates 300MW through micro generation but also 145MW at Rusizi III and 90MW at Rusumo Fall) as well as geothermal (which generates between 170 MW and 340MW), peat (up to 1200MW), and solar (which has a potential of 66.8Twh) (Manfred Hafner,2019).

About 1.2 million households far from the national grid will be able to receive electricity through solar PV installations, according to Mininfra (2018). By the end of 2014, it was installed 2 photovoltaic-based power plants where the first one could generate 250Kw and second one was expected to generate 8.5MW. According to studies, Rwanda was experienced to have most useful micro and Pico hydropower plants which were attached to the rivers' runoff. (Mininfra, 2018).

The overall technical hydropower potential of Rwanda has been estimated to reach up to 400 MW; this varies depending on the study. The African Development Bank evaluated Rwanda's domestic hydro-power potential at 313 MW in 2013, divided between the totality of 130MW of the domestic energy use and 183 MW which are shared with next kin of countries in the region. As a result of the government's promotion of investment prospects in power generation, a major amount of the country's hydro resources have been utilized by private companies. The government is currently concentrating on utilizing extremely water- based resources for lightening of local towns though installation of mini-grids (Awad, 2017). Therefore, these are the source of energy used in Rwanda:

Peat to power: During the year 2016, it has been estimated that there was 13,571 hectare that contained the peat and it was estimated that approximately 23 to 33 million of dry tones of peat can be extracted in the area of 4057 hectares and this amount can be produced and generate between 121 MW and 161 MW where it can become between 97 to 129 Twh in 30 years ahead. Rwanda's dry reservoirs of peats are estimated to be worth 155 million megatons and cover an area of 50,000 km2. Their energy production capacity is 700 MW, which will be fully utilized in 30 years. Near the Akanyaru and Nyabarongo rivers, as well as the Rwabusoro plain, 77% of these reserves will be reserved. Gishoma and Gisagara Power plants expect to produce 15MW and 80MW, respectively. (Janvier Munyaneza,2016). Apart from Gisagara peat plant which is owned by Hakan company, there is also Gishoma peat power plant which is situated in western province specifically in Rusizi district and it produces 15MW (Kwibuka, 2015).

Hydropower Plant: Rwanda was benefited to have the substantial hydroelectric sources that make up the big part of the electricity generation. The Rwandan hydroelectric generation is headed by Nyabarongo Hydropower plant with 28MW of generation and it has been funded by around 80 Million US$.

The second is Rukarara 1 hydropower project which generates 9.0 MW, the Rusumo hydropower project is with 90MW and the electricity from Rusumo is regionally shared, that is the power is equally shared by three (3) countries namely Rwanda, Burundi and Tanzania with the share of 30MW per each country **(** Sengeyimana, 2016)**.**

Table 1: Various solar power plants and their total installed capacities

No	Plant name	Installed capacity (MW)
1	Ntaruka	11.5
2	Mukungwa 1	12
3	Nyabarongo	28
4	Gisenyi	1.00
5	Gihira	1.8
6	Murunda	0.1
7	Rukarara	1 9.0
8	Rugezi	2.4
9	Keya	2.4
10	Nkora	0.6
11	Cyimbili	0.3
12	Mazimeru	0.5
13	Nshili 1	0.4
14	Musarara	0.4
15	Mukungwa 2	2.5
16	Rukarara 2	2.4
17	Giciye	4
	Total generation	**79.50MW**

Source: (Awad, 2017).

Geothermal energy resources: The heat found deep within the ground is referred to as geothermal energy. The existence of a geothermal resource in Rwanda has yet to be established. However, investigations pointed out that areas such as Karisimbi, Kinigi, Gisenyi, and Bugarama were prospective places, with a total generation capacity of 47.3 MW accessible from five sites Cipcigan (2015). Given the complexities of assessing geothermal power's commercial viability, much more comprehensive exploratory investigations and subsurface drilling are required.

Solar energy: The collaboration between United States National Ai and Space agency (NASA) and University of Rwanda has put together the Rwandan radiation and they found that Rwandan Eastern province has best potential for the electricity delivered from sun. Another scholarly study from 2007 employed the data collection to present the monthly average global irradiation and this was under the help of Ministry of Infrastructures. Therefore, it was observed that the Rwandan irradiation lies between 4.3 and 5.2 Kwh per meter square at day basis (Mutabazi,2007).

Among the solar power plants, the Rwamagana solar energy which is located in Agahozo shalloon youth community was the first solar energy power plant across all the areas of Sub Saharan Africa. Aside From South Africa, With A Total generation of 8.5MW. The plant occupies 20 hectares (49 acres) of land, employs 28,360 solar panels, and generates 6% of Rwanda's total electricity supply.. The project of building the Agahozo Shalom youth village was under control of Israel, Dutch, Norwegian, Finish and United Kingdom Funding including the manpower (Jean de Dieu Uwisengeyimana, 2016)**.**The figure 1 present all the solar power plants in Rwanda and their total installed capacity.

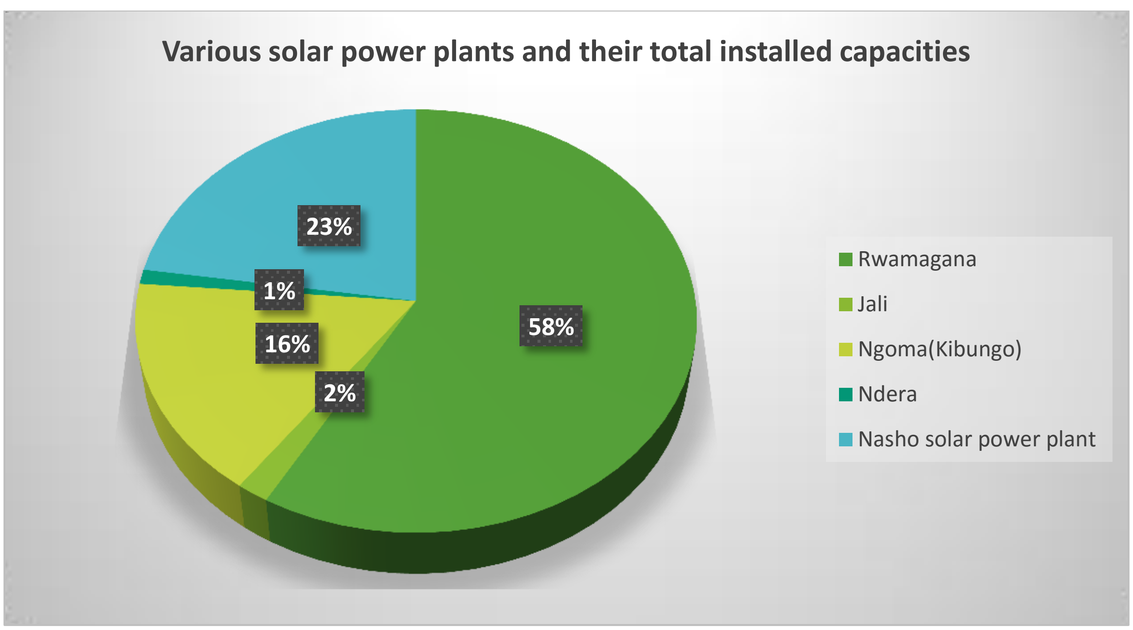

Figure 1: Various solar power plants and their total installed capacities

Source: Mininfra, 2016

The results from figure 1 revealed that Rwamagana/Gigawatt is the big producer of solar energy by 8.5 among the total 13.4 MW of solar energy generation across the country and it is shown at 58% of the total national solar energy generation. Nasho solar energy power plant is also presented by 3.3MW equalling to 23% of the total Rwandan solar generation. Ngoma solar power plant which is located in Ngoma District, former Kibuye in Eastern Province produces 2.4MW which is equal to16% of the total Rwandan solar generation Jali and Ndera produce 0,25MW and 0.16 MW and their portion at the percentage is 2% and 1% respectively. Additionally, the solar energy generation of these power plants depends upon the yearly radiation. The higher the radiation, the higher the generated energy is realised across the year. The data on figure 2 present the Monthly average daily global solar irradiance in Rwanda.

Month	**Generation (Gwh /m^2/day**
January	4.9
February	5.3
March	5.1
April	5.08
May	4.9
June	5.3
July	5.8
August	5.7
September	5.4
October	5.1
November	4.9
December	4.8

Table 2: Monthly average daily global solar irradiance in Rwanda

Source: (Uwisengeyimana, 2016)

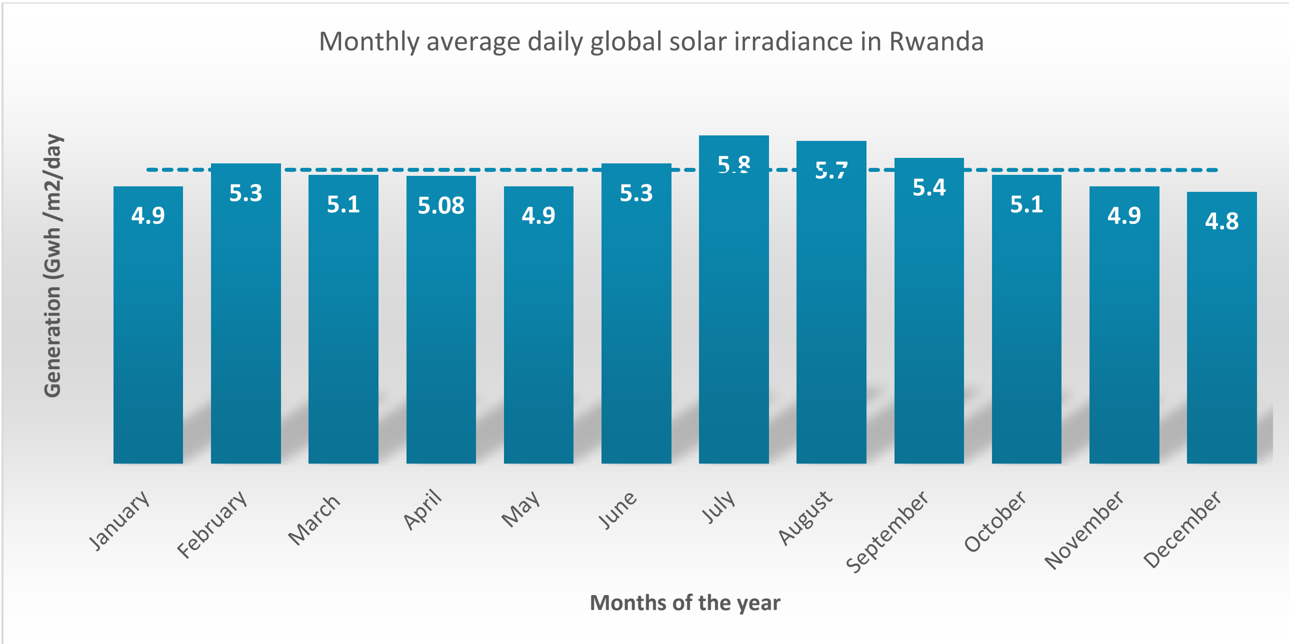

Figure 2: Monthly average daily global sola irradiance in Rwanda

Source: (Habyarimana, 2016)

The summer time (months of June, July, August and the Mid-September experiences high radiation and they are intersected with the trend line). The period of higher rainfall (November, December and January) experience the lower radiation.

Moreover (15 days of February, March, April and Mid-May indicate the Moderate ate of radiation as the rainfall is also mixed with the sunrise. This indicates that the variation in season affects the rate of radiation hence the expectation of uneven solar energy in Rwanda across the year.

Methane Gas: The Methane Gas is produced from Lake Kivu and it goes deeper at 60-70 kilometre cubes under which among them 44.7 kilometres cube can be harvested. When expecting the amount of methane gas to be obtained from this lake, the method of extraction which was used is taken as a driving instrument. Although electricity is expected to be the first at the final user's energy resources, methane gas offers a wide range of commercial and industrial applications. There is also the Kibuye power plant.

The Government of Rwanda began its search for qualified engineering forms to design and build the Methane Gas in Kivu in 2006. With partial funding from the International Finance Cooperation (IFC), it began its operational activities in 2006.

Beginning in 2006, the Rwandan government began looking for appropriate engineering firms to develop the methane gas from Kivu with partial funding from the International Finance Corporation (IFC). It is now held by the Rwandan government in conjunction with Dan Associates, an Edinburgh-based company that split up over financial issues over the project's performance. However, in 2016, Symbion Power, an American electricity-generating business, paid an undisclosed sum for the Kibuye power plant, which was increased to 25MW in 2018 and 50MW in 2019. The Kibuye power plant generates electricity at 3.5 MW (Bamundekere, 2018).

Biomass: The biomass is not widely extracted in the territory of Rwandan because of lower amount of wastes and due to the fact of way people lives in cities, there are opportunities to find large volumes of decayed garbage and among the we can mention organic wastes, papers, and woods which can be used in form of electricity generation (Safari and J. Gasore (2009).

2.2.4. The Proportion of Rwandan renewable energy generation mixes

Renewable energy plays a critical part in Rwanda's socioeconomic growth, and it is closely linked to the development of other economic sectors. The country places a premium on the usage of environmentally friendly and energy-efficient technologies. Rwanda gets the majority of its electricity from renewable sources. Off-grid and on-grid generation are included in the renewable electricity blends. More than 60 percent of overall renewable energy generation comes from hydrological resources and other indigenous sources, while less than 40 percent comes from diesel-powered generating. Rwanda plans to attain at 563MW in the year 2023/2014 and this will come from internal or domestic generation and the import. In this period of 203/2024 Rwanda is expecting to have the 100% full electrification target. (Mininfra, 2013). The figure below presents the total renewable energy generation mixes

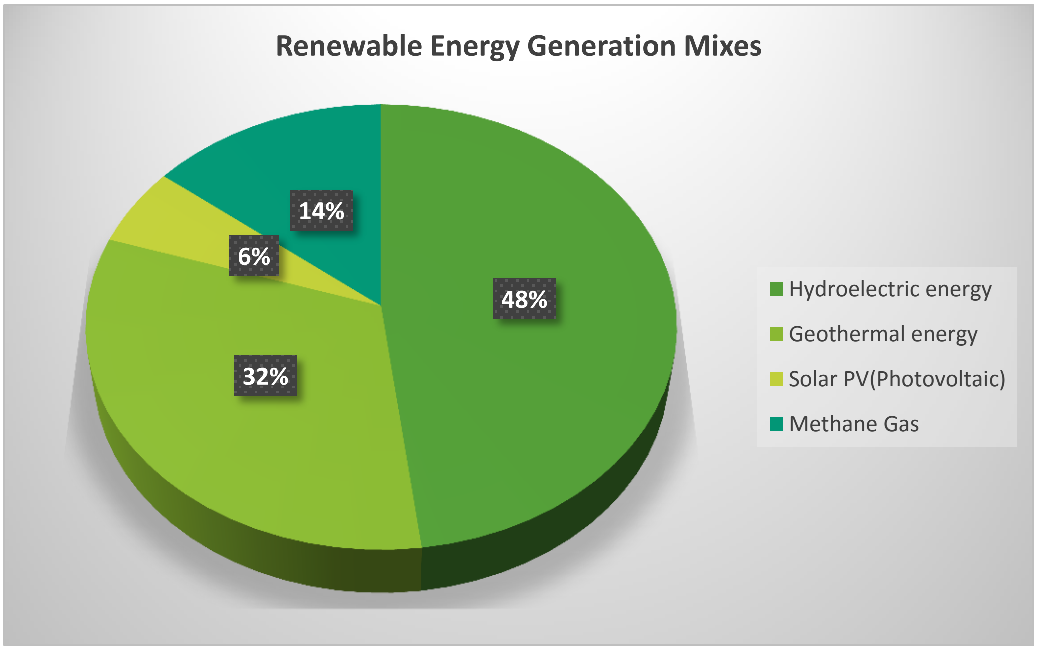

Figure 3: Renewable Energy Generation Mixes

Source: (Manfred Hafner,2019).

As indicated in the figure 3, Rwanda has different generation mixes where the big part of renewable source is presented by hydropower energy at 48%, the Geothermal present about 32%. There is also the methane gas and solar that takes the proportion of 14% and 6% respectively.

2.2.5. Role of renewable energy consumption in economic growth of countries

The report from International Energy Agency (2013) indicates that the renewable share of electricity generation will increase to 39% by 2015 from 18.3% in 2002.This increase in use of renewable energy will reduce the $C0_2$ emission by 50% in the same year of 2050 which reflect the economic growth and removal from poverty trap (poverty line by many countries), the facts of increase in this use of renewable energy is the subsidies from Government-supported programs, tax credits and increase in cost-competitiveness of renewable energy sources (International Energy Agency,2013).

Energy would be of great importance because it facilitates the development of engines which is the crucial tool toward the developed industrialization. Nonetheless, it contributes to a number of issues that countries face today. Some of these concerns include: Energy price increases, population growth, increased energy density per person and Environmental issues. As a result, energy infrastructure investments become increasingly important in order to address these issues and meet current energy demand (Zawaydeh, 2015).

2.3. Review of the empirical studies

This part aimed at presenting the broad literature which is lined to the current research and shows what were the points they considered, the variables used, the methodologies that these researchers have used in attaining at their findings. Several researches have tried to mention the nexus (relationship) between the amount of renewable energy consumption and economic countries economic growth and regional's consideration namely the regions (Like European Union, Caribbean Region, G7 countries, COMESA Countries), agriculture, manufacturing, transportation, and the environment are only a few examples.

As a result, in this study, the researcher used the vector autoregressive model created by (Inessa Love, 2016) to look at the effects of renewable energy consumption and economic growth at the same time. The current research makes three contributions to energy consumption and economic growth through the impacts of renewable on economic growth and the research revealed that some regions has different attributes to consider such as solar and winds. The table below contains the information on empirical studies which was one in respect to the countries and the utilised methodologies. It also show the obtained results and their implications .In brief, some of the research used the Vector error correction model (VECM)), Cointegration theory, GMM estimation GMM (Generalized Method of Moments) method, autoregressive distributed lag (ARDL) estimation. Unlike these past studies, the current research will use the vector autoregressive model to reduce the spurious regression and this will be done through testing the unit root, cointegration and present the descriptive statistics from obtained regressions

Authors	**Countries**	**Time**	**Methods**	**Expected outcome or results**
Part: Research that used Time series Data				
Menyah And Wolde	USA	1960-2007	Toda-Yamamoto causality	Bi-directional relationship better renewable energy consumption and carbon emission
Rufael, Tawani	India	1960-2009	Structural autoregressive model(SVAR)approach	The energy consumption in the renewable sources enhances the economic growth and decease the level of carbon emission
Lin and Moubrack	China	1977-2011	VECM (Grange causality test	RE↔Y and Co2→RE in long run RE….CO2 and RE….Y (Short run)
Jaforullah&King	USA	1965-2012	Cointegration test(VECM) Grange causality test	RE→CO2 …RE…Y; The increase in consumption of renewable energy is an effective solution to mitigate the emission of Carbon dioxide
Long et al	China	1952-2012	Cointegration analysis(Grange causality analysis)	Y→RE: RE→CO2: The renewable energy consumption has a positive

				effect on economic growth and negative impact on carbon mission
Bento and Mourinho	Italy	1962-2011	ARDL Model/Toda Yamamoto test	Y→RE: RE reduces the level of carbon emission per capita in short run
Chunark et al.	Thailand	2015-2035	Asian integrated model/computable general equilibrium(AIM/CGE	RE will mitigate the carbon emotion and boost the economic growth
Beladi and Youssef	Algeria	1980-2012	ARDL Model/VECM Granger causality test	RE→CO2(Long run) RE→Y(Long run)
Danish et al.	Pakistan	1970-2012	ARDL Model/ FMOLS/VCM and grange causality	RE→CO2; RE---Y; Renewable energy plays the vital role I curbing the carbon emission
Part 2:Research That Used Panel Data Analysis				
Sadorsky	G7 countries	1980-2005	FMOLS(Fully-modified ordinary least square/DOLS(Dynamic Ordinary Least Squares	Y→RE CO2→RE
Silva et al.	USA, Denmark, Portugal, Spain	1960-2004	Structural Vector Autoregressive Model(SVAR)	Expert for USA revealed that an increase in the use of RE sources have an

				attached economic cost in term of GDP Per capita, (that is it harms economic growth and decease the CO_2 emission per capita
Apergis and Payne	7 central American countries	1980-2008	FMOLS (Regime wise Granger causality test	RE↔Y RE↔CO_2
Beoluk and Mertt	16 EU(European Union countries	1990-2008	Panel fixed effect model	Renewable energy consumption appreciably reduces the carbon emission around one half(1/2
Al-Mula et al.	Latin America and the Caribbean countries	1980-2010	Cointegration test/VECM Grange causality test	RE↔Y RE↔CO_2
Apergis& Payne	South America	1980-2010	FMOLS/VECM Grange Causality Test	RE↔Y
Mourinho and Robaina	20 European Countries	1991-2010	Cointegration analysis/the innovative accounting approach/VECM/Grange Causality Test	RE↔Y RE↔CO_2
Bhattacharya Et al.	85 developed and developing countries	1991-2012	The systems of GMM(/FMOLS Model	The increase in renewable energy consumption has an important positive and

				negative effect on economic productivity and carbon dioxide
Ito	42 developing countries	2002-2011	GMM/PMG(Portfolio Management Guide	RE contributes to the environmental quality improvements and has the positive effect on economic growth

Table 3: Empirical review on renewable energy consumption –economic growth nexus

Source: Researcher's tabulation

Note: The signs → ↔ and… denote the unidirectional causality relationship, bi-directional causality and no causality relationship respectively.CO2, RE and Y are the denoted abbreviations of carbon dioxide, renewable energy and income or economic growth or GDP respectively.

2.4. Conceptual Framework

The figure below depicts the variables and their factors of existence. It is made of independent variable which is the country' output or GDP, with its determinants such as the income of the population Ability to explore the resources, level of technological progress, employment situation of the country. In the side of dependent is the Renewable Energy consumption with its deterministic factors such as total number of Labor force in country, the amount of carbon dioxyde emmitted in atmosphere, the capital (total capital) used in renewable energy production and distribution and the amount of available renewable sources (in Terajule).

In the corner of intervening variables, factors such as rules and regulation, government policies, Private-public partnership, Power Purchase Agreement (PPA), and the role of IPPs (Independent Power Producers) were taken into account.

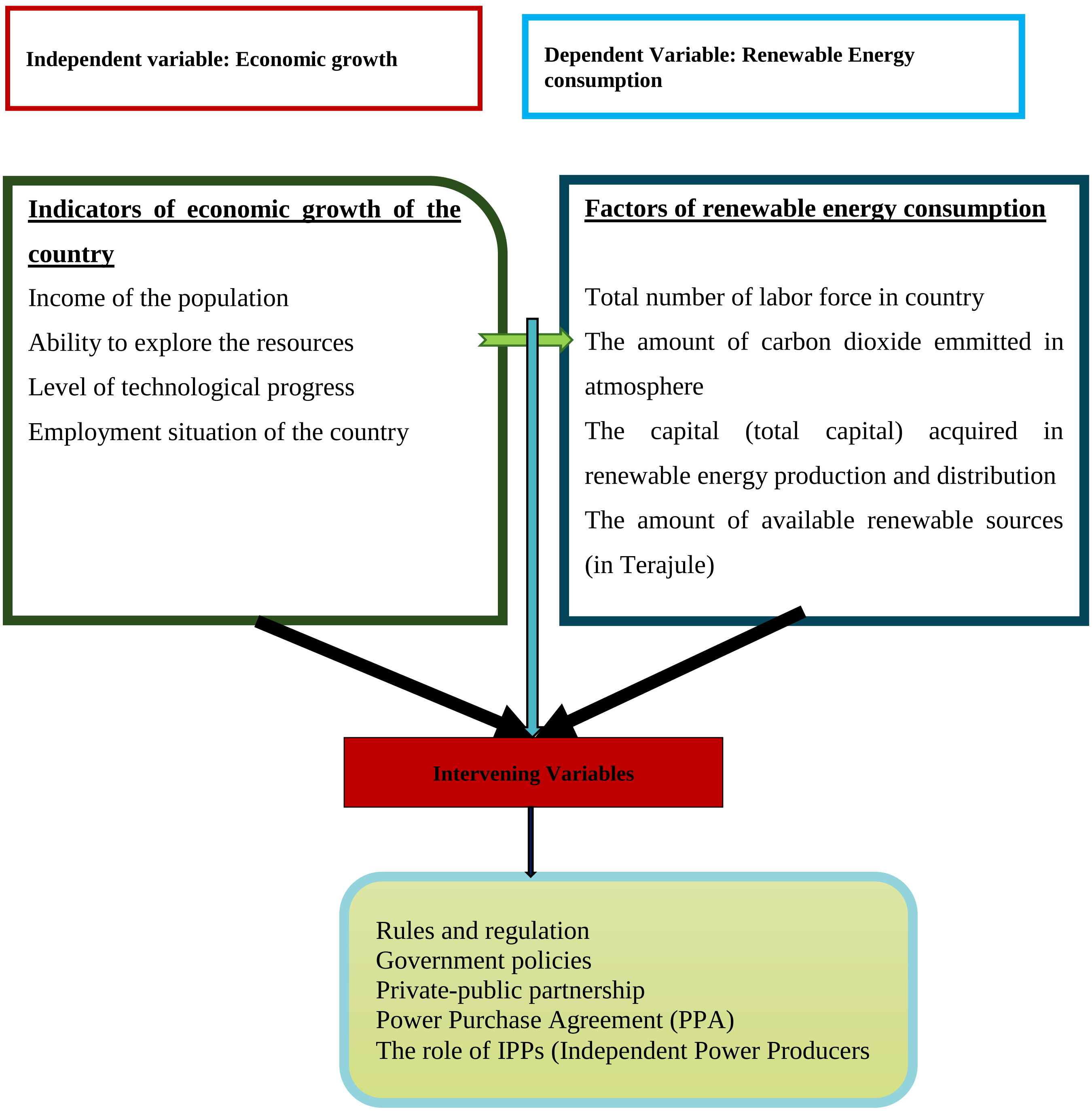

Figure 4: Conceptual framework

Source: Researcher's tabulation, 2021

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Research Design

This study utilized the correlative design to analyze the available data and test whether there is a significant relationship between renewable energy consumption and Rwandan economic growth in the period from1990-2015. The method which was used is the vector autoregressive model (VARM) as was defined by Im et al. (2003) where author used the method of test panel unit root test which allows developing the method of heterogeneous autoregressive coefficients and how it will be utilized. Moreover, (Pedroni, 1999, 2004) proposed the cointegration test where panel test is based on the within dimensions' approach.

3.2. Model specification and data source

The model is the reduced form of the complex reality which aims at narrowing big characters in small portions as to make the relationship between 2 variables be taken under consideration and be explained in clear ways Therefore, the renewable energy consumption-economic growth nexus can be structured in the model by considering that all these variables affect one another. Therefore, the level of renewable energy consumption is planned to be in the function of its determinants like economic growth (Labor force, Capital, labor force and C02 emission).

The model will explain the GDP with its respective explanatory variables such as Renewable Energy Labor force, Capital, labor force and C02 emission:

$$Y_t = \beta_o + \beta_1 REC + \beta_2 TLF + \beta_3 Kapital + \beta_4 CO2emission + \varepsilon_t \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Y_{it}= Real GDP in billions of country i in time t

βo= intercept

βo, β_1, β_2, β = Coefficients to be estimated basing on recorded observations

REC: Renewable energy consumption defined in % of total final energy consumption

TLF: Labour force

Kapital: Capital

$CO2emission$: Carbon dioxide emission in kt (Kilotons)

E_t : Error Term or disturbance

The mathematical form of the vector auto regression model to be estimated including the lags of the variables is as follows:

$$Y_t = \beta_1 + \sum_{i=1}^{d} \gamma_{1i} Y_{t-i} + \sum_{i=i}^{d} \delta_{1i} REC_{t-i} + \sum_{i=1}^{d} \tau_{1i} TLF_{t-i+} + \sum_{i=1}^{d} \varphi_{1\mathrm{i}} Kapital_{t-i} + \sum_{i=1}^{d} \omega_{1i} CO2_{t-i} + \varepsilon_{it} \ldots \ldots \ldots (1)$$

$$Kapital_t = \beta_2 + \sum_{i=1}^{d} \gamma_{2i} Kapital_{t-i} + \sum_{i=1}^{d} \delta_{2i} REC_{t-i} + \sum_{i=1}^{d} \tau_{2i} TLF_{t-i} + \sum_{i=1}^{d} \tau_{2i} Real\ GDP_{t-1} + \sum_{i=1}^{d} \omega_{2i} CO2_{t-1} + \varepsilon_{2t} \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

$$REC_t = \beta_3 + \sum_{i=1}^{d} \gamma_{3i} REC_{t-i} + \sum_{\mathrm{i}=1}^{d} \delta_{3i} Kapital_{t-i} + \sum_{i=1}^{d} \tau_{3i} TLF_{t-i} + \sum_{i=1}^{d} \tau_{3i} Real\ GDP_{t-i} + \sum_{i=1}^{d} \omega_{3i} CO2_{t-i} + \varepsilon_{3t} \ldots \ldots \ldots .. (3)$$

$$TLF_t = \beta_4 + \sum_{i=1}^{d} \gamma_{4i} TLF_{t-i} + \sum_{i=1}^{d} \delta_{4i} REC_{t-i} + \sum_{i=1}^{d} \tau_{4i} Kap\mathrm{ital}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \tau_{4\mathrm{i}} \mathrm{Real\ GDP}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \omega_{4\mathrm{i}} \mathrm{CO2}_{\mathrm{t-i}} + \varepsilon_{4\mathrm{t}} \ldots \ldots \ldots \ldots .. (4)$$

$$\mathrm{CO2_t} = \beta_5 + \sum_{\mathrm{i=1}}^{\mathrm{d}} \gamma_{5\mathrm{i}} \mathrm{CO2}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \delta_{5\mathrm{i}} \mathrm{REC}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \tau_{5\mathrm{i}} \mathrm{TLF}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \tau_{5\mathrm{i}} \mathrm{Kapital}_{\mathrm{t-i}} + \sum_{\mathrm{i=1}}^{\mathrm{d}} \omega_{5\mathrm{i}} \mathrm{RealGDP}_{\mathrm{t-i}} + \varepsilon_{5\mathrm{t}} \ldots \ldots \ldots \ldots \ldots \ldots (5)$$

In bringing the variable under same context of relationship testing, the methods such as the test of unit root, the cointegration test, the anger Grange test were all tale into account. The reason why the time series data was generally chosen is that these data provides yearly changes in variable over another one hence it is easy to know what policies can be taken in 1 year when certain variation in variables behave abnormally when the CO2 emission become higher in first year, direct policies can be taken so that in next year against this environmental degradation and this justifies the role of time series unlike the panel data which can take more than 1 year to collect data on same subject matter.

In this study, the VAR (Vector Auto-Regressive) model shall be used to test for causal relation of different variables as it was used by other researchers in energy related researches (James, 2007) and (Nicholas Apergis et Al., 2009). VAR model various advantages which makes it more suitable for the research to test causality effects, these advantages are:
The estimates from VAR Model are flexible and less demanding in terms of information and time and it allows the easy integration of new data.

3.3. Data and their sources

The overall data in this research were collected from the online records from Word bank the World Bank through World Development Indicators (WDI). The utilized data on every variable under consideration were based on Rwandan records from WDI in the period from 1990-2015. The limitation in time (not including data from 2016 up to now) was due to the data availability in publication of World development indicators (WDI) where all the data related to the study were to be gathered.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1. Trend of research variables from 1990-2015

Recalling to the variables which were used in the research, the independent variable was the country's Gross Domestic Product and the independent variables were: Renewable energy consumption, total labor force, capital and the carbon emission

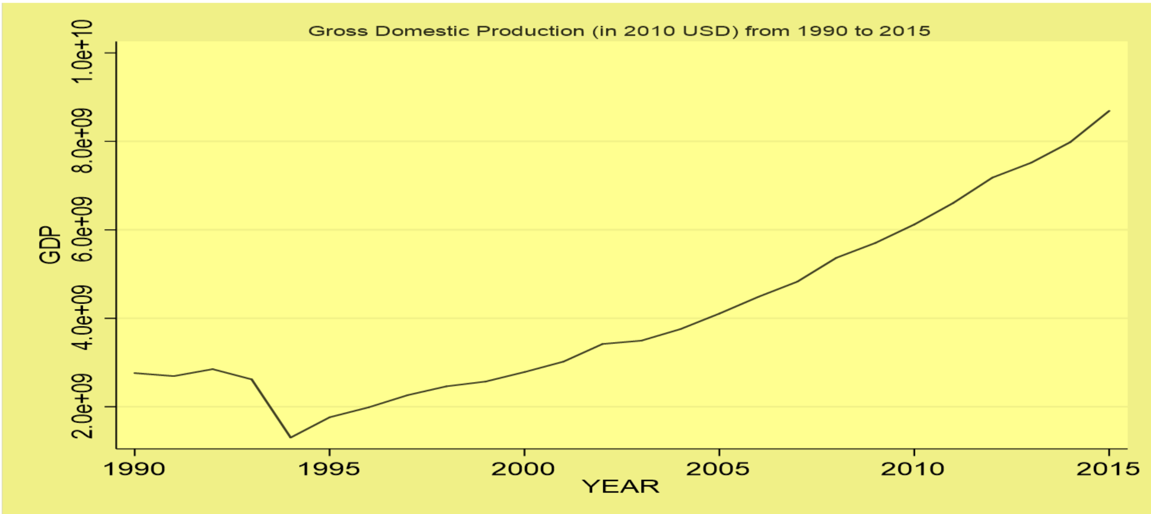

Figure 5: Trend of Gross Domestic Product (in 2010 USD) from 1990-2015

Source: Secondary Data from World Development Indicators (WDI), 2021

As seen in the figure 5, the Gross Domestic Product (which was estimated in 2010 USD) was 2761876034.83884 Rwf. Unfortunately, with the 1994(the year that Rwanda experienced the Genocide against Tutsi,) the country's GDP have fallen to 2850551118.46405 USD due to the fact that the country's production was not at good mood as resulting from killing of labor force and destruction of economic outputs which could contribute to the economic rise. The good story is that after the Genocide, the country started at looking at best ways of recovering the economy which was devastated in 1994 and the trend of GDP shifted in upwards direction until now. The fact of increase in GDP is seen in argument whereby in 1995, the country's GDP was 1762248929.88672 while in 2015 it has increased up to 8688928705.95013USD.

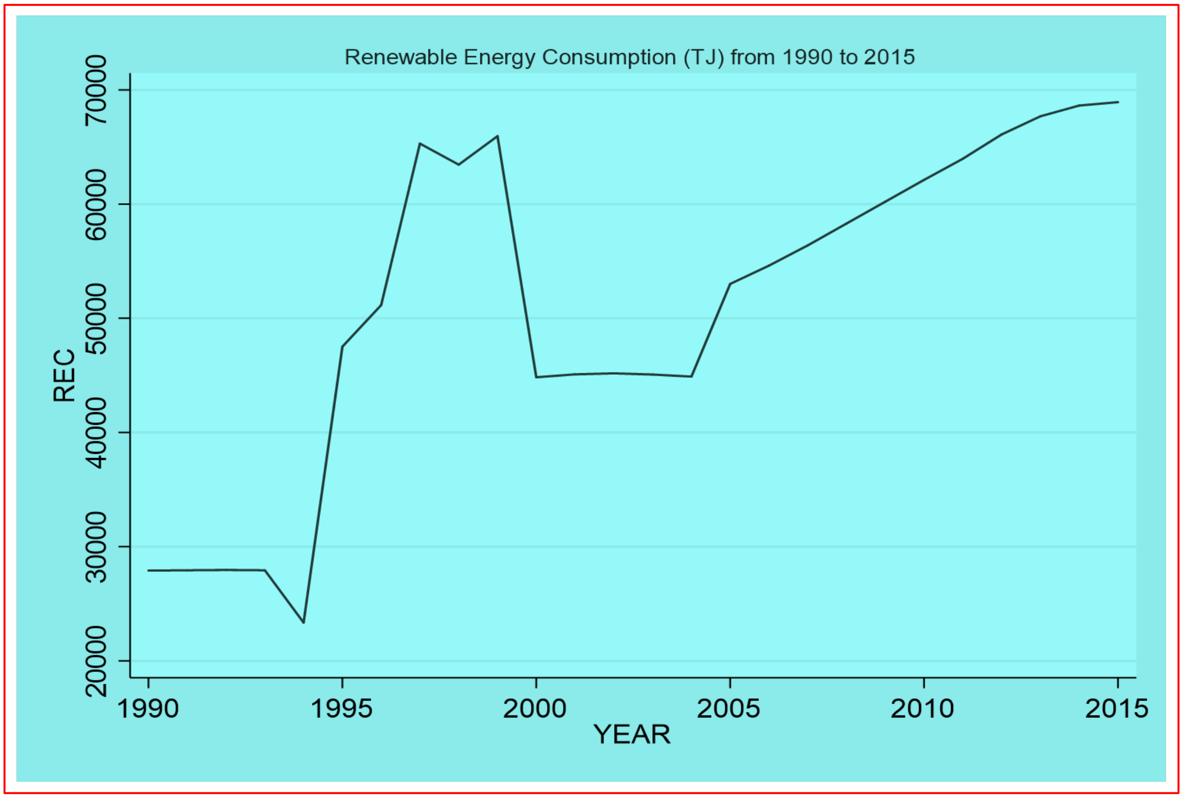

Figure 6: Trend of renewable energy consumption (expressed in TJ) from 1990-2015

As depicted in figure 6, the total summation of energy from the consumption of renewable source in 1990 was depicted at 27900.6 kt. The same downward sloping was realized in 1994 as the consequence of genocide against Tutsi. This period of 1994. Rwanda recorded 23345.19 TJ of renewable energy consumption. In the period from 1995, the shape of renewable energy consumption was looking upwards until the quarterly of 1990.This was associated with the use of it in industrialization rebuilding and home policies of spreading the electricity. At the end of 1990 and beginning of 2000, the level of renewable energy consumption started to go down as resulting from the energy substitution where the use of non-renewable energy was increased. His was seen whereby in 1990, the total renewable energy consumption was estimated at 65955.63 TJ and in 2000; the total renewable energy consumption was estimated at 44838.63 TJ.

The period from 2000-2005 showed the almost same renewable energy consumption as the energy substitution was also taking place to see how to adopt the Kyoto and Paris agreement on climate change. Additionally, it can be seen that the outputs from Rwanda's adaptation of Kyoto and Paris agreement on climate change was seen whereby in the period from 2006 up to 2015, the amount of renewable energy consumption increased from 54611.52 TJ up to 68929.6 TJ which was recorded in the year 2015.

Figure 7: Trend of total labor force from 1990-2015

The figure 5indicates that the Rwandan Labor force has decreased in the period of 1994 as result of genocide against Tutsi but after this year, the labor force increased

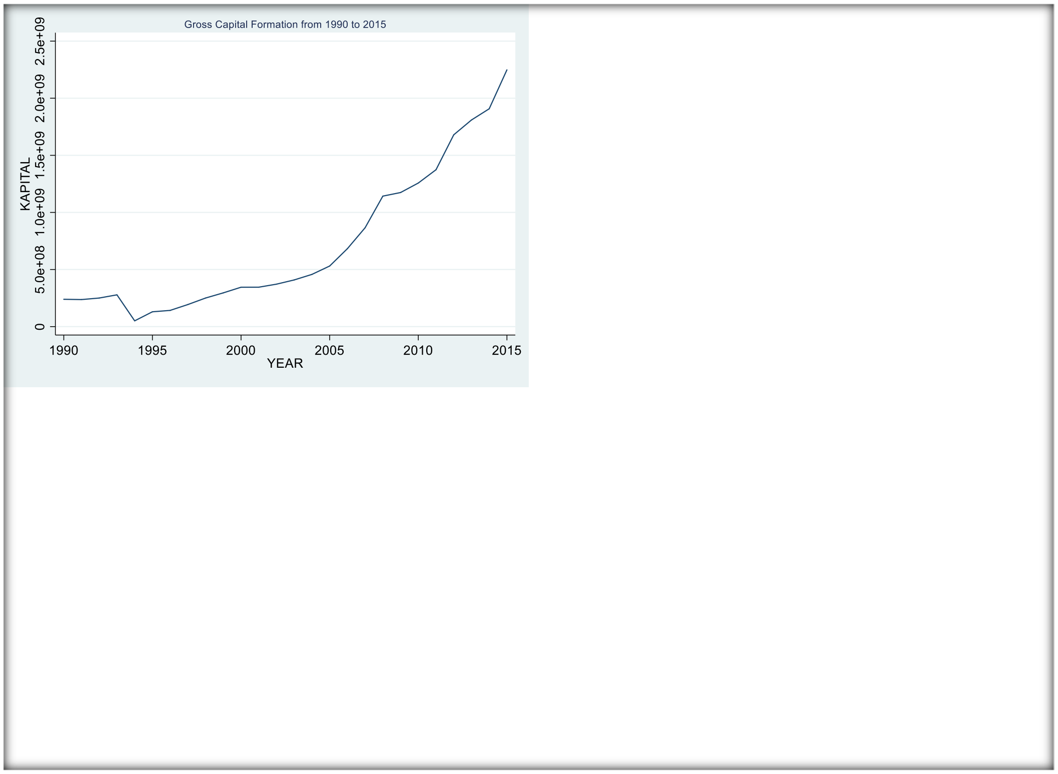

Figure 8: Trend of Gross Capital Formation from 1990-2015

The figure 8 indicates that the Rwandan Gross Capital Formation has decreased in the period of 1994 as result of genocide against Tutsi but after this year, Gross Capital Formation increased. The reason why the curve is not straight upwards was due to the fact that in capital allocation and funding sources were not equal across the time of consideration but normally its looks upwards.

4.2. Description of statistics for Variables Utilized in the study

Variable	Mean Value	Standard. Deviation	Minimum	Maximum
Log Real gross domestic production	22.03	0.505	20.988	22.885
Renewable energy consumption	51289.737	14535.104	23345.189	68929.602
Total labor force	4107133.1	872059.41	2939305	5668121
Log Gross Capital formation	19.981	0.968	17.742	21.534
Carbon dioxide emission	570.783	129.519	454.708	960.754

Table 4: The descriptive statistics

Table 4 above reports the descriptive statistics of all the dependent and independent variables used in this study. where the real gross domestic production is measured in 2010 United States dollars whereby the consumed energy sources in form of renewables was measured in Telajoules (TJ), total labor force is measured as number of population, carbon dioxide emission as measure in the metric tons of CO_2 equivalence and the gross capital formation is finally measured as 2010 US dollars.

Additionally, in Rwanda, the average value of the gross domestic production is UD $ 4.17 billion. The real gross domestic production varies in between US$ 1.3billion and 8.69 billion. Moreover, the level of change of variability is also witnessed by the standard deviation of US$ 2.1 billion indicating that the data are not scattered away from the mean value. The renewable energy consumption has a mean value of 51,289.74 TJ with the variation range between 23,345.19 TJ and 68,929.6 TJ where the degree of variability of renewable energy consumption is revealed by the standard deviation of 14,535.1 TJ and this indicates that the data are scattered away from the mean value of the renewable energy consumption.

The total labor force has its mean value at 4,107,133 people and the variation range of total labor force is in between 2,939,305 and 5,668,121 people while the degree of variability for the total labor force is shown by its standard deviation of 872,059 people and this indicates that the data for the total labor force are deviated away from its mean value.

From the table the description of statistics reports that the gross capital formation has its mean value at US $ 718 million with the variation between US$ 50,725,256 and US $2.25 billion while is standard deviation of US$ 641 million indicate the degree of its variability and this reveal that the gross capital formation data are close to its mean value. The statistics described above indicates that the carbon dioxide emission has its mean value of 570.8 metric tons with the variation range between 454.7 and 960.75 metric tons while its variability is shown by the standard deviation of 129.519 metric tons revealing that the carbon dioxide emission data are scattered away from its mean value.

4.3. Empirical Results

4.3.1.Stationarity Tests

The stationarity property of all the variables is examined to avoid the potential problem of spurious regression. Three common methods of examining stationarity, namely the augmented Dickey and Fuller (1981) (ADF) test, the Phillips and Perron (1988) (PP) test are used to ensure that the estimated results avoid the problem of spurious inferences. The estimated results in figure below reveal that, according to the ADF, PP tests, only the first difference of all the variables are stationary at the I (1) level.

4.3.2. Checking unit root using augmented dickey fuller test (ADF)

The results below present the unit root of the variables

Variable	dfuller_statis	dfuller_cvalue	dfuller_pvalue	dfuller_lags	pperron_statistic	pperron_rho	pperron_pvalue	pperron_lag
lngdp_dif	-5.112	-3.000	0.000	0.000	-5.125	-25.126	0.000	2
lnrec_dif	-5.393	-3.000	0.000	0.000	-5.369	-28.924	0.000	2
lntlf_diff	-1.558	-3.000	0.505	0.000	-1.814	-5.356	0.374	2
Lnkapital	-6.762	-3.000	0.000	0.000	-6.840	-31.699	0.000	2
lnco2_di	-3.395	-3.000	0.011	0.000	-3.431	-15.872	0.010	2

Table 5: Results from Unit root test using Augmented dickey fuller test (ADF)

4.3.3. Determination of optimal lag length

In the VAR model, the determination of the optimal lag length is crucial. For this purpose, the number of previous periods in which economic growth influences current economic growth can be determined. With an initial lag length of 4, the VAR model automatically calculates the optimal lag lengths. The results of calculating the lag lengths are shown in figure below. According to the results in figure below, based on all three criteria, AIC, SBIC and HQIC, the optimal lag length of the model is 4. As all the variables are stationary at I(1), according to AIC the optimal VAR model for the data is VAR(4) such that, in equation (2), p = 4.

Selection-order criteria
Sample: 2458q3 - 2463q4 Number of obs = 22

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	89.2543				3.2e-10	-7.65948	-7.60107	-7.41152
1	219.69	260.87	25	0.000	2.4e-14	-17.2445	-16.894	-15.7567
2	293.722	148.06	25	0.000	4.2e-16	-21.702	-21.0594	-18.9744
3	379.191	170.94	25	0.000	7.5e-18	-27.1991	-26.2645	-23.2317
4	2049.43	3340.5*	25	0.000	1.2e-79*	-176.766*	-175.539*	-171.559*

Endogenous: lngdp lnrec lntlf lnkapital lnco2
Exogenous: _cons

Table 6 : Table indicating the optimal lag length (Quarterly basis

4.3.4. Cointegration Test

According to the examination of the cointegration property for time series data developed in Johansen (1995), there may be long run cointegration among the variables. Table7 below shows that the trace statistic of 6.25 is lower than the critical value of 12.53 for maximum rank of 3 cointegration equations at the 5% significance level. The results of the cointegration test show that there exists long run cointegration for the seven variables. Therefore, equation (1) should be estimated using the error correction model since the co-integration test shows that there exist a long run relationship among the endogenous variables hence the vector autoregressive model with consideration of error correction was applied

Johansen tests for cointegration

Trend: none				Number of obs =	24
Sample: 2458q1 - 2463q4				Lags =	2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	25	190.04852	.	81.7722	59.46
1	34	205.17784	0.71657	51.5136	39.89
2	41	218.00936	0.65675	25.8505	24.31
3	46	227.80922	0.55809	6.2508*	12.53
4	49	230.92952	0.22897	0.0102	3.84
5	50	230.93463	0.00043		

Table 7: Results from co-integration test

4.4. Estimation Results from vector autoregressive (VAR) model

The vector autoregressive model was used as the method of checking for spurious regression. In this regards, the univariate autoregressive model can be applied so as to see whether the research variable with its coefficients are statistically significant or not.

Variables	Real Gross Domestic Production	
	Coefficient	S.E
L.gdp	-0.077	0.0759
L2.gdp	0.214***	0.0804
L3.gdp	0.643***	0.086
L4.gdp	0.512***	0.0918
L5.gdp	0.157***	0.0263
L6.gdp	-0.118***	0.0376
L7.gdp	-0.0477**	0.0236
L8.gdp	-0.202***	0.0248
Renewable energy consumption	9,004***	2863
Total labor force	-889.3***	304.6
Gross Capital formation	1.195***	0.0803
Carbon dioxide emission	-1.763e+06***	297194
Constant	4.048e+09***	1070000000
Observations	18	
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1		

Table 8: Estimation results from univariate autoregressive model

Table 8 reports the results from the estimation of the independent variables which are renewable energy consumption is measured in Terajoules (TJ). The total labor force is measured as number of population, carbon dioxide emission as measure in the metric tons of CO2 equivalence and the gross capital formation measured as 2010 US dollars including the lags of the real gross domestic production on the dependent variable which is the real gross domestic production as the main indicator utilized for measuring/ determining the economic growth.

It is indicating the relationship of real gross domestic production and its lags including other exogenous variable and this showed the positive short run relationship between the real gross domestic production and the lags in less than 6years with negative relationship with its lags above 5years before.

From the results estimation in table 9 indicates that the renewable energy consumption has a positive effect on the real gross domestic production that is when the renewable energy consumption is increased by 1 TJ this is associated with the incline of US$ 9,004 in the real gross domestic production of the country given other factors are held constant which is significant at $p<0.01$ and this accords what is reported in the study carried out by (Pirlogea, C. and Cicea, C., 2012) and this goes in line with the fact that when the consumption is increase in energy sector this will lead to the increase in the real gross domestic production as the consumption is one of the components of the country output /gross domestic production and the consumption component has the positive proportionality and relationship with the real gross domestic production.The total labor force will have a positive relationship with the real gross domestic production only when the total labor force increase with increase in the employment and the unemployment held fixed and this derive the positive relationship between the employment and economic growth which is measured by real gross domestic production for this study.

From the estimation results In table 9, too much interesting the positive relationships between the gross capital formation and the real gross domestic production that is when the gross capital formation is increased by 1 US dollar this is associated with the increase in the real gross domestic production by 1.9 US dollar and this is significant at $p<0.01$and this goes in line with the fact that the gross capital formation is just a form of investment, and the investment is a crucial component of the national output /real gross domestic production and the fundamental relation of gross domestic production and its components including the investment in form of gross capital formation proves the positive relationship and proportionality between the investment component and the real gross domestic production.

From the results estimation in table 9 ,too interestingly the negative relationship between the metric tons of carbon dioxide emission and the real gross domestic production that when the carbon dioxide emission is increased by 1 metric ton this is related to the severe decline in the real gross domestic production by US$ 1.76 million which is significant at $p<0.01$ which accords the findings from the study by (Apergis, N.and Payne, J.E., 2010) and this goes in line with the facts that the industry sector is seriously influencing the economic growth through the increasing the national output and hence the real gross domestic production but most of the industries use fossil fuels and polluting fuels throughout their processes leading to the increase in the greenhouse gases emissions due to the industrial production for improving the national domestic output / real gross domestic production. Due to the Kyoto protocols, IPCC and Paris agreements on the global environmental protection due to the severe greenhouse gases emissions from the developed and developing country which their economies mostly rely on the industry sector. And the agreements and protocols set up the global carbon taxing and charges and carbon markets for the countries due to the quantity/ metric tons of carbon dioxide emission equivalences emitted in atmosphere and this entails country payment of the carbon charges due to carbon dioxide emission equivalences subjected into the atmosphere.

From the estimation results in table 2, as the carbon dioxide emission increase this leads to the country out payments for the greenhouse gases emissions subjected into atmosphere and this leads to the decline in the national domestic output/production/ real gross domestic production.

Table 9: Estimation Results for full Panel Vector Autoregressive Model

VARIABLES	Gdp	Rec	Tlf	Capital	co2
L.gdp	-0.461***	4.17e-06***	-3.79e-05***	-0.173***	-6.87e-08***
	(0.050)	(0.000)	(0.000)	(0.050)	(0.000)
L2.gdp	-0.142***	0.000	-8.82e-05***	0.375***	1.83e-08***
	(0.052)	(0.000)	(0.000)	(0.052)	(0.000)
L3.gdp	-0.821***	1.38e-05***	-3.57e-05***	-0.587***	-9.99e-09***
	(0.051)	(0.000)	(0.000)	(0.051)	(0.000)
L4.gdp	-0.324***	-5.10e-06***	-6.04e-05***	0.023	-7.49e-08***
	(0.077)	(0.000)	(0.000)	(0.077)	(0.000)
L.rec	-8,318**	-0.645***	1.641*	-17,406***	0.00740***
	(4036.000)	(0.079)	(0.915)	(4030.000)	(0.000)
L2.rec	11,965***	-0.176***	3.791***	1398.000	0.00554***
	(2617.000)	(0.051)	(0.593)	(2613.000)	(0.000)
L3.rec	42,953***	-0.233***	1.395**	26,581***	0.000995***
	(2492.000)	(0.049)	(0.565)	(2489.000)	(0.000)
L4.rec	1765.000	0.126**	0.702	-3555.000	0.00546***
	(3152.000)	(0.062)	(0.714)	(3147.000)	(0.000)
L.tlf	-436.700	0.333***	1.673***	-3,325***	0.000844***
	(657.700)	(0.013)	(0.149)	(656.700)	(0.000)
L2.tlf	9,626***	-0.389***	-1.229***	13,021***	-0.00412***
	(1864.000)	(0.037)	(0.422)	(1861.000)	(0.000)

L3.tlf	-18,804***	-0.058	0.404	-18,327***	0.00452***
	(2060.000)	(0.041)	(0.467)	(2057.000)	(0.000)
L4.tlf	13,770***	0.102***	0.408**	9,581***	-0.00115***
	(765.800)	(0.015)	(0.174)	(764.700)	(0.000)
L.kapital	1.308***	-8.72e-06***	5.78e-05**	1.234***	1.39e-07***
	(0.105)	(0.000)	(0.000)	(0.105)	(0.000)
L2.kapital	-0.267	2.77e-05***	0.000117***	-1.615***	-2.57e-07***
	(0.170)	(0.000)	(0.000)	(0.170)	(0.000)
L3.kapital	1.127***	-4.94e-05***	0.000	1.327***	6.12e-08***
	(0.233)	(0.000)	(0.000)	(0.233)	(0.000)
L4.kapital	1.765***	4.33e-05***	0.000161***	0.129	2.96e-07***
	(0.242)	(0.000)	(0.000)	(0.241)	(0.000)
L.co2	-555087.000	-49.20***	26.720	554445.000	0.0933***
	(383060.000)	(7.526)	(86.810)	(382477.000)	(0.024)
L2.co2	-499846.000	-13.880	46.080	-2.039e+06***	-0.0679**
	(507332.000)	(9.967)	(115.000)	(506560.000)	(0.032)
L3.co2	2.566e+06***	-71.55***	-12.090	4.177e+06***	0.931***
	(465328.000)	(9.142)	(105.500)	(464619.000)	(0.029)
L4.co2	2.157e+06**	153.3***	326.3*	-813154.000	0.629***
	(852535.000)	(16.750)	(193.200)	(851238.000)	(0.054)
Constant	-1.159e+10***	73,713***	-802,684***	-3.309e+09***	-1,113***
	(830700000.000)	(16320.000)	(188260.000)	(829400000.000)	(52.310)
Observations	22	22	22	22	22

Notes_Titles Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results extracted from table above revealed that all the four lags of real gross domestic production have a 1 percent significant negative relationship with the current real gross domestic production when all other factors are held fixed and this implies that the previous period real domestic production are negatively influencing the current real domestic production hence decline in the current real domestic production in both short run and long run period while if first lag of the renewable energy consumption increase by 1Tj and this is associated with a decrease of US$8,318 on the real domestic production and this is significant causal relationship at 5 percent significance level and the second and third has the positive relationship with the increase of US$11,965 and US$42,953 on the real gross domestic production respectively at 1 percent significance level.

The increase in second lags of total labor force by people is also associated with the increase of US$9,626 on the gross domestic production at significance level of 1percent where the increase of 1 people on the third lags of total labor force is associated with the decline of the real gross domestic production by US$18,804 at 1percent significance level. The all lags of the gross capital formation have a positive causal relationship with real gross domestic production where the change in fourth lags by US$1 this is associated with the increase of real domestic production by US$1.7 and all are significant at $p<0.01$. the increase of 1 tonne of CO_2 emission is associated with an incline of US$2.5million n the real domestic and this is significant at $p<0.01$ and this implies that there were high industrial production as the more carbon dioxide come from the industries and this sector contribute higher to the national real domestic production and hence higher current real domestic production due to the previous year's industrial production resulting to increased carbon dioxide emissions.

In this perspective, the increase of US$1 on the first lags of real gross domestic production is associated with a significant increase of amount of renewable energy consumption by 1Tj on the renewable energy consumption at 1 percent significance level and this goes in line with the economic priori that consumption and the real domestic production are positively directly proportional. Interestingly, the lags of the renewable energy consumption have significant negative causal relationship with the current renewable energy consumption where the 1Tj change in its first lag is also linked to the decrease in current renewable energy consumption at 0.64 Tj and this at 1 percent significance level.

The change of the fourth lag of carbon dioxide emission by 1 tonne of CO_2 emission is associated with an incline of 49 Tj on the renewable energy consumption which is significant at $p<0.01$ and this goes in line with the fact that when the renewable energy consumption increase there would be the reduction of greenhouse gases as the most of renewable energies are clean and hence the greenhouse gases emission reduced with the renewable energy consumption inclination which accords the findings from the study by (Pirlogea, C. and Cicea, C., 2012).

The increase in the second lag of capital formation by 1 US$ is associated with the increase in the renewable energy consumption by 1Tj at 1percent significance level and this goes in line with the fact that the renewable energy consumption is implemented through increasing the investment /capital in the energy sector for fostering the renewable energy technologies hence there is an incline can be realized within the consumption of renewable sources of energy.
Surprisingly, all the lags of the real gross domestic production have significant negative causal relationship at $p<0.01$ indicating that when the lag of the real domestic production is increased by US$1 this is associated with the decline of 1 people on the total labor force and this implies that the total labor force increase but the employment rate is fixed hence the increased unemployment leads to the decreased real gross domestic production hence the declined economic growth.

The after estimation and regression of data, it has been depicted that all the lags for the renewable energy consumption have positive significant causal relationship at $p<0.01$ where this indicates that when the second lag of renewable energy consumption increased by 1Tj this is associated with increase of 3 people on the total labor force implying that focusing and shifting to renewable energy source will not only save our environment but also improve the total labor force through employment opportunities and job creation as result of renewable energy access and consumption.

It was also revealed that the first and third lags of the gross capital formation have the positive significant casual effect at $p<0.01$ indicating that when the third lag of capital formation is increased by US$1 this is associated with an incline of the total labor force by 1 people implying that when the investment increase there will be project implementations, employment opportunities and job creation through different venture investment and hence the total labor force will rise.

Moreover, all the lags of the real gross domestic production have negative significant causal relationship at $p<0.01$ and this revealed that when the real domestic production is increased by US$1 this is associated with the decline in the tonnes of CO2 emission rejected into the atmosphere by 1tonne and this implies that when the nation output the real gross domestic production increases there will be financial opportunity for investing in the nonpolluting, renewable and clean energy source and hence this will reduce the metric tons of carbon dioxide emitted in atmosphere.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

Although the economic growth and the renewable energy consumption in any economic sector have been extensively studied, the role played by the renewable energy sources towards the economic growth of the country has received a less attention, especially in Africa. In this study we have analyzed the short run and long run causal relationships between the renewable energy consumption and economic growth for Rwanda as measured by real gross domestic production in this study.

The results revealed that the quantity, metric tons of the carbon dioxide emission has a negative relation with the real gross domestic production and this goes to the Kyoto protocols and Paris agreements through carbon taxing, carbon credits and carbon market through the carbon emitted in the country atmosphere and this declines the real gross domestic production, when the level of total labor force in increase while the employment held fixed this leads to decline in real gross domestic production hence the decline in economic growth while the gross capital formation increased and associated to the incline in the real gross domestic production and hence the economic growth .

Since the objective of the environmental sustainability policy is not to slow down the economic growth or to reduce the production of certain sector, it is important it allows for the wider range of innovative technological solution for environmental issues like usage of renewable clean energy sources in energy sector of economy and usage of energy efficient appliances in given country.

5.2. RECOMMENDATIONS

Rwanda was recommended to control the pricing and the environmental concerns on energy imports especially fossil fuels, lower greenhouse gas emission, increase employment through job creation through deployment and dissemination of clean and non-polluting energy so as to create the suitable non-polluting industries. These policies could help to increase the contribution of the renewable energy source generation in the full energy access to minimize the non-clean and polluting energy consumption in general, which in turn reduce their carbon taxes and carbon charges which decline the economic growth due to decrease in real gross domestic production and hence environmental sustainability could be achieved.

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APPENDICES

Appendix 1: Dataset used in Analysis

Country Name	Rwanda	Rwanda	Rwanda	Rwanda	Rwanda
Series Name	GDP (constant 2010 US$)	Renewable energy consumption (TJ)	labor force, total	Gross Capital Formation,2010 Currrent US$	CO2 emissions (kt)
1990	2761876035	27900.6	3360296	239405965.8	528.048
1991	2692431986	27930.68	3300162	236821190.9	476.71
1992	2850551118	27959.23	3171437	250382295.5	484.044
1993	2619408711	27933.54	3028915	278285616.6	487.711
1994	1303206464	23345.19	2945589	50725254.91	462.042
1995	1762248930	47520.78	2939305	129747553.1	454.708
1996	1986859817	51158.6	3021105	141841840.6	469.376
1997	2262034984	65303	3196110	193197628.5	487.711
1998	2462421187	63454.4	3413952	250302431.3	487.711
1999	2569583007	65955.63	3617953	295428622.1	509.713
2000	2784680700	44838.63	3782154	344855499.4	528.048
2001	3020948720	45090.34	3933742	345232616.5	531.715
2002	3419474470	45179.87	4045336	371892986.7	531.715
2003	3494783797	45075.46	4135563	408676109.5	520.714
2004	3755064100	44894.33	4224948	457313882.2	528.048
2005	4107210234	53013.39	4325676	530714816.2	528.048

2006	4486185721	54611.52	4440289	682469574.8	528.048
2007	4828628893	56386.99	4563108	865823387.6	557.384
2008	5367563908	58301.91	4691967	1142681575	542.716
2009	5702943253	60215.09	4824224	1174205722	575.719
2010	6121234529	62125.47	4958770	1257467235	590.387
2011	6608387228	63978.12	5089202	1373988667	663.727
2012	7179451021	66101.18	5226213	1679731182	740.734
2013	7518310642	67693.28	5368369	1809410385	817.741
2014	7981977392	68636.33	5512954	1907725585	847.077
2015	8688928706	68929.6	5668121	2248675597	960.754

Appendix 2:Geographical location of Rwanda in Africa

Rwanda as a study area

Source: World Atlas, 2021