DETERMINANTS OF RENEWABLE ENERGY USE AND CARBON EMISSION INTENSITY IN SUB SAHARA AFRICA.

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ABSTRACT
The effectiveness of renewable energy use as a mitigation means to carbon emission tops the list of the global debate. Despite the global acceptance for energy transition, the regeneration of renewable energy are conditional on some natural forces and gains. This study used principal component analysis to fathom the components that best explain the variations between renewable energy use and carbon emission intensity. Population density was revealed as one condition upon which the renewable energy regenerates. One other gain of renewable energy revealed is the Carbon emission reduction by renewable energy use. Carbon trading and renewable energy promotion through policies and programmes were recommended together with population control and management of sustainable economic gains.

Key words: *Renewable, Energy, Emission, Sustainable,*

1. Background to the Study

The emission of carbon dioxide has been a common challenge that bedevils possibility of clean climate system vis a viz environmental regulation. Renewable energy use has been claimed as an alternative to fossil energy use. Renewable resources are resources or deposits of nature which grow overtime: wind, solar, biomass, hydro while non-renewable resources are resources which do not grow over time or the resources that are exhaustible, examples are earth mineral, metal ores, fossil fuel (coal, petroleum, natural gas) etc. In contrast to the belief that renewable energy replenishes by nature, Farmer and Friedl (2010) use regeneration function to distinguish the economics of renewable resources from that of exhaustible resources. The basic idea behind the distinction is that there are conditions to which renewable energy can replenish thereby violating the absolute growth claim of the renewable

energy. Some of the posed conditions for renewable energy availability are on light, air, example in biomass and existence of human capital. The sustainable implication suggested that without human intervention the (logistic) resources dynamics converge towards the natural equilibrium of having stock addiction to be zero-exhaustible.
Energy generation and transmission ordinarily affect the environment, as it is evident with the rate of air pollution, water, land, harmful radiation resulting to unsafe climate system.(Tsoutsos, Frantzekaki and Gekas 2003). In spite the facts that both renewable and non-renewable energy generation could have effects on the environment, the renewable energy is said to be sustainable and environmental enhancing compared to the non-renewable energy use without sacrificing economic activities. In the recent time, renewable energy use represents a tiny fraction of its potential electricity output worldwide. It is stated that renewable energyprovides about 19% of electricity generation worldwide. In transportation fuel, the 93 million litre of biofuel produced worldwide in 2009 displaced the equivalent of an estimated 68billion litres of gasoline, equal to about 5% of world gasoline production (Ewa,2014).
In sub-Saharan Africa with a substantial deposits of renewable resources, an alarming two out of three people do not have electricity access, which limits economic advancement for 600 million people who lack quality health care, education, business opportunities and more all (Herscowitz and Pielli 2016)

The relative gains of renewable energy over non-renewable energy use remains numerous. Venzmar et al.,(2014) accounts for the benefits from the several forms of renewable which include solar energy exploited through photovolatanic system and emit no greenhouse gases in electricity generation. Likewise, solar thermal power plant are built for high power and they greatly reduce carbon emission. In similar way, Biomass energy produces carbon that is equivalent to consumption in the process of photosynthesis. The biomass energy like other form of renewable energy provides greater opportunities for the development of rural area and employment. Amidst the perceived gains of explored renewable energy, it is of important in this paper to investigate the relationship between renewable energy and carbon emission in sub-Sahara Africa.

2. Statement of the Problem

The future of the green climate system has been threaten by the increase in the use of the conventional fossil energy use. The over dependence on fossil fuel for economic activities questions the possibility of achieving a world green climate zone as proposed by United Nation at the 1992 U.N. Framework Convention on Climate Change(UNFCCC). Toman(2001) stated that life on earth is possible because some gases such as carbon dioxide (Co_2) and water vapour, which naturally occur in earth's atmosphere trap heat. Some of the trapped heat are in form of greenhouse gases which human existence contributes to greatly. The historical neglects on the management of conventional energy use has increased the global warming in the recent time like climate change, flood, drought etc, which pose multi-dimensional negative impacts on the society. IPCC(1996 and 1998) respectively supported the case on the account of historical neglect on the management of the conventional energy use and stated that human economic activities have in the last 100 years contributed to an increase in the concentration of greenhouse gases in the atmosphere. Africa is conceived to be hardest hit by the climate change caused by the conventional energy use for economics activities which is more in developed countries. The common reason to the vulnerability of Africa to climate change is because of the over dependence on agriculture with little or no technological progress for climate change mitigation. World Bank has declared climate change as an acute threat to global development and emphasized that all effort to end poverty and to save 100million people on the risk of being pushed into poverty by 2030, if no action is in place is to mitigate climate change which could be driven by renewable energy use. Although the validity of the natural regeneration of the renewable energy is still uncertain, a greater percentage of argument support the regeneration of renewable energy. Likewise, some of the renewable energy source is faced with the possibility of going into extinction due to the current pressure by population on the sources. The possibility of human pressure on some renewable energy sources cut on the expectation of renewable energy as a substitute to conventional energy. Renewable energy source is also dependent on some conditions such as location, energy quantity, technology, intermittency, Liquid fuel problem, and other uses of fossil fuels, area density of energy collection activities and others. Since the production of the energy is ordered by nature (Heinberg and Fridley 2016). Amidst of these factors capable of militating against renewable energy adoption, sharp argument on renewable energy use and environmental sustainability becomes inevitable. Nwaobi (2014) also proposed that sustainable energy path required a dramatic shift in the energy mix from fossil fuels to renewable energy and possibly nuclear power.

Statistics from World Bank development indicator (2017) showed that the energy use growth in Sub-Sahara Africa was 3.8% between 1990-2013 from which the fossil fuel use was 40.7% and 38.3% in 1990 and 2013 respectively. The renewable and other alternative energy use in the year 1990 and 2013 were given as 2.2% and 2.6% respectively. Also, carbon intensity growth in 1990 and 2013 was on a constant growth of 1.5% while the economic growth per energy use was 4.2% and 5.8% in the years 1990 and 2013 respectively. Evidences above further reveal that there is a slight decline in the use of fossil fuel energy in sub-Sahara African as against the increase in the rate of renewable energy use. Carbon intensity has in other hand remained unchanged overtime in the region while the energy per use as it relates to population also has grown over time. Despite the emphasis on energy transition and on the observed growth in the use of alternative energy, renewable energy provides only 14 percent of the global primary energy consumption (Johansson T.B et al., 2004).

In other words, it has become evident to study the determinants of renewable energy use over the use of conventional energy use in sub-Sahara Africa. *Therefore, the research questions from this study are; what are the key determinants of renewable energy use in Sub Sahara Africa? Is renewable energy use sustainable for economic activities growth in sub-Sahara Africa? What are the effects of renewable energy use on carbon emission intensity in sub-Sahara Africa? In order to address the raised questions, this study aims (1) t*o analyse the key sources of variations in renewable energy use and Carbon Emission intensity in sub-Sahara Africa. (2) to examine the correlates of renewable energy use and carbon emission in Africa.

3. Literature Review

Renewable energy possess the characteristic variable of the overlapping model for growth such as time and renew (birth) and degenerate (death).Renewable energy as its name implies regenerate over time and example include hydro energy, biomass, solar etc. Although there is a conflicting debate on the possibility of renewable becoming exhaustible as stated by Farmer and Friedl (2010) could be as a result of time and population pressure on the various renewable energy. Timmons et al.,(2014) maintained that renewable energy is unlimited, as supplies are continually replenished through natural processes. Environmental sustainability, a focus in the recent time supports renewable energy use as a better alternative to fossil fuel.

Environmental sustainability is at the centre of energy use and economic growth. The negative externalities from the environment in turn affect the health status of the population. Renewable energy as an emerging alternative for green growth will be plugged into the growth model that accommodates the population dynamics.

Kutznet curve "inverted U shaped" depicts the relationship between growth and measured pollution indicators (environmental quality). The environmental Kutznet curve hypothesis shows a long term relationship between environmental impact and economic growth. In turn, economic cost of greenhouse gases emission on the economy grow over time. Economic activities primarily caused the externalities both in negative and positive capacity that affect the welfare of the nation and the environment as conceptualized by (Asogw et al 2017). It is the combination of the overlapping growth model, Renewable Energy concepts and Environment theory like Kutznet curve will form the base of this study.

The essence of energy transition has both national and regional objective of target. While Energy transition has competition role with the conventional energy, it also has the climate change policy dimension with target to reduce greenhouse gases. Within the energy transition objective, the change in the composition of energy sector with the underline aim to reduce the level of carbon emission drives energy transition promotion (Mulder 2017). Despite the large deposit of renewable energy resources in Africa, dearth in renewable energy investment still persist. Bello and Ojoyi (2017) stated that the investment on low carbon energy transition is inimical to the mitigation of climate change. But comparing the effects of carbon emission to the dwindling access to electricity as in Africa reveals that out of 300.7 million citizens of ECOWAS, only 126.2 million enjoy access to electricity. Sub-Sahara Africa with the substantive potential for energy transition in a growing population has a high demand for energy services. Although, meeting the current demand of conventional energy services is becoming global challenge, energy transition viability is still uncertain. The experience of United States of America on energy transition has offered grounds for optimism for developing countries to improve its technology means, which suggest that an increased amount of energy services can be provided with a relative small amount of fuel (Connor 2010). In energy market, commercial energy provider increasingly seek out fuel alternative to conventional energy associated with lower cost. On the term of conventional energy, coal requires railway while natural gas requires tanker, pipelines etc. For example, wood requires a mere axe for procession. Political and economic synergy are required for the promotion of investment on the low carbon energy

Bigerna et al.,(2015) stated that renewable energy source more sustainable over fossil fuel but it is faced with a lot of development challenges like cost. Using Europe as a case study, renewable energy is mostly used for transportation and electricity and so could be in other regions in the world, In order for renewable energy to compete with the conventional energy source, renewable energy must be subsidized because renewable energy requires a profound modification of our infrastructures to be fully effective which is always capital intensive.

Panwar et al.,(2011) described climate change as the global concern of humanity. This is because the effects of climate changes are observed on the health of the populace. The contending issues of climate change as a result of irrational human activities of the resource. The renewable energy is considered a climate change mitigation and adaptation instrument and a potential substitution for the conventional energy source. Crosson,(2001) stated that scientists has now come to an agreement that the continued accumulation of heat-trapping greenhouse gases in the atmosphere will eventually lead to changes in regional climate as well as global climate. The IPCC 1996 report as discussed in Crosson (2001) reveals that the an increase in atmospheric concentrations of greenhouse gases equivalent to a doubling of atmospheric carbon dioxide will force a rise in global average surface temperature of 1.0-3.5^{o}C by 2100.

5. Significance of the Study and Data Source

Findings from this study will reveal the actual effects of renewable energy on inclusive growth and environmental development. Policy recommendations from the study can be applied by world international organisation like UNFCC, OECD, in environmental policies formulation for sub-Sahara Africa. In addition, the study will add to the growth of empirical studies in the region and on the area.

6. Data Sources and Description

The data for this study was collected from World Bank development indicator time series data base on the sub-Sahara Africa 1990 to 2014 as was available. The variable are defined as Reuc is the renewable energy use on consumption, non-hydro is the non-hydro renewable energy, output_reueo is the output of renewable energy on electricity, C_{O2i} is the carbon emission intensity in Africa, rgdp is the real gross domestic product of sub-Sahara Africa, hydro_reu is the hydro renewable energy, and Pop is the population density in sub-Sahara Africa.

7. Component Analysis Method

Ordinary Least Square Estimation methods, Principal Component analysis and component Regression method will be adopted to estimate the opportunity cost of industrial carbon emission and industrial growth. Likewise, the determination of the principal components for industrial carbon will adopt the principal component analysis. Principal component analysis is primarily targeted to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set (Jolliffe 2002). The Principal component values for each observation are given by

$$Z = X_i A \ldots (1)$$

Where the (i k)th element of is the value (Score) of the kth principal component for the ith observation, and A is a (p x p) matrix whose kth column is the kth eigenvector of X^IX .

8.1 Result and Discussion

The summary data show that 25 observation were collected from 1990 to 2014. The mean of the variable are given as shown above likewise the standard deviation of the variables respectively.

In order to determine the key cause of renewable energy use and Carbon Emission intensity in sub-Sahara Africa and the correlates of renewable energy use and carbon emission in Africa the result below is analysed.

Table I:Data Summary and Description

Variable	Obs	Mean	Std. Dev.	Min	Max
Reuc	25	71.8337	1.073515	69.96992	73.94012
nonhydro_r~h	25	.515388	.3098757	.2213398	1.725675
outpu_reueo	25	21.07896	2.163324	17.8185	26.36979
co2i	25	1.535866	.0506386	1.452377	1.662753
Rgdp	25	4.56404	.6409249	3.892475	5.824021
hydro_reu	25	17.60098	1.691081	14.88386	21.1745
Pop	25	7.20e+08	1.42e+08	5.11e+08	9.79e+08

8.2. Correlation Matrix

The correlation matrix is applied in order to determine the associativity among the variable of interest. The correlation coefficient will used to ascertain the cause and direction in the relation between renewable energy use and carbon emission in sub-Sahara Africa as show below

Table II:

	Reuc	nonhyd~h	outpu_~o	co2i	rgdp	hydro_~u	pop
Reuc	1.0000						
nonhydro_r~h	-0.7056	1.0000					
outpu_reueo	-0.7219	0.8476	1.0000				
co2i	-0.0093	-0.1406	-0.3057	1.0000			
Rgdp	-0.8646	0.8345	0.8735	-0.1406	1.0000		
hydro_reu	-0.7043	0.7924	0.9944	-0.3341	0.8578	1.0000	

Pop	-0.7751	0.8218	0.8613	-0.1307	0.9412	0.8339	1.0000

The strength of the associativity among variables are said to be averagely strong when the correlation coefficient is above 0.5. The correlation coefficient with a negative sign shows an inverse relationship while a positive coefficient show a direct relationship. It observed that carbon emission intensity has an inverse association with all the renewable energy forms in the model. This suggests that an increase in the renewable energy use reduces carbon intensity. Likewise, economic growth has an inverse relationship with renewable energy consumption but direct relationship with other forms of renewable energy use.This implies that economic activities cannot speedily drive on the wheels of renewable energy consumption in sub-Sahara Africa while other forms of renewable energy with a direct relation suggest that economic activities are gradually accepting the energy source but not on a high speed to drive economic growth through consumption. The outcome may be as a result of low accessibility and acceptability rate of renewable energy use in sub-Sahara Africa. Population in sub-Sahara Africa showed an inverse relationship with renewable energy consumption but a direct relationship with other forms of renewable energy. This suggests that population growth adds pressure on the regeneration of renewable energy and the increase in the population will bring about a decline in the consumption of renewable energy. This is supported by the conditionality of renewable energy use as non-exclusively inexhaustible energy resource.

Table III: Principal Components

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	5.1964*	4.13269	0.7423	0.7423
Comp2	1.06371*	0.752629	0.1520	0.8943
Comp3	0.311086	0.0963429	0.0444	0.9387
Comp4	0.214743	0.0417312	0.0307	0.9387
Comp5	0.173012	0.132235	0.0247	0.96994
Comp6	0.0407774	0.0405115	0.0058	1.0000
Comp7	0.000265901		0.0000	1.0000

*Comp denotes component, * denotes eigenvalues greater than 1*

From table III, the components with eigenvalue above one will be retained as the components that best summarised the variance in the variable. Comp1 and comp2 have the eigenvalue above 1. 74.23 percent variation among the variables was explained by Comp1 followed by 15.20 percent accounted for by comp2. The cumulative of the explained variation by the components with eigenvalue above 1 is about 89.43 percent.

8.3. Component Loadings

Component loadings represent the correlation between the components and the original variables. The seven components loading on all the variables in the model shows the strength of the correlation of the original variables and the components. The components with close to 1 loadings across the variable is said to have a very high loading on the variable. Table IV shows the component loading across the real variable in the model.

Table IV:

Variable	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7	Unexplained
Reuc	-0.3710	-0.2805	0.7331	-0.0006	0.4237	0.2577	-0.0140	
Nonhydro	0.3937	0.0628	0.4271	-0.7257	-0.3435	-0.0098	0.1177	
Reueo	0.4213	-0.1268	0.2936	0.3571	-0.1800	-0.1125	-0.7400	
C_{02i}	-0.1030	0.9234	0.3017	0.2109	-0.0187	0.0302	0.0047	
Rgdp	0.4228	0.1101	-0.2113	-0.0592	0.3133	0.8092	-0.0898	
Hydro_reu	0.4130	-0.1637	0.2413	0.5370	-0.1690	0.0466	0.6521	
Pop	0.4122	0.0988	0.0021	-0.0970	-0.75128	0.0705		

8.4. Component Retention and Components Loadings

Recall from table III, component1 and components two are supposed to be retained given Eigen value retention rule as shown in table V below.

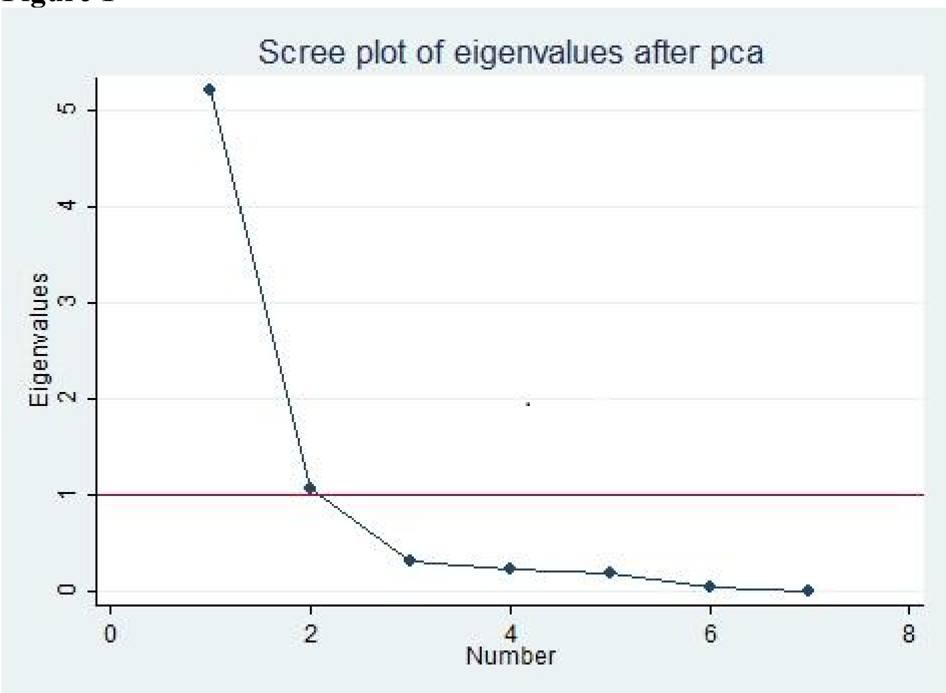
Table V

Variable	Comp1	Comp2	Unexplained
Reuc	-0.3710*	-0.2805	0.201
Nonhydro	0.3937*	0.0628	0.1903
Reueo	0.4213*	-0.1268	0.06048
Carbon intensity	-0.1030	0.9234**	0.03796
Rgdp	0.4228**	0.1101	0.05833
Hydro renewable energy	0.4130*	-0.1637	0.08519
Population density	0.4122*	0.0988	0.1067

Restricting the component loadings to two components that have eigenvalue above 1, it is observed from the table that about 20.1 percent variation in the data was unexplained with renewable energy consumption, 19.03 percent variation in the data with non-hydro renewable energy, 6.04 percent variation in the data was unexplained with the renewable energy from electricity output, 3.79 percent variation in the data cannot be unexplained with carbon emission intensity, 5.83 percent variation in the data cannot be unexplained with real gross domestic product, 8.52 percent unexplained variation in the data with hydro renewables and 10.67 unexplained variation in the data by the population density.

The component loadings with are asterix (*) are consider high loading above 0.3. Carbon emission intensity has a very high loading of 92.34 percent, hence, the second components is named after the carbon emission intensity and retained in the model. Likewise, real gross domestic product with relatively high loading of 0.4228 in component two correlation vector, therefore, the comp1 is named as real gross domestic product.Other variable in component one are fairly above 0.3 and could not be referred as very high loadings.

Figure 1



Screeplot graph represents the components with Eigen value above one. From the graph, while the first component has the eigen value very far above 1, Comp2 has a little above 1 eigenvalue.

8.5. Kaiser-Meyer-Olkin Measure of Sampling Adequacy

According to Kaiser-Meyer-Olkin, the overall kmo statistics is expected to be above 0.5 to consider the application of principal components analysis appropriate. This by indication shows that the use of principal component analysis is appropriate and suitable for policy implications as shown below

Table VI:

Variable	Kmo

Renewable use on consumption	0.7262
Non hydro renewable energy output	0.4991
Renewable electricity output	0.5280
Carbon emission Intensity	0.5490
Rgdp	0.5511
Hydro renewable energy use	0.5163
Population density	0.5565
0verall	05504

9. Summary

The debate on the relationship between renewable energy and carbon emission intensity has been on top list of international organisations, regional government and national government. The understanding of the associativity of renewable energy and carbon emission intensity has become inimical to the actualization of clean climate and green economic growth. Evidence above showed that carbon emission intensity has an inverse relationship with renewable energy. Likewise, population density has an inverse association with renewable energy and real gross domestic product has an inverse associativity with renewable energy consumption. In other hand, population showed a direct association with other sources of renewable energy. In the same way, carbon emission intensity has a very high and positive loading on the comp2, this implies that an increase in the carbon emission intensity will have an increasing effects on the comp2.In this same way, real gross domestic product has relatively highest loading on comp1 vector and could assume the comp1 in the model. From the result, the variation in the data can summarily be explained by two components namely real gross domestic product and carbon emission intensity.

10. Policy Implication

The policy dimensions based on the finding are as follows:

i. Renewable energy consumption and the regeneration of renewable resource showed to be a reliable tool to reduce carbon emission intensity in sub-Sahara Africa since carbon emission intensity showed an inverse correlation with all the renewable consumption and renewable resources in sub-Sahara Africa. Policies, programmes and technologies geared toward promoting the use of renewable and regeneration of renewable resources in sub-Sahara Africa are advised.

ii. Population control and management should be advocated for in sub-Sahara Africa in order to sustain the regeneration of renewable energy. The direct and high correlation coefficient between population density and renewable resources suggests that the growing population in the region aids in the regeneration of renewable resources. Likewise, the positive correlation between population and real gross domestic product also affirms the essence of population for economic growth. In contrast, population growth also has an inverse relationship with renewable energy consumption. This suggests that the regeneration capacity of the renewable resources cannot sustain the demand of the dense population in sub-Sahara Africa.

The outcome of the analysis also revealed that the sustainability of renewable energy use is dependent on the economic growth and carbon emission intensity. Real gross domestic product and carbon intensity showed to be the components capable of summarizing the variation in the other variables. This therefore suggests that the energy use for economic activities and carbon emission source should constantly be check through policies such as carbon trading and renewable energy installation.

11. Conclusion

The advantages of renewable energy use and energy transition cannot be downplayed. Although the natural regeneration of renewable resources is under contention, renewable energy has received some acceptance by world development agents. Apart from creating completion in the energy sector, the policy dimension of renewable energy use targets carbon emission. This study has under studied the pros and cons of renewable energy used in the sub-Sahara Africa. The underlined components capable of explaining the variations in renewable energy, carbon intensity and economic growth are summarized by carbon emission and real gross domestic product. The roles of the population growth in sub-Sahara Africa show some positive contribution to the regeneration of renewable energy resources and in economic growth. The optimism in the achievement of carbon emission mitigation has its support from the carbon emission intensity having inverse associativity with all the renewable energy resources and renewable energy consumption.

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