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Energy consumption and environmental degradation in ECOWAS countries

Matthew Tari[1] & Azebi Oyeinbrakemi Innocent[2]

[1]*Federal University, Otuoke, Bayelsa State – Nigeria*
[2]*Department of Economics and Development Studies, Federal University, Otuoke, Bayelsa State – Nigeria*

Abstract
The study examines the impact of energy consumption on environmental degradation in West African countries from 2000 – 2019 using the System Generalized Method of Moments (System-GMM) estimation technique. Energy consumption is measured by renewable energy consumption and fossil fuel energy consumption, while environmental degradation, is measured by total greenhouse emissions, and $C0_2$ from electricity and heat production. Results from the Breitung, and Im, Pesaran and Shin panel unit root tests reveals that all the variables were non-stationary at level, but however, became stationary after first difference. The p-values of the Pedroni cointegration test which was conducted reveals that there is long –run relationship between the variables. Empirical results from the regression analysis showed that renewable energy consumption had inverse and statistically significant impact on $C0_2$ from electricity and heat production, and an inverse but statistically insignificant impact on greenhouse emissions. It was also found that fossil fuel energy consumption had positive and statistically significant impacts on total greenhouse emissions and $C0_2$ from electricity and heat production. It was therefore concluded that renewable energy consumption contributes to reduction of environmental degradation, while fossil fuel energy consumption increases environmental degradation in ECOWAS countries. Furthermore, gross fixed capital formation, and population growth were found to have contributed to environmental degradation. Based on the above, the study recommended among others that, West African countries should develop and encourage the use of other energy sources especially renewable energy, alternative and nuclear energy, beside fossil fuel energy sources.

Keywords: Environmental degradation, energy consumption, greenhouse effect, fossil fuel.

1. Introduction

Energy consumption is the amount of energy produced and used by human civilization at a given period of time. It includes all energy put to use by a country from every source of energy, applied towards humanity's endeavours in mostly the industrial and technological sectors. Considered as the power source metric of civilization, energy consumption all over the World has important socio-economic implications, and also serves as a vital input to almost every form of modern goods and services in the whole world. In fact, in both developed and developing countries, energy consumption is considered as the lifeblood of the economy given that its consumption enables transportation and communication, and helps to expand industries, and promote agricultural development and trade, which are the basis for employment creation, economic growth and poverty reduction (Imperial, 2019).

Despite the enormous advantages of energy, its consumption has been alleged to have some serious negative implications on the environment. The link between energy consumption and environmental degradation is that, increase energy consumption causes the release of higher number of fumes by power plants, destroys the natural resources and ecosystems. Increasing energy consumption likely increases power plant emissions.

Furthermore, electricity though a clear and relatively safe form of energy usage, its generation and transmission affect the environment. According to the U.S Energy Information and Administration – EIA (2018), almost every type of electric power plants negatively affects the environment differently. In traditional electricity generation, for example, most of the power plants usually burn coal, crude oil or other fossil fuels.

The Economic Community of West African States is one of the regions in the African continent that is rich in natural endowments and energy potentials. However, despite the region's vast natural endowments and huge energy potentials, the installed energy capacity is 10,640 MW. Out of this installed capacity, just about 60% (6,500 MW) is well functional and meets consumption demand. The annual per capital energy consumption of the region is below 150 kWh, estimated to be among the lowest in the World. Only about 20% is accessed by households. The lack of access to energy to meet up the increasing energy consumption demand have made households to depend on traditional biomass and solid fuels for cooking and heating, which has consequences on the environment, including carbon dioxide (CO_2), Carbon monoxide (CO), Sulfur dioxide (SO_2), Nitrogen Oxides (NOx), Particulate Matter (PM) and others. Approximately 257.8 million people are victims of household air pollution either through carbon monoxide, indoor smoke, nitrogen oxides or small particle pollution.

Also of serious concern is the increasing emission that results from fossil fuel burning in the ECOWAS region and the World at large. Fossil fuel burning has resulted to estimated CO_2 emission of 10 billion tones yearly from the world's electrical power sector. Global CO_2 emissions from energy combustion and industrial processes rebounded in 2021 to reach their highest ever annual level. A 6% increase from 2020 pushed emissions to 36.3 gigatonnes (Gt) (IEA, 2022). This has caused an increase in the Earth's levels of atmospheric carbon dioxide that has facilitated more greenhouse effect and adds to global warming. Depending on the type of fossil fuel and the burning method, other emission is generated. Ozone, NO_2, sulfur dioxide, particulate matter and other gases are associated with Fossil fuel. These have contributed to increasing smog and acid rain among other impacts in the ECOWAS region.

With the increasing energy consumption demand in the ECOWAS and the increase efforts by the governments of the ECOWAS countries and other bodies such as WAPP to meet up with the energy consumption demand, it is appropriate to examine the environmental impact of energy consumption.

There are many studies on energy consumption and environmental degradation [(see Aboagye, 2019; Rehman and Rashid, 2017; Aiyetan and Olomola, 2017; and Jamel and Derbali, 2016)]. Dogan and Turkekul (2016) studied the relationship between carbon dioxide (CO_2) emissions, energy consumption, and real output (GDP), while Kohler (2013) examined the long run relationship between environmental quality, level of per capita energy use and foreign trade in South Africa. To the best of the researcher's knowledge, none of the study has directly examined the impact of energy consumption on environmental degradation in ECOWAS countries. This study therefore, departs from previous studies by examining the relationship between energy consumption and environmental degradation in ECOWAS countries. The specific objectives are to: examine the impact of renewable energy consumption on environmental degradation in ECOWAS countries and to determine the impact of fossil fuel energy consumption on environmental degradation in ECOWAS countries.

2. Literature Review

A. Conceptual Clarifications

It is pertinent that we make clarifications on some of the concepts (energy consumption and environmental degradation) used as it pertains to the study. In addition, for proper understanding, we define the dependent and independent variables stated in our models as contained in section three. These variables include green house gas emissions, CO_2 from electricity and heat production, renewable energy consumption, fossil fuel energy consumption, gross fixed capital formation and population growth.

Energy Consumption

Energy consumption refers to the amount of energy used by an individual or organization. Energy is more or less a part of human existence because almost nothing can be done or achieved in the world without the use of energy; it could be accessed from a renewable or non-renewable source. Renewable sources of energy may include solar energy (Sun), hydro energy, wind energy, nuclear energy, tar-sand and biomass while those from nonrenewable sources include fossil fuel (crude oil), natural gas, coal, wood and so on.

West Africa (ECOWAS) which has an estimated population of over 376,793,844 million people as at 2018, has the lowest access to energy (electricity) consumption rate. Some of the countries like Niger, Liberia, Sierra-Leone and Burkina Faso have less than 20% access to electricity, Senegal accounts for less than 50% and more than 70% in Ghana. Nigeria which is the largest country in the region has about 85 million people, who do not have access to grid electricity. This value implies that 43% percent of the country's population are denied access to electricity, and thus makes Nigeria the country with the largest energy access deficit in the world (World Bank, 2021).

Environmental Degradation

Tyagi, Garg and Paudel, (2014) defined environmental degradation as the deterioration of the environment through depletion of natural resources such as air, water and soil, the destruction of the ecosystem and extinction of wildlife. The United Nations International Strategy for Disaster reduction defines environmental degradation as the reduction of the capacity of the environment to meet social ecological objectives, and needs.

Environmental degradation thus is the continuous disturbance of the environment through depletion of resources such as air, water, and soil; the destruction of ecosystem, habitat destruction, extinction of wildlife, and pollution. Scientist stated that human activities pushed the earth into sixth mass extinction event. This is attributed to overpopulation, continued human population growth and over consumption of world natural resources by the worlds wealthy. Jhingan (2012) also noted that the causes of environmental degradation include; population growth, poverty, agricultural development, industrialization, transport development, urbanization, foreign indebtedness and market failure.

Total Greenhouse Gas Emissions (GHE): This is the greenhouse gas compound in the atmosphere emitted from the earth, which can absorb infrared radiation, therefore, trapping and holding heat in the atmosphere. By holding and increasing the heat in the atmosphere, greenhouse gas could cause greenhouse effect, which is capable of resulting to global warming. This has a potentially harmful impact on the environment – biodiversity, ecosystems and human livelihoods.

Carbon dioxide (CO_2) from Electricity and Heat Production (% of Total Fuel Combustion) (CO2EH): This is a colourless gas generated from electricity and heat production with a density of about 60% higher than that of dry air. Since carbon dioxide is soluble in water, it can occur in groundwater, rivers, and lakes. It can also be in ice caps, glaciers and seawater. Though at normal concentration, it is odorless but at high concentration, it has high and sharp acidic odor. The presence of the gas in the atmosphere holds most of the radiant energy received by earth from returning to space, therefore, capable of causing greenhouse effect that can lead to environmental degradation. Belgian chemist, Jan Baptista van Helmont recognized carbon dioxide as a gas different from others in the 17th century, as a product of combustion. Concentration of carbon dioxide of about 5% could cause environmental degradation, and prolonged exposure of humans and most other living things could lead to unconsciousness and death (Lallanilla, 2019).

Renewable Energy Consumption (% of Total Final Energy Consumption) (RENC): This is the ratio between gross inland consumption of energy from renewable energy sources and aggregate (primary) gross inland energy consumption estimated for a period of time, usually a year. It is the sum of the gross inland energy consumption from renewable energy sources. Renewable energy sources include renewable non-fossil energy sources like wind, hydropower, solar, wave, tidal, geothermal, biomass, landfill gas, biogases and sewage treatment plant gas. The amount of energy consumption from renewable sources provides a broad indication for the level of progress in reducing the environmental impact of energy consumption, even though; the total impact has to be seen within the context of the aggregate fuel mix. Renewable energy sources are commonly seen as environmental benign, given a very small amount of net emissions of CO_2 per unit of energy produced.

Fossil Fuel Energy Consumption (% of Total Final Energy Consumption) (FENC): This is the energy consumption from petroleum, natural gas, and coal. Fossil fuels are finite resources that are capable of harming the environment. Gases from Fossil fuels contribute to the greenhouse effect, and may result to potentially catastrophic changes in the climate conditions of the earth.

Gross Fixed Capital Formation (GFCF): GFCF is defined as the total expenditure on investment by the production units of a country. It is the changes in the stock of a year and the net acquisition valuables by businesses and households. Since investment is the expenditure incurred on acquisition of capital goods that result in capital formation, the gross fixed capital formation is used as a measure of domestic investment of the West African countries in this study.

Population Growth (POPG): Population of a country is the number of persons in that country. Therefore, population growth rate could be described as the rate at which population of a country (the respective West African countries) grow. This study uses population growth rate to proxy for the growth of labour force because a growing population is in most cases endured with a growing labour force.

B. Empirical Review

Several researches have been conducted in respect to energy consumption and its effects on the environment and other variables such as economic growth, agricultural productivity, manufacturing output and so on. The findings from these researches are however conflicting.

Aboagye (2019) studied the environmental effect of energy consumption in Ghana, using the Environmental Kuznets Curve (EKC) framework. The study covered the period from 1980 – 2016. The author adopted Autoregressive Distributed Lagged Model technique. The result of the study showed that energy consumption increases air, water and land pollutions – measured respectively by CO_2 emissions, Biological Oxygen Density (BOD) and deforestation. The study could not establish any evidence of EKC in any of the three environmental degradation indicators in Ghana.

Raza and Shah (2018) examined the effect of financial sector development, economic growth and energy consumption on environmental degradation in Pakistan. Their study applied unit root test, cointegration test, and ordinary least square analyses on the historical data over the period of 1972-2014. The result from the study indicated that the variables had a significant and positive effect on environmental degradation.

In Ghana, Naminse and Zhuang, (2018) also examined the relationship between economic growth, energy intensity, and CO_2 emission. The study employed static and dynamic regressions, and Granger causality test, and the impulse response function. The study covered the 1952 – 2012 sample periods. The results suggest that China's dependence on coal consumption is likely a major reason for the increase in carbon dioxide emissions. The result also indicated that CO_2 emissions had an inverted U-shaped effect on per capita income, which invariably points to the presence of the environmental Kuznets curve (EKC) hypothesis in China. Also, the result showed that economic growth and coal energy consumption had a bidirectional relationship, while coal consumption also had a bidirectional relationship with CO_2 emissions.

Hongxian (2017) investigated the relationship between China's total energy consumption growth and GDP growth. The study covered the period from 1997-2016. Path analysis was used to analyze the direct and indirect influence of energy consumption ratios on GDP growth as well as their relationship and the influence of each of the ratios on GDP. The author proposed that the amount of natural gas consumption in relation to other energy consumption is the primary driver of GDP growth. While coal and oil consumption proportion inhibit GDP Growth in China.

Balin, Akan and Altayligil (2018) examined the causal effect between CO_2 emissions, trade openness, economic growth, energy consumption and foreign direct investment in Turkey. The study covered the period 1974-2013. Autoregressive Distributed Lag (ARDL) bounds testing approach to Cointegration and Error Correction Method (ECM) was employed to examine the long run relationship. The result showed an inverted U-shape effect between economic growth and CO_2 emissions. Also, trade openness had a positive and insignificant effect on CO_2 emissions. Foreign direct investment and energy consumption also had a direct effect on CO_2 emissions in Turkey.

In another study, Rehman and Rashid (2017) examined the role of energy consumption on environmental degradation in a multivariate framework frontier for Asian markets. The study employed panels root test OLS and dynamic OLS. They found significant co-integration among the variables as well as the existence of an environmental Kuznets curve. Furthermore, bidirectional causality was found between the CO_2 emission and economic growth. Also, their result showed that an increase in energy consumption brings about increase in environmental degradation.

Using a panel context, Çetin and Ecevit (2015) examined the causal relationship between urbanization, energy consumption and carbon dioxide (CO_2) emissions in Sub-Saharan countries using the Pedroni and Kao cointegration technique. Also, the Granger causality test based on vector error correction model (VECM) was used. The study covered the period 1985 - 2010. The result showed cointegration between the variables within the study period. A bi-directional Granger causality was also found running among some variables including energy consumption and CO_2 emissions both in the long-run and short-run.

Alvorado and Toledo (2017) investigated the effect of economic growth on environmental degradation in Ecuador within the 1971 – 2010 sample periods. The authors adopted Johansen cointegration and ECM techniques. The result of their findings showed an inverse relationship between real GDP and vegetation cover. Also, the authors found that there is short term relationship between vegetation cover, real GDP and urbanization. They also noted that Granger causality does not run between the variables.

Sepehrdoust and Zamani (2017) in a panel context examined the economic growth and environmental protection challenges of developing nations. The countries involved were ranked based on oil-producing and non-oil-based covering the period 2001 – 2012 sample periods. Result of the study indicated renewable energy, population growth and the number of internet users had inverse effect on CO_2 emission per unit of GDP. The portion of industrial sector value added, on the other hand, had direct effect on CO_2 emission per unit of GDP for the countries involved. Also, the rate of urbanization had inverse effect on CO_2 emission per unit of GDP in oil importer nations.

In their study, Aiyetan and Olomola (2017) examined the impact of CO_2 emissions, energy consumption, and population growth on economic growth in Nigeria. The study covered the sample period from 1980-2012. The study adopted Autoregressive Distributed Lag (ARDL) technique and Toda-Yamamoto non-granger causality technique. The result showed unidirectional causality that runs from CO_2 emissions to economic growth and, from energy consumption to economic growth. Also, unidirectional causality was found to run from CO_2 emissions and energy consumption to economic growth. Causality also runs from economic growth to population growth. It was also found that energy consumption and population growth had positive and statistically significant impact on CO_2 emissions both in the long and short-run.

The effect of GDP on carbon emission in selected West African countries was examined by Omojolaibi (2010). Data set for the period 1970-2006 was used for analysis. The pooled OLS technique was employed in analyzing the data. The result was discovered to be in harmony with the predictions of EKC.

In another study, Saboori and Sulaiman (2013) examined the effects of economic growth, carbon dioxide (CO_2) emissions and energy consumption in Malaysia from 1980–2009, using the ARDL technique. The result contradicted inverted U-shaped effect (EKC). Also, a bi-directional causality was found between economic growth and CO_2 emissions, as well as gas, electricity and energy consumption.

3. Methodology

3.1 Research Design

This study employed a longitudinal research design. Longitudinal research design could be described as a plan on the collection, analyzing and interpreting of time series data that enables a researcher to make causal inferences.

3.2 Model specification

This study uses the System Generalized Method of Moments (System-GMM) technique in analyzing the data. For the purpose of robustness of findings, environmental degradation would be captured by two measures, which are total greenhouse gas emissions (GHE), and CO_2 from electricity and heat production (% of total fuel combustion) (CO_2EH). Also, Energy consumption is represented by renewable energy consumption (RENC) (% of total final energy consumption) and fossil fuel energy consumption (FENC) (% of total final energy consumption).

A dynamic panel environmental degradation equation is used to capture the objectives of this study. The functional form of the model is specified as:

$$ENDG_{it} = g(X_{it}, Z_{it}) \quad (3.1)$$

The panel model specification of equation (3.1) is:

$$ENDG_{it} = \vartheta + \vartheta_x X_{it} + \vartheta_z Z_{it} + \gamma_{it} + \varepsilon_{it} \quad (3.2)$$

Where:

ENDG = environmental degradation, measured by total greenhouse gas emissions and CO_2 from electricity and heat production.

X_{it}= a set of energy consumption (ENC) variables, which are renewable energy consumption (RENC) (% of total final energy consumption) and fossil fuel energy consumption (FENC) (% of total energy consumption).

Z_{it}= a set of control variables which are gross fixed capital formation (GFCF) and Population growth (POPG) – proxy for labour force growth.
γ_{it} = a between-country error term
ε_{it} = a within-country error term
i = observational units
t = time

To fit a linear model with one dynamic variable ($ENDG_{i,t-1}$), we add the dynamic variable as:

$$ENDG_{it} = \vartheta_0 + \vartheta_1 ENDG_{i,t-1} + \vartheta_2 \text{RENC}_{it} + \vartheta_3 \text{FENC} + \vartheta_4 GFCF_{it} + \vartheta_5 POPG_{it} + \gamma_{it} + \varepsilon_{it} \quad (3.3)$$

In order to ensure robustness of findings and, also, for the purpose of showing the impact of the energy consumption variables (renewable energy consumption and fossil fuel energy consumption), on each of the environmental degradation measures (total greenhouse gas emissions and CO_2 from electricity and heat production), the environmental degradation measures are modeled separately. On this basis, taking the log of the variables, the models for estimation are presented as:

$$\text{GHE}_{it} = \vartheta_0 + \vartheta_1 \text{GHE}_{i,t-1} + \vartheta_2 \text{RENC}_{it} + \vartheta_3 \text{FENC}_{it} + \vartheta_4 gfcf_{it} + \vartheta_5 popg_{it} + \gamma_{it1} + \varepsilon_{it1} \quad (3.4)$$

$$\text{CO2EH}_{it} = \vartheta_6 + \vartheta_7 \text{CO2EH}_{i,t-1} + +\vartheta_8 \text{RENC}_{it} + \vartheta_9 \text{FENC}_{it} + \vartheta_{10} gfcf_{it} + \vartheta_{11} popg_{it} + \gamma_{it2} + \varepsilon_{it2} \quad (3.5)$$

Where:
GHE = Total greenhouse gas emissions
CO_2EH = CO_2 from electricity and heat production (% of total fuel combustion)
RENC = Renewable energy consumption (% of total final energy consumption)
FENC = Fossil fuel energy consumption (% of total final energy consumption)
gfcf = Gross fixed capital formation
popg = Population growth – proxy for labour force growth

Where all γ_{it} and ε_{it} are between-country and within-country error terms respectively, as earlier defined. While i and t are observational units and time. The small lettered variables are log transformed variables. The capital lettered variables are not logged because the variables are already in rate.

The a priori expectations of the variables in the models are as follows:
Equation (3.4): ϑ_2 *and* ϑ_4 < 0, while ϑ_3 and ϑ_5 > 0
Equation (3.5): ϑ_8 and ϑ_{10} < 0, while ϑ_9 and ϑ_{11} > 0
In order words, in each model, the signs of the parameters for renewable energy consumption (RENC) and gross fixed capital formation (gfcf) are expected to be negative. This means that an increase in it will lead to reduction in environmental degradation. For example, an increase in the use of renewable energy consumption (sources) - (RENC) like solar, wave, and tidal is expected to reduce environmental degradation (total greenhouse gas emissions). On the other hand, the signs of the parameters for fossil fuel energy consumption (FENC) and Population

growth – proxy for labour force growth (popg) are expected to be positive. This means that an increase in it will lead to an increase in environmental degradation. For example, an increase in fossil fuel energy consumption (FENC) such as petroleum, natural gas, and coal is expected to increase environmental degradation (total greenhouse gas emissions).

3.3 Sources of Data Collection

The data set used in this study are data on total greenhouse gas emissions, CO_2 from electricity and heat production (% of total fuel combustion), renewable energy consumption (% of total final energy consumption), fossil fuel energy consumption (% of total final energy consumption), gross fixed capital formation and population growth – proxy for labour force growth. These data covering the period of 2000 – 2019 are collected for a panel of fifteen ECOWAS Countries. The fifteen members of the Economic Community of West African States (ECOWAS) are Benin, Burkina Faso, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. The data is drawn from the World Development Indicators of the World Bank.

3.4 Data Estimation/Analysis Technique

The technique of analysis for this study is the Generalized Method of Moments (GMM), developed by Lars Peter Hansen in 1982. The reason for employing this technique is because a couple of econometric problems could occur from estimating the specified equations under the model specification section. The Breitung, and Im, Pesaran and Shin panel unit root tests are employed to test for the stationarity of variables, while the Pedroni cointegration test is employed to determine if there exists any long run relationship between the variables in the model.

4. Results and Discussion

4.1 Descriptive Statistics of Dependent and Independent Variables

Table 4.1: Mean, standard deviation, maximum values, minimum values, Skewness and Kurtosis of the variables

Variables	GHE	CO_2EH	RENC	FENC	gfcf	popg
Mean	8645.276	12207.92	72.5662	2290.093	20.6273	0.8943
Standard Deviation	23277.41	29387.2	18.8540	4987.654	1.3539	0.9318
Minimum value	100	186.864	20.8079	11.8479	17.5607	-9.1255
Maximum value	120449	113370.7	93.8742	26669.8	23.6744	4.5719
Pr(Skewness)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pr(Kurtosis)	0.0000	0.0000	0.5365	0.0000	0.0000	0.0000
Obs.	N = 300 n = 15 T = 20	N = 300 n = 15 T = 20	N = 300 n = 15 T = 20	N = 300 n = 15 T = 20	N = 300 n = 15 T = 20	N = 300 n = 15 T = 20

Source: Authors Computation

As shown in Table 4.1, popg has a small standard deviation value that is close to its mean value. This means that the value of the population growth centered about its mean value. The values of GHE, CO_2EH, RENC, FENC and gfcf; however, have high standard deviation values, which are far greater than their mean values respectively. This means that Greenhouse emissions, Co_2 from electricity and heat production, renewable energy consumption, fossil fuel energy consumption, and gross fixed capital formation are farther away from their respective mean values. The minimum values of GHE, CO_2EH, RENC, FENC, gfcf and popg are less than their respective mean values. Similarly, the maximum values GHE, CO_2EH, RENC, FENC, gfcf and popg are greater than their respective mean values.

Concerning the skewness of the variables, we can reject the hypothesis that GHE, CO_2EH, RENC and FENC are normally distributed at the 5 per cent level. This is guided by the fact that the respective p-values are significant at the 5 per cent level. On the other hand, on the basis of Kurtosis alone, p-values of GHE, CO_2EH and FENC shown in the table indicate that it is significantly different from the kurtosis of a normal distribution at the 5 per cent significance level. But given the insignificant p-value of RENC, we can say that the variable is not significantly different from the kurtosis of a normal distribution at the 5 per cent significance level.

4.2 Data Analysis

4.2.1 Unit Root Tests

Before estimating the models specified in section three, the variables in the models were tested for unit root using the Breitung and The Im, Pesaran and Shin (IPS) panel unit root tests and the results are presented in Table 4.2 below:

Table 4.2: Breitung and The Im, Pesaran and Shin (IPS) unit root test results

Variable	Breitung unit-root Test Result		Im, Persaran and Shin (IPS) Test Result		~I(d)
	Level	**1st Difference**	**Level**	**1st Difference**	
GHE	-1.5741 (0.0577)	-9.4234* (0.0000)	-1.0100 (0.0622)	-2.0140* (0.0032)	I(1)
CO_2EH	-0.8493 (0.1202)	6.8493* (0.0000)	0.7290* (1.0210)	5.7290* (0.0000)	I(1)
RENC	-1.1159 (0.0672)	2.1159* (0.0172)	-0.9447 (0.1406)	3.9447* (0.0000)	I(1)
FENC	-1.2377 (1.0000)	9.7741* (0.0000)	-0.8999 (1.0000)	8.6054* (0.0000)	I(1)
GFCF	1.1024 (0.1606)	4.1024* (0.0000)	-0.4697 (0.1263)	3.4697* s(0.0003)	1(1)
POPG	-1.3239 (1.0000)	-7.4098 * (0.0000)	-1.0741 (1.0000)	-13.5461* (0.0000)	1(1)

(1) P-values are in parenthesis
(2) * denotes significant at 5% and the rejection of the null hypothesis of the panels containing unit-roots.
(3) TheBreitung and the IPS p-values are presented in parenthesis.

Cross-sectional means were removed to help control for possible correlation of panels.

The Breitung unit-root test showed that the p-values of none of the variables were less than 0.05 at their level form. This means that the test statistic of the variables respectively was not significant. For this reason, the variables were differenced once and the test was carried out again. At their first difference, the variables respectively became significant at the 5 per cent level. Thus, the null hypothesis is rejected at the 5 per cent level. This means that the variables are integrated of order one, I(1). That is, stationary at 1st difference. Similarly, the Im, Pesaran and Shin (IPS) test showed that none of the variables was stationary at their level form, as indicated by their insignificant p-values. But at their 1st difference, the variables became stationary. Therefore, confirming that the variables are all stationary at 1st difference. Since the variables are integrated of the same order, Pedroni's cointegration test was conducted and is presented below.

4.2.2 Pedroni's Cointegration Test

The Pedroni cointegration test was employed to test the presence or otherwise of level form relationship among the variables in equations (3.4) and (3.5).

The results are presented respectively in Tables 4.3a and 4.3b below.

Table 4.3a: Result of Pedroni test for cointegration among the variables in equation (3.4)

Test Statistics	Panel	Group
V	-4.514	-
Rho	5.231	6.04
T	1.078	-2.575
ADF	4.819	10.18
t = 2.0747 p = 0.0444		
The model underlying the reported statistics includes panel-specific means and panel-specific AR parameters and does not include a time trend. Bartlett kernel with 2 lags was used, as selected by the Newey–West methods, to adjust for serial correlation.		

Source: Author's Computation

Table 4.3b: Result of Pedroni test for cointegration among the variables in equation (3.5)

Test Statistics	Panel	Group
V	-3.827	-
Rho	4.487	5.793
T	-6.258	-7.445
ADF	10.27	9.587
t = 2.0371 p = 0.0212		
The model underlying the reported statistics includes panel-specific means and panel-specific AR parameters and does not include a time trend. Bartlett kernel with 2 lags was used, as selected by the Newey–West methods, to adjust for serial correlation.		

Source: Author's Computation

As shown in Tables 4.3a and 4.3b, the significant p-values suggest the rejection of the null hypothesis of no cointegration. This means that there is cointegration in the models specified respectively for total greenhouse gas emission and CO_2EH from electricity and heat production as specified in equations (3.4) and (3.5).

4.2.3. System GMM Regressions of Energy Consumption and Environmental Degradation

Table 4.4: Result of System GMM Regressions of Energy Consumption and Environmental Degradation

VARIABLES	(1) Total Greenhouse Emissions	(2) $C0_2$ from Electricity and Heat Production
RENC	-2.3421 (z = -0.08) (p = 0.934)	-578.6529* (z = -3.00) (p = 0.003)
FENC	0.4848* (z = 5.33) (p = 0.0000)	1.1009* (z = 2.01) (p = 0.045)
Gfcf	-631.8049 (z = -1.73) (p = 0.084)	1211.679 (z = 0.43) (p = 0.665)
POPG	-0.9043 (z = -1.48) (p = 0.139)	3.1378 (z = 0.70) (p = 0.481)
Constant	12141.7 (z = 1.37) (p = 0.169)	7762.698 (z = 0.12) (p = 0.905)
Wald chi2(9)	10114.82 (p= 0.0000)	168.34 (0.0000)
Arellano-Bond Test:		
AR (1)		
AR (2)	-1.7716 (p = 0.0765)	-1.7716 (p =0.0765)
	1.6195 (p = 0.1053)	1.6195 (p = 0.1053)
Hansen Test	9.4299 (p =0. 0290)	9.4299 (p = 0.0290)

Source: Computed by the Author

The impact of renewable energy consumption on environmental degradation, in line with objective one, showed negative coefficients of -2.3421, and -578.6529 in columns (1) and (2) with z-values of -0.08, and -3.00 respectively. The z-values of -0.08 is less than 2 in an absolute sense, while the z-value of-3.00 is greater than 2 in an absolute sense. Therefore, using the 2-t rule of thumb, the null hypothesis that renewable energy consumption has no statistically significant impact on total greenhouse emissions in column (1) is accepted at the 5 percent level. The insignificant probability values of 0.934 also support the decision of accepting the null hypothesis. However, the null hypothesis that renewable energy consumption has no statistically significant impact on $C0_2$ from electricity and heat production in column (2) is rejected at the 5 percent level. The significant probability value of 0.003 also supports the decision of rejecting the null hypothesis by showing that there is a significant error in accepting the null hypothesis in column (2). In specific terms, a percentage increase in renewable energy consumption such as solar, wave and tidal leads to a reduction in greenhouse emissions and $C0_2$ from electricity and heat production by 2.34 and 578.65 percent respectively.

On the other hand, in respect to objective two, fossil fuel energy consumption showed positive coefficients of 0.4848 and 1.1009 with z-values of 5.33 and 2.01 for total greenhouse emissions and $C0_2$ from electricity and heat production, in columns (1) and (2). The z-values of 5.33 and 2.01 are statistically significant; therefore, the null hypothesis that fossil fuel energy consumption has no statistically significant impact on total greenhouse emissions and $C0_2$ from electricity and heat production is rejected at the 5 per cent level. The significant probability values of 0.0000 and 0.045 support the decision of rejecting the null hypothesis by showing that there is a significant error in accepting the null hypothesis in columns (1), and (2). Fossil fuel energy consumption has a positive impact on total greenhouse emissions and $C0_2$ from electricity and heat production. Specifically, If fossil fuel energy consumption such as petroleum, natural gas, and coal increase by a percentage, total greenhouse emissions and $C0_2$ from electricity and heat production increases by 0.48 percent and 1.19 percent respectively.

The coefficients of gross fixed capital formation are -631.8049 and 1211.679 with z-values of -1.73 and 0.43 in columns (1) and (2) respectively. The insignificant p-values in each of the columns guides us to accept the null hypothesis that gross fixed capital formation has no statistically significant impact on total greenhouse emissions and $C0_2$ from electricity and heat production. The coefficient of population growth is negative (-0.9043) in column (1), implying the negative impact of the variable on total greenhouse emissions with a z-value of -1.48. In columns (2), the coefficient is positive (3.1378) with z-value of 0.70. None of the p-values (0.139, 0.481) is statistically significant at the 5 percent level. Therefore, the null hypothesis that, population growth has an insignificant impact on total greenhouse emissions and $C0_2$ from electricity and heat production, is accepted at the 5 percent level of significance. Population growth has a negative and statistically insignificant impact on greenhouse emissions. If population growth increases by a percentage, greenhouse emissions decrease by 0.90 per cent. However, if the population growth increases by a percentage, $C0_2$ from electricity and heat production also increases by 3.14 percent.

4.3 Discussion of Findings

The findings that renewable energy consumption had negative impacts on greenhouse emissions and $C0_2$ from electricity and heat production imply that increased use of renewable energy sources such as solar, wave and tidal will reduce emissions. The significant p-values for $C0_2$ from electricity and heat production mean that reduction in environmental degradation as a result of increase renewable energy use will even be more noticeable in $C0_2$ from electricity and heat production reduction. Less harmful substances or byproducts are generated in renewable energy sources like solar and released to the natural environment. Therefore, its contribution to environmental degradation is low, which is the reason for the minus sign (the negative impact). This finding aligns with the study of Al-Mulali, Ozturk and Lean (2015).

The positive impact of fossil fuel energy consumption on total greenhouse emissions and $C0_2$ from electricity and heat production imply that the use of fossil fuel energy such as coal, natural gas and petroleum as energy sources add to emissions increase as well as deteriorating arable land use. Though electricity is a clear and relatively safe form of energy in usage, its generation and transmission contribute to environmental degradation. By the burning of solid fuels such as coal, more carbon waste traps excess heat and send ash to landfills, therefore, causing degradation of the environment. The significant p-values for total greenhouse emissions and $C0_2$ from electricity and heat production imply that fossil fuel energy contributes more to greenhouse emissions and $C0_2$ from electricity and heat production. The findings correlates with the works of Naminse and Zhaung (2018) and Hongxian (2017).

The negative impact of gross fixed capital formation on total greenhouse emissions means that an increase in domestic investment leads to a decrease in total greenhouse emissions. However, the positive impacts of gross fixed capital formation on $C0_2$ from electricity and heat production mean that domestic investment contributes to more $C0_2$ from electricity and heat production. Increase in domestic investment brings about increase economic activities that in most cases come with higher demand for electricity and the use of land for industrial activities, thus, leading to an increase in $C0_2$ from electricity and heat production, and infertile arable land available for use. Growing demand for energy consumption is also reinforced by an increasing population and urbanization. This leads to $C0_2$ from electricity and heat production. The findings from Al-Mulali and Ozturk (2015), and Dogan and Turkekul (2016) give further proof to this finding.

5. Conclusion and Recommendations

5.1 Conclusion

This study examined the impact of energy consumption and environmental degradation in ECOWAS countries. The main results are summarized under three points. First, renewable energy consumption had a negative impact on total greenhouse emissions and $C0_2$ from electricity and heat production. Second, fossil fuel energy consumption positively impacted on total greenhouse emissions and $C0_2$ from electricity and heat production. Third, other variables such as gross fixed capital formation and population growth though not significant, also contribute to environmental degradation in varying degrees. Hence, our overall conclusion is that the use of renewable energy consumption does reduce environmental degradation, and help sustain the natural environment. But fossil fuel energy sources do reduce environmental quality in West African countries, which confirms and strengthens the conclusions of Aboagye (2019), Aiyetan and Olomola (2017), and Rehman and Rashid (2017).

5.2 Recommendations

The following recommendations are proffered:

i. West African countries should develop and encourage the use of other energy sources especially renewable energy, alternative and nuclear energy, and combustible renewable and waste beside fossil fuel energy sources.
ii. We also recommend that emission palliation policies in West Africa should focus on environmentally friendly growth, enhancing consumption of cleaner energy.
iii. It is also recommended that West African countries should increase environmental taxation to cushion the rate of fossil fuel used by individuals and firms. This could reduce per capita CO_2 emission.
iv. Also, ECOWAS countries should synergize and develop a common power grid from renewable energy sources which will help reduce the consumption of energy from fossil fuel and other forms of emissions.

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