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# Does Energy Consumption Impact Sustainable Development in Nigeria?

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## Abstract
*This study examined the sustainable development implications for energy consumption in Nigeria spanning from 1986 to 2022 using the Fully Modified Ordinary Least Squares (FMOLS) technique. The estimated FMOLS results revealed that petroleum resource consumption has an adverse and statistically non-significant impact on sustainability in Nigeria as a positive relationship means that petroleum consumption increases carbon emission and unsustainability in Nigeria. Further, the study revealed that electricity consumption and sustainable development are negatively and significantly related. This implies that the consumption of fossil fuel-related energy like petroleum leads to increased environmental degradation which tends to jeopardize the chances of the future generation from benefiting from such resource rent. This situation is seen as a lack of sustainable development. The result also showed that biomass consumption positively and significantly impacts sustainable development in Nigeria. This implies that the consumption of renewable resources like biomass is environmentally friendly and sustainability-enhancing. Thus, the study recommended among others that the government should enact energy-efficient policies such as carbon tax or emissions trading, fuel efficiency standards for vehicles, Electric vehicle incentives, energy efficiency tax credits, and others to curb the emission of carbon monoxide.*
**Keywords: Energy Consumption, Non-Renewable Energy, Renewable Energy, Sustainable Development**
**JEL Classification Codes: Q4, Q3, Q2, O3**

## 1. Introduction

Nigeria, with rapidly growing inhabitants, faces significant energy challenges. The country's energy sector is characterized by inadequate supply, inefficient distribution, and over-reliance on fossil fuels, which poses environmental and health risks. For instance, the energy crisis that has beset Nigeria for nearly two decades has fueled an increase in poverty through the decline in commercial activities during this time. The Council for Renewable Energy of Nigeria has estimated that power outages result in an annual loss of approximately 126 billion naira (US$ 984.38 million) (Statista, 2022). Among the negative effects of power outages are health hazards of various forms that arise from constant exposure to carbon emission through the use of wood charcoal for fuels, resulting in deforestation, the use of generators in various homes and businesses, and an increased cost of living that contributes to declining living conditions.

Energy consumption is crucial for sustainable development, directly impacting economic growth, social welfare, and environmental sustainability. Nigeria's energy landscape is dominated by fossil fuels, which account for over 90% of the country's energy mix (International Energy Agency [IEA], 2020). This reliance on non-renewable energy sources greatly impacts greenhouse gas emissions, climate change, and environmental degradation. Furthermore, the nation's energy infrastructure is insufficient, resulting in regular power outages and energy insecurity. The Nigerian government has established ambitious goals to improve energy access, improve energy efficiency, and promote sustainable development. Nonetheless, reaching these objectives necessitates a thorough understanding of the country's energy consumption trends, the effects of energy utilization on sustainable development, and the potential of renewable energy sources.

Nigeria has faced an immense energy shortage causing blackouts and a slow pace in economic growth and development. Energy consumption, economic growth, development, and poverty reduction are associated with themselves and socioeconomic development indicators (Winkler, 2006). Moreover, according to the (Nigerian National Petroleum Corporation [NNPC], 2019), Nigeria consumed 57.2 million liters of premium motor spirit (PMS), and 39.4 million liters in 2020. However, in 2021 it reported 22.35 billion liters which amounts to about 61 million liters dail, similarly, the PMS consumption report by NNPC placed petroleum consumption at 65.7 million liters in 2022. This has culminated into an increase in carbon emissions in the country hence, the quest for more environmentally friendly alternatives like hydroelectric, solar, wind, tidal, and biomass.

Many Nigeria-based researchers have studied the sustainable development implications for both renewable and non-renewable energy consumption in Nigeria. For instance, Onyebuchi (2018); Chineke and Igwiro (2018) in their works showed the solar energy potential as an alternative source of energy. Their studies have quantified sunshine of about six and a half hours to be equivalent to about 1,934.5 kWh/m2 /year of solar energy strength. This is approximately one hundred and twenty thousand times the electrical energy produced by the Power Holding Company of Nigeria (PHCN) per annum.

Assuming a 10% conservative conversion efficiency, the available solar energy resource is roughly 23 times the Energy Commission of Nigeria's (ECN) forecast for total final energy demand in Nigeria by 2030 (ECN, 2015). To foster development in the country, it is essential to supplement the current unreliable energy sector with a sustainable power supply from solar energy.

Consequently, this article seeks to explore whether energy consumption impacts sustainable development in Nigeria as it relates to petroleum resources consumption, electricity consumption, and biomass fuel consumption being some forms of non-renewable and renewable sources of energy. This research contributes to extant literature on energy and sustainable development, providing intuitions for policymakers, energy practitioners, and stakeholders to develop effective approaches for promoting sustainable energy development in Nigeria.

This article is fragmented into five distinct sections. The first section covers the introduction, section two contains a review of the literature. Section three is dedicated to elucidating the methodology employed in this study, while section four focuses on the presentation, and result interpretation. Finally, section five encapsulates a summary, concluding remarks, and recommendations.

## 2. Literature Review

### 2.1 Conceptual Review

#### 2.1.1 Sustainable Development

Sustainable development is a multidimensional term that emphases on meeting the needs of the present without compromising the future generation's ability to meet their own needs. This approach integrates the economic, social, and environmental sustainability. The term got its fame in the 1980s following the Brundtland Report, "Our Common Future," by the (World Commission on Environment and Development [WCED], 1987). Literally, SD would simply mean "development that can be continued either indefinitely or for the given time period (Dernbach, 1998, and Dernbach, 2003). Browning and Rigolon (2019) sees sustainable development as a development paradigm as well as concept that calls for improving living standards without jeopardising the earth's ecosystems or causing environmental challenges such as deforestation and water and air pollution that can result in problems such as climate change and extinction of species.

#### 2.1.2 Energy Consumption

Energy consumption denotes all the energy used to implement an action, manufacture something or power a facility or a building. Energy consumption could be in the form of renewable and non-renewable types, including petroleum, electricity, Biomass, wind, and water energy. Electricity is often described as an energy carrier, which can be transformed into other forms of energy. Primary energy sources can be either renewable or non-renewable; however, the electricity we utilize in Nigeria is mainly hydroelectric-based. About 98% of the electricity consumption in Nigeria, is centered on the Power Holding Company of Nigeria (PHCN) (National Bureau of Statistics [NBS], 2022).

Biomass is a naturally occurring carbon-based resource derived from biological materials. It is a complex renewable substance characterized by its significant chemical diversity (Iwayemi, 2008). Tursi (2017) observed that biomass can be categorized according to the various types found in nature, aligning with ecological classifications or types of vegetation.

## 2.2 Theoretical Review

Some theories have been promulgated to provide a grasp on the sustainable development concept and to explain how energy production and consumption influence sustainable development. Some of the theories are discussed as follows;

### 2.2.1 Resource Curse Theory

The resource curse theory which was popularized by Auty (1993) and was described as a paradoxical scenario in which a nation rich in natural resources faces stagnation or decline in economic growth and development. The resource curse theory shows a paradoxical situation in which countries with an abundance of non-renewable natural resources experience stagnant economic growth. Put differently, the resource Curse theory posits that natural resource-rich countries tend to experience poor economic growth and development due to the negative impact of the "resource curse" on institutions and governance. The occurrence of this phenomena has been attributed to many factors but majorly to countries over dependence or reliant on a particular sector at the detriment of others to the extent that the country will focus all of its production means on a single industry, such as mining or oil production, and neglects investment in other major and viable sectors like agriculture and manufacturing.

This phenomenon is visible in Nigeria as the advent of oil led to the neglect of agriculture and manufacturing sector to the extent that the former which tends to be the mainstay of the economy prior to the discovery of oil is seen to be existing in its past glory. This could result to unsustainability as the extraction and consumption of such resources that ought to translate to the development of other sectors is rather seen to be the problem and this in no doubt will pose more problem not just the current but to the future generations if the rents from the resources are not channelled into productive uses. This theory has received some huge levels of reactions and support from resource economists in most part of the world (Sach & Warner, 1997a, Sach & Warner, 1997b and Robinson, Ragnar &Thierry 2006)

### 2.2.2 Staple Theory and Daly Sustainable Development Path Theory

The staple theory as advanced by a famous Canadian scholar, Mackintosh (1923) showed the impact of staples or traditional commodities on growth of economies in the face of abundant resources. Staple thesis was introduced to describe Canada's resource-rich economy and posits that a country can evolve following their resource abundance. The theory believes that an increase in the export demand for a country's resources can trigger an economic growth of that country and also leads to development of infrastructure and technology which helps in the extraction or production of the abundant resources. Put differently, the staple theory also stressed the fact that having markets for staple products (with an emphasis on raw materials) and the ability of people to take advantage of geographical factors to bring the staples to these markets competitively are critical for the economic development of the Canadian and United State economies.

This also implies that natural resources consumption and production can translate to growth in such economies and in the long-run lead to sustainable development especially when such products are exported in a good volume that can yield rents for further development of the resources and other sectors for both the current and future generations. But the extent to which this can happen may also depend on the level of environmental friendliness of such resources.

Daly’s sustainable development path theory by Daly (1996) opined that the primary goal of any society is economic development and not just for the satisfaction of basic material needs but also the provision of the resources needed to improve the quality of life including meeting the demands for healthcare, education and a good environment both for the current and future generation. The theory also argued that it is impossible to respect ecological limits and to have growth in the world economy. One of Daly’s important operational principles is that renewable resources should provide a sustainable yield. This implies that the rate of harvest of natural resources should not exceed the rate of regeneration and in the case of non-renewable resources there should be equivalent development of renewable substitutes if the resources can translate to sustainable development. Also, the use of non-renewable resources was seen in light of sustainability that led to him suggesting that such resources could be exploited in a quasi-sustainable manner by limiting their rate of depletion to the rate of creation of renewable substitutes. Whether discussing renewable or nonrenewable resources, the aim is to limit resource throughputs, and to emphasize technologies that increase the amount of value extracted per unit of resource, rather than increasing the throughput itself.

In a nutshell, this theory believes that there is a limit of the exploration and exploitation of natural resources that can promote sustainability after which harms will set in. From a macroeconomic perspective, population times per capita resource use must remain within the limits of the region's carrying capacity without resorting to non-regenerated capital consumption.

### 2.2.3 Hartwick Rule Theory

The Hartwick (1977) rule theory opined that a constant efficient consumption path (sustainability) is guaranteed only when rents from natural resources are used in reproducible capital. The Hartwick's rule suggested the sitting aside of some amount of investment in produced capital (like buildings, roads, knowledge stocks, etc.) to offset the exact depleting stocks of non-renewable resources such as oil as one of the ways non-renewable resources production and consumption can bring about sustainability. Such investments should be undertaken with the intension to sustain or improve the standard of living of the future generation. Hartwick's rule – often abbreviated this investment as "invest resource rents" – requires that a nation invest all rent earned from exhaustible resources currently extracted, where "rent" is defined along paths that maximize returns to owners of the resource stock. The rule speaks of sustainable development and extends to the case of many types of capital goods, as it maintains the total stock of capital and the consumption constant along time by taking into consideration depreciation in all three forms of capital. The difference between total investment in some kinds of capital and total disinvestment in other types of capital has been labelled "genuine savings".

### 2.2.4 Environmental Kuznet Curve (EKC) Hypothesis

The environmental Kuznet curve (EKC) hypothesis was developed by Grossman and Krueger (1991) begin the pioneer of the inverted U-shaped relation and Panayotou (1993) who coined the term environmental Kuznet curve. The EKC opines that an inverted U-shaped relationship runs between economic growth and environmental degradation. It implies that at the early stages of economic growth and development, pollution or other forms of degradation appear to be very high but it tends to fall as economic growth declines. The EKC took its root from the work of Kuznets (1955), who revealed the existence of an inverted U-shape curve in the relationship between inequality of income distribution and the level of income. The idea has become one of the "stylized facts" of environmental and resource economics. The idea behind EKC has be adopted by authors in related studies to ascertain the existence of this hypothesis.

For instance, the World Bank (1992) and Shafik (1994) showed the relationship between environmental degradation indicators and income per capita. They concluded that an increase in pollution emissions can result in a decline in environmental quality in the initial phases of economic growth, and a certain pattern prevails; however, as per capita income rises beyond a specific threshold (which may differ for various indicators), the trend reverses, resulting in environmental improvements at higher income levels.

In line with this study on energy consumption and sustainable development as measured by environmental quality, it is pertinent to say that as economic activities increase, pollution also rises which can be translated to low environmental quality or unsustainability. This therefore implies that energy consumption which tends to rise as economic activities increases can impact environmental quality at every point and its impact will depend on the type of energy that is consumed. Despite the popularity, the EKC hypothesis has been criticised on several grounds among which is on its failure to explicitly state the requirements for the selection of environmental pollution indicators, which could be attributed to the reason for the very significant impact that the chosen environmental pollution indicators had on the results of the study.

## 2.3 Empirical Review

Studies on how energy consumption impacts industrial productivity have emerged for instance, Okungbowa and Abhulimen (2021) in their study on the effects of the consumption and supply of energy on industrial productivity in Nigeria from 1981 to 2018 using the Error correction model (ECM) found that the consumption of petroleum and coal, among other factors, positively contributes to business productivity, whereas electricity and natural gas harm business productivity. Some studies have shown that energy consumption especially non-renewable ones have adverse effects on sustainable development as it tends to increase the emission of greenhouse gas and carbon monoxide which tends to breed environmental pollution that can affect the current and future generations. The study among others, recommended a sectorial-based energy policy implementation process for the variables that significantly impact industrial output growth.

For instance, Halkos and Tsirivis (2023) focused on shedding light on the impact of electricity production on sustainable development from 1995 to 2018 among 31 countries including 26 European countries. The study employed panel least squares, difference, and system GMM techniques to analyse the data. The results confirmed that renewable energy (RES) appears have a positive effect on sustainability, but it was also seen to have a reversed effect after a certain percentage of total RES reliance. Electricity and GFCF both adversely affect electricity $CO_2$ intensity, indicating that many new investments in the power sector concern carbon-intensive technologies. The dynamic analysis outcome revealed to policy makers the necessary time frame after which the implementation of new energy policies can have the full impact on the carbon emissions of electricity generation.

Okungbowa and Soriwei (2023) in their study on how international trade and energy consumption influence sustainable development in Nigeria for a period of 1986 to 2022 with the help of the autoregressive distributed lag (ARDL) approach found sustainable development to be adversely affected by energy consumption and international trade, especially export trade. They, however, recommended among others, the Nigerian government enacts an export product base diversification policy to promote exportation of environmentally friendly goods.

Agbede, Bani, Azman-Saini, and Naseem (2021) investigated the impact of energy consumption on environmental quality in the MINT countries from 1971 to 2017 using a panel PMG/ARDL modelling technique, and the Granger causality test. Economic growth, energy consumption, and bio-capacity were observed to have a positive and statistically significant effect on environmental degradation during the long-run period. Among others, this study recommends utilization of energy resources, biocapacity, and urbanization as instruments for achieving some level of energy efficiency, reducing global warming, and carbon dioxide-related problems aimed at abating climate change and improving environmental quality by governments and private enterprises.

In line with the above, other studies found that renewable energy sources have high implications for promoting environmental quality and in turn sustainable development.

Nate *et al.* (2021) studied energy consumption on impacts on the three pillars of sustainable development in 74 countries. The results found that the changes in the ecological pillar and that a 1% reduction in energy consumption per capita gives only a 0.6% ecological footprint reduction, which indicates a low efficiency of reducing energy consumption policy and its danger for the social pillar. The study recommends expansion of renewable energy for all sustainable development pillars.

A similar study by Hassan and Chinedu (2021) estimated the effects of renewable energy consumption and environmental sustainability on economic growth in Africa. The study had a scope of thirty-seven African countries from 2008 to 2014 and was analysed with the Generalized Method of Moments estimation technique. This study found that renewable energy adoption and development triggered an increase in economic growth in Africa, as a one percent increase in renewable energy consumption translated to a 0.07% and 1.9% increase in economic growth in the short-run and long-run respectively. The study recommended adopting policies among African countries that will intensify and encourage the renewable sector growth while also harnessing the already mature non-renewable industry for more rapid growth in the continent and the attainment of Agenda 2063.

Adedoyin, Nathaniel, and Adeleye (2020) investigated the long-run relationship between energy consumption, tourist arrivals, economic policy uncertainty, and ecological footprint in the top ten earners from international tourism over the period 1995 to 2015. The fully modified ordinary least square and dynamic ordinary least square estimation techniques and the Dumitrescu and Hurlin causality tests were used in the study. Empirical estimates suggest that the contribution of energy consumption to ecological footprint is significantly moderated by economic policy uncertainties such that a 1% increase in the latter reduces environmental damage by 0.71%. This study suggests the implementation of environmental protection policies for green economic growth to be possible.

Specifically, Asghar, Majeed, Khan, and Anwar (2023) empirically investigated the impact of biomass on sustainable development in the Asian region from 1990 to 2017. The Fully modified ordinary least square, dynamic ordinary least square, and Driscoll and Kraay methods are used to estimate the model. They found that environmental quality was positively and significantly impacted by the consumption of biomass in Asian economies. It is recommended that the region should efficiently utilize biomass to the maximum extent to travel on the path of sustainable development.

Also, Achuo, Miamo, and Nchofoung (2022) examined environmental sustainability implications for renewable and non-renewable energy consumption in about 173 countries from 1996 to 2020 with panel-fixed effect approach. Their research revealed that renewable energy augments environmental quality by plummeting the emission of greenhouse gas, the consumption of non-renewable energy was found to be harmful to environmental quality as it increases greenhouse gas emissions.

Okwanya and Abah (2018) with FMOLS investigated the impact of energy consumption on poverty reduction in 12 African countries from 1981 to 2014. The study discovered that energy consumption has a long-term negative correlation with poverty levels, highlighting the significance of energy for poverty alleviation in the chosen countries in Nigeria. The study advises that the governments of the affected nations should improve infrastructure and maintain political stability to optimize the effects of energy consumption on poverty alleviation

From the literature, it was observed that much emphasis in this line of discourse has been on the use of aggregated data to capture the natural resources effect, others focused on non-renewable resources, and a few others employed disaggregated techniques in their study but their focus was on how energy consumption affects either economic growth, economic development, and industrial productivity without any recourse to how the renewable and non-renewable energy consumption impact sustainable development in Nigeria. Lastly, most of the previous studies were cross-country based. This study therefore aimed at filling some of the identified gaps by disaggregating the energy resources into specific types of renewable and non-renewable energy, employing the carbon emission variable to capture environmental quality and by implication, sustainable development and by confining our study to Nigeria, that is, a country specific.

## 3. Methodology

### 3.1 Model Specification

This study utilized time series data from Nigeria spanning from 1986 to 2022. The data used in this article were sourced from the World Bank (2022); Central Bank of Nigeria (2022); and International Energy Agency (2022) database. To evaluate the hypotheses earlier stated, the study adopts and modifies the model as specified by Halkos and Tsirivis (2023) using the fully modified ordinary least square as well as by disaggregating the energy sources into renewable (Biomass and electricity) and non-renewable (petroleum) energy sources to analyse their impact the emission of carbon monoxide which is the proxy of sustainable development. To avoid omitted variable issues other variables like the economic growth measure and the level of domestic investment to GDP were included as control variables since they can also influence sustainability alongside the energy-related variables. for a country-based study.

The functional model is specified as;

$$LNCO_2E = f(LNPETR, ELECT, BIOM, GDPGR, GFCF) \quad (1)$$

The econometrics model looks thus:

$$LNCO_2E_{t-1} = \beta_0 + \beta_1 LNPETR_t + \beta_2 ELECT_t + \beta_3 BIOM_t + \beta_4 GDPGR_t + \beta_5 GFCF_t + \varepsilon_{t-1} \quad (2)$$

The FMOLS form of model 2 is as follows:

$$LNCO_2E_{t-1} = \beta_0 + \beta_1 LNPETR_{t-1} + \beta_2 ELECT_{t-1} + \beta_3 BIOM_{t-1} + \beta_4 GDPGR_{t-1} + \beta_5 GFCF_{t-1} + \sum_{j=-q}^{p} d_1 \, \Delta LNPETR_{t-1} + \sum_{j=-q}^{p} d_2 \, \Delta ELECT_{t-1} + \sum_{j=-q}^{p} d_3 \, \Delta BIOM_{t-1} + \sum_{j=-q}^{p} d_4 \, \Delta GDPGR_{t-1} + \sum_{j=-q}^{p} d_5 \, \Delta GFCF_{t-1} + \varepsilon_{t-1} \quad (3)$$

Where; $CO_2E$ represents carbon dioxide emission as measured in kiloton (kt), PETR is petroleum resource consumption being measured by Barrels per day(bpd) in millions, ELECT represents electricity resource consumption proxied by Kilowatt per hour, BIOM represents Biofuels consumption being the Domestic Material Consumption (Tonnes), GDPGR represents Gross Domestic Product growth rate being the growth rate of RGDP and GFCF is Gross Fixed Capital Formation being a proxy for total domestic investment measured as a total domestic investment to GDP. Note that carbon emission ($CO_2E$) and petroleum consumption (PETR) was logged and captured as $LNCO_2E$ and LNPETR to ensure that all the variables are of the same magnitude and to eliminate the issue of outliers.

*Apriori* expectations: $\beta_1 > 0$ showing a positive relationship between petroleum consumption and cardon dioxide emission which is a depletion or adverse effect on sustainable development.

$\beta_2, \beta_3, \beta_4, \beta_5 < 0$ showing a negative relationship between the variables and $CO_2E$ being a positive implication for sustainable development.

The Fully Modified Ordinary Least Squares (FMOLS) method as advanced by Stock and Watson (1993) was employed for the data analysis in this study. The FMOLS is a nonparametric that addresses the issues of endogeneity and serial correlation present in the OLS estimator with the help of leads and lags. The FM-OLS model is a robust estimator that enhances the reliability of regression results when working with time series data.

## 4. Results and Discussion

### 4.1 Descriptive Statistics

Some of the important aspects of descriptive statistics captured in this study include; mean, median, range, and standard deviation, among others. The result is presented in Table 1.

**Table 1: Descriptive Statistics**

| | $LNCO_2E$ | LNPETR | ELECT | BIOM | GDPGR | GFCF |
|---|---|---|---|---|---|---|
| Mean | 4.977685 | 5.421503 | 23.49486 | 30.76919 | 4.162427 | 30.74020 |
| Median | 4.977708 | 5.418798 | 21.91000 | 33.00000 | 4.195924 | 28.64594 |
| Maximum | 5.077528 | 5.631444 | 32.78000 | 41.86000 | 15.32916 | 54.94827 |
| Minimum | 4.861945 | 5.301030 | 14.15000 | 16.65000 | -2.035119 | 14.16873 |
| Std. Dev. | 0.055544 | 0.082108 | 5.309298 | 7.388137 | 3.854065 | 12.70218 |
| Skewness | -0.010095 | 1.053000 | 0.442423 | -0.270794 | 0.515553 | 0.300443 |
| Kurtosis | 2.096007 | 4.205795 | 2.030766 | 1.715164 | 3.459191 | 1.910055 |
| Jarque-Bera | 1.260484 | 9.791565 | 2.655315 | 2.997187 | 1.964140 | 2.388109 |
| Probability | 0.532463 | 0.010678 | 0.265097 | 0.223444 | 0.374535 | 0.302990 |
| Observations | 37 | 37 | 37 | 37 | 37 | 37 |

Source: Authors' compilation using E-views Output (2024)

The summary of the descriptive analysis shows the mean, range, standard deviation amongst others. The dependent variable $CO_2$ emissions per energy ($CO_2E$) have maximum and minimum values of 5.077528 and 4.861945, a mean of about 4.977685 which implies that on the average the carbon emission is less than the minimum value of emission for the period under study. The standard deviation stood at 0.055544 showing a huge dispersion from the mean. The result shows that petroleum consumption (PETR) have maximum and minimum values of 5.631444 and 5.301030 barrels/day, a mean of about 5.421503 which implies that on the average the petroleum exceed the minimum value of petroleum for the period under study. The standard deviation stood at 0.082108 showing a huge dispersion from the mean. The descriptive statistics of electricity (ELECT) showed maximum and minimum values of 32.78000 and 14.15000 units, a mean of about 23.49486 which implies that on the average the consumption of electricity is very high for the period under study. The standard deviation stood at 5.3092 showing a huge dispersion from the mean.

Biomass (BIOM) was found to have maximum and minimum values of 41.86000 and 16.65000 units, a mean of about 30.26919 which implies that on the average the consumption of biomass is very high for the period under study. The standard deviation stood at 7.3881 showing a huge dispersion from the mean. The result also showed that the gross domestic product growth rate (GDPGR) maximum and minimum values stood at 15.3291 and -2.03511 for the period. The huge variation in the maximum and minimum values could be due to some periods where the country experienced recession and low growth rate like the COVID era. GDPGR has a mean value of 4.1624 this implies that for the period, the average growth rate was 4.1% and a standard deviation of 3.8540 which shows some minimal level of dispersion from the mean. Lastly, gross fixed capital formation (GFCF) had a maximum and minimum values of 54.9482 and 14.1687 respectively. This shows some form of fluctuations. the average growth rate of GFCF was 30.74% and a standard deviation of 12.7021 which shows huge dispersion from the mean.

More particular, the descriptive statistics shows that all variables were positively skewed except for $CO_2E$ and biofuels (BIOM). This implies that the distribution is not symmetrical in nature. The results also show that carbon emission ($CO_2E$), electricity power (ELECT), BIOM, and gross fixed capital formation (GFCF) were platykurtic distribution (meaning that the variables are less peaked than the normal distribution) with kurtosis value of less than 3. While petroleum resources (PETR) and gross domestic product growth rate (GDPGR) was leptokurtic distributions. judging by the probability values of the Jarque-Bera statistics, all variables safe for (PETR) were normally distributed.

## 4.2 Correlation Analysis

A correlation analysis demonstrates the degree of relationship among the variables employed in any given analysis. Table 2 contains the correlation result.

**Table 2: Correlation Matrix**

| | **LNCO$_2$E** | **LNPETR** | **ELECT** | **BIOM** | **GDPGR** | **GFCF** |
|---|---|---|---|---|---|---|
| PETR | 0.560013 | 1 | | | | |
| ELECT | 0.688483 | 0.526654 | 1 | | | |
| BIOM | -0.468002 | -0.414776 | -0.735998 | 1 | | |
| GDPGR | -0.151167 | -0.067868 | -0.237451 | -0.027944 | 1 | |
| GFCF | -0.537459 | -0.424341 | -0.552396 | 0.8052454 | -0.207263 | 1 |

Source: Authors' compilation using E-views Output (2024)

The results show that the correlation ranged from 0.80 to -0.73. PETR and ELECT were found to be positively and moderately correlated with $CO_2E$ looking at their correlation coefficients of 0.560013 and 0.688483 respectively. $CO_2E$ maintained a negative relationship with the other variables like BIOM, GDPGR, GFCF with correlation coefficients as follows; 0.688483, -0.151167, and -0.537459 respectively. The conclusion is that we should not expect multicollinearity in the model since the correlation coefficient of the independent variables was less than 0.85.

## 4.3 Unit Root Test

The Augmented Dickey Fuller (ADF) test result for unit root examination looks thus, in Table 3.

**Table 3: Augmented Dickey Fully Test for Stationarity**

| Variables | Levels | | | Remarks | First Difference | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | ADF Stats | 5% Crit. Value | Prob | | ADF Stats | 5% Crit. Value | Prob. | |
| $LNCO_2E$ | 2.036821 | -2.945842 | 0.2705 | Non-stationary | -6.679690 | -2.948404 | 0.0000 | Stationary |
| LNPETR | -1.008129 | -2.945842 | 0.7400 | Non-stationary | -7.426341 | -2.948404 | 0.0000 | Stationary |
| ELECT | -0.729275 | -2.945842 | 0.8265 | Non-stationary | -6.608348 | -2.948404 | 0.0000 | Stationary |
| BIOM | -1.334205 | -2.945842 | 0.6030 | Non-stationary | -3.594269 | -2.951125 | 0.0112 | Stationary |
| GDPGR | -4.037118 | -2.945842 | 0.0034 | Stationary | -- | -- | | Stationary |
| GFCF | -1.615999 | -2.948404 | 0.4640 | Non-stationary | -4.861428 | -2.948404 | 0.0004 | Stationary |

Source: Authors' compilation using E-views Output (2024)

From Table 3, all the variables ($LNCO_2E$, LNPETR, ELECT BIOM, GFCF) were stationary at first difference which implies that they are integrated of order one, I(1) except for GDPGR which was stationary at levels indicating it is an I(0) variable. Thus, the study would proceed to estimate a cointegration test since they were stationary at different orders of integration.

## 4.4 Cointegration Test

A cointegration test establishes if a long run relationship exists among the variables was utilised in the study. The study employed the Johansen cointegration test. The test is based on the straightforward premise that whenever the residuals of the variables are cointegrated, we say the variables are cointegrated.

**Table 4: Johansen Cointegration**

| No. of co-int. eqs. | Eigen value | Trace stat. | 0.05 crit. value | Prob. Value |
|---|---|---|---|---|
| None* | 0.988182 | 276.0210 | 95.75366 | 0.0000 |
| At most 1* | 0.825333 | 129.5622 | 6981889 | 0.0000 |
| At most 2* | 0.641992 | 771.68137 | 47.85613 | 0.0001 |
| At most 3* | 0.481941 | 38.08380 | 29.79707 | 0.0044 |
| At most 4* | 0.354994 | 16.38084 | 15.49471 | 0.0367 |
| At most 5 | 0.056250 | 1.910511 | 3.841465 | 0.1669 |

Source: Authors' compilation using E-views Output (2024)

Table 4 illustrates the result of the co-integration test, the result of the trace statistics and Eigenvalue statistics revealed the rejection of the null hypotheses at a 5% level of significance based on our decision rule, as the result shows that there are four co-integrating equations or vectors among the variables of interest, indicating that there is a unique long-run relationship between the variables within the period of study.

## 4.5 Fully Modified Ordinary Least Squares Result

**Table 5: FMOLS Result**

| Dependent Variable: $LNCO_2E$ | | | | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | **Std. Error** | **t-Stat** | **P-value.** |
| LNPETR | 0.127910 | 0.093290 | 1.371098 | 0.1805 |
| ELECT | -0.015580 | 0.004677 | -3.331343 | 0.0023 |
| BIOM | -0.010616 | 0.004189 | -2.534273 | 0.0167 |
| GDPGR | 0.003271 | 0.004292 | 0.762140 | 0.4519 |
| GFCF | -0.006238 | 0.002145 | -2.908496 | 0.0068 |
| C | 9.382513 | 1.142840 | 8.209822 | 0.0000 |
| R-squared | 0.595057 | Mean dependent var | | 11.46556 |
| Adjusted R-squared | 0.527566 | S.D. dependent var | | 0.127323 |
| S.E. of regression | 0.087514 | Sum squared resid | | 0.229763 |
| Long-run variance | 0.007542 | | | |

Source: Authors' compilation using E-views Output (2024)

The results show that approximately 60% of the variation in $CO_2E$ are explained by the independent variables given by the R-square, and 52.7% when adjustments are made for the degree of freedom. It was observed that all things being equal, petroleum consumption (PETR) and GDPGR was positive and statistically non-significant at the 5% level of significance. These imply that a 1% increase in PETR and a 1 unit increase in GDPGR would translate to 0.12% and 0.003 increases in Carbon emission accordingly. Meaning that the consumption of petroleum and increase in economic activity impact sustainability negatively as it was seen to cause a rise carbon emission, and by implication a decline in environmental quality. The results also show that electricity consumption (ELECT) and Biofuel consumption (BIOM) are inversely and significantly related to $CO_2E$ at a 5% level of significance. More explicitly, the estimates show that a unit increase in the consumption of ELECT and BIOM would translate to a 0.02 and 0.01 percent decrease in carbon emission respectively. This therefore implies that electricity and biomass consumption tend to improve sustainable development. Finally, the result shows that (GFCF) as a controlled variable was negative and statistically significant at the 5% level of significance. Implying that domestic investments trigger an increase in carbon emission hence inhibiting economic sustainability.

## 4.6 Post-Diagnostic Tests

The correlogram Q statistic and the histogram normality tests were used to ascertain the validity of the estimated model, they are shown in Table 6.

**Table 6: Correlogram Q Statistics**

| Autocorrelation | Partial Correlation | Lag | AC | PAC | Q-Stat | Prob* |
|---|---|---|---|---|---|---|
| .*\| . \| | .*\| . \| | 5 | -0.104 | -0.105 | 7.5656 | 0.182 |

Source: Authors' compilation using E-views Output (2024)

The correlogram Q statistics was utilized for a period of 5 lags. The null hypothesis states that the model is free from any issues of serial correlation. Since the probability in the 5 lags exceeds 0.0. This implies that the result is serial correlation free.

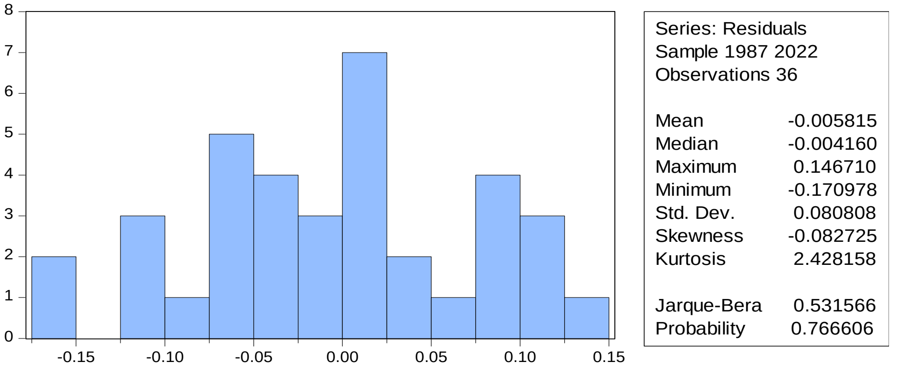


**Figure 1: Histogram Normality Test**
Source: Authors computation using E-views (2024)

Figure 1 indicates the histogram normality test. The Jarque-Bera (JB) test of normality hence showed that the residual series from the model was normally distributed. This was revealed by the Jarque Bera statistic value of 0.53 and its corresponding probability value of 0.76 that was not significant. Thus, a hypothesis of normal distribution of the residual series was retained.

## 4.7 Results and Discussion

The result of PETR in this study showed that petroleum consumption has a positive relationship with carbon emission which implies that it promotes environmental degradation and does not support sustainable environmental quality. This result is in tandem with the findings in the studies of Agbede *et* *al.* (2021); and Achuo *et. al* (2022) respectively. From the estimates, both electricity and biomass consumption were seen to be inversely related to carbon emissions. This implies that they promote environmental quality and in turn, encourage sustainable development. The result on electricity negates the findings by Halkos and Tsirivis (2023) while the finding on biomass is in line with Achuo *et al.* (2022) who stated that all forms of biofuels culminating renewable energy sources improve environmental quality Agbede *et al.* (2021).

## 5. Conclusion and Recommendations

Energy being a vital resource for the advancement of human society, serves as the primary catalyst for economic development. However, while energy engenders economic growth, it also contributes to environmental pollution, which increasingly hinders sustainable economic progress. Given the swift pace of urbanization and industrialization, society's reliance on energy consumption continues to rise, creating a tension between economic growth and energy usage. Therefore, finding ways to align energy consumption with economic development has emerged as a significant opportunity for promoting sustainable development. This study hence evaluates the critical aspects of energy consumption including mainly petroleum resource consumption, electricity consumption, and biofuel consumption, and how they impact sustainable development. The study concludes that petroleum resource consumption has an adverse but insignificant effect on sustainable development, while electricity consumption and biofuel consumption deplete carbon emissions and thus, improve sustainable economic development.

From the foregoing, the study draws the following recommendations;

i. The government should enact energy-efficient policies such as carbon tax or emissions trading, fuel efficiency standards for vehicles, Electric vehicle incentives, energy efficiency tax credits to mention but a few.

ii. The government should promote and adopt energy efficiency technologies and subsequently orient citizens on the significance of energy efficiency.

iii. The government and other stakeholders should leverage global partnerships to support the country's innovative integration of renewable energy systems. Additionally, they should establish a renewable energy funding or financing agency, similar to India's Indian renewable energy agency.

iv. The government and relevant stakeholders should establish appropriate incentives to facilitate the implementation of energy efficiency policies. Additionally, clean energy facilities should be integrated throughout different sectors of the Nigerian economy.

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